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Hydraulic Characteristics of Rills

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HYDRAULIC CHARACTERISTICS OF RILLS

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ABSTRACT

Rill density and rill flow rates were determined during rainfall simulation tests conducted at 11 sites located throughout the eastern United States. A mean rill density of 1.0 rills/m was found for the study locations. From measurements of the relative distribution of flow rates, a procedure is identified for partitioning flow between individual rills.

Regression equations were developed for relating rill width and hydraulic roughness coefficients to flow rate. Equations were also derived for predicting mean flow velocity from visually determined measurements of advance velocity. Information reported in this study can be used to estimate hydraulic characteristics of rills.
KEYWORDS. Hydraulics, Hydrologic modeling, Runoff.

INTRODUCTION

Well established procedures have been developed for predicting infiltration and its variation with time (Rawls and Brakensiek, 1983). If rainfall rate exceeds infiltration rate, the amount of precipitation resulting in runoff (rainfall excess) can be determined. Routing procedures use rainfall excess to estimate flow rates at selected positions along a hillslope. Many routing procedures assume broad sheet flow as the basis for development of flow equations (Lane and Woolhiser, 1977).

Overland flow on upland areas frequently occurs as a mixture of broad sheet flow which is found on interrill areas and concentrated flow which occurs within rills. The quantity of flow within a particular rill is influenced by rill drainage area. Due in part to differences in microtopography across a slope, variations in flow rate frequently occur between rills.

The area draining into a rill influences the quantity of water and sediment delivered to the rill through interrill flow. Rill discharge, in turn, significantly affects the ability of the rill to detach and transport sediment. Thus, it is important to know not only the number of rills which may form per unit cross-sectional area, but also the variation in flow rate between individual rills. At present, information regarding rill density is limited.

In addition to flow rate, identification of other rill hydraulic variables such as rill width, hydraulic roughness coefficient, and flow velocity may also be important. Rill flow serves as the mechanism by which sediment is transported from upland areas. If the hydraulic characteristics of rill flow can be more accurately defined, upland erosion processes can be better understood and more accurately modeled.

A laboratory study of rill hydraulics was described by Foster et al. (1984 a, b). A full-scale fiberglass replica of a rill which formed on an erosion plot was constructed. Hydraulic data were collected and then used to develop regression equations which related mean velocity and average shear stress to a power function of discharge rate and slope gradient.

Little progress has been made in characterizing upland flow because of difficulties experienced in measuring the relatively small discharge quantities found on upland areas. It has been shown that dye dilution techniques can be employed to obtain information on upland flow characteristics (Finkner and Gilley, 1988). Bromide salts have proven to serve as excellent tracer materials (Gilley et al., 1989). Dye dilution procedures have considerable potential for use in upland flow characterization. This study employs dye dilution techniques to obtain data used to develop regression equations for estimating hydraulic characteristics of rills.

HYDRAULIC EQUATIONS

The Darcy-Weisbach, Manning and Chezy equations have been widely used to describe flow characteristics. Each of these relations contains a roughness coefficient. Under uniform flow conditions, the Darcy-Weisbach roughness coefficient, f, is given as (Chow, 1959):

$$f = \frac{8gRS}{V^2} \qquad (1)$$

where
g = acceleration due to gravity,
S = average slope,
V = flow velocity, and
R = hydraulic radius, which is defined as,

$$R = \frac{A}{P} \qquad (2)$$

where
A = cross-sectional flow area, and

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P = wetted perimeter.

If a rill is assumed to be rectangular with width b, then:

$$R = \frac{b\,y}{b + 2y} \tag{3}$$

where y is flow depth.

The Manning roughness coefficient, n, in metric form is given as:

$$n = \frac{R^{2/3}\,S^{1/2}}{V} \tag{4}$$

The Chezy roughness coefficient, c, is calculated as:

$$c = \frac{V}{[R\,S]^{1/2}} \tag{5}$$

The Chezy roughness coefficient can be determined directly from the Darcy-Weisbach roughness coefficient using the relationship:

$$c = \left[\frac{8g}{f}\right]^{1/2} \tag{6}$$

Information on existing flow characteristics is needed to relate the Manning roughness coefficient to either Chezy or Darcy-Weisbach roughness coefficients since:

$$n = \frac{R^{1/6}}{c} \tag{7}$$

The Darcy-Weisbach roughness coefficient is dimensionless, but the Manning and Chezy roughness coefficients both have characteristic units.

