DIVISION S-6—SOIL AND WATER MANAGEMENT AND CONSERVATION

Soil Aggregates and Primary Particles Transported in Rill and Interrill Flow[1]

E. E. ALBERTS, W. C. MOLDENHAUER, AND G. R. FOSTER[2]

ABSTRACT

The size distribution of soil particles detached and transported in rill and interrill flow was determined on a silt loam soil in northcentral Indiana. Eroded soil was separated by field and laboratory sieving into > 2-, 2- to 1-, 1- to 0.5-, 0.5- to 0.21-, 0.21- to 0.05-, and < 0.05-mm size classes. The amount of primary clay (< 0.002 mm) transported as discrete particles in rill and interrill flow was also determined.

Large differences were found in the size of soil aggregates and primary particles in rill and interrill sediment. Rill flow transported a greater proportion of larger particles as compared with interrill flow because of basic differences in the detachment and transport mechanisms. Less than 5% of the rill and interrill sediment was composed of primary clays, indicating that most eroded clay was transported within soil aggregates.

The primary particle composition of the eroded aggregates was also determined. For all sizes > 0.05 mm, the percentage of sand in rill and interrill sediment was considerably higher than that in the matrix soil. The high sand content decreased the percentage of silt in some size classes more than the percentage of clay, indicating that primary clays may either flocculate or adsorb to the surfaces of larger aggregates during transport.

Water was added to the top of preformed rills at several rates to simulate various upland slope lengths. Discharge and rill erosion rates were not related for this soil that had not been tilled or cropped for 1 year.

Additional Index Words: runoff, soil loss, soil detachment, soil transport.

Alberts, E. E., W. C. Moldenhauer, and G. R. Foster. 1980. Soil aggregates and primary particles transported in rill and interrill flow. Soil Sci. Soc. Am. J. 44:590–595.

---

[1] Contribution from the Soil, Water, & Air Sciences, USDA-SEA-AR, in cooperation with the Purdue Agric. Exp. Stn. Purdue Journal Paper no. 7367. Received 1 Feb. 1979. Approved 27 Dec. 1979.

[2] Soil Scientist, USDA, Columbia, Mo. (formerly West Lafayette, Ind.); Soil Scientist, USDA, and Professor of Agronomy; and Hydraulic Engineer, USDA; and Assistant Professor of Agrci. Engineering, respectively, Purdue Univ., West Lafayette, Ind.

THE EROSION PROCESS includes detachment on rill and interrill areas and subsequent transport downslope (Meyer et al., 1975b; Foster et al., 1977). Sediment yield is determined by detachment or transport depending upon which one is smaller (Ellison, 1946; Meyer and Wischmeier, 1969).

Clay is usually considered to be the mineral component of the sediment most important in the transport of soil adsorbed chemicals (Young and Onstad, 1976). The source area of the sediment can have a large effect on the chemical composition of the sediment as well as the sediment yield (Young and Onstad, 1978). The estimation of sediment and associated chemical transport requires information on the size and composition of particles in the sediment (Frere et al., 1977). The objective of this study was to determine the size and composition of sediment detached and transported from rill and interrill areas.

BACKGROUND

The rill-interrill erosion concept facilitates basic erosion mechanics and erosion modeling studies (Foster and Meyer, 1975; Meyer et al., 1975b). Rills are areas where flow concentrates in narrow channels a few centimeters wide because of natural topographical features, soil roughness, or tillage marks and tracks. Shear and flow velocity are two parameters often used to measure the erosive potential of rill flow.

Erosion from areas between the rills is defined as interrill erosion. By definition, all detachment is by raindrop impact and none by flow. Raindrops not only detach soil aggregates and primary sand, silt, and clay particles from the soil mass, but subsequent raindrop impact probably breaks the detached aggregates down further as they are transported to the rills. In addition, raindrops create turbulence within the flow layer which greatly increases the transport capacity of interrill flow (Meyer et al., 1975b). Sediment that is detached on interrill areas moves laterally to rills in the thin interrill sheet flow (Young and Wiersma, 1973). Direct splash to the rills or downslope is not a major mode of transport.

