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Erosion of Strip Mine Lands

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EROSION OF STRIP MINE LANDS

by

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FOREWORD

The Federal Water Pollution Control Act Amendments of 1972, in part, stress the control of nonpoint source pollution. Sections 102 (C-1), 208 (b-2,F) and 304(e) authorize basin scale development of water quality control plans and provide for area-wide waste treatment management. The act and the amendments include, when warranted, waters from agriculturally and silviculturally related nonpoint sources, and requires the issuance of guidelines for both identifying and evaluating the nature and extent of nonpoint source pollutants and the methods to control these sources. Research program at the Northeast Watershed Research Center contributes to the aforementioned goals. The major objectives of the Center are to:

- study the major hydrologic and water-quality associated problems of the Northeastern U.S. and
- develop hydrologic and water quality simulation capability useful for land-use planning. Initial emphasis is on the hydrologically most severe land uses of the Northeast.

Within the context of the Center's objectives, stripmining for coal ranks as a major and hydrologically severe land use. In addition, once the site is reclaimed and the conditions of the mining permit are met, stripmined areas revert legally from point to nonpoint sources. As a result, the hydrologic, physical, and chemical behavior of the reclaimed of the reclaimed land needs to be understood directly and in terms of control practices before the goals of Sections 102, 208 and 304 can be fully met.

Signed:

Harry B. Pionke
Director
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ABSTRACT

The plot studies were carried out at Karthaus and Klingerstown to verify the accuracy of the erosion pin method of soil loss evaluation compared to soil loss measured in runoff samples. Subsequently, field studies at Kylertown and Kittaning were used to apply these methods. Kylertown site showed no concentrated areas of erosion for the 4 month study period. However, over the 12 year existence of this site, observable rills and gullies have accounted for large soil losses. The newly reclaimed site at Kittaning was quite vulnerable to erosion, with one area experiencing a concentrated soil loss of 12-16 mm during the study period.

When erosion pins are used with the surface contouring program areas of potential concentrated soil loss can be readily located on reclaimed strip mines. For best results it is recommended that the erosion pins be initially placed in a grid network on slope of interest.

CONCLUSIONS

The methods described in this paper to quantify erosion were applied to four different sites. The plot studies at Karthaus and Klingerstown established the accuracy of the erosion pins compared to collected runoff samples. The Alutin method could not be evaluated, as no rills were observed on the plots. The field studies at Kylertown and Kittanning were used to apply the methods described in the paper. The Kylertown site showed no concentrated areas of erosion according to the erosion contour map produced for the 4 month study period. However, over the 12 year existence of the site, rills and gullies have accounted for large soil losses. The newly reclaimed site at Kittanning was quite vulnerable to erosion, as indicated by the contour map drawn from the erosion pin data. One area had experienced a concentrated soil loss of 12-16 mm over the study period. Rills developing on the site resulted in noticeable erosion, particularly in the area of concentrated soil loss noted by the contour maps.

In conclusion, the erosion pins with the surface contouring program offer one method for locating concentrated areas of soil loss on reclaimed strip mines. It is recommended that the erosion pins be initially placed in a grid network across the slope profile in such a manner as to cover the slope by equally spaced erosion pins. Erosion contour maps produced from this arrangement can produce an overall picture of surface erosion. If concentrated areas of soil loss are noted by these contour maps, it is recommended that more erosion pins be placed in these areas for more detailed information. Once located, areas of concentrated soil loss can then be stabilized by effective soil and water conservation practices.

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SECTION 1

INTRODUCTION

The surface of a reclaimed strip mine may change rapidly in response to erosional processes as this relatively new land form evolves. Initially, large volumes of soil (spoil) can be eroded from the reclaimed site and transported throughout the drainage basin (Curtis, 1974). The following conditions are likely to contribute to high erosion rates; unaggregated fine material from crushed rocks, the lack of a protective vegetative cover, and long steep slopes. Runoff from these slopes can attain the necessary volume and velocity to erode at an accelerated rate. During a period of many years the original surface will be eroded, transported, redeposited, and scarred with rills and gullies.

To reduce the amount of eroded surface, it is first necessary to locate areas where most soil is eroding. One method used to monitor surface erosion has been erosion pins. (Schumm, 1967). The erosion pin can act as a reference point in the soil surface for noting ground advance or retreat by measuring the distance between the soil surface and pin head. Also the amount of surface eroded by rills has been estimated by using the Alutin method (Oleson, 1977). This is accomplished by measuring the cross-sectional area of rills occurring along the surface. These methods are relatively simple to use, inexpensive and require no specialized equipment.

The objectives of this study were to 1) review the mechanisms and processes of soil erosion and 2) test the use of erosion pins and the Alutin method for quantifying surface erosion.

SECTION 2

LITERATURE REVIEW ON EROSION PROCESSES

In the process of land form evolution, erosion by rain and runoff can be considered the most effective mechanism. Raindrops which impact on the soil surface initiate the process of particle detachment by splash erosion. During a storm the rain falling on the surface is initially absorbed until the surface becomes saturated. Continued precipitation may collect on the surface and begin moving downslope as runoff. The eroding force of the runoff is referred to as sheet erosion. When runoff by sheet flow concentrates into small channels rill erosion starts. This occurs where the erosive force (F) of the flow exceeds the resistive force (R) of the surface. Rills merge to form increasingly concentrated flow, which increases the ratio of F to R, thereby accelerating erosion. The entire process takes place in response to many interacting factors and inherent properties of the surface soil or spoil. Following is a review of some of these factors.

Splash Erosion

Splash erosion is a direct result of raindrop impact. A raindrop falling through the atmosphere attains a certain amount of kinetic energy which, upon impact with the soil surface, is transferred to the soil particles. Mihara (1951) calculated that a raindrop 2.5 mm in diameter possesses a kinetic energy of 10^4 ergs. This amount of energy is capable of elevating a 4.6 g particle 1.0 cm. An increase in drop size would increase the energy available for detachment. Laws (1940) found that rainsplash erosion increased up to 1200 percent as drop size doubled. A relationship between drop size and rainfall intensity was developed by Laws and Parsons (1943):

$$D_{50} = 2.231(I^{0.182})$$

where:

D_{50} = median drop size (mm).
I = rainfall intensity (in/hr).

Wischmeier and Smith (1958) developed an equation to determine total storm energy based on rainfall intensity by:

$$Y = 916 + 331(\text{Log}_{10} I)$$

where:

Y = kinetic energy (foot tons/acre in).
I = rainfall intensity (in/hr).

The kinetic energy from a falling raindrop must attain a critical lift force to elevate a soil particle from its bed. The larger the particle, the higher the critical lift torce for detachment. Particle size is influenced by the degree of aggregation which markedly affects soil detachment (Young and Mutchler, 1977). The effect of binding agents in the soil tends to increase the critical lift force. If energy is sufficient, an impacting raindrop can expell soil particles in a cratering fashion. Mutchler (1971) found that raindrop impact was most erosive where a thin sheet of water is present at approximately one-fifth the drop diameter. However, splash erosion can be non-existent if the water film is greater than three drop diameters.

The continuous impact of raindrops throughout a storm can detach and make available for transport large amounts of sediment. The process is most active during intense summer storms (McGuiness et al., 1971).

Sheet-Interrill Erosion

This phase of the erosional process can be regarded as a transporting mechanism of already detached soil particles and an eroding mechanism through its velocity of flow. This process is initiated when precipitation collected on the surface is augmented by an outward component of flow. The process is partly controlled by the infiltration capacity of the soil.

Farmer and Richardson (1976), found that infiltration capacity of the soil was related to the percent of clay and the percent of macro-pore space. Soil puddling, which decreased infiltration, occurred when available pore space in the soil became clogged with fine particles such as clay or silt. Soil crusting, which generally follows puddling, will also reduce infiltration since particles can bind to each other more strongly from repeated wetting and drying cycles. Tackett and Pearson (1965) found that crusting can create a 1 to 3 mm seal on the soil surface.

Once the infiltration capacity of the soil has been exceeded, other factors become more important in producing sheet erosion. Young and Onstad (1978) found that as slope increases from 4 to 9 percent the amount of soil lost from interrill areas increased markedly. On shallow slopes the transport capacity may be limiting. Although raindrops are capable of detaching large soil particles, the particles are not likely to be transported very far. The rate of detachment and subsequent sheet erosion is also affected by soil properties. This factor is represented in the Universal Soil Loss Equation by the soil erodibility factor K (Wischmeier and Smith, 1965).

The transport of particles by sheet flow is significantly increased by falling rain. This creates a turbulent state which more easily suspends particles in the flow. This has been referred to as agitated laminar flow (Emmett, 1970). The transport capacity is also influenced by runoff rate, roughness of the surface, and the transportability of detached soil particles (Foster and Meyer, 1975).

Rill Erosion

Rills develop when runoff by sheet flow becomes concentrated in a small channel. Also, rill erosion will occur in previously defined channels because of local microrelief, equipment marks, and cracks. The rill can be considered an ephemeral channel, the existence of which from one season to the next depends upon the presence and concentration of sheet runoff. If one of the channels persists, it is generally able to develop its own valley and capture other rills to become a master rill or gulley.

Rills are active in two processes: 1) the erosion of their own channels by detaching soil particles in the progressive deepening of the channel, and 2) the transport of runoff and sediment delivered by sheet flow along with the transport of material eroded from the rill channel. Rill detachment or erosion occurs when the shear stress of the flow overcomes the critical shear stress of the channel (soil). This is influenced by soil properties in the channel. Young and Onstad (1978) found that a loamy sand which was well drained, unaggregated, and had a K value of .11 was highly susceptible to rill erosion. The Yalin equation has been used to estimate rill detachment per unit area per unit time (Yalin, 1963).

The transport of detached sediment in rills was found to be primarily as a bedload by the process of rolling and saltation along the channel bottom (Foster and Meyer, 1972). Bedload equations have been used to estimate the transport capacity of rills which is influenced by the following hydraulic variables: 1) hydraulic radius, 2) percent slope, 3) discharge volume, 4) average velocity, 5) channel roughness, and 6) particle size (Foster and Meyer, 1975). If the influx of sediment from sheet wash and rill detachment exceeds the transport capacity of rill flow, deposition will occur. Einstein (1968) developed the following equation to estimate the rate of deposition:

$$D_d = C_d(T_c - G)$$

where:

D_d = rate of deposition (weight/time).
C_d = a coefficient which is a function of sediment-fall velocity, water quality, and depth of flow.
T_c = flow transport capacity at a location (weight/unit width/time).
G = sediment load of flow at any location on a slope (weight/unit width/time).

In summary, the erosion process can be divided into 1) sheet erosion in which soil is detached by raindrops (splash) and transported by a thin overland flow, and 2) rill erosion in which soil is detached and transported by concentrated runoff. Mathematically, Foster et al. (1977), in plot studies, developed an erosion equation based on the source area of sediment:

$$A = \underbrace{\frac{(X\ K_r\ (as^e)\ F_t\ C_r\ P_r)}{D_r}}_{\text{rill erosion}} / \underbrace{\frac{(U + K_i\ (bs + C)\ I_t\ C_i\ P_i)}{D_i}}_{\text{sheet erosion}}$$

where:

- A = average soil loss for slope length X.
- F_t = runoff erosivity.
- I_t = rainfall erosivity.
- $K_r + K_i$ = soil erodibility factors for rill and interrill erosion, respectively.
- $C_r + C_i$ = cropping management factors for rill and interrill erosion.
- $P_r + P_i$ = supporting factors for rill and interrill erosion.
- a,b,c,e = coefficients.
- X = length of a unit plot (22.1 m).
- s = sine of the slope angle.
- U = length of a unit plot
- D_r = average rill soil loss over the slope length X.
- D_i = average interrill soil loss over the slope length X.

SECTION 3

METHODS USED TO QUANTIFY EROSION

The second objective of this study was to test the use of erosion pins and the Alutin method for quantifying erosion. The methods were used for a plot scale analysis and for a field scale application.

Erosion Pins.

An erosion pin is essentially a rod placed in the soil to measure the surface retreat or advance in relation to the rod. A decrease in the length of the erosion pin exposed is due to surface advance. An increase in pin exposure is due to surface retreat. These processes may occur independently of erosion or deposition due to expansion or contract ion of the ground surface by wetting and drying, and freezing and thawing. The technique of erosion pins was pioneered by Schumm (1956) in the use of wooden stakes. Colbert (1956), advocated the use of metal pins as being more permanent. Ground retreat or advance was measured by recording the differences between the top of the erosion pin and the height of the soil. Schumm (1967) employed a removable washer which was placed over the pin down to the soil surface. This helped to average out the unevenness of the soil around the erosion pin. The time interval between recordings varied from 7 days (Bridges, 1969), to over a year (Schumm, 1956).

The erosion pins used in this study were five-eight´s inch diameter reinforcing rods approximately 1 m in length. These pins were driven into the soil (spoil) using a 10 pound sledge hammer, leaving 5 to 10 cm of the pin above the surface. The number and locations of the pins depended on the site. Each pin was numbered or coded in a manner to facilitate the use of a computer program developed to compare pin measurements between recordings (Appendix A). Following insertion of the erosion pins an initial pin reading was recorded to note the difference between the top of the pin and the soil surface. This was done by using a pin measuring device and a removable metal washer. Using a micrometer, accurate to within 0.02 mm, a pin measurement was recorded (Figure 1). The pins were then measured periodically to monitor changes in soil height. Each time the pins were measured, a comparison was made to the initial pin reading to note total changes, and to the last previous reading to note changes between readings. The erosion program was used to evaluate and list these comparisons. In addition, the program calculated the average ground advance or retreat for a recorded event, plus indicating the order of 10 pins which had the largest ground advance or retreat.

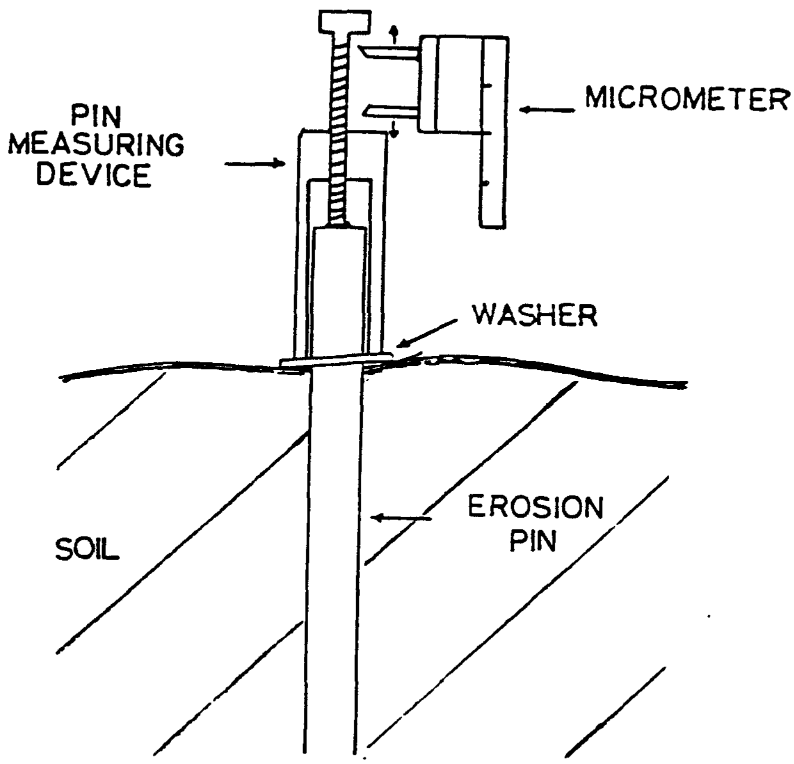

Figure 1. Diagram of erosion pin and measuring technique.