Reynolds number, a dimensionless parameter, is also used to describe flow characteristics. Reynolds number, Rn, is given as:

$$Rn = \frac{V R}{\nu} \tag{8}$$

where ν is kinematic viscosity. Kinematic viscosity can be determined directly from water temperature. In this study, regression equations were developed for estimating hydraulic roughness coefficients of rills from values of Reynolds number.

The continuity equation for flow is defined as:

$$Q = V A \tag{9}$$

where Q is flow rate. For a rectangular rill, water depth is given as:

$$y = \frac{Q}{V\,b} \tag{10}$$

Measurement of relatively shallow rill flow depths under field conditions is difficult. Identifying the soil surface-rill channel interface for eroding situations is not always possible. Thus, indirect determination of water depth using equation 10, and measurements of discharge rate, flow velocity and rill width was used in this investigation.

PROCEDURE

The study was conducted at 11 sites located throughout the eastern United States. The location, slope, and particle size analysis of soils at the study sites are shown in Table 1. These soils were selected to cover a broad range of physical, chemical, biological, and mineralogical properties. These properties resulted from diverse soil-forming factors acting through time, including climate, parent material, vegetation, biological activity, and topography. Each soil is considered to be of regional or national importance.

The study areas were located on uniform slopes having homogeneous soil characteristics. Either corn or small grains had been planted the previous year. All surface residue was first removed, and the area was then moldboard-plowed 3 to 12 months before the tests were conducted. After plowing, the sites were disked lightly and maintained free of vegetation either by tillage or application of herbicide. The study areas were disked immediately preceding testing. Two plots, 3.7 m across the slope by 10.7 m long, were established at each site using sheet metal borders. The plots were raked by hand prior to testing to provide a uniform surface.

A portable rainfall simulator designed by Swanson (1965) was used to apply rainfall at an intensity of approximately 57 mm/h. The first rainfall application (initial run) of 1 h duration occurred at existing soil-water conditions. A second rainfall simulation run (wet run) was then conducted approximately 24 h later, again for a duration of 1 h. A final, very wet rainfall application was applied within 1 h after completion of the wet run.

After steady state conditions had become established during the very wet simulation run, additional inflow was added at the top of each plot to simulate greater slope lengths. Inflow quantities of approximately 3.16×10^{-4}, 7.57×10^{-4}, 13.3×10^{-4}, and 18.9×10^{-4} m^3/s were added.

TABLE 1. Location, slope, and particle size analysis of selected soils

	Location		Slope	Particle size analysis (% by weight)		
Soil	County	State	(%)	Sand	Silt	Clay
Caribou	Aroostook	Maine	6.4	47.0	40.3	12.7
Cecil	Oconee	Georgia	6.2	64.6	15.6	19.8
Collamer	Tompkins	New York	8.2	7.0	78.0	15.0
Gaston	Rown	North Carolina	5.9	35.5	25.4	39.1
Grenada	Panola	Mississippi	6.7	2.0	77.8	20.2
Lewisburg	Whitley	Indiana	9.6	38.5	32.2	29.3
Manor	Howard	Maryland	9.8	43.6	30.7	25.7
Mexico	Boone	Missouri	3.8	5.3	68.7	26.0
Miami	Montgomery	Indiana	6.4	4.2	72.7	23.1
Miamian	Montgomery	Ohio	8.8	30.6	44.1	25.3
Tifton	Worth	Georgia	5.5	86.4	10.8	2.8

Flow addition for each inflow increment occurred only after steady state runoff conditions for the previous inflow increment had become established and selected hydraulic measurements had been made. A trough extending across the bottom of each plot gathered runoff, which was measured using an HS flume with stage recorder.

Steady state runoff conditions were determined using the stage recorder and HS flume. Runoff samples for sediment content determinations were collected at 5-min intervals during the initial and wet simulation runs. During the initial and wet rainfall events, rill formation occurred on the bare plots. Once steady state runoff conditions had become established during the very wet simulation run, the number of rills on each plot discharging into the collection trough was noted and rill width was measured. A thermometer was used to determine water temperature.