Relationships that describe rill and interrill processes are different because of the basic differences in the detachment and transport mechanisms. Improved erosion equations are based upon separate terms for the two processes so the relative contribution of rill and interrill sediment can be determined.

Much of the sediment that is eroded from cohesive agricultural soils is composed of various sized soil aggregates (Weakly, 1962; Swanson et al., 1965). In many erosion studies that have determined aggregate and primary particle distribution, no differentiation was made between the particle sizes being eroded from rill and interrill areas. Based upon results from field plots, Meyer et al. (1975b) reasoned that particles eroding from interrill areas would generally be smaller than those eroding from the rill areas. Repeated raindrop impact on the detached particles in interrill flow and the more intense local forces of detachment were assumed to be responsible for the greater particle breakdown. Particle selectivity during the erosion process is almost impossible when rill erosion is significant because of the massive removal of particles from the rills (Meyer et al., 1975a). Therefore, selectivity in the erosion process is assumed to occur either on the interrill areas or during deposition on the landscape (Foster and Meyer, 1975).

Several laboratory studies using disturbed soils have determined the particle size distribution of interrill sediment. Young and Onstad (1978) found that interrill sediment was enriched in sand and not in clay, while rill sediment was enriched in clay and not in sand. Their findings conflict with the conclusions of Meyer et al. (1975b). They also conflict with the results of Monke et al. (1977), who found that for three soils of normal tilth and two of the same three soils in excellent tilth that clay and not sand was enriched in the interrill sediment. Young and Onstad (1978) attributed sand enrichment in the interrill sediment to the downward movement of fines in the soil matrix.

Less information is available on rill erosion and the particle sizes which can be transported. Meyer et al. (1975a) found that about 15% of the particles transported in rill flow from a tilled soil (6% slope) was larger than 1 mm. Almost 3% of the sediment was larger than 5 mm, which indicates that rill flow can transport very large particles. Selective erosion under these conditions is highly unlikely.

Information on the sizes of particles detached and transported by rill and interrill erosion processes is not complete and is somewhat contradictory. Also, much of the reported data were for broad size classes. Accurate estimation of transport capacity requires a breakdown of the sediment into five or more size classes (Li, 1977). Information is also needed on the primary particle composition of the eroded aggregates. Because most of the studies have been conducted on disturbed soils in the laboratory, we wanted to characterize the size distribution of rill and interrill sediment from a soil that had not been disturbed recently.

MATERIALS AND METHODS

The study was conducted in the summer of 1976 on a Miami silt loam (fine-loamy, mixed, mesic Typic Hapludalf) located in northcentral Indiana near Lafayette. The study site had a uniform slope of 8% and had not been tilled or cropped for 1 year. All residues had been removed from the plot surfaces the previous spring. Weeds were controlled by light hoeing.

The surface texture of the in situ soil was a silt loam (see Table 1 for some surface soil properties). The slope had been severely eroded, and most of the original loess mantle had been completely removed. However, organic matter and clay content were high enough to make the soil well aggregated and quite cohesive. The soil was quite firm because of the lack of disturbance for 1 year.

Plots 0.9 by 4.6 m were used to study rill erosion, while 0.6- by 0.6-m plots were used to study interrill erosion (Fig. 1). The upper and lower plots were replicates. Metal border strips enclosed the sides and upper ends to keep out excess surface runoff.

Small elliptical channels (preformed rills) about 8.3 cm wide at the surface and 5 cm deep were formed down the middle of each rill plot using a special tool. Rails parallel to the rills guided the tool to insure that the rills were straight and

Table 1—Properties of the in situ soil (0- to 5-cm zone).

