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SEDIMENTATION AND LAND USE IN COREY CREEK AND ELK RUN BASINS, PENNSYLVANIA, 1954-60

(A PROGRESS REPORT)

By

Benjamin L. Jones

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

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ABSTRACT

Analyses of data collected from two small basins in northern Pennsylvania during the period May 1954-September 1960 indicated a general relationship between changes in land use and land treatment and changes in 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 while 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.

The multiple-regression method and a digital computer were used to analyze the factors that affect sediment yield in each basin. The independent variable that correlated most highly with suspended-sediment yield was runoff.

Surveys at selected cross sections on the two streams indicated that most channel changes were in the stream banks rather than in the beds. At points where the stream channel slopes were 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).

Double-mass analyses indicated significant trends in the rate of suspended-sediment discharge from both basins. During the last half of the record, sediment discharge from Corey Creek basin decreased by 11 percent, compared to the sediment discharge from Elk Run. All, or most of this decrease, was the result of a trend in sediment discharge during the May-October growing seasons. No significant trends were detected in data collected during the November-April dormant season.

A factor, termed the relative erosion potential, was developed 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

This report evaluates the progress of a continuing investigation. The purpose of the investigation is to measure and explain the hydrology and sedimentation of two small Pennsylvania watersheds in the light of 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 flood-control structures are installed, they tend to be the dominant factors in hydrologic changes and, therefore, they 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 Cerek basin under the influence of a less intensive conservation program.

This report presents a preliminary evaluation of data collected during the period May 1954-September 1960. The analyses presented are intended to aid in the development of evaluative techniques and to determine the need for future data collection. Many of the evaluation techniques developed during this study, as well as some of the conclusions, should be applicable to similar basins in other areas.

Analytical techniques were used to define the relationships between precipitation, streamflow, and sedimentation. Each of these variables was tested for changes in trend and finally, a test was made of the relation between land use and the trend in sediment discharge.

Previous Studies

Culbertson (1957) gave a preliminary evaluation of the two basins, using data 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).

The Tioga County Soil Conservation district watershed work plan (1954) outlined the conservation problems encountered and the suggested remedial practices to be installed, as well as the financial arrangements for the project.

Acknowledgments

This investigation is being conducted by the U. S. Geological Survey in cooperation with the Pennsylvania Department of Agriculture, State Soil Conservation Commission, David G. Unger, 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 are obtained at the downstream limit of each study area. Suspended-sediment data are collected at the stream-gaging station. In addition, sediment data and records of water stage are collected at several upstream locations in each watershed. These are obtained on an intermittent, or storm, basis and are used to compute suspended-sediment discharge contributed from each part of the basin.

There is a rain gage for every 2 square miles in the basins. This increased density insures greater accuracy, and maintains the record during periods when one or more gages might be inoperative. These gages have been located at elevations representative of the variations in basin topography. Recording rain gages, centrally located in each basin, are used to determine intensity as well as the quantity of precipitation.

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

The cross-sectional area of the stream channels is 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 reveals whether the channel is filling or scouring at the section. Special note is made of any changes in the type of channel materials.

Figure 1 shows the location of instrumentation and data-collection points in the two basins.

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

A computer punch-card system has been devised to facilitate the classification and analysis of the data. Three different punch cards are used, corresponding to the three classes of data. (Fig. 2.) Table 1 summarizes the classes of data found on the cards and explains the units. The three cards are arranged so that the data fields coincide; one machine program may, therefore, be used to sort and compile all of the cards.

