Effects of Agricultural Conservation Practices on the Hydrology of Corey Creek Basin Pennsylvania, 1954–60

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1532–C

Prepared in cooperation with the Pennsylvania Department of Agriculture, State Soil and Water Conservation Commission

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By BENJAMIN L. JONES

HYDROLOGIC EFFECTS OF LAND USE

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By Benjamin L. Jones

ABSTRACT

Analyses of data collected from two small basins in northern Pennsylvania during the period May 1954 to September 1960 indicated that changes in land use and land treatment have affected suspended-sediment discharge from the basins. Extensive land use and land-treatment changes have taken place in the 12.2-square-mile Corey Creek study basin, whereas such changes in the 10.2-square-mile Elk Run basin, which is adjacent to the northeast, have been relatively slight. Elk Run basin, which is topographically and hydrologically similar to Corey Creek basin, was used as an external control for the Corey Creek basin study.

Multiple-regression analysis showed that of all the variables, runoff correlated most highly with the sediment yield of each basin.

Surveys at selected cross-sections of the two streams indicated that most channel changes were in the banks rather than in the bed. At points where the stream channel slope was greater than 70 feet per mile, the average annual change in cross-sectional area at the measured ranges was less than ±2.5 square feet. Filling of the stream channel occurred where the slope was 70 feet per mile or less, and such filling was greater in Corey Creek than in Elk Run.

Trend analyses of data from both basins indicated no persistent changes in quantity of runoff, precipitation, or runoff intensity (peakedness), although similar analyses indicated significant changes in the rate of suspended-sediment discharge from both basins. During the period September 1957 to September 1960, sediment discharge from Corey Creek basin decreased by 11 percent relative to the sediment discharge from Elk Run. All, or most, of this decrease was the result of a decrease in sediment discharge during the May to October growing seasons. No significant trends were detected in data collected during the November to April dormant season.

A factor, termed the relative erosion potential, was formulated for evaluating the effects of changes in the hydrologic cover conditions. This factor was adjusted for the effects of diversion terrace construction in the Corey Creek basin. A rank correlation test of the adjusted relative erosion potential versus the growing season Corey Creek–Elk Run suspended-sediment discharge ratio

resulted in a correlation coefficient, $\tau=0.71$, significant at the 3 percent level.
The least-squares regression equation derived from the same data was

$$Y=0.276X-6.89,$$

where Y was the Corey Creek–Elk Run sediment-discharge ratio and X was the adjusted relative erosion potential. The correlation coefficient was 0.65, significant at the 12 percent level. Standard error of estimate was 0.44, or about ±20 percent of the observed variation in the sediment-discharge ratio.

INTRODUCTION

The purpose of the investigation was to measure and explain the hydrologic and sedimentation characteristics of two small Pennsylvania watersheds with respect to changing land use and agronomic practices. Well documented, quantitative information regarding the effects of conservation practices in natural basins is vital to the effective and efficient planning of conservation programs.

In November 1953, the Corey Creek basin was selected by the U.S. Soil Conservation Service for extensive conservation treatment under the Federal Watershed Protection Law (P.L. 566) Pilot Watershed Program. The conservation plan provided for collection and evaluation of hydrologic data by the U.S. Geological Survey during and after conservation treatment. Because no major flood-control structures were planned for the Corey Creek basin, the study afforded an excellent opportunity to correlate the hydrologic data with the changes in land use and land treatment. Where installed, flood-control structures tend to be the dominant factors in hydrologic changes and, therefore, increase the difficulty of evaluating the effects of other practices.

The study necessitated collection and evaluation of data on precipitation, streamflow, suspended sediment, water chemistry, land use, and agronomic and engineering practices.

Elk Run, an adjacent basin of similar size, topography, and hydrologic characteristics, was chosen as a control for the study because changes in land use and treatment were expected to take place at a much slower rate than in Corey Creek basin. Elk Run data were used, therefore, as a means of estimating the probable behavior of the Corey Creek basin under the influence of a less intensive conservation program.

This report presents an evaluation of data collected during the period May 1954 to September 1960. The analyses presented were used to define the relationships between precipitation, streamflow, and sedimentation. Each of these variables was tested for changes in trend and, in addition, a test was made of the relation between land use and the trend in sediment discharge.

PREVIOUS STUDIES

The Tioga County Soil Conservation District watershed work plan (1954) outlined the conservation problems and suggested the remedial practices to be initiated.

Culbertson (1957) made a preliminary evaluation of hydrologic data from the two basins, using information collected during the first year and a half of the study.

The techniques developed for analyses of the data, and a brief history of the project were reported by Jones and Unger (1962).

ACKNOWLEDGMENTS

The investigation was conducted by the U.S. Geological Survey in cooperation with the Pennsylvania Department of Agriculture, State Soil and Water Conservation Commission, Charles F. Hess, Director. The project is under the general supervision of Norman H. Beamer, district chemist, U.S. Geological Survey, Philadelphia, Pa., and John R. George, geologist-in-charge, Harrisburg subdistrict office.

INSTRUMENTATION AND DATA COLLECTION

Continuous records of streamflow were obtained at the downstream limit of each study area, and suspended-sediment data were collected at the stream-gaging station. In addition, sediment data and records of water stage were collected at several upstream locations in each watershed. The water-stage data were obtained on an intermittent, or storm, basis and were used to compute suspended-sediment discharge contributed from each part of the basin. Figure 1 shows the instruments sites and data collection points in the two basins.

Cross-sectional area of the stream channels was measured each year at selected permanent sites as an aid in determining the channel contribution to suspended-sediment discharge. The difference in area from one year to the next revealed whether the channel was filling or scouring at the section. Special note was made of any change in the type of channel materials.

There was a rain gage for every 2 square miles in the basin. This density insured accuracy and maintained the record during periods when one or more gages were inoperative. These gages were at elevations representative of the variations in basin topography. Recording rain gages, centrally located in each basin, were used to determine the intensity as well as quantity of precipitation.

Specific conductance and pH of the water were measured on the 1st, 11th, and 21st day of each month. Complete chemical analyses were performed at less frequent intervals.

Land use and agronomic and engineering practices were determined yearly for each farm in the Corey Creek and Elk Run basins. This information was collected from the county tax offices, Soil Conservation district offices, and Agricultural Stabilization Conservation Committee offices and from studies of aerial photographs and field tours of the basins. Each farm was located by a grid system that was keyed to an overlay. This overlay corresponded to an aerial photo mosaic on which farm boundaries were shown. In addition, each farm was located by subbasin.

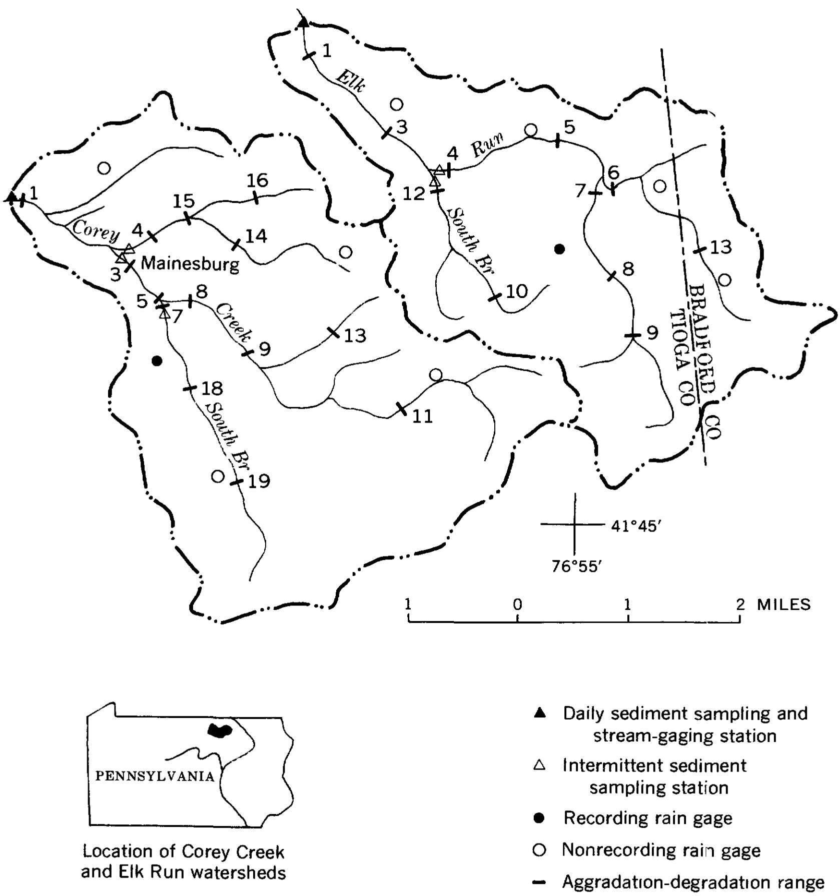

FIGURE 1.—Map of Corey Creek and Elk Run basins, showing instrument sites and data collection points.

A computer punchcard system was devised to facilitate the classification and analysis of the data. This system was discussed by Jones (1964).

In Corey Creek basin, 132 individual parcels of land were in the area being evaluated, whereas in Elk Run basin there were 79. Part of this difference was caused by the greater number of small urban properties in the town of Mainesburg, which was included in the Corey Creek study area.

Designation of both time and location for the land-use data was somewhat different from that for the hydrologic data; because of the sources of land-use data, calendar years were used in this record.

Tables 1–3 are yearly summaries of land use, agronomic practices, and engineering practices in the two basins. The major land-use categories (table 1) are cropland, woodland, grassland, urban land, idle land, and wildlife. The sum of these categories equals the total area surveyed. Because of the several sources of information, and the possibility of multiple uses of the same acreage, it was not always possible to balance pasture and hayland against the total grassland.

In Corey Creek basin, 160,000 feet of diversion terrace and seven farm ponds of 24 acre-feet total capacity were installed between 1954 and 1960, whereas in Elk Run basin, 19,460 feet of diversion terrace and one farm pond of 4 acre-feet capacity were constructed. A similar contrast between the two basins can be seen in the rate of application of agronomic practices. Figure 2 shows a newly constructed farm pond.

TABLE 1.—*Land use, in acres*

Year	Permanent hay	Spring grain	Crops	Hay	Urban settlement	Idle	Wooded	Pasture	Grass	Wildlife
Corey Creek basin										
1954	103	94	2,388	436	99.9	262	2,336	2,405	2,609	23
1955	111	79	2,388	436	99.9	257	2,345	2,385	2,605	23
1956	111	90	2,364	437	99.9	259	2,355	2,380	2,617	23
1957	105	94	2,356	416	100.9	235	2,373	2,271	2,630	23
1958	159	85	2,266	374	100.9	212	2,438	2,233	2,678	23
1959	490	105	1,981	713	100.9	197	2,419	2,178	2,997	23
1960	536	54	2,052	667	100.9	300	2,470	1,915	2,771	24
Elk Run basin										
1954	20	--------	2,288	20	26	390	2,113	1,075	1,445	--------
1955	20	--------	2,288	20	26	390	2,113	1,075	1,445	--------
1956	20	--------	2,312	20	26	390	2,110	1,054	1,424	--------
1957	23	--------	2,312	23	26	390	2,110	1,054	1,424	--------
1958	23	--------	2,312	23	26	390	2,110	1,054	1,424	--------
1959	23	--------	2,312	23	26	390	2,104	998	1,430	--------
1960	56	--------	2,278	56	26	390	2,104	998	1,464	--------

TABLE 2.—*Agronomic practices*

[Measurements in acres unless otherwise indicated]

Year	Conservation cropping system	Fertilizer (tons)	Lime (tons)	Contour farming	Tree planting	Soil bank tree planting	Cover cropping	Strip cropping system	Woodland protection	Hayland planting	Soil bank hayland planting	Pasture planting	Pasture improvement	Land clearing	Woodland improvement
Corey Creek basin															
1954	------	------	------	17	1	------	------	17	------	------	------	23	10	9	----
1955	------	47	------	204	7	------	------	129	5	7	------	64	2	2	----
1956	326	10	398	323	13	------	------	236	35	74	------	58	116	10	----
1957	592	16	497	501	42	------	42	402	61	65	------	26	19	13	----
1958	662	28	471	641	238	8	------	550	277	------	------	12	------	------	----
1959	475	38	343	278	148	------	42	557	304	346	274	------	11	----	17
1960	120	8	462	130	3	------	------	130	------	72	72	16	109	------	----
Elk Run basin															
1954	------	------	------	------	------	------	------	------	------	------	------	------	------	------	----
1955	------	------	------	------	------	------	------	------	------	------	------	------	------	------	----
1956	------	2	354	15	------	2	------	15	------	------	------	------	------	3	----
1957	------	4	277	------	------	------	------	------	------	------	3	18	10	------	----
1958	------	3	321	------	------	------	------	------	------	------	------	------	------	------	----
1959	29	39	420	52	------	------	------	45	------	17	------	------	------	6	----
1960	------	------	30	------	41	41	------	8	------	35	------	19	10	1	17

TABLE 3.—*Engineering practices*

Year	Open drains		Stream channel alteration (feet)	Diversion terrace length (feet)	Impoundments				Closed drains		Grassed outlets and waterways	
	Length (feet)	Drainage area (acres)			Surface area (acres)	Drainage area (acres)	Flood storage (acre-feet)	Capacity (acre-feet)	Length (feet)	Drainage area (acres)	Length (feet)	Drainage area (acres)
Corey Creek basin												
1954	1,600	82	--------	52,605	0.3	4.0	0.3	1.5	715	2	1,950	48
1955	400	5	--------	19,020	2.2	25.5	2.2	12.7	------	--------	2,370	222
1956	--------	--------	1,300	19,985	.7	14.0	.8	2.7	------	--------	670	5
1957	--------	--------	--------	38,275	.3	8.0	.3	1.6	400	1	600	--------
1958	--------	--------	--------	16,785	.6	8.0	.6	2.7	------	--------	150	90
1959	--------	--------	--------	6,320	------	--------	--------	------	------	--------	--------	--------
1960	--------	--------	--------	7,010	------	--------	--------	------	------	--------	500	--------
Elk Run basin												
1954	--------	--------	--------	--------	------	--------	--------	------	------	--------	--------	--------
1955	--------	--------	--------	1,000	------	--------	--------	------	------	--------	--------	--------
1956	--------	--------	--------	--------	------	--------	--------	------	------	--------	--------	--------
1957	--------	--------	--------	3,835	0.7	7.0	0.5	4.0	------	--------	300	18
1958	--------	--------	--------	725	------	--------	--------	------	------	--------	--------	--------
1959	--------	--------	--------	5,045	------	--------	--------	------	------	--------	--------	--------
1960	--------	--------	--------	8,854	------	--------	--------	------	750	15	--------	--------

DESCRIPTION OF THE BASINS

Corey Creek and Elk Run occupy adjacent basins in north-central Pennsylvania (fig. 1). Corey Creek flows from its source on Armenia Mountain, approximately 10 miles to its confluence with Tioga River

FIGURE 2.—A newly constructed farm pond, Elk Run basin.

at Mansfield. The main gaging station is 4.2 miles upstream from the mouth of Corey Creek. The basin area above the gage is 12.2 square miles.

Elk Run flows into Mill Creek, a tributary of Tioga River, and has a total length of about 10 miles. The gaging station is 5.5 miles upstream from the mouth. Drainage area above the gage is 10.2 square miles.

PHYSIOGRAPHY AND TOPOGRAPHY

Both basins have rolling to steep topography (fig. 3), and the elevation ranges from approximately 1,300 feet above mean sea level at the gaging stations to about 2,400 feet at the divide. Mean elevation and mean slope of the basins are as follows:

	Mean elevation above sea level (feet)	*Mean basin slope (percent)*
Corey Creek	1,750	15
Elk Run	1,800	17

The basins lie within the folded part of the Appalachian Plateaus Province. This part of the Province is a greatly dissected high plain, the two dominant structural features being the Wellsboro anticline and Pine Creek syncline, both of which trend northeast-southwest and

FIGURE 3.—View of the typical rolling topography of Corey Creek basin. Ridge in the distance is the basin divide.

plunge northeastward. Both Elk Run and Corey Creek rise southeast of the axis of the Wellsboro anticline and flow across the northwest limb toward the axis of the Pine Creek syncline, which underlies the hills to the northwest. Corey Creek, Elk Run, and most other streams in the area exhibit a modified dendritic pattern.