Soil property	Mean (five samples)
Sand, %	19
Silt, %	55
Clay, %	26
Organic matter, %	2.60
Bulk density, g/cm^3	1.46

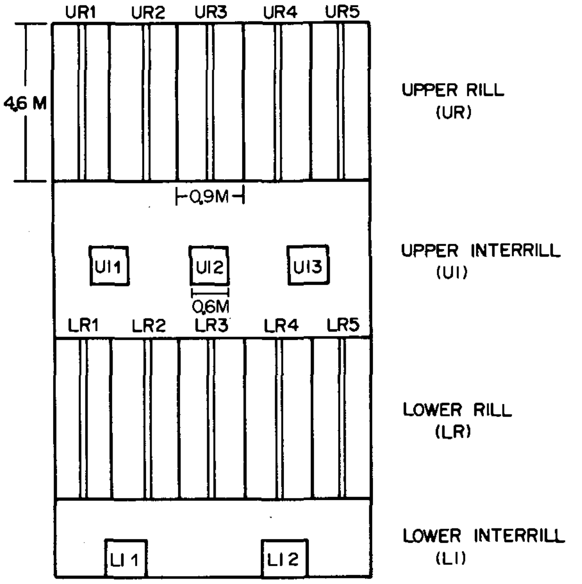

Fig. 1—Configuration of rill and interrill erosion plots.

of uniform depth. The blade of the tool sheared the soil much like a moldboard plow shears the bottom of a furrow.

Runoff in the rills was produced by simulated rainfall at 6.4 cm/hour and inflow added at a precalibrated, controlled rate to the upper end of each rill. The various inflow rates (shown in Table 2) simulated different upland slope lengths that might occur in the field. Three layers of window screen were laid between the edge of the rills and the plot border to reduce erosion by raindrop impact by an estimated 90% (Meyer et al., 1975b).

Flow velocity in the rill was measured by timing the movement of a food coloring dye through a 3-m length. Cross-sectional geometry was determined at three locations along the rill using a profilemeter (Meyer et al., 1975b), with pins spaced 0.64 cm apart which were lowered to the surface. Measurements were taken initially and after the completion of the four runs. We chose flow shear stress to represent the erosivity of the flow (Graf, 1971; Foster and Meyer, 1975), which was calculated assuming uniform flow. At each of the profilemeter locations, the flow area was estimated by dividing the discharge rate by the velocity. From the cross sectional geometry, the depth and hydraulic radius required for the flow area were determined. Shear stress was calculated from $\Upsilon=\gamma RS$, where Υ is the unit shear stress, γ is the density of the runoff, R is the hydraulic radius, and S is the slope. The effect of the various inflow rates on these hydraulic parameters is shown in Table 2.

The Meyer and McCune (1958) rainfall simulator was used to artificially apply rainfall at the rate of 6.4 cm/hour. Raindrop size and impact from this simulator are near that of natural rainfall so that its energy is 80% of that of natural rainfall. Four 30-min runs were conducted. Runs 3 and 4 were 24 hours after runs 1 and 2 with a 15-min period separating the two daily runs. Three layers of window screen were placed over the rills for the last run to determine the influence of direct raindrop impact on the erosivity of the flow in the rills. One of the interrill plots (U12) was covered with window screen during all the runs to evaluate the importance of raindrop impact on soil detachment.

Runoff rates from the rill plots were measured with a standard precalibrated HS flume and water stage recorder. A rotating slot sampler driven by an electric motor was used to divert one-hundredth of the outflow into 1-liter collection bottles. Runoff and sediment loss rates from the interrill plots were determined by recording the time required to fill 1-liter collection bottles. The sediment content of samples collected from the rill and interrill areas was determined gravimetrically.

The size distribution of the eroded particles was determined by field and laboratory sieving. A stack of four sieves 13 cm in diam with screen openings of 2, 1, 0.5, and 0.21 mm were enclosed in a plastic bag and gently swirled in the runoff for 5 to 10 sec, or until about 2 liters of runoff had been collected. Sieve samples were obtained after 10 and 20 min of rainfall. The soil particles caught on each sieve were washed into aluminum cans in the field. Although some aggregate breakdown may have occurred when the runoff cascaded onto the sieves, the amount is believed to be small because the aggregates appeared to be very stable with handling.