To locate areas of erosion and deposition, SURFACE 2, a contouring program was used to draw contour lines of erosion from the erosion pin data (Simpson, 1975). Each erosion pin is given an X and Y coordinate for determining its location on a grid of a specified number of rows and columns. A Z coordinate for each pin is used to represent changes in surface elevation at the pin. Using this information, the SURFACE 2 program sets up a grid matrix and estimates Z values at each node from the erosion pin data points. To determine Z values at each node, a given search radius is used to collect information in estimating the node value. If a sufficient number of points is not located, a Z value cannot be estimated at that node and the contour map may be incomplete.

In addition to measuring the erosion pins, total rainfall between measurements was also recorded. A recording rain gauge was used at the two field sites to note rainfall and intensities for each storm. Wischmeier and Smith (1958) developed an equation for estimating the rainfall erosion index (R) of a storm based on the maximum 30 minute intensity (I_{30}). The erosive potential is calculated by the following method:

$$R = E \times I_{30}$$

where:

E = kinetic energy of a storm in m-ton meters per hectare per cm of rain

$= [210 + 89(\log_{10} I_{30})]$

I_{30} = maximum 30 minute intensity (cm/h).

By summing the R values for each storm, the erosive potential of rainfall between pin measuring events can be determined.

Alutin Rill Erosion.

This method, developed by Oleson (1977), is used to estimate soil loss from rills in metric tons per hectare. The method calls for adding the cross-sectional area of all rills in cm^2 occurring within a measured linear distance of 12.8 m across the slope. Based on this method, a number of 1 m sets of erosion pins (2 pins one m apart) were placed along the slope at several contour intervals. At each contour interval across the slope profile, the number of one meter sets was summed and divided by 12.8 m to give a surface length across the slope equivalent to 12.8 m. The area of rills occurring between the 2 pin sets was divided by 6.45 to give the equivalent area in square inches. The equation here is:

Soil loss by rills =
(metric tons/hectare)

$$\frac{\text{rill area cm}^2}{6.45} \times \frac{12.8\ \text{m}}{\#\ 1\ \text{meter sets}} \times 0.75$$

Plot Scale Analysis of Methods.

Plot studies were conducted to evaluate the methods described for quantifying erosion. At this small scale it was possible to sample runoff from the plots to estimate soil erosion and compare this information to the erosion pins and Alutin method. Following is a discussion on plot design, soil sampling procedure, runoff sampling procedure, and calculations to determine plot erosion in mm.

Plot design. To test the correspondence between erosion at a point and erosion over an area, a rotating-boom rainfall simulator, similar to the one developed by Swanson (1965), was used on a plot scale at 2 sites. The simulator was centered between 2 erosion plots 3.0 m by 9.1 m in each of which were placed erosion pins. Plot borders were constructed from 4 cm by 25 cm wooden planks. The planks were buried 12 cm below the soil to keep runoff inside the plot. The runoff from the study area was channeled into a trough at the lower end of the plot from which was sampled the runoff rate in cm^3/sec and soil concentration in mg/l (Figure 2).

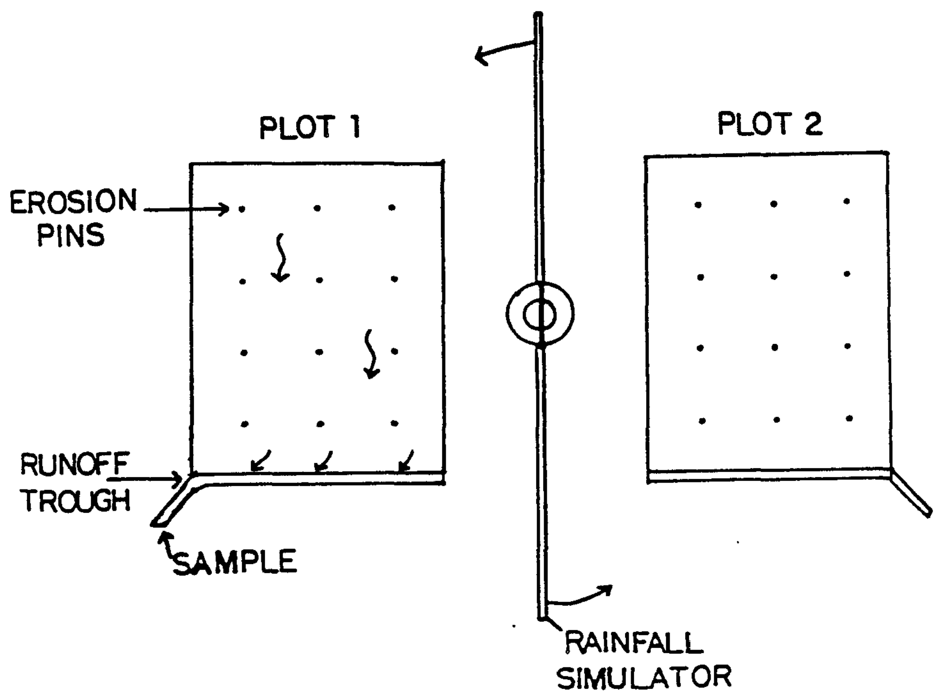

Figure 2. Plot design for rainfall simulator.

Estimating soil in runoff. In order to estimate the total soil eroded from the plot, runoff samples were analyzed to determine the concentration of soil in mg/l. Approximately 8 samples were taken from each plot during the 45 min simulated rainfall. The samples were taken back to the lab and allowed to sit for 3 days so that suspended sediment would settle. The water was then decanted off into a graduated cylinder, measured and recorded. The sediment left in the bottles was transferred to pre-weighed drying pans and placed in a drying oven at 105^{o} C. After 3 days the weight of eroded soil in the cans was determined and recorded with the other information.

Estimating runoff rate. Two methods were used to estimate runoff rate in cm^3/sec. At the Karthaus site, the rate of runoff at each sampling interval was estimated by using a stop watch to record the amount of time (sec) to fill the volume of the sample collected (cm^3). This rate of runoff was assumed to be a representative sample for the sampling interval. Therefore, the total runoff for that sampling period is estimated by multiplying the rate of runoff by the sample time interval.

The runoff rate from the Klingerstown site was determined by using a v-notch barrel equiped with a revolving chart to record runoff. The v-notch barrel was calibrated to determine the relationship between chart reading and flow through height (Appendix C). Using this relationship and the equation developed by Cone (1916), the rate of runoff in cm^3/sec during any time of the run could be determined from the chart height by the following equation:

$$Q = (1.322 + \frac{0.522\ N}{3.281^e H_m^{\ e}})\ \tan(\theta/2)\ H_m^{\ 2.5}$$

where:

H_m = head in m (from chart calibration).

θ = angle for v-notch.

$N = 0.035 + 0.033[\tan(\theta/2)]^{-0.8}$

$e = 0.2475[\tan(\theta/2)]^{0.09} + 0.340[\tan(\theta/2)]^{0.035}$

Calculating plot erosion.

For each sample collected, the amount of surface decline in mm was calculated by solving the equation below. The total surface decline of the plot surface for each simulated rainfall was determned by summing the calculated surface decline from the soil in each sample.

Total soil eroded in mm of plot surface =

sample interval (sec) X soil concentration (g/cm^3)

X flow (cm^3/sec) X dry bulk density (cm^3/g)

X plot area ($1/273000\ cm^2$) X conversion (10 mm/cm)

Field Scale Application of Methods.

The erosion pins and Alutin method were used to quantify erosion from strip mined sites for a field scale application. These sites are described in the results section of the paper.

SECTION 4

RESULTS AND DISCUSSION

The methods discussed in this paper were applied to 4 sites, Karthaus and Klingerstown on a plot scale, and Kylertown and Kittaning on a field scale.

Plot Scale

Karthaus. This site is located near Karthaus, Pennsylvania, and is actively being strip mined. Mining and reclamation are taking place simultaneously at this location. As the coal is taken out, the trench is backfilled with overburden from the next cut. Cover soil is then replaced, fertilized, and seeded. The area where the two 3 m by 9.1 m erosion plots were constructed had been reclaimed in this manner approximately 1 month prior to the study. There was no vegetation on the plots, which had a 5 percent slope and an average bulk density of 0.95 g/cm^3.

For this plot study, 12 erosion pins per plot were located according to Figure 3 on August 20, 1981. The pins were measured for the first time on August 27 to determine the initial height of the soil surface prior to the simulated rainfall. The first simulated rainfall (run 1)

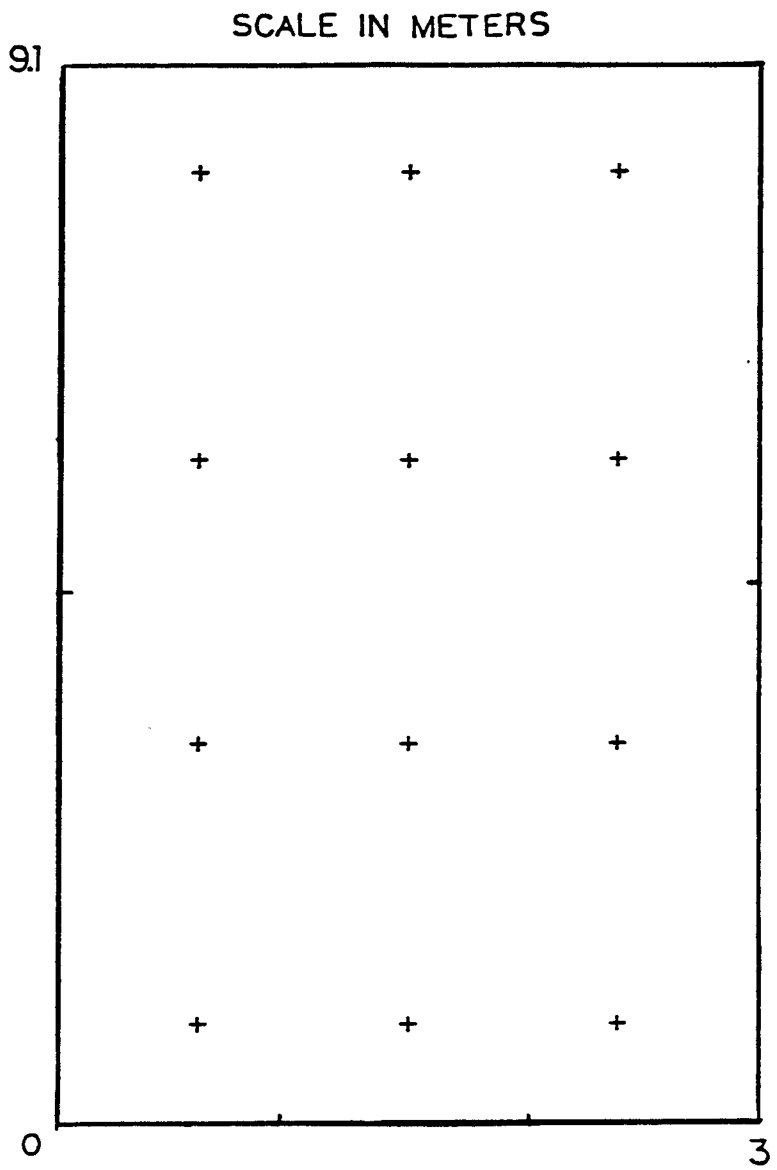

Figure 3. Location of erosion pins at the Karthaus site.

began at 11:00 AM on August 27 and lasted for 45 minutes. During the rainfall, runoff samples were collected and analyzed for sediment according to the procedure outlined in the methods section of this paper. At the end of each run the erosion pins were measured to note the change in soil surface elevation. The erosion pin measurements were then compared to the amount of sediment collected in the runoff samples. Three runs were completed at the site before the simulator and plots were disassembled.

Results:

The sequence of events for plots 1 and 2 is listed in Table 1 along with the total rainfall and runoff collected for each run. Little runoff occurred until the plots were saturated. During run 1, both plots 1 and 2 absorbed the initial rainfall, after which the runoff slowly increased. The total estimated erosion in mm of surface decline is relatively small when compared to the amount of surface decline as measured by the erosion pins (Table 1). The sediment eroded from the plot as noted by the erosion pins may have been deposited in depressions in the plot surface. Also, a significant amount of fine sediment was noted along the upper lip of the collection trough as the plot was being dismantled. Thus, the amount of surface eroded as measured by the erosion pins may not have been transported into the runoff samples.

Using the X-Y-Z coordinates for each erosion pin, a contour map from the SURFACE 2 program was drawn for plots 1 and 2 (Figure 4). The contour values represent the total change in sediment height since the initial reading.

The amount of measured erosion from the erosion pins at the Karthaus site did not compare well with the estimated erosion from the runoff samples. More runoff may have been needed to transport the eroded sediment off the plot. Also the number of pins in the plot may not have been sufficient to calculate a more accurate amount of surface decline. The data may not have compared based on 1) eroded soil was not transported from the plot or 2) more erosion pins were needed to give a better picture of surface erosion on the plots. Contour maps from the plots were not very detailed due to the small number of erosion pins. No areas of concentrated erosion were evident therefore, the Alutin method could not be evaluated.

Runoff and erosion pin data from the site is listed in appendix B.

Table 1. Rainfall simulator Summary at Karthaus.

Date	Run #	Total rain (cm)	Total runoff (L)	Runoff % rain (%)	Estimated erosion (mm)	Measured pin change (mm)
Plot 1						
8/27/81	1	9.14	18.36	0.65	0.0012	-2.47
	2	9.40	106.27	3.77	0.0061	-1.50
8/28/81	3	9.45	326.75	11.52	0.0143	+0.07
Total		27.99	451.38	5.31	0.0189	-3.90
Plot 2						
8/27/81	1	9.27	50.29	1.80	0.0094	-3.08
	2	9.40	153.57	5.45	0.0241	-1.79
8/28/81	3	10.16	307.66	10.09	0.0342	+0.30
Total		28.83	511.52	5.78	0.0633	-4.57

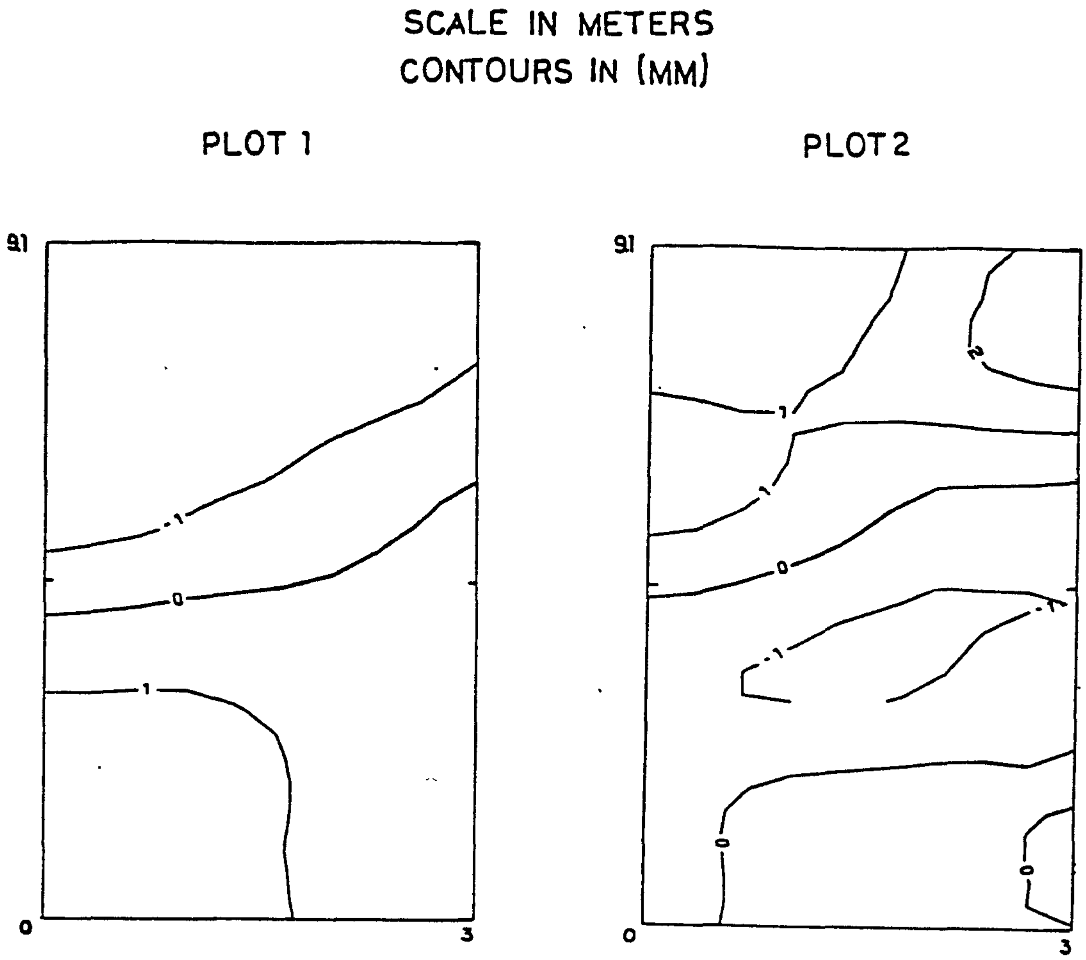

Figure 4. Karthaus erosion contour map after final run.