To measure rill discharge, a known concentration of bromide solution was continuously injected into each rill at a constant rate (Replogle et al., 1966). Runoff samples containing the diluted bromide solution were collected at the point where each rill discharged into the collection trough. Samples of approximately 800 mL were obtained using polyethylene bags. These samples were stored for future analysis which was performed using an ion analyzer. From measurements of the bromide injection rate and concentration, and diluted concentration, rill discharge rate was determined.

Mean flow velocity in each rill was measured using a fluorometer (Hubbard et al., 1982). A slug of dye was injected into the rill and the length of time required for the concentration peak to pass a downstream point was determined. A time-concentration curve resulted from continuous pumping of runoff from the rill through the fluorometer flow cell. Due to the symmetric shape of the dye concentration curve, the velocity associated with the peak concentration was assumed to equal mean flow velocity. Mean flow velocity was obtained by dividing travel distance by time of travel. Advance velocity was determined from visual measurements of the amount of time required for the leading edge of the dye to reach a downstream point.

RESULTS AND DISCUSSION

The study sites were selected to represent a broad range of soil physical, chemical, biological, and mineralogical properties. As a result, the regression relationships derived in this investigation should be applicable to a wide range of cropland soils. Information concerning runoff and erosion measurements, rill density measurements, partitioning flow between rills, rill width estimates, hydraulic roughness coefficients, and flow velocity estimates is presented below.

RUNOFF AND EROSION MEASUREMENTS

Runoff, runoff rate, sediment concentration, soil loss and soil loss rate for the initial and wet simulation runs are presented in Tables 2 and 3, respectively. Much larger variations in runoff amounts between soils were found for the initial run than occurred during the wet runs. For the wet run, only the Cecil, Collamer, and Tifton soils differed significantly in total runoff amount.

Significant differences in soil loss were identified between study sites for both the initial and wet runs. For the initial run, soil loss varied from 0.73 to 14.18 t/ha on the Tifton and Lewisburg soils, respectively. Soil loss for the wet run ranged from 1.08 t/ha on the Tifton soil to 17.34 t/ha for the Collamer.

TABLE 2. Runoff, runoff rate, sediment concentration, soil loss, and soil loss rate for initial run on selected soils*

Soil	Runoff (mm)†	Runoff rate (mm/h)‡	Sediment concentration ppm × 10^3	Soil loss (t/ha)	Soil loss rate (t/ha/h)‡
Caribou	27.4bc	32.1bc	13.7cd	3.76cd	5.01cd
Cecil	22.1cd	28.0c	28.1bc	6.80cd	9.97abc
Collamer	26.7bc	32.1bc	51.9a	14.03a	17.63a
Gaston	28.0bc	38.7ab	29.5bc	8.80abc	14.30ab
Grenada	28.8bc	40.9a	40.5ab	11.97ab	16.56ab
Lewisburg	35.8a	40.9a	39.0ab	14.18a	9.83bc
Manor	17.2d	30.0c	41.2ab	8.24abc	16.46ab
Mexico	17.2d	19.3d	24.6cd	4.39cd	9.57bc
Miami	31.6ab	38.5ab	26.6bc	8.66abc	9.32bc
Miamian	6.6e	18.1d	17.7cd	1.45d	5.83cd
Tifton	7.9e	12.2d	7.1d	0.73d	0.97d

* Plots were 3.7 × 10.7m. Values given are the average of two replications. The initial run lasted for a 60-min duration. Rainfall intensity was approximately 57 mm/ h.

† Within each column, differences are significant at the 5% level (Duncan's multiple range test) if the same letter does not appear.

‡ Average rate during the final 5 min of the run.

In general, we can conclude that for the wet simulation run, total runoff amounts for most of the experimental sites were similar. However, significant differences in soil loss values were found between soils. Thus, substantial variations in soil erodibility existed between many of the study locations.

RILL DENSITY MEASUREMENTS

Rill density measurements for the study sites are presented in Table 4. Rill density values varied from 0.7 rills/m on the Miami soil to 1.5 rills/m for the Grenada soil. With the exception of these two soils, no significant difference in rill density was measured between study sites.