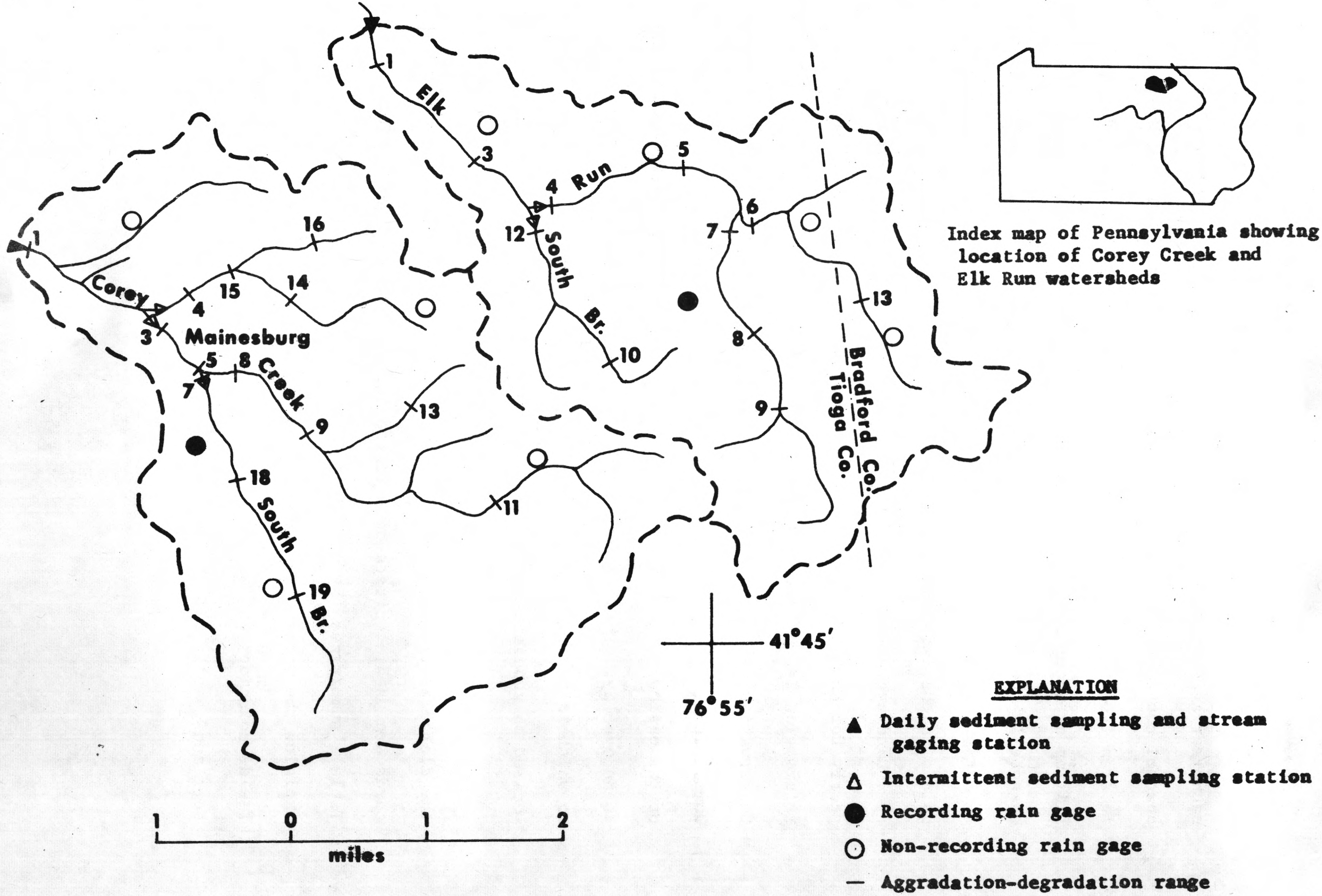
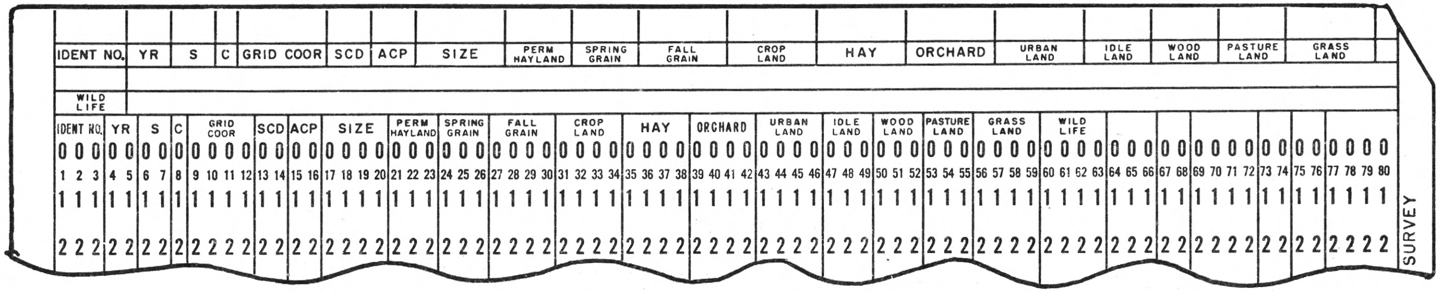
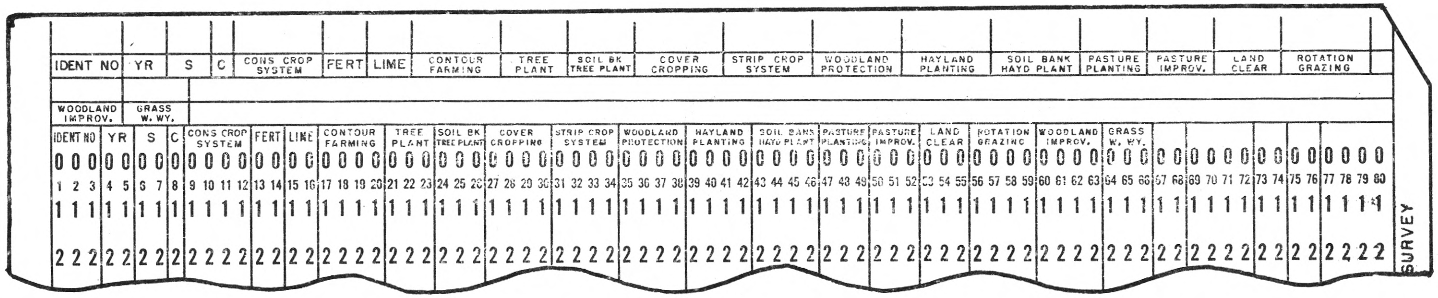


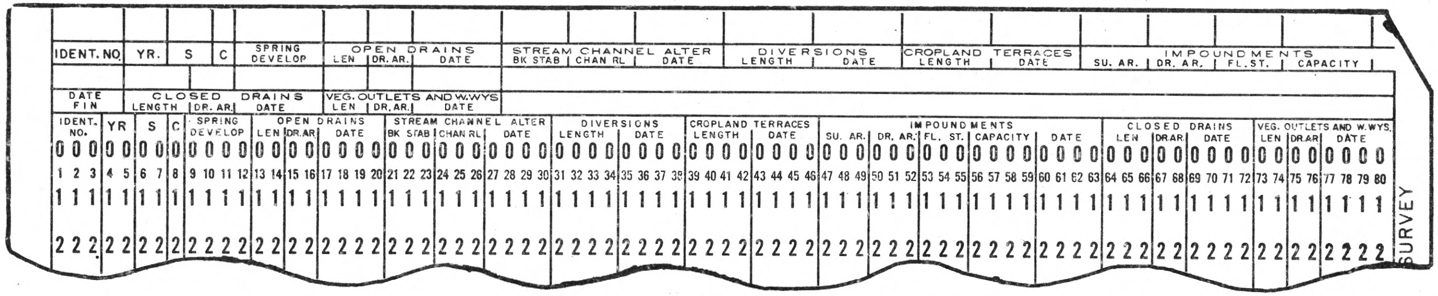
Figure 1.--Map of Corey Creek and Elk Run basins, showing the location of instruments and data-collection points.



BASIC DATA CARD



AGRONOMIC PRACTICES CARD



ENGINEERING PRACTICES CARD

Figure 2.--Format of cards used to record land use, agronomic practices and engineering practices data.

Table 1.--Explanation of land-use evaluation cards

Card	Columns	Symbol	Explanation
	1-3	IDENT. NO.	Farm identification number (corresponds to numbers on aerial photographs).
	4-5	YR.	Separate card for each year.
	6-7	S	Subwatersheds outlined on photographs.
	8	C	Card numbers--(1) basic land-use data, (2) agronomic data, (3) engineering practices.
Basic-data card	9-12	GRID. COORD.	Corresponds to overlay of photo mosaic. Second letter shows location of farm house or majority of farm.
	13-14	SCD	Year that farmer became soil conservation district cooperator.
	15-16	ACP	Agricultural Conservation Program cooperator. No. 1 in column 16 means "yes".
	17-20	SIZE	Size of farm, in acres.
	20-63		Record of area (in acres) under specific type of cover.
Agronomic-practices card	1-8		Same as basic-data card.
	9-66		Dimensional record of agronomic practices performed during year.
Engineering-practices card	1-8		Same as basic-data card.
	9-80		Dimensional record of engineering practices performed during year, with dates of completion.