GEOLOGY

The streams traverse two rock formations. Both streams rise in the Catskill Formation of Late Devonian and Early Mississippian age and flow across the Chemung Formation of Late Devonian age. The Catskill is composed of greenish-gray sandy shales, fine-grained greenish-gray sandstones and some fresh-water and marine red shales. The underlying Chemung consists of similar rocks but locally may contain thin layers of impure limestone.

The basins have been subjected to continental glaciation at least three times. Evidence of the latest, or Wisconsin, glaciation can be found in deposits mantling the consolidated rock and in glacial outwash deposits formed in the flooded streams during times of glacial melting and retreat (Lohman, 1939). This fill largely consists of fragments of sandstone or conglomerate in the gravel and cobble size range (2–256 mm).

SOILS

Soil characteristics are determined by the interaction of five factors: climate, parent material, biological activity, slope or relief, and time. Land utilization by man may also be a soil modifying factor. Factors of importance in evaluating or predicting the sediment yield from a specific locality are slope of the soil surface, infiltration capacity, permeability, and erodibility of the soil. Infiltration capacity and permeability of the soil, as well as degree and length of slope, are important in determining the amount of surface runoff and soil erosion during a given storm. Infiltration capacity is determined largely by the texture, structure, organic matter content, dispersibility, and moisture conditions of the surface soil. Permeability is affected by texture, structure, mineral composition, and chemical characteristics of the soil profile. During prolonged periods of rainfall, the ultimate infiltration capacity of the soil profile is determined by the least permeable horizon.

More than 90 percent of the soils in each of the two basins may be classified as channery silt loams. Approximately two-thirds of these soils are well drained to moderately well drained and have a surface soil consisting of a strongly acid friable channery silt loam less than 1 foot thick, a subsoil of channery silt loam or silt loam to about 2 feet deep, and a substratum of channery silty clay loam or silty clay loam. About one-third are fragipan soils and have poor internal drainage. The surface soil consists of a friable channery silt loam to a depth of 8 inches; a subsoil of silt loam is underlain at a depth of 15 inches by a fragipan which is very firm and dense while in place but brittle when removed. Both these situations are important agriculturally because much of the cropland is on the well-drained soil; the more poorly drained soil is devoted to pasture and grassland.

On the hill tops, the soil is thinner. Much of the forested land is either gravelly silt loam or rocky silt loam, which are similar soils except that the surface and subsoils of the rocky silt loam contain angular cobbles and glacial boulders. The remainder of the timberland is rough stony land that has extensive outcrops of bedrock and areas of loose slab rock.

Less extensive than the channery silt loams, but still agriculturally important, are the silt loams of the flood plains. The surface soil is a very friable silt loam as much as a foot in thickness, and the subsoil is silty clay or silty clay loam extending to a depth of 24 inches. The substratum is a sandy or silty clay which contains some gravel. The bottom lands that are composed of this type soil are extensively cultivated.

Small areas of poorly drained loam occur on gentle slopes or flats near the streams in both basins. These soils have a dark-gray to reddish-gray silt loam surface and a subsoil of gray to bluish-gray plastic silty clay or clay. The surface soil is 3–6 inches thick, and the subsoil may extend to a depth of 36 inches or more. The areas underlain by these soils are used largely for pasture or woodland.

In general, soils in the Corey Creek and Elk Run basins are similar in type, distribution, and abundance.

CLIMATE

The climate of the study area is typical of continental climate in the North Temperate Zone. The minimum temperatures in winter are below 0°F, and the maximum summer temperatures may exceed 100°F. The mean temperature for the month of January is 26°F, and the mean for July is 71°F (Wellsboro, Pa., data, U.S. Weather Bureau, 1960).

Frost depth is almost at the surface under grasslands or forest cover and extends as much as 3 feet beneath bare cropland during severe winters. If a long period of subfreezing weather precedes the first snowfall, the soil under all cover conditions may be frozen. During many winters, however, the soil remains unfrozen in those areas protected by heavy forest cover. The average frost-free growing season is 118 days.

HYDROLOGY

Mean annual precipitation and runoff of the two basins for the period October 1954 to September 1960 were as follows:

	Precipitation (inches)	*Runoff (inches)*
Corey Creek	37.94	15.05
Elk Run	40.69	17.56

In Corey Creek basin, mean annual runoff was 40 percent of mean annual precipitation, whereas in Elk Run basin, runoff was 43 percent of precipitation.

Considerable variation exists in the precipitation-runoff relation from year to year and from season to season. Figure 4 shows the mean monthly precipitation and runoff in the two basins. Higher average elevation of the Elk Run basin probably influences the quantity of precipitation. Elk Run basin receives an average of about 0.2 inch per month more precipitation than Corey Creek basin.

During months of high streamflow (as in March and April), the runoff from Elk Run basin is greater than that from Corey Creek basin, but during months of recession and low flow (as in May to September), runoff from Elk Run basin is less than that from Corey Creek basin.

The higher average streamflows during the dormant season can be partially accounted for by the somewhat greater precipitation in the Elk Run basin, but the lower base flow indicates that the Elk Run basin has less capacity for retaining precipitation in ground-water storage. Reasons for this smaller capacity probably include the greater proportion of cropland and somewhat steeper slopes in the Elk Run basin.

Difference in runoff from the two basins is also reflected in the duration curves of mean daily water discharge shown in figure 5. Although the Elk Run basin is 18 percent smaller than the Corey Creek basin, mean flow at Elk Run is only 1.5 percent less than at Corey Creek, and median flow is only 12 percent less. Flows that occur less than 4 percent of the days are greater at Elk Run, and those that occur 4 percent or more of the days are of lesser magnitude than those at Corey Creek.

Monthly runoff bears no fixed relationship to precipitation, as is shown by figure 4. During the summer, most of the precipitation is lost through evaporation, is used and returned to the atmosphere by vegetation, or is allowed to percolate downward to the water table. Beginning with the dormant season in October, more of the precipitation is available as overland runoff because of decreased evaporation and plant use. During the winter, the base flow of the streams remains moderately high, even though most of the precipitation is stored in the form of snow. The snow melts in March and April, and runoff during these months often exceeds precipitation. The month of May usually is a transitional period of declining streamflow as rising temperatures and the demands of growing plants again become the dominant factors.

It is necessary to detect and explain variations in precipitation and streamflow because these factors are important to the production and transportation of sediment. A trend analysis of precipitation and streamflow follows.

PRECIPITATION AND RUNOFF

The double-mass-curve technique described by Searcy and Hardison (1960) was used to test for changes in the hydrologic characteristics of each basin. Figure 6 shows the double-mass relation of precipitation for the Corey Creek and Elk Run basins, and figure 7 shows the double-mass relation of runoff. These figures indicate that the relative rates of accumulation of both precipitation and runoff have been very uniform.

Further tests were made of cumulative precipitation and runoff versus time for each basin. The rates of accumulation by quarters of the 6-year period agreed within 2 percent. These tests indicated that there has been no persistent change in the time rate of precipitation or runoff in either of the basins.

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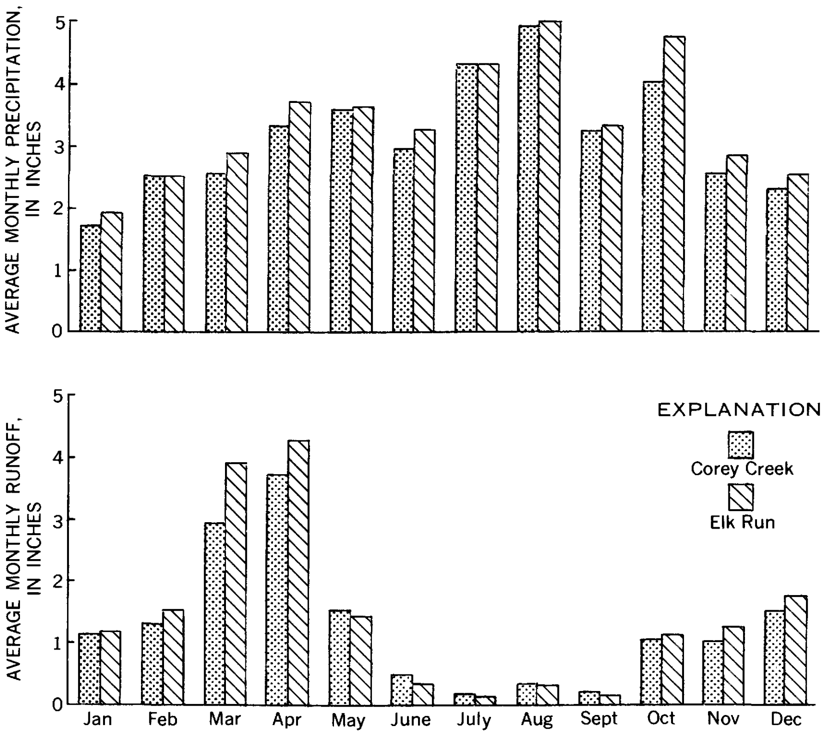

FIGURE 4.—Average monthly precipitation and runoff, Corey Creek and Elk Run basins, October 1954 to September 1960.

RUNOFF PEAKEDNESS

Runoff peakedness, as used in this report, is the ratio of the peak rate of direct water discharge to the mean direct water discharge for a given storm. High peakedness indicates a more rapid runoff from the basin, and the rapid runoff usually results in a higher suspended-sediment discharge. Most soil conservation practices are designed to decrease runoff peakedness by slowing overland runoff and extending the time required for storm water to reach the stream channel. The decrease in runoff generally increases the retention of water as soil moisture. Decreasing runoff peakedness results in lower peak stages and, therefore, less flooding.

To test whether there had been a change in runoff peakedness at Corey Creek, 70 storms were analyzed. Each storm resulted in a rainfall of one-half inch or more. The peakedness factor (P) was computed as

$$P=\frac{Q_p-Q_b}{Q_m-Q_b},$$

in which Q_p is the instantaneous peak water discharge, Q_b is base flow, and Q_m is the time-weighted mean flow for the storm period.

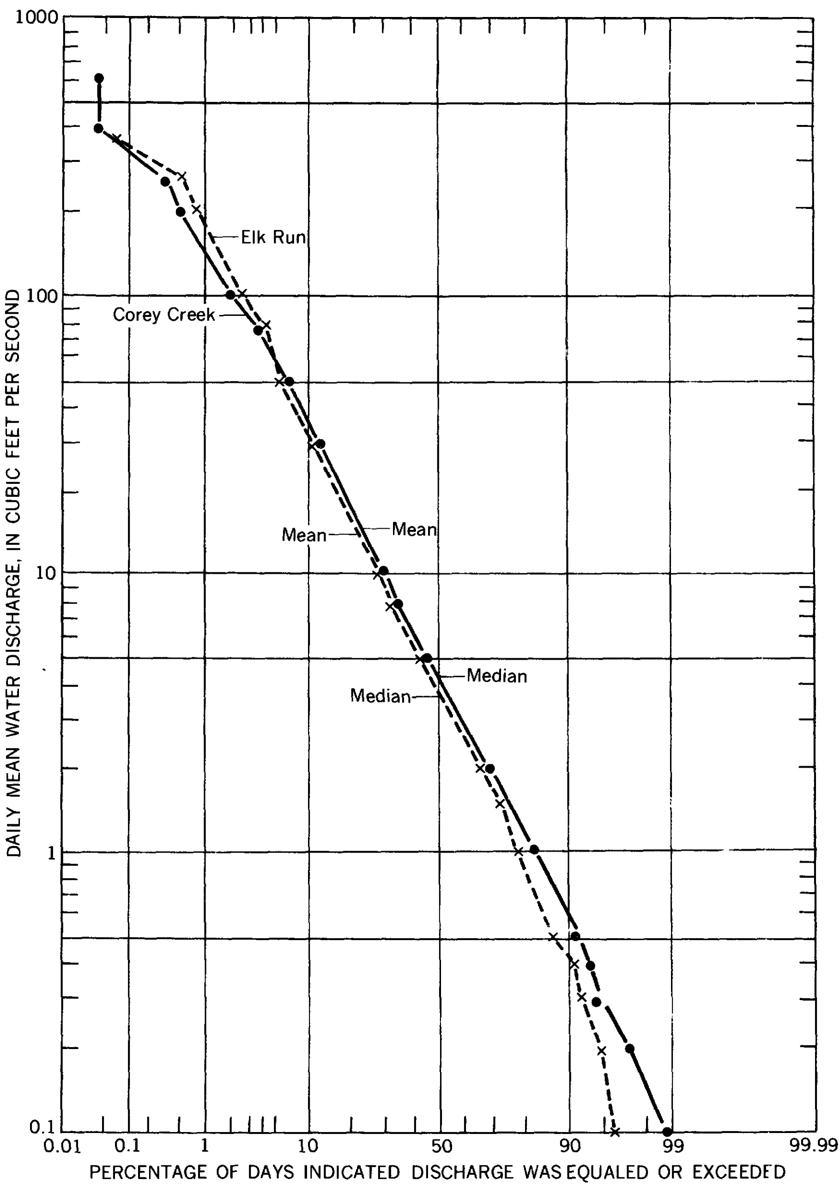

Figure 5.—Duration curves of daily mean water discharge, Corey Creek and Elk Run near Mainesburg, October 1954 to September 1960.

Two methods were used to analyze for a change in peakedness factor: first, a double-mass curve was constructed relating peakedness to mean water discharge; and second, the rank correlation method, as discussed by Guy (1957), was used to test for any change in peakedness with time.

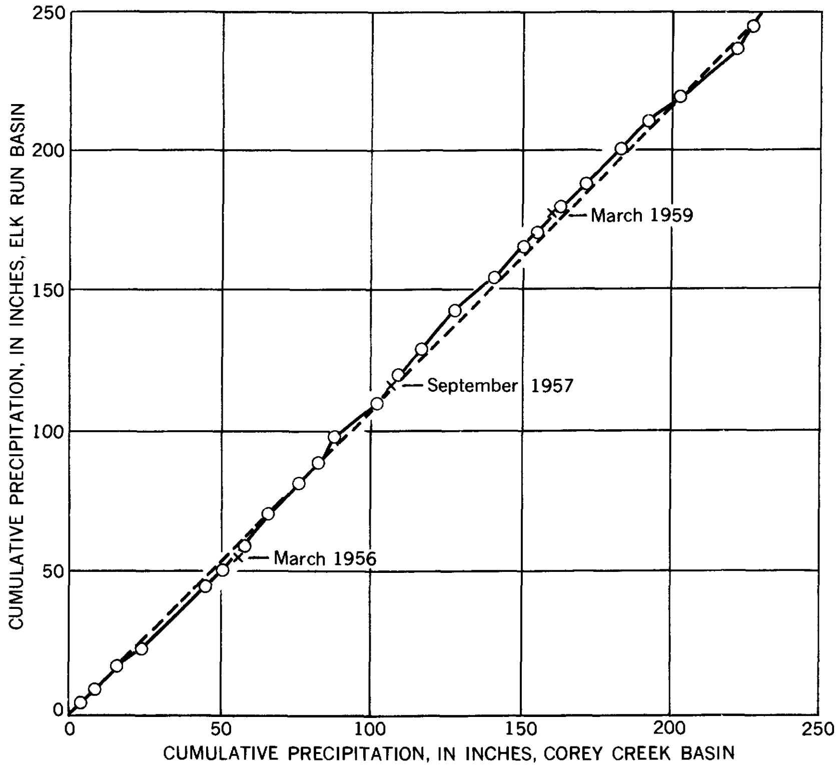

FIGURE 6.—Double-mass relation of precipitation, Corey Creek and Elk Run basins, 1954–60.

Runoff was used in the double-mass analysis because it is an independent variable with no change in trend. Figure 8 shows this double-mass curve. There are fluctuations in the rate of accumulation which probably are caused by seasonal variations in the intensity of rainfall; however, no persistent change in trend is apparent in these data.

For the rank correlation analysis, the largest peakedness factor was designated as 1, proceeding to the smallest peakedness factor, 70. These factors were then arranged in order of time sequence. The method resulted in a rank correlation coefficient (τ) of -0.15, significant at the 10 percent level, which suggests an increase rather than a decrease in peakedness with time. The 5 percent level of significant is generally considered to be the upper limit for which any degree of certainty can be ascribed to a correlation; so, evidence for increasing peakedness is not conclusive. The results do serve as strong evidence against any significant decrease in runoff peakedness.

