#486

LA-UR -84-1000 (Revised)

TITLE: PRELIMINARY RESULTS OF EROSION AND CONTAMINANT TRANSPORT RESEARCH ON THE NEVADA TEST SITE

AUTHOR(S): K.V. Bostick
J.R. Simanton
L.J. Lane
T.E. Hakonson

SUBMITTED TO: Proceedings of 1983 NAEG Symposium in Las Vegas, NV
(Note: Presented 1983, Proceedings published in 1984)

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

PRELIMINARY RESULTS OF EROSION AND CONTAMINANT TRANSPORT RESEARCH ON THE NEVADA TEST SITE

By

K.V. Bostick, J.R. Simanton, L.J. Lane, and T.E. Hakonson

ABSTRACT

A cooperative research program on the Nevada Test Site involving application of rainfall simulators on runoff-erosion plots is described and discussed relative to parameter estimation for hydrologic models and erosion, sediment transport, and contaminant transport models. Preliminary results from experiments conducted in 1983 are used to illustrate the influence of vegetation and erosion (or desert) pavement (a natural gravel mulch) on runoff and erosion. Preliminary results from the plots demonstrate that the magnitude of runoff and erosion is greatly influenced by the erosion pavement and moderately influenced by the plant cover.

INTRODUCTION

Since May 1983, cooperative research involving rainfall simulator plots has been underway at two areas on the Nevada Test Site (NTS). The purpose of the research is to quantify parameter values for hydrologic, erosion, sediment transport, and contaminant transport models to allow their application in arid and semiarid ecosystems.

Many of the techniques used to predict runoff, erosion, sediment transport, and contaminant movement are based on procedures developed in more humid areas of the country. As a result, there was a need to

---

1. K.V. Bostick, L.J. Lane, and T.E. Hakonson are members of the Environmental Science Group, Los Alamos National Laboratory. J.R. Simanton is a hydrologist with USDA-ARS in Tucson, Arizona.

extend these studies and develop similar procedures for ecosystems in arid and semiarid regions such as the Southwest.

This has resulted in a cooperative project involving several agencies and organizations. Department of Energy (DOE) sponsored organizations include the Los Alamos National Laboratory, the Civil Effects Test Office, and the Nevada Operations Office. DOE funding is provided from the Office of Health and Environmental Research and from Operations.

The USDA-Agricultural Research Service is involved through the Southwest Watershed Research Center at Tucson, AZ and the National Soil Erosion Laboratory at West Lafayette, IN. Universities involved include: University of California-Los Angeles, New Mexico State University, University of New Mexico, and Colorado State University.

The diverse support is also reflected in the multidisciplinary nature of the study. While at first appearance this is a study of physical contaminant transport processes, studies of hydrology and erosion require expertise in a number of fields including physical, biological, and chemical sciences. This approach demonstrates the value of pooling knowledge resources and applying this expertise to problems of national interest.

Need for Predictive Capability for Contaminant Transport

A state of the art assessment of transuranics and their behavior in the environment was presented by Hanson (1980) and reflected a consensus view of that time. A more recent state of the art assessment was presented by Watters et al. (1983). As is well documented in these reports and elsewhere, the soil compartment is usually the major repository for actinide elements in the environment. Therefore, processes which affect soil (e.g. soil erosion, sediment transport and deposition as well as resuspension) can affect the transport and redistribution of sediment-associated contaminants. Our discussions herein will be limited to water, rather than wind, erosion and subsequent transport and deposition processes.

Because many of the sediment-associated contaminants of concern at the NTS and elsewhere have long half lives, accurate predictions of erosion and contaminant transport processes are needed over rather long time periods. On time scales such as these, redistribution processes affecting contaminant enrichment or dilution become significant. Therefore, there is a real need for on-site evaluation of runoff and erosion processes and model parameter determinations for NTS conditions.

Need for Erosion Research in Arid and Semiarid Areas

The need to predict the effect of hydrologic processes on land and water quality arose in the 1920s and 30s as a result of drought and poor farming practices. As a result, the U.S. Department of Agriculture (USDA) began an extensive research program to understand hydrology and erosion in cropland situations. From this they have developed the foremost expertise in the country on predicting water balance and erosion in disturbed systems such as croplands.