Klingerstown. This site is located near Klingerstown, Pennsylvania at the field station for the Northeast Watershed Research Center. Two erosion plots 3.0 m by 9.1 m were constructed for use with the rainfall simulator. The plot area was plowed, disked, and cultipacked. Each plot was then raked to remove sod and produce a smooth surface. There was no vegetation on the plots, which sloped 6.5 percent and had an average dry bulk density of 1.4 g/cm^3.

For this plot study, 40 erosion pins per plot were located according to Figure 5. The pins were measured for the first time on June 29, 1982 to note the initial height of the soil surface prior to the simulated rainfall. The first simulated rainfall (run 1) began at 11:00 AM on June 29 and lasted for 45 minutes. During the rainfall, runoff samples were collected. Immediately following the first run, a second run was made which also lasted 45 minutes. At the end of run 2 the pins were measured to note the change in surface height at each pin. After all the pins were measured, the plots were covered with plastic to protect the surface from natural rainfall. One week later the plots were subjected again to two simulated rainfalls 45 minutes each, after which the erosion pins were measured. At the end of run 4 sediment remaining in the runoff troughs was collected and dried.

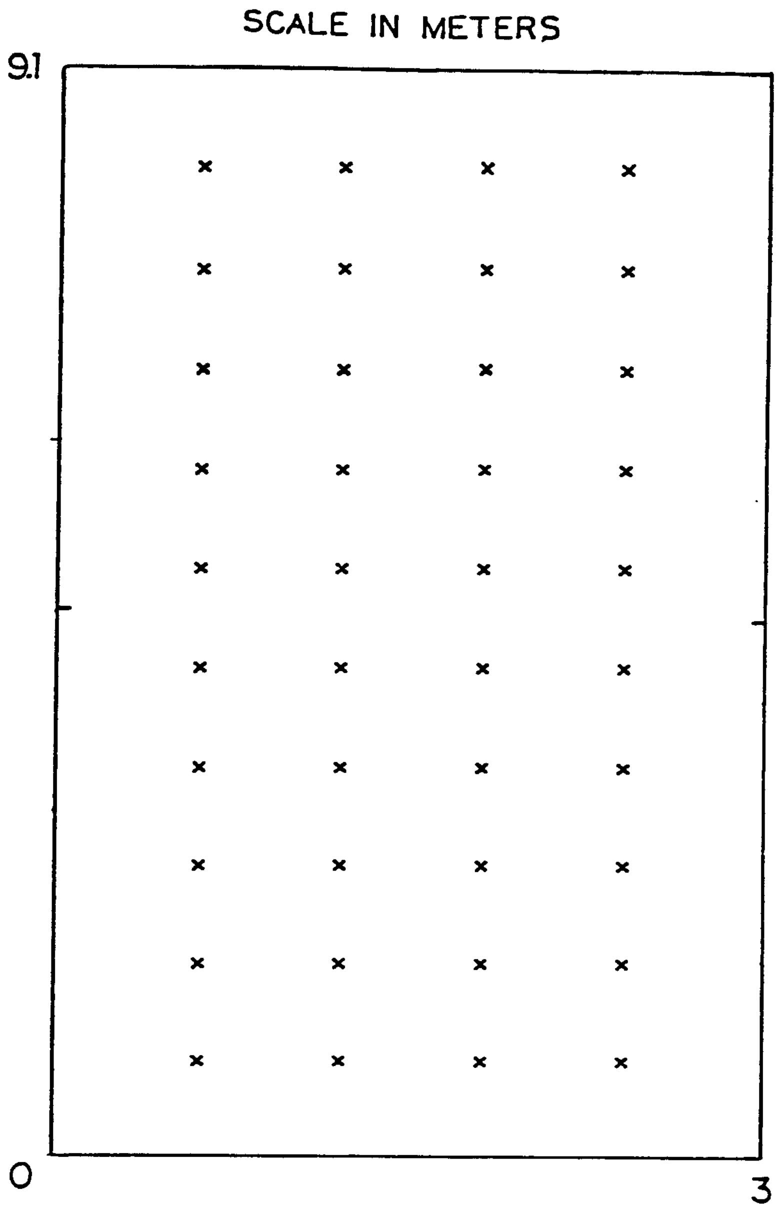

Figure 5. Location of erosion pins at the Klingerstown site.

Results:

The sequence of events for plots 1 and 2 along with total rainfall and runoff collected for each run is listed in Table 3.

From the amount of soil collected in the samples and runoff trough, the amount of surface decline was determined. This was then compared to the measured pin erosion (Table 2). The total overall surface decline was very little, less than 1 mm. An erosion contour plot after the final run notes an overall redistribution of sediment to the effect of leveling the surface in both plots 1 and 2 (Figure 6).

The plot scale analysis of the Klingerstown site seems to compare favorably with the estimated erosion from the soil collected in the runoff samples. At this site a total of 4 simulated rainfalls may have produced a sufficient amount of runoff to transport the eroded sediment off the plot. Also, the number of erosion pins used on the plot produced a more detailed erosion contour map of the surface. The contour maps overall indicate a redistribution of sediment to the effect of leveling the plot surface. Soil eroded may have deposited in depressions in the plot surface such that the average amount of surface decline was very small. This agreed with the actual amount of surface

Table 2. Rainfall simulator summary at Klingerstown.

Date	Run #	Total rain (cm)	Total runoff (L)	Runoff % rain (%)	Estimated erosion (mm)	Measured erosion (mm)
Plot 1						
6/29/82	1	7.10	287	13.0	0.08	
	2	9.34	400	14.0	0.07	
						0.56
7/ 5/82	3	10.97	485	14.7	0.03	
	4	9.45	410	14.1	0.03	
		(sediment in trough)			0.20	0.17
Total		36.86	1582	13.9	0.41	0.73
Plot 2						
6/29/82	1	7.10	177	8.3	0.03	
	2	9.34	260	9.3	0.03	
						0.68
7/ 5/82	3	10.97	320	9.7	0.02	
7/ 5/82	4	9.45	330	11.6	0.02	
		(sediment in trough)			0.20	0.24
Total		36.86	1087	9.7	0.30	0.92

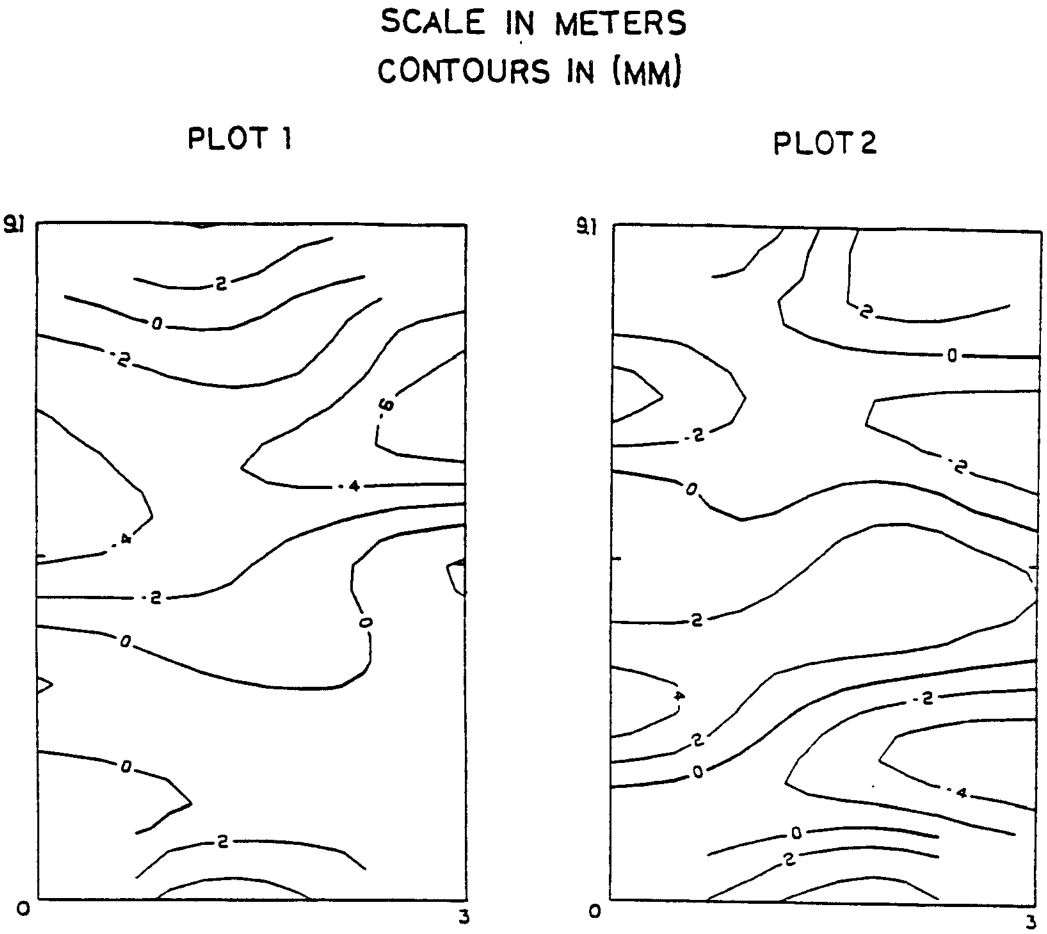

Figure 6. Klingerstown erosion contour map after final run.

decline estimated from the collected soil. Finally, no rills were observed on the plots to evaluate the Alutin method.

Runoff and erosion pin data for the site is listed in appendix C.

Field Scale

Kylertown. This site, located near Kylertown, Pennsylvania, was strip mined in 1969. Reclamation laws at that time did not require the replacement of top soil. Since 1969, pedogenic development was minimal and the resulting minesoil consisted of coarse fragments of shale, sandstone, and coal. The average bulk density of the minesoil is 1.7 g/cm^3. The 2.02 hectare study site, ranging from 0 to 10 percent slope, does support various weeds in discontinuous patches. Due to the lack of erosion control practices, the site has undergone severe erosion, as evidenced by several deep gullies.

Erosion pins inserted into the minesoil during the fall of 1980 were measured in the spring of 1981. A total of 68 pins were used, 42 of which occurred in 2 pin sets 1 m apart. The pins were arranged in clusters and along various slope contours (Figure 7). Also,the slope profile was divided into 5 cross-sections to calculate rill erosion by

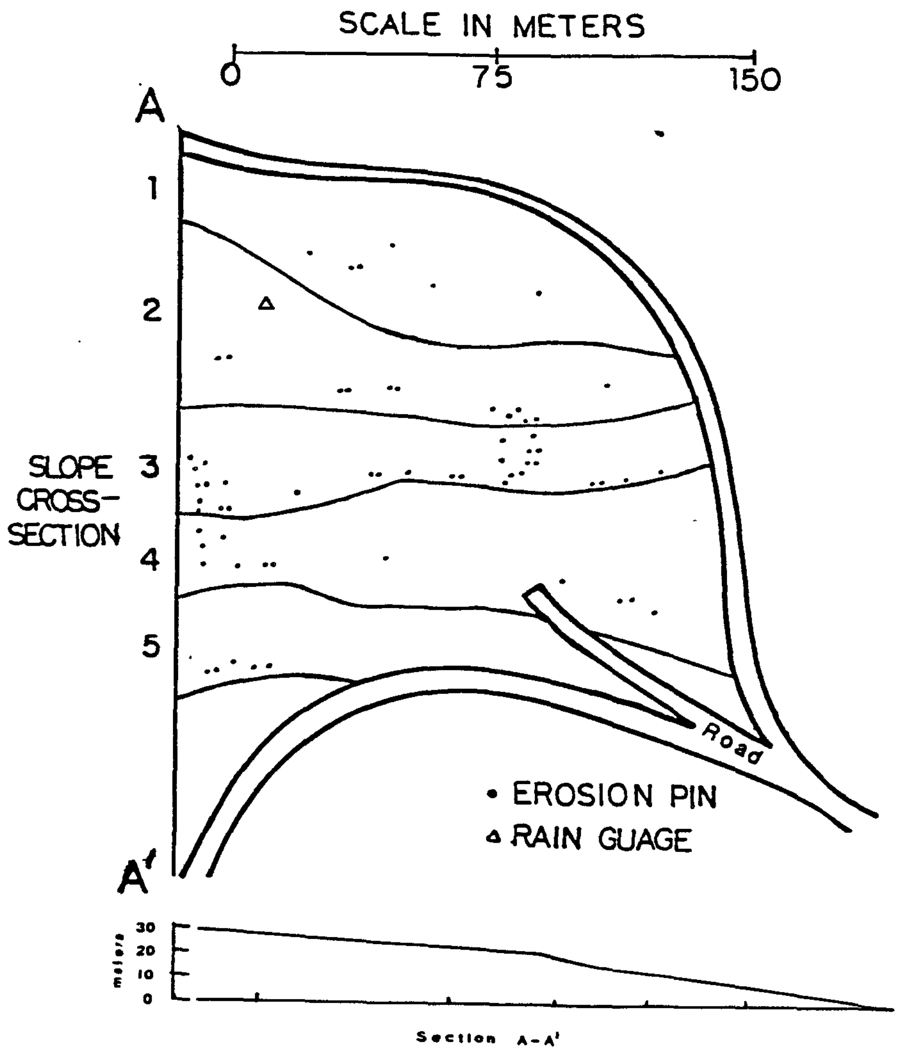

Figure 7. Sketch map of Kylertown site.

the Alutin method. Pins were identified by 3 numbers: cross-section, set, and member. The pins were measured on April 21, 1981, to note the initial height of the minesoil surface in relation to the top of the pin. During the next 4 months, the pins were measured 6 times to determine the progressive change in ground surface and also the total surface change in comparison to the initial measurement. A recording rain gauge was located on the site to determine total rainfall between pin readings and R values for each storm. Also, on June 16, 1981, the cross-sectional area of all the rills occurring between the 2 pin sets were measured to determine soil loss by rills using the Alutin method.

Results:

The data collected from the Kylertown site is summarized in Table 3. During the study period, 15 rainfalls delivered a total of 22.05 cm of rain, which resulted in an average surface decline of 0.42 mm according to the erosion pins.

The rill erosion estimated from the Alutin method is summarized in Table 4. The 14 rills measured at the site had been developing within the past 12 years since the site was reclaimed.

Table 3. Summary of Erosion Pin Data at Kylertown.