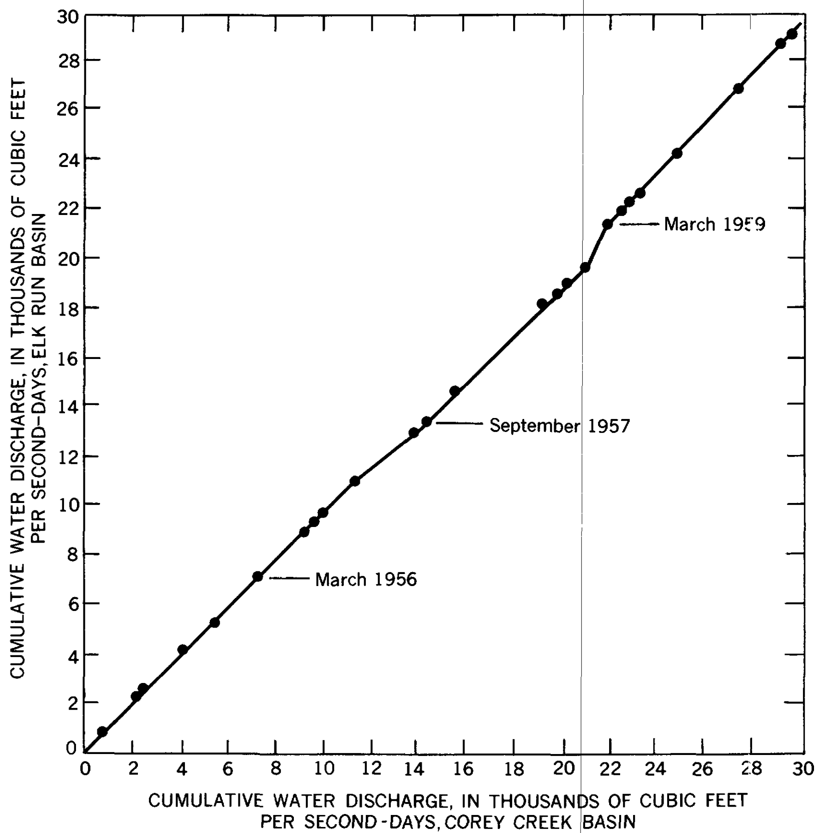

FIGURE 7.—Double-mass relation of runoff, Corey Creek and Elk Run near Mainesburg, 1954-60.

RELATION OF RUNOFF TO LAND USE AND LAND TREATMENT

Trend analyses indicated no significant change either in the quantity of runoff or in the peakedness of runoff during storm events. The practices initiated during the conservation program have affected runoff characteristics very little or else the various effects of the changes have been such as to balance one another.

The study by Schneider and Ayer (1961) showed that even in extensively reforested basins the changes in runoff characteristics take place rather gradually. Although there have been extensive land-use changes in the Corey Creek basin, nothing approaching the magnitude of a complete reforestation has been attempted. About 2 percent of the basin area was planted in trees through 1960, but even when the trees mature, they probably will have little effect on the runoff characteristics of the entire basin.

Of all the conservation practices initiated, diversion terracing might be expected to exert the greatest effect on runoff characteristics. About

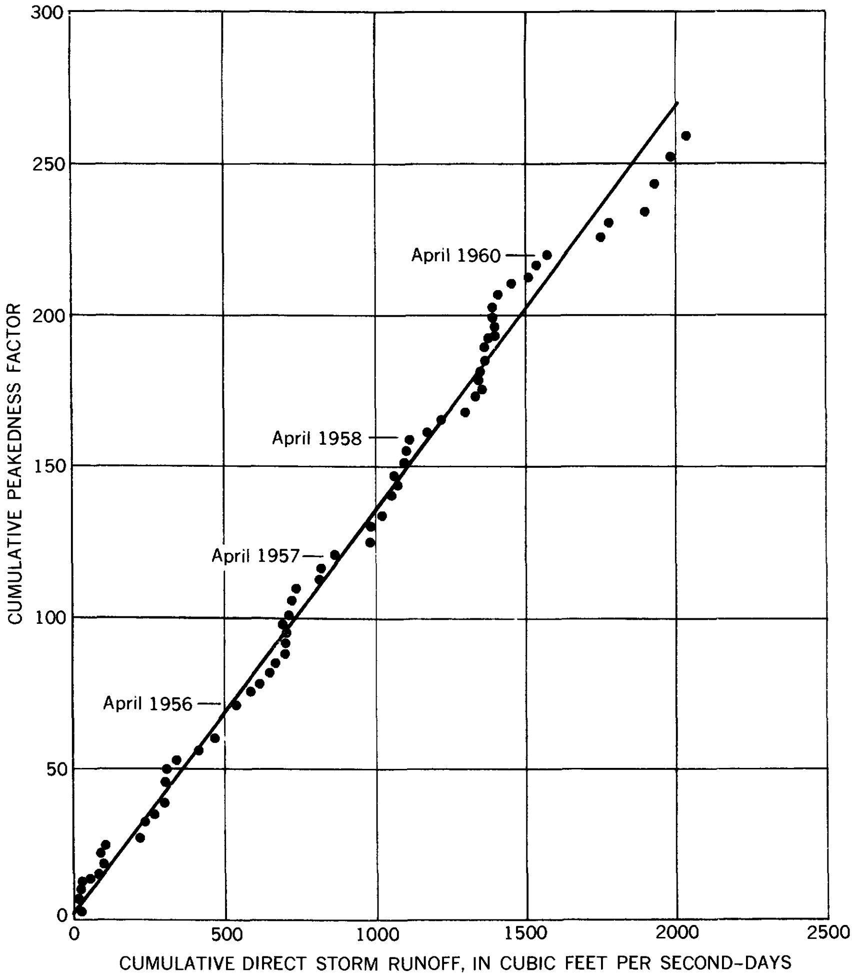

FIGURE 8.—Double-mass relation of storm runoff and peakedness factor, Corey Creek near Mainesburg, 1954–60.

19 percent of the Corey Creek basin area was affected by diversion terrace construction between 1953 and 1960. The increase in evaporation of water released to the terraces, as well as the increase in the effective permeability of the slope above the terraces, should have resulted in a reduction in streamflow, but apparently this reduction, if present, is too small to be detected.

SEDIMENTATION

When erosion removes the fertile upper layer of the soil, a valuable resource has been lost and cannot be replaced quickly or easily. If soil erosion exceeds the rate of soil formation, the result is reduction of the land's ability to support crops. In addition to the effects on the soil itself, eroded material chokes stream channels and causes flooding, fills, reservoirs, renders the stream incapable of supporting desirable animal and plant life, and reduces the usefulness of the water for industrial or domestic purposes.

SUSPENDED-SEDIMENT TRANSPORT

In this report, no attempt is made to estimate soil erosion in the basins, but instead it is assumed that any changes in erosion will alter the quantity of sediment reaching the stream and that these changes will be reflected in the measured suspended-sediment discharge.

Suspended-sediment discharge varies with changes in the factors affecting both erosion and sediment transport. It is necessary, therefore, to examine these factors before any meaningful correlations can be made between the rate of suspended-sediment discharge and the effects of conservation treatment.

ANALYSIS OF SEDIMENT-TRANSPORT VARIABLES

In most natural streams, a relation exists between water discharge and suspended-sediment discharge. This relation may be expressed as an average curve, or sediment-transport curve. This method of determining the sediment-transport relation involves plotting water discharge versus sediment discharge and drawing an average curve through the scatter of points. The general relation between sediment discharge and water discharge is

$$Q_s = aQ_w{}^m,$$

where Q_s is sediment discharge, in tons per day; Q_w is water discharge, in cubic feet per second; and a and n are constants. The equation may be adjusted for other factors which affect the relation, such as season, runoff peakedness, and rainfall intensity by using the multiple-regression technique described by Linsley, Kohler, and Paulhus (1949).

Because many of the computations used in this report were performed by a digital computer and a standard multiple-regression program, the above equation was transformed to a straight-line function by taking the logarithm of both sides

$$\log_{10} Q_s = \log_{10} a + n \log_{10} Q_w.$$

Variables, such as temperature (T), which bear a straight-line relationship to $\log_{10} Q_s$ were not transformed so that the form of the equation becomes

$$\log_{10} Q_s = \log_{10} a + n \log_{10} Q_w + bT \ldots,$$

where b is a constant.

The data analyzed by computer for this progress report were of two major types: (1) daily data collected at Corey Creek near Mainesburg, Pa., and Elk Run near Mainesburg, Pa., and (2) storm data, Corey Creek near Mainesburg, Pa., (daily sampling station), and Corey Creek at Mainesburg, Pa., (intermittent sampling station).

SEASONAL ANALYSIS OF DAILY DATA

Preliminary plotting indicated that the daily streamflow and sediment data should be classed by dormant season (November to April) and by growing season (May to October). Within these classes, the data were divided by streamflow because the sediment-transport characteristics at low flows were found to be different from those at high flows. The point at which this change occurred was at a mean daily water discharge of about 10 cfs for both stations. At flows below 10 cfs, suspended-sediment concentration varied only slightly with water discharge; at flows above 10 cfs, concentration increased rapidly with increasing water discharge. More than 99 percent of annual sediment discharge from the basins is transported by daily streamflows of 10 cfs or greater, and therefore, this part of the sediment-transport relation was used in determining trends in the amount of sediment being transported. The complete grouping of daily data was as follows:

A. Dormant season (November to April)
  1. Water discharge=0–9.9 cfs
     a. Suspended-sediment concentration
     b. Suspended-sediment discharge
  2. Water discharge=10 cfs or greater
     a. Suspended-sediment concentration
     b. Suspended-sediment discharge
B. Growing season (May to October)
  1. Water discharge=0–9.9 cfs
     a. Suspended-sediment concentration
     b. Suspended-sediment discharge
  2. Water discharge=10 cfs or greater
     a. Suspended-sediment concentration
     b. Suspended-sediment discharge.

The following variables were used in this analysis:

A. Dependent variables:
   $\text{Log}_{10}\, Q_s$=logarithm of daily suspended-sediment discharge, in tons per day
   $\text{Log}_{10}\, C$=logarithm of mean daily concentration of suspended sediment, in parts per million
B. Independent variables:
   M=month of observation (1–12)
   Y=year of observation (1954–60)
   i=a measure of time duration, in days, since the beginning of record (first day of record=1)
   $\text{Log}_{10}\, Q_w$=logarithm of mean daily water discharge, in cubic feet per second

$\text{Log}_{10}\, Q_{wp}$=logarithm of mean water discharge on the day previous to the one being measured (a measure of antecedent streamflow conditions), in cubic feet per second

T=daily water temperature, in degrees Fahrenheit.

In the first computations, all the independent variables were used in the equation. The least significant independent variable was eliminated in each successive computation. These eliminations were continued until sediment discharge or concentration was shown only as functions of the most significant independent variable.

Figure 9 shows the average sediment-transport curves for streamflows of 10 cfs or greater. The curves have somewhat steeper slopes for the dormant season than for the growing season. The slopes of both curves for the Elk Run basin are steeper than the slopes of the Corey Creek curves, indicating a higher rate of sediment discharge per unit water discharge in Elk Run.

The equations that can be used to estimate sediment concentration or sediment discharge with the smallest degree of error are the most efficient. Table 4 gives the most efficient equations for water discharges of 10 cfs and greater and the standard error of estimate of the dependent variable for each equation.

TABLE 4.—*Most efficient regression equations for daily suspended-sediment concentration and discharge for water discharges of 10 cfs or greater*

Season	Standard error ($\log_{10}$ units)	Equation
Corey Creek near Mainesburg		
Growing	0.5564	$\text{Log}_{10} Q_s = 2.306 \log_{10} Q_w + 0.01957T - 0.4991 \log_{10} Q_{wp} - 3.830.$
	.4630	$\text{Log}_{10} C = 1.216 \log_{10} Q_w + 0.01252T - 0.4531 \log_{10} Q_{wp} - 0.04810Y + 1.896.$
Dormant	.4750	$\text{Log}_{10} Q_s = 2.441 \log_{10} Q_w - 0.3188 \log_{10} Q_{wp} - 0.0002862i - 0.02405M - 0.0114T - 2.110.$
	.4047	$\text{Log}_{10} C = 1.523 \log_{10} Q_w - 0.3350 \log_{10} Q_{wp} - 0.02512M - 0.01333T - 0.0003119i + 0.4130.$
Elk Run near Mainesburg		
Growing	0.4512	$\text{Log}_{10} Q_s = 2.526 \log_{10} Q_w + 0.01692T - 0.4700 \log_{10} Q_{wp} - 3.992.$
	.3536	$\text{Log}_{10} C = 1.539 \log_{10} Q_w + 0.01244T - 0.4220 \log_{10} Q_{wp} + 0.2974Y - 0.0008764i - 17.17.$
Dormant	.4304	$\text{Log}_{10} Q_s = 2.601 \log_{10} Q_w - 0.4186 \log_{10} Q_{wp} - 0.01105M - 0.03088Y - 1.326.$
	.3883	$\text{Log}_{10} C = 1.654 \log_{10} Q_w - 0.3786 \log_{10} Q_{wp} - 0.04670Y - 0.01484M + 1.965.$

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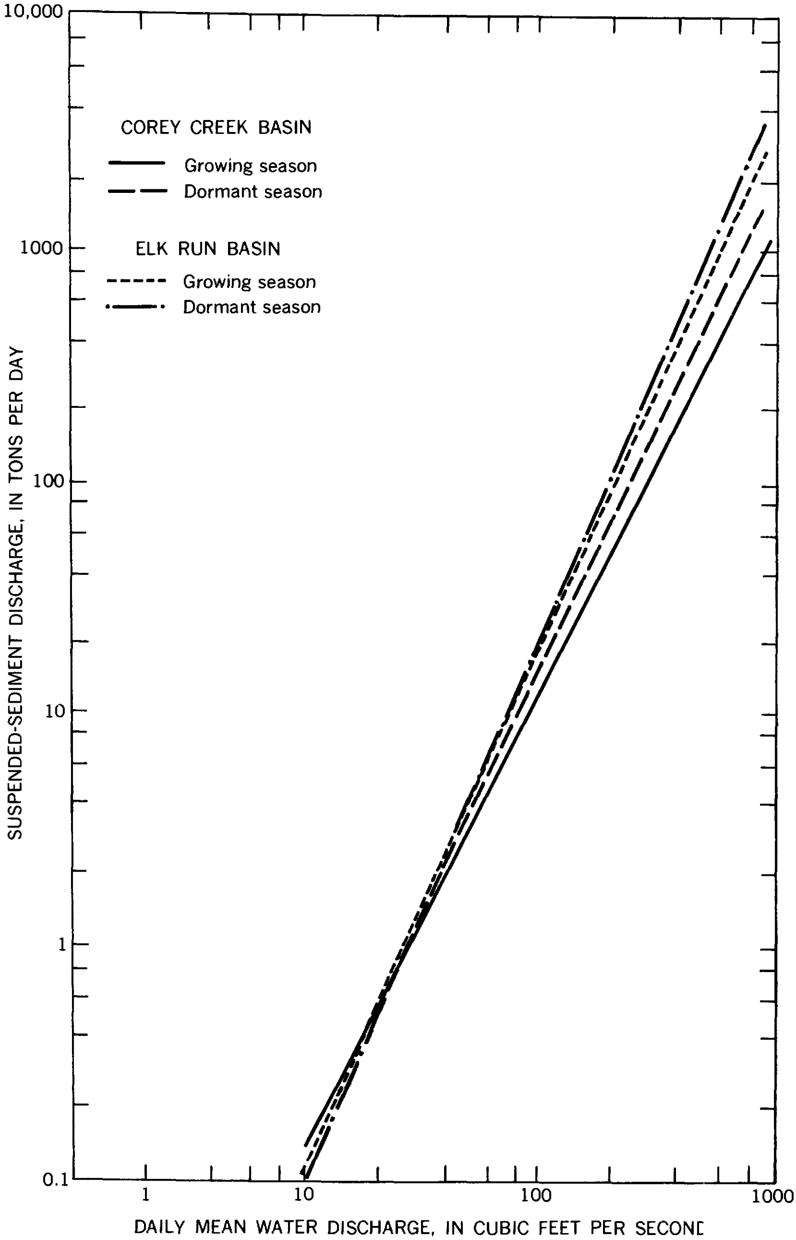

FIGURE 9.—Seasonal suspended-sediment-transport curves, Corey Creek and Elk Run near Mainesburg, May 1954 to September 1960.