In 1978 about 50 scientists from USDA and other agencies undertook a cooperative effort to develop a water balance-erosion model based on those several decades of research. The resultant model was intended as a tool for use by agencies with land management responsibilities.

The model developed as a result of these efforts, called CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), is described by Knisel (1980).

The CREAMS simulation model consists of a hydrology or water balance component and an erosion component. In the hydrology component, the soil profile is represented by from one to seven layers. Each layer can have different properties. Precipitation is the input of water to the soil profile to the rooting depth. The output or losses are runoff, evapotranspiration, and seepage below the root zone. The water balance equation shows that the rate of change of soil moisture with time is equal to the difference between the input and the outputs. Parameters for the hydrologic component were derived for more humid sites and cultivated agricultural areas.

Coupled with the hydrology component of CREAMS is the erosion component which is partially based of the Universal Soil Loss Equation (USLE). The parameters in the USLE are K, a soil erodibility factor which is a function of soil properties; C, a cover term, influenced by such things as vegetation, gravel mulch, rocks, etc.; LS which is the topographic factor related to slope length and steepness; P, a management practice factor related to the formation of terraces or other conservation practices in agricultural systems; and R, a rainfall energy runoff parameter. These together form the USLE used to predict erosion on agricultural areas. Some of these same parameters are also used in the CREAMS model to predict erosion and sediment yield. The primary purpose of the Rainfall Simulator experiments is to determine C, the influence of the cover vegetation and rock cover; and K, the soil erodibility.

There are two ways to obtain parameters on erosion and hydrologic models. One is to monitor natural rainfall events and deal with the long time periods and extremely large variability inherent in these measurements. The other is to apply artificial rainfall by means of a rainfall simulator on standardized plots. The latter method is being used for model verification studies and in determining parameter values for both the hydrology and erosion component of the CREAMS model.

METHODS AND RESULTS

The experimental design follows the paired-plot, three treatment design developed earlier (see Simanton and Renard, 1982). Briefly, six plots (3 by 11m) were established at each of two areas on the NTS (Area-11 and Mercury). At each area, two natural plots were selected as the control, vegetation was clipped at ground level with minimal disturbance to the soil surface on two plots, and the final two plots had vegetation clipped as described above and the rock and gravel mulch (erosion or desert pavement) was removed with minimal soil disturbance (see Simanton and Renard, 1982, for a more complete description). Thus, the experimental design involves evaluating natural conditions (control plots), influence of vegetation (clipped plots), and influence of vegetation and erosion pavement (cleared plots).

The characteristics of the rainfall simulator in terms of drop size, terminal velocity of the drops, and energy have also been well defined. This experimental configuration allows us to measure or control all of the variables associated with water dynamics and erosion. A unique feature of this simulator is that it is portable and can be used in a variety of ecosystems to apply the same amount and rate of precipitation as opposed to relying on natural events that are extremely variable in space and time.

The procedure is to apply rainfall to the plot pairs at a uniform rate of 6.4m (2.5 inch)/hour . All of the runoff is collected in troughs at the bottom of the plots and passed through a flume that measures rate and volume. Samples of runoff are collected at the flume outlet to determine sediment concentration as a function of time. Psychrometer measurements of soil moisture are also made throughout the year at NTS.

Direct measurements on precipitation input, soil moisture (both before and after a simulator run) and runoff allow computation of a water balance under the assumption of no seepage or percolation out of the rooting zone. Analysis of sediment loads in runoff allows computation of erosion rates and sediment yields.

An important variable in experiments of this kind is antecedent moisture. Rain is applied to the plots in a set sequence to determine the influence of antecedent moisture on measurement parameters. The first run, called a "dry" run is a one-hour run made under existing soil moisture conditions (usually very dry). During this run about 6.4 cm (2.5 inches) of artificial rain is applied. Twenty four hours later a second run of 30 minutes duration is made, again applying the rainfall at the 6.4 cm/hour rate. This is called the "wet" run. Thirty minutes later, another 30 minute run is made at the same rainfall rate. This is called the "very wet" run. That sequence of conditions is used to determine effects of antecedent soil moisture. Notice that twice as much total water is applied to the plots during the first one-hour run as is applied in each of the two half-hour runs.

A brief summary is presented of the results from the runs made during May, 1983 at two study areas, Area 11 and Mercury, at the Nevada Test Site. Both areas are Mojave Desert locations but with indentifiable differences in vegetation and soil.