The sediment in the plastic bag was stored in a 2-liter plastic carton 2 to 6 weeks before additional sieving could be performed. Aggregate stability decreased slightly upon storage, but the effect became negligible after a few days. After resuspending, the contents were passed through a 23-cm diam sieve with 0.05-mm screen openings. The sediment passing through the sieve was stirred and a pipette sample taken after the appropriate settling time to determine the fraction of the total sample transported as primary clay. The fraction of the total sediment in the > 2-, 2- to 1-, 1- to 0.5-, 0.5- to 0.21-, 0.21- to 0.05-, and < 0.05-mm size classes was determined by dividing the air-dry weight of each size fraction by the total air-dry weight. Mechanical analyses to determine the primary particle size distribution of the various particle-size classes were then performed using standard pipetting procedures.

We observed in 1976 that rill erosion was insensitive to increases in flow velocity and shear stress, which appeared to be contrary to accepted views. In order to check our results, we conducted a similar rill erosion study in the summer of 1977 on the same field site used in 1976. Some slope reshaping by heavy equipment was done between the two studies. The rills were preformed in the same manner, except that the lengths were reduced from 4.6 to 3.0 m to maintain a constant slope gradient. The areas between the rills and plot borders were covered with plastic to eliminate interrill erosion alongside the rills. Simulated rainfall was applied at the rate of 6.4 cm/hour for two 30-min runs separated by a 15-min nonapplica-period. None of the rills were covered with window screen.

RESULTS AND DISCUSSION

Rill Erosion

Discharge and rill erosion rates for the five inflow levels tested in 1976 are shown in Table 3. Rill erosion was independent of flow rate or shear stress for the conditions studied, which was unexpected because Meyer et al. (1975a) found a linear relationship between the discharge rate and rill erosion. Their study variables (rainfall, inflow, soil, and slope) and experimental procedures were very similar to those in our study. The basic difference between the two studies was tillage; they tilled their site with a field cultivator just before rainfall was applied.

Tillage not only increases the porosity and roughness of the surface horizon, but it also detaches many aggregates from the soil mass. The soil remains quite loose and well aggregated until it is subjected to repeated wetting and drying or compacting traffic. Assuming that rill erosion can be described by $D_r = A(\Upsilon-\Upsilon_{cr})^B$ (Foster et al., 1977), the rill erosion rate would decrease as Υ_{cr} increases, which it does as a soil consolidates (Graf, 1971). This partially explains the increase in rill erosion following tillage. Perhaps the

Table 2—Effect of successively higher inflow rates on some rill flow parameters (1976).

Inflow rate	Flow velocity	Flow depth	Wetted perimeter	Hydraulic radius	Shear stress
$(m^3/sec) \times 10^{-4}$	m/sec	cm			N/m^2
0.7	0.32	0.66	7.14	0.37	2.92
1.2	0.32	0.69	7.09	0.39	3.21
2.3	0.48	0.91	7.72	0.55	4.32
5.0	0.59	1.50	11.76	0.79	6.20
10.0	0.85	1.68	11.28	0.95	7.75

parameters *A* and *B* are also functions of tillage. More research is needed in this area.

Meyer et al. (1975a) noted locally intense erosion at small headcuts. Rill erosion processes after tillage seem to resemble the erosion mechanics of soils where headcutting and undercutting are prevalent. Similar headcuts did not develop in our tests indicating that their development is perhaps related to soil consolidation and cohesiveness. On many tilled soils or on soils susceptible to erosion, rilling may be more closely related to flow hydraulics than it is on a consolidated soil or one not susceptible to erosion. For the latter condition, the type of soil management may completely control rill erosion with little or no dependence on flow hydraulics.

The window screen that was placed over the rills during the last 30-min run in 1976 reduced rill erosion rates by about 80% when compared to those from run 3 (Table 3). This screen reduced the detachment and splash erosion from the area between the edge of the flow and the screen adjacent to the rills. The reduction in raindrop energy also apparently reduced the capacity of the flow to erode (Meyer et al., 1975a).