The independent variables having the highest degree of correlation with the dependent variables are water discharge and the previous day's water discharge. During the growing season, the daily water temperature shows a high degree of correlation, but it is less significant during the dormant season. The measures of time, duration, and season (i, M, and Y) exhibit varying degrees of significance.

Table 5 lists the simple correlation coefficients of all the variables and the level of significance of each.

TABLE 5.—*Simple correlation coefficients and level of significance for daily water discharge of 10 cfs or greater, 1954–60*

	i	$Log_{10}Q_{wp}$	T	$Log_{10}Q_s$	$Log_{10}C$	$Log_{10}Q_w$	Y
COREY CREEK NEAR MAINESBURG							
Growing season							
M	[1]−0.2145	[2]−0.1427	[2]0.1414	[2]0.1659	[2]0.1934	0.09036	[1]−0.2911
Y	[1].9968	[3].06951	[1]−.3606	.01381	−.03971	[2].1556	
$Log_{10}Q_w$	[2].1639	[1].2893	[1]−.2089	[1].7108	[1].3274		
$Log_{10}C$	−.02498	[1]−.3150	[4].1382	[1].6849			
$Log_{10}Q_s$	.02691	[4]−.1099	[4].1089				
T	[1]−.3548	[1]−.3734					
$Log_{10}Q_{wp}$	.05831						
Dormant season							
M	[3]−0.03077	0.006457	[1]0.1450	[1]−0.1063	[4]−0.05871	0.002464	[1]−0.2280
Y	[1].9785	.05527	[1]−.1902	−.05230	[1]−.1362	[2].1047	
$Log_{10}Q_w$	[1].1061	[1].5189	[1].1374	[1].8142	[1].3919		
$Log_{10}C$	[1]−.1544	[1].2026	[2].1028	[1].5397			
$Log_{10}Q_s$	[2]−.07691	[1].3156	.03649				
T	[1]−.1657	[1].1799					
$Log_{10}Q_{wp}$	.05525						
ELK RUN NEAR MAINESBURG							
Growing season							
M	[1]−0.2012	−0.09604	[2]0.1950	[2]0.1802	[1]0.2367	[4]0.1331	[1]−0.2726
Y	[1].9972	[4].1192	[1]−.4017	−0.02073	.0009311	.09970	
$Log_{10}Q_w$	[3].1101	[1].2917	[1]−.2039	[1].8024	[1].5987		
$Log_{10}C$	.01864	[1]−.2042	[2].1515	[1].9028			
$Log_{10}Q_s$	−.008495	−.04686	.06657				
T	[1]−.3920	[1]−.3157					
$Log_{10}Q_{wp}$	[4].1137						
Dormant season							
M	[1]−0.1424	−0.02879	[1]0.1574	−0.05645	−0.007384	−0.03485	[1]−0.3461
Y	[1].9777	[1].1229	[2]−.1093	[1].1394	[2].08864	[1].2009	
$Log_{10}Q_w$	[1].2003	[1].5007	−.005353	[1].8781	[1].6785		
$Log_{10}C$	[2].09110	[1].2356	.05832	[1].8390			
$Log_{10}Q_s$	[1].1320	[1].3002	−.007093				
T	[4]−.07878	.02295					
$Log_{10}Q_{wp}$	[1].1185						

[1] Significant at 0.01 level.
[2] Significant at 0.05 level.
[3] Absence of a qualifying note indicates level of significance at greater than 0.10.
[4] Significant at 0.10 level.

ANALYSIS OF STORM DATA FOR COREY CREEK BASIN

The sediment sampling program at the upstream, or intermittent, locations in Corey Creek basin was designed to provide coverage of the major storm events. The multiple-regression technique was used to analyze hydrologic data collected during these storm events. The analyses were performed on data representing 21 storm events sampled at the daily station, Corey Creek near Mainesburg, Pa., (drainage area, 12.2 sq mi) and at the largest intermittent station, Corey Creek at Mainesburg, Pa. (drainage area, 8.44 sq mi).

The following variables were used in this analysis:

A. Dependent variables:

$\mathrm{Log}_{10} C_w =$ / $\mathrm{Log}_{10} C_{w_1} =$ } logarithm of mean water-weight sediment concentration for daily and intermittent stations, respectively, computed as

$$C_w = \frac{Q_s}{Q_{w_t} K}, \text{ where}$$

Q_s = storm sediment load, in tons,

Q_{w_t} = total storm runoff, in cubic feet per second-days,

K = a constant which varies with the length of the storm.

B. Independent variables:

M_t = time, in months (January 1954 = 1)

$\mathrm{Log}_{10}\ Q_{wd} =$ / $\mathrm{Log}_{10}\ Q_{wd_1} =$ } logarithm of direct storm runoff ($Q_m - Q_b$) for daily and intermittent stations, respectively, in cubic feet per second-days

T_{a_1} = mean air temperature (°F) for 10 days previous to storm

T_{a_2} = mean air temperature (°F) for 30 days previous to storm (data from U.S. Weather Bureau Wellsboro, Pa., station)

$\mathrm{Log}_{10}\ R_q$ = logarithm of rainfall quantity during storm period, in inches

$\mathrm{Log}_{10}\ R_i$ = logarithm of rainfall intensity for the most intense period of the storm, in inches per hour

P and P_1 = peakedness factor for daily and intermittent stations, respectively, defined as

$$\frac{Q_p - Q_b}{Q_m - Q_b}, \text{ where}$$

Q_m = time-weighted mean storm runoff, in cubic feet per second

Q_b = base flow, in cubic feet per second

Q_p = instantaneous peak runoff, in cubic feet per second.

Suspended-sediment concentration, rather than discharge, was used because the length of storms varied. Water-weighted sediment concentration provided a more direct comparison, regardless of storm duration. The number of the month in which the storm occurred was used to indicate time duration since the beginning of the record.

Because air temperature is related to season and thus to storm characteristics, a test was devised to determine if the temperature conditions prior to a storm runoff were significant. Two periods of antecedent air temperature were considered to determine if the temperature conditions for a specific period prior to a storm were significant to the storm characteristics. Both measures of antecedent temperature conditions were about equally significant, indicating that temperature is probably largely a measure of season. After the initial computations, only T_{a_1} was retained for the remaining computations.

The most efficient equations are shown in the following table:

Station	Standard error ($\log_{10}$ units)	Equation
Corey Creek near Mainesburg.	0.3883	$\text{Log}_{10}\, C_w = 0.5129 \log_{10} Q_{wd} + 0.00701 T_{a_1} + 0.8542$
Corey Creek at Mainesburg.	.3699	$\text{Log}_{10}\, C_{w_1} = 0.3197 \log_{10} Q_{wd_1} - 0.008204 M_t + 0.9574 \log_{10}(100 R_q) + 0.1017 P_1 + 0.5439$

Direct storm runoff was the most important variable affecting suspended-sediment concentration at both stations. At the upstream station, the month in which a storm occurred seemed to be more significant than the antecedent air temperature, which was the significant seasonal variable at the downstream station. The retention of runoff peakedness and rainfall quantity as significant variables in the equation for the upstream location may be a reflection of the less complex drainage system of the smaller area, which causes a more direct response to precipitation. There was a wider variation in runoff peakedness at the upstream location, and the average peakedness factor was 4.3, compared with an average of 3.5 at the downstream (daily) station.

The simple correlation coefficients between all variables and the levels of significance are shown in table 6.

SIZE DISTRIBUTION OF SUSPENDED SEDIMENT

Size distribution of the suspended sediment was an important characteristic measured during the study. The proportion of sand, silt, and clay being carried by the stream gives some indication of the

TABLE 6.—*Simple correlation coefficients and level of significance for storm data, Corey Creek near Mainesburg and Corey Creek at Mainesburg, 1954–60*

	P_1	$Log_{10} Q_{wd_1}$	$Log_{10} C_{w_1}$	P	$Log_{10} (100R_q)$	$Log_{10} (100R_i)$	T_{a_2}	T_{a_1}	M_t	$Log_{10} Q_{wd}$
$Log_{10} C_w$	[1]−0.0008376	[2]0.5963	[3]0.4524	0.1822	0.3469	0.2173	−0.1886	−0.1391	0.2464	[2]0.5681
$Log_{10} Q_{wd}$	−.2434	[2].9311	[4].3921	−.03131	[4].3713	−.003887	[2]−.5878	[2]−.5625	.06269	
M_t	.1068	−.08262	−.1682	.08567	.05005	.2625	−.02669	−.04828		
T_{a_1}	.3245	[3]−.4571	.1641	.2218	.2792	[4].3930	[2].9563			
T_{a_2}	.2869	[2]−.4695	.1305	.2142	.3131	[3].4340				
$Log_{10} (100R_i)$	.1719	.03321	[3].4684	[4].4214	[2].5510					
$Log_{10} (100R_q)$	.03058	[4].3951	[2].6881	.1569						
P	[2].8126	−.07281	[3].4501							
$Log_{10} C_{w_1}$	.2718	[4].4129								
$Log_{10} Q_{wd_1}$	−.3262									

[1] Absence of a qualifying rate indicates significance at a level greater than 0.10.
[2] Significant at 0.01 level.
[3] Significant at 0.05 level.
[4] Significant at 0.10 level.

type of soil being eroded. Significant changes in these proportions might also be indicative of changing basin conditions. Figure 10 shows the proportion of sand, silt, and clay as percent of the total weight in suspended-sediment samples from the two basins. Most of these samples contain more than 50 percent silt. The shaded area in figure 10 indicates the silt loam soil texture, which is the predominant textural class in the Corey Creek and Elk Run basins. More than three-fourths of the suspended-sediment size analyzes correspond to this soil class.

Differences between the two basins seem to be the relative content of sand and clay. Suspended sediment from Corey Creek basin has a higher clay content, and suspended sediment from Elk Run has a higher sand content; however, there is enough similarity in the particle-size composition so that some general relation can be formulated by combining the analyses from the two basins.

The water discharges represented by the data points in figure 10 were relatively high and were at least 10 times the mean water discharge. Although streamflow of this magnitude or larger occurs only about 2 percent of the time, 70 percent or more of the annual sediment discharge occurs during these high flow periods. Figure 11 shows the

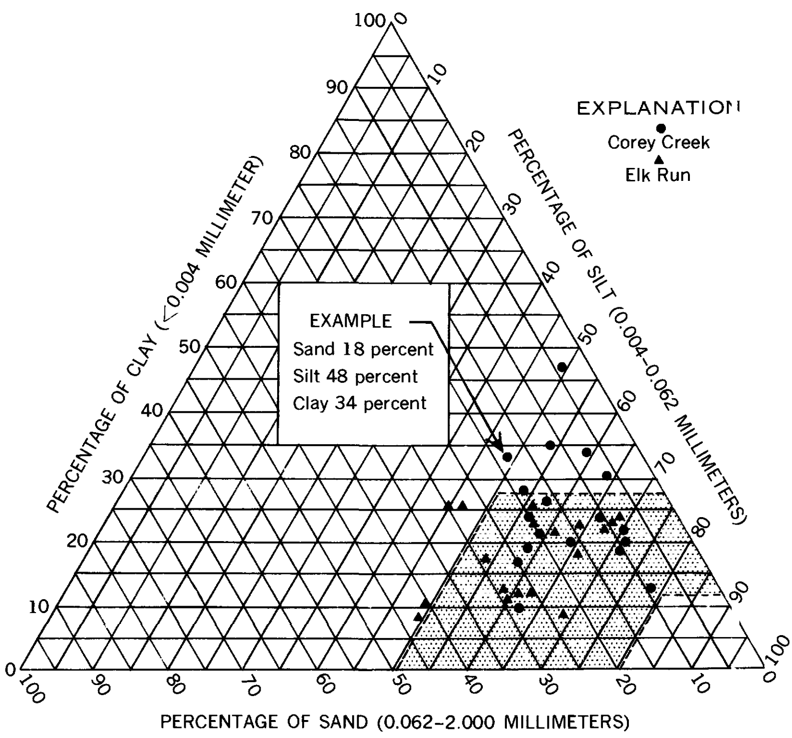

FIGURE 10.—Percentages of sand, silt, and clay in suspended-sediment samples, Corey Creek and Elk Run near Mainesburg, 1955–60. Shaded area indicates silt loam soil texture.

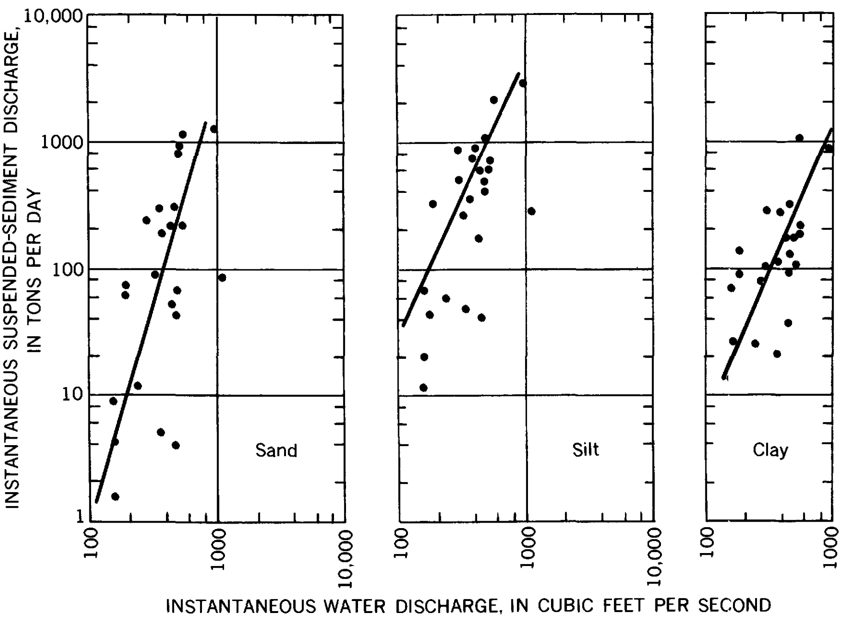

FIGURE 11.—Relation of the sand, silt, and clay discharge to instantaneous water discharge for Corey Creek and Elk Run near Mainesburg, 1955–60.

relationship between suspended-sediment discharge and water discharge for each size range. The discharge of sand increases more rapidly with water discharge than does the discharge of either silt or clay.

The steeper slope of the sediment-transport curve of sand may be caused by the immediate availability of sand-size sediment in the stream channel or may result because sand is deposited near the stream channel during the smaller runoff events.

STREAM-CHANNEL CHANGES

Generally, the aggradation-degradation ranges in Corey Creek show a tendency toward deposition of sediment throughout the period of this study. Of the 14 ranges surveyed, 10 were filling and 4 were scouring.

Most changes have taken place in the streambanks by addition or removal of material of sand size or finer. Undercutting and slumping of streambanks are commonly observed in both basins. Changes in bed elevation generally have been very slight, and, in those places where the bed elevation has changed, the change usually has been a result of filling rather than scouring.

In Elk Run, changes at the cross sections were almost evenly divided between scour and fill. Table 7 summarizes the results of the surveys for both basins. The locations of the ranges are shown in figure 1. Range 5 in Elk Run basin is on an actively migrating meander and, therefore, represents a type of channel regimen different from that at the other ranges.

The distribution of changes in the cross sections is indicated in figure 12.

In both stream channels, the bed is composed mostly of material that is gravel size (2.0–64 mm) or larger (fig. 13). The range data indicate that there has been very little redistribution of this material within the measured cross sections.