The Miami and Grenada soils had similar soil textures and slope gradients. For the wet simulation run, no significant difference in runoff rate was found between these two locations. However, the Grenada soil with a larger rill density produced significantly greater soil loss. The reason for differences in rill formation between these two sites is not known. Until additional information concerning rill formation becomes available, use of a rill density approximation of 1.0 rills/m (the mean value for the 11 study sites) is suggested.

It should be noted that rill density measurements obtained in this investigation were made at the end of a 10.7 m plot. Convergence or divergence of flow may occur on some eroding upland areas. As a result, the number of rills

TABLE 3. Runoff, runoff rate, sediment concentration, soil loss, and soil loss rate for wet run on selected soils*

	Runoff	Runoff rate	Sediment concentration	Soil loss	Soil loss rate
Soil	(mm)†	(mm/ h)‡	ppm × 10^3	(t/ ha)	(t/ ha/h)‡
Caribou	40.9ab	40.9ab	12.7e	5.14d	5.90de
Cecil	44.0a	44.0a	21.2de	9.40bc	12.04bc
Collamer	28.7b	30.0b	60.3a	17.34a	18.56a
Gaston	40.9ab	40.9ab	23.8cd	9.70bc	11.25bc
Grenada	40.9ab	40.9ab	30.7bc	12.61b	14.73ab
Lewisburg	32.4ab	32.1ab	21.2de	6.86cd	8.30cd
Manor	30.1ab	30.1b	39.2b	11.52b	12.40bc
Mexico	33.0ab	34.3ab	22.6cd	7.40cd	10.30cd
Miami	34.2ab	34.2ab	18.0de	6.15cd	8.19cd
Miamian	33.1ab	36.4ab	33.9b	11.51b	14.16b
Tifton	29.3b	30.1b	3.5f	1.08e	2.04e

* Plots were 3.7 × 10.7m. Values given are the average of two replications. The wet run lasted for a 60-min duration. Rainfall intensity was approximately 57 mm/ h.

† Within each column, differences are significant at the 5% level (Duncan's multiple range test) if the same letter does not appear.

‡ Average rate during the final 5 min of the run.

occurring per unit cross sectional area may vary with downslope distance.

At each of the 11 sites, simulated rainfall was applied at a nearly uniform intensity of approximately 57 mm/h. Thus, with this experimental constraint it was not possible to evaluate potential effects of varying rainfall intensity on rill initiation and development. Additional tests are required to determine if rill density is dependent upon rainfall rate.

PARTITIONING FLOW BETWEEN RILLS

To determine the relative flow rate between rills on a given plot at a particular inflow level, the flow rate for each rill was divided by the maximum rill flow rate on that plot. This procedure was used to normalize flow rates between plots. A total of 397 measurements were used to develop the relative frequency versus relative flow rate information presented in figure 1.

Figure 1 shows the relative distribution of flow rates between rills. It can be seen from figure 1 that for the given experimental sites, 30% of the rills had flow rates equal to the maximum rill flow rate. In comparison, only 6% of the rills had flow rates which were 50% of the maximum.

We have identified previously that under steady state conditions, total runoff rates from most of the experimental locations were similar. Also, the number of rills occurring per unit cross sectional area was similar between most sites. However, it is evident from figure 1 that for the given experimental conditions, differences in flow rate existed between individual rills.

TABLE 4. Rill density measurements for selected soils*

Soil	Rill density (rills/m)†
Caribou	0.8bc
Cecil	0.8bc
Collamer	1.1abc
Gaston	1.0bc
Grenada	1.5a
Lewisburg	1.0bc
Manor	0.8bc
Mexico	1.0bc
Miami	0.7c
Miamian	1.2ab
Tifton	1.1abc

* Plots were 3.7 × 10.7m. Values given are the average of two replications. Approximately 114 mm of rainfall was applied during the initial and wet simulation runs.

† Differences in rill density are significant at the 5% level (Duncan's multiple range test) if the same letter does not appear.

