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HYDROLOGIC PARAMETERS FOR SELECTED SOILS IN ARIZONA AND NEW MEXICO AS DETERMINED BY RAINFALL SIMULATION

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NEW MEXICO WATER RESOURCES RESEARCH INSTITUTE
New Mexico State University
Box 30001, Dept. 3167
Las Cruces, New Mexico 88003-0001
Telephone (505) 646-4337 FAX (505) 646-6418

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By

Timothy J. Ward

and

Susan M. Bolton

Principal Investigators
Department of Civil, Agricultural,
and Geological Engineering
New Mexico State University
Las Cruces, New Mexico

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ABSTRACT

Estimation of runoff and sediment yield from small, ungaged watersheds is a difficult hydrologic task. Watershed models are useful in this regard, but require some information which is directly related to the hydrologic processes. Rainfall simulation is an important experimental technique for gathering such information, particularly in the pinyon-juniper forest lands of the Southwest.

This technical report contains the results from a study to determine hydrologic parameters for selected soils in Arizona and New Mexico. A small area (approximately 1 square meter or 10 square feet) spray-type simulator was used to collect water and sediment runoff from five pinyon-juniper forest and range sites. A total of 104 plot experiments were performed at the five sites. Two sites had been experimental areas during a previous study and revisited during this study to determine year-to-year variability in hydrologic parameters. The other three sites were new to this study. At two of the three new sites, a recently constructed rainfall simulator was used.

Data analyses indicate that the infiltration characteristics among the sites are quite similar. Differences can be attributed to the amount of organic ground cover on a plot, the antecedent water content of the soil prior to the experiment, and the soil's percent silt fraction. Based on visual estimates in the field, plots were designated as having "high" or "low" cover. At the two sites revisited during this study, there were no statistical differences in hydrologic parameters between the previous and current experiments. Differences which appeared to exist in the data could be attributed to soil moisture and other transient site conditions.

Numerous water chemistry samples were analyzed to determine potential nutrient loadings from forest lands to water bodies. Total phosphorus and volatile solids are related to inorganic sediment yield. Total nitrogen appears to be related to total phosphorus.

Keywords: pinyon-juniper, computer models, data collection, hydrologic models, hydrologic processes, infiltration, parametric hydrology, runoff plot, sediment yield, simulated rainfall, soil erosion, nutrients

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ACKNOWLEDGMENTS

The authors wish to express their gratitude to several individuals who made this study possible. Dr. J. Sam Krammes of the USDA Forest Service, Tempe, Arizona, recognized the utility of rainfall simulation for studying hydrologic processes. He initiated this project in order to integrate erosion and sediment yield studies on pinyon-juniper forest and range lands into the investigations being conducted for other USDA projects. Dr. Richard Cole of New Mexico State University has continually supported the role of effective watershed management in fisheries habitat protection.

The 1989 field crew consisted of Saeed Jorat, Miguel Gabaldon, and Steve Van Vactor. Saeed Jorat helped with the 1990 experiments. The experiments at San Ysidro were carried out by USDA personnel from Albuquerque with the assistance of Saeed Jorat. Kristel Gillespie, Ellen Endebrock, and Miguel Gabaldon assisted in the lab work and data preparation.

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INTRODUCTION

The pinyon-juniper (PJ) vegetation type covers much of the semiarid Southwest and at least 17 million hectares of North America (West 1988). It forms the transition zone between the typically overgrazed lower elevation grasslands and the higher elevation pine and fir forests. Pinyon-juniper areas are subjected to a variety of stresses including roads to higher elevations for timber, fuelwood harvest and livestock grazing. Because the PJ is subject to intense land-use pressures, it is important that land managers have as much information as possible about how the PJ will respond to these pressures.

One important aspect of these stresses is how they affect the movement of water and soil over the land surface. Ideal surface conditions would exist if all incident precipitation would infiltrate and the soil would not erode. In reality, water runs over the soil surface transporting soil particles, litter and nutrients. This loss of material reduces potential site productivity and can damage downslope areas through gullying or excess loadings of materials to water bodies. To understand the PJ's hydrologic function, controlled experiments must be conducted which measure key variables affecting that function. Specifically, parameters for infiltration and erosion which characterize the hydrologic function, and the site variables found in the PJ which influence the parameters, must be identified and quantified. With this information, scientists, managers, and engineers can make informed decisions as to the hydrologic effects of a given land-use practice.

Rainfall simulators are important for gathering data that can be analyzed to define the hydrologic and hydraulic characteristics of natural and disturbed lands. Information obtained from rainfall simulator experiments includes infiltration characteristics of the soil/vegetation complex, sediment yield/erosion parameters, and nutrient export indices. During the spring-summer period of 1989 and 1990, rainfall simulation experiments were conducted on selected soil-vegetation complexes in New Mexico and Arizona. Most sites were located in the PJ vegetation zone on soils derived from extrusive igneous rocks. Some sites were located under the canopy and others in the open rangelands at the canopy edge.

This report presents a summary and analyses of the data collected from the pinyon-juniper soil-vegetation complexes during the experiments. Comparisons are made among the sites and at the sites among different vegetation covers for different hydraulic and hydrologic characteristics. The information provided in this report should aid resource managers in policy formation related to land use and expand the data base needed by scientists and engineers for modeling complex water-soil-vegetation systems.

Goals and Objectives

This study's primary goal was to determine the magnitude of annual variation in infiltration and soil erosion parameters for a variety of soil-vegetation complexes in the PJ vegetation zone of western New Mexico and eastern Arizona. The parameters were determined so that they can be used in mathematical models of surface erosion being prepared for the interagency USDA - Water Erosion Prediction Project (WEPP). They were derived from field rainfall simulation experiments using two different small-area simulators (Seiger 1984; Endebrock 1990). Primary parameters included the hydraulic conductivity of soil, average capillary head in the soil during the experiment, soil porosity, soil moisture content, and soil splash/flow transport erosion.

Determination of these parameters alone does not help a potential user of the WEPP model unless the parameters can be functionally and statistically related to other site or soil characteristics such as rock cover, vegetative cover, soil texture, slope, or surface roughness. Still photographs and color video recordings (VHS) were taken of the sites and the experiments to document field conditions and other observations. These photographs and video tapes should prove useful in describing the sites and conditions to potential model users.

Specific objectives related to the overall goal of this study were to:

1. Use artificial rainfall simulation with a spray-down type simulator to collect water and material runoff from selected sites in the PJ.

2. Use the water runoff data to determine the infiltration rate of the soil; this was done by determination of parameters used in the Green-Ampt infiltration equation as implemented by the USDA Agricultural Research Service (ARS) in WEPP.

3. Use the sediment runoff data to develop a parameter, as described below, for splash/transport erosion, similar to a raindrop detachment coefficient.

4. Measure soil and surface conditions at the sites including soil gradation, soil moisture, soil porosity, cover, slope, and relative roughness.

5. Collect treated, preserved samples to determine the type and quantity of nutrient export from the sites, specifically, nitrogen, phosphorus, and organic solids.

6. Functionally and statistically relate soil and surface conditions to the parameters determined in objectives 3, 4, and 5 above and compare to 1988 results with data collected at the same sites.

7. Field test a modified version of the original simulator (Endebrock 1990).

8. Document the findings and observations with scientific reports, photographs and video tapes.

These objectives were met as detailed in this report.

Scope of Report

This report is a summary and analysis of rainfall-runoff and erosion data collected from five sites on range and forest lands using small area simulators. Primary data collection methods and techniques were presented previously in Ward (1986) and Ward and Bolin (1989a, 1989b) and are modified or reiterated in this report only as needed (Appendix A). This final report includes data analyses as related to the study's goals and objectives.

Previous Studies

In this study, rainfall simulation was used to gather runoff data from several small plots (1 meter by 1 meter) on soil-vegetation complexes at selected locations in New Mexico and Arizona. Rainfall simulation was used, because it allows the investigator to decided when and where runoff will take place. This is very important in the semiarid, PJ zone as timing and location of rainstorms producing significant runoff is completely random. Through simulation, a controlled volume of water can be delivered exclusively to the plots of interest. Using small plots increases the number that can be sampled and thus provides more information on the range of conditions that may be present in the PJ. Small plot simulators also require a smaller field crew and less water to operate than do large area simulators. Disadvantages of small plot simulators are that they: do not cover a large integrated area; tend to measure only the raindrop splash/transport of sediment; are more susceptible to edge effects; and, like large simulators, are not precisely matched to variations in rainfall intensities and energies.

Two general problems occur when trying to compare data from different simulators. First is the effect of scale. Wicks et al. (1988) used the small plot data of Devaurs and Gifford (1984) to estimate hydraulic conductivity for Agricultural Research Service (ARS) simulator experiments at Reynolds Creek, Idaho. Wicks et al. concluded that the average of the small plot data gave good results when used to model the behavior of the larger ARS plots. Previous work by Ward (1986) demonstrated how results from a small plot simulator were related to a Colorado State University type large-plot simulator. Results indicated that infiltration parameters were comparable between plots, but sediment yields per unit area (kg/ha) were higher for the small plots than for the large plots. It appears that the small plots are more controlled by splash/transport erosion (Serrag 1987), whereas the larger plots are more a combination of interrill splash/transport and concentrated flow in shallow rill channels. Although the total sediment mass (kg) for the large plots was higher, as expected, the contributing area was also much larger, thus reducing the per unit area yield (kg/ha). The factors controlling sediment yield for the big plots were more complicated and integrated than on the small plots.

A study by Ward and Bolin (1989a) related the results from the small simulator to results from the ARS rotating-boom simulator on selected ARS sites in New Mexico and Arizona. Findings confirmed those found in the Ward (1986) investigation, but indicated an even higher level of sediment yield per unit area for the small plots above that measured from the ARS plots. The difference in the 1986 study was about two to three times higher sediment yields per unit area for the small plots, whereas in the 1988 study (Ward and Bolin 1989a), the yields per unit area were about four times higher for the small plots.

The second general problem when comparing data from different simulators is developing an accurate and reliable method of measuring rainfall energy for simulators and natural storms. Tracy et al. (1984) show that kinetic energies for rainfall at the Walnut Gulch watershed are in excess of what would be computed from the Universal Soil Loss Equation (USLE) algorithm. Therefore, the approach used to scale the sediment yields based on the fraction of USLE energy is open to criticism. Until a better approach is suggested, that method will probably persist. Unfortunately, as Wicks et al. (1988) found, this may lead to large errors when trying to use simulator results to predict yields from field-sized (one hectare in this instance) plots.

Information on nutrient export from rangelands using rainfall simulation has provided a data base (e.g. Cole et al. 1986; Ward and Bolin, 1989b) to be used in examining relationships between vegetation complexes, nutrient export and sediment export. Bolton et al. (1990) found that export of phosphorus and volatile solids was a function of sediment export for all vegetation types studied.

Density of vegetative and rock cover usually affects plot response to rainfall, but not necessarily as one might expect. This is important because many beliefs based upon conventional wisdom can be hypothesized, tested and confirmed through scientific field tests. Studies of natural rainfall plots have found that differences in runoff may be difficult to detect between plots in arid regions. Cordery et al. (1983) report on runoff from small (25 square meters or about 270 square feet) natural rainfall plots in western New South Wales, Australia. Under some climatic conditions, systematic differences in runoff between plots were not evident despite differences in the plots' physical properties. Runoff from all of the plots was lower during a wet period with lush vegetation than during a dry period with sparse vegetation. The authors attributed this difference to the increased interception losses caused by denser vegetation.

Many studies in arid regions that have used rainfall simulators have shown significant differences in plot responses based on vegetative and soil surface conditions. Lane et al. (1987) found rock and gravel cover and canopy cover to be negatively correlated with runoff depth. Kincaid et al. (1964) also found shrub cover, grass and litter cover, and gravel cover to be negatively related to runoff. In contrast, some studies (e.g., Blackburn 1975; Tromble et al. 1974) found rock cover and erosion pavement to be positively related to runoff.

These studies and others that used rainfall simulators in arid and semiarid regions with low vegetative cover have found that cover (shrub canopy cover in particular) is an important factor in reducing runoff and erosion. However, other studies of runoff from natural rainfall plots indicate that differences due to vegetation cover and rock cover are difficult to detect. A rainfall simulator study (Bolin and Ward 1987; Bolton et al. 1990) at the Jornada Long Term Ecological Research (LTER) site north of Las Cruces supported the results of the natural rainfall plot studies at the same site regarding sediment yields. In that study, average water and sediment yields were not significantly different between plots with and without shrubs. The natural rainfall data set contained information from low energy storms only. This may help explain why statistical differences were not found between natural rainfall plots with different vegetation and soil characteristics.

At lower energies in a sparsely vegetated area like the Jornada LTER site, the role of rainfall energy predominates in determining runoff and sediment yield. At higher energy levels, a threshold is reached in terms of additional sediment yield from energy increases alone. It was noted that when simulated rainfall was applied at almost twice the normal rate, some differences appeared which could be attributed to plot cover characteristics. These results are supportive of Gifford's (1985) suggestion that vegetal cover may be of minimal importance in determining infiltration and erosion rates on some semiarid rangelands. He indicates erosion rates may be a complex function of plant-soil-storm characteristics that are not well understood. Gifford also suggests that cover density above about 50 to 60 percent has little effect on increasing infiltration or reducing erosion. Ward et al. (1990) confirm this observation with data from Ward and Bolin (1989b). It is in between the low cover situations like those found at the Jornada and the high cover situations as suggested by Gifford where cover improvements may improve infiltration and reduce soil erosion.

A related measure of surface conditions is "roughness" as measured with a point frame. This type of roughness is defined as the standard deviation of elevation measurements for the plot surface. Jorat (1991) has found that point frame roughness measured parallel to the direction of water flow can be correlated with flow resistance. This result may explain the findings of Sanchez and Wood (1987) relative to infiltration and sediment yield. The importance of surface roughness has been recognized by a WEPP study (Gilley et al. 1987), and numerous measurements were gathered during that study.

METHODOLOGY

Location of Sample Sites

Three sites sampled in this study were located in New Mexico and two were in Arizona (Figure 1.). The sites were, in order of sampling, Beaverhead, New Mexico; Springerville, Arizona; Heber, Arizona; White Oaks, New Mexico; and San Ysidro, New Mexico. Experiments were conducted at the Beaverhead and Springerville sites in 1988 (Ward and Bolin 1989b) on plots with natural vegetation and plots that had all vegetation scraped off. Then, in 1989, experiments were carried out on some of the same plots as in 1988. The same small area simulator as used in 1988 was used at the Beaverhead, Springerville and Heber sites. A newly built, modified design, small-area simulator was used at White Oaks and San Ysidro. The experiments were conducted between May 15 and June 10, 1989, at Beaverhead, Springerville and Heber, from May 14-15, 1990, at White Oaks and from June 25-28, 1990, at San Ysidro.

Beaverhead, New Mexico. The Beaverhead site was located north and east of the USDA Forest Service's Beaverhead Work Center in the Gila National Forest west of Truth or Consequences, New Mexico. The site is in a pinyon-juniper area and is adjacent to natural rainfall-runoff plots maintained by M. Karl Wood of the College of Agriculture and Home Economics, New Mexico State University. The simulator plots were located on the flanks of the ridges above the natural rainfall plots. The soils at the site have been described as Lithic Haplustalfs by Charles Souders

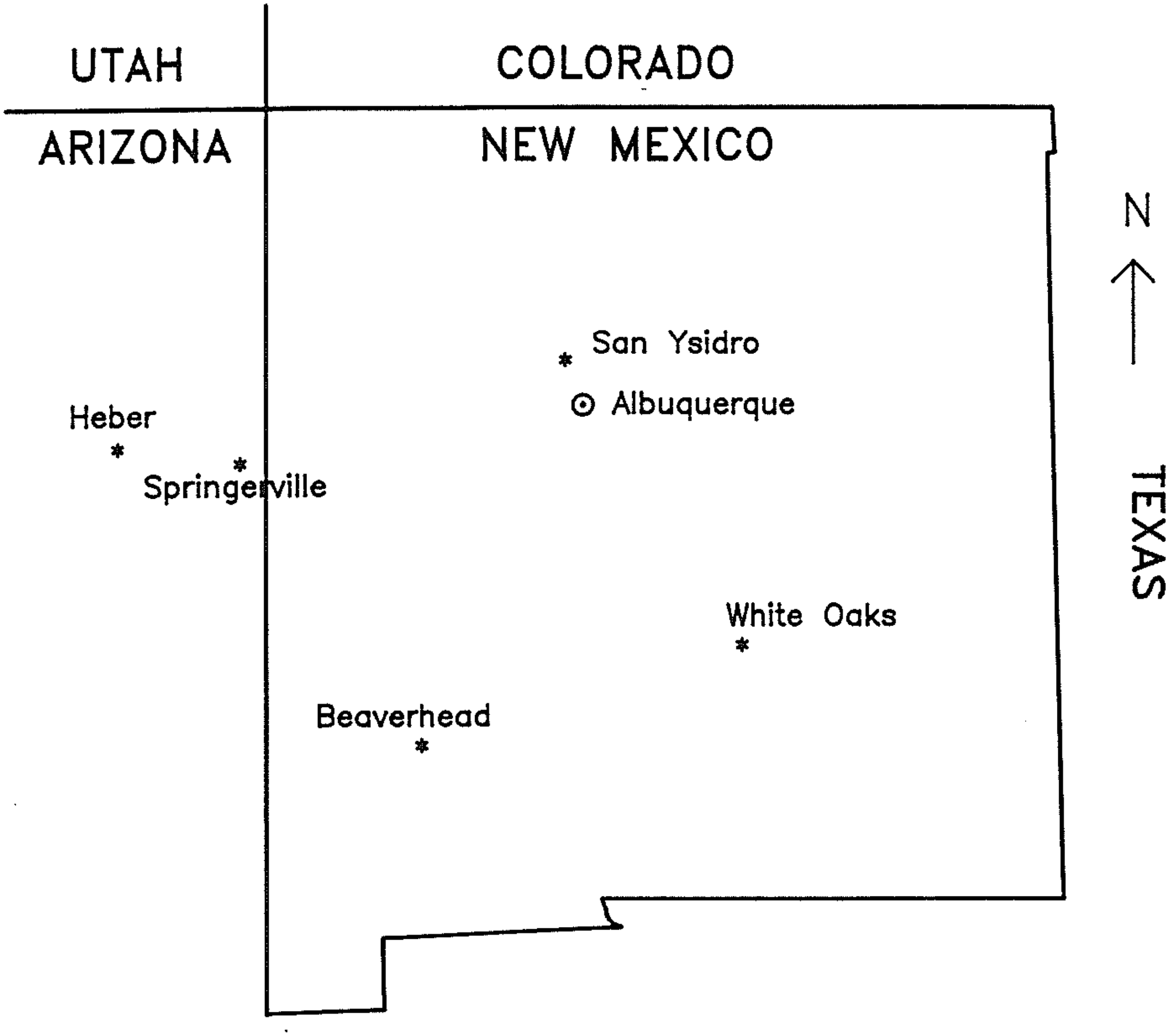

Fig. 1. Location of Sample Sites

(pers. com. 1988), soil scientist, Gila National Forest, Silver City, New Mexico. Elevation at the site is about 2280 meters.