Figure 14 shows the relationship between the average annual scouring or filling and the slope of the stream channel at each range. Ranges on slopes of greater than 70 feet per mile in either basin

TABLE 7.—*Changes in cross-sectional area of aggradation-degradation ranges, 1954–60*

Range	Scour (sq ft)		Fill (sq ft)	
	Net change	Average annual change	Net change	Average annual change
Corey Creek				
1	5.29	0.88		
3			12.50	2.08
4			7.26	1.21
5			20.47	3.41
7			39.55	6.59
8			9.22	1.54
9			4.96	.83
11			55.67	9.28
13			9.98	1.66
14	8.40	1.40		
15	.54	.09		
16	.15	.02		
18			2.04	.34
19			4.11	.68
Elk Run				
1			8.33	1.39
3			2.16	.36
4			4.53	.91
5	79.86	13.31		
6			8.37	2.09
7			3.73	.62
8	1.77	.30		
9	2.28	.38		
10	4.14	1.03		
12	3.84	.64		
13			8.06	1.54

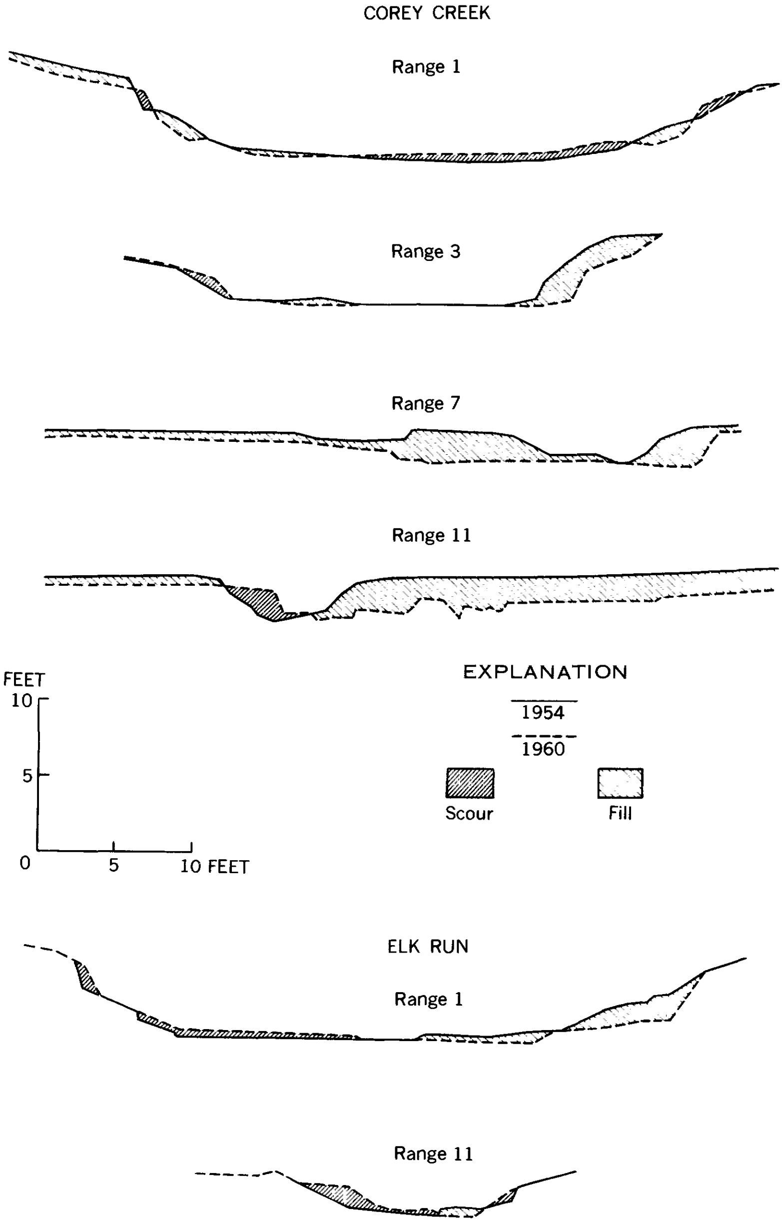

Figure 12.—Changes in stream cross sections at selected ranges in the Corey Creek and Elk Run basins, 1954–60. Location of ranges is shown in figure 1.

FIGURE 13.—Elk Run, showing bed material typical of both stream channels. Note undercutting of trees on right bank.

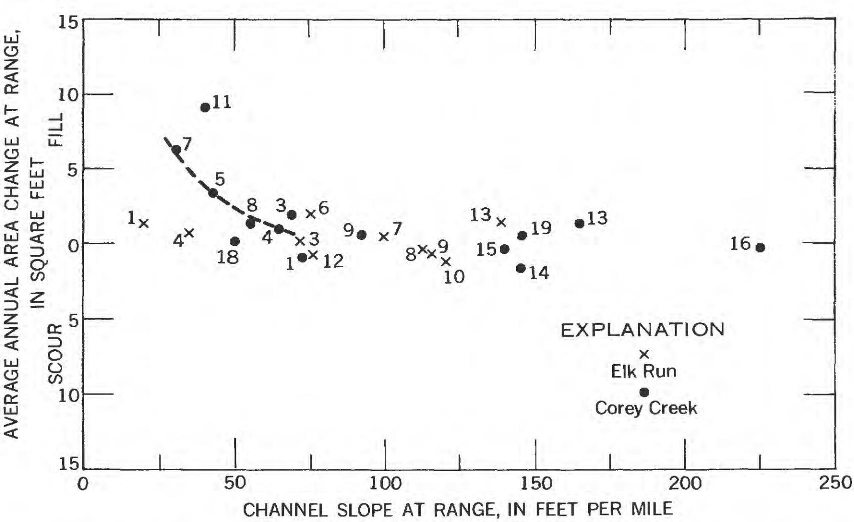

FIGURE 14.—Relation between average annual scouring or filling and stream slope at Corey Creek and Elk Run aggradation-degradation ranges, 1954–60.

showed an average annual scour or fill of less than 2.5 square feet. Filling of the stream channels occurred where the slope was 70 feet per mile or less. At such locations, the amount of filling was greater in Corey Creek than in Elk Run.

SUBBASIN SEDIMENT YIELDS FOR COREY CREEK BASIN

The average annual suspended-sediment discharges from the major Corey Creek subbasins were computed by using data from the upstream sampling stations. This computation was made to determine the variations in the sediment-transport characteristics within the basin.

Two methods were used for the computations. In the first method, double-mass curves were constructed comparing sediment discharge for individual storms at the downstream station with that at each upstream station (fig. 15). The average slope of this double-mass curve was taken as the proportion of the basin sediment discharge being contributed by each subbasin.

In the second method, the sediment discharge for individual storms at each intermittent station was related to the daily station sediment discharge for the same storm. The average relation (fig. 16) then was used with a cumulative frequency curve of sediment discharge (fig. 17) to compute an average annual sediment discharge.

Table 8 shows this second method of calculation. Percentage intervals were selected from figure 17, and the sediment discharges corresponding to the midordinate of the percentage intervals were tabulated. The corresponding values of sediment discharge for the intermittent stations were then read from the curves in figure 16 and tabulated. Each of these was then multiplied by the percentage interval and the sum of the products was the mean daily sediment discharge, which was multiplied by 365 to obtain the annual sediment discharge.

Table 9 compares the suspended-sediment discharges computed by the two methods. Results agree within a few percent. The computed sediment discharge from the remainder of the basin is the difference between the measured basin discharge and the sum of the computed subbasin discharges. This remaining part of the basin includes most of the urban land and has the highest proportion of cropland and the lowest proportion of woodland. In view of these facts, the relatively high computed yield is not unrealistic, as will be demonstrated in the discussion of land-use effects.

Data from the third intermittent sampling station (South Branch Corey Creek at Mainesburg) were not used in this evaluation, but the drainage area for this sampling station is included in the area of the largest intermittent station (Corey Creek at Mainesburg).

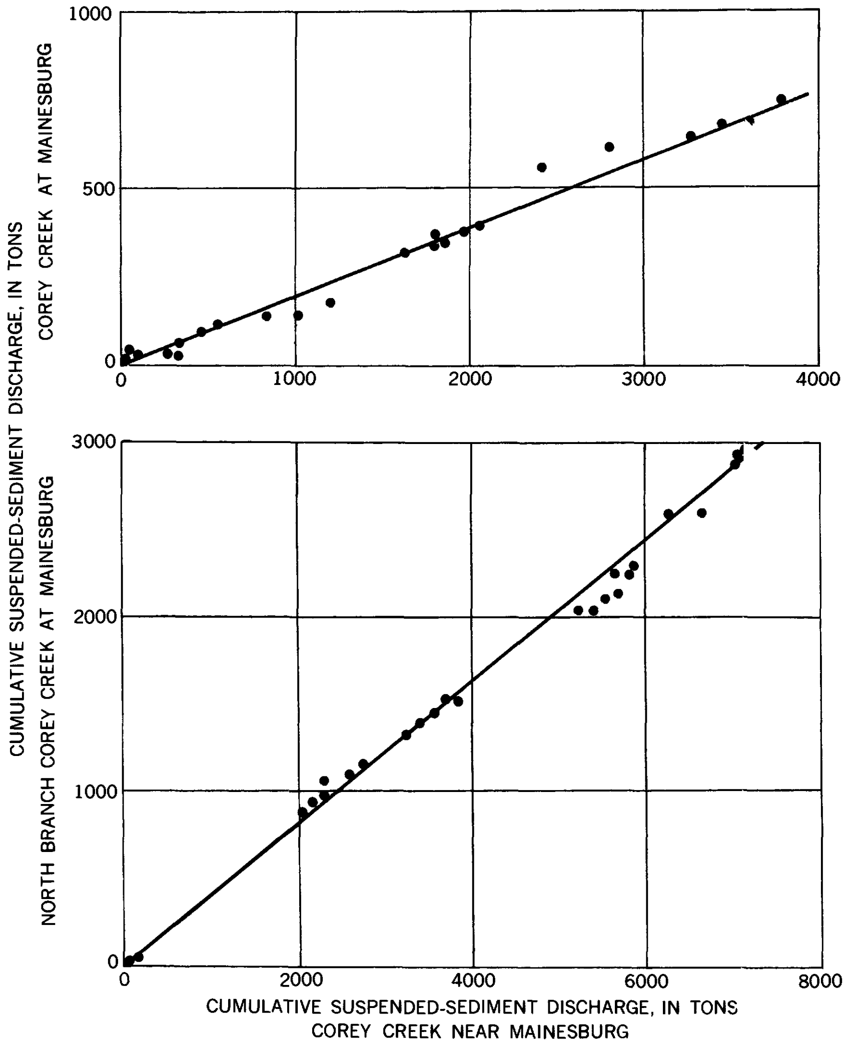

FIGURE 15.—Double-mass comparisons of storm suspended-sediment discharges from the Corey Creek basin with storm suspended-sediment discharges from the Corey Creek subbasins.

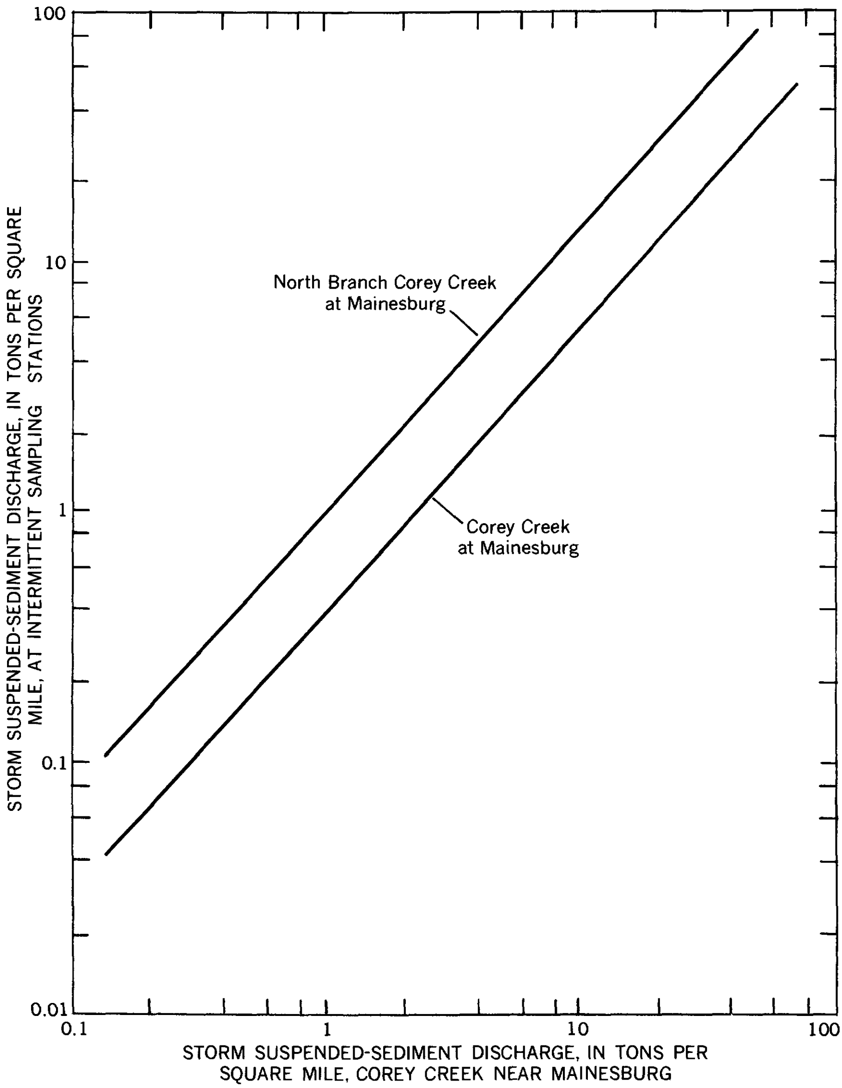

FIGURE 16.—Relation between storm suspended-sediment loads for daily station and intermittent stations, Corey Creek basin, 1954–60.

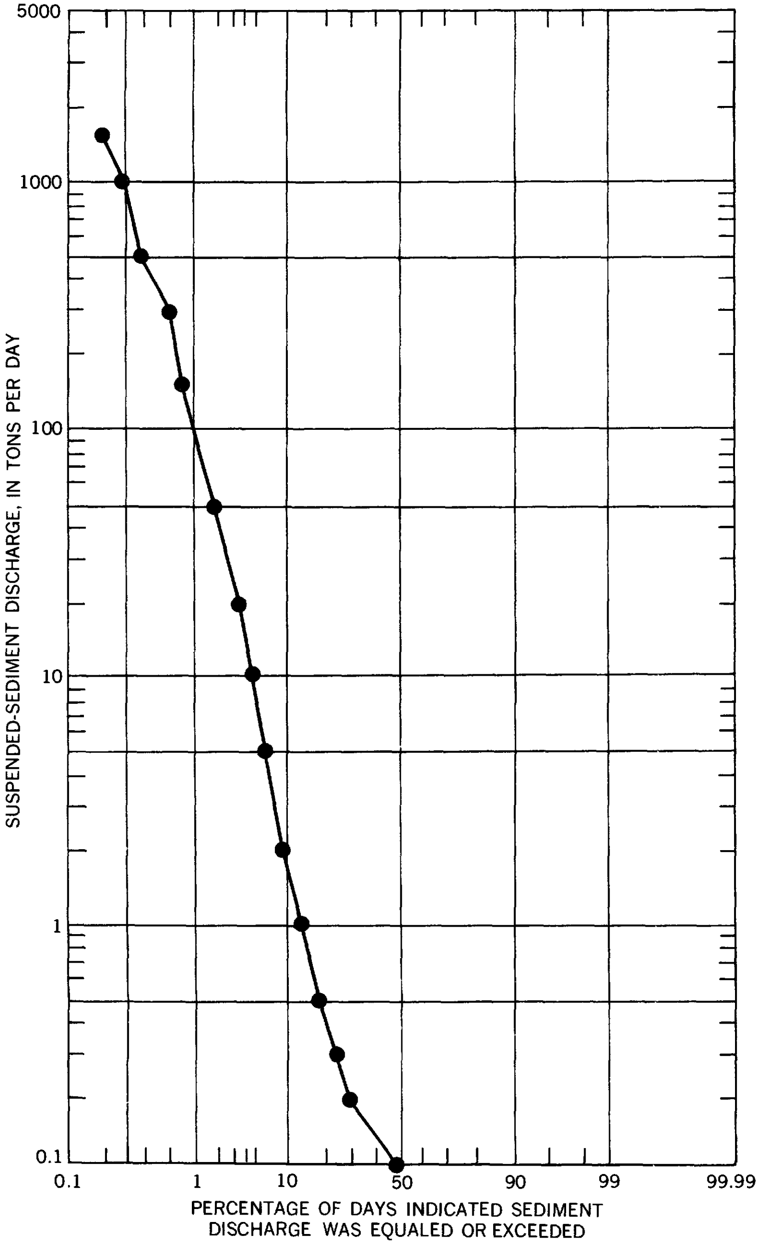

FIGURE 17.—Cumulative frequency curve of daily suspended-sediment discharge, Corey Creek near Mainesburg, October 1954 to September 1960.