Vegetation and plot surface characteristics were determined for each of the 12 plots using a 490 point grid. The data were averaged over the replicated treatments and are summarized in Table 1. The average land slope of the plots varied from 6.5 to 8.8% but are fairly close to the desired 97% standard or unit plot slope. Data such as are summarized in Table 1 are necessary to quantify the influence of vegetation and plot surface characteristics when comparing runoff and erosion data from plots at different locations.

Results from Area 11 under natural cover conditions, show almost no runoff under dry conditions but that runoff increased by factors of 3 and 7 for the wet and very wet runs, respectively, (Table 2). Similar results were seen when the vegetation was removed suggesting that plants play a minor role in reducing runoff. However, when the erosion pavement was removed, runoff increased by two- to ten-fold over that observed for control and clipped plots (Table 2).

At the Mercury plots, there was much greater runoff on the natural plots compared to corresponding plots at Area 11, a slight increase in runoff when the vegetation was removed and about a factor of two increase (over control plots) when both the plants and erosion pavement were removed. Recall that removing the plant and rock cover at Area 11, increased runoff by a factor of 2-10. The differences in runoff yields between the sites primarily reflect differences in soils.

Sediment yield, in grams per square meter, follows the runoff data closely (Table 3). There was not much difference in sediment yield between the natural plots and the plots with vegetation removed, but a ten- to one hundred-fold increase in sediment yield with the removal of both the plants and erosion pavement. At Mercury, the higher runoff (Table 2) resulted in higher sediment yields than at Area 11 (2-50 times more). Sediment yield from the clipped plots was slightly greater than the control plots while sediment yield from the clipped and cleared plots averaged about 10 times the control.

When sediment yield was normalized to runoff volume (Table 4), sediment concentrations in runoff at Area 11 were about the same under all antecedent moisture conditions on the control plots, about double when the vegetation was removed, and about 5 times the control when both the plants and erosion pavement were removed. At Mercury, there is about the same sediment concentration in runoff on the control and clipped plots at all antecedent soil moisture conditions while concentrations increased by factors of 5-8 when both plants and erosion pavement were removed. The data suggest that for a given treatment there is not much difference between the two areas in terms of suspended sediment concentrations in runoff suggesting that the differences are due to the runoff.

Under humid conditions, where dense vegetation cover exists, the removal of the vegetation would likely be much more significant in affecting erosion than we have observed at NTS. Under desert conditions, where vegetation is sparse to begin with, the erosion pavement or gravel mulch is providing most of the protection of the soil surface against erosion. However, the vegetation is important in depleting soil moisture by transpiration.

DISCUSSION

Preliminary results from the Spring 1983 erosion plot studies demonstrate the need for field data to parameterize hydrologic and erosion models. For example, while the qualitative appearance of the natural ground cover at the Area 11 and Mercury study plots is similar, runoff and erosion from the two areas is quite different suggesting significant differences exist in the physical and/or biological makeup of the sites. Differences in runoff and erosion between locations persisted when the ground surface was subjected to disturbances such as might be encountered during site cleanup. Based upon the response of the plots after removing plants and/or plants and erosion pavement, much of the differences in runoff and erosion between locations can probably be attributed to differences in soils.

Preliminary results also demonstrate the overwhelming importance of erosion pavement in controlling runoff and erosion while the sparse plant cover contributes little to the direct reduction of runoff and erosion. However, plants indirectly affect runoff and erosion by affecting soil moisture. Our results suggest that antecedent soil moisture influenced both runoff and erosion, particularly at Area 11.

The data reported herein represent one set of simulator runs during Spring 1983. Therefore, as additional data are collected, the absolute differences in runoff and erosion due to treatment effects may change.

This means that these results are preliminary and conclusions based upon them are tentative. Additional data from the Fall 1983 simulator runs (data are now being processed) and from simulator runs in 1984 will extend the data base and allow more definitive interpretation of data and relationships between imposed treatments and CREAMS model parameters.

In summary, the cooperative research on hydrology, erosion and contaminant transport is contributing new information important in understanding physical transport processes in arid and semi-arid ecosystems. The Nevada Test Site studies extend this research to the Mojave desert and contribute to a national data resource which will form a basis for evaluating the environmental impacts of defense, energy, and agricultural activities in western rangelands.