Eighteen plots, located in Section 36, T.9S., R.12W. near the junction of forest roads 584 and 953, were rained upon in 1988. The twelve natural cover plots, (i.e. those not scraped in 1988) were rained upon again in 1989. Of the twelve plots, six were placed in "high" vegetative cover (based on visual estimates), six in "low" cover. Data on twenty-four plot-runs were collected at this site.

Springerville, Arizona. The Springerville site was located south of Springerville, Arizona, in Section 14, T.8N., R.29W. on the Apache-Sitgreaves National Forest. Site elevation is about 2240 meters. Of the eighteen plots rained upon in 1988, twelve were rained upon again in 1989. Four were under the canopy and eight were in the rangeland on the edge of the canopy. The plots were equally divided into the two groups as used at Beaverhead: high and low vegetative cover. Data on twenty-four plot-runs were collected during the experiments. These plots were adjacent to USDA Forest Service WEPP paired-plots.

Heber, Arizona. A site near Heber was rained upon in 1988, but in 1989 the experiments were conducted at a new site closer to the large WEPP plots installed by the USDA Forest Service. Fourteen plots were rained upon at the new site in an area north and west of Heber, Arizona, in Section 27, T.13N., R.17E. The site is in the Apache-Sitgreaves National Forest at an elevation of about 2000 meters. Because this was a new site, plots with the cover scraped off were installed in order to have a complete comparison to the 1988 data. Unlike 1988, screens were not used on the bare plots in 1989 to evaluate the effect of raindrop impact. Of the fourteen plots, four had natural grass cover, three were in pinyon pine litter, three were in juniper litter, and four plots were scraped bare of vegetation. Data on 28 plot-runs were collected during the experiments.

White Oaks, New Mexico. This site is near the town of White Oaks about 14 miles northeast of Carrizozo. The site is in the Lincoln National Forest, Section 22, T.6S, R.12E. at an elevation of about 2200 meters. Three plots were placed in areas that had been burned the previous year and three plots were placed in unburned areas. Data on 12 plot-runs were collected at this site. All plots were within the pinyon-juniper canopy.

San Ysidro, New Mexico. This site is about 10 miles south of San Ysidro and 9.4 miles west of the Zia Pueblo near natural rainfall-runoff plots maintained by Earl Aldon of the USDA Forest Service, Albuquerque (Scholl and Aldon 1988). The plots are located within the Jemez River basin at an elevation of about 1850 meters in Section 6, T.14N, R.1E. The plots are in an open rangeland with scattered PJ vegetation. Four plots were placed in Querencia soils and 4 plots in San Mateo soils. A total of 16 plot-runs were conducted at this site.

Procedures

Procedures generally conform to those followed and reported in Ward (1986) and Ward and Bolin (1989b) (Appendix A). For this study, new experiments and measurements were added to supplement those used previously. Unlike the 1988 study (Ward and Bolin

1989b), plots were scraped only at Heber. The experiments at Beaverhead and Springerville involved the same natural cover plots as were used in 1988 in order to assess annual variability in hydrologic parameters. Cover and roughness were measured as in 1988 using a point frame device (see Appendix A).

During 1989 and 1990, a new, modified small-area simulator was designed and built which was field tested during the 1990 field season. This simulator is portable and provides more flexibility in gaining access to a wider variety of locations. For more information on the design and features of this rainfall simulator, see Ward et al. (in preparation).

Derivation of Parameters

Selected parameters were derived from the data using statistical and numerical techniques. For infiltration, the key model parameters are steady-state infiltration rate and a soil water parameter such as capillary suction. These values can be determined from rainfall rate and measured runoff. In the reports by Ward (1986) and Ward and Bolin (1989b), the hydraulic conductivity (infiltration) was found from either a least squares fit of the incremental loss rate and the reciprocal of the infiltrated depth or, if this method yielded unreasonable results, by averaging the last few steady loss rates. It is now thought that averaging the last few steady loss rates yields the most appropriate estimate of steady-state infiltration rate. This rate, however, is not equivalent to saturated hydraulic conductivity in most cases. The capillary suction parameter was derived from the least squares parameters, the appropriate loss rate (steady infiltration rate), and soil characteristics of porosity and saturation. Ward and Bolin (1989b) also used a numerical technique to determine capillary suction when the least squares approach yielded unrealistic results. This method was employed as needed and provided reasonable results for capillary suction in most cases. However, there were certain instances when, given variations in the data or the small magnitude of "a", the method did not converge. In those cases, a direct trial and error procedure was employed. This procedure for estimating capillary suction when other techniques fail has some advantages and some disadvantages as discussed in Ward and Bolin (1989b).

Erosion on overland flow surfaces occurs when there is sufficient kinetic energy to dislodge and move the soil materials. The two sources of kinetic energy present in simulator studies are from raindrop impact and overland flow. Raindrop impact works by dislodging particles and transporting them relatively short distances in splash water. In the absence of overland flow, splash is an inefficient transport mechanism. Overland flow, specifically sheet and rill flow, typically has lower energy for detachment, but is more efficient at transporting sediment. In combination, the two energy inputs provide an effective method of soil erosion. It is difficult to separate precisely the two processes when analyzing soil erosion data. Instead, a balance between the two is found by analyzing data from different rainfall intensity and overland flow rate experiments. This is a primary reason for conducting a series of experiments at a site.

For determining surface erosion, the key parameters are raindrop splash detachment and overland flow detachment coefficients. Of primary importance for the small area simulator experiments is the raindrop splash erosion/transport parameter (Ward 1986; Ward and Bolin 1989b). That parameter was determined following the procedures outlined by Ward (1986).

The remainder of this report is dedicated to data presentation and analyses. Of interest are the comparisons of plot responses between sites, among the plots at a site, and between years for the different types of experiments.

RESULTS AND ANALYSES

Data collected from the different sites were reduced, analyzed and summarized. The results, as presented in the following sections, are compared among the sites in order to identify differences and similarities in the hydrologic functions between areas. The results also provide a basis for relating the small plot data to WEPP requirements. The following conversions apply in the discussions: 25.4 mm = 1 inch, 1 kilogram force) = 2.205 pounds, 1 kilogram (force)/hectare = 0.893 pounds/acre, 1 kilogram force/hectare-mm (unit area yield per unit of runoff depth) = 22.682 tons/acre-in. The units of kg (force)/hectare-mm are equivalent to the units of mg/L divided by 100.

Site Characteristics

Tables 1 and 2 list summarized site measurements for the simulator plots. Means and standard deviations of each measured variable were determined from the data listed in Appendices B and C. Most information in these tables is self-explanatory. Gradation was determined by dry and wet sieving samples and by using hydrometer analysis to determine the silt-clay division of the dry material which passed a #200 sieve (0.075 mm). Wet sieving involves using water to rinse the soil through a stack of sieves. Particles passing a #200 sieve are washed away. A higher percent of fine materials is expected when using wet sieve techniques because water and gravity combined do a more thorough job of removing fine particles attached to larger particles and breaking down aggregates, than does simply shaking the sample. In the past, only dry sieving was done to facilitate

TABLE 1

Means and Standard Deviations (in parentheses) of Plot Characteristics for Each Site

Site	#	Cover	Poros %	Slope (degrees)	Canopy Cover %	Organic Cover %	Rock Cover %	Rough-ness (cm)	Amc	
									Dry %	Wet %
BH	6	L	40.2	2.8	13.3	37.1	4.4	0.29	3.6	16.9
			(4.2)	(0.6)	(9.5)	(10.1)	(6.5)	(0.06)	(2.2)	(3.5)
BH	6	H	38.7	2.8	26.2	58.2	2.4	0.36	3.5	15.4
			(5.4)	(0.9)	(14.6)	(8.7)	(3.2)	(0.03)	(2.3)	(3.0)
HB	4	B	33.9	4.5	0.0	0.0	0.0	0.22	2.0	14.3
			(7.7)	(2.7)	(0.0)	(0.0)	(0.0)	(0.06)	(0.8)	(8.1)
HB	2	L	20.8	4.8	25.4	26.6	2.6	0.44	0.6	8.6
			(8.0)	(0.4)	(1.9)	(3.7)	(1.9)	(0.01)	(0.2)	(1.1)
HB	2	H	40.6	2.5	39.4	54.7	0.6	0.49	2.6	16.9
			(0.0)	(0.0)	(0.9)	(17.0)	(0.9)	(0.03)	(0.0)	(1.1)
HB	3	J	46.2	5.7	0.0	100.0	0.0	0.63	4.3	21.2
			(11.5)	(0.6)	(0.0)	(0.0)	(0.0)	(0.06)	(2.6)	(7.9)
HB	3	P	58.5	6.8	1.3	100.0	0.0	0.70	6.4	16.2
			(2.7)	(3.2)	(1.4)	(0.0)	(0.0)	(0.09)	(2.5)	(8.1)
SP	6	L	33.7	5.1	30.2	32.7	8.0	0.33	3.0	16.3
			(7.2)	(2.4)	(11.0)	(11.8)	(9.9)	(0.05)	(0.6)	(2.0)
SP	6	H	37.6	5.6	42.2	60.4	1.3	0.36	2.8	18.4
			(6.8)	(1.0)	(33.2)	(13.2)	(2.7)	(0.06)	(0.7)	(2.8)
WO	3	F	56.5	2.5	0.0	0.0	0.0	*	10.4	20.5
			(12.4)	(0.0)	(0.0)	(0.0)	(0.0)	*	(4.2)	(1.7)
WO	3	N	45.8	2.7	32.0	54.7	0.0	0.38	3.5	16.7
			(2.7)	(0.8)	(10.1)	(17.4)	(0.0)	(0.06)	(0.1)	(3.1)
SY	4	Q	34.3	4.8	*	45.0	*	*	1.4	14.0
			(5.2)	(0.3)	*	(4.1)	*	*	(0.1)	(1.1)
SY	4	M	44.2	2.4	*	25.2	*	*	1.9	16.9
			(4.8)	(0.6)	*	(13.0)	*	*	(0.2)	(2.4)

Amc = antecedent soil moisture
BH = Beaverhead; HB = Heber; SP = Springerville; WO = White Oaks; SY = San Ysidro
# - number of plots at each location
* - data not collected
Cover is the assigned cover categories, B=bare, L=low cover, H=high cover, F=burned plots, N=natural plots, P=pinyon litter, J=juniper litter, Q=Querencia soils, M=San Mateo soils.

Note: Organic cover is basal vegetation, cryptogams and litter.
Rock cover is rock and gravel cover.
Roughness is the mean standard deviation in point frame pin heights across and down the plot in centimeters.

TABLE 2

Means and Standard Deviations (in parentheses) of Soil Gradations for Each Site

			DRY SIEVING				WET SIEVING			
Site	#	Cover	Gravel %	Sand %	Silt %	Clay %	Gravel %	Sand %	Silt %	Clay %
BH	6	L	16.5	70.0	11.3	2.2	14.5	52.5	27.5	5.4
			(2.1)	(4.5)	(2.2)	(0.3)	(5.1)	(8.3)	(5.7)	(1.4)
BH	6	H	16.5	70.0	11.3	2.2	14.5	52.5	27.5	5.4
			(2.1)	(4.5)	(2.2)	(0.4)	(5.1)	(8.3)	(5.7)	(1.4)
HB	4	B	26.2	62.5	9.6	1.6	20.0	48.5	26.8	4.8
			(6.5)	(2.2)	(3.4)	(0.8)	(10.1)	(12.3)	(18.6)	(3.8)
HB	2	L	31.9	60.6	6.7	0.9	31.9	60.6	6.7	0.9
			(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
HB	2	H	20.6	64.4	12.6	2.4	11.1	37.8	43.0	8.1
			(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
HB	3	J	13.1	72.6	11.9	2.4	20.8	44.9	28.1	6.1
			(4.6)	(3.5)	(1.6)	(0.5)	(13.6)	(22.2)	(5.8)	(2.8)
HB	3	P	19.4	68.1	10.0	2.5	30.5	35.9	26.8	6.8
			(6.2)	(4.3)	(1.7)	(0.3)	(3.3)	(6.7)	(8.2)	(1.7)
SP	6	L	28.7	63.9	6.0	1.4	17.0	49.2	27.2	6.6
			(15.9)	(13.0)	(2.5)	(0.5)	(6.1)	(4.4)	(1.9)	(0.7)
SP	6	H	28.7	63.9	6.0	1.4	17.0	49.2	27.2	6.6
			(15.9)	(13.0)	(2.5)	(0.5)	(6.1)	(4.4)	(1.9)	(0.7)
WO	3	F	2.4	76.4	17.4	3.8	4.7	40.2	45.1	9.9
			(3.4)	(5.7)	(4.0)	(0.9)	(7.3)	(5.3)	(5.6)	(1.8)
WO	3	N	0.1	78.0	18.9	3.0	0.1	42.9	49.0	7.9
			(0.1)	(4.7)	(4.6)	(0.3)	(0.2)	(1.3)	(2.7)	(1.6)
SY	4	Q	0.0	72.5	22.6	4.8	0.0	63.0	30.5	6.5
			(0.0)	(0.5)	(0.7)	(0.2)	(0.0)	(3.5)	(3.4)	(0.2)
SY	4	M	0.1	84.0	12.7	3.2	1.0	58.5	32.2	8.3
			(0.0)	(3.3)	(3.3)	(0.0)	(0.4)	(1.9)	(3.1)	(1.5)

BH = Beaverhead; HB = Heber; SP = Springerville; WO = White Oaks; SY = San Ysidro
\# - number of plots at each location

Cover is the assigned cover categories, B=bare, L=low cover, H=high cover, F=burned plots, N=natural plots, P=pinyon litter, J=juniper litter, Q=Querencia soils, M=San Mateo soils.

comparisons with other studies which typically use dry sieving methods.

Gravel percent is the average percent by total sample weight of particles larger than 4.75 mm in diameter. Sand represents the size fraction between 4.75 mm and 0.075 mm, and fines are less than 0.075 mm in size. The silt fraction is defined to be between 0.075 mm and 0.002 mm. The clay fraction is below 0.002 mm in size. Dry and wet AMCs are the antecedent moisture contents on a dry weight basis sampled just prior to the rainfall application.

Soil Gradation Comparisons- Dry vs. wet sieving

Differences in soil textures based on dry versus wet sieving were examined. At all sites except Springerville, the two techniques resulted in different percentages of textures for all classes except gravels. At Springerville, all classes including gravel were different between dry and wet sieving. Typically the wet sieving method decreased sand percentages and increased silt and clay percentages.

Among sites, dry sieving. San Ysidro and White Oaks had the least gravel, Beaverhead and Heber had moderate amounts of gravel and Springerville had more gravel than the other sites. The sites had significant overlap in sand content. Springerville and Heber had the lowest amounts of sand and White Oaks and San Ysidro had the highest amount of sand. Springerville soils had lower silt content than the other sites. Heber and Beaverhead had intermediate amounts of silt and White Oaks and San Ysidro had higher silt content that the other sites. Clay content of the soil and the ratio of fines to sand followed the same pattern as the silt contents.

Among sites, wet sieving. San Ysidro and White Oaks had lower gravel content in the soil than the other sites. Beaverhead and Springerville had intermediate gravel content and Heber had higher gravel content than the other sites. The sand fraction was low at White Oaks, Heber and Springerville. Sand content at Springerville and Beaverhead was similar and San Ysidro had more sand than the other sites. Silt content was similar at all sites except White Oaks which had significantly more silt. Clay fractions overlapped among sites with Beaverhead, Heber and Springerville having the lowest fractions and San Ysidro and White Oaks having the most clay. The ratio of fines to sand was similar at all sites except White Oaks where the ratio was higher than at the other sites.

Results from Rainfall Experiments

Table 3 lists the summarized results of the rainfall experiments at the five sites. Plots at each site were assigned to different cover categories. For the repeat sites at Beaverhead and Springerville, plots were assigned the same perceived cover category as in 1988, i.e., high or low cover. At Heber there were five plot cover categories: high, low, pinyon-pine litter, juniper litter, or scraped bare of vegetative cover. At White Oaks, plots either had all vegetation burned off or had natural vegetation. At San Ysidro, plots were not separated by vegetation characteristics, but rather as being situated either

TABLE 3

Means and Standard Deviations (in parentheses) of Rainfall and Runoff Characteristics for Each Site

Site	#	Cover	Intensity (mm/hr)		Duration of Rain (min.)		Runoff (mm)		Runoff/Rainfall (percent)	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BH	6	L	88.5	88.7	31.4	20.8	10.2	13.6	27.0	46.2
			(5.8)	(3.1)	(12.5)	(5.3)	(4.4)	(2.8)	(16.7)	(12.7)
BH	6	H	88.4	89.7	23.8	18.0	6.4	8.0	18.5	29.9
			(3.7)	(1.2)	(5.1)	(1.4)	(2.2)	(2.8)	(6.3)	(11.4)
HB	4	B	88.0	87.9	31.8	22.3	21.9	23.0	47.5	69.5
			(3.2)	(2.9)	(4.6)	(6.4)	(1.9)	(7.8)	(7.1)	(7.4)
HB	2	L	89.0	91.3	23.4	18.1	11.2	14.1	32.5	51.4
			(3.2)	(2.8)	(0.8)	(1.5)	(0.2)	(0.5)	(2.9)	(4.2)
HB	2	H	90.0	90.7	28.8	16.9	13.0	14.8	29.6	57.6
			(1.9)	(2.5)	(9.0)	(1.2)	(5.3)	(1.3)	(3.7)	(0.5)
HB	3	J	87.1	89.4	50.2	34.5	4.0	18.7	5.1	36.2
			(1.6)	(2.1)	(16.9)	(5.4)	(4.5)	(7.5)	(4.5)	(13.8)
HB	3	P	92.2	91.0	28.3	28.4	9.9	15.7	22.6	36.8
			(2.7)	(1.4)	(5.5)	(9.9)	(11.7)	(8.2)	(25.4)	(17.7)
SP	6	L	85.6	90.8	26.2	22.2	12.6	17.4	33.7	52.3
			(5.1)	(2.3)	(4.2)	(4.4)	(5.8)	(2.4)	(14.4)	(8.3)
SP	6	H	81.3	89.6	36.6	20.3	10.2	10.0	22.8	31.8
			(6.3)	(4.1)	(15.4)	(1.7)	(6.9)	(5.8)	(17.0)	(15.0)
WO	3	F	87.5	90.0	30.9	22.5	20.4	25.0	54.9	74.8
			(2.8)	(1.2)	(22.0)	(1.2)	(4.6)	(4.0)	(20.6)	(14.4)
WO	3	N	91.4	92.7	29.6	18.3	20.6	17.8	45.5	64.1
			(6.6)	(2.2)	(12.3)	(4.4)	(10.6)	(2.1)	(5.3)	(6.3)
SY	4	Q	82.6	83.0	35.5	31.4	13.3	21.7	27.6	49.9
			(2.3)	(2.4)	(6.8)	(1.4)	(2.8)	(2.5)	(4.8)	(4.5)
SY	4	M	83.1	82.8	25.5	31.4	21.2	34.6	60.5	79.4
			(3.4)	(4.1)	(4.8)	(6.5)	(4.9)	(8.4)	(9.8)	(6.9)

BH = Beaverhead; HB = Heber; SP = Springerville; WO = White Oaks;
SY = San Ysidro
# - number of plots at each location

Cover is the assigned cover categories: B=bare, L=low cover, H=high cover, J = Juniper litter, P = Pinyon Pine litter, F = burned, N = natural, Q = Querencia soils, M = San Mateo soils.