TABLE 8.—*Computation of average annual suspended-sediment discharges, Corey Creek near Mainesburg, Corey Creek at Mainesburg, and North Branch Corey Creek at Mainesburg, 1954–60*

Percentage limits	Percentage interval	Percentage midordinate	Suspended-sediment discharge (tons per day)			Suspended-sediment discharge (tons per day) times percentage interval		
			Corey Creek near Mainesburg	Corey Creek at Mainesburg	North Branch Corey Creek at Mainesburg	Corey Creek near Mainesburg	Corey Creek at Mainesburg	North Branch Corey Creek at Mainesburg
0.0–0.1	0. 1	0. 05	1, 450	710	345	1. 45	0. 71	0. 34
0.1–0.2	. 1	. 15	740	330	165	. 74	. 33	. 16
0.2–0.3	. 1	. 25	430	180	90	. 43	. 18	. 09
0.3–0.5	. 2	. 4	330	135	70	. 66	. 27	. 14
0.5–0.7	. 2	. 6	200	77	41	. 40	. 15	. 08
0.7–1.0	. 3	. 85	130	48	26	. 39	. 14	. 08
1.0–3	2. 0	2	44	14	8	. 88	. 28	. 16
3–5	2. 0	4	14	5. 5	2. 4	. 28	. 11	. 05
5–7	2. 0	6	6. 4	1. 2	1. 0	. 13	. 02	. 02
7–10	3. 0	8. 5	2. 7	. 6	. 4	. 08	. 02	. 01
10–15	5. 0	12. 5	1. 1	. 2	. 2	. 05	. 01	. 01
15–20	5. 0	17. 5	. 5			. 02		
20–30	10	25	. 3			. 03		
30–40	10	35	. 2			. 02		
40–50	10	45	. 1			. 01		
Mean daily discharge tons						5. 57	2. 22	1. 14
Mean annual discharge (daily ×365) tons						2, 030	806	416

TABLE 9.—*Comparison of average annual suspended-sediment discharges from subbasins within Corey Creek basin, as computed by two methods, 1954–60*

Station	Drainage area (sq mi)	Mean annual suspended-sediment discharge (tons)		Mean annual suspended-sediment discharge (tons per sq mi)	
		Double-mass-curve method	Suspended-sediment duration-curve method	Double-mass-curve method	Suspended-sediment duration-curve method
Corey Creek near Mainesburg	12. 2	----------	1, 990	----------	163
Corey Creek at Mainesburg	8. 44	800	810	95	96
North Branch Corey Creek at Mainesburg	2. 13	400	420	188	197
Remainder of basin (by difference)	1. 63	790	760	475	466

TRENDS IN SEDIMENT DISCHARGE

Data collection for this study was not initiated until after the beginning of the construction phase of the conservation program in Corey Creek basin. As will be shown, the soil disturbed during the construction phase of the program undoubtedly affected the rate of suspended-sediment discharge; thus, no data are available to allow a precise determination of the rate of sediment discharge in Corey Creek basin during a period of normal activity.

Compared to Corey Creek basin, Elk Run basin has received relatively little conservation treatment. Suspended-sediment data from Elk Run provide the best available estimate of the sediment-discharge rate under relatively undisturbed conditions. In the following trend analyses the Elk Run data used as a base against the Corey Creek data were evaluated.

Double-mass curves were constructed to detect any change in the rate of suspended-sediment discharge from the two basins. Figure 18 is a double-mass comparison of suspended-sediment discharge from both basins. The curve shows that definite changes occurred in the relationship in December 1956 and again in December 1958. Comparison of the first and last parts of the curve indicates a relative decrease of about 11 percent from the Corey Creek basin but a temporary sharp increase during the middle period.

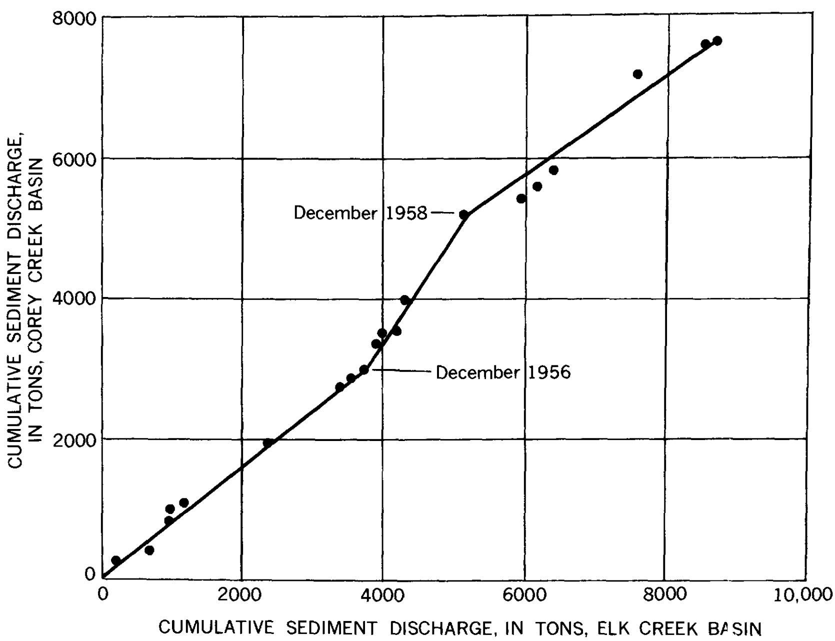

FIGURE 18.—Double-mass comparison of suspended-sediment discharge for Corey Creek and Elk Run near Mainesburg, October 1954 to September 1960.

To investigate seasonal distribution of the trends, double-mass curves were constructed for the growing season (May to October) and the dormant season (November to April).

Data for October 1955 were eliminated because the sediment discharge for that month was abnormally high at both stations and amounted to a significant proportion of the total sediment discharge for the period of record. Data for April 1957 were eliminated from the dormant season curve for the same reason.

The curves in figure 19 compare the rates of sediment discharge from the two basins by season. The dormant season curve shows no significant long-term change in the relation.

The double-mass curve for the growing season indicates three distinct periods in the relative rate of sediment discharge from the two basins:

	Average slope of double-mass curve (percent)
May 1954 to May 1955	83
June 1955 to May 1958	200
June 1958 to September 1960	41

Comparison of the slope of the curve for the May 1954 to May 1955 period with the slope for the June 1958 to September 1960 period indicates a relative decrease of 51 percent in sediment discharge from the Corey Creek basin. Approximately 25 percent of the total suspended-sediment discharge from the Corey Creek basin occurred during the growing season. The maximum possible contribution of the growing season trend in sediment discharge was, therefore, 13 percent, which was more than sufficient to have produced the previously indicated overall trend of 11 percent. This fact, along with the fact that no significant trend was indicated in the double-mass relation for the dormant season, serves as strong evidence that the significant changes in suspended-sediment discharge have occurred during the growing season.

RELATION OF SEDIMENTATION TO LAND USE AND LAND TREATMENT

The trend analyses of sediment discharge indicated a significant decrease in the suspended-sediment discharge from Corey Creek basin during the growing season. It was necessary to use statistical techniques in relating this decrease to the agronomic changes which have taken place in the basin. The techniques used were rank correlation and least-squares regression. Both these techniques required a numerical evaluation of the effects of changing land use and agronomic practices.

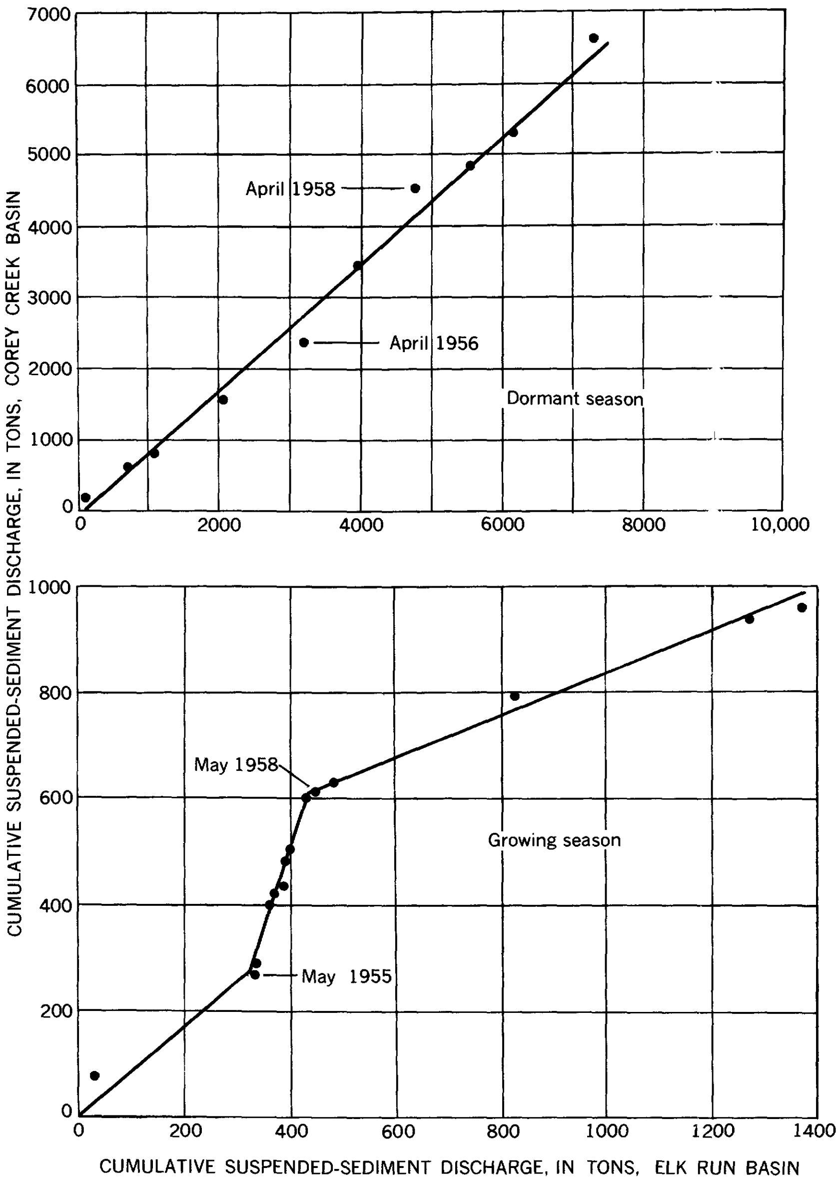

FIGURE 19.—Double-mass comparisons of monthly sediment discharge for growing and dormant seasons, Corey Creek near Mainesburg versus Elk Run near Mainesburg, May 1954 to September 1960.

The changes taking place in the basins are of two general kinds: changes in the type and density of vegetative cover, and changes in the physical or topographic characteristics of the land.

Land-use changes are considered first. Because each of these changes affects the erosion potential of the basins to a different degree, it was necessary to evaluate their combined effects. To estimate the relative erosion under different cover conditions, relative erosion factors were assigned for different types of cover:

	Factor
Woodland	1
Idle land	2
Grassland	6
Urban land	50
Cropland	100

The numbers assigned to the various land-use categories are dimensionless. The values are based on the cover factors used by Musgrave (1947) for computing erosion losses. The values indicate that urban land, for example, has 50 times the erosion potential of woodland.

The relative erosion potential for each type of cover can be computed with the formula

$$E_R = F_e \times \frac{P}{100},$$

where E_R is the relative erosion potential, F_e is the relative erosion factor, and P is the percent of the basin area in a specific type of cover. The summation of erosion potentials for all types of hydrologic cover is then the relative erosion potential for the whole basin.

The annual relative erosion potentials computed for each basin are as follows:

	Relative erosion potential	
Year	*Corey Creek basin*	*Elk Run basin*
1954	34.1	38.5
1955	34.0	38.5
1956	33.8	38.5
1957	33.5	38.8
1958	32.5	38.8
1959	29.2	38.8
1960	29.8	38.5

These figures represent the relative degree of erosion that theoretically would occur if the forces causing erosion were constant with time; however, these forces are seldom, if ever, constant. The sediment discharge of a stream at any given time can be related to the erosion potential of the basin only if the proper adjustment is made to account for the variations in the factors acting to produce erosion and transportation. The sediment-discharge data from Elk Run basin, where there has been little change in land use, were used to adjust the Corey Creek basin data. The factor used was the average monthly ratio of the growing season suspended-sediment discharge from Corey Creek basin to the sediment discharge from Elk Run basin. This method is another way of expressing the mean annual slope of the growing season double-mass curve. These factors are as follows:

Year	*Suspended-sediment-discharge ratio*
1954	1.66
1955	2.70
1956	1.54
1957	3.40
1958	1.52
1959	1.44
1960	1.15

Data used for the correlation of relative erosion potential with sediment-discharge ratio were limited to the growing season because the computed erosion potential is based on growing season conditions and because during the dormant season, other factors such as temperature, snow cover, and depth of frost affect both the cover conditions and the relations between precipitation, runoff, and sediment discharge.

Figure 20 shows the relation of the relative erosion potential to the sediment-discharge ratio. The rank correlation coefficient was 0.62, significant at the 0.07 level.

It was evident from this test that the fluctuations in the sediment-discharge ratio could not be accounted for by the crop changes alone, as evaluated by the relative erosion potential. Other conservation practices that affect the sediment yield also were considered.

EFFECTS OF DIVERSION TERRACE CONSTRUCTION

The changes next considered were those associated with engineering practices. More diversion terraces were installed than any other practice. In the Corey Creek basin, 160,000 feet of diversion terraces were constructed between 1954 and 1960. In the Elk Run basin, 19,460 feet of terraces were constructed during the same period. Diversion terrace construction accounted for about 90 percent of the engineering practices, on the basis of acreage affected.

A somewhat unusual aspect of these diversion terraces is that many were constructed for the purpose of improving the drainage characteristics of those soils having impermeable substrata. By constructing a terrace to intersect these substrata, drainage of the surface

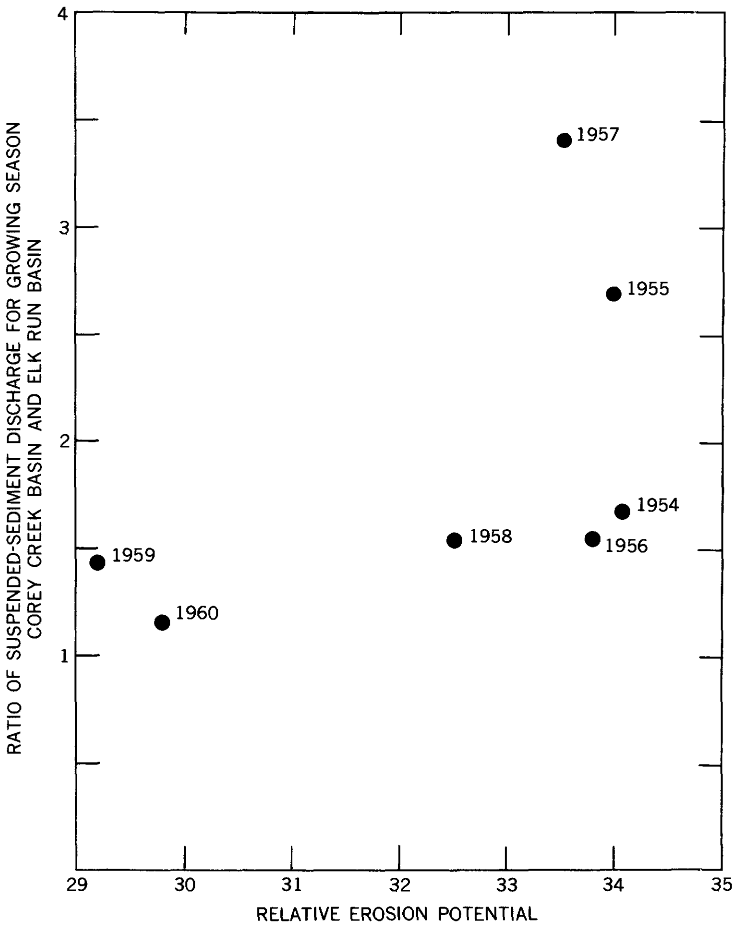

Figure 20.—Relation of relative erosion potential to Corey Creek–Elk Run sediment-discharge ratio, 1954–60 growing seasons.

soil above the terrace is more rapid. Interception of the water by the terraces also decreases the amount of water reaching the lower parts of the slope. The slope immediately below each terrace receives the most benefit from this treatment, and the effect of the improvement in drainage may extend for one-third of the way down the slope between terraces. The improved drainage may allow a more deeply rooted type of vegetation to be grown on this part of the slope, and this vegetation, in turn, should eventually increase the permeability of the substratum. Seepage of water from the soil above the terraces may occur almost continuously throughout the spring and early summer. The usual result is an increase in soil moisture in the terrace, and generally, this seepage between storms does not reach the outlet waterways but evaporates or is transpired by the terrace vegetation.