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

Designation of both time and location for the land-use data are somewhat different than for the hydrologic data. Because of the sources of land-use data, calendar years are used in this record.

Tables 2-4 are yearly summaries of land use, agronomic practices, and engineering practices in the two basins. The major land-use categories (table 2) 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 the pasture and hayland against the total grassland.

Between 1954 and 1960, 160,000 feet of diversion terrace and seven farm ponds of 24-acre feet total capacity were installed in the Corey Creek basin, while 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 3 shows a newly-constructed farm pond.

Table 2.--Land use in the Corey Creek and Elk Run basins, Pennsylvania, 1954-60

Year	Permanent hayland	Spring grain	Cropland	Hayland	Urban land	Idle land	Woodland	Pasture land	Grassland	Wild life
	(acres)									
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 3.--Agronomic practices in the Corey Creek and Elk Run basins, 1954-60

Year	Conservation cropping system	Fertilizer (tons)	Lime (tons)	Contour farming (acre)	Tree planting (acre)	Soil bank tree planting (acre)	Cover cropping (acre)	Strip cropping system (acre)	Woodland protection (acre)	Hayland planting (acre)	Soil bank hayland planting (acre)	Pasture planting (acre)	Pasture improvement (acre)	Land clearing (acre)	Woodland improvement (acre)
								COREY CREEK							
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							
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 4.--Engineering practices in the Corey Creek and Elk Run basins, 1954-60

Year	Open drains (feet)	Open drains drainage area (acre)	Stream channel alteration (feet)	Diversion terrace length (feet)	Impoundments: Surface area (acre)	Impoundments: Drainage area (acre)	Impoundments: Flood storage (acre-feet)	Impoundments: Capacity (acre-feet)	Closed drains: (feet)	Closed drains: Drainage area (acre)	Grassed outlets and waterways: (feet)	Grassed outlets and waterways: Drainage area (acre)
COREY CREEK												
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												
1954	--	--	--	--	--	--	--	--	--	--	--	--
1955	--	--	--	1,000	--	--	--	--	--	--	--	--
1956	--	--	--	--	--	--	--	--	--	--	--	--
1957	--	--	--	3,835	.7	7.0	.5	4.0	--	--	300	18
1958	--	--	--	725	--	--	--	--	--	--	--	--
1959	--	--	--	5,045	--	--	--	--	--	--	--	--
1960	--	--	--	8,854	--	--	--	--	750	15	--	--

Figure 3.--A newly-constructed farm pond, Elk Run basin.

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 at Mansfield, Pa. 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. 4) with altitudes 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 slopes of the basins are as follows:

Basin	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. The area 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 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.

Figure 4.--View of Corey Creek basin showing the typical rolling topography. Ridge in the distance is the basin divide.

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, and fine-grained, greenish sandstones, with some fresh-water and marine red shales. The underlying Chemung consists of similar rocks, but locally it 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. This fill largely consists of gravel- to boulder-size (2.0-256 mm) fragments of sandstone or conglomerate (Lohman, 1939).

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 area 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 with 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 depth, and a substratum of channery silty clay loam or silty clay loam. About one-third are fragipan soils, with poor internal drainage. The surface soil consists of a friable channery silt loam to a depth of 8 inches, with a subsoil of silt loam which is underlain at a depth of 15 inches by a fragipan which is very firm and dense while in place but is brittle when removed. Both of the above are agriculturally important, much of the cropland being on the well-drained soil while the more poorly drained soil is devoted to pasture and grassland.

On the hill tops, the soil is thinner. Much of the forested area is either gravelly silt loam or rocky silt loam, which are similar soils except that the surface and subsoils of the latter contain angular cobbles and glacial boulders. The remainder of the timber land is rough stony land with 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, with a subsoil of silty clay or silty clay loam extending to a depth of 24 inches. The substratum is a sandy or silty clay with some gravel. The bottom lands that are composed of this type of 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 plastic silty clay or clay. The surface soil is 3 to 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 Corey Creek and Elk Run basins are similar in type, distribution, and relative abundance.

Climate

The climate of the area is typical of continental climate in the North Temperate Zone, where minimum temperatures in winter months 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 varies from near zero under grasslands or forest cover to as much as 3 feet under bare cropland during severe winters. If a long period of subfreezing weather preceeds the first snowfall, the soil under all cover conditions may be frozen. During many winters, however, the soil remains unfrozen in areas protected by heavy forest cover. The average time between the last killing frost in the spring and the first one in the fall is 118 days.

HYDROLOGY

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

Basin	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; while 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 5 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 considerably greater than that from Corey Creek basin, but during months of recession and low flow (as in May-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 probably include the greater proportion of cropland and somewhat steeper slopes in the Elk Run basin.