Because rill erosion rates did not increase with discharge as expected in 1976, we decided to repeat the study in 1977. Discharge and rill erosion rates were generally lower in 1977 than in 1976 (Table 4). This was partially because the plastic sheets next to the rills completely eliminated erosion from the interrill areas. Also, about 25 cm of soil was removed during slope reshaping in the fall of 1976. Topsoil removal undoubtedly affected some soil properties that influenced the erodibility of the soil. Again rill erosion did not correlate well with inflow rate, particularly for the three lowest rates. We found some evidence from a replication of the highest inflow rate that the critical discharge was reached, above which discharge and rill erosion rates might become related. Unfortunately, the inflow-metering device for the other replication was improperly adjusted. Therefore, we could not conclusively evaluate this inflow rate on rill erosion. For the conditions studied, these results again indicated that the tractive forces of rill flow were not adequate for appreciable scouring of rills when this soil was in a cohesive and consolidated condition. We know of no other studies of rill erosion that can be used for a comparison with our results. This comparison is certainly an important research need.

Table 3—Effect of added inflow on rill erosion from 4.6-m rills (1976).

Inflow rate	Run†	Water loss	Rill erosion
(m³/sec) × 10⁻⁴		kg hour⁻¹ m⁻¹ length of rill	
0.7	1	66	2.1
	2	74	1.9
	3	63	1.0
	4	74	0.4
1.2	1	64	3.8
	2	77	2.0
	3	79	1.1
	4	84	0.1
2.3‡	1	155	3.1
	2	193	2.5
	3	208	1.8
	4	206	0.3
5.0	1	422	3.1
	2	440	2.1
	3	438	1.3
	4	449	0.2
10.0	1	723	2.5
	2	766	2.0
	3	742	1.8
	4	721	0.3

† Three layers of window screen were placed over the rills for run 4.
‡ Values are based on one replication only. Three layers of window screen were placed over the rill of the other replicate for runs 1, 2, and 3.

The practical signifcance of our finding is quite important for evaluating the effect of tillage on erosion and nonpoint pollution. The conventional practice of plowing and disking is being replaced by conservation tillage practices which keep residues on the soil surface for erosion control. A number of researchers (Mannering and Meyer, 1963; Meyer et al., 1970) have shown the benefits associated with different levels of crop residue. Moldenhauer et al. (1971) investigated the effect of different tillage practices on soil erosion, while holding the residue level constant. Harrold and Edwards (1972) found that soil losses from a no-till planted corn watershed were negligible for a severe, 100-year frequency storm. Generally, the effect of the tillage system or residue level on rill separate from interrill erosion has not been determined. For soils that have been chiseled or loosened considerably, conservation tillage systems probably have the largest effect on interrill erosion. However, for certain tillage systems, such as till-plant or no-till, which do not appreciably disturb the soil, the reduction in rill erosion could be the principal factor that reduces sediment yield. A conservation tillage system that leaves a residue cover and minimizes soil disturbance affects both types of erosion and will probably be the most effective in reducing sediment yield, particularly from the severe storms that occur in the late spring and early summer in the Corn Belt.

Interrill Erosion

Discharge and interrill erosion rates are shown in Table 5. The three layers of window screen that covered the UI2 plot simulated a low canopy like that provided by small grains, grasses, or alfalfa. The low erosion rates from UI2 compared with the rates from the UI and LI plots illustrate the significant reduction in interrill erosion from raindrop interception near the soil surface. The difference in raindrop fall height between the covered and uncovered plots greatly reduced the impact energy of the raindrops and their potential for detaching and transporting soil.

Table 4—Effect of added inflow on rill erosion from 3.0-m rills (1977).

Inflow rate	Run	Water loss	Rill erosion
(m³/sec) × 10⁻⁴		kg hour⁻¹ m⁻¹ length of rill	
1.2	1	84	0.9
	2	67	0.5
2.3	1	293	1.3
	2	288	0.5
5.0	1	533	0.8
	2	532	0.4
10.0	1	901	2.8
	2†	1,179	4.6

† Values are based on one replication only. The inflow metering device for the other replicate was not adjusted properly.

Table 5—Runoff and interrill erosion from 0.6-m square plots (1976).

Run	UI1 and UI3 (avg.)	Plot no. UI2†	LI1 and LI3 (avg.)
	Runoff, cm/hour		
1	3.4	3.1	3.9
2	6.8	4.6	5.9
3	6.7	4.2	7.1
4	8.6	4.9	6.1
	Interrill erosion, $kg\ hour^{-1}\ m^{-2}$		
1	0.9	0.4	1.0
2	2.0	0.7	1.6
3	1.8	0.4	1.9
4	2.1	0.4	1.6

† Three layers of window screen were placed over the plot for all runs.