The average drainage area of terraces in the Corey Creek basin (including the drainage above the uppermost terrace) is 9 acres per 1,000 linear feet of terrace. The average length of slope between terraces is 400 feet, of which about 70 feet represents the width affected by terrace construction. Therefore, about 17.5 percent of the terrace drainage area is distributed during terrace construction (fig. 21).

Approximately 80 percent of the terraces in the basin were constructed on grassland, and 20 percent were constructed on cropland. The average erosion factor for the terraced areas before terrace construction was

$$F_e=0.8(6)+0.2(100)=24.8.$$

During construction, 17.5 percent of the terrace drainage area was disturbed, and for this part the erosion factor became 100. The increase in erosion potential caused by this soil disturbance was

$$\Delta E_R\left[\frac{(17.5\times 100)+(82.5\times 24.8)}{(100\times 24.8)}\right]-1=0.53,$$

or approximately 50 percent.

A method of estimating the effect of terraces after maximum stabilization of the soil was suggested by Van Doren and Bartelli (1956).

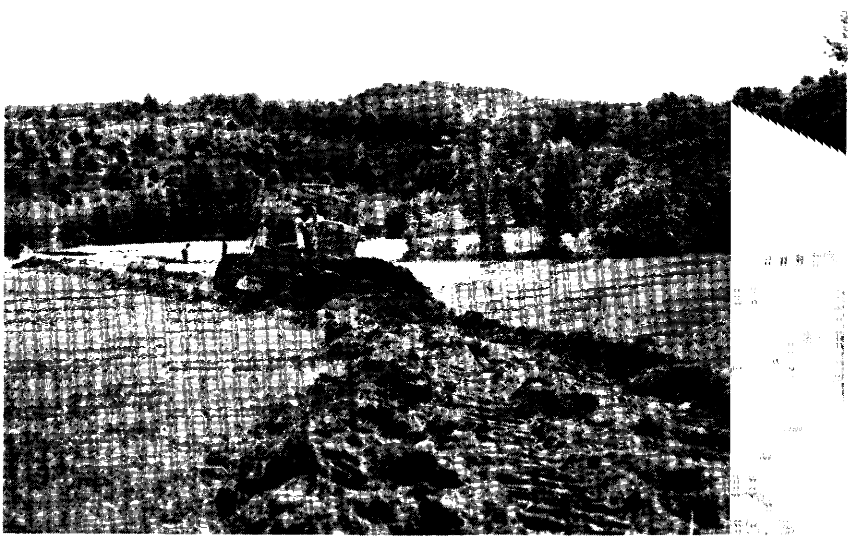

Figure 21.—Construction of a diversion terrace in the Corey Creek basin.

In that study, erosion losses from silt loam soils in Illinois were computed as the 0.6 power of the slope length (L) for slopes over 200 feet long.

In Corey Creek basin, the average length of slope before terracing was 1,600 feet (an average of three terraces in a series). The average slope of terraced areas was 12 percent. For this order of slope of Flanigan silt loam in Illinois, Van Doren and Bartelli estimated the soil loss factor as 0.65, or a reduction in soil loss of 35 percent due to terracing alone.

Using the combined factors for slope length and terracing, the computed reduction in potential after terrace stabilization was

$$E_R=1-0.65\left(\frac{1{,}600^{0.6}-400^{0.6}}{1{,}600^{0.6}}\right)=0.72,$$

or approximately 70 percent.

Observations of terraces constructed during the early stages of the program indicated that maximum cover conditions were attained after about 5 years.

Figure 22 represents graphically the effect of cover establishment after construction of a single set of terraces. The coefficient of adjustment is the ratio of the erosion potential produced by terrace construction to the erosion potential of the undisturbed slope. The reduction in erosion potential is greatest during the first growing season because of the combined effect of reduction in length of slope and the beginning of vegetation growth. In the following years, the reduction in erosion potential is the result of increased cover density, and therefore, additional decreases are shown as taking place only during the growing seasons. In figure 22, it is assumed that the terraces were constructed during May, the beginning of the growing season. To compute the effects of terraces constructed in June, the curve must be shifted to intersect the vertical line representing June at the 1.50 line.

As an example, the following table shows the use of the curve in computing the cumulative effect of construction. In this example, it is assumed that no terraces have been installed during the periods between the months shown, that the average drainage area is 9 acres per 1,000 linear feet of terrace, and that the total basin area is 12.2 square miles, or 7,808 acres.

Date of construction	Terraces constructed (feet)	Basin area affected		Adjustment coefficient	Adjustment coefficient times percentage of basin affected
		Acres	Percent		
May, 1st year	10, 000	90	1. 2	1. 50	1. 8
2d year	14, 000	126	1. 6	1. 50	2. 4
3d year	9, 000	81	1. 0	1. 50	1. 5

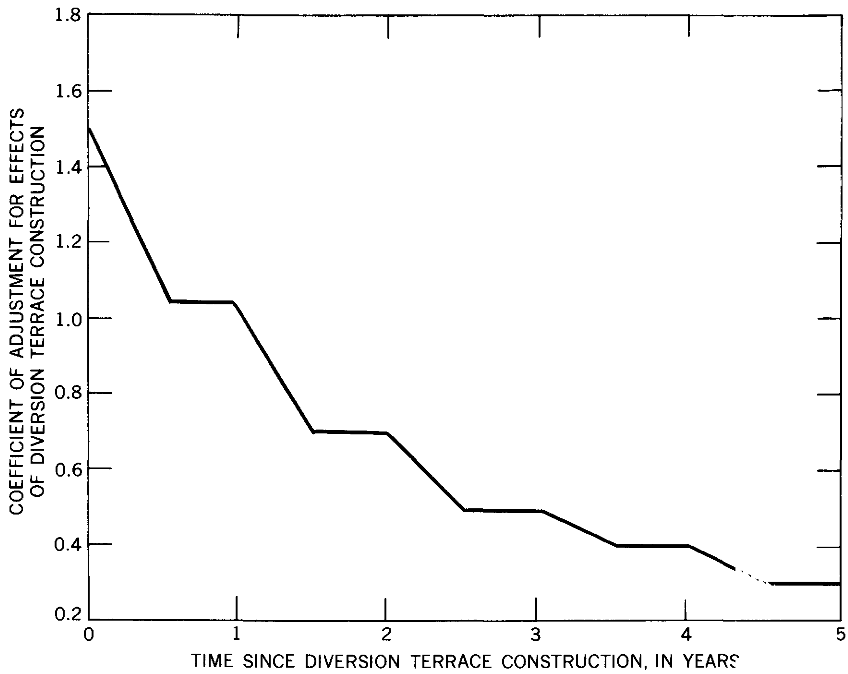

FIGURE 22.—Adjustment for the change in erosion potential produced by diversion terrace construction.

The cumulative effect of the terraces may now be computed. From the curve, the reduction in erosion potential is 45 percent during the first growing season, and 35 percent during the second growing season. The values, therefore, are as follows:

Terrace construction during—	Adjustment coefficient times percentage of basin affected			Σ Percentage of basin times coefficient	Cumulative percentage of basin affected
	1st year	2d year	3d year		
1st year	1. 8			1. 8	1. 2
2d year	1. 3	2. 4		3. 7	2. 8
3d year	. 8	1. 7	1. 5	4. 0	3. 8

The difference between the computed erosion effects and the percent of the basin affected is the adjustment factor to be applied to the previously computed relative erosion potential (p. C39); for example, if, for the third year, the relative erosion potential were 35.0, the adjustment applied would be

$$35\left(\frac{4.0-3.8}{100}\right)=0.07 \text{ or } 0.1,$$

and the adjusted value would be 35.1.

Figure 23 presents the results of such computations for the Corey Creek basin. The vertical distance between the two curves in the figure is the adjustment, in percent, to be applied to the relative erosion potential. During the early part of the program, the construction phase dominated and the positive adjustment increased the erosion potential. As more of the soil became stabilized, the construction effect on the erosion potential decreased until June 1957, when the conditions were about equal to those before construction. After June 1957, the adjustment factor become negative, causing a progressive decrease in the erosion potential. The adjustment factor is projected through 1964 on the basis of the average construction rate in 1959–60.

The bar graph in the lower part of figure 23 shows the distribution of terrace construction within the study period.

The following table table gives the mean annual terrace adjustment factors and the relative erosion potential after adjustment for terrace construction:

Year	*Terrace adjustment factor (percent of relative erosion potential)*	*Adjusted relative erosion potential*
1954	+1. 07	34. 5
1955	+3. 24	35. 1
1956	+1. 13	34. 2
1957	−. 56	33. 3
1958	−1. 86	32. 9
1959	−5. 59	27. 6
1960	−7. 76	27. 5

Figure 24 is a plot of the adjusted relative erosion potential against the Corey Creek–Elk Run sediment-discharge ratio. The rank correlation coefficient is 0.71 and is significant at the 0.03 level. There are 97 chances in 100 that true positive correlation exists between the ranks of the two variables. This correlation is evidence that the sediment-discharge ratio has decreased with decreasing relative erosion potential in the Corey Creek basin. It should be emphasized, however, that the rank correlation method only defines the degree of correlation between the ranks and gives no quantitative information about one variable with respect to the other.

The curve in figure 24 is the computed least-squares regression line of best fit through the scatter of points. The equation of this curve is

$$Y=0.276X-6.89,$$

where Y is the Corey Creek–Elk Run sediment-discharge ratio and X is the adjusted relative erosion potential.

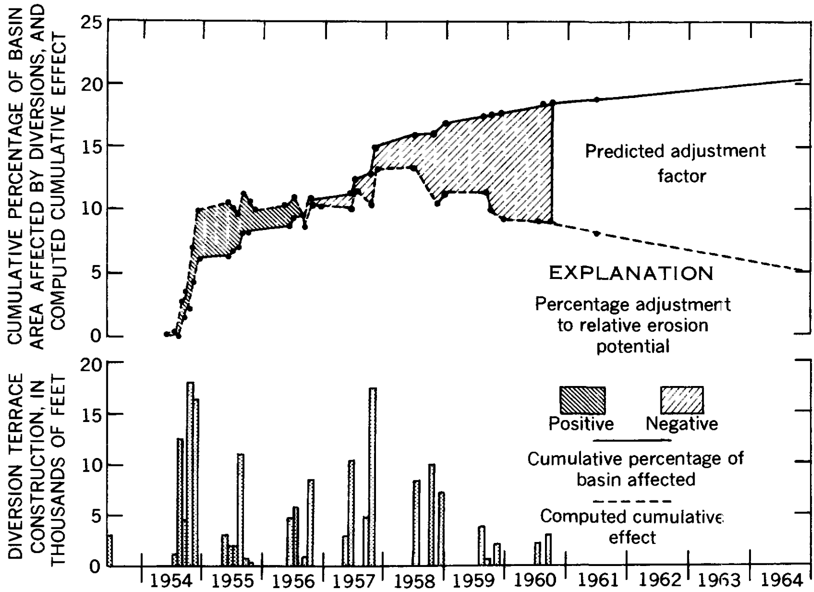

Figure 23.—Time distribution of diversion terrace construction and the computed effect of diversion terrace construction for Corey Creek basin, 1953–60.

The standard error of estimate of Y is 0.44. This means that, if Y is estimated from a computed value of X, using the equation given, the average estimated value of Y will be within ± 0.44 units of the true value of Y about 66 percent of the time. This amounts to ± 20 percent of the observed range of Y.

The coefficient of correlation for the equation is 0.65, significant at the 0.12 level, which indicates one chance in eight that a coefficient of this size may be the result of chance.

The foregoing analyses indicate a general relationship between the effects of conservation practices, as estimated by the relative erosion potential, and the observed changes in the Corey Creek–Elk Run sediment-discharge ratio. The rank correlation test indicates a significant qualitative correlation between the two variables. The correlation coefficient obtained in the regression analysis is indicative of the degree to which the computed relative erosion potential measures the effects of the conservation practices on sedimentation.

WATER CHEMISTRY

Information on the chemical characteristics of the water is necessary for an understanding of the hydrologic environment. Such information is used to evaluate the suitability of the water for various uses, estimate the behavior of the sediment under different hydro-

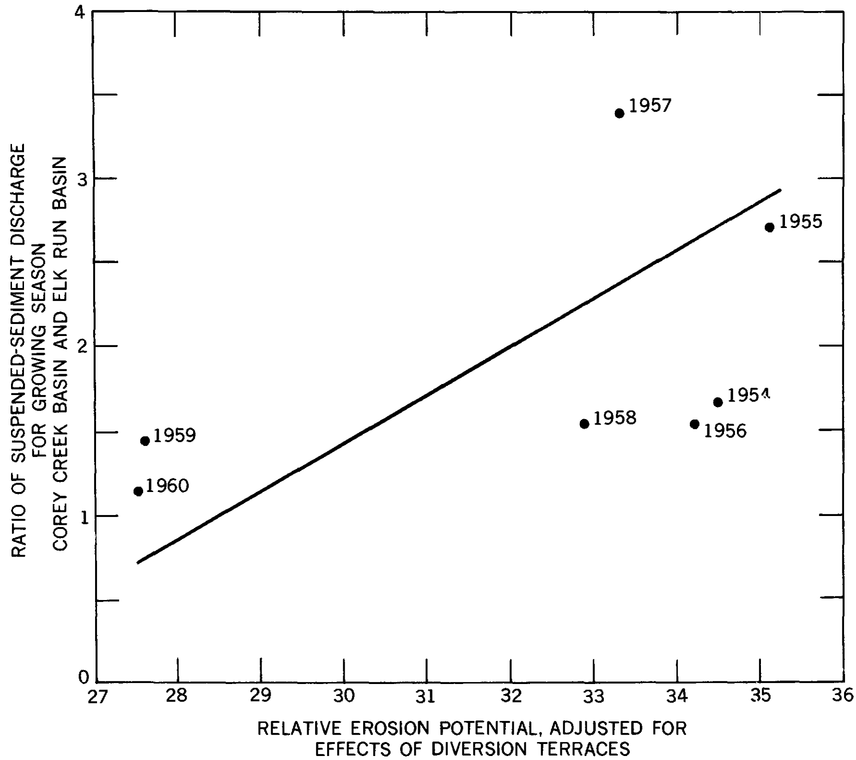

FIGURE 24.—Adjusted relative erosion potential versus the ratio of Corey Creek suspended-sediment discharge to Elk Run suspended-sediment discharge, 1954–60 growing seasons.

logic conditions, and estimate the magnitude of chemical weathering and erosion.

The waters of Corey Creek and Elk Run are similar in chemical composition and in total amount of dissolved solids (table 10). The principal ions present are calcium, bicarbonate, and sulfate. During periods of low flow, a large proportion of streamflow is from ground-water sources. This water has percolated through the carbon dioxide rich soil profile and has been in contact with soluble materials in the relatively unleached zone below the soil. Ground water, therefore, contains a much higher concentration of dissolved solids than does overland runoff. During storm events, most of the streamflow is derived from precipitation. The surface runoff from precipitation is normally low in dissolved solids and dilutes the water in the stream to a lower dissolved-solids concentration.