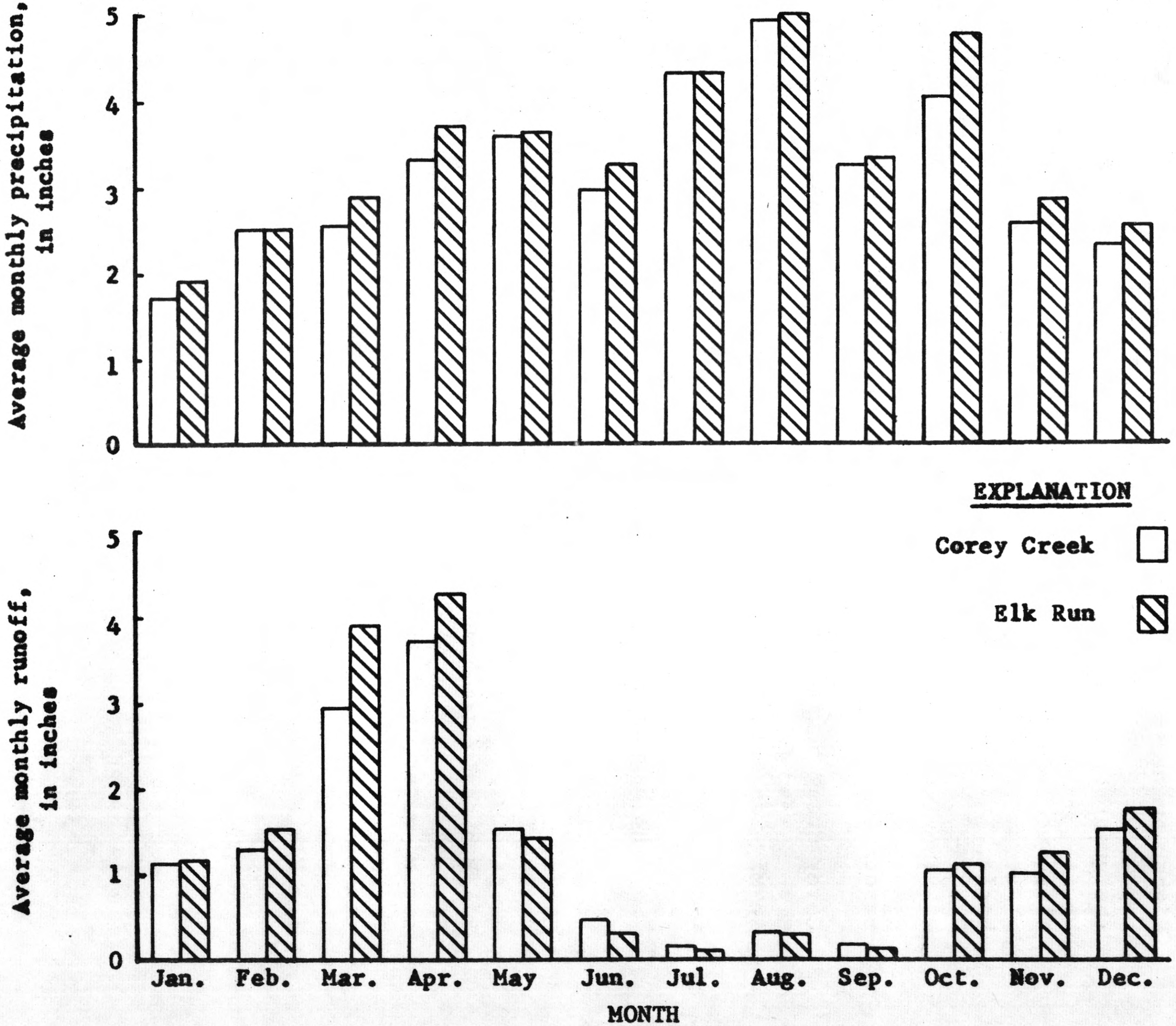


Figure 5.-- Average monthly precipitation and runoff, Corey Creek and Elk Run basins, October 1954-September 1960.

Difference in yield of the two basins is also reflected in the duration curves of mean daily water discharge shown in figure 6. 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 shown in figure 5. During the summer, most of the precipitation is lost through evaporation, is used and returned to the atmosphere by vegetation, or percolates downward to the water table. Beginning with the dormant season in October, more of the precipitation is available as 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 being stored in the form of snow. The snow melts in March and April and runoff during these months often exceeds precipitation. May usually is a transition month of reduced streamflow as rising temperatures and the demands of growing plants again become the dominant factors.