Size Distribution of Eroded Particles

Table 6 shows the size distribution of the soil particles from rill erosion for the six size classes. Although we did not separate the primary sands from the aggregates, we observed that most of the sediment was aggregated. About two-thirds of the total sediment was > 0.05 mm in diam. Many particles of this size are readily deposited if the flow velocity within the rill is significantly reduced (Neibling and Foster, 1977). About one-half of the total sediment was in the 2- to 0.21-mm size class. Generally, less than one-fifth of the total sediment was in the > 2- and 0.21- to 0.05-mm size classes. Discharge rate did not significantly affect the size distribution of the soil particles.

Table 7 shows the size distribution of the soil particles from interrill erosion. The size of the transported particles was reduced markedly when compared with the size of the particles transported by rill flow. Less than 10% of the total sediment was > 1 mm, while about 60% was < 0.05 mm. Two factors are assumed to have caused the decrease in the amount of larger particles being transported. First, the thin interrill flow did not have enough velocity to transport the largest and heaviest soil aggregates and primary particles. Consequently, these heavier particles remained on the interrill areas, which could eventually lead to sand enrichment of the surface horizon. Secondly, raindrop impact produced small aggregates that were susceptible to further raindrop breakdown as they moved in thin flow off the plot.

Table 6—Size distribution of soil particles transported in rill flow (1976).

Inflow rate	Run	Size classes, mm >2	2-1	1-0.5	0.5-0.21	0.21-0.05	<0.05
$(m^3/sec) \times 10^{-4}$		% of total sediment					
0.7	1	5.5	12.9	22.9	20.2	7.6	30.9
	2	5.4	11.6	21.4	22.3	8.7	30.6
	3	9.2	17.6	21.9	16.6	6.5	28.2
	4	2.4	5.1	15.8	13.8	8.7	54.2
1.2	1	6.3	11.6	24.0	21.3	7.8	29.0
	2	4.9	9.2	21.6	20.8	9.9	33.6
	3	10.3	11.5	21.9	23.6	11.7	21.0
	4	3.1	5.1	11.4	32.6	9.4	38.4
2.3	1	5.3	7.7	19.4	23.3	6.8	37.5
	2	6.4	11.1	15.8	14.7	6.2	45.8
	3	5.9	6.0	21.9	23.6	12.8	29.8
	4	0.7	6.4	14.2	21.2	24.8	32.7
5.0	1	8.3	11.3	20.7	23.4	8.1	28.2
	2	5.9	14.4	26.7	14.7	6.7	31.6
	3	6.0	8.8	15.5	17.9	4.6	47.2
	4	11.5	9.6	14.5	16.0	9.8	38.6
10.0	1	7.7	11.7	19.1	22.7	9.4	29.4
	2	5.8	11.0	13.8	14.6	7.5	47.3
	3	10.2	11.4	16.2	12.0	10.0	40.2
	4	18.6	13.5	13.8	13.5	9.8	30.8

Table 7—Size distribution of soil particles transported in interrill flow (1976).

Plot	Run	Size classes, mm >2	2-1	1-0.5	0.5-0.21	0.21-0.05	<0.05
		% of total sediment					
UI 1 and 3	1	1.7	6.6	23.1	13.3	9.4	45.9
	2	1.1	2.3	14.3	23.9	10.0	48.4
	3	0.4	1.6	11.3	17.9	8.2	60.6
	4	0.8	2.1	11.0	14.5	9.2	62.4
LI 1 and 2	1	0.3	2.7	5.7	22.3	14.3	54.7
	2	0.3	0.6	4.7	12.0	33.9	48.5
	3	0.2	0.9	4.9	19.4	9.2	65.4
	4	0.7	1.2	5.6	16.5	12.3	63.7

Primary Clay Transport

Because detached primary clays are easily transported by interrill flow, sediment often has a higher clay content than the in situ soil (Meyer et al., 1975b; Monke et al., 1977). These primary clays are not easily deposited and may remain in suspension through much of the field and watershed flow system. If the clays are transported in aggregated form, however, they may be deposited on the field surface when the flow velocity significantly decreases. Table 8 shows that < 5% of the sediment was transported as primary clay in rill and interrill flow. Assuming that the sediment had the same clay content as the matrix soil (26%), > 80% of the soil clay was transported in aggregated form. The primary clay content of the sediment was higher for interrill flow than it was for rill flow because of the basic differences in the detachment and transport mechanisms.