TABLE 10.—*Chemical analyses of water, in parts per million, Corey Creek and Elk Run near Mainesburg, 1956–61*

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Corey Creek																			
6- 2-56	2.9	----	2.6	0.02	18	3.2	5.5		60	17	2.0	0.1	0.2	93	58	9	141	7.7	4
12-10-56	15	----	4.6	.01	15	2.3	2.0	1.7	38	18	2.7	.1	1.6	78	47	16	113	7.8	3
10- 8-58	1.1	60	1.1	.03	26	3.9	4.3	1.9	80	19	3.9	.1	.4	110	81	16	172	7.5	5
4- 2-59	67	39	4.1	.02	10	2.4	2.0	1.9	22	15	3.6	.3	5.2	80	35	17	90	6.5	7
8- 8-59	.1	----	5.6	.02	30	4.3	6.2	2.5	107	13	4.8	0	.6	126	93	5	205	7.4	5
4-11-60	14	48	4.9	.02	11	3.3	2.5	1.3	28	17	2.6	.1	1.8	76	41	18	92	7.3	5
6-24-60	93	----	3.9	.03	8.6	1.8	2.0	2.4	22	9.6	1.8	.1	3.4	59	29	11	71	7.1	22
7-14-60	8.9	63	10	.01	21	3.6	4.0	3.0	61	15	7.3	.1	1.1	114	68	18	155	7.1	7
6- 5-61	3.2	78	1.1	.02	16	3.0	3.4	2.0	53	14	2.4	.2	.4	77	53	9	126	7.2	4
10-12-61	.6	68	1.6	.02	24	5.6	5.4	2.2	90	14	5.2	.1	.2	105	83	9	176	8.2	3
Elk Run																			
6- 2-56	1.4	----	1.8	0.02	16	2.5	6.7		55	16	1.5	0.1	0.8	88	50	5	126	7.1	5
12-10-56	14	----	5.5	.02	14	1.8	1.8	1.2	34	16	2.5	.0	1.0	58	42	14	100	7.6	3
10- 8-58	.8	60	6.4	.03	24	3.2	4.6	2.5	78	15	4.6	.1	.5	107	73	9	169	7.3	3
8- 8-59	.1	68	3.1	.02	27	3.4	6.2	2.4	96	12	5.8	.0	.1	139	82	3	189	7.4	5
3-29-60	291	----	6.9	.01	8.2	1.6	1.5	1.9	16	12	1.9	.2	6.8	57	27	14	71	6.6	12
4-11-60	14	49	4.1	.00	9.8	2.8	2.5	1.3	24	18	2.8	.1	1.8	69	36	17	86	6.8	3
7-12-60	.9	81	6.6	0.0	19	2.7	4.0	2.2	61	13	3.4	.1	.7	97	59	9	134	7.3	3
6-15-61	2.9	78	.9	.01	15	7.3	3.4	2.0	49	13	2.1	.1	.2	70	47	7	113	7.6	6
10-12-61	.5	70	1.1	.02	21	3.6	4.3	3.0	56	12	4.6	.1	.2	85	68	5	154	8.7	3

The general relation between water discharge and total dissolved-solids concentration is shown in figure 25. The average curve has a negative slope, and this slope indicates that dissolved-solids concentration decreases as water discharge increases; however, dissolved-solids discharge increases with increasing water discharge, because even though the water is more dilute at higher flows, the dilution effect is not enough to offset the increasing volume. The increased load may come from solids dissolved by surface runoff, from increased ground-water discharge during storm periods, or from dissolved solids present in the precipitation. The load-discharge relation is shown in the lower set of curves in figure 25. These load-discharge curves and

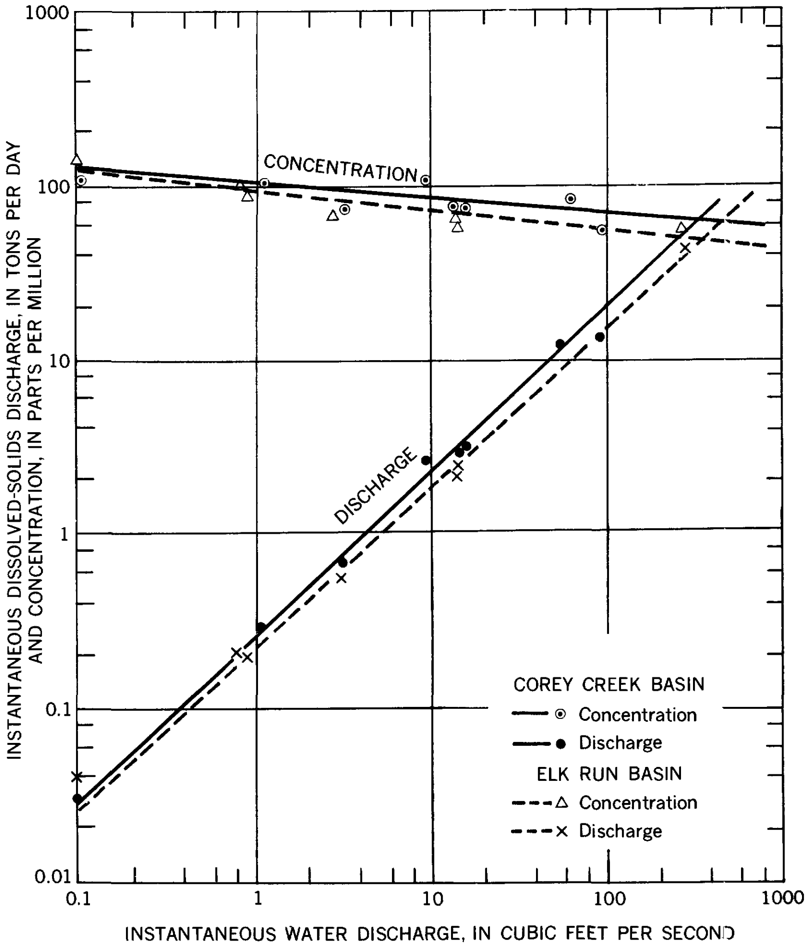

Figure 25.—Relation of instantaeous water discharge to concentration and discharge of dissolved solids, Corey Creek and Elk Run near Mainesburg, June 1956 to October 1961.

flow-duration curves were used to compute the data and the average annual discharge of dissolved solids in the following table. The results indicate that the average annual dissolved-solids discharge is approximately one-half the average annual suspended-sediment discharge.

Basin	Average annual dissolved-solids discharge		Average water-weighted dissolved-solids concentration (ppm)	Average total hardness as $CaCO_3$ (ppm)
	Tons	Tons per square mile		
Corey Creek	1, 000	82	75	52
Elk Run	818	80	63	54

In addition to the complete chemical analysis performed, specific conductance and pH were measured for more than 300 samples from each basin. Measured specific conductance of the water ranged from 60 to 235 micromhos in Corey Creek and from 61 to 206 micromhos in Elk Run. Measured pH of the water ranged from 6.5 to 8.3 in Corey Creek and from 6.6 to 8.7 in Elk Run.

The ability of water to conduct an electric current is dependent upon the concentration of dissolved solids in the water; therefore, specific conductance can be used as an indirect method of determining dissolved-solids content. Figure 26 is the relation of specific conductance to dissolved-solids concentration and to hardness. Both dissolved-solids content and hardness can be estimated from these curves if the specific conductance is known.

Because specific conductance is directly related to dissolved-solids concentration, it follows that the relation between water discharge and conductance will be similar to the water discharge–dissolved-solids concentration relation. The curves in figure 27 can be used to estimate the specific conductance (and thus, the dissolved-solids concentration) for any given rate of water discharge.

SUMMARY AND CONCLUSIONS

Data collected during the period 1954–60 have been used in this report to describe the differences and similarities in both the natural and artificially created environments of Corey Creek and Elk Run basins. Changes occurring within each basin have been evaluated, and some projections have been made concerning the probable effects of future changes.

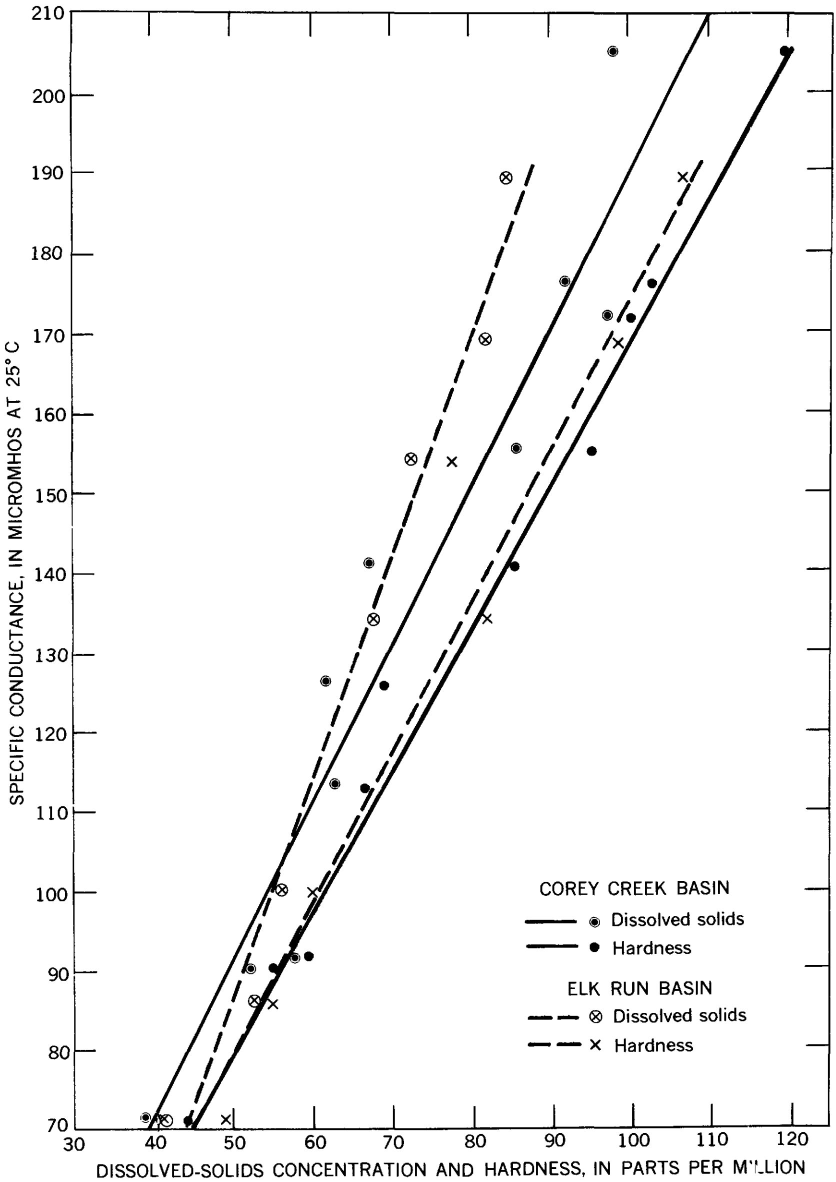

FIGURE 26.—Relation of dissolved-solids concentration and hardness to specific conductance, Corey Creek and Elk Run near Mainesburg, June 1956 to October 1961.

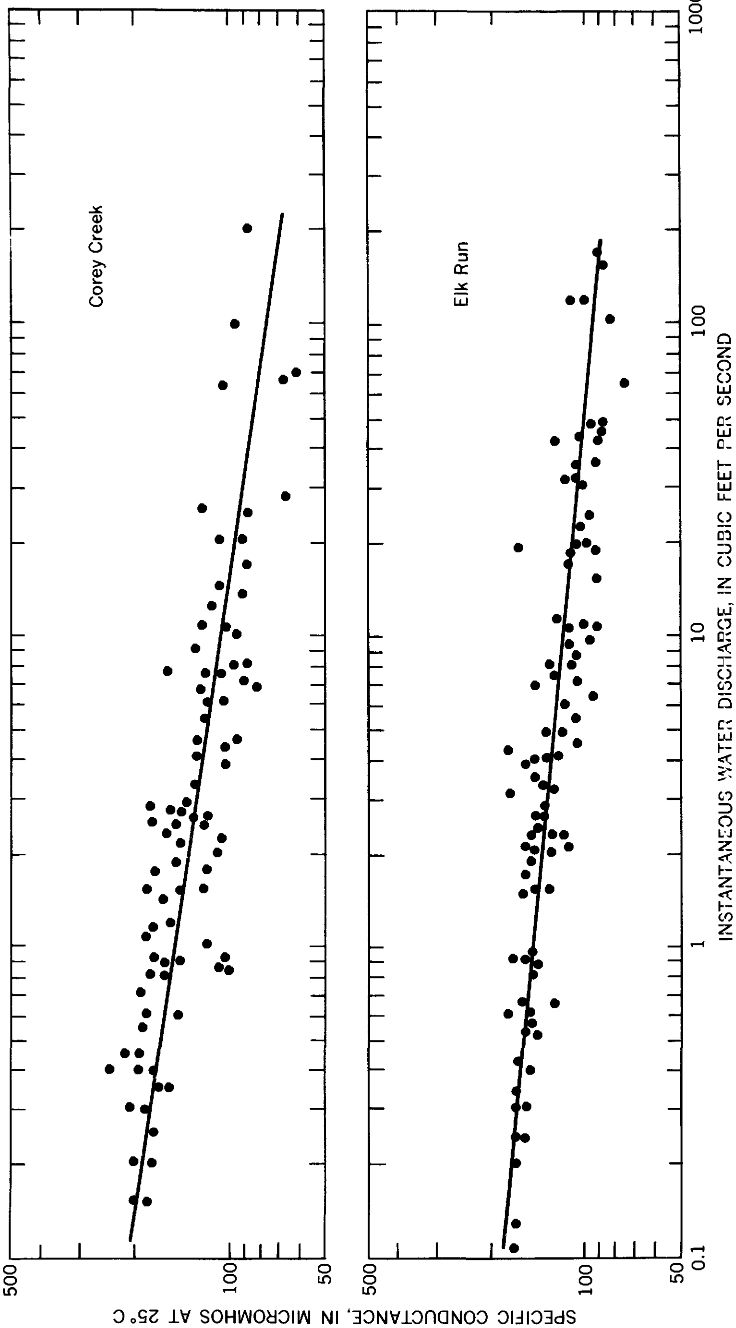

FIGURE 27.—Relation of specific conductance to instantaneous water discharge, Corey Creek and Elk Run near Mainesburg, May 1954 to September 1960.

The mean elevation is somewhat higher and slopes are somewhat steeper in Elk Run basin. These factors may cause the observed difference in precipitation, which has averaged 2.75 inches more per year in Elk Run basin than in Corey Creek basin.

About 90 percent of the soils in the two basins are classified as silt loam. The size distribution of suspended sediments generally corresponds to this soil texture.

The aggradation-degradation ranges in both basins indicate an average change in cross-sectional area of less than ±2.5 square feet for ranges on portions of the stream channels having slopes greater than 70 feet per mile. On slopes of less than 70 feet per mile, the range data indicate filling, especially in the Corey Creek basin. Most changes have taken place in the banks rather than in the streambeds.

Of the independent variables tested by regression analyses, those correlating most highly with sediment yield were quantity of runoff, precipitation, and temperature. Tests of temperature as a variable indicated that it was largely an indicator of variations in seasons. Precipitation and runoff peakedness were the two most important variables determining storm suspended-sediment concentration for the intermittent station, Corey Creek at Mainesburg.

During the period 1954–60, there was no significant change in precipitation, total runoff, or direct runoff in either basin. Double-mass curves and rank correlation analysis indicated no significant change in the peakedness of runoff in the Corey Creek basin during the study period.

The rate of suspended-sediment discharge has changed in both basins. The trend since 1957 has been toward decreasing sediment discharge, but the decrease has been greater in the Corey Creek basin. The net decrease in Corey Creek basin with respect to Elk Run has been about 11 percent. The double-mass analyses indicated this change was the result of a 51-percent relative decrease during the growing season, when about 25 percent of the average annual suspended-sediment discharge occurred. There was little or no change during the dormant season.

The application of conservation practices has been an important factor in decreasing the suspended-sediment discharge from the two basins; the most important change probably has been the shift from cropland to grassland. The rank correlation test indicated a significant correlation between the adjusted relative erosion potential of Corey Creek basin and Corey Creek–Elk Run sediment-discharge ratio during the growing season.

Although diversion terraces affected about 19 percent of the Corey Creek basin and reduced the relative erosion potential by about 8 percent through 1960, the data indicate that the terraces have had little or no effect on runoff characteristics.

The generalizations used in formulating the relative erosion potential obviously did not account for all of the subtle variations in cover conditions within the two basins. Measurement of the total effect of the conservation practices may be possible only after the major construction and land use changes in the basins have ceased. New data, along with that presently available, could be analyzed by other techniques, such as that suggested by Van Doren and Bartelli (1956), to obtain a more quantitative solution of the erosion-sedimentation relationship.

During the period 1954 through 1958, there was an intensive application of conservation techniques in the Corey Creek basin. The temporary sharp rise in sediment yields that resulted from the construction phase of the program probably would not be observed in an area where treatment progressed at a slower, more uniform rate.

The reduction in sediment yield was not directly proportional to the intensity of conservation activity. Elk Run basin showed a reduction in sediment yield of more than half that in Corey Creek basin, while receiving only about one-tenth as much treatment.

Improvements in land treatment often are aimed at increased crop yields as well as soil conservation, and these techniques are, therefore, applied more intensively during the growing season. More than 75 percent of the sediment discharge from the two basins, however, occurs during the dormant season. If a further reduction in annual erosion is desirable, attention might be given to increasing acreage and density of ground cover during the dormant season.

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