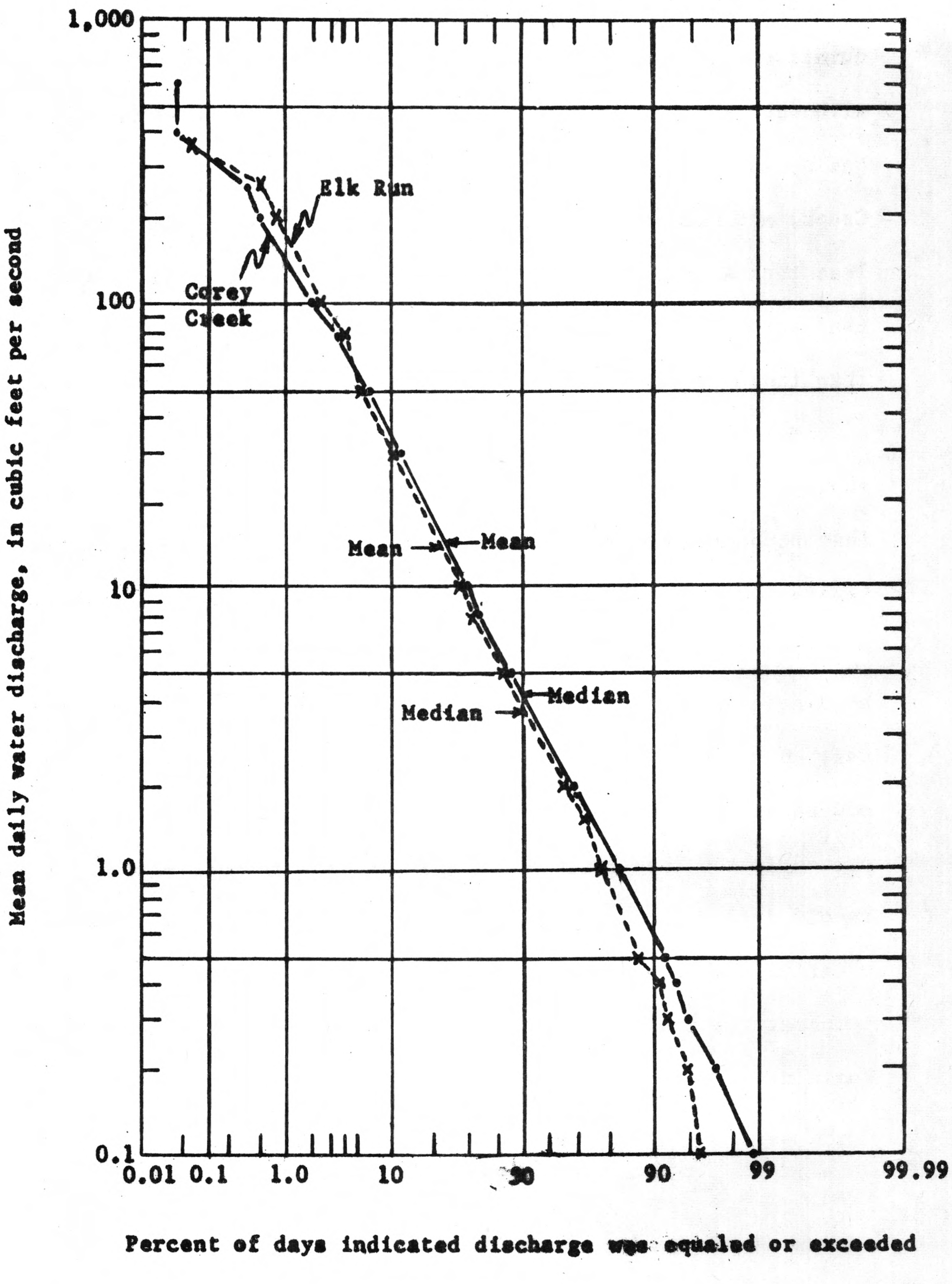


Figure 6.-- Duration curves of mean daily water discharge, Corey Creek and Elk Run near Mainesburg, Pa. October 1954-September 1960.

Trend Analysis

Precipitation and Runoff

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

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 7 shows the double-mass relation of precipitation for the Corey Creek and Elk Run basins, and figure 8 shows the double-mass relation of runoff. These figures indicate that the rates of accumulation of both precipitation and runoff have been very uniform. During the 6-year period of record, very nearly one quarter of the precipitation and runoff in both basins occurred during each quarter of the time. When the rate of accumulation for each basin is compared, the result agrees within 2 percent.

These tests indicate that there has been no persistent change in the cumulative rate of precipitation or runoff in either of the basins.

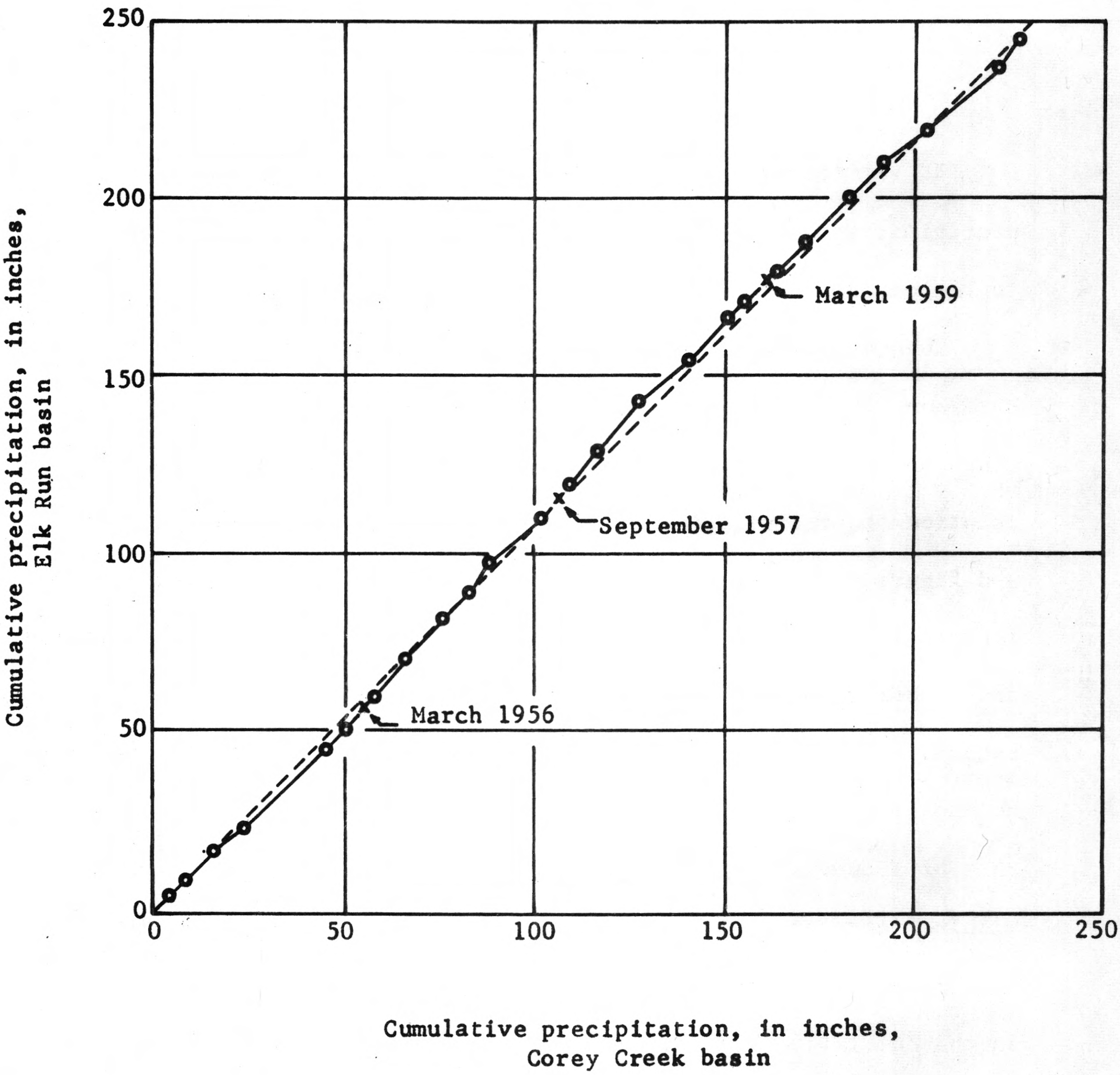


Figure 7.--Double-mass relation of precipitation, Corey Creek and Elk Run basins, 1954-60.