The information shown in figure 1 was used to generate the cumulative relative frequency (CRF) versus relative flow rate (RFR) curve shown in figure 2. Regression analysis of the measured values was used to develop the relationship:

$$CRF = 2.14\,(RFR) - 3.27\,(RFR)^2 + 2.07\,(RFR)^3 \quad (11)$$

Relative flow rate can be determined from cumulative relative frequency values using the equation:

$$RFR = -\,0.351\,(CRF) + 4.01\,(CRF)^2 - 2.64\,(CRF)^3 \quad (12)$$

For the above equations, the coefficient of determination, r^2, is 0.968.

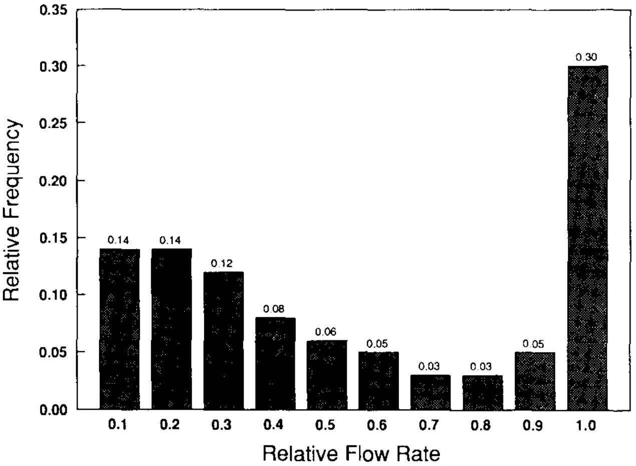

Figure 1–Relative frequency of measured relative flow rates.

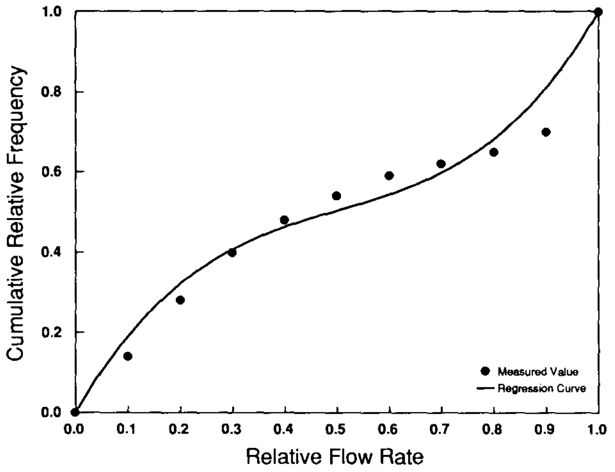

Figure 2–Cumulative relative frequency of measured relative flow rates.

The cumulative relative frequency distribution curve shown in figure 2 was developed from measurements of rill flow. It was derived assuming that the flow rate for individual rills varied in a random fashion. A relatively large number of measurements were collected at several eroding upland sites to define the shape of this curve.

Figure 2 can be used to partition flow between individual rills. The number of rills occurring along a particular cross section must first be identified (from information provided previously, a value of 1.0 rills/m should provide a reasonable estimate). A random number corresponding with the cumulative relative frequency shown in figure 2 can be selected for each rill. Cumulative relative frequency values can then be associated with values of relative flow rate using figure 2 or equation 11. The total relative flow rate for rills along the cross section under consideration can then be related to rainfall excess to determine flow rates for each of the individual rills.

RILL WIDTH ESTIMATES

Regression equations relating rill width to rill discharge are presented in Table 5. Regression coefficients are identified for each soil and also for all soils combined. Results of regression analysis for the Tifton soil were not sufficiently accurate to justify publication. The equations were derived for rill widths ranging from 0.019 to 0.270 m. Rill discharge varied from 1.98×10^{-5} to 1.83×10^{-3} m^3/s.

Regression coefficients were first identified using nonlinear regression procedures. The regression coefficients were then used to estimate values for rill width. Finally, simple linear regression of predicted versus measured rill width was performed to obtain the r^2 values shown in Table 5.

The soils on which the rainfall simulation tests were conducted were recently tilled. Soil characteristics within the tillage zone were relatively uniform. On each of the sites, the rills had not yet reached a nonerodible boundary during the test period. Rill width at a particular cross-section has been reported to rapidly increase once a nonerodible boundary has been reached (Lane and Foster, 1980).