Reading Date	Rain Date	Storm #	Rain-fall cm	Maxi-mum I cm/h	R (E*I)	Pin Erosion% Deposit (-/+) (mm) net	total
	4/24/81	1	0.38	0.38	0.67		
	4/28/81	2	4.85	0.76	1.54		
4/30/81	Total	2	5.23		2.21	-0.10	-0.10
	5/ 6/81	1	0.33	0.13	0.16		
	5/11/81	2	5.13	1.52	3.44		
5/15/81	Total	2	5.46		3.60	-0.09	-0.19
	6/ 2/81	1	1.14	1.02	2.14		
	6/ 3/81	2	1.40	1.40	3.12		
	6/ 3/81	3	0.76	0.64	1.22		
	6/ 4/81	4	0.64	0.64	1.22		
6/16/81	Total	4	3.94		7.70	-0.83	-1.02
	6/21/81	1	0.76	1.52	2.80		
	6/22/81	2	0.13	0.25	0.41		
6/23/81	Total	2	0.89		3.21	-0.65	-1.67
	7/ 1/81	1	0.51	0.25	0.41		
	7/ 1/81	2	0.38	0.25	0.41		
	7/20/81	3	3.18	3.30	8.45		
	7/21/81	4	0.30	0.61	1.17		
7/23/81	Total	4	4.37		10.44	+1.21	-0.46
	7/26/81	1	2.16	2.54	6.25		
8/13/81	Total	1	2.16		6.25	+0.04	-0.42
Grand	Total	15	22.05		33.41		-0.42

Table 4. Rill Erosion Using Alutin Method at Kylertown.

Slope profile #	Location of rills #	Area of rills cm^2	Number of 1 meter sets #	Soil loss (m tons / hectare)
3	1.64	72.0	9	
	1.93	15.0		
	1.99	240.0		
	2.09	210.0		
	2.99	280.0		
	2.09	22.5		
	3.99	20.0		
	4.34	37.5		
	6.76	35.0		
	7.47	30.0		
	10.65	108.0		
				176.95
4	1.40	80.0	2	
	1.99	45.0		
				93.02
5	2.80	999.0	3	
				495.63
Total	14 rills			765.60

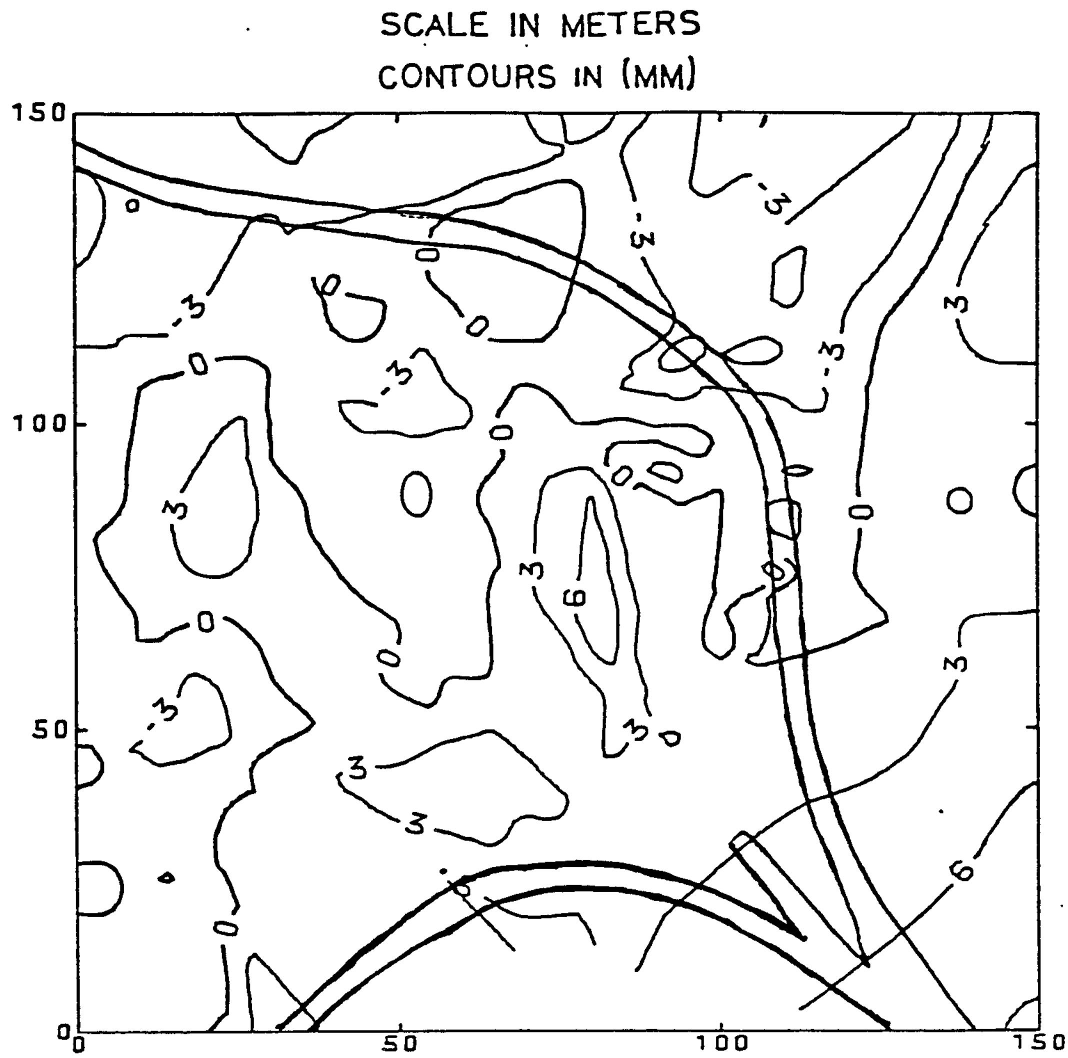

Figure 8. Kylertown erosion contour map after final run.

Using the X-Y-Z coordinates from each erosion pin, a contour map from the SURFACE 2 program was drawn (Figure 8). The contours represent the total change in sediment height since the initial reading. The contour map indicated no concentrated areas of erosion.

Kittaning site. This site is located near Kittaning, Pennsylvania and is part of the Allegheny River drainage basin. A sketch of the study area is shown in Figure 9. Approximately 15 acres of land make up the study site. In 1980 the entire area was strip mined for coal. As part of the mining operation, the overlying soil was reclaimed under the direction of the Soil Conservation Service in Kittaning. Spoil piles were regraded to approximately 15 percent slopes, which conformed to the surrounding topography. The stock-piled top soil was then replaced. The slope of the land is very steep and ranges between 10 and 20 percent. The average bulk density of the soil is 0.91 g/cm^3. Due to the steepness of the slope, terraces were constructed to reduce the effective length of runoff. A sedimentation pond was also constructed at the base of the slope to collect all runoff water before it entered a nearby receiving stream draining into the Allegheny River. Finally, the soil was fertilized, planted with grasses, and mulched with straw. By the end of May, 1981, reclamation was completed and a grass cover was developing.

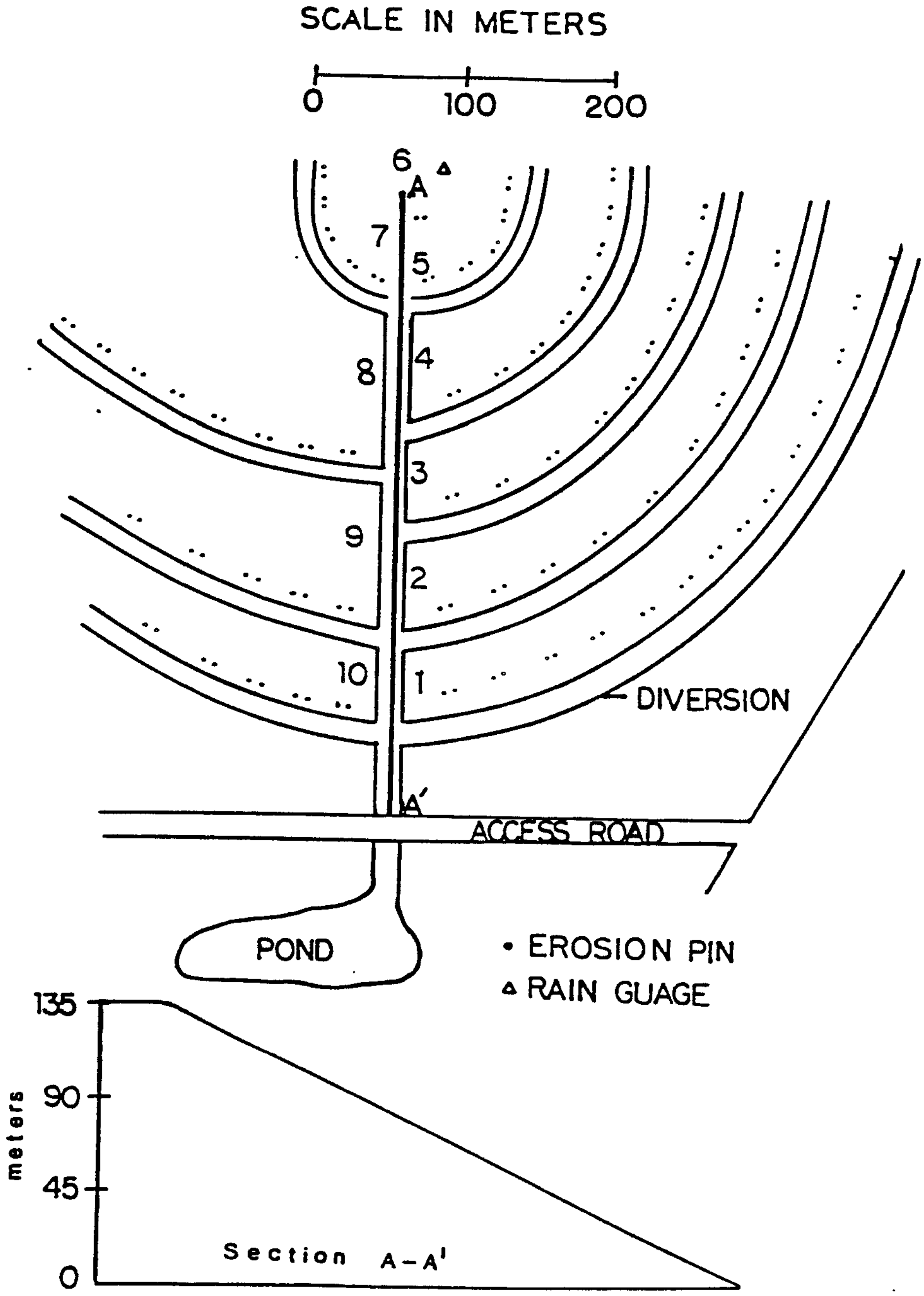

Figure 9. Sketch map of Kittaning site.

To quantify erosion, 138 erosion pins in sets of 2 pins, 1 m apart, were placed at the site on June 20, 1981. The 69 sets of erosion pins were located along the contour line on each terrace interval 30.5 m apart (Figure 9). The pins were identified by 3 numbers: terrace row, pin set, and pin member. For example, Pin 1-2-1 occurs in terrace row 1, set 2, and member 1. On June 29 the pins were measured to note the initial height of the soil surface in relation to the top of the pin. During the next 3 months the pins were measured 8 times to note the progressive change in ground surface and also the total change in comparison to the initial measurement. On July 28 the cross-sectional area of all rills occurring between the 1 m pin sets at each terrace interval were measured to determine soil loss from the rills by the Alutin method.

Results:

The data collected from the erosion pins is summarized in Table 5.

Overall, a total of 25 storms resulted in 31.52 cm of rain and a average surface decline of 2.71 mm. The amount of erosion due to the rills is summarized in Table 6. A total of 9 rills was measured at the site at 5 terrace intervals. Rill erosion produced an estimated soil loss of 309.20 m ton/hectare.

Using X-Y-Z coordinates from the erosion pin data a contour map from the SURFACE 2 program was drawn (Figure 10). The contour values represent the total change in sediment height since the initial reading. One particular area undergoing concentrated erosion is evident at the site. This area noted on the contour map as 12 to 16 mm of erosion was exposed to a greater length of runoff due to the longer distances between terraces on this side of the slope. Also, grass cover in this area was not complete (55%).

Appendix D contains contour maps for each time the pins were measured.

Table 5. Summary of erosion pin data at Kittaning.

Reading Date	Rain Date	Storm #	Rain-fall cm	Maxi-mum I cm/h	R (E*I)	Pin Erosion% Deposit (-/+) (mm) net	total
	6/31/81	1	6.48	3.81	9.98		
	7/ 2/81	2	0.13	0.13	0.16		
	7/ 3/81	3	0.15	0.15	0.22		
	7/ 5/81	4	4.19	3.56	9.34		
7/ 8/81	Total	4	19.95		19.70	+1.12	+1.12
	7/13/81	1	2.03	2.03	4.81		
7/14/81	Total	1	2.03		4.81	-2.16	-1.04
	7/19/81	1	3.68	3.56	9.26		
	7/21/81	2	0.25	0.25	0.41		
7/21/81	Total	2	3.94		9.67	-1.14	-2.18
	7/26/81	1	1.52	1.52	3.43		
	7/28/81	2	0.89	0.38	0.67		
7/28/81	Total	2	2.41		4.10	+0.14	-2.04
	8/ 3/81	1	0.76	1.02	2.14		
	8/15/81	2	0.38	0.13	0.17		
	8/16/81	3	0.25	0.50	0.92		
8/18/81	Total	3	1.40		3.23	-1.05	-3.09

Table 5. (Continued).

	8/24/81	1	0.33	0.66	1.30		
	8/28/81	2	1.02	2.03	4.81		
	8/30/81	3	0.64	0.38	0.67		
	8/30/81	4	0.76	1.02	2.14		
	9/ 1/81	5	0.38	0.38	0.67		
	9/ 1/81	6	0.76	1.52	3.44		
9/ 1/81	Total	6	3.89		13.02	-0.56	-3.65
	9/ 2/81	1	0.25	0.25	0.41		
	9/ 3/81	2	2.92	0.25	0.41		
	9/ 8/81	3	2.03	2.54	6.25		
9/ 8/81	Total	3	5.21		7.07	+1.32	-2.32
	9/12/81	1	0.25	0.25	0.41		
	9/15/81	2	0.76	0.63	1.20		
	9/26/81	3	0.51	1.02	2.14		
	9/27/81	4	0.07	0.18	0.27		
9/29/81	Total	4	1.70		4.02	-0.38	-2.71
Grand Total		25	31.52		65.62		-2.71

Table 6. Rill erosion using Alutin method at Kittaning.