ACKNOWLEDGMENTS

A cooperative project undertaken between several agencies and organizations such as this study involves support from numerous groups and individuals. In addition to DOE/OHER and USDA-ARS, we wish to acknowledge the cooperation and support of the Civil Effects Test Office personnel at Mercury, NV and personnel of the Nevada Applied Ecology Group. Many personnel in the Radiological Safety Division of Reynolds Electrical and Engineering Co. provided valuable assistance as well as a supply of water necessary to the simulation runs. And finally, a special thanks is owed to the staff of the Los Alamos National Laboratory's On-Site Support Office (J-3) for providing lodging and transportation, arranging clearances and handling the many details involved in working at NTS.

REFERENCES

Hanson, W.C. ed. 1980. Transuranic Elements in the Environment. Pub. by Technical Information Center, U.S. Dept. of Energy, DOE/TIC-22800, Washington, D.C.

Knisel, W.G. Jr. ed. 1980. CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Department of Agriculture, Conservation Research Report No. 26, 640 pp. USDA, Washington, D.C.

Simanton, J.R. and Renard, K.G. 1982. Seasonal Changes in Infiltration and Erosion from USLE Plots in Southeastern Arizona. Hydrology and Water Resources in Arizona and the Southwest, Vol. 12, pp 37-46.

Watters, R.L., Hakonson, T.E., and Lane, L.J. 1983. The Behavior of Actinides in the Environments. Radiochemica Acta,89-103 (1983).

Table 1. Summary of vegetation and plot surface characteristics from 12 experiment runoff-erosion plots on the Nevada Test Site. Average percent cover, two plots per treatment. Spring 1983.

Location	Treatment[a]	% Slope	% Crown Cover[b]	% Surface Letter	% of Plot Surface as: Soil[c]	Gravel	Rock
Area 11	Control	7.4	19.0	19.3	21.4	46.1	14.5
	Clipped	6.5	0	14.6	27.0	42.0	15.7
	Cleared	7.8	0	3.4	83.4	9.6	3.6
Mercury	Control	8.8	17.8	15.0	21.8	50.5	12.4
	Clipped	8.6	0	7.8	18.8	50.2	23.0
	Cleared	8.7	0	1.5	86.2	6.8	5.6

a. Control is the natural plot, clipped has vegetation removed, and cleared has vegetation and erosion pavement removed.

b. Crown cover of existing vegetation on the control plots at the start of the experiment

c. Soil is designated as non-litter and particle size smaller than 5mm in diameter. Gravel is designated as particles between 5 and 20mm and rock is designated as largerthan 20mm in diameter. Note, % litter, soil, gravel, and rock sum to 100% except for roundign errors.

Table 2. Summary of runoff data from 12 experimental runoff-erosion plots on the Nevada Test Site. Average runoff volumes in mm per unit area (or per plot), two plots per treatment, Spring 1983.

Location	Treatment	Dry	Wet	Very Wet
Area 11	Control	0.8	3.3	6.6
	Clipped	Trace	2.0	7.1
	Cleared	10.3	11.3	14.9
Mercury	Control	19.4	14.7	16.8
	Clipped	27.6	20.0	22.7
	Cleared	39.6	23.1	25.3

Table 3. Summary of sediment yield data from 12 experimental runoff-erosion plots on the Nevada Test Site. Average sediment yields in g/m^2, two plots per treatment, Spring 1983.

Location	Treatment	Dry	Wet	Very Wet
Area 11	Control	1.3	6.0	12.3
	Clipped	1.2	8.2	16.2
	Cleared	82.6	104.0	179.0
Mercury	Control	49.5	25.9	29.0
	Clipped	61.9	46.2	52.6
	Cleared	555.0	404.0	302.0

Table 4. Summary of sediment concentration data from 12 experimental runoff-erosion plots on the Nevada Test Site. Sediment concentration in mg/l, two plots per treatment, Spring 1983.

Location	Treatment	Dry	Wet	Very Wet
Area 11	Control	1600.	1800.	1900
	Clipped	-*	4100.	2300.
	Cleared	8000.	9200.	12,000.
Mercury	Control	2600.	1800.	1700.
	Clipped	2200.	2300.	2300.
	Cleared	14,000.	17,500.	12,000.

* Only a trace of runoff recorded, not sufficient to determine runoff volume or sediment concentration.