Primary Particle Composition of Eroded Aggregates

The amounts of sand, silt, and clay in the eroded aggregates affect their physical and chemical transport properties. Table 9 shows the primary particle composition of the sediment from rill and interrill flow for the various size classes. For each class, the percentage of sand was considerably higher than that for the matrix soil (19%). Our study indicated that if the amounts of rill and interrill erosion were equal, about 50% of the sediment would be composed of particles > 0.05 mm (Tables 6 and 7). The aggregates

Table 8—Percent of total sediment transported as primary clay (1976).

Run	Rill erosion Avg.	Range	Interrill erosion Avg.	Range
	% of total sediment			
1	2.8	1.9-3.9	3.3	1.1-4.9
2	3.5	1.1-4.2	4.5	3.1-6.7
3	2.5	1.2-3.8	4.7	2.6-7.1
4	1.9	1.5-2.4	4.6	3.5-6.5

and primary particles < 0.05 mm do not contain primary sand particles because the smallest sand grain in the USDA soil particle classification is 0.05 mm. Therefore, the size classes > 0.05 mm are enriched with sand when the percentage of sand in the sediment is about equal to the percentage of sand in the matrix soil. Sand enrichment was greatest in the > 2- and 0.21- to 0.05 mm size classes for both rill and interrill sediment. The 2-mm sieve caught the small pebbles that were transported off the plot. Because these pebbles were not removed from the screen, the percentage of sand in the > 2-mm size class was uncharacteristically high. The high sand content of the 0.21- to 0.05-mm size class may have been the result of a large very fine sand fraction of the matrix soil.

Particularly for the 1- to 0.21-mm particles, silt content decreased as compared with that for the matrix soil (55%), whereas clay content remained about the same (26%). Originally we felt that the increase in the percentage of sand would decrease the silt and clay contents by about the same proportion. The glacial till soils surrounding Lafayette are high in Ca and Mg salts, which result in high concentrations of Ca^{2+} and Mg^{2+} in runoff. Perhaps during transport some of the primary clays either flocculated or were adsorbed to the soil aggregates through covalent bonding between the divalent cations and the mineral surfaces. If soil clays flocculate or are adsorbed during transport as these data suggest, then removing the larger aggregates with their clay content from runoff using any conservation practice that causes deposition would be extremely beneficial. Grass or residue strips at the base of a slope would be examples of this type of conservation practice.

SUMMARY

1) Particles eroded from interrill areas were smaller than those eroded from rills for an undisturbed soil. Consequently for a given erosion rate, less deposition would be expected further downslope where most of the sediment comes from interrill rather than rill flow.

2) Most of the eroded clay is transported within soil aggregates. Less than 5% of the sediment was primary clay for a soil with 26% clay in its matrix. The percentage of primary clay was higher for interrill sediment than rill sediment probably because of greater particle breakdown during detachment and the lower transport capacity of interrill flow.

Table 9—Primary particle composition of soil aggregates and particles transported in rill and interrill flow (1976).

Primary particle	Size classes, mm					
	>2	2-1	1-0.5	0.5-0.21	0.21-0.05	<0.05
	%					
			Rill erosion			
Sand	40	24	20	27	50	†
Silt	39	50	53	47	30	72
Clay	21	26	27	26	20	28
			Interrill erosion			
Sand	44	36	24	26	41	†
Silt	36	42	49	49	36	70
Clay	20	22	27	25	23	30

† The smallest sand particle in the USDA soil particle classification system is 0.05 mm.

3) Clay detached as discrete particles may be adsorbed to the surfaces of other particles during transport. The silt content of the 1- to 0.21-mm particles decreased as compared with the matrix soil, whereas the clay content remained about the same.