Note: For BH and SP the number of plot runs for the wet runs is 5 not 6 due to equipment trouble.

in Querencia or San Mateo soils. Individual small plot measurements are listed in Appendix D for the five sites.

Runoff to Rainfall Ratios - Within Sites. Comparisons were made at each site among the different cover types. At sites with only two cover levels, t-tests were used and homogeneity of variances were checked. Heber had five levels of cover so a least squares means test was used there to test for differences among cover types.

At Beaverhead, even though the low cover plots had higher runoff to rainfall ratios, there was no significant difference between the ratios for either dry or wet runs. At Springerville, there was no statistical difference between the low and high cover plots with respect to runoff to rainfall ratios on the dry runs, but the low plots had significantly higher ratios on the wet runs. The burned plots at White Oaks had higher mean runoff to rainfall ratios but the differences were not statistically significant for the dry or wet runs. At San Ysidro the San Mateo soils had significantly higher runoff to rainfall ratios than the Querencia soils for dry and wet runs. The Heber dry runs showed considerable overlap in runoff to rainfall ratios among the five cover types. Juniper and pinyon litter plots and the high cover plots had statistically the same runoff to rainfall ratios. The pinyon litter, high and low cover plots were not significantly different and the high, low, and bare plots were not different. At Heber, for the wet runs, the litter plots and the high and low cover plots had statically the same runoff to rainfall ratios and the low, high and bare plots were not statistically different.

Runoff to Rainfall Ratios - Among Sites. Plots that were scraped bare of vegetation or were burned were not included in comparisons among sites. A paired difference t-test indicated a significantly higher ratio of runoff to rainfall from the wet runs than from the dry runs. Further analyses of runoff to rainfall ratios were conducted on dry runs and wet runs separately. A least squares means test was conducted to examine the differences in the runoff to rainfall ratio among the five sites.

For the dry runs, considerable overlap among sites in runoff to rainfall ratios was found. The sites were not all statistically the same but all sites overlapped with at least one other site. Results were a little clearer from the wet runs where the runoff to rainfall ratios were statistically the same from Beaverhead, Springerville, and Heber. Runoff from San Ysidro, White Oaks and Heber were also statistically the same.

Sediment Yields - Within Sites. Table 4 is a summary of the sediment yields collected with the small simulator. Individual plot data is presented in Appendix E. The yields are reported in weight per area and weight per area per unit depth of runoff. The latter values are equivalent to concentrations in mg per liter divided by 100 and are calculated to remove the effects of runoff energy from the yields. Suspended yields are sampled from the pumped runoff water while deposited yields are comprised of those sediments which were deposited on the runoff tray or in the runoff trough. The filtered sample technique was used to determine sediment concentrations for these sediment measures

TABLE 4

Means and Standard Deviations (in parentheses) of the Components of Sediment Yield for Each Site

Site	#	Cover	Runoff (mm)		Suspended Yield (kg/ha)		Suspended Conc. (kg/ha/mm)		Deposit (kg/ha)		Deposit (kg/ha/mm)	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BH	6	L	10.2	13.6	71.7	93.3	6.0	7.5	200.0	184.7	19.2	12.5
			(4.4)	(2.8)	(65.4)	(132.3)	(4.5)	(10.8)	(214.5)	(197.8)	(19.6)	(17.4)
BH	6	H	6.4	8.0	35.1	38.8	5.8	4.8	124.2	142.2	19.5	17.9
			(2.2)	(2.8)	(16.8)	(18.8)	(2.4)	(1.8)	(46.8)	(91.9)	(5.7)	(6.0)
HB	4	B	88.0	87.9	998.7	939.7	45.9	35.3	3812.1	4846.4	176.0	215.9
			(3.2)	(2.9)	(793.8)	(1172.1)	(36.0)	(37.3)	(2025.2)	(2304.5)	(95.6)	(71.9)
HB	2	L	11.2	14.1	89.5	53.9	7.9	3.8	743.7	564.6	66.0	40.3
			(0.2)	(0.5)	(11.0)	(2.2)	(0.8)	(0.3)	(142.6)	(214.8)	(11.4)	(16.4)
HB	2	H	13.0	14.8	189.8	212.2	15.7	14.7	928.7	812.6	65.0	54.1
			(5.3)	(1.3)	(15.0)	(77.0)	(5.3)	(6.6)	(767.8)	(395.4)	(32.7)	(21.9)
HB	3	J	4.0	18.7	5.8	50.9	3.4	2.5	45.3	358.6	13.7	18.2
			(4.5)	(7.5)	(6.2)	(71.1)	(3.6)	(3.2)	(40.3)	(370.3)	(16.7)	(16.2)
HB	3	P	9.9	15.7	48.2	36.3	3.4	2.6	46.5	122.6	9.1	9.8
			(11.7)	(8.2)	(69.7)	(30.6)	(2.0)	(1.7)	(25.8)	(70.7)	(7.6)	(6.3)
SP	6	L	12.6	17.4	188.2	236.1	20.0	13.6	857.9	521.7	80.7	34.3
			(5.8)	(2.4)	(156.6)	(247.3)	(19.7)	(13.8)	(329.0)	(358.8)	(46.5)	(21.0)
SP	6	H	10.2	10.0	53.1	80.6	6.6	9.5	444.5	376.3	63.4	43.2
			(6.9)	(5.8)	(18.0)	(37.1)	(2.8)	(5.0)	(253.2)	(161.5)	(57.9)	(7.9)
WO	3	F	20.4	25.0	1168.2	993.3	59.5	39.3	7689.5	8113.4	404.7	312.9
			(4.6)	(4.0)	(857.6)	(406.5)	(43.4)	(14.5)	(3949.5)	(5824.3)	(274.8)	(183.2)
WO	3	N	20.6	17.8	534.1	354.9	26.3	20.1	2238.5	957.0	108.8	54.0
			(10.6)	(2.1)	(279.0)	(34.7)	(11.5)	(2.9)	(1707.9)	(683.3)	(97.1)	(40.9)
SY	4	Q	13.3	21.7	220.5	319.3	17.2	14.9	2838.8	2300.5	210.2	109.5
			(2.8)	(2.5)	(30.0)	(81.5)	(4.4)	(4.2)	(2135.6)	(1262.2)	(144.7)	(64.5)
SY	4	M	21.2	34.6	684.8	1015.4	33.2	28.4	2224.6	3055.8	103.2	93.8
			(4.9)	(8.4)	(157.5)	(443.7)	(8.4)	(6.6)	(1362.8)	(1032.7)	(56.2)	(47.9)

Total yields are found by adding suspended and deposit values.

BH = Beaverhead; HB = Heber; SP = Springerville; WO = White Oaks; SY = San Ysidro
\# - number of plots at each location

Cover is the assigned cover categories: B=bare, L=low cover, H=high cover,
J = Juniper litter, P = Pinyon Pine litter, F = burned, N = natural,
Q = Querencia soils, M = San Mateo soils.

Note: For BH and SP the number of plot runs for the wet runs is 5 not 6 due to equipment trouble for all sediment parameters except deposited yield.

(Ward and Bolin, 1989b). Values were log-transformed for analysis. The log-transformed values were tested and found to be normally distributed and thus met the assumptions of the statistical tests.

A paired difference t-test was used to compare the dry run and wet run sediment yields. At Beaverhead, there were no significant differences between dry run and wet run sediment yields, total, suspended or deposited. For Heber, differences were found for suspended yield per mm of runoff only. At Springerville, differences existed for deposited yield. At White Oaks, only suspended sediment yield differed significantly from dry to wet runs. At San Ysidro, differences existed only for total yield per mm of runoff.

At all sites, except Heber, cover conditions were compared with a t-test for differences in total sediment yield from the cover types. Because there are more than two cover types at Heber, a t-test could not be used and a least squares means test was used to test for differences in total sediment yield from the five cover types. Since few significant differences were found in total yield between the dry and wet runs, the analyses was not split by moisture condition.

At Beaverhead, there were no significant differences in the total sediment concentrations (kg/ha/mm of runoff) or yields (kg/ha) from the high and low cover plots. At Springerville, the total sediment yields were significantly higher from the low cover plots but there was no difference in total sediment concentrations between the high and low cover plots. At Heber, the total sediment concentrations and yields were significantly lower from the pinyon pine and juniper litter plots compared to the other cover types. Sediment yields and concentrations were not significantly different from the low and high cover plots. The bare plots had significantly higher total sediment yields and concentrations than the other plots. At White Oaks, the burned plots had significantly higher total sediment yields and concentrations than the unburned plots. There were no significant differences in sediment yields or concentrations from the two soil types at San Ysidro.

Sediment Yields - Among Sites. A least squares means test was conducted on log-transformed values of the sediment yields to test for differences among sites. Suspended sediment yields and concentrations were significantly lower at Beaverhead than at the other sites. White Oaks and San Ysidro had significantly higher suspended sediment yields and concentrations than the other sites. Suspended sediment yields and concentrations were statistically the same between Heber and Springerville.

Deposited yields and concentrations were significantly lower at Beaverhead compared to the other sites. San Ysidro had significantly higher deposited yields that the other sites and San Ysidro and White Oaks had statistically higher deposited concentrations than the other sites.

Beaverhead had statistically lower total sediment yields and concentrations than the other sites. White Oaks and San Ysidro had the highest total sediment yields and concentrations. Figure 2 shows the mean and range of total sediment concentration

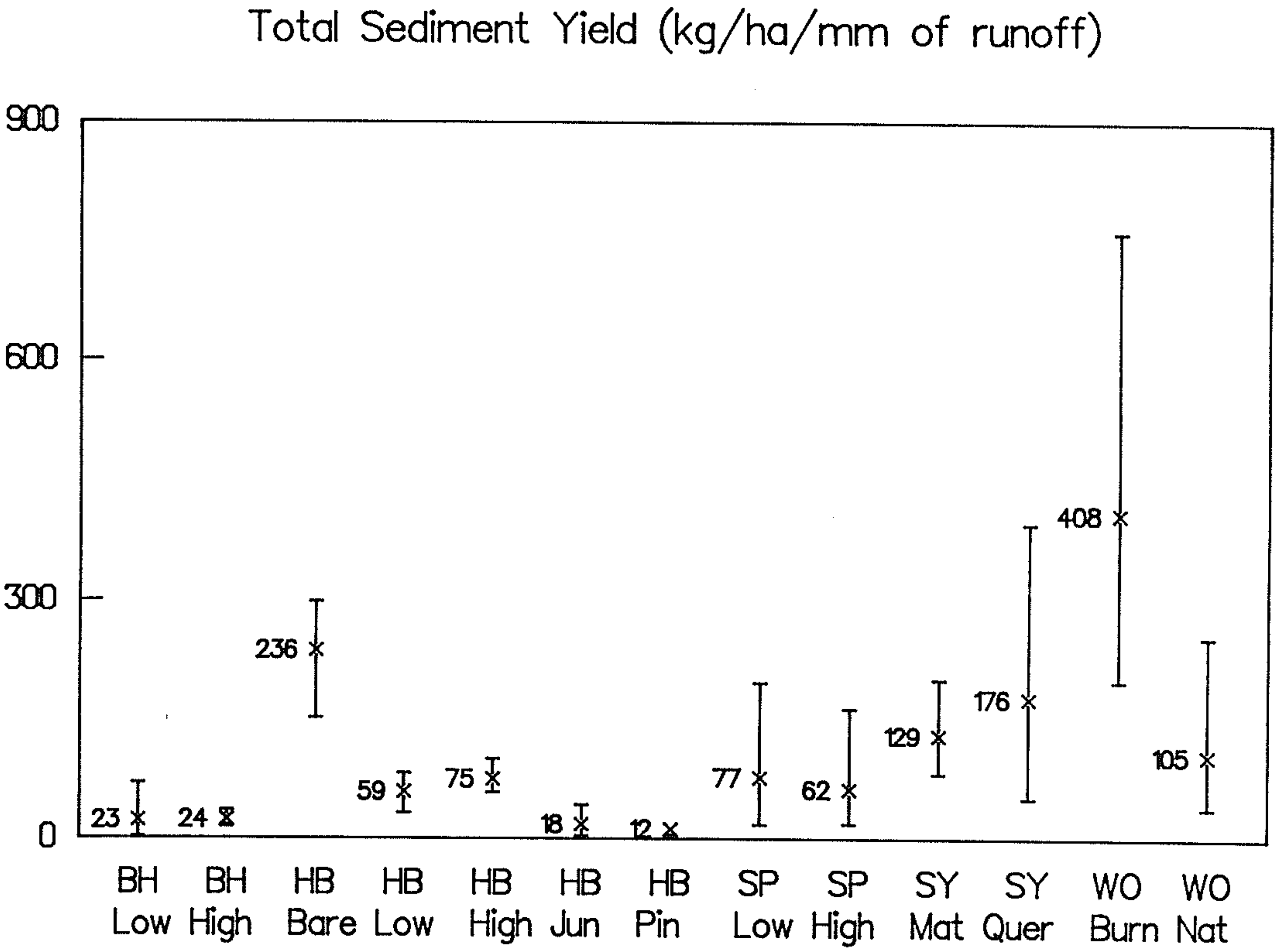

Fig. 2. Mean and Range of Total Sediment Concentrations

from each site and cover type. Findings from Ward and Bolin (1989a) indicate that yields determined from the small simulator should be scaled down by a factor of 3.5 to 5 (depending on the energy adjustment) to be more comparable with the WEPP simulator.

Infiltration Characteristics-Within Sites. For the small plots, hydraulic conductivity (infiltration) and capillary head were derived from the runoff data as detailed in the methodology section. Table 5 lists means and standard deviations for derived infiltration parameters.

Small plot data indicate that the estimated average value of hydraulic conductivity (steady-state infiltration or loss rate) decreases between dry and wet runs. The capillary head is extremely variable and at the sampled sites may increase or decrease with the antecedent moisture condition. Paired difference t-tests were performed on the infiltration and capillary head values between the soil moisture conditions. There were significant differences in infiltration rates at all sites between dry and wet runs. Although average capillary heads values were typically higher on the wet runs, the differences were significant only at San Ysidro. The dry-run infiltration rates are higher while the capillary heads are lower, and for wet-runs, infiltration rates are lower and capillary heads are higher. It should be noted, however, that the confidence in the derived capillary head values is very low compared to the other values determined in this study. Differences in the capillary heads may be artifacts arising from the particular method of data analysis. As with the sediment analyses, t-tests are used for

TABLE 5

Means and Standard Deviations (in parenthesis) of Derived Infiltration and Erosion Parameters for Each Site

			Steady Infiltration Rate (mm/hr)		Derived Capillary Head (mm)		Splash Coefficient (kg-hr/ha-sq.mm)	
Site	#	Cov	Dry	Wet	Dry	Wet	Dry	Wet
BH	6	L	55.0	31.9	9.0	37.9	0.21	0.27
			(16.4)	(7.5)	(9.1)	(49.6)	(0.22)	(0.37)
BH	6	H	67.1	57.7	2.1	3.6	0.20	0.26
			(9.6)	(15.6)	(2.6)	(5.7)	(0.08)	(0.13)
HB	4	B	27.6	19.7	19.3	51.4	1.16	2.00
			(7.9)	(4.0)	(8.7)	(92.2)	(0.24)	(0.48)
HB	2	L	44.9	31.0	6.3	10.1	0.52	0.46
			(1.6)	(4.7)	(5.5)	(11.7)	(0.12)	(0.13)
HB	2	H	43.8	22.8	17.4	19.4	0.61	1.03
			(5.5)	(3.0)	(1.6)	(15.6)	(0.10)	(0.15)
HB	3	J	72.9	31.1	8.4	110.3	1.13	7.90
			(9.2)	(15.0)	(11.3)	(52.7)	(1.12)	(7.18)
HB	3	P	66.2	43.6	1.8	13.3	2.34	4.92
			(29.3)	(24.8)	(2.8)	(11.8)	(2.25)	(4.27)
SP	6	L	42.4	36.6	6.0	13.1	0.70	0.60
			(17.5)	(18.6)	(4.3)	(15.4)	(0.36)	(0.52)
SP	6	H	56.2	51.9	2.7	10.1	0.42	0.58
			(17.1)	(6.2)	(3.7)	(4.4)	(0.26)	(0.31)
WO	3	F	34.0	19.7	0.6	5.0	2.95	3.03
			(25.9)	(15.7)	(0.8)	(8.1)	(2.03)	(1.99)
WO	3	N	33.3	17.6	10.0	8.7	1.29	1.10
			(4.0)	(4.4)	(8.0)	(6.4)	(0.48)	(0.28)
SY	4	Q	48.3	28.7	10.6	39.7	1.35	1.36
			(6.2)	(1.8)	(1.6)	(30.1)	(0.87)	(0.73)
SY	4	M	23.0	10.5	4.3	28.7	1.30	1.57
			(8.9)	(5.6)	(2.4)	(40.2)	(0.46)	(0.56)

BH = Beaverhead; HB = Heber; SP = Springerville; WO = White Oaks;
SY = San Ysidro
\# - number of plots at each location

Cover is the assigned cover categories: B=bare, L=low cover, H=high cover, J = Juniper litter, P = Pinyon Pine litter, F = burned, N = natural, Q = Querencia soils, M = San Mateo soils.

Note: For BH and SP the number of plot runs for the wet runs is 5 not 6 due to equipment trouble.

those sites with two cover types and least squares means tests are used at Heber where there are five cover types.

At Heber, the pinyon pine and juniper litter plots had significantly higher infiltration rates on the dry runs than the bare plots. There were no significant differences among the other cover categories. For the wet runs, only the pinyon pine litter plots had significantly higher infiltration rates than the bare plots and there were no statistical differences among the other cover types.

At the other sites, for the dry runs, only San Ysidro had significant differences between plot types. At that site, the differences are not cover related but rather caused by differences in soil types. For the wet runs, the Querencia soils at San Ysidro again had significantly higher infiltration rates than the San Mateo soils. For the wet runs at Beaverhead, the high cover plots had significantly higher infiltration rates than did the low cover plots.