Terrace number #	Location of rills #	Area of rills cm^2	Number of 1 meter sets #	Soil loss (m tons / hectare)
1	1.60	125.0	13	
				14.31
3	1.25	60.0	9	
3	5.50	120.0	9	
				29.77
4	5.09	150.0	8	
4	7.75	40.0	8	
				35.35
8	4.43	195.0	8	
				36.28
10	1.35	75.0	5	
10	2.55	500.0	5	
10	3.30	75.0	5	
				193.49
Total of 9 rills				309.20

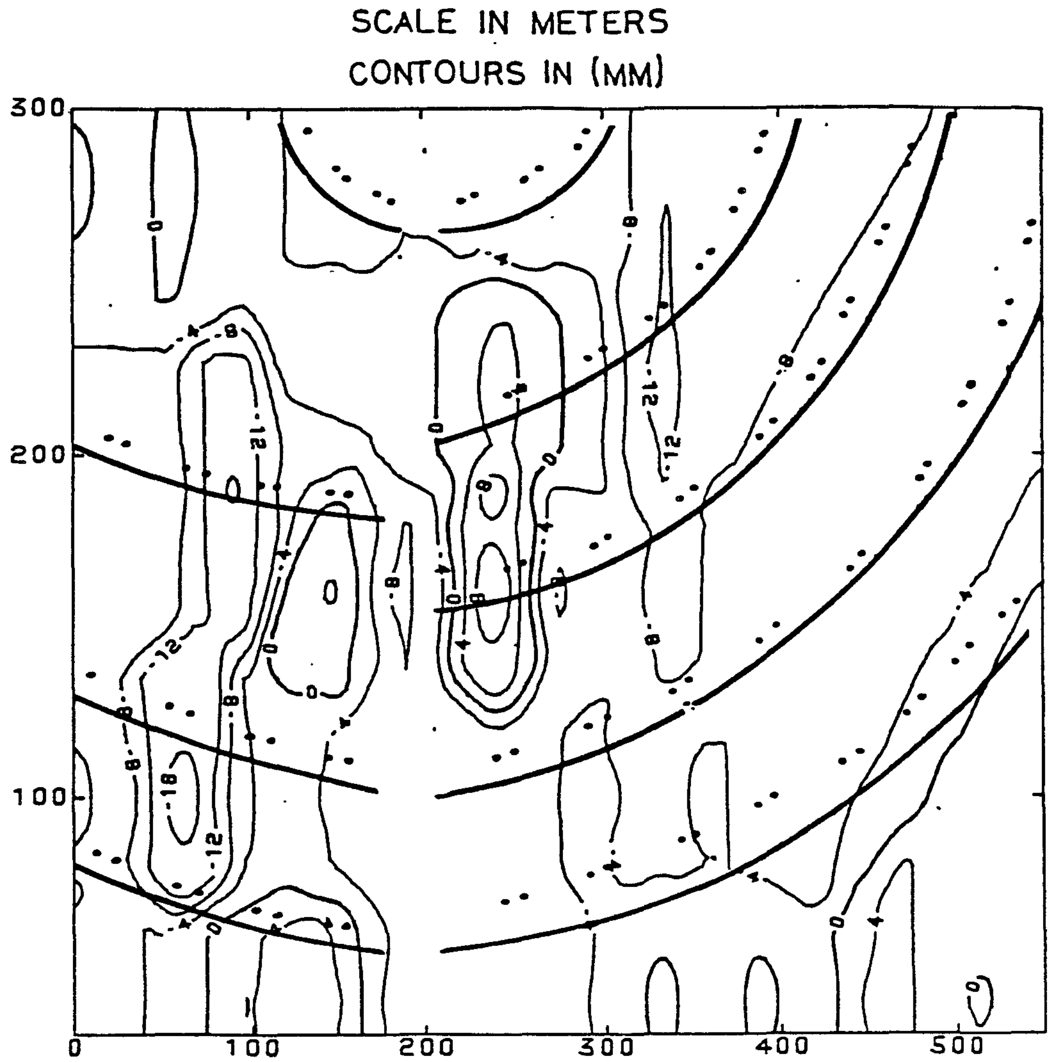

Figure 10. Kittaning erosion contour map after final run.

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APPENDIX A

EROSION PIN PROGRAM AND FORMAT

APPENDIX A

EROSION PIN PROGRAM AND FORMAT

PURPOSE: TO COMPARE EROSION PIN MEASUREMENTS AND COMPUTE THE DIFFERENCE FROM THE LAST MEASUREMENT AND THE INITIAL MEASUREMENT.

TO AVERAGE THE DIFFERENCES AND COMPUTE THE AVERAGE SURFACE ADVANCE OR DECLINE AT EACH SLOPE CROSS-SECTION AND FOR THE ENTIRE SITE.

TO LIST THE TOP 10 EROSION PINS WHICH UNDERWENT THE LARGEST CHANGE IN ELEVATION SINCE THE LAST RUN.

INPUT FORMAT:

COLUMNS	INFORMATION
1-3	LOCATION
4-9	DATE
10-11	RUN
12-16	PIN
17-21	READING
23-27	PIN
28-32	READING
34-38	PIN
39-43	READING
45-49	PIN
50-54	READING
56-60	PIN
61-65	READING
67-71	PIN
72-76	READING

PROGRAM:

```
      CHARACTER * 3 LOC
      INTEGER DATE,DAT(100),RUN,ROW,SET,MEMBER,COUNT,A,B,C,D,ORDER(200)
      REAL  DRUNA, DRUNB,READNG(20,11,21,3),SUMA,SUMB,TOTALA,TOTALB
     1,AVEA,AVEB,AVEC,AVED,DIFF
      DIMENSION DIFF(200),A(200),B(200),C(200),D(200)
      WRITE (6,9)
9     FORMAT ('0',/,1X,'LOCATION',5X,'DATE',5X,'RUN*N',5X,
     1'PIN',5X,'READING(MM)',5X,'DRUN 1',5X,'DRUN N-1')
      SUMA=0
      SUMB=0
      TOTALA=0
      TOTALB=0
      AVEA=0
      AVEB=0
      AVEC=0
      AVED=0
      ICOUNT=0
      COUNT=0
      KOUNT=0
      DO 12 RUN = 1,10
      DO 13 ROW = 1,10
      DO 14 SET = 1,21
      DO 15 MEMBER = 1,3
      READNG(RUN,ROW,SET,MEMBER)=0
15    CONTINUE
14    CONTINUE
13    CONTINUE
12    CONTINUE
      LOOP
```

```
      READ (55,11,END=20)LOC,DATE,RUN,(ROW,SET,MEMBER,READNG(RUN,ROW
     1,SET,MEMBER),I=1,6)
      DAT(RUN)=DATE
      END LOOP
11    FORMAT (A3,I6,I2,6(I2,I2,I1,F5.2,1X))
20    DO 16 RUN = 2,10
      DO 17 ROW = 1,10
      DO 18 SET = 1,21
      DO 19 MEMBER = 1,3
      IF(READNG(RUN,ROW,SET,MEMBER).EQ.111.11) GO TO 40
      IF(READNG(RUN,ROW,SET,MEMBER).EQ.0.0)GO TO 40
      COUNT=COUNT+1
      ICOUNT=ICOUNT+1
      DRUNB=READNG(RUN-1,ROW,SET,MEMBER)-READNG(RUN,ROW,SET,MEMBER)
      DRUNA=READNG(1,ROW,SET,MEMBER)-READNG(RUN,ROW,SET,MEMBER)
      IF (ABS(DRUNB).NE.READNG(RUN,ROW,SET,MEMBER)) THEN DO
      IF (ABS(DRUNA).EQ.READNG(RUN,ROW,SET,MEMBER))DRUNA=DRUNB
      KOUNT=KOUNT+1
      DIFF(KOUNT)=DRUNB
      D(KOUNT)=ABS(DRUNB)
      A(KOUNT)=ROW
      B(KOUNT)=SET
      C(KOUNT)=MEMBER
      SUMA=SUMA+DRUNA
      SUMB=SUMB+DRUNB
      TOTALA=TOTALA+DRUNA
      TOTALB=TOTALB+DRUNB
      WRITE(6,21)LOC,DAT(RUN),RUN,ROW,SET,MEMBER,READNG(RUN,ROW,SET,M
     1EMBER),DRUNA,DRUNB
      END IF
40    CONTINUE
19    CONTINUE
18    CONTINUE
      IF(COUNT.EQ.0) GO TO 17
      AVEA=SUMA/COUNT
      AVEB=SUMB/COUNT
```

```
      IF(AVEA.NE.0.0) WRITE(6,30)AVEA,AVEB
      COUNT=0
      AVEA=0
      AVEB=0
      SUMA=0
      SUMB=0
17    CONTINUE
      IF(ICOUNT.EQ.0) GO TO 16
      AVEC=TOTALA/ICOUNT
      AVED=TOTALB/ICOUNT
      IF(AVEC.NE.0.0) WRITE(6,31)AVEC,AVED
      ICOUNT=0
      AVEC=0
      AVED=0
      TOTALA=0
      TOTALB=0
      IF (KOUNT.NE.0) THEN DO
      CALL QSORT(D(1),D(2),ORDER,KOUNT,1,20)
      WRITE(6,27)
      WRITE(6,28)
      DO 10 I=1,10
      J=KOUNT-I+1
      JJ=ORDER(J)
      WRITE(6,29) A(JJ),B(JJ),C(JJ),DIFF(JJ)
10    CONTINUE
      KOUNT=0
         END IF
      WRITE (6,9)
16    CONTINUE
21    FORMAT(' ',3X,A3,6X,I6,5X,I2,5X,I2,I2,I1,3(7X,F6.2))
27    FORMAT('0','LARGEST SEDIMENT CHANGE FROM PREVIOUS RUN')
28    FORMAT('0',/,10X,'PIN',5X,'SEDIMENT CHANGE(MM)',/)
29    FORMAT ('0',8X,I2,I2,I1,10X,F6.2)
30    FORMAT('0',50X,'AVEA=',F6.2,3X,'AVEB=',F6.2,/)
31    FORMAT('0',48X,'TOTALA=',F7.2,1X,'TOTALB=',F7.2,/)
      STOP
      END
```

APPENDIX B

KARTHAUS DATA

APPENDIX B

TABLE 7. EROSION PIN DATA FROM KARTHAUS

RUN*N	PIN	READING(MM)		DRUN 1		DRUN N-1
		PLOT 1				
2	1 11	36.43		-4.73		-4.73
2	1 12	37.34		-0.64		-0.64
2	1 13	28.00		-0.08		-0.08
2	1 21	34.78		-1.46		-1.46
2	1 22	39.00		-5.38		-5.38
2	1 23	42.30		-7.20		-7.20
2	1 31	24.60		0.08		0.08
2	1 32	39.20		-0.20		-0.20
2	1 33	5.65		-1.30		-1.30
2	1 41	37.10		-2.50		-2.50
2	1 42	27.70		-1.60		-1.60
2	1 43	29.30		-4.68		-4.68
			AVEA=	-2.47	AVEB=	-2.47
		PLOT 2				
2	2 11	37.10		-1.80		-1.80
2	2 12	30.44		-9.34		-9.34
2	2 13	32.58		0.24		0.24
2	2 21	23.72		-5.72		-5.72
2	2 22	33.90		-4.28		-4.28
2	2 23	29.80		-3.23		-3.23
2	2 31	31.46		-0.18		-0.18
2	2 32	17.20		-5.80		-5.80
2	2 33	17.50		4.70		4.70
2	2 41	35.00		-2.13		-2.13
2	2 42	38.84		-0.44		-0.44
2	2 43	41.00		-8.95		-8.95
			AVEA=	-3.08	AVEB=	-3.08
			TOTALA=	-2.78	TOTALB=	-2.78

LARGEST SEDIMENT CHANGE FROM PREVIOUS RUN

PIN	SEDIMENT CHANGE(MM)
2 12	-9.34
2 43	-8.95
1 23	-7.20
1 22	-5.38
2 21	-5.72
2 32	-5.80
2 22	-4.28
2 33	4.70
1 43	-4.68
1 11	-4.73

TABLE 7. CONTINUED

PLOT 1

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
3	1 11	36.92	-5.22	-0.49
3	1 12	35.80	0.90	1.54
3	1 13	27.26	0.66	0.74
3	1 21	34.84	-1.52	-0.06
3	1 22	39.06	-5.44	-0.06
3	1 23	43.41	-8.31	-1.11
3	1 31	35.10	-10.42	-10.50
3	1 32	38.00	1.00	1.20
3	1 33	6.28	-1.93	-0.63
3	1 41	38.24	-3.64	-1.14
3	1 42	32.18	-6.08	-4.48
3	1 43	32.26	-7.64	-2.96
			AVEA= -3.97	AVEB= -1.50

PLOT 2

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
3	2 11	36.38	-1.08	0.72
3	2 12	32.24	-11.14	-1.80
3	2 13	35.12	-2.30	-2.54
3	2 21	23.00	-5.00	0.72
3	2 22	37.02	-7.40	-3.12
3	2 23	31.64	-5.07	-1.84
3	2 31	33.74	-2.46	-2.28
3	2 32	18.60	-7.20	-1.40
3	2 33	27.00	-4.80	-9.50
3	2 41	37.28	-4.41	-2.28
3	2 42	39.15	-0.75	-0.31
3	2 43	38.87	-6.82	2.13
			AVEA= -4.87	AVEB= -1.79

TOTALA= -4.42 TOTALB= -1.64

LARGEST SEDIMENT CHANGE FROM PREVIOUS RUN

PIN	SEDIMENT CHANGE(MM)
1 31	-10.50
2 33	-9.50
1 42	-4.48
2 22	-3.12
2 43	2.13
2 31	-2.28
2 13	-2.54
2 41	-2.28
1 43	-2.96
1 23	-1.11

TABLE 7. CONTINUED

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
		PLOT 1		
4	1 11	36.28	-4.58	0.64
4	1 12	34.30	2.40	1.50
4	1 13	27.20	0.72	0.06
4	1 21	34.10	-0.78	0.74
4	1 22	37.53	-3.91	1.53
4	1 23	43.65	-8.55	-0.24
4	1 31	36.75	-12.07	-1.65
4	1 32	38.88	0.12	-0.88
4	1 33	6.30	-1.95	-0.02
4	1 41	37.12	-2.52	1.12
4	1 42	34.18	-8.08	-2.00
4	1 43	32.24	-7.62	0.02
		AVEA=	-3.90	AVEB= 0.07
		PLOT 2		
4	2 11	38.00	-2.70	-1.62
4	2 12	27.44	-6.34	4.80
4	2 13	37.80	-4.98	-2.68
4	2 21	23.37	-5.37	-0.37
4	2 22	39.42	-9.80	-2.40
4	2 23	31.40	-4.83	0.24
4	2 31	31.20	0.08	2.54
4	2 32	18.40	-7.00	0.20
4	2 33	28.80	-6.60	-1.80
4	2 41	35.60	-2.73	1.68
4	2 42	41.75	-3.35	-2.60
4	2 43	33.30	-1.25	5.57
		AVEA=	-4.57	AVEB= 0.30
		TOTALA=	-4.24	TOTALB= 0.18

LARGEST SEDIMENT CHANGE FROM PREVIOUS RUN

PIN	SEDIMENT CHANGE(MM)
2 43	5.57
2 12	4.80
2 42	-2.60
2 13	-2.68
2 22	-2.40
1 42	-2.00
2 31	2.54
2 11	-1.62
2 41	1.68
1 41	1.12

TABLE 8. RUNOFF SAMPLE DATA FROM KARTHAUS

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
1	1	1	2.14	1894.	0.0000
1	1	5	2.42	1055.	0.0000
1	1	12	2.62	2200.	0.0001
1	1	15	6.87	1500.	0.0001
1	1	18	14.25	1842.	0.0002
1	1	19	20.35	1944.	0.0001
1	1	20	18.52	1814.	0.0001
1	1	22	18.52	1663.	0.0002
1	1	29	6.90	909.	0.0001
1	1	32	10.18	1004.	0.0001
1	1	36	25.89	1803.	0.0005
1	1	41	35.92	1478.	0.0007
1	1	45	38.92	1542.	0.0006
					CUMA
					0.0028

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
2	1	3	7.91	2157.	0.0001
2	1	5	58.50	2222.	0.0007
2	1	10	67.00	1876.	0.0017
2	1	15	88.20	1579.	0.0018
2	1	20	86.06	1663.	0.0019
2	1	27	78.85	1695.	0.0025
2	1	34	99.58	1404.	0.0026
2	1	41	1.51	1362.	0.0000
					CUMA
					0.0113

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
3	1	3	11.19	3854.	0.0003
3	1	3	10.71	1785.	0.0000
3	1	12	46.56	1258.	0.0014
3	1	15	89.42	1204.	0.0009
3	1	18	11.67	1130.	0.0001
3	1	24	15.50	1255.	0.0003
3	1	25	14.75	1242.	0.0000
3	1	30	13.50	1145.	0.0002
3	1	33	23.16	1197.	0.0002
3	1	35	21.05	1087.	0.0001
3	1	38	33.14	1288.	0.0003
3	1	38	33.14	1137.	0.0000
3	1	40	94.20	1146.	0.0006
3	1	41	14.75	1133.	0.0000
3	1	42	55.67	1113.	0.0002
3	1	43	34.86	1123.	0.0001
					CUMA
					0.0048