HYDRAULIC ROUGHNESS COEFFICIENTS

Calculation of hydraulic roughness coefficients required identification of other hydraulic variables. Rill hydraulic values and water depth were first determined using equations 3 and 10, respectively. Calculated values for hydraulic radius were then substituted into equations 1 and 8 to identify Darcy-Weisbach roughness coefficients and Reynolds number, respectively.

The regression equations shown in Table 6 were developed to relate Darcy-Weisbach roughness coefficients to Reynolds number. Regression coefficients are reported for each of the individual soils and for all soils combined. For the all soils combined analysis, Darcy-Weisbach roughness coefficients ranged from 0.17 to 8.0 while Reynolds number varied from 300 to 10,000.

Manning roughness coefficients were calculated using equation 4. Regression equations used to relate Manning roughness coefficients to Reynolds number are presented in Table 7. Again, values for individual sites and for all soils combined are reported. For the all soils combined analysis, Manning roughness coefficients ranged from 0.02 to 0.13 while Reynolds number varied from 300 to 10,000.

The fluorometer which was used to measure flow velocity was not functioning properly during most of the run on the Miamian soil. As a result, information from this site was omitted from the regression analysis, and regression coefficients for the Miamian soil are absent in Tables 6 and 7.

Chezy roughness coefficients can be calculated directly

TABLE 5. Statistical analysis of equations used to estimate rill width from rill discharge

	Regression coefficient*	Regression coefficient*	Coefficient of determination
Soil	a	b	r^2
Caribou	2.25	0.398	0.633
Cecil	0.717	0.278	0.632
Collamer	1.27	0.301	0.654
Gaston	2.50	0.393	0.614
Grenada	2.36	0.399	0.634
Lewisburg	0.805	0.251	0.901
Manor	1.09	0.285	0.722
Mexico	0.825	0.268	0.749
Miami	4.44	0.467	0.871
Miamian	0.283	0.144	0.604
All soils combined †	1.13	0.303	0.616

* Regression coefficients a and b are used in the equation

$$\text{rill width} = a\,(\text{rill discharge})^b$$

where rill width is in meters and rill discharge is in cubic meters per second.

† For the "All soils combined" analysis, rill widths ranged from 0.019 to 0.270 m while rill discharge varied from 1.98×10^{-5} to 1.83×10^{-3} m^3/s.

TABLE 6. Statistical analysis of equations used to estimate Darcy-Weisbach roughness coefficient from Reynolds number

	Regression coefficient*	Regression coefficient*	Coefficient of determination
Soil	a	b	r^2
Caribou	4.99×10^3	- 1.12	0.825
Cecil	9.72×10^2	- 0.874	0.702
Collamer	1.14×10^2	- 0.670	0.678
Gaston	2.57×10^2	- 0.767	0.702
Grenada	3.41×10^2	- 0.695	0.601
Lewisburg	8.75×10^2	- 0.889	0.614
Manor	6.01×10^3	- 1.12	0.879
Mexico	5.27×10^5	- 1.85	0.860
Miami	1.51×10^2	- 0.621	0.816
Tifton	2.36×10^4	- 1.24	0.731
All soils combined †	1.35×10^3	- 0.934	0.665

* Regression coefficients a and b are used in the equation

$$f = a\,Rn^b$$

where f = Darcy-Weisbach roughness coefficient and Rn = Reynolds number.

† For the "All soils combined" analysis, Darcy-Weisbach roughness coefficients ranged from 0.17 to 8.0 while Reynolds number varied from 300 to 10,000.

from Darcy-Weisbach roughness coefficient values using equation 6. It should be noted from equation 6 that Chezy and Darcy-Weisbach roughness coefficients are inversely proportional. Regression relationships for estimating Chezy roughness coefficients were not identified in this study.

The rill roughness coefficients determined in this investigation were obtained from recently tilled sites under actively eroding conditions. These equations should not be applied to broad sheet flow found on interrill areas. The addition of small quantities-of residue would be expected to significantly increase the rill roughness coefficients reported in this study for bare soil conditions.

FLOW VELOCITY ESTIMATES

Well accepted, widely used procedures for measuring flow velocity on upland areas are presently not available. In this investigation, a fluorometer was employed to measure mean flow velocity using dye tracing techniques. Corresponding visual estimates of advance velocity were also made.