<u>Infiltration Characteristics-Among Sites</u>. The bare and litter plots at Heber and the burned plots at White Oaks are not included in the analyses comparing infiltration or erosion characteristics among sites. Even so, there is considerable overlap in infiltration rates among sites. San Ysidro and White Oaks had significantly lower infiltration rates on the dry and wet runs than Springerville and Beaverhead. Heber infiltration rates on the dry and wet runs were not statistically different from any of the sites. Figures 3 and 4 show the mean and range

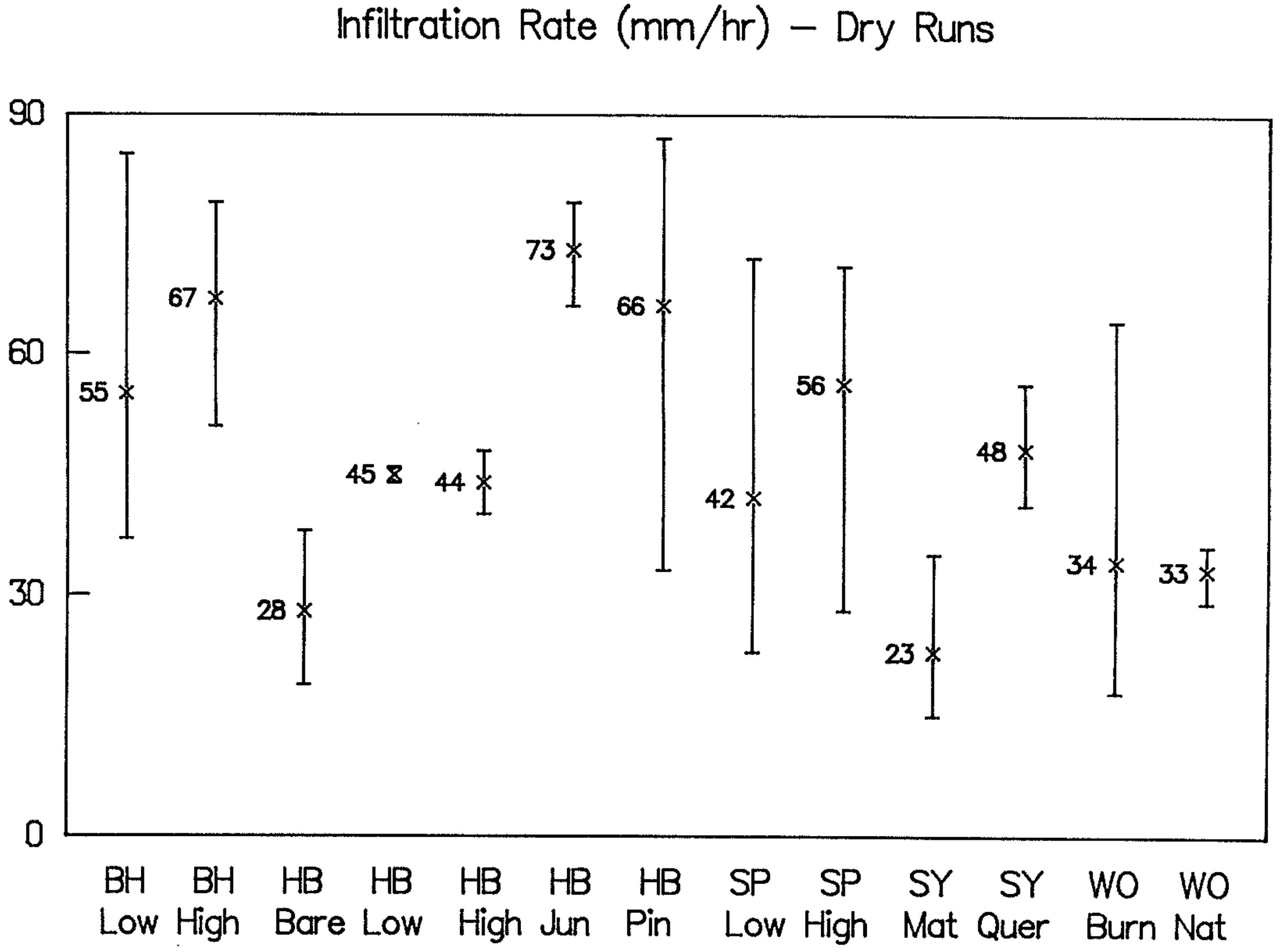

Fig. 3. Mean and Range of Infiltration Rates for Dry Runs

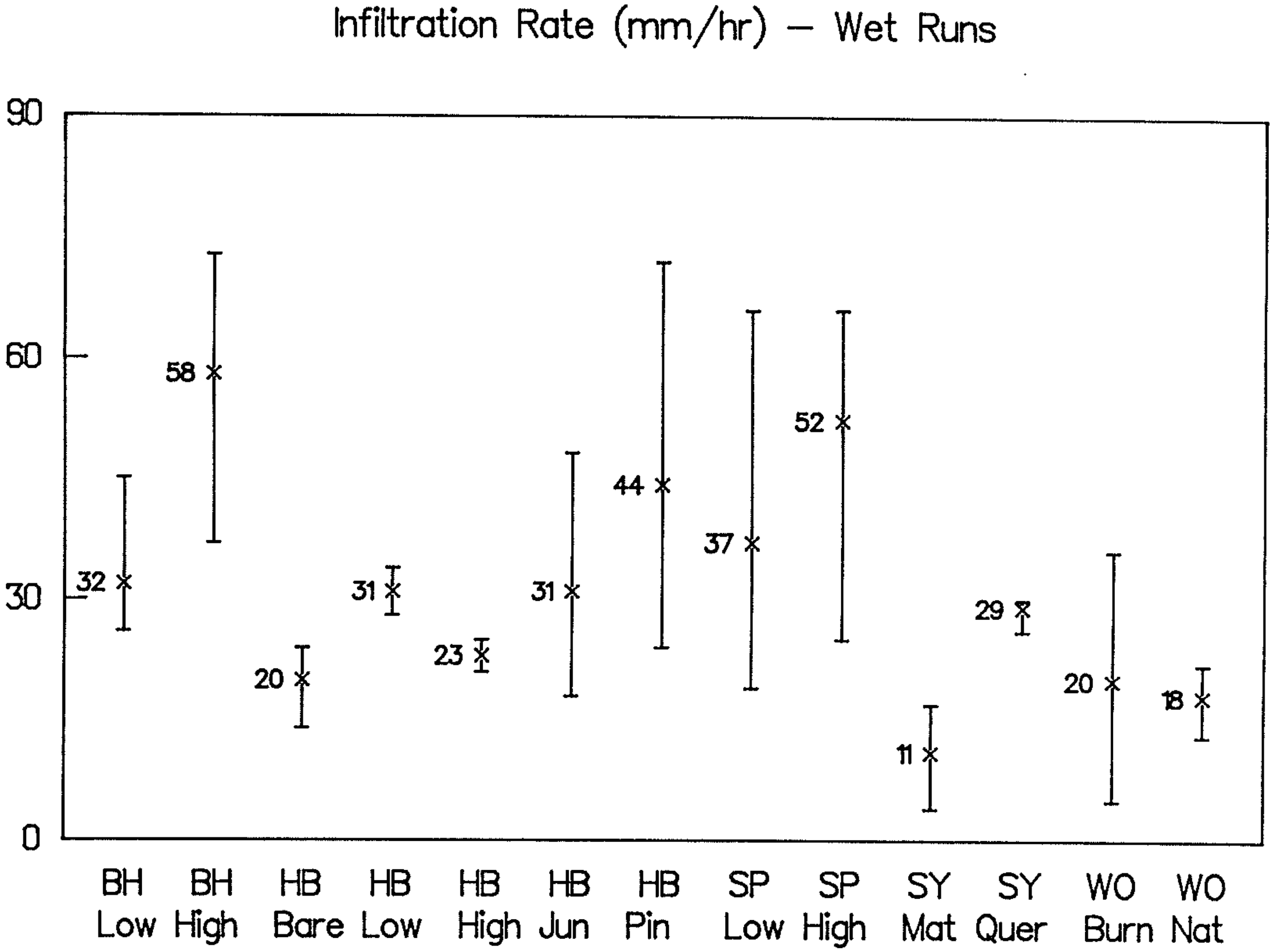
Infiltration Rate (mm/hr) — Wet Runs

Fig. 4. Mean and Range of Infiltration Rates for Wet Runs

of infiltration rates for each site and cover type for dry and wet runs, respectively.

Comparison of Splash Detachment Coefficients. The raindrop splash erosion/transport coefficient was derived from the total sediment yield, cover, and rainfall data as presented in detail by Ward (1986). The coefficient is determined from the following equation:

$$Dr = Y/(I^2 \; t \; Ab) \tag{1}$$

where Dr is the detachment (splash) coefficient, Y is the sediment yield (any component), I is the rainfall intensity, t is the duration of rainfall on the plot, and Ab is the fraction of the plot soil which is exposed to the rainfall, i.e. has no cover. The splash coefficient is dimensional depending on the units used to derive it.

The individual plot values for the splash coefficient for total sediment yield are listed in Appendix F and summarized in Table 5. Note that average splash coefficients for the suspended and deposited yields can be calculated from the coefficients for total sediment yield listed in Table 5 and values for suspended or deposited yields in Table 4 by dividing by the total sediment yield per unit area and then multiplying by the appropriate yield: suspended or deposited, calculated for the wet and the dry experiments. For example, the splash coefficient for suspended sediment for the dry runs on the low cover plots at Beaverhead is:

$$D_{r\text{-suspended}} = \frac{0.21}{71.7 + 200.0} * 71.7 = 0.055 \tag{2}$$

These splash coefficients were derived using the method applied to the small simulator data. This may not be the most appropriate methodology, but it is consistent and as Table 5 shows, it produces comparable results among the sites.

The splash detachment coefficients are an index of rainfall erosion at a site per unit area of bare ground. Sites with higher values indicate higher erodibility of the exposed soil. These values tend to complement the yield values but also account for rainfall and cover effects. Although differences exist among sites as shown by the data tables, there is no significant difference between dry and wet runs because the variability of this coefficient is so high. The splash coefficient derived from small simulator data should be useful in the WEPP effort to provide an estimate for modeling.

Correlation of Parameters. The hydraulic and sediment yield values were correlated to site and rainfall characteristics to identify factors that affect runoff and erosion processes. Spearman correlation coefficients and a p-level of 0.01 were used to assess significant correlations. Not all correlations can be explained physically, but are presented to provide insights into data relationships. Only significant correlations are presented.

Runoff was positively correlated with percent bare ground and the wet sieve fractions of silt and clay and negatively correlated with percent gravel. Sediment yields and concentrations (suspended, deposited and total) were negatively correlated with rainfall intensity and wet sieved gravel fraction, and positively correlated with runoff, bare soil, and the wet sieve fractions of silt and clay. The counterintuitive negative relationship between sediment yields and concentrations and rainfall intensity appears to be a spurious correlation caused by lower than average intensities applied at a site with highly erodible soils (San Ysidro).

Hydraulic conductivity, capillary head, and the detachment coefficient are derived parameters, therefore some correlations are spurious. Conductivity is negatively correlated with bare soil, the wet sieve fractions of silt and clay, and initial saturation. Conductivity is positively correlated with plot slope. Capillary head is positively correlated with the dry-sieved fractions of silt and clay. The total sediment detachment coefficient is negatively correlated with the percent of gravel in the soil and positively correlated with percent of silt and clay from wet sieving. It is negatively correlated with the percent gravel cover and cryptogam cover of the soil and positively correlated with horizontal and total roughness and basal cover.

Chemical Concentrations and Yields - Within Sites. Water chemistry data collected with the small simulator is summarized in Table 6, and the individual values are listed in Appendix G. Before analysis, chemical concentrations in the simulator rainwater (background concentrations) were subtracted from the runoff concentrations (Appendix H). For three of the wet runs at San Ysidro, subtracting the rainwater concentration of total nitrogen resulted in negative total nitrogen concentration from the plots, i.e., there was nitrogen retention on the plot.

TABLE 6

Means and Standard Deviations (in parentheses) of Chemical Yields for Each Site

Site	Cov	Total Phos. (kg/ha)		Total Phos. (kg/ha/mm)		Total Nitrogen (kg/ha)		Total Nitrogen (kg/ha/mm)		Total Volatile Suspended (kg/ha)		Total VSS (kg/ha/mm)	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BH	L	0.020	0.024	0.002	0.002	0.08	0.05	0.009	0.004	16.45	15.89	1.325	1.254
		(0.016)	(0.032)	(0.001)	(0.003)	(0.08)	(0.07)	(0.009)	(0.006)	(17.81)	(21.50)	(1.083)	(1.770)
BH	H	0.013	0.015	0.003	0.002	0.06	0.05	0.010	0.006	7.75	7.43	0.928	0.553
		(0.009)	(0.010)	(0.002)	(0.001)	(0.04)	(0.05)	(0.009)	(0.006)	(3.69)	(3.64)	(0.393)	(0.264)
HB	B	0.466	0.438	0.021	0.017	1.39	1.01	0.064	0.041	166.39	131.96	7.615	4.972
		(0.280)	(0.424)	(0.012)	(0.013)	(0.93)	(0.64)	(0.043)	(0.015)	(171.6)	(166.38)	(7.733)	(5.307)
HB	L	0.070	0.024	0.006	0.002	0.41	0.22	0.037	0.015	17.04	11.64	1.515	0.825
		(0.047)	(0.002)	(0.004)	(0.0002)	(0.04	(0.04)	(0.003)	(0.003)	(0.08)	(0.85)	(0.021)	(0.035)
HB	H	0.133	0.103	0.010	0.007	0.54	0.58	0.041	0.041	32.18	31.39	2.625	2.165
		(0.084)	(0.019)	(0.002)	(0.002)	(0.25)	(0.29)	(0.003)	(0.024)	(5.04)	(8.87)	(0.686)	(0.799)
HB	P	0.201	0.117	0.013	0.007	0.88	0.76	0.065	0.043	15.88	11.76	1.077	0.797
		(0.307)	(0.103)	(0.009)	(0.003)	(1.27	(0.52)	(0.031)	(0.019)	(23.37)	(12.49)	(0.679)	(0.682)
HB	J	0.029	0.107	0.005	0.005	0.13	0.57	0.031	0.027	1.91	9.62	0.670	0.490
		(0.034)	(0.072)	(0.003)	(0.002)	(0.17)	(0.51)	(0.007)	(0.017)	(2.39)	(8.61)	(0.435)	(0.364)
SP	L	0.163	0.187	0.018	0.011	0.51	0.63	0.044	0.036	27.91	32.40	2.663	1.862
		(0.115)	(0.142)	(0.015)	(0.008)	(0.18)	(0.32)	(0.012)	(0.017)	(15.20)	(22.17)	(1.900)	(1.214)
SP	H	0.074	0.081	0.010	0.009	0.31	0.31	0.039	0.035	10.98	16.31	1.385	2.022
		(0.034)	(0.031)	(0.006)	(0.004)	(0.13)	(0.08)	(0.018)	(0.012)	(3.50)	(5.00)	(0.607)	(1.472)
WO	F	0.684	0.495	0.036	0.019	3.41	2.83	0.166	0.111	232.92	203.63	11.727	8.273
		(0.515)	(0.329)	(0.026)	(0.013)	(0.91)	(1.18)	(0.023)	(0.041)	(191.46)	(62.60)	(9.597)	(2.700)
WO	N	0.179	0.075	0.009	0.004	0.93	0.90	0.048	0.050	67.14	42.97	3.227	2.407
		(0.113)	(0.008)	(0.003)	(0.0003)	(0.38)	(0.23)	(0.013)	(0.012)	(37.32)	(8.28)	(1.175)	(0.370)
SY	M	0.124	0.220	0.006	0.006	0.17	0.01	0.008	-0.0004	68.44	81.71	3.305	2.360
		(0.038)	(0.091)	(0.003)	(0.002)	(0.13)	(0.52)	(0.006)	(0.013)	(8.34)	(21.21)	(0.520)	(0.170)
SY	Q	0.076	0.127	0.006	0.006	0.28	0.24	0.020	0.011	35.29	45.94	2.705	2.140
		(0.019)	(0.045)	(0.001)	(0.002)	(0.18)	(0.14)	(0.011)	(0.006)	(6.50)	(8.84)	(0.526)	(0.477)

BH = Beaverhead; HB = Heber; SP = Springerville; WO = White Oaks; SY = San Ysidro

Cover is the assigned cover categories: B=bare, L=low cover, H=high cover,
J = Juniper litter, P = Pinyon Pine litter, F = burned, N = natural,
Q = Querencia soils, M = San Mateo soils.

Chemical values were log-transformed to approximate a normal distribution. As with the sediment yields, chemical yields are computed as yields (kg/ha) and as concentrations (kg/ha/mm).

A paired difference t-test was performed for each site to define differences between dry runs and wet runs. At Beaverhead, Springerville and White Oaks, there were no differences in the chemical yields or concentrations (total phosphorus, total nitrogen, or total volatile suspended solids) between dry runs and wet runs. Total phosphorus, total nitrogen, and total volatile suspended solids concentrations were significantly lower for the dry runs at Heber compared to the wet runs. At San Ysidro, total phosphorus concentrations and total volatile suspended solids yields and concentrations were significantly different between dry runs and wet runs, but total nitrogen yields and concentrations were not different from dry to wet runs.

As with the sediment analyses, paired t-tests were used at sites with two cover types and at Heber a least squares means test was used to identify differences in chemical yields or concentrations which may be attributed to cover differences.

At Beaverhead, there were no significant differences in total phosphorus, total nitrogen or total suspended volatile solids yields or concentrations from the low and high cover types for the dry or wet runs.

At Heber, comparisons were made among three cover types: bare, natural (high and low cover combined) and litter (pinyon and juniper litter combined). Despite the higher yields and concentrations on average from the pinyon litter plots compared to the juniper litter plots, no significant differences were found, so lumping the two types into one category should not be a problem.

For total phosphorus yield and concentration at Heber for the dry runs, the bare plots had significantly higher yields and concentrations than the litter plots. The natural cover plots were not significantly different from either the bare plots or the litter plots. Total volatile suspended solids yields from the litter plots were significantly lower compared to the bare and natural plots. Total volatile suspended solids concentrations were significantly different from each cover type for the dry runs. There were no significant differences among the cover types for total nitrogen concentration for the dry runs, but total nitrogen yields from the bare plots were significantly higher than from the litter plots.

For the wet runs at Heber, total phosphorus yields and concentrations were significantly higher from the bare plots compared to the litter and natural plots. Total volatile suspended solids yields from the bare plots were also significantly higher than from the litter and cover plots. Concentrations of total volatile suspended solids were significantly higher from the bare plots compared to the litter plots. There were no significant differences in total nitrogen yields or concentrations among the three cover types for the wet runs.

At Springerville, the total phosphorus yield was greater from the low cover plots compared to the high cover plots for the dry runs. The low cover plots also produced significantly greater concentrations of total volatile solids than the high cover plots for the dry runs. No significant differences were found between the high and low cover plots for the dry runs for total nitrogen yields or concentrations. There were no significant differences between cover types for the wet runs for phosphorus or total volatile solids yields or concentrations, but total nitrogen yields were significantly higher from the low cover plots.

For dry and wet runs, the San Mateo soil plots at the San Ysidro site produced significantly higher total volatile suspended solids yields than the Querencia soils. All other chemical yields and concentrations were not significantly different from the two soil types.

At White Oaks, even though the burned plots produced, on average, higher yields and concentrations of phosphorus and volatile solids, the differences were significant only for total volatile suspended solids yields and concentrations for the wet runs. Total nitrogen yields and concentrations for dry and wet runs were significantly greater from the burned plots compared to the natural plots.