TABLE 8. CONTINUED

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
1	2	1	8.31	3939.	0.0001
1	2	5	8.42	3326.	0.0003
1	2	9	8.22	3650.	0.0003
1	2	13	13.06	4311.	0.0006
1	2	17	12.22	6084.	0.0008
1	2	18	22.00	6000.	0.0003
1	2	20	30.20	5350.	0.0009
1	2	21	28.13	5467.	0.0004
1	2	28	44.90	5234.	0.0043
1	2	30	42.31	5327.	0.0012
1	2	36	51.44	4536.	0.0037
1	2	40	57.75	4416.	0.0027
1	2	44	56.00	4732.	0.0028
					CUMA 0.0184

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
2	2	1	35.38	5130.	0.0005
2	2	4	58.00	4935.	0.0023
2	2	10	65.57	4423.	0.0046
2	2	14	49.14	3843.	0.0020
2	2	20	63.79	3843.	0.0039
2	2	26	60.13	3764.	0.0036
2	2	33	57.81	3319.	0.0035
2	2	40	74.16	3312.	0.0045
					CUMA 0.0248

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
3	2	2	83.09	3654.	0.0016
3	2	3	81.64	3296.	0.0007
3	2	10	87.69	2982.	0.0048
3	2	14	99.13	2961.	0.0031
3	2	18	92.92	2892.	0.0028
3	2	23	12.25	2806.	0.0005
3	2	25	31.78	2838.	0.0000
3	2	30	50.00	2933.	0.0019
3	2	33	56.79	2733.	0.0012
3	2	35	60.36	2918.	0.0009
3	2	37	62.86	2697.	0.0009
3	2	38	40.00	2634.	0.0003
3	2	40	25.71	2818.	0.0004
3	2	41	32.00	2619.	0.0002
3	2	42	49.67	2606.	0.0003
3	2	43	55.00	2645.	0.0004
					CUMA 0.0201

TABLE 9. DENSITY DATA FROM KARTHAUS

(9/11/81)

DRY DENSITY (G/CC)	% MOISTURE
0.97	12.8
0.89	10.6
0.88	10.1
1.10	12.1
0.94	6.5
0.84	14.2
0.95	7.5
0.87	9.8
0.91	7.7
1.16	8.7

TABLE 10. RAINFALL DATA FROM KARTHAUS

CAN #	RUN 1 RAIN (FT)	RUN 2 RAIN (FT)	RUN 3 RAIN (FT)
111	0.12	0.36	0.39
112	0.10	0.28	0.29
121	0.12	0.31	0.28
122	0.07	0.12	0.13
131	0.12	0.35	0.37
132	0.19	0.43	0.40
211	0.11	0.32	0.27
212	0.14	0.37	0.43
221	0.07	0.13	0.12
222	0.10	0.24	0.34
231	0.10	0.30	0.37
232	0.21	0.49	0.47

APPENDIX C

KLINGERSTOWN DATA

APPENDIX C

TABLE 11. EROSION PIN DATA FROM KLINGERSTOWN

PLOT 1

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
2	1 11	12.64	-4.14	-4.14
2	1 12	2.96	10.96	10.96
2	1 13	5.10	4.48	4.48
2	1 14	3.82	1.28	1.28
2	1 21	12.45	-3.95	-3.95
2	1 22	6.05	-2.05	-2.05
2	1 23	10.22	-1.84	-1.84
2	1 24	7.54	-1.96	-1.96
2	1 31	13.22	-0.52	-0.52
2	1 32	16.12	-4.92	-4.92
2	1 33	11.73	-2.37	-2.37
2	1 34	13.50	-0.75	-0.75
2	1 41	7.55	4.61	4.61
2	1 42	16.77	-1.73	-1.73
2	1 43	4.24	0.76	0.76
2	1 44	4.88	0.06	0.06
2	1 51	19.56	-6.96	-6.96
2	1 52	12.54	0.50	0.50
2	1 53	12.22	-0.58	-0.58
2	1 54	8.35	1.73	1.73
2	1 61	15.35	-4.23	-4.23
2	1 62	13.72	-0.02	-0.02
2	1 63	11.27	1.13	1.13
2	1 64	6.90	6.15	6.15
2	1 71	9.58	-3.83	-3.83
2	1 72	7.50	-1.76	-1.76
2	1 73	9.42	-7.22	-7.22
2	1 74	21.50	-11.20	-11.20
2	1 81	8.08	-0.48	-0.48
2	1 82	13.20	-2.92	-2.92
2	1 83	4.86	2.47	2.47
2	1 84	18.00	-8.70	-8.70
2	1 91	9.16	-0.06	-0.06
2	1 92	8.04	2.36	2.36
2	1 93	11.58	-1.98	-1.98
2	1 94	11.00	-2.22	-2.22
2	1101	10.92	-0.62	-0.62
2	1102	6.50	5.84	5.84
2	1103	13.22	4.33	4.33
2	1104	14.23	7.77	7.77
			AVEA= -0.56	AVEB= -0.56

TABLE 11. CONTINUED

PLOT 2

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
2	2 11	2.20	3.80	3.80
2	2 12	6.00	3.90	3.90
2	2 13	6.22	4.68	4.68
2	2 14	4.88	-2.32	-2.32
2	2 21	13.52	-5.14	-5.14
2	2 22	7.56	-1.76	-1.76
2	2 23	10.80	-4.15	-4.15
2	2 24	12.60	-2.80	-2.80
2	2 31	12.30	0.38	0.38
2	2 32	14.80	5.20	5.20
2	2 33	19.26	-10.50	-10.50
2	2 34	6.70	-0.32	-0.32
2	2 41	6.18	5.44	5.44
2	2 42	13.00	-1.46	-1.46
2	2 43	7.82	1.94	1.94
2	2 44	10.18	-7.04	-7.04
2	2 51	2.60	3.40	3.40
2	2 52	11.60	2.24	2.24
2	2 53	11.30	-1.45	-1.45
2	2 54	6.65	-3.35	-3.35
2	2 61	13.00	-2.20	-2.20
2	2 62	4.84	5.54	5.54
2	2 63	13.65	-4.03	-4.03
2	2 64	7.30	4.32	4.32
2	2 71	8.42	-0.04	-0.04
2	2 72	5.00	-1.00	-1.00
2	2 73	7.38	1.27	1.27
2	2 74	13.20	-5.27	-5.27
2	2 81	18.00	-6.57	-6.57
2	2 82	9.76	-2.99	-2.99
2	2 83	14.05	-2.70	-2.70
2	2 84	6.78	-0.56	-0.56
2	2 91	8.20	0.88	0.88
2	2 92	16.58	-1.01	-1.01
2	2 93	10.62	0.92	0.92
2	2 94	3.25	0.15	0.15
2	2101	11.10	-4.10	-4.10
2	2102	10.06	1.49	1.49
2	2103	7.00	3.44	3.44
2	2104	12.06	-5.36	-5.36
		AVEA=	-0.68	AVEB= -0.68

TOTALA= -0.62 TOTALB= -0.62

TABLE 11. CONTINUED

LARGEST
SEDIMENT CHANGE FROM PREVIOUS RUN

PIN	SEDIMENT CHANGE(MM)
1 74	-11.20
1 12	10.96
2 33	-10.50
1 84	-8.70
1 73	-7.22
1104	7.77
2 44	-7.04
1 64	6.15
2 81	-6.57
1 51	-6.96

TABLE 11. CONTINUED

PLOT 1

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
4	1 11	13.63	-5.13	-0.99
4	1 12	2.46	11.46	0.50
4	1 13	5.34	4.24	-0.24
4	1 14	5.52	-0.42	-1.70
4	1 21	10.74	-2.24	1.71
4	1 22	7.80	-3.80	-1.75
4	1 23	8.97	-0.59	1.25
4	1 24	4.20	1.38	3.34
4	1 31	14.00	-1.30	-0.78
4	1 32	7.70	3.50	8.42
4	1 33	7.10	2.26	4.63
4	1 34	14.00	-1.25	-0.50
4	1 41	7.27	4.89	0.28
4	1 42	15.80	-0.76	0.97
4	1 43	6.37	-1.37	-2.13
4	1 44	2.88	2.06	2.00
4	1 51	14.73	-2.13	4.83
4	1 52	14.45	-1.41	-1.91
4	1 53	13.00	-1.36	-0.78
4	1 54	8.00	2.08	0.35
4	1 61	17.65	-6.53	-2.30
4	1 62	17.73	-4.03	-4.01
4	1 63	13.20	-0.80	-1.93
4	1 64	8.50	4.55	-1.60
4	1 71	9.73	-3.98	-0.15
4	1 72	8.23	-2.49	-0.73
4	1 73	10.52	-8.32	-1.10
4	1 74	20.34	-10.04	1.16
4	1 81	12.82	-5.22	-4.74
4	1 82	13.74	-3.46	-0.54
4	1 83	6.00	1.33	-1.14
4	1 84	17.60	-8.30	0.40
4	1 91	10.00	-0.90	-0.84
4	1 92	8.00	2.40	0.04
4	1 93	12.71	-3.11	-1.13
4	1 94	14.70	-5.92	-3.70
4	1101	11.57	-1.27	-0.65
4	1102	6.00	6.34	0.50
4	1103	13.80	3.75	-0.58
4	1104	15.47	6.53	-1.24
4			AVEA= -0.73	AVEB= -0.17

TABLE 11. CONTINUED

PLOT 2

RUN*N	PIN	READING(MM)	DRUN 1	DRUN N-1
4	2 11	4.11	1.89	-1.91
4	2 12	3.84	6.06	2.16
4	2 13	3.10	7.80	3.12
4	2 14	1.20	1.36	3.68
4	2 21	13.30	-4.92	0.22
4	2 22	10.00	-4.20	-2.44
4	2 23	4.64	2.01	6.16
4	2 24	14.48	-4.68	-1.88
4	2 31	6.33	6.35	5.97
4	2 32	19.50	0.50	-4.70
4	2 33	17.22	-8.46	2.04
4	2 34	12.80	-6.42	-6.10
4	2 41	5.70	5.92	0.48
4	2 42	8.70	2.84	4.30
4	2 43	9.20	0.56	-1.38
4	2 44	4.50	-1.36	5.68
4	2 51	6.44	-0.44	-3.84
4	2 52	12.10	1.74	-0.50
4	2 53	3.70	6.15	7.60
4	2 54	2.00	1.30	4.65
4	2 61	6.30	4.50	6.70
4	2 62	14.20	-3.82	-9.36
4	2 63	4.00	5.62	9.65
4	2 64	12.24	-0.62	-4.94
4	2 71	8.00	0.38	0.42
4	2 73	9.45	-0.80	-2.07
4	2 74	13.88	-5.95	-0.68
4	2 81	22.35	-10.92	-4.35
4	2 82	7.48	-0.71	2.28
4	2 83	16.30	-4.95	-2.25
4	2 84	8.30	-2.08	-1.52
4	2 91	4.14	4.94	4.06
4	2 92	16.53	-0.96	0.05
4	2 93	6.36	5.18	4.26
4	2 94	1.00	2.40	2.25
4	2101	12.70	-5.70	-1.60
4	2102	21.02	-9.47	-10.96
4	2103	3.25	7.19	3.75
4	2104	14.34	-7.64	-2.28
		AVEA=	-0.24	AVEB= 0.42

TOTALA= -0.48 TOTALB= 0.12

TABLE 11. CONTINUED

LARGEST
SEDIMENT CHANGE FROM PREVIOUS RUN

PIN	SEDIMENT CHANGE(MM)
2102	-10.96
2 62	-9.36
2 63	9.65
1 32	8.42
2 53	7.60
2 61	6.70
2 23	6.16
2 34	-6.10
2 31	5.97
2 44	5.68

TABLE 12. RUNOFF SAMPLE DATA FROM KLINGERSTOWN

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
1	1	5	106.43	9778.	0.0090
1	1	10	106.43	9067.	0.0083
1	1	15	106.43	11818.	0.0108
1	1	20	106.43	12000.	0.0110
1	1	25	106.43	10933.	0.0100
1	1	30	106.43	9333.	0.0086
1	1	40	106.43	8593.	0.0158
1	1	45	106.43	4500.	0.0041
					TOTAL 0.0776

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
2	1	5	106.43	13846.	0.0127
2	1	10	106.43	2923.	0.0027
2	1	15	106.43	9077.	0.0083
2	1	20	106.43	9429.	0.0087
2	1	25	106.43	10462.	0.0096
2	1	30	106.43	9217.	0.0085
2	1	35	106.43	8966.	0.0082
2	1	45	106.43	8667.	0.0159
					TOTAL 0.0745

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
3	1	5	106.43	6333.	0.0058
3	1	10	106.43	4154.	0.0038
3	1	15	106.43	2647.	0.0024
3	1	20	106.43	3095.	0.0028
3	1	25	106.43	3733.	0.0034
3	1	30	106.43	3188.	0.0029
3	1	35	106.43	4026.	0.0037
3	1	40	106.43	3766.	0.0035
					TOTAL 0.0284

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
4	1	5	106.43	4853.	0.0045
4	1	10	106.43	3286.	0.0030
4	1	15	106.43	3611.	0.0033
4	1	20	106.43	3662.	0.0034
4	1	25	106.43	4737.	0.0043
4	1	30	106.43	4444.	0.0041
4	1	35	106.43	3867.	0.0035
4	1	40	106.43	4242.	0.0039
					TOTAL 0.0300

TABLE 12. CONTINUED

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
1	2	5	65.55	8250.	0.0047
1	2	10	65.55	8320.	0.0047
1	2	15	65.55	7680.	0.0043
1	2	20	65.55	6769.	0.0038
1	2	25	65.55	7111.	0.0040
1	2	30	65.55	6444.	0.0036
1	2	40	65.55	5833.	0.0066
1	2	45	65.55	4727.	0.0027
					TOTAL 0.0345

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
2	2	5	65.55	9273.	0.0052
2	2	10	65.55	7375.	0.0042
2	2	15	65.55	6909.	0.0039
2	2	20	65.55	6261.	0.0035
2	2	25	65.55	6261.	0.0035
2	2	30	65.55	6308.	0.0036
2	2	35	65.55	6133.	0.0035
2	2	45	65.55	5600.	0.0063
					TOTAL 0.0337

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
3	2	5	65.55	2321.	0.0013
3	2	10	65.55	1286.	0.0007
3	2	15	65.55	1452.	0.0008
3	2	20	65.55	1154.	0.0007
3	2	25	65.55	1667.	0.0009
3	2	30	65.55	1467.	0.0008
3	2	35	65.55	2286.	0.0013
3	2	45	65.55	1818.	0.0021
					TOTAL 0.0086

RUN	PLOT	TIME MIN	RUNOFF CM***3/SEC	S.CONC MG/L	EROSION MM
4	2	5	65.55	3553.	0.0020
4	2	10	65.55	3000.	0.0017
4	2	15	65.55	2571.	0.0015
4	2	20	65.55	2615.	0.0015
4	2	25	65.55	1852.	0.0010
4	2	30	65.55	3766.	0.0021
4	2	35	65.55	3077.	0.0017
4	2	45	65.55	11053.	0.0125
					TOTAL 0.0240

TABLE 13. DENSITY DATA FROM KLINGERSTOWN

PLOT 1		PLOT 2	
DRY DENSITY (G/CC)	% MOIST.	DRY DENSITY (G/CC)	% MOIST.
1.53	21.7	1.40	25.6
1.41	28.2	1.47	24.4
1.41	25.2	1.50	24.1
1.37	28.1	1.45	23.7
1.36	27.3	1.47	23.8

TABLE 14. CALIBRATION OF V-NOTCH BARREL

PLOT 1

Chart value (in.)	V-notch head (in.)	factor (in.)	factor (m)
1.36	2.00	1.47	0.0374

To get Hm in m.
(chart value) (0.0374)

PLOT 2

Chart value (in.)	V-notch head (in.)	factor (in.)	factor (m)
0.80	2.40	3.00	0.0762

To get Hm in m.
(chart value) (0.0762)