4) Rill erosion from an undisturbed soil was independent of the erosivity of the flow (discharge rate or shear stress). Rill erosion for some soils may increase significantly following tillage. This is an important research area because more information is needed on rill erosion mechanics and the effect on particle size distribution.

LITERATURE CITED

1. Ellison, W. D. 1946. Soil detachment and transportation. Soil Conserv. 11:179.
2. Foster, G. R., and L. D. Meyer. 1975. Mathematical simulation of upland erosion using fundamental erosion mechanics. Proc. Sediment Yield Workshop, USDA Sedimentation Lab., Oxford, Miss. ARS-S-40:190–207.
3. Foster, G. R., L. D. Meyer, and C. A. Onstad. 1977. An erosion equation derived from basic erosion principles. Trans. ASAE 20:678–682.
4. Frere, M. H., D. A. Woolhiser, J. H. Caro, B. A. Stewart, and W. H. Wischmeier. 1977. Control of nonpoint water pollution from agriculture: some concepts. J. Soil Water Conserv. 32:260–264.
5. Graf, W. H. 1971. Hydraulics of sediment transport. McGraw-Hill Book Co., New York, New York.
6. Harrold, L. L., and W. M. Edwards. 1972. A severe rainstorm test of no-till corn. J. Soil Water Conserv. 27:30.
7. Li, R. M. 1977. Water and sediment routing from watersheds. Ch. 9. Proc. of River Mechanics Institute, Colorado State Univ., Fort Collins, Colo.
8. Mannering, J. V., and L. D. Meyer. 1963. The effects of various rates of surface mulch on infiltration and erosion. Soil Sci. Soc. Am. Proc. 27:84–86.
9. Meyer, L. D., G. R. Foster, and S. Nikolov. 1975a. Effect of flow rate and canopy on rill erosion. Trans. ASAE 18: 905–911.
10. Meyer, L. D., G. R. Foster, and M. J. M. Romkens. 1975b. Mathematical simulation of upland erosion using fundamental erosion mechanics. Proc. of Sediment Yield Workshop, USDA Sedimentation Laboratory, Oxford, Miss. ARS-S-40:177–189.
11. Meyer, L. D., and D. L. McCune. 1958. Rainfall simulator for runoff plots. Agric. Eng. 39:644–648.
12. Meyer, L. D., and W. H. Wischmeier. 1969. Mathematical simulation of the process of soil erosion by water. Trans. ASAE 12:754–758, 762.
13. Meyer, L. D., W. H. Wischmeier, and G. R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Am. Proc. 34:928–931.
14. Moldenhauer, W. C., W. G. Lovely, N. P. Swanson, and H. D. Currence. 1971. Effect of row grades and tillage systems on soil and water losses. J. Soil Water Conserv. 26: 193–195.
15. Monke, E. J., H. J. Marelli, L. D. Meyer, and J. F. DeJong. 1977. Runoff, erosion, and nutrient movement from interrill areas. Trans. ASAE 20:58–61.
16. Neibling, W. H., and G. R. Foster. 1977. Estimating deposition and sediment yield from overland flow processes. p. 75–86. *In* D. T. Kao (ed.) Proc. Int. Symp. on Urban Hydrology, Hydraulics and Sediment Control. Univ. of Kentucky, Lexington, Ky.
17. Swanson, N. P., A. R. Dedrick, and H. E. Weakly. 1965. Soil particles and aggregates transported in runoff from simulated rainfall. Trans. ASAE 8:437–440.
18. Weakly, H. E. 1962. Aggregation of soil carried in runoff from simulated rainfall. Soil Sci. Soc. Am. Proc. 26:511–512.
19. Young, R. A., and C. A. Onstad. 1976. Predicting particle-size composition of eroded soil. Trans. ASAE 19:1071–1075.
20. Young, R. A., and C. A. Onstad. 1978. Characterization of rill and interrill eroded soil. Trans. ASAE 21:1126–1130.
21. Young, R. A., and J. W. Wiersma. 1973. The role of rainfall impact on soil detachment and transport. Water Resour. Res. 9:1629–1636.