<u>Chemical Concentrations and Yields - Among Sites</u>. A least squares means test was used to examine differences among sites. Analyses were conducted on wet runs and dry runs separately and compared natural vegetation plots only. Beaverhead had

significantly lower yields and concentrations of total phosphorus compared to the other sites for the dry and wet runs. Total volatile suspended solids yields were also significantly lower at Beaverhead for the wet runs compared to the other sites. Total volatile suspended solids concentrations were significantly lower at Beaverhead compared to all sites except Heber which were not significantly different.

Total nitrogen yield (kg/ha) and concentration (kg/ha/mm) were significantly lower at Beaverhead and San Ysidro compared to the other sites for the dry run. Yields and concentrations were also significantly different between Beaverhead and San Ysidro for dry runs. For the wet runs, Beaverhead had significantly lower total nitrogen yields and concentrations compared to all other sites.

Spearman correlation analysis was done on the chemical yields to investigate relationships between the chemicals and site characteristics. A significance level of 0.01 and a correlation coefficient greater than 0.50 were used to determine if a relationship would be reported. Chemical yields were not significantly correlated with initial soil saturation. Therefore, subsequent analyses focused on dry and wet runs combined.

Total phosphorus yield was most strongly correlated with total sediment yield, the two components of total sediment yield (suspended and deposited yield) and total volatile suspended sediment yield. It was inversely related to cryptogamic cover and positively correlated with percent clay determined by wet sieving.

In addition to total phosphorus, total volatile suspended solids yields were positively correlated with the wet sieved fractions of fines, silt and clay and negatively correlated with the fraction of gravel of the soil. Total nitrogen yield was not strongly correlated with any variables except total phosphorus yield.

Comparisons with Previous Experiments.

The plot-runs at Beaverhead and Springerville were made on the same natural cover plots as those in 1988. This was done to assess annual variation in runoff and erosion characteristics at these sites and to demonstrate the reproducibility of the rainfall simulator experimental results.

At Beaverhead, canopy cover and bare ground were significantly higher in 1989 than 1988 and gravel and rock cover were significantly lower in 1989 than in 1988. At Springerville, the canopy cover and basal ground cover were significantly higher in 1989. However, litter cover was significantly higher in 1988. The steady-state infiltration rates at the two sites were slightly higher but not significantly different based on paired t-tests on the dry runs. The wet run infiltration rates were significantly higher for 1989 at Beaverhead, but not at Springerville. The applied rain intensity was also significantly higher for the wet runs at Beaverhead in 1989, but appears to be coincidental rather than causative. The runoff to rainfall ratios were not significantly different between years at the sites for either dry runs or wet runs.

At Beaverhead for the dry runs and wet runs, deposited and total sediment yields were significantly lower in 1988 compared to 1989. Suspended yield and all sediment concentrations were not significantly different between 1988 and 1989 at Beaverhead. At Springerville, for the dry runs, deposited and total sediment concentrations were significantly higher in 1989. For the wet runs, suspended sediment concentrations and total sediment concentrations were significantly higher in 1989.

Total phosphorus and total nitrogen yields and concentrations were significantly lower at Beaverhead for the dry runs in 1988. For the wet runs, the phosphorus and nitrogen yields and the nitrogen concentration were significantly higher in 1988. At Springerville, the total nitrogen yield and concentration was higher in 1989 for the dry runs. For the wet runs at Springerville, total nitrogen yields and concentrations and phosphorus concentrations were significantly higher in 1989.

Estimation of Parameters

The primary model parameters of steady-state infiltration rate (hydraulic conductivity), soil capillary suction, and raindrop splash/detachment coefficient were regressed against site and soil characteristics to determine if they could be estimated from the other measured variables. A model for the conductivity as determined by stepwise regression is:

$$\mathrm{Log}_{10}\ \mathrm{Kw} = 1.93 - 0.68\ \mathrm{Rgh} - 0.01\ \mathrm{AMC} + 0.004\ \mathrm{Corg} - 0.007\ \mathrm{Silt} \quad (r = 0.64) \tag{3}$$

where Kw is the hydraulic conductivity in mm/hr, Rgh is the plot roughness, in cm, determined from all 75 point frame measurements across the plot, AMC is the antecedent soil moisture content in percent of dry soil weight, Corg is the percent of organic ground cover (litter + cryptogams + basal) as measured with the point frame and Silt is the percent silt as determined by wet sieving. Except for the intercept term, variables are listed in order of increasing contribution to explained variance. The root mean squared error is 0.15 (log units) compared with the mean Kw value of 1.62 (log units) (= 42 mm/hr).

This model was developed to be comparable to one presented by Ward and Bolin (1989b). The 1989 model had a positive sign on roughness and did not include percent silt. It is not clear why the sign changed on the roughness variable. The data set for this report includes a wider variety of sites and soils which may account for the inclusion of silt in equation 3. The 1989 report had a very narrow range of soil types. For data in this report, roughness is not significantly correlated with conductivity but does appear as positive in a correlation matrix. The negative sign in equation 3 may be an artifact. At any rate, roughness only explains 5% of the variance in equation 3. A better equation for this data set is:

$$\text{Log}_{10}\ \text{Kw} = 1.81 - 0.01\ \text{AMC} + 0.003\ \text{Corg} - 0.009\ \text{Silt} \qquad (4)$$

$$(r = 0.60)$$

where Kw is the hydraulic conductivity in mm/hr, AMC is the antecedent soil moisture content in percent of dry soil weight, Corg is the percent of organic ground cover (litter + cryptogams + basal) as measured with the point frame and Silt is the percent silt as determined by wet sieving.

The coefficients have changed slightly with the removal of the roughness variable. Organic cover increases infiltration by acting to retain or retard water on the plot and increase infiltration "opportunity". The decrease in infiltration rate caused by an increase in soil moisture was observed at almost every plot, as discussed previously. Equation 4 supports that observation. The increase in soil moisture may cause changes in the clay fraction of the soil which result in a lowered infiltration rate. A wet soil also may have a lower conductivity to air, or capacity for air movement, which may reduce the infiltration rate. Effects of trapped air may be important, particularly in clay-rich soils, but no field measurements were taken to confirm this hypothesis. It would seem, however, that there would be sufficient escape routes for air through the plot boundaries so that the trapped air effect would be insignificant. The hydraulic conductivity was negatively correlated with the clay fraction, but the correlation was not statistically significant.

The capillary head is a much more difficult parameter to quantify as it is derived from the runoff data, hydraulic conductivity, soil moisture, and porosity. A poor equation for capillary head is:

$$\mathrm{Log10}(Yc) = 4.75 - 0.04\ Grv - 0.05\ Sand + 0.02\ AMC \qquad (r = 0.38) \tag{5}$$

where Yc is the capillary head in mm of water, Grv is the percent of gravel in the soil sample, Sand is the percent of sand in the soil sample, and AMC is the antecedent moisture content as defined previously. This equation is similar to that developed in 1989 (Ward and Bolin 1989b) except that the sign on gravel has changed and sand has replaced silt with a change in sign. The AMC is a spurious variable because it is used to derive the value of Yc from the measured data (see Appendix A). It is recommended that equation 5 not be used to estimate the capillary head in the soil, but as a guide to variable relationships.

Another relationship for estimating purposes is that between hydraulic conductivity and the capillary head. Once the hydraulic conductivity is estimated from an equation such as equation 4, then the capillary head can be estimated from a power equation between head and conductivity. For the data set used in this study, the power equation (log-log equation) is:

$$\mathrm{Log10(Yc)} = 2.53 - 1.18\ \mathrm{Log10(Kw)} \qquad (r = 0.40) \qquad (6)$$

where all terms were defined previously. The slope is statistically the same as for the equation developed in 1989 (Ward and Bolin 1989b), but the intercept is lower and the correlation coefficient is lower. This equation shows that the capillary head should be inversely related to the hydraulic conductivity.

The final parameter estimated was the splash detachment/transport coefficient. The resultant equation for that coefficient was:

$$\mathrm{Log_e(Dr)} = -1.81 - 0.03\ \mathrm{Grv} + 0.22\ \mathrm{Clay} \qquad (r = 0.57) \qquad (7)$$

where Dr is the detachment coefficient in kg-hr/ha-mm^2, Grv is the percent of gravel in the soil sample and Clay is the percent of clay in the soil sample as determined by wet sieving. This equation differs from the 1989 equation (Ward and Bolin 1989b) in that the sign on gravel has changed, clay replaced fines as a predictor variable and the sign changed, and AMC did not enter the stepwise regression. The loss of AMC reflects that there were few differences between sediment yields from dry and wet runs in this study. The reasons for changes in signs on gravel and clay are not apparent at this time.

Comparison of Techniques for Estimating Total Suspended Solids

As in the 1988 study (Ward and Bolin 1989b), suspended sediment concentrations were measured using three different methods. The three methods are 1) centrifuging a sample, decanting the liquid, drying the concentrated residue, and weighing it, 2) filtering a sample through a micropore filter under a negative pressure gradient, then drying and weighing the residue and filter paper, and 3) drying the entire sample in a plastic sample bottle to determine the dry material weight to total weight.

Unlike previous years when a liter sample was subsampled for 400 milliliters to centrifuge, a 400 milliliter sample was taken in the field for centrifuging and the entire sample was centrifuged. The concentrated residue is removed with distilled water and the sample is weighed after drying.

In previous studies, the three techniques yielded slightly different estimates of total suspended sediment. The method that dries the entire sample actually measures total solids (suspended and dissolved), not total suspended solids, and as expected the concentrations computed by this method are higher compared to the other two methods. Centrifuging and filtering eliminates most if not all of the dissolved solids. For sites where runoff samples contain a substantial amount of dissolved solids, the bottle-dry technique will result in a higher estimate of sediment. All of these techniques are used by researchers so it would be helpful to develop techniques that can be used to convert the concentration computed by one method into the equivalent by another method as was suggested by Ward and Bolin (1989b).

During this study, a random sample of twenty-seven bottles were collected from different plot runs at Beaverhead, Heber, and Springerville. The sample bottles were weighed before being sent to the field. A laboratory electrical conductivity meter was used to estimate dissolved solid content in the full bottle. Then, the bottles were weighed with water and residue (sediments/dissolved materials), dried, weighed with residue, cleaned and weighed without residue. The appropriate weights were used to determine the weight of water plus residue, and residue only. The twenty-seven random measurements were compared to the corresponding centrifuge and filtration samples. In addition, the filtration and centrifuge samples were compared.

In general, the bottle-dried samples produced higher calculated suspended sediment concentrations than did the other two methods. The average ratio of centrifuged samples to filtered sample suspended sediment concentrations was 1.03 ($n = 103$). This ratio was less than 1.00 in Ward and Bolin (1989b) but in that study the centrifuged sample was a 400 ml subsample of a liter sample and in this study a 400 ml sample was taken in the field and the entire sample centrifuged. The average ratio of bottle-dried to centrifuge sample concentrations was 1.69 (n = 27), if the dissolved solid content was ignored, and 1.35 if the dissolved concentration is considered. The average ratio of bottle-dried to filtered sample concentrations was 1.73, if the dissolved solids content was ignored, and 1.39 if the dissolved concentration is removed.

A paired-difference t-test indicated that no significant difference between centrifuge estimates of suspended sediment and filtered estimates of suspended sediment. However, the bottled-dried estimates were significantly higher than either the centrifuged samples or the filtered samples even if corrected for the dissolved solids component.

Models were developed to provide methods of converting values from one technique to other techniques. These equations are:

$$Bs = 235 + 1.14\ Fs \qquad (r = 0.97), \qquad (8)$$

$$Cs = 319 + 0.72\ Fs \qquad (r = 0.91), \qquad (9)$$

and

$$Cs = 283 + 0.66\ Bs \qquad (r = 0.94) \qquad (10)$$

where Fs is the sediment concentration from the filtration technique (all concentrations in mg/L), Cs is the concentration from the centrifuge technique, and Bs is the concentration from the dried bottle technique (after correction for dissolved solids calculated from conductivity). The intercept values of 235 and 283 in equations 8 and 10, respectively, are not significantly different than 0.0, but are the best estimates of the intercepts. **For this report, filtered sediment concentrations were used in the analyses.**

Summary

One hundred and four plot runs using a small simulator were conducted at five pinyon-juniper sites in New Mexico and Arizona. Information was developed for rainfall rate, runoff rate, types and percent of ground cover, surface roughness and slope of the sampled plots, soil particle size gradation, soil water content, soil porosity, sediment yield, infiltration parameters, erosion parameters, and water chemistry. The analyses presented here compared site characteristics, how the sites responded to simulated rainfall, how different plots at a site responded to the rainfall simulation, and how derived parameters related to site characteristics. The data base developed during this study will provide information for better land management practices in the pinyon-juniper zones of the Southwest.

CONCLUSIONS AND RECOMMENDATIONS

The primary goal of this study was to determine infiltration and soil erosion parameters for a variety of soil-vegetation complexes in the PJ vegetation zone of western New Mexico and eastern Arizona. Rainfall simulation on small area (1 meter by 1 meter) plots was used to collect the necessary runoff data from which parameters could be derived. A total of 104 plot runs were conducted at five sites on plots which had natural cover, were scraped bare, were covered by pinyon or juniper litter, or were burned. Infiltration and erosion responses of the plots were different depending on whether the plot had been rained upon previously in a prior experiment. On average, the "wet" plot runs had significantly lower steady-state infiltration rates (hydraulic conductivities) than the "dry" plot runs. Sediment yields and concentrations were typically lower from the "wet" plot runs, but not significantly lower than the "dry" plot runs.

In general, infiltration rates increased as the amount of surface or ground cover on the plot increased, but the only statistically significant differences occurred at Heber where the litter plots had higher infiltration rates than the other plots and at San Ysidro where the two soil types had significantly different infiltration rates. The infiltration rates at White Oaks were not significantly different between the burned and unburned plots. The average infiltration rates on the San Mateo soils at San Ysidro were even lower than the infiltration rates on the bare plots at Heber.

For the sites sampled, average infiltration rates on the dry runs ranged from 23 mm/hr on the San Mateo soils at San Ysidro to 73 mm/hr on the juniper litter plots at Heber. Average wet run infiltration rates ranged from 10.5 mm/hr on the San Mateo soils at San Ysidro to 58 mm/hr on the high cover plots at Beaverhead.

Average total sediment concentration (kg/ha/mm of runoff) ranged from 12.5 kg/ha/mm from the pinyon litter plots at Heber to 464.2 kg/ha/mm from the burned plots at White Oaks.

The steady-state infiltration rate can be modeled as a function of ground cover, soil moisture at the beginning of rainfall, and silt fraction of the soil. Models for capillary head in the soil and for the rainfall splash detachment (erosion/transport) coefficient were not as good as for infiltration rate. Capillary head was related to antecedent soil moisture and percent of gravel and sands or alternatively to steady-state loss rate. The splash detachment coefficient was related to percent gravel and clay as determined by wet sieving. Use of the models to estimate capillary head or the splash coefficient are not recommended due to low confidence in their ability to make reliable estimates.

Three techniques for measuring suspended sediment concentration were used, then compared in this study. Results show that although the methods provide highly correlated results, the answers are different. In this study, no significant differences were found between centrifuging and filtering samples to estimate suspended sediment, but bottle-dried samples, even when corrected for dissolved solids (as measured by electrical conductivity), gave significantly higher estimates of suspended sediment than the other two techniques.

Numerous water quality samples were collected during the simulations to determine the magnitude of phosphorus, nitrogen, and volatile suspended solids, which might run off during rainfall. Results indicated, as in previous studies, that phosphorus and organic suspended solids are strongly related to the inorganic sediment yields. Nitrogen was significantly correlated with phosphorus, but not with organic or inorganic suspended solids.

Considering the results of this study, the following topics for further investigations are suggested:

1) Conduct additional experiments on interspace (between tree) areas because these are the primary source of runoff generation and sediment production.

2) Evaluate the effects of cover over a broader range of natural conditions including exclosed areas.

3) Design experiments for a more in-depth analysis of organic carbon transport from plots.

4) Conduct longer (time) experimental runs on plots to determine long-term infiltration rate variations and degree of surface armoring.

5) Modify the rainfall simulator boom system to produce rainfall on a 1 meter by 3 meter long plot to better analyze overland flow effects.

6) Conduct more experiments on burned areas to determine recovery of hydrologic function.

7) Conduct more experiments on different soil-vegetation types to determine effects on infiltration.

In conclusion, this study collected information that illustrated the similarities and differences between various sites in the pinyon-juniper vegetation zone of New Mexico and eastern Arizona, including annual variation in hydrologic function at sites, effects of burning and the effects of heavy litter cover beneath tree canopies.

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APPENDICES

Appendix A. Field and Laboratory Procedures for Small Simulator Experiments

The following standardized procedures have been developed for collecting and processing data from the small plot rainfall simulator. These procedures are followed except as modified for specific needs.

Data are collected using a modified Purdue simulator (Seiger 1984) mounted on a trailer 4.9 meters (16 feet) long. A pair of nozzles is mounted on two separate booms, one boom on either side of the trailer. At each parking spot, it is possible to collect simultaneously two samples from the one square-meter (10 square feet) target shape with one side driven flush with the soil surface. That side is where runoff exits the plot, enters a collection trough and is sampled with a small aquarium pump. Water is delivered simultaneously to both booms by a pump and water tank mounted on the trailer. First a dry run, then a wet run, is conducted as described by the following sequence.

DRY RUN

1. Select site and complete general information on sample (data) sheet.
2. Initially position one square meter plot frames.
3. Position trailer carrying rainfall simulator so that it covers the plots as desired.
4. Install plot frames with trench for collection trough.
5. Repair disturbed edges of soil with gravel and water as needed.
6. Photograph the plots and estimate cover.
7. Connect suction pumps to troughs.

8. Collect soil moisture and density samples from top five cm of surface in a 2-inch internal diameter sampling tube. Collect on outside edge of plot frame. Put in soil cans, label and seal.
9. Place impervious rainfall collection cover on plot.
10. Install wind screens as needed.
11. Begin rainfall.
12. Measure rainfall rate using runoff from impervious cover.
13. Remove cover.
14. Note times of ponding and runoff into the trough.
15. Pump troughs as necessary (every one to five minutes).
16. Record pumped volume and save sample in barrel.
17. Rain for 25 to 45 minutes until a steady-state runoff is achieved.
18. Replace cover and again measure rainfall rate.
19. Stop rain and pump trough a final time, then drain pump and hoses into collection barrel.
20. Measure depths in barrels.
21. Agitate barrels and collect a pint jar of water and sediment. Label the jars as to site and run. These samples are for the analysis of total suspended solids.
22. At selected representative sites, agitate barrels and collect two, 250 ml samples of water and sediment. Preserve one of the 250 ml samples with sulfuric or hydrochloric acid and place both 250 ml samples in an ice chest. (These samples are for the analysis of phosphorus, nitrogen, and organic solids).
23. At selected sites, fill a 500 ml plastic bottle after agitating the barrel. These samples are for the oven-dry technique of measuring suspended solids.
24. Remove deposited material from runoff trough and runoff tray (metal flume between plot and trough). Bag material in plastic sealable bags and label.