TABLE 15. RAINFALL DATA FROM KLINGERSTOWN

DISTANCE OF CAN FROM CENTER (feet)	RUN 1 RAIN cm	RUN 2 RAIN cm	RUN 3 RAIN cm	RUN 4 RAIN cm
4	3.6	6.6	12.2	13.2
6	3.6	7.4	10.2	12.1
8	11.0	9.9	13.9	13.7
10	7.1	10.7	8.9	9.9
12	5.0	6.9	9.4	8.8
14	7.1	12.1	9.9	9.3
16	9.3	9.6	10.2	9.9
18	10.1	11.5	13.3	7.7

Figure 11. Summary of erosion pin data at Kittaning (run 1).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	6/31/81	6.48	3.81	9.98	
	7/ 2/81	0.13	0.13	0.16	
	7/ 3/81	0.15	0.15	0.22	
	7/ 5/81	4.19	3.56	9.34	
		Total			
7/ 8/81		10.95		19.70	+1.12

SCALE IN METERS
CONTOURS IN (MM)

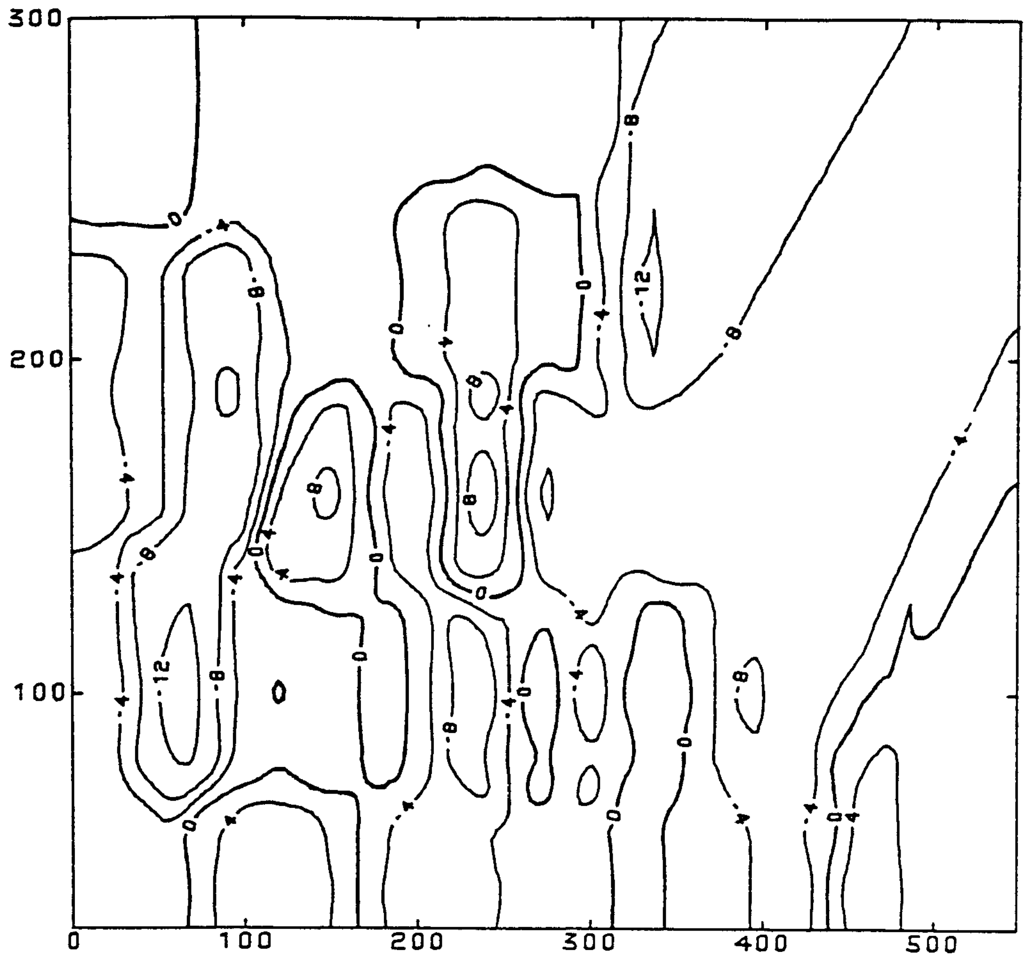


Figure 12 Summary of erosion pin data at Kittaning (run 2).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	7/13/81	2.03	2.03	4.81	
		Total			
7/14/81		2.03		4.81	-2.16

SCALE IN METERS
CONTOURS IN (MM)

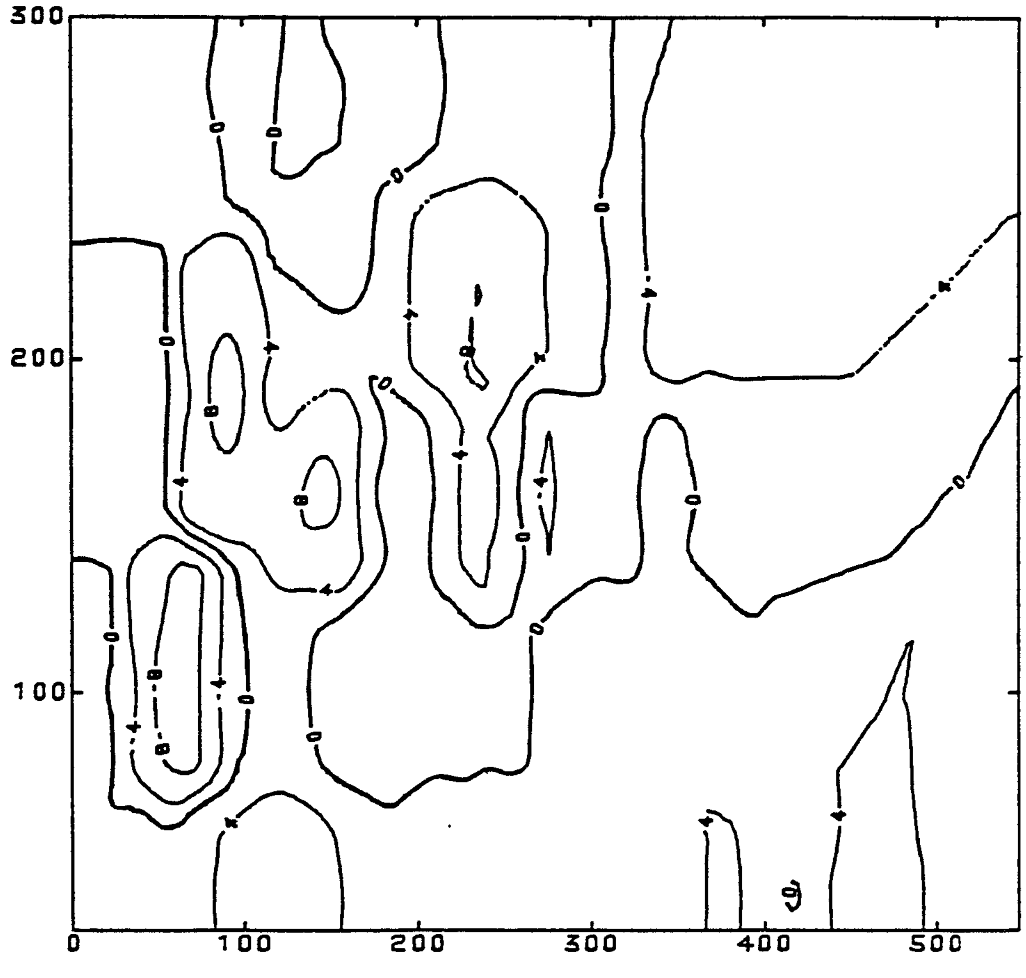


Figure 13. Summary of erosion pin data at Kittaning (run 3).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	7/19/81	3.68	3.56	9.26	
	7/21/81	0.25	0.25	0.41	
		Total			
7/21/81		3.94		9.67	-1.14

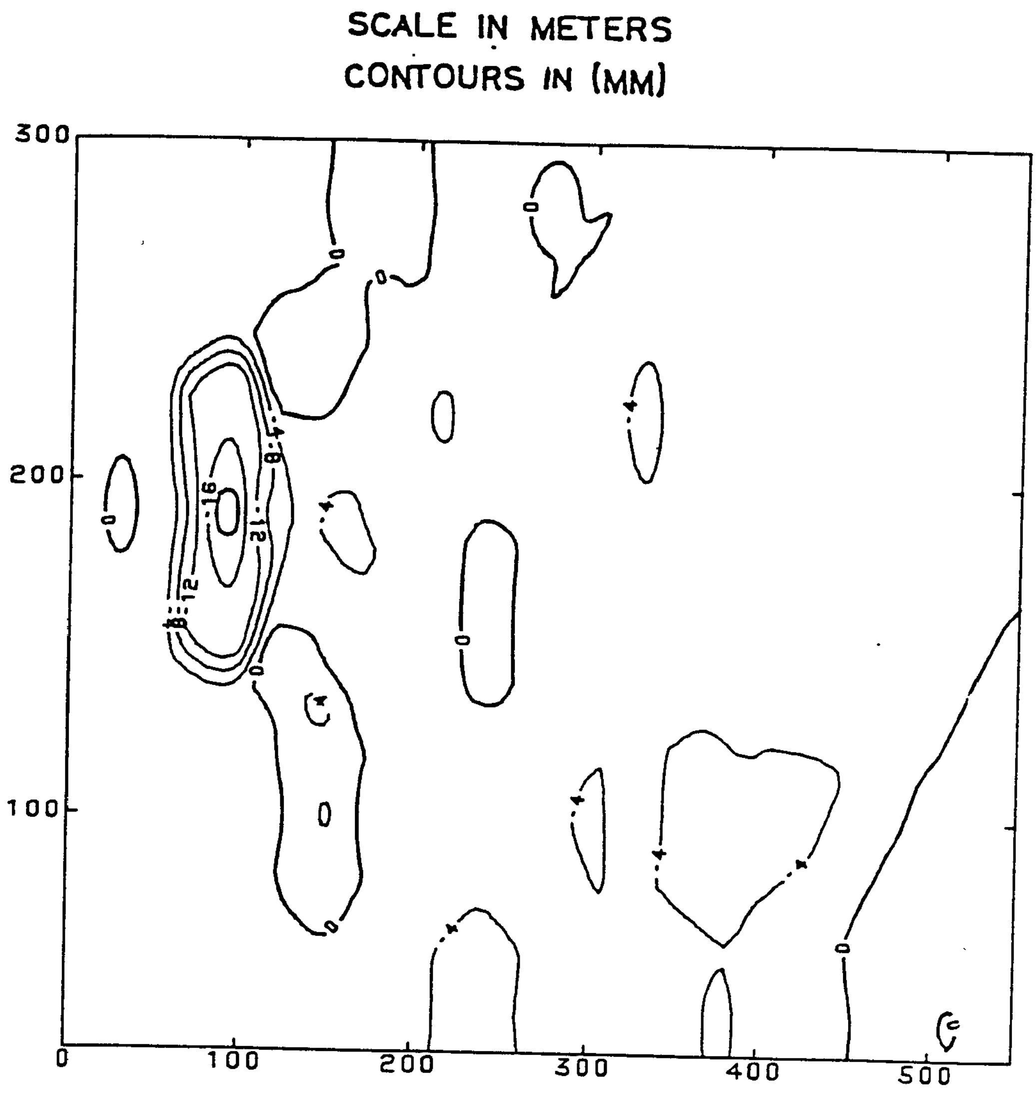


Figure 14. Summary of erosion pin data at Kittaning (run 4).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	7/26/81	1.52	1.52	3.43	
	7/28/81	0.89	0.38	0.67	
		Total			
7/28/81		2.41		4.10	+0.14

SCALE IN METERS
CONTOURS IN (MM)

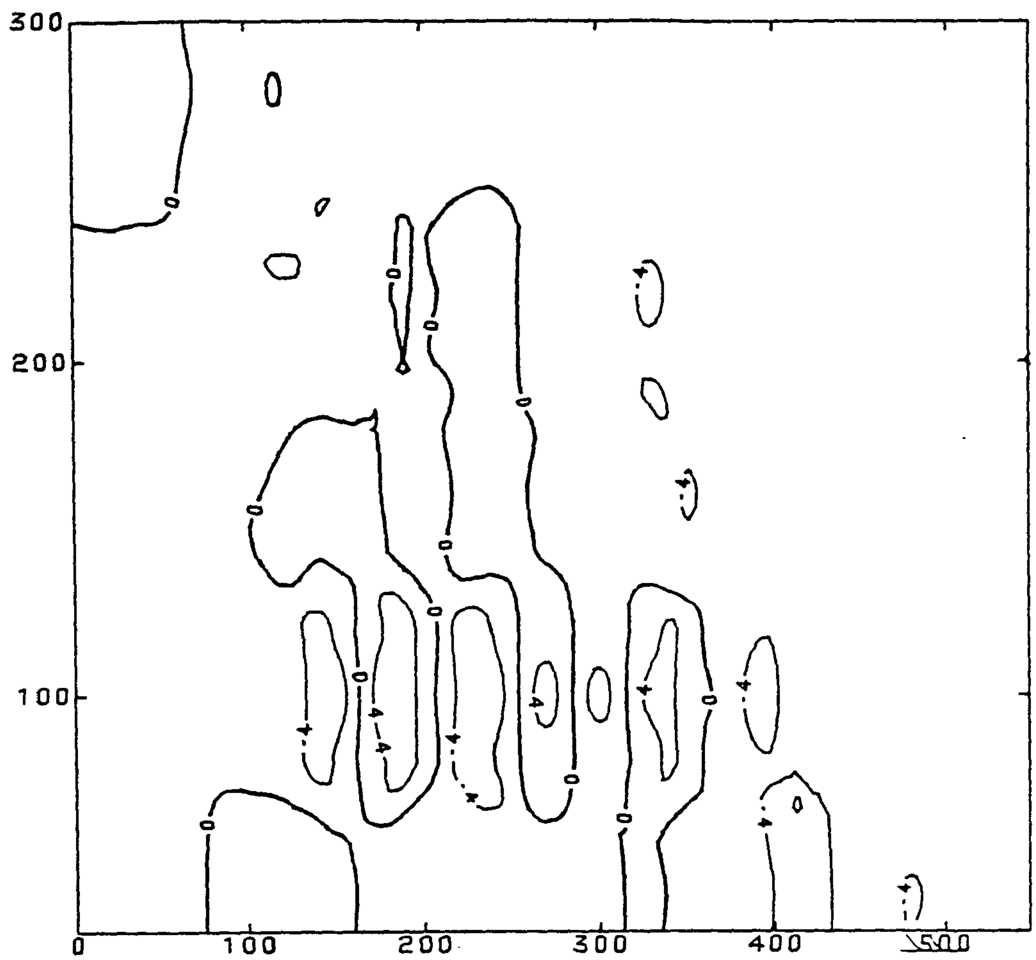


Figure 15. Summary of erosion pin data at Kittaning (run 5).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	8/ 3/81	0.76	1.02	2.14	
	8/15/81	0.38	0.13	0.17	
	8/16/81	0.25	0.50	0.92	
		Total			
8/18/81		1.40		3.23	-1.05

SCALE IN METERS
CONTOURS IN (MM)