Table 8 presents regression coefficients used to relate mean velocity to advance velocity. Regression coefficients are identified for individual soils and also for all soils combined. Measured values for mean velocity ranged from 0.043 to 0.61 m/s, while advance velocities varied from 0.10 to 0.95 m/s.

The regression equations shown in Table 8 allow use of straight-forward, inexpensive procedures for measuring flow velocity. Dyes or food coloring can be employed to determine advance velocity. Advance velocity readings can then be used to estimate mean flow velocity using the generalized equation presented in Table 8.

SUMMARY AND CONCLUSIONS

Simulated rainfall was applied to 11 soils located throughout the eastern United States. The number of rills occurring per unit cross sectional area on each of the soils was identified. In addition, flow rate, flow velocity, rill width, and slope gradient of each rill were determined.

For most of the soils, the total runoff amount during the wet simulation run was similar. However, significant differences in soil loss were found between sites. Thus, substantial variations in soil erodibility existed between many of the study locations.

Except for two of the soils, no significant difference in rill density was found between study sites. A mean rill density of 1.0 rills/m was measured at a downslope distance of 10.7 m. Due to convergence or divergence of flow, a different rill density value may be appropriate at other downslope distances.

Discharge measurements from the individual sites were combined to identify the relative distribution of flow rates between rills. This information, in turn, was used to obtain a cumulative relative frequency versus relative flow rate

TABLE 7. Statistical analysis of equations used to estimate Manning roughness coefficient from Reynolds number

	Regression coefficient*	Regression coefficient*	Coefficient of determination
Soil	a	b	r^2
Caribou	1.62	- 0.447	0.741
Cecil	1.40	- 0.436	0.696
Collamer	0.313	- 0.261	0.633
Gaston	1.24	- 0.431	0.575
Grenada	0.791	- 0.343	0.652
Lewisburg	0.985	- 0.392	0.712
Manor	2.03	- 0.517	0.900
Mexico	1.57	- 0.479	0.415
Miami	0.388	- 0.246	0.801
Tifton	8.53	- 0.637	0.798
All soils combined †	1.03	- 0.395	0.603

* Regression coefficients a and b are used in the equation

$$n = a\,Rn^b$$

where n = Manning roughness coefficient and Rn = Reynolds number.

† For the "All soils combined" analysis, Manning roughness coefficients ranged from 0.02 to 0.13 while Reynolds number varied from 300 to 10,000.

TABLE 8. Statistical analysis of equations used to estimate mean velocity from advance velocity

	Regression coefficient*	Coefficient of determination
Soil	a	r^2
Caribou	0.788	0.893
Cecil	0.750	0.899
Collamer	0.824	0.897
Gaston	0.729	0.696
Grenada	0.654	0.774
Lewisburg	0.815	0.891
Manor	0.809	0.914
Mexico	0.623	0.518
Miami	0.755	0.916
Miamian	0.795	0.941
Tifton	0.596	0.677
All soils combined †	0.742	0.818

* Regression coefficient, a, is used in the equation:
mean velocity = a (advance velocity).

† For the "All soils combined" analysis, mean velocity ranged from 0.043 to 0.61 m/s while advance velocity varied from 0.10 to 0.95 m/s.

relationship. This equation can be used to partition flow between individual rills on an eroding landscape.

A regression relationship was developed to relate rill width to flow rate. Information used to derive the equation was obtained from recently tilled sites having uniform soil characteristics. The equation is applicable to rill formation occurring before a nonerodible boundary is reached.

Darcy-Weisbach and Manning roughness coefficients were calculated from rill hydraulic measurements. Regression equations were identified for estimating roughness coefficients from values of Reynolds number. The equations can be used to predict roughness coefficients for actively eroding rills without crop residue.

A fluorometer was employed to measure mean flow velocity using dye tracing techniques. Corresponding visual estimates of advance velocity were also made. Regression coefficients were developed for relating mean flow velocity to advance velocity. The regression equations allow use of straight-forward, inexpensive procedures for measuring flow velocity.

Process based models for predicting runoff and erosion on upland areas require information on flow hydraulics. Dye tracing procedures were used in this study to measure selected hydraulic variables. The ability to understand and properly model flow processes will improve as additional information on the hydraulic characteristics of upland areas becomes available.

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