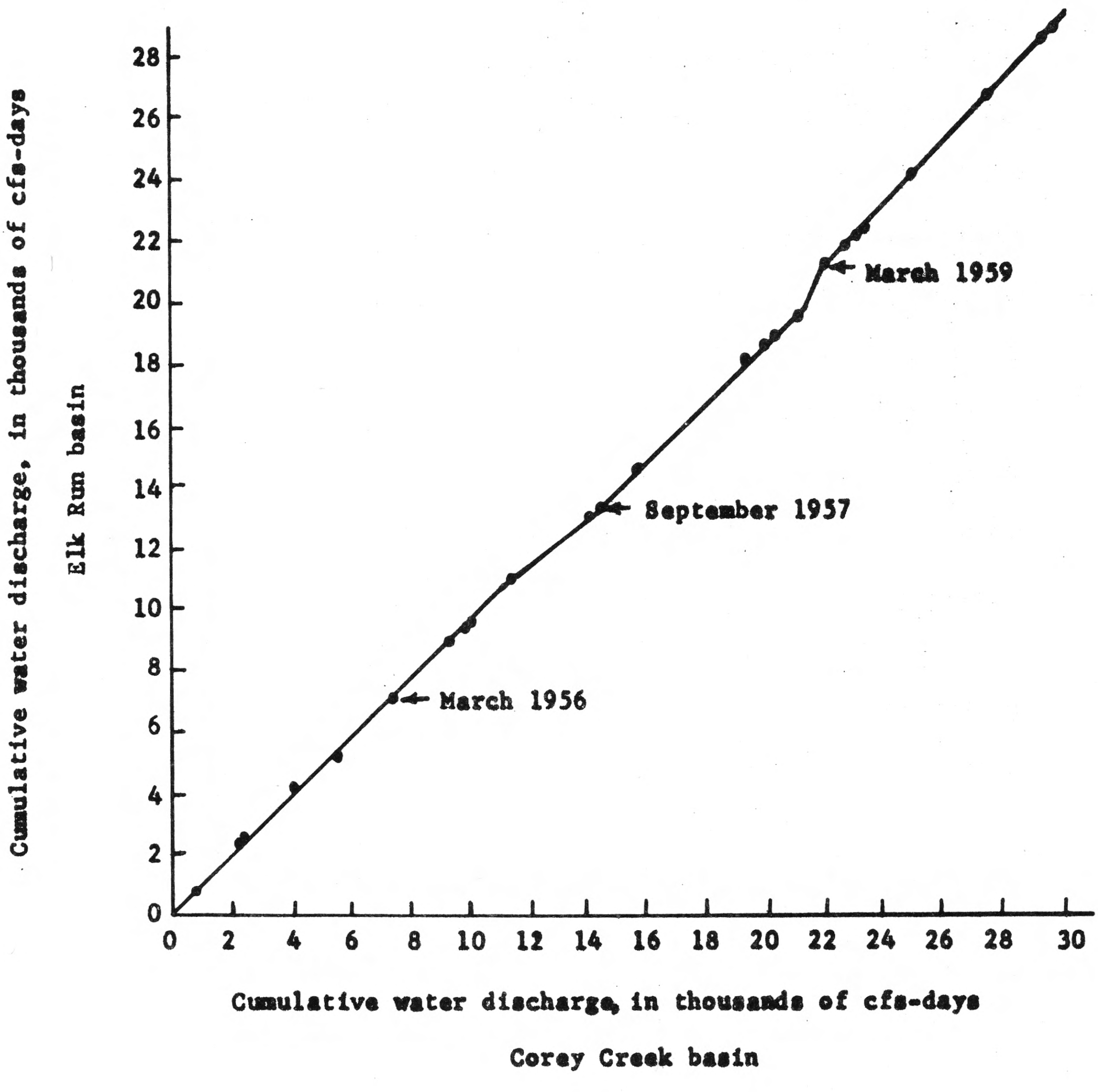


Figure 8.--Double-mass relation of runoff, Corey Creek and Elk Run near Mainesburg, Pa., 1954-60.

Runoff Peakedness

Runoff peakedness, as used in this report, is a 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 conservation practices should decrease runoff peakedness by slowing overland runoff and extending the time required for storm water to reach the stream channel. This generally increases the retention of water as soil moisture. Decreasing runoff peakedness results in lower peak stages and, therefore, less flooding.

In order to test whether there had been a change in runoff peakedness at Corey Creek, 70 storms were analyzed. Each storm resulted from 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.

Two methods were used in an attempt 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 the peakedness with time.

Runoff was used in the double-mass analysis because it is an independent variable with no change in trend. Figure 9 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 No. 1, proceeding to the smallest peakedness factor, No. 70. These 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 significance is generally considered to be the upper limit for which any degree of certainty can be ascribed to a correlation, so that evidence for increasing peakedness is not conclusive. The results do, however, serve as strong evidence against any significant decrease in runoff peakedness.