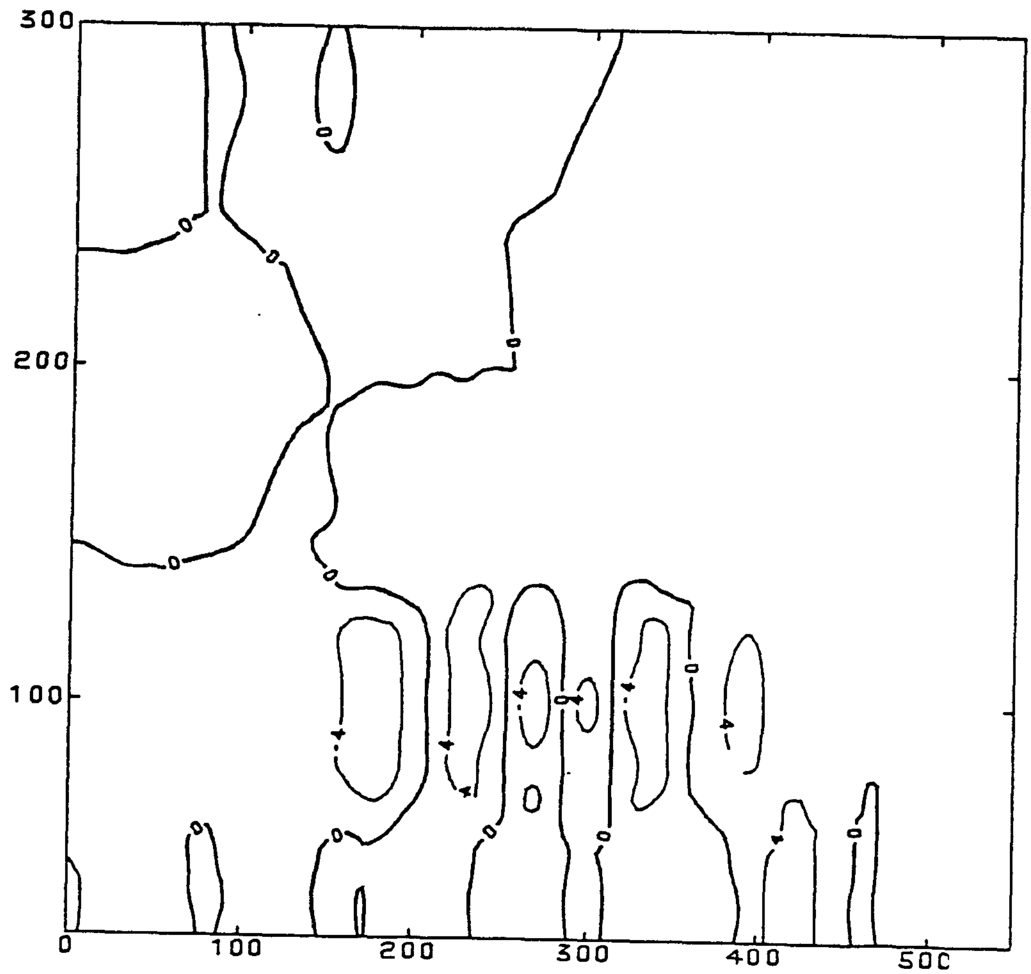


Figure 16. Summary of erosion pin data at Kittaning (run 6).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	8/24/81	0.33	0.66	1.30	
	8/28/81	1.02	2.03	4.81	
	8/30/81	0.64	0.38	0.67	
	8/30/81	0.76	1.02	2.14	
	9/ 1/81	0.38	0.38	0.67	
	9/ 1/81	0.76	1.52	3.44	
		Total			
9/ 1/81		3.89		13.02	-0.56

SCALE IN METERS
CONTOURS IN (MM)

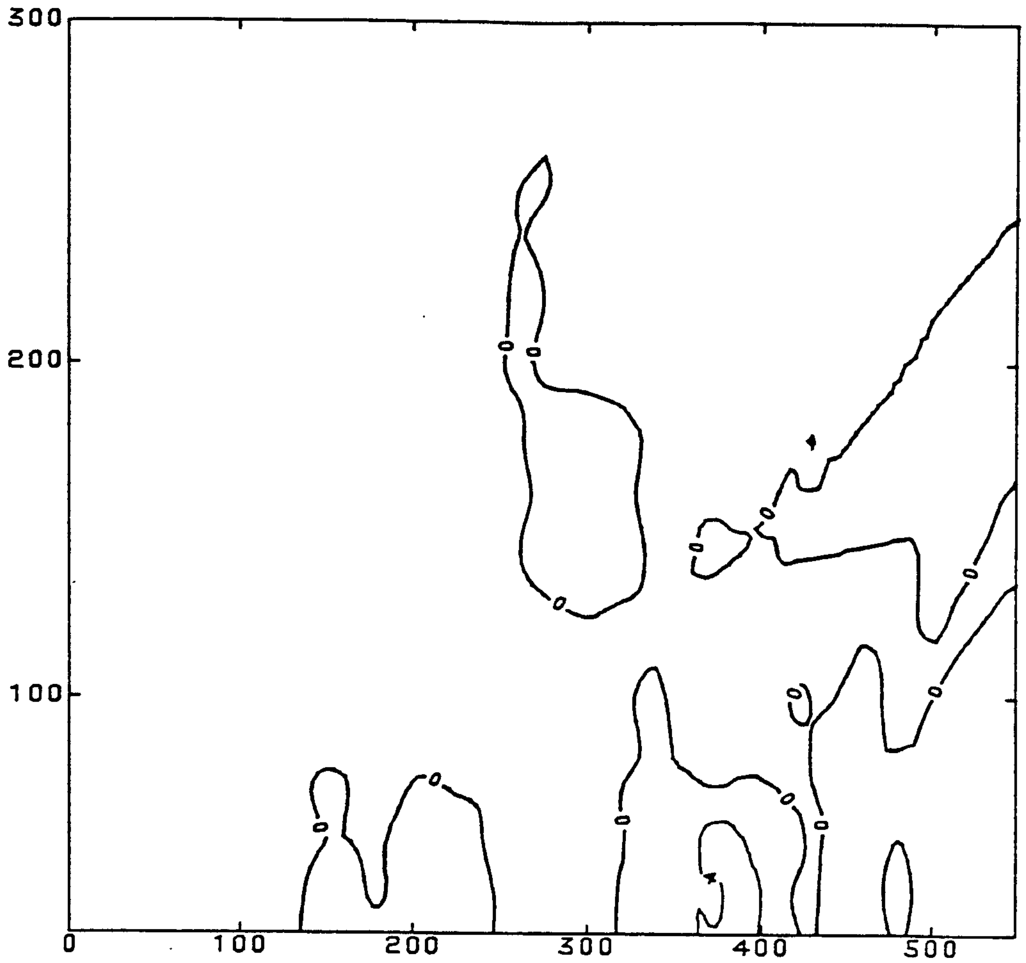


Figure 17. Summary of erosion pin data at Kittaning (run 7).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	9/ 2/81	0.25	0.25	0.41	
	9/ 3/81	2.92	0.25	0.41	
	9/ 8/81	2.03	2.54	6.25	
		Total			
9/ 8/81		5.21		7.07	+1.32

SCALE IN METERS
CONTOURS IN (MM)

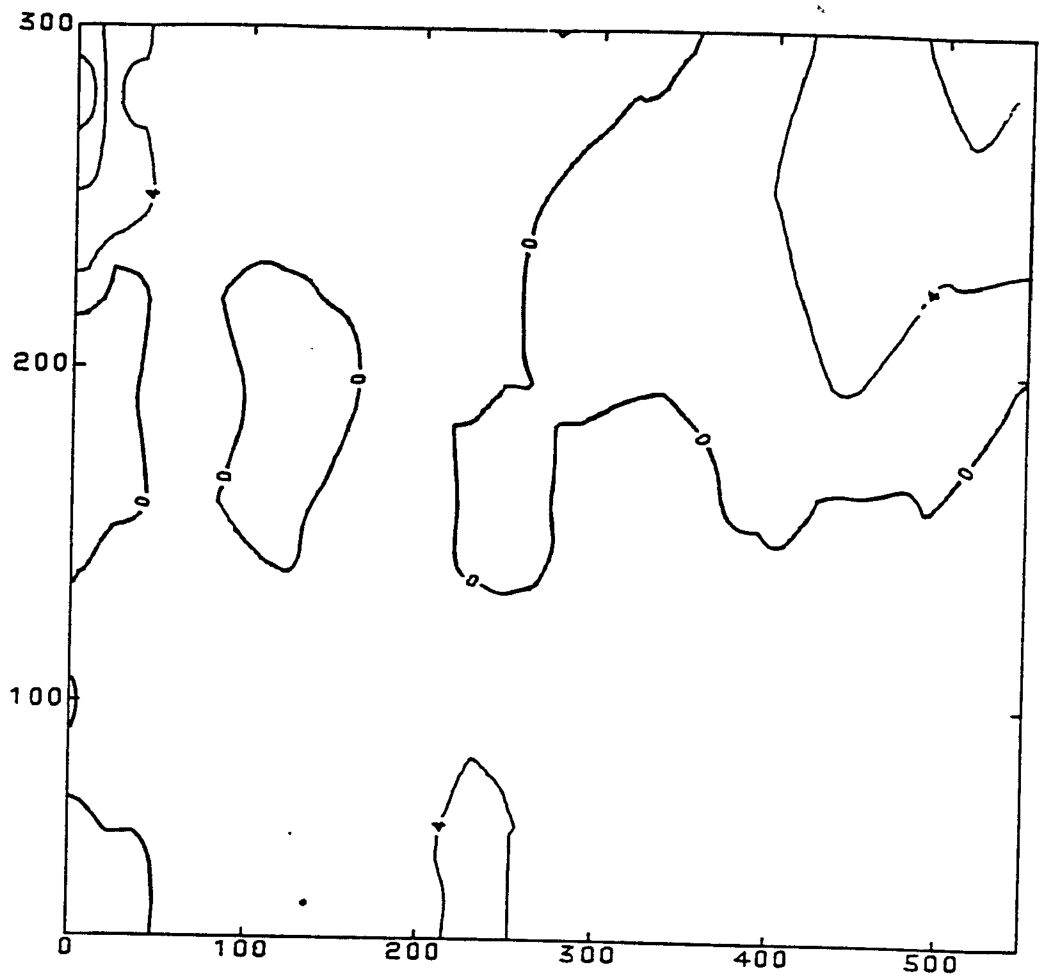
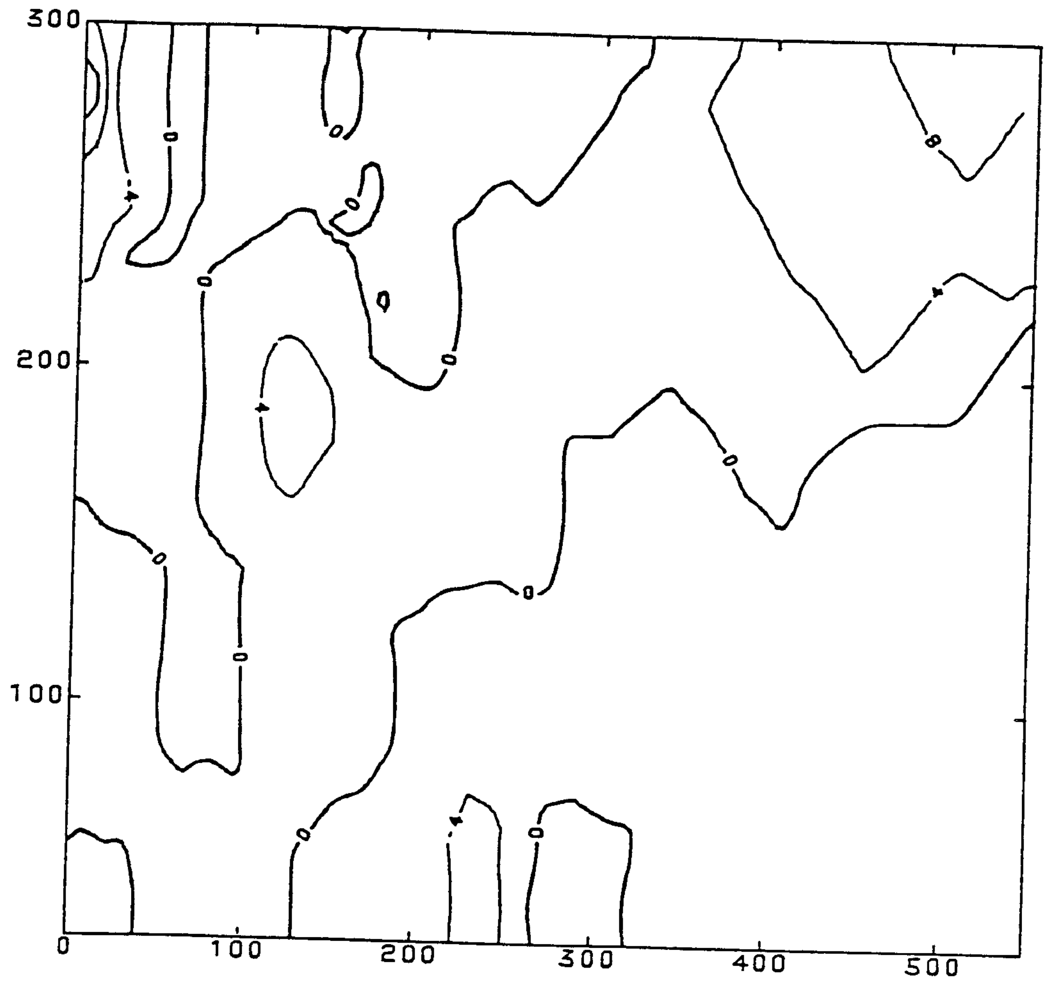


Figure 18. Summary of erosion pin data at Kittaning (run 8).

Erosion Measured Date	Rain Date	Rainfall cm.	Maximum Intensity cm/hr	R	Ave. Pin (-) Erosion (+) Deposit
	9/12/81	0.25	0.25	0.41	
	9/15/81	0.76	0.63	1.20	
	8/30/81	0.76	1.02	2.14	
	9/27/81	0.07	0.18	0.27	
		Total			
9/29/81		1.70	.	4.02	-0.38

SCALE IN METERS
CONTOURS IN (MM)



TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-84-041	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Erosion of Strip Mine Lands		5. REPORT DATE March 1984 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) James I. Sams and Andrew S. Rogowski		8. PERFORMING ORGANIZATION REPORT NO. 5
9. PERFORMING ORGANIZATION NAME AND ADDRESS Northeast Watershed Research Center USDA-ARS, 110 Research Building A University Park, Pennsylvania 16802		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. EPA-IAG-D5-E763
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15. SUPPLEMENTARY NOTES

This project is part of the EPA-planned and coordinated Federal Interagency Energy/Environment R&D Program.

16. ABSTRACT

The plot studies were carried out at Karthaus and Klingerstown to verify the accuracy of the erosion pin method of soil loss evaluation compared to soil loss measured in runoff samples. Subsequently, field studies at Kylertown and Kittaning were used to apply these methods. Kylertown site showed no concentrated areas of erosion for the 4 month study period. However, over the 12 year existence of this site, observable rills and gullies have accounted for large soil losses. The newly reclaimed site at Kittaning was quite vulnerable to erosion, with one area experiencing a concentrated soil loss of 12-16 mm during the study period.

When erosion pins are used with the surface contouring program areas of potential concentrated soil loss can be readily located on reclaimed strip mines. For best results it is recommended that the erosion pins be initially placed in a grid network on slope of interest.

17. (Circle One or More) KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ecology Environments Earth Atmosphere Environmental Engineering Geography Hydrology Limnology Biochemistry Earth Hydrosphere Combustion Refining Energy Conversion Physical Chemistry Materials Handling Inorganic Chemistry Organic Chemistry Chemical Engineering Other:	Control Technology: Energy Extraction, Coal Cleaning, Flue Gas Cleaning, Direct Combustion, Synthetic Fuels, Nuclear, Thermal, Improved Efficiency, Advanced Systems Processes & Effects: Transport Processes, Ecological Effects, Charac. Meas. & Monit., Health Effects, Integrated Assessment Energy Cycle: Extraction, Processing, Conversion, Utilization Fuel: Coal, Oil/Gas, Oil Shale, Nuclear, Geothermal, Solar, Waste as Fuel, Hydroelectric, Multi-fuel (2 or more) Other	6F 8A 8F 8H 10A 10B 7B 7C 13B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
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