25. Measure depth to wetted front on outside edge of plot.
26. Measure surface roughness and cover with point frame.
27. Cover plot with plastic sheet, plywood, and dirt until wet run.
28. Collect two 250 ml samples of the rainwater from the trailer after the water has passed through the filters, usually from impervious runoff tray. Treat as in Step 22.

<u>WET RUN</u> (6 to 24 hours later)

29. Repeat steps 8 to 28 above as necessary except rain for a minimum of 20 minutes or until steady runoff is observed.
30. Measure slope in plot with a Brunton compass.
31. Remove about 1 kilogram of soil for sieve analysis from the center of the plot (destructive sampling) or from an undisturbed area near the plot (nondestructive sampling).

Samples of water, sediment, and soil are transferred along with sample sheets.

Once the data sheets and field samples are returned to New Mexico State University, they are measured and analyzed for several basic items including:

1. Rainfall depth and duration.
2. Total runoff.
3. Suspended sediment concentration and yield.
4. Deposited sediment yield.
5. Final infiltration rate.
6. Infiltration parameters.
7. Soil moisture and porosity.

8. Depth to wetted front.
9. Soil particle size distribution.
10. Percent and type of cover.
11. Erosion parameters.

Suspended solid samples are centrifuged in a Beckman J2-21 centrifuge. After centrifuging, the water is poured out of the bottles into preweighed dishes. Distilled water is used to wash all of the soil particles out of the bottle into the sample dish. The dish and soil is dried in a 105 degree C oven for 24 hours and then weighed again. Since a known volume of sample was centrifuged, and the sample weight is known, the concentration of total suspended solids can be computed. When water chemistry samples are collected, those samples are filtered and sediment concentrations are computed. The oven dry bottles are weighed and then dried in a 100 degree C oven until the water has evaporated. The oven dry bottles are then reweighed. When this is done, the three types of measurements are compared. The techniques provide slightly different, but comparable results.

The samples in the 250 ml bottles are taken to the Soil and Water Testing Laboratory at New Mexico State University. The samples are analyzed on auto-analyzing equipment for total phosphorus, total Kjeldahl nitrogen, nitrate-nitrite, and organic suspended solids. Cover estimates from the field are checked with photographs of the plots. Soil moisture is measured following procedures found in USGS (1977). Soil gradation is determined on a split sample following ASTM specifications D421-58 and D422-63. Bulk density is measured from oven dried weights of measured cores.

Cover and "roughness" measurements were collected using a point frame device. The point frame consisted of twenty-five small metal rods spaced approximately 3.8 cm apart. The rods were suspended from a 1 m long frame which rested on the plot borders. For cover measurements, two "hits" for each rod were recorded, a hit of vegetation above the ground surface (canopy) and a ground hit. Canopy hits were recorded as shrub, grass or forb. Ground hits were classified as basal vegetation, cryptograms, soil (less than 5mm particle size), gravel (less than 20mm), rock (greater than 20mm), persistent litter or non-persistent litter. Three measurements across the plot, spaced about 25 cm apart, were made for vegetation. Average cover for each category was computed as the number of hits out of seventy-five possible hits.

For roughness, the same frame was used. Six measurements were made, three down the plot and three across the plot. A backboard to the point frame with horizontal lines across it was used to estimate the height of each rod after it was carefully placed on the ground. The standard deviation of the heights of the rods was used as the roughness measure. Mean standard deviations were computed for each line, for the three lines across the plot, for the three lines down the plot, and for all six lines. In the analyses, the mean standard deviations across the plot, down the plot and for all six lines were used.

A battery-powered video camcorder was used to make a visual record of how plots behave under rainfall simulation. Video tapes were made of the general experimental sites to get a broad view of the area. Rainfall simulations showing how plots respond to applied rainfall were also taped.

The primary hydrologic parameters that can be derived from the field and the analyzed data include final infiltration rate, the Green-Ampt parameters of hydraulic conductivity and capillary suction head, and a rainfall splash/transport coefficient. Approaches for determining the desired parameters have previously been used by Ward (1986a and 1986b) and was employed in this study. The techniques for determining the hydrologic parameters are as follows.

The Green-Ampt infiltration model can be rewritten as:

$$f = Kw \frac{(F + Hc)}{F} \qquad (A1)$$

where f is infiltration rate. Hc is a grouping of soil parameters which is computed as the difference between final and initial soil saturation times the porosity times the capillary suction head. F is the infiltrated volume, and Kw is hydraulic conductivity. Using rainfall simulator data, the following method can be used to obtain estimates of hydraulic conductivity, Kw, and capillary suction head, Yc.

1. Plot the infiltration rate and infiltrated volume as a function of time. The infiltration rate is the measured rainfall rate minus the measured runoff rate, in inches per hour.

2. Plot the infiltration rate versus the reciprocal of the infiltrated volume using the curves plotted in step 1 of the procedure.

3. The curve of infiltration rate as a function of the reciprocal of infiltrated volume is nearly a straight line, to the extent that the Green-Ampt equation represents the actual soil process. If a straight line is fitted to these data (excluding the first point and the last point as they include rainfall simulator operation and non-infiltration effects), then the y-intercept is Kw and the slope is (Kw)(Hc). Thus estimates of Kw and Yc can be obtained by measuring the slope and intercept of the line fit to the data.

This approach does not always work as negative intercepts can be obtained which do not have a physical interpretation. Therefore, this alternative approach is suggested:

1. Plot and examine the data as suggested in the first approach.

2. Use an average infiltration rate calculated from the last three steady rate values. This average value is assumed to be Kw.

3. Calculate a revised set of data pairs as $y = (f - Kw)/Kw$ and $x = 1/F$. Note that the first data point is not used since it represents an amount of water that has been infiltrated and intercepted. The last data point is excluded also from the analysis because it represents water that was on the soil surface and ran off after the rainfall stopped.

4. Fit a no-intercept straight line to the revised data (a no-intercept line passes through the data point (0,0)). The slope of this line is (Kw)(Hc).

Both approaches are suggested as a method of obtaining the necessary soil hydrologic characteristics. The standard approach should be used first, then if the intercept Kw is negative, the time approach should be used.

A rainfall erosion/transport (detachment) coefficient can be derived from rainfall simulation data. This coefficient is used as a measure of sediment supply. The coefficient is determined from the following equation:

$$Dr = Y/(I^2 \ t \ Ab) \qquad (A2)$$

where Dr is the detachment coefficient, Y is the sediment yield, I is the rainfall intensity, t is the duration of rainfall on the plot, and Ab is the fraction of the plot soil which is exposed to the rainfall, i.e., has no cover. The detachment coefficient is dimensional depending on the units used to derive it. The rainfall splash detachment coefficient is a function of soil type, soil structure, moisture conditions, and cohesion.

The measured and derived data and parameters are subjected to a wide variety of statistical tests. As a first step, the data are subjected to a frequency distribution analysis to determine the form of their distribution curves (normal, log-normal, etc.). This enables a more appropriate selection of parametric or non-parametric tests for later analyses. Correlation analyses is performed on the original and transformed data to check for anticipated and spurious correlations. Paired difference t-tests are run on the variables using the dry and wet data sets as the different experiments on the same subject (plot). An appropriate ANOVA is run among the sites on selected variables to determine site/soil differences. Multiple regression analyses are performed on the hydrologic parameters in order to relate them to soil and site characteristics. Statistical analyses and practical considerations will help in determination of which type of equation should be used for predictive purposes.

Appendix B. Physical Characteristics of Each Plot.

SITE	COVER	INITIAL WATER CONTENT % DRY	INITIAL WATER CONTENT % WET	SLOPE (degrees)	POROS-ITY %	ORGANIC COVER %	ROCK COVER %	TOTAL COVER %	CANOPY COVER %	VERTICAL ROUGHNESS (mm)	HORIZONTAL ROUGHNESS (mm)
BH 1	E L	5.53	16.85	2.5	42.2	45.3	6.7	48.0	9.3	0.380	0.400
BH 2	E H	5.71	19.82	2.5	47.5	54.6	9.3	58.6	32.0	0.470	0.300
BH 2	O L	5.71	19.82	2.0	47.5	48.0	2.7	48.0	8.0	0.370	0.240
BH 3	O H	5.53	16.85	2.5	42.2	62.7	5.3	62.7	34.7	0.300	0.430
BH 5	E H	1.04	14.92	3.0	33.8	69.3	10.7	69.3	0.0	0.340	0.340
BH 5	O H	1.04	14.92	4.0	33.8	53.3	13.3	53.3	29.3	0.330	0.290
BH 6	E L	1.36	19.28	3.5	38.5	28.0	28.0	30.7	4.0	0.330	0.160
BH 6	O L	1.36	19.28	2.5	38.5	45.4	20.0	45.4	8.0	0.280	0.260
BH 7	E L	2.25	15.30	3.5	39.3	26.7	30.7	30.7	24.0	0.320	0.240
BH 7	O H	2.25	15.30	1.5	39.3	64.0	17.4	66.7	20.0	0.410	0.300
BH 8	E H	5.62	10.69	3.5	35.4	45.3	26.7	53.3	41.3	0.400	0.270
BH 9	O L	5.62	10.69	3.0	35.4	29.3	41.3	46.6	26.7	0.230	0.200
HB 7	E P	3.56	14.40	10.5	61.3	100.0	0.0	100.0	1.3	0.580	0.630
HB 7	O L	0.48	9.38	4.5	33.7	24.0	21.3	25.3	24.0	0.450	0.380
HB 8	E L	0.70	7.86	5.0	21.7	29.3	20.0	33.3	26.7	0.480	0.400
HB 8	O J	1.37	12.14	5.0	33.0	100.0	0.0	100.0	0.0	0.610	0.610
HB 9	E B	1.30	8.26	6.5	27.3	0.0	0.0	0.0	0.0	0.150	0.160
HB 9	O B	1.30	8.40	7.0	27.3	0.0	0.0	0.0	0.0	0.240	0.140
HB 10	E B	2.61	15.03	1.5	40.6	0.0	0.0	0.0	0.0	0.340	0.170
HB 10	O B	2.61	25.57	3.0	40.6	0.0	0.0	0.0	0.0	0.290	0.230
HB 11	E H	2.61	17.72	2.5	40.6	42.7	4.0	44.0	38.7	0.500	0.430
HB 11	O H	2.61	16.17	2.5	40.6	66.7	0.0	66.7	40.0	0.520	0.470
HB 12	E P	7.81	9.14	5.5	56.0	100.0	0.0	100.0	0.0	0.730	0.690
HB 12	O J	5.25	24.94	6.0	53.9	100.0	0.0	100.0	0.0	0.660	0.740
HB 13	E P	7.94	25.04	4.5	58.2	100.0	0.0	100.0	2.7	0.730	0.840
HB 13	O J	6.27	26.46	6.0	51.6	100.0	0.0	100.0	0.0	0.510	0.620
SP 1	E L	2.90	14.53	3.5	36.2	30.7	25.3	38.7	36.0	0.370	0.250
SP 1	O L	2.90	16.30	4.0	34.9	22.7	24.0	32.0	22.7	0.310	0.270
SP 3	E H	2.23	19.76	5.0	40.9	53.4	9.3	54.7	73.3	0.300	0.290
SP 3	O H	2.23	15.37	7.0	40.9	42.7	12.0	49.4	54.7	0.370	0.390

BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro;
WO = White Oaks
L=low cover; B=bare; H=high cover; F=burned; N=unburned; S=San Mateo soils; Q = Querencia soils; P = pinyon litter; J = juniper litter
Canopy cover is measured separately from ground cover. Bare ground is 100 - total cover. Rock cover includes gravel. Organic cover is basal + litter + cryptogams.
* - data not collected

APPENDIX B. (cont.)

SITE	COVER	INITIAL WATER CONTENT %		SLOPE (degrees)	POROS- ITY %	ORGANIC COVER %	ROCK COVER %	TOTAL COVER %	CANOPY COVER %	VERTICAL ROUGHNESS (mm)	HORIZONTAL ROUGHNESS (mm)
		DRY	WET								
SP 4	E H	3.88	14.69	5.0	32.6	74.7	2.7	74.7	0.0	0.330	0.300
SP 4	O L	3.88	15.07	9.5	32.6	16.0	40.0	42.7	14.7	0.310	0.300
SP 6	E L	3.18	14.25	2.8	39.6	37.3	13.4	40.0	26.7	0.250	0.270
SP 6	O H	3.18	20.28	6.5	39.1	58.6	1.3	58.6	1.3	0.350	0.260
SP 7	E H	2.80	19.09	4.5	38.4	56.0	0.0	56.0	53.3	0.410	0.310
SP 7	O L	2.80	18.49	5.0	38.4	44.0	4.0	45.3	36.0	0.460	0.350
SP 9	E H	2.18	21.48	5.5	46.0	77.3	1.3	77.3	70.7	0.470	0.420
SP 9	O L	2.18	19.00	6.0	46.0	45.3	8.0	45.3	45.3	0.390	0.320
WO 1	E F	5.69	18.50	2.5	44.9	0.0	0.0	0.0	0.0	.	.
WO 1	O F	13.80	21.20	2.5	69.7	0.0	0.0	0.0	0.0	.	.
WO 2	E F	11.60	21.70	2.5	54.9	0.0	0.0	0.0	0.0	.	.
WO 2	O N	3.57	14.40	2.0	47.9	52.0	1.3	52.0	41.3	0.273	0.370
WO 3	E N	3.38	20.20	3.5	42.8	73.3	0.0	73.3	33.3	0.409	0.418
WO 3	O N	3.42	15.50	2.5	46.8	38.7	1.3	38.7	21.3	0.448	0.368
SY 1	E Q	1.51	14.13	5.0	46.0	45.0	*	*	*	*	*
SY 1	O Q	1.18	15.53	4.5	34.4	50.0	*	*	*	*	*
SY 2	E Q	1.40	13.14	4.5	40.0	40.0	*	*	*	*	*
SY 2	O Q	1.44	13.31	5.0	35.0	45.0	*	*	*	*	*
SY 3	E M	2.09	16.21	3.2	38.3	35.0	*	*	*	*	*
SY 3	O M	1.72	18.02	2.5	50.1	30.0	*	*	*	*	*
SY 4	E M	2.09	13.98	1.8	44.2	30.0	*	*	*	*	*
SY 4	O M	1.72	19.53	2.0	44.2	6.0	*	*	*	*	*

BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro;
WO = White Oaks
L=low cover; B=bare; H=high cover; F=burned; N=unburned; S=San Mateo soils; Q = Querencia soils; P = pinyon litter; J = juniper litter
Canopy cover is measured separately from ground cover. Bare ground is 100 - total cover. Rock cover includes gravel. Organic cover is basal + litter + cryptogams.
* - data not collected

Appendix C. Grain Size Analyses.

		Dry Sieve				Wet Sieve			
SITE	COVER	GRAVEL %	SAND %	SILT %	CLAY %	GRAVEL %	SAND %	SILT %	CLAY %
BH 1 E	L	13.98	75.12	9.13	1.82	16.96	41.95	34.26	6.83
BH 2 E	H	13.98	75.12	9.13	1.82	16.96	41.95	34.26	6.83
BH 2 O	L	13.98	75.12	9.13	1.82	16.96	41.95	34.26	6.83
BH 3 O	H	13.98	75.12	9.13	1.82	16.96	41.95	34.26	6.83
BH 5 E	H	18.63	65.02	13.97	2.40	18.56	56.16	21.58	3.70
BH 5 O	H	18.63	65.02	13.97	2.40	18.56	56.16	21.58	3.70
BH 6 E	L	18.63	65.02	13.97	2.40	18.56	56.16	21.58	3.70
BH 6 O	L	18.63	65.02	13.97	2.40	18.56	56.16	21.58	3.70
BH 7 E	L	16.84	69.78	10.89	2.49	8.05	59.46	26.70	5.79
BH 7 O	H	16.84	69.78	10.89	2.49	8.05	59.46	26.70	5.79
BH 8 E	H	16.84	69.78	10.89	2.49	8.05	59.46	26.70	5.79
BH 9 O	L	16.84	69.78	10.89	2.49	8.05	59.46	26.70	5.79
HB 7 E	P	26.60	63.13	8.04	2.23	34.31	43.61	17.28	4.80
HB 7 O	L	31.86	60.56	6.68	0.90	28.66	59.17	10.73	1.44
HB 8 E	L	31.86	60.56	6.68	0.90	28.66	59.17	10.73	1.44
HB 8 O	J	7.73	76.67	13.72	1.85	5.17	70.55	21.40	2.88
HB 9 E	B	31.86	60.56	6.68	0.90	28.66	59.17	10.73	1.44
HB 9 O	B	31.86	60.56	6.68	0.90	28.66	59.17	10.73	1.44
HB 10 E	B	20.63	64.37	12.63	2.37	11.11	37.85	42.96	8.08
HB 10 O	B	20.63	64.37	12.63	2.37	11.11	37.85	42.96	8.08
HB 11 E	H	20.63	64.37	12.63	2.37	11.11	37.85	42.96	8.08
HB 11 O	H	20.63	64.37	12.63	2.37	11.11	37.85	42.96	8.08
HB 12 E	P	15.79	70.57	10.95	2.70	28.66	32.04	31.52	7.77
HB 12 O	J	15.79	70.57	10.95	2.70	28.66	32.04	31.52	7.77
HB 13 E	P	15.79	70.57	10.95	2.70	28.66	32.04	31.52	7.77
HB 13 O	J	15.79	70.57	10.95	2.70	28.66	32.04	31.52	7.77
SP 1 E	L	38.93	55.25	4.50	1.32	16.76	48.10	28.61	6.53
SP 1 O	L	38.93	55.25	4.50	1.32	16.76	48.10	28.61	6.53
SP 3 E	H	38.93	55.25	4.50	1.32	16.76	48.10	28.61	6.53
SP 3 O	H	38.93	55.25	4.50	1.32	16.76	48.10	28.61	6.53
SP 4 E	H	44.41	51.33	3.50	0.76	22.99	44.94	24.84	7.23
SP 4 O	L	44.41	51.33	3.50	0.76	22.99	44.94	24.84	7.23
SP 6 E	L	32.34	61.13	5.25	1.30	24.94	45.01	24.70	5.35
SP 6 O	H	32.34	61.13	5.25	1.30	24.94	45.01	24.70	5.35
SP 7 E	H	8.71	80.23	9.09	1.97	10.38	54.55	28.13	6.94
SP 7 O	L	8.71	80.23	9.09	1.97	10.38	54.55	28.13	6.94
SP 9 E	H	8.71	80.23	9.09	1.97	10.38	54.55	28.13	6.94
SP 9 O	L	8.71	80.23	9.09	1.97	10.38	54.55	28.13	6.94
WO 1 E	F	6.29	72.47	17.71	3.53	13.16	37.68	40.96	8.20
WO 1 O	F	0.08	73.83	21.24	4.85	0.09	36.72	51.49	11.70
WO 2 E	F	0.75	82.95	13.27	3.03	0.90	46.27	43.01	9.82
WO 2 O	N	0.14	73.69	23.38	2.79	0.04	42.01	51.76	6.19
WO 3 E	N	0.03	83.02	14.13	2.82	0.00	44.41	46.36	9.23
WO 3 O	N	0.22	77.40	19.10	3.28	0.31	42.34	48.95	8.40
SY 1 E	Q	0.00	73.01	21.97	5.02	0.05	66.06	27.59	6.30
SY 1 O	Q	0.04	72.08	23.25	4.63	0.00	59.92	33.42	6.66
SY 2 E	Q	0.00	73.01	21.97	5.02	0.05	66.06	27.59	6.30
SY 2 O	Q	0.04	72.08	23.25	4.63	0.00	59.92	33.42	6.66
SY 3 E	M	0.12	81.18	15.59	3.11	1.24	56.86	34.94	6.96
SY 3 O	M	0.14	86.86	9.81	3.19	0.57	60.22	29.60	9.61
SY 4 E	M	0.12	81.18	15.59	3.11	1.24	56.86	34.94	6.96
SY 4 O	M	0.14	86.86	9.81	3.19	0.57	60.22	29.60	9.61