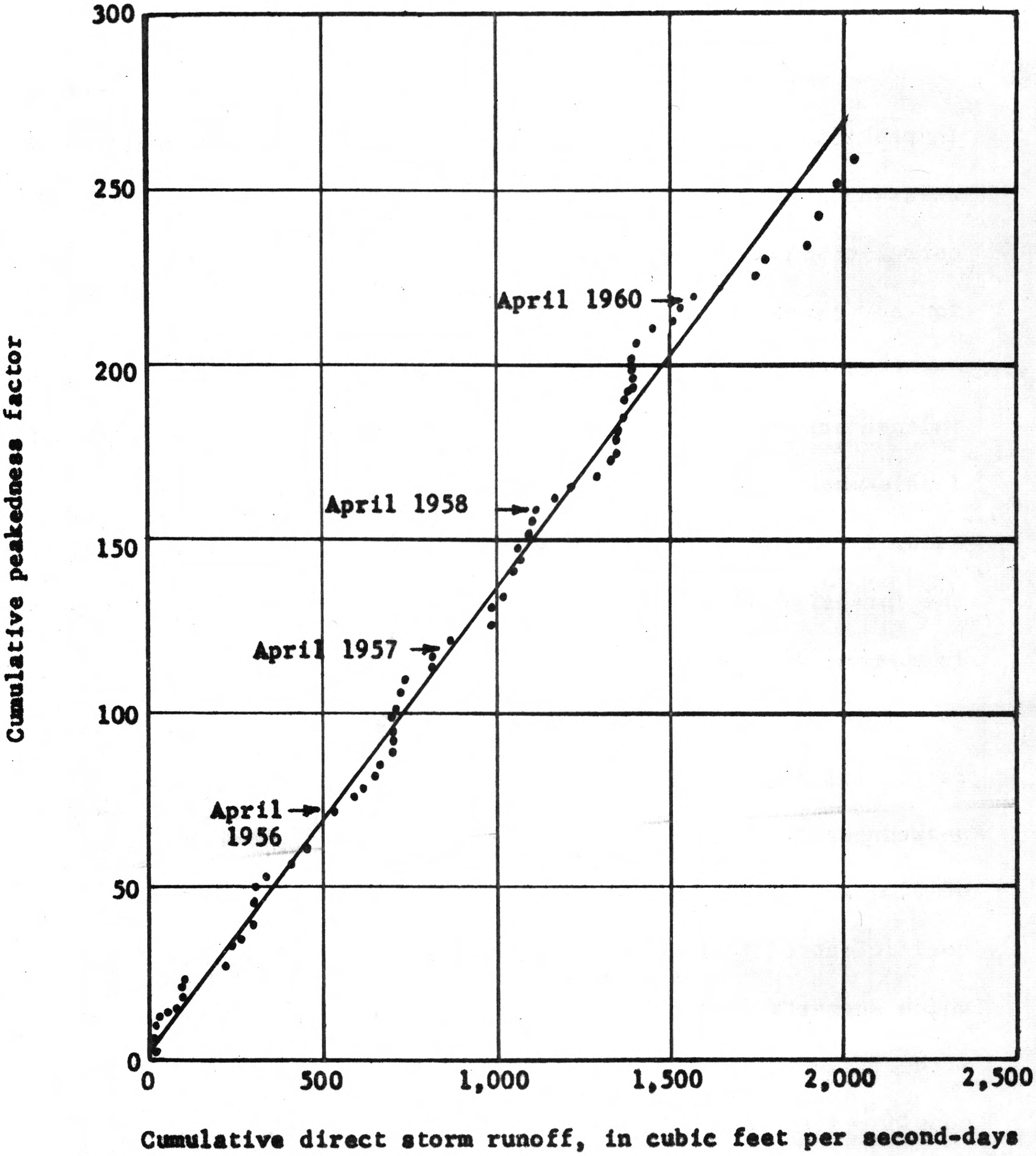


Figure 9.--Double-mass relation of storm runoff and peakedness factor, Corey Creek near Mainesburg, Pa., 1954-60.

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 installed during the conservation program either have had little effect, or else the various effects of the changes have been such as to balance one another out.

The study by Schneider and Ayer (1961) shows that even in extensively reforested basins the changes in runoff characteristics take place quite 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 has been planted in trees, but even when these mature this relatively small area will probably have little effect on the runoff characteristics of the entire basin.

Diversion terrace installation is the practice that might be expected to exert the greatest effect on runoff characteristics. About 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 which 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 result in a change in the quantity of sediment reaching the stream, and that this will be reflected in the measured suspended-sediment discharge.

Suspended-sediment discharge varies with variations 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 often is expressed as an average curve, or sediment-transport curve. The graphical 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 curve is then adjusted for other factors which affect the relation, using the multiple-regression technique described by Linsley, Kohler, and Paulhus (1949).

In the mathematical approach, an equation is computed that represents the average relation. In this study, multiple regression was used, and the computations were performed by a digital computer. Analysis by digital computer requires knowledge of the mathematical form of the equation. The general relation between sediment discharge and water discharge is

$$Q_s = aQ_w^{\ n}$$

where Q_s = sediment discharge, in tons per day; Q_w is water discharge, in cfs (cubic feet per second); and a and n are constants.

This is the equation of a curved line on rectangular coordinates, and the multiple-regression program requires a straight-line function. This requirement was met by converting the above equation to logarithmic form:

$$\mathrm{Log}_{10}Q_s = \mathrm{Log}_{10}a + n\mathrm{Log}_{10}Q_w$$

Variables such as temperature (T) which bears a straight-line relationship to $\mathrm{Log}_{10}Q_s$ were submitted to the computer without conversion, so that the form of the equation became

$$\mathrm{Log}_{10}Q_s = \mathrm{Log}_{10}a + n\mathrm{Log}_{10}Q_w + bT \ldots$$

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 tests were performed to determine the most desirable grouping of data for computer analysis. These tests indicated that the daily data should be classed by dormant season (November-April) and by growing season (May-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 at 10 cfs or greater, and therefore this portion of the sediment-transport relation is more important for determining trends in the amount of sediment being transported. The complete grouping of daily data for computer analysis was:

A. Dormant season (November-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-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:

Dependent variables:

$Log_{10}Q_s$ = Logarithm of daily suspended-sediment discharge in tons per day

$Log_{10}C$ = Logarithm of mean daily concentration of suspended sediment, in ppm (parts per million)

Independent variables:

M = Month of observation (1-12)

Y = Year of observation (54-60)

i = A measure of time duration in days since the beginning of record, (first day of record = 1, etc.)

$Log_{10}Q_w$ = Logarithm of mean daily water discharge, in cfs

$Log_{10}Q_{wp}$ = Logarithm of mean water discharge on the day previous to the one being measured (a measure of antecedent streamflow conditions), in cfs

T = Daily water temperature, in degrees Fahrenheit

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

Figure 10 shows the average sediment-transport curves for streamflows of 10 cfs or greater. The curves for the dormant season are somewhat steeper than those for the growing season. Both curves for the Elk Run basin are steeper than those for Corey Creek, 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 equations. Table 5 lists 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.

The independent variables having the highest degree of correlation with the dependent variables are water discharge and 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 6 lists the simple correlation coefficients of all the variables and the level of significance of each.