Gravel > 4.75 mm; Sand between 4.75 and 0.075 mm; Silt between 0.075 and 0.002 mm; Clay < 0.002 mm
BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks
L=low cover; B=bare; H=high cover; F=burned; N=unburned; S=San Mateo soils; Q = Querencia soils; P = pinyon litter; J = juniper litter

Appendix D. Plot Rainfall-Runoff Characteristics

SITE	AMC	INTENSITY	DURATION	RAINmm	RUNmm	RORAIN
BH 1 E	DRY	91.4	21.87	33.3	17.4	0.523
BH 2 E	DRY	82.9	19.92	27.5	8.1	0.295
BH 2 O	DRY	78.7	24.33	31.9	11.5	0.360
BH 3 O	DRY	89.4	33.97	50.6	9.6	0.190
BH 5 E	DRY	93.3	20.83	32.4	5.9	0.182
BH 5 O	DRY	91.4	22.23	33.9	4.0	0.118
BH 6 E	DRY	88.0	43.67	64.0	9.0	0.141
BH 6 O	DRY	94.3	50.63	79.6	3.7	0.046
BH 7 E	DRY	85.6	21.97	31.3	9.0	0.288
BH 7 O	DRY	89.4	23.35	34.8	7.0	0.201
BH 8 E	DRY	83.7	22.53	31.4	4.0	0.127
BH 9 O	DRY	93.3	25.93	40.3	10.7	0.266
BH 1 E	WET	87.5	16.42	23.9	14.3	0.598
BH 2 E	WET	86.0	17.58	25.2	12.3	0.488
BH 2 O	WET	84.2	16.07	22.5	12.3	0.547
BH 3 O	WET	82.9	20.57	28.4	7.9	0.278
BH 5 E	WET	96.2	17.30	27.7	6.1	0.220
BH 5 O	WET	91.4	16.95	25.8	5.2	0.202
BH 6 E	WET	93.2	25.05	38.9	18.1	0.465
BH 6 O	WET	91.4	27.83	42.4	11.4	0.269
BH 7 E	WET	88.1	*	*	*	*
BH 7 O	WET	87.5	*	*	*	*
BH 8 E	WET	94.1	17.73	27.8	8.6	0.309
BH 9 O	WET	88.3	18.70	27.5	11.8	0.429
HB 7 E	DRY	89.9	32.93	49.3	2.1	0.043
HB 7 O	DRY	86.7	22.83	33.0	11.4	0.345
HB 8 E	DRY	91.3	23.90	36.4	11.1	0.305
HB 8 O	DRY	85.2	33.20	47.1	2.9	0.062
HB 9 E	DRY	88.1	27.17	39.9	19.4	0.486
HB 9 O	DRY	84.2	31.63	44.4	24.1	0.543
HB 10 E	DRY	92.0	38.17	58.5	22.0	0.376
HB 10 O	DRY	87.9	30.38	44.5	22.1	0.497
HB 11 E	DRY	88.7	35.13	51.9	16.7	0.322
HB 11 O	DRY	91.4	22.42	34.1	9.2	0.269
HB 12 E	DRY	91.4	29.75	45.3	23.4	0.517
HB 12 O	DRY	88.3	67.05	98.7	8.9	0.090
HB 13 E	DRY	95.2	22.30	35.4	4.2	0.119
HB 13 O	DRY	87.7	50.40	73.6	0.1	0.002
HB 7 E	WET	92.2	39.62	60.9	23.1	0.379
HB 7 O	WET	89.3	19.12	28.5	13.8	0.484
HB 8 E	WET	93.3	17.03	26.5	14.4	0.543
HB 8 O	WET	88.4	29.95	44.1	10.3	0.234
HB 9 E	WET	92.2	26.55	40.8	30.0	0.735
HB 9 O	WET	85.7	16.30	23.3	17.6	0.755
HB 10 E	WET	87.1	17.42	25.3	14.9	0.589
HB 10 O	WET	86.5	29.08	41.9	29.4	0.702
HB 11 E	WET	92.5	17.75	27.4	15.7	0.573
HB 11 O	WET	88.9	16.08	23.8	13.8	0.580
HB 12 E	WET	89.4	21.12	31.5	17.0	0.540
HB 12 O	WET	88.0	33.07	48.5	24.6	0.507
HB 13 E	WET	91.4	24.33	37.1	6.9	0.186
HB 13 O	WET	91.8	40.45	61.9	21.3	0.344
SP 1 E	DRY	89.7	23.22	34.7	17.4	0.501
SP 1 O	DRY	82.6	32.48	44.7	17.2	0.385
SP 3 E	DRY	80.7	25.08	33.7	2.7	0.080
SP 3 O	DRY	70.9	59.08	69.8	6.0	0.086

INTENSITY = rainfall intensity in mm/hr; DURATION= duration of rainfall in minutes; RAINmm=rainfall in mm; RUNmm=runoff in mm; RORAIN= runoff/rainfall; AMC=antecedent soil moisture condition.
BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks
* - equipment failure resulted in no data collected

Appendix D. (continued)

SITE	AMC	INTENSITY	DURATION	RAINmm	RUNmm	RORAIN
SP 4 E	DRY	81.3	18.38	24.9	8.0	0.321
SP 4 O	DRY	81.4	26.83	36.4	9.2	0.253
SP 6 E	DRY	79.8	29.03	38.6	18.4	0.477
SP 6 O	DRY	80.2	43.67	58.4	7.6	0.130
SP 7 E	DRY	84.6	45.68	64.4	14.9	0.231
SP 7 O	DRY	92.8	24.53	37.9	4.7	0.124
SP 9 E	DRY	90.2	27.90	41.9	21.7	0.518
SP 9 O	DRY	87.5	20.90	30.5	8.7	0.285
SP 1 E	WET	91.9	28.80	44.1	19.2	0.435
SP 1 O	WET	90.9	18.22	27.6	13.4	0.485
SP 3 E	WET	95.7	20.73	33.1	9.6	0.290
SP 3 O	WET	90.4	19.55	29.5	6.9	0.234
SP 4 E	WET	84.8	19.00	26.9	7.5	0.279
SP 4 O	WET	90.1	20.88	31.4	17.8	0.567
SP 6 E	WET	94.8	18.72	29.6	19.1	0.645
SP 6 O	WET	91.4	19.32	29.4	6.1	0.207
SP 7 E	WET	85.0	*	*	*	*
SP 7 O	WET	88.0	*	*	*	*
SP 9 E	WET	90.1	23.13	34.7	20.1	0.579
SP 9 O	WET	89.4	24.47	36.5	17.6	0.482
WO 1 E	DRY	90.0	17.33	26.0	16.0	0.615
WO 1 O	DRY	88.0	19.08	28.0	20.0	0.714
WO 2 E	DRY	84.4	56.37	79.3	25.2	0.318
WO 2 O	DRY	88.9	43.17	64.0	32.7	0.511
WO 3 E	DRY	86.5	19.87	28.6	12.9	0.451
WO 3 O	DRY	98.9	24.45	40.3	16.3	0.404
WO 1 E	WET	90.2	21.78	32.7	29.0	0.887
WO 1 O	WET	91.1	21.83	33.2	25.1	0.756
WO 2 E	WET	88.7	23.96	35.0	21.0	0.600
WO 2 O	WET	90.2	23.37	35.0	20.2	0.577
WO 3 E	WET	93.6	14.92	23.3	16.4	0.704
WO 3 O	WET	94.4	16.72	26.3	16.9	0.643
SY 1 E	DRY	80.8	36.32	48.9	16.3	0.333
SY 1 O	DRY	82.7	40.67	56.1	12.1	0.216
SY 2 E	DRY	85.8	25.75	36.8	10.1	0.274
SY 2 O	DRY	81.0	39.37	53.1	14.8	0.279
SY 3 E	DRY	85.9	23.58	33.8	22.6	0.669
SY 3 O	DRY	82.2	27.02	37.0	17.1	0.462
SY 4 E	DRY	85.6	31.27	44.6	27.5	0.617
SY 4 O	DRY	78.6	19.97	26.2	17.6	0.672
SY 1 E	WET	81.9	32.58	44.5	23.7	0.533
SY 1 O	WET	81.0	30.57	41.3	18.0	0.436
SY 2 E	WET	86.5	29.87	43.1	22.8	0.529
SY 2 O	WET	82.6	32.70	45.0	22.4	0.498
SY 3 E	WET	83.9	25.70	35.9	29.7	0.827
SY 3 O	WET	81.3	26.98	36.6	25.3	0.691
SY 4 E	WET	87.8	33.25	48.7	41.0	0.842
SY 4 O	WET	78.0	39.90	51.9	42.4	0.817

INTENSITY = rainfall intensity in mm/hr; DURATION= duration of rainfall in minutes; RAINmm=rainfall in mm; RUNmm=runoff in mm; RORAIN= runoff/rainfall; AMC=antecedent soil moisture condition. BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks
* - equipment failure resulted in no data collected

Appendix E. Sediment Yields and Concentrations from the Plots

SITE	AMC	INTENSITY (mm/hr)	RUNOFF (mm)	SUSPENDED SEDIMENT (kg/ha)	SUSPENDED SEDIMENT (kg/ha/mm)	DEPOSITS (kg/ha)	DEPOSITS (kg/ha/mm)	TOTAL SEDIMENT (kg/ha/mm)
BH 1 E	DRY	91.4	17.4	152.6	8.8	7.5	4.7	13.5
BH 2 E	DRY	82.9	8.1	68.6	8.5	15.3	20.5	29.0
BH 2 O	DRY	78.7	11.5	151.0	13.1	53.1	50.1	63.2
BH 3 O	DRY	89.4	9.6	29.5	3.1	16.2	18.3	21.4
BH 5 E	DRY	93.3	5.9	23.1	3.9	12.8	23.5	27.4
BH 5 O	DRY	91.4	4.0	28.6	7.2	4.4	12.1	19.2
BH 6 E	DRY	88.0	9.0	10.1	1.1	7.9	9.5	10.7
BH 6 O	DRY	94.3	3.7	7.2	2.0	1.2	3.4	5.4
BH 7 E	DRY	85.6	9.0	60.5	6.7	30.9	37.2	43.9
BH 7 O	DRY	89.4	7.0	27.4	3.9	9.7	15.1	19.0
BH 8 E	DRY	83.7	4.0	33.3	8.3	10.2	27.7	36.0
BH 9 O	DRY	93.3	10.7	49.1	4.6	10.0	10.1	14.7
BH 1 E	WET	87.5	14.3	37.6	2.6	8.4	6.4	9.1
BH 2 E	WET	86.0	12.3	50.9	4.1	26.9	23.7	27.9
BH 2 O	WET	84.2	12.3	325.5	26.5	49.2	43.4	69.8
BH 3 O	WET	82.9	7.9	56.2	7.1	11.3	15.5	22.6
BH 5 E	WET	96.2	6.1	13.6	2.2	7.2	12.8	15.0
BH 5 O	WET	91.4	5.2	23.9	4.6	6.0	12.6	17.2
BH 6 E	WET	93.2	18.1	16.3	0.9	7.4	4.4	5.3
BH 6 O	WET	91.4	11.4	10.9	1.0	0.8	0.7	1.7
BH 7 E	WET	88.1	*	*	*	28.0	*	*
BH 7 O	WET	87.5	*	*	*	7.3	*	*
BH 8 E	WET	94.1	8.6	49.4	5.8	19.9	25.1	30.9
BH 9 O	WET	88.3	11.8	76.2	6.5	8.3	7.6	14.1
HB 7 E	DRY	89.9	2.1	2.9	1.4	3.4	17.7	19.1
HB 7 O	DRY	86.7	11.4	97.2	8.5	77.9	74.1	82.6
HB 8 E	DRY	91.3	11.1	81.7	7.4	59.3	57.9	65.3
HB 8 O	DRY	85.2	2.9	3.6	1.3	6.8	25.5	26.7
HB 9 E	DRY	88.1	19.4	779.3	40.2	391.8	219.0	259.2
HB 9 O	DRY	84.2	24.1	541.3	22.5	347.1	156.2	178.7
HB 10 E	DRY	92.0	22.0	499.2	22.7	559.7	275.9	298.6
HB 10 O	DRY	87.9	22.1	2174.9	98.4	107.3	52.7	151.1
HB 11 E	DRY	88.7	16.7	200.4	12.0	135.7	88.1	100.1
HB 11 O	DRY	91.4	9.2	179.2	19.5	35.6	41.9	61.4
HB 12 E	DRY	91.4	23.4	128.5	5.5	7.0	3.2	8.7
HB 12 O	DRY	88.3	8.9	12.7	1.4	1.6	1.9	3.3
HB 13 E	DRY	95.2	4.2	13.4	3.2	2.4	6.3	9.5
HB 13 O	DRY	87.7	0.1	1.0	7.6	*	*	*
HB 7 E	WET	92.2	23.1	18.2	0.8	5.9	2.8	3.5
HB 7 O	WET	89.3	13.8	55.5	4.0	66.1	51.9	55.9
HB 8 E	WET	93.3	14.4	52.4	3.6	38.0	28.7	32.3
HB 8 O	WET	88.4	10.3	8.9	0.9	9.7	10.2	11.1
HB 9 E	WET	92.2	30.0	564.3	18.8	750.9	271.5	290.3
HB 9 O	WET	85.7	17.6	292.5	16.6	433.5	267.2	283.8
HB 10 E	WET	87.1	14.9	218.4	14.7	285.1	207.5	222.2
HB 10 O	WET	86.5	29.4	2683.6	91.3	317.8	117.2	208.5
HB 11 E	WET	92.5	15.7	157.8	10.0	100.7	69.6	79.6
HB 11 O	WET	88.9	13.8	266.6	19.3	49.1	38.6	57.9
HB 12 E	WET	89.4	17.0	71.6	4.2	18.5	11.8	16.0
HB 12 O	WET	88.0	24.6	10.8	0.4	17.3	7.6	8.0
HB 13 E	WET	91.4	6.9	19.0	2.8	9.5	14.9	17.7
HB 13 O	WET	91.8	21.3	132.9	6.2	72.2	36.8	43.0

BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks

* - equipment failure resulted in no data collected

Appendix E. (continued)

SITE	AMC	INTENSITY (mm/hr)	RUNOFF (mm)	SUSPENDED SEDIMENT (kg/ha)	SUSPENDED SEDIMENT (kg/ha/mm)	DEPOSITS (kg/ha)	DEPOSITS (kg/ha/mm)	TOTAL SEDIMENT (kg/ha/mm)
SP 1 E	DRY	89.7	17.4	95.9	5.5	71.2	44.4	49.9
SP 1 O	DRY	82.6	17.2	149.5	8.7	105.3	66.4	75.1
SP 3 E	DRY	80.7	2.7	30.7	11.4	37.8	151.8	163.2
SP 3 O	DRY	70.9	6.0	50.7	8.4	66.4	120.1	128.6
SP 4 E	DRY	81.3	8.0	44.0	5.5	18.4	24.9	30.4
SP 4 O	DRY	81.4	9.2	504.8	54.9	119.8	141.2	196.1
SP 6 E	DRY	79.8	18.4	119.0	6.5	81.9	48.3	54.8
SP 6 O	DRY	80.2	7.6	45.5	6.0	9.0	12.8	18.8
SP 7 E	DRY	84.6	14.9	66.2	4.4	58.7	42.7	47.1
SP 7 O	DRY	92.8	4.7	150.7	32.1	60.0	138.5	170.5
SP 9 E	DRY	90.2	21.7	81.4	3.8	55.8	27.8	31.6
SP 9 O	DRY	87.5	8.7	109.6	12.6	36.4	45.4	58.0
SP 1 E	WET	91.9	19.2	39.0	2.0	28.5	16.1	18.1
SP 1 O	WET	90.9	13.4	113.0	8.4	49.5	40.0	48.5
SP 3 E	WET	95.7	9.6	138.9	14.5	41.7	47.2	61.6
SP 3 O	WET	90.4	6.9	88.2	12.8	34.1	53.6	66.4
SP 4 E	WET	84.8	7.5	39.5	5.3	27.0	39.0	44.3
SP 4 O	WET	90.1	17.8	656.1	36.9	112.0	68.3	105.1
SP 6 E	WET	94.8	19.1	118.4	6.2	36.0	20.5	26.7
SP 6 O	WET	91.4	6.1	73.0	12.0	24.3	43.2	55.1
SP 7 E	WET	85.0	*	*	*	20.4	*	*
SP 7 O	WET	88.0	*	*	*	19.4	*	*
SP 9 E	WET	90.1	20.1	63.1	3.1	60.8	32.8	36.0
SP 9 O	WET	89.4	17.6	254.1	14.4	43.3	26.7	41.1
WO 1 E	DRY	90.0	16.0	760.3	47.5	11411.6	713.2	760.7
WO 1 O	DRY	88.0	20.0	2153.6	107.7	3724.1	186.2	293.9
WO 2 E	DRY	84.4	25.2	590.7	23.4	7932.8	314.8	338.2
WO 2 O	DRY	88.9	32.7	746.2	22.8	2935.0	89.8	112.6
WO 3 E	DRY	86.5	12.9	218.0	16.9	292.4	22.7	39.6
WO 3 O	DRY	98.9	16.3	638.0	39.1	3488.1	214.0	253.1
WO 1 E	WET	90.2	29.0	1004.6	34.6	14675.3	506.0	540.7
WO 1 O	WET	91.1	25.1	1394.0	55.5	3556.5	141.7	197.2
WO 2 E	WET	88.7	21.0	581.3	27.7	6108.3	290.9	318.6
WO 2 O	WET	90.2	20.2	350.3	17.3	883.1	43.7	61.1
WO 3 E	WET	93.6	16.4	322.8	19.7	313.7	19.1	38.8
WO 3 O	WET	94.4	16.9	391.7	23.2	1674.3	99.1	122.3
SY 1 E	DRY	80.8	16.3	186.2	11.4	1354.4	83.1	94.5
SY 1 O	DRY	82.7	12.1	214.2	17.7	3422.0	282.8	300.5
SY 2 E	DRY	85.8	10.1	222.8	22.1	972.9	96.3	118.4
SY 2 O	DRY	81.0	14.8	259.0	17.5	5606.0	378.8	396.3
SY 3 E	DRY	85.9	22.6	492.7	21.8	1436.7	63.6	85.4
SY 3 O	DRY	82.2	17.1	659.7	38.6	2753.3	161.0	199.6
SY 4 E	DRY	85.6	27.5	875.0	31.8	3877.0	141.0	172.8
SY 4 O	DRY	78.6	17.6	711.7	40.4	831.5	47.2	87.7
SY 1 E	WET	81.9	23.7	218.0	9.2	1762.0	74.3	83.5
SY 1 O	WET	81.0	18.0	311.4	17.3	2935.2	163.1	180.4
SY 2 E	WET	86.5	22.8	331.1	14.5	823.7	36.1	50.6
SY 2 O	WET	82.6	22.4	416.6	18.6	3681.0	164.3	182.9
SY 3 E	WET	83.9	29.7	604.1	20.3	1804.8	60.8	81.1
SY 3 O	WET	81.3	25.3	662.9	26.2	4129.0	163.2	189.4
SY 4 E	WET	87.8	41.0	1449.8	35.4	3628.0	88.5	123.8
SY 4 O	WET	78.0	42.4	1344.9	31.7	2661.5	62.8	94.5

BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks
* - equipment failure resulted in no data collected

Appendix F. Estimated Plot Hydraulic Parameters

SITE	AMC	KW	PSI	ACOEFF
BH 1 E	DRY	37.4	3.50	0.16
BH 2 E	DRY	50.7	1.90	0.29
BH 2 O	DRY	45.4	0.53	0.59
BH 3 O	DRY	63.9	7.15	0.14
BH 5 E	DRY	73.3	0.25	0.27
BH 5 O	DRY	78.6	0.13	0.07
BH 6 E	DRY	59.6	20.97	0.04
BH 6 O	DRY	84.8	5.32	0.01
BH 7 E	DRY	53.3	3.25	0.35
BH 7 O	DRY	65.4	2.58	0.23
BH 8 E	DRY	70.4	0.78	0.20
BH 9 O	DRY	49.9	20.21	0.14
BH 1 E	WET	26.0	0.92	0.13
BH 2 E	WET	37.2	2.21	0.44
BH 2 O	WET	30.2	1.30	0.92
BH 3 O	WET	47.0	13.67	0.24
BH 5 E	WET	72.6	0.13	0.17
BH 5 O	WET	72.3	0.13	0.11
BH 6 E	WET	28.3	62.30	0.06
BH 6 O	WET	45.0	114.15	0.01
BH 7 E	WET	*	*	*
BH 7 O	WET	*	*	*
BH 8 E	WET	59.3	1.81	0.36
BH 9 O	WET	30.0	10.94	0.23
HB 7 E	DRY	86.6	0.04	**
HB 7 O	DRY	43.8	2.37	0.60
HB 8 E	DRY	46.0	10.17	0.43
HB 8 O	DRY	79.3	0.39	**
HB 9 E	DRY	27.6	12.38	1.43
HB 9 O	DRY	19.0	31.98	1.15
HB 10 E	DRY	38.1	16.39	1.22
HB 10 O	DRY	25.5	16.33	0.85
HB 11 E	DRY	39.9	18.52	0.68
HB 11 O	DRY	47.6	16.33	0.54
HB 12 E	DRY	32.6	5.10	**
HB 12 O	DRY	66.4	16.40	**
HB 13 E	DRY	79.5	0.30	**
HB 13 O	DRY	*	*	**
HB 7 E	WET	35.3	22.84	**
HB 7 O	WET	34.3	1.80	0.56
HB 8 E	WET	27.7	18.36	0.37
HB 8 O	WET	47.5	53.82	**
HB 9 E	WET	19.5	3.25	2.32
HB 9 O	WET	14.3	7.47	2.50
HB 10 E	WET	23.7	5.37	1.50
HB 10 O	WET	21.4	189.66	1.69
HB 11 E	WET	20.6	30.46	0.93
HB 11 O	WET	24.9	8.38	1.13
HB 12 E	WET	24.1	17.00	**
HB 12 O	WET	17.9	118.77	**
HB 13 E	WET	71.6	0.03	**
HB 13 O	WET	27.9	158.30	**

KW=estimated hydraulic conductivity in mm/hr; PSI=derived capillary suction in mm; ACOEFF=splash coefficient in kg-hr/ha-sq. mm.
BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks
* - equipment failure resulted in no data collected
** - litter plots, not computed

Appendix F. (continued)

SITE			AMC	KW	PSI	ACOEFF
SP	1	E	DRY	23.3	10.70	0.63
SP	1	O	DRY	38.7	2.38	0.66
SP	3	E	DRY	70.8	0.40	0.43
SP	3	O	DRY	65.5	0.35	0.34
SP	4	E	DRY	43.9	0.62	0.53
SP	4	O	DRY	46.2	8.88	1.38
SP	6	E	DRY	27.4	9.74	0.66
SP	6	O	DRY	71.1	0.00	0.07
SP	7	E	DRY	57.5	6.56	0.29
SP	7	O	DRY	72.3	3.52	0.44
SP	9	E	DRY	28.3	8.21	0.85
SP	9	O	DRY	46.8	0.77	0.40
SP	1	E	WET	66.4	0.17	0.20
SP	1	O	WET	32.3	29.06	0.49
SP	3	E	WET	55.6	16.45	0.50
SP	3	O	WET	62.5	4.33	0.38
SP	4	E	WET	50.7	0.62	0.64
SP	4	O	WET	24.5	30.44	1.51
SP	6	E	WET	19.0	5.42	0.37
SP	6	O	WET	65.6	8.00	0.31
SP	7	E	WET	*	*	*
SP	7	O	WET	*	*	*
SP	9	E	WET	24.9	10.55	1.08
SP	9	O	WET	40.9	0.32	0.48
WO	1	E	DRY	17.66	1.53	5.20
WO	1	O	DRY	20.48	0.10	2.39
WO	2	E	DRY	63.85	0.05	1.27
WO	2	O	DRY	28.70	15.10	1.39
WO	3	E	DRY	35.85	0.82	0.77
WO	3	O	DRY	35.45	14.20	1.73
WO	1	E	WET	4.73	14.37	5.31
WO	1	O	WET	18.16	0.30	1.64
WO	2	E	WET	36.10	0.34	2.13
WO	2	O	WET	22.20	14.99	0.83
WO	3	E	WET	13.34	2.13	1.09
WO	3	O	WET	17.39	8.86	1.39
SY	1	E	DRY	41.21	10.54	0.71
SY	1	O	DRY	56.24	9.83	1.57
SY	2	E	DRY	49.09	9.35	0.63
SY	2	O	DRY	46.51	12.88	2.48
SY	3	E	DRY	15.13	5.93	1.02
SY	3	O	DRY	35.29	3.68	1.60
SY	4	E	DRY	23.56	6.42	1.78
SY	4	O	DRY	18.19	1.13	0.80
SY	1	E	WET	28.43	12.57	0.99
SY	1	O	WET	30.02	82.67	1.94
SY	2	E	WET	26.20	30.04	0.52
SY	2	O	WET	30.11	33.71	2.00
SY	3	E	WET	4.18	87.66	1.23
SY	3	O	WET	17.31	5.37	2.30
SY	4	E	WET	12.42	1.11	1.70
SY	4	O	WET	8.26	20.49	1.05

KW=estimated hydraulic conductivity in mm/hr; PSI=derived capillary suction in mm; ACOEFF=splash coefficient in kg-hr/ha-sq. mm.
BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro; WO = White Oaks
* - equipment failure resulted in no data collected

Appendix G. Sediment and Chemical Concentrations in Milligrams/Liter

SITE	AMC	TP	TKN	NO2-3	TVSS	CTSS	BTSS	FTSS	WATER
BH 1 E	DRY	0.27	0.90	0.15	258	808	*	877	D
BH 2 E	DRY	0.19	1.30	0.06	161	858	1438	847	D
BH 2 O	DRY	0.30	1.50	0.02	280	972	*	1313	D
BH 3 O	DRY	0.04	0.50	0.01	72	272	*	307	D
BH 5 E	DRY	0.16	0.90	0.07	73	505	1097	391	A
BH 5 O	DRY	0.72	2.60	0.08	123	568	*	715	A
BH 6 E	DRY	0.08	0.30	0.05	27	55	*	112	A
BH 6 O	DRY	0.24	2.30	0.07	56	138	*	196	A
BH 7 E	DRY	0.12	0.10	0.04	88	940	*	672	C
BH 7 O	DRY	0.18	0.30	0.10	81	348	*	391	C
BH 8 E	DRY	0.22	0.30	0.06	291	618	1066	832	C
BH 9 O	DRY	0.12	0.10	0.01	86	348	*	459	C
BH 1 E	WET	0.08	0.40	0.07	61	845	*	263	E
BH 2 E	WET	0.16	0.70	0.01	70	355	*	414	E
BH 2 O	WET	0.66	1.30	0.02	440	2632	2777	2646	E
BH 3 O	WET	0.34	1.60	0.00	156	248	*	711	E
BH 5 E	WET	0.08	0.70	0.21	53	170	603	223	B
BH 5 O	WET	0.10	0.00	0.03	86	352	*	459	B
BH 6 E	WET	0.04	0.00	0.03	29	82	*	90	B
BH 6 O	WET	0.06	0.00	0.02	26	130	*	96	B
BH 7 E	WET	0.04	0.20	0.04	67	628	*	409	D
BH 7 O	WET	0.08	0.70	0.15	80	410	*	492	D
BH 8 E	WET	0.23	0.30	0.01	99	695	990	575	D
BH 9 O	WET	0.12	0.00	0.03	71	712	*	646	D
HB 7 E	DRY	0.65	3.60	0.74	51	190	*	140	F
HB 7 O	DRY	0.91	3.80	0.06	150	698	1189	853	F
HB 8 E	DRY	0.34	3.50	0.02	153	685	956	736	F
HB 8 O	DRY	0.70	2.10	0.13	33	145	*	126	G
HB 9 E	DRY	1.76	6.70	0.03	447	2182	*	4017	G
HB 9 O	DRY	1.80	3.50	0.03	246	5986	5091	2246	G
HB 10 E	DRY	1.02	3.10	0.11	440	2192	*	2269	H
HB 10 O	DRY	3.92	12.30	0.11	1913	7055	12473	9841	H
HB 11 E	DRY	1.15	4.25	0.04	214	1590	2423	1200	I
HB 11 O	DRY	0.80	3.85	0.08	311	1660	*	1948	I
HB 12 E	DRY	2.38	7.65	2.36	183	392	931	549	J
HB 12 O	DRY	0.74	2.85	0.71	52	132	*	143	J
HB 13 E	DRY	0.80	4.15	0.86	89	330	709	318	K
HB 13 O	DRY	0.18	3.05	0.33	116		*	760	K
HB 7 E	WET	0.46	4.10	0.62	20	82	*	79	H
HB 7 O	WET	0.18	1.30	0.04	80	490	1401	402	H
HB 8 E	WET	0.16	1.70	0.03	85	340	607	364	H
HB 8 O	WET	0.24	1.30	0.28	30	73	*	86	G
HB 9 E	WET	1.16	3.90	0.06	262	1885	*	1881	G
HB 9 O	WET	1.38	3.40	0.05	175	2145	2691	1662	G
HB 10 E	WET	0.70	2.95	0.04	261	1491	*	1466	J
HB 10 O	WET	3.60	6.25	0.05	1291	7360	10451	9128	J
HB 11 E	WET	0.58	2.35	0.05	160	1162	1486	1005	J
HB 11 O	WET	0.84	5.65	0.08	273	165	*	1932	J
HB 12 E	WET	1.33	4.05	1.96	154	455	751	421	L
HB 12 O	WET	0.55	3.15	1.50	26	78	*	44	L
HB 13 E	WET	0.30	1.95	0.29	65	270	576	276	L
HB 13 O	WET	0.75	1.95	0.00	91	586	1082	624	L

TP=total phosphorus; TKN=Kjeldahl nitrogen; NO2-3=nitrate-nitrite; TVSS=total volatile suspended solids; BTSS=oven dried suspended solids; FTSS=filtered suspended solids; CTSS=centrifuged suspended solids; WATER=I.D. in Appendix H.
* = data not collected.
BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro;
WO = White Oaks

Note: Phosphorus and nitrogen values have rainwater concentrations subtracted, sediment values do not have rainwater concentrations subtracted.

Appendix G. (continued)

SITE	AMC	TP	TKN	NO2-3	TVSS	CTSS	BTSS	FTSS	WATER
SP 1 E	DRY	0.46	2.30	0.08	109	572	*	551	M
SP 1 O	DRY	0.92	4.00	0.06	160	1115	*	869	M
SP 3 E	DRY	2.12	6.55	0.10	235	1372	1439	1137	O
SP 3 O	DRY	0.80	4.75	0.06	171	855	*	845	O
SP 4 E	DRY	1.04	4.70	0.20	143	562	*	550	Q
SP 4 O	DRY	4.16	5.60	0.03	599	4282	5465	5487	Q
SP 6 E	DRY	0.34	4.00	0.04	185	700	*	647	Q
SP 6 O	DRY	0.60	2.60	0.08	131	635	*	599	Q
SP 7 E	DRY	0.50	1.90	0.03	72	1452	*	444	R
SP 7 O	DRY	3.00	4.80	0.51	389	2832	3389	3207	R
SP 9 E	DRY	0.64	2.40	0.05	79	305	*	375	T
SP 9 O	DRY	1.78	5.20	0.06	156	1702	*	1260	T
SP 1 E	WET	0.32	1.70	0.03	46	261	*	203	N
SP 1 O	WET	0.76	2.90	0.03	142	862	*	843	N
SP 3 E	WET	1.34	4.20	0.02	207	2756	2729	1447	P
SP 3 O	WET	1.16	5.00	0.02	228	1422	*	1279	P
SP 4 E	WET	1.16	3.10	0.02	141	72	*	527	P
SP 4 O	WET	2.22	6.20	0.08	379	2950	5887	3686	P
SP 6 E	WET	0.54	4.00	0.03	175	775	*	620	P
SP 6 O	WET	0.72	3.40	0.05	372	908	*	1197	P
SP 7 E	WET	0.56	2.10	0.00	74	545	*	418	S
SP 7 O	WET	1.30	5.10	0.02	269	2222	3300	2040	S
SP 9 E	WET	0.34	1.80	0.02	63	330	*	314	T
SP 9 O	WET	1.54	3.00	0.02	189	1520	*	1444	T
WO 1 O	DRY	6.23	17.06	2.15	2270	6265	*	10768	AA
WO 1 E	DRY	3.57	12.20	2.52	758	4235	*	4752	AA
WO 2 O	DRY	0.93	4.26	-0.11	310	1565	*	2282	AA
WO 2 E	DRY	0.93	15.66	0.29	490	3316	*	2344	AA
WO 3 O	DRY	0.52	3.84	0.04	446	3338	*	3914	BB
WO 3 E	DRY	1.14	6.34	-0.04	212	947	*	1690	BB
WO 1 O	WET	3.30	14.48	1.16	1098	3915	*	5554	CC
WO 1 E	WET	1.68	9.38	0.89	558	1572	*	3464	CC
WO 2 O	WET	0.41	5.08	-0.06	240	1452	*	1734	CC
WO 2 E	WET	0.81	7.48	0.01	826	1982	*	2768	CC
WO 3 O	WET	0.40	6.14	0.04	278	2180	*	2318	BB
WO 3 E	WET	0.46	3.84	0.01	204	1365	*	1968	BB
SY 1 O	DRY	0.625	1.16	0.08	304	1745	*	1770	DD
SY 1 E	DRY	0.625	1.80	0.04	192	1515	*	1142	DD
SY 2 O	DRY	0.475	3.60	0.03	296	1838	*	1750	DD
SY 2 E	DRY	0.565	1.40	0.04	290	1838	*	2206	DD
SY 3 O	DRY	0.805	0.80	0.08	380	3540	*	3858	EE
SY 3 E	DRY	0.575	1.50	0.08	278	2529	*	2180	EE
SY 4 O	DRY	0.905	0.60	0.08	370	4640	*	4044	FF
SY 4 E	DRY	0.255	0.10	0.08	294	3005	*	3182	FF
SY 1 O	WET	0.825	0.99	0.02	246	1860	*	1730	DD
SY 1 E	WET	0.345	0.30	0.02	162	1189	*	920	DD
SY 2 O	WET	0.805	1.40	0.08	262	1787	*	1860	FF
SY 2 E	WET	0.435	1.70	0.01	186	1515	*	1452	FF
SY 3 O	WET	0.735	-0.60	0.10	252	2738	*	2620	EE
SY 3 E	WET	0.465	-0.60	0.08	212	1789	*	2034	EE
SY 4 O	WET	0.825	-1.09	0.06	238	3905	*	3172	FF
SY 4 E	WET	0.505	1.80	0.08	242	3102	*	3536	FF

TP=total phosphorus; TKN=Kjeldahl nitrogen; NO2-3=nitrate-nitrite; TVSS=total volatile suspended solids; BTSS=oven dried suspended solids; FTSS=filtered suspended solids; CTSS=centrifuged suspended solids; WATER=I.D. in Appendix H.
BH = Beaverhead; HB = Heber; SP = Springerville; SY = San Ysidro;
WO = White Oaks
* = data not collected.

Note: Phosphorus and nitrogen values have rainwater concentrations subtracted, sediment values do not have rainwater concentrations subtracted.

Appendix H. Sediment and Chemical Concentrations in Simulator Rainwater

I.D. Letter	Total Phosphorus	Kjeldahl Nitrogen	Nitrate-Nitrite	Total Volatile Suspended Solids	Total Suspended Solids
A	< 0.01	0.3	0.91	14	30
B	< 0.01	0.2	1.05	8	10
C	< 0.01	0.5	1.07	10	32
D	0.04	0.4	1.06	1	5
E	< 0.01	0.1	1.06	3	4
F	0.02	0.2	0.14	< 1	25
G	< 0.01	0.2	0.20	< 1	< 1
H	< 0.01	0.1	0.14	1	53
I	0.03	< 0.1	0.13	5	22
J	< 0.01	< 0.1	0.12	6	41
K	< 0.01	< 0.1	0.08	3	32
L	0.02	< 0.1	0.12	< 1	< 1
M	< 0.01	0.3	0.08	10	18
N	< 0.01	0.1	0.22	2	35
O	< 0.01	< 0.1	0.02	8	17
P	< 0.01	0.1	0.31	9	48
Q	< 0.01	0.3	0.06	2	20
R	< 0.01	0.3	0.05	2	25
S	< 0.01	0.1	0.04	< 1	< 1
T	< 0.01	0.1	0.20	< 1	32
AA	0.08	0.2	1.55	4	10
BB	0.08	0.5	1.37	< 1	< 1
CC	0.07	0.3	1.37	< 1	< 1
DD	< 0.01	1.9	0.32	< 1	6
EE	< 0.01	2.1	0.32	< 1	4
FF	< 0.01	1.7	0.32	< 1	< 1

*See previous appendix for the plots to which the I.D. letters correspond.