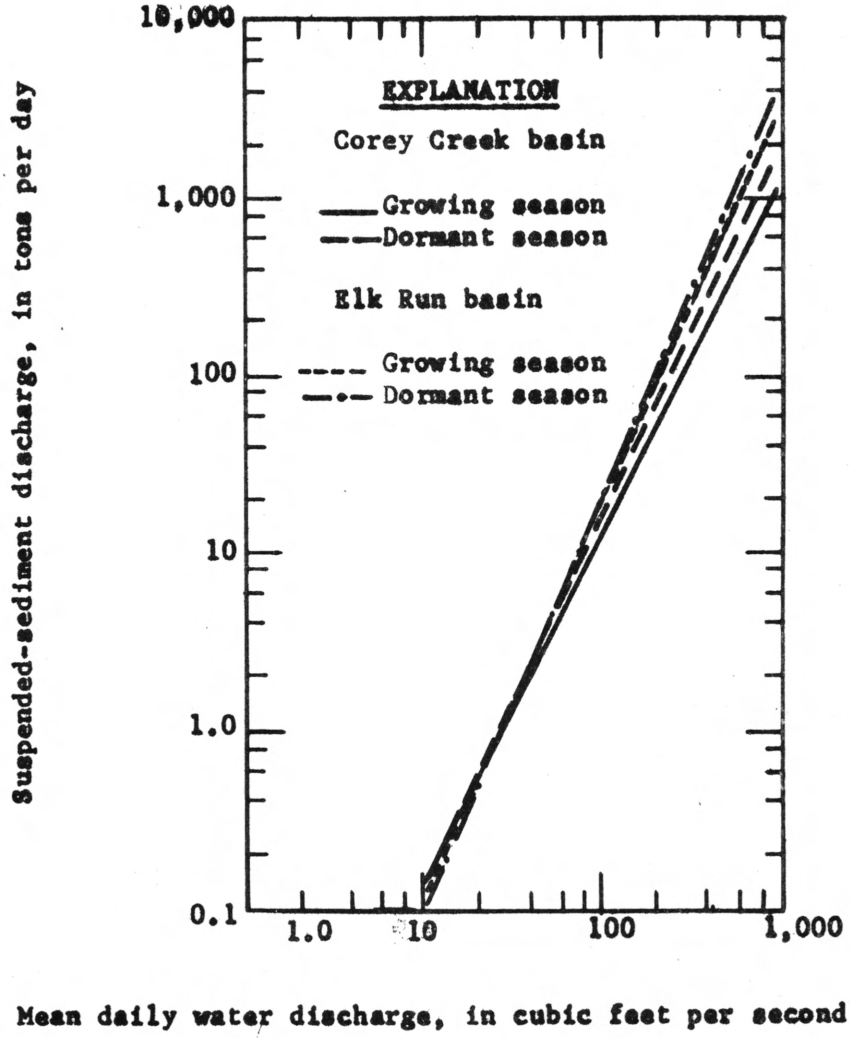


Figure 10.--Seasonal suspended-sediment transport curves, Corey Creek and Elk Run near Mainesburg, Pa., May 1954-September 1960.

Table 5.--**Most efficient regression equations for daily suspended-sediment concentration and discharge, for water discharges of 10 cfs or greater, Corey Creek near Mainesburg, Pa., and Elk Run near Mainesburg, Pa.**

Station	Season	Standard error (Log_{10} units)	Equation
Corey Creek near Mainesburg, Pa.	Growing	0.5564	$Log_{10}Q_s = 2.306\ Log_{10}Q_w + 0.01957T - 0.4991\ Log_{10}Q_{wp} - 3.830$
	Growing	.4630	$Log_{10}C = 1.216\ Log_{10}Q_w + 0.01252T - 0.4531\ Log_{10}Q_{wp} - 0.04810Y + 1.896$
	Dormant	.4750	$Log_{10}Q_s = 2.441\ Log_{10}Q_w - 0.3188\ Log_{10}Q_{wp} - 0.0002862i - 0.02405M - 0.0114T - 2.110$
	Dormant	.4047	$Log_{10}C = 1.523\ Log_{10}Q_w - 0.3350\ Log_{10}Q_{wp} - 0.02512M - 0.01333T - 0.0003119i + 0.4130$
Elk Run near Mainesburg, Pa.	Growing	.4512	$Log_{10}Q_s = 2.526\ Log_{10}Q_w + 0.01692T - 0.4700\ Log_{10}Q_{wp} - 3.992$
	Growing	.3536	$Log_{10}C = 1.539\ Log_{10}Q_w + 0.01244T - 0.4220\ Log_{10}Q_{wp} + 0.2974Y - 0.0008764i - 17.17$
	Dormant	.4304	$Log_{10}Q_s = 2.601\ Log_{10}Q_w - 0.4186\ Log_{10}Q_{wp} - 0.01105M - 0.03088Y - 1.326$
	Dormant	.3883	$Log_{10}C = 1.654\ Log_{10}Q_w - 0.3786\ Log_{10}Q_{wp} - 0.04670Y - 0.01484M + 1.965$

Table 6.--Simple correlation coefficients and level of significance for daily water discharge of 10 cfs of greater, Corey Creek near Mainesburg, Pa., and Elk Run near Mainesburg, Pa., 1954-60

	i	$Log_{10} Q_{wp}$	T	$Log_{10} Q_s$	$Log_{10} C$	$Log_{10} Q_w$	Y
				COREY CREEK NEAR MAINESBURG, PA.			
				Growing season			
M	a/-0.2145	b/-0.1427	b/0.1414	b/0.1659	b/0.1934	0.09036	a/-0.2911
Y	a/.9968	d/.06951	a/-.3606	.01381	- .03971	b/.1556	
$Log_{10} Q_w$	b/.1639	a/.2893	a/-.2089	a/.7108	a/.3274		
$Log_{10} C$	-.02498	a/-.3150	c/.1382	a/.6849			
$Log_{10} Q_s$	.02691	c/-.1099	c/.1089				
T	a/-.3548	a/-.3734					
$Log_{10} Q_{wp}$	.05831						

Table 6.--Simple correlation coefficients and level of significance for daily water discharge of 10 cfs or greater, Corey Creek near Mainesburg, Pa., and Elk Run near Mainesburg, Pa., 1954-60--Continued

	i	Log_{10} Q_{wp}	T	Log_{10} Q_s	Log_{10} C	Log_{10} Q_w	Y
COREY CREEK NEAR MAINESBURG, PA.--Continued							
Dormant season							
M	d/-0.03077	0.006457	a/0.1450	a/-0.1063	c/-0.05871	0.002464	a/-0.2280
Y	a/ .9785	.05527	a/-.1902	- .05230	a/-.1362	b/.1047	
Log_{10} Q_w	a/.1061	a/.5189	a/.1374	a/.8142	a/.3919		
Log_{10} C	a/-.1544	a/.2026	b/.1028	a/.5397			
Log_{10} Q_s	b/-.07691	a/.3156	.03649				
T	a/-.1657	a/.1799					
Log_{10} Q_{wp}	.05525						

Table 6.--Simple correlation coefficients and level of significance for daily water discharge of 10 cfs or greater, Corey Creek near Mainesburg, Pa., and Elk Run near Mainesburg, Pa., 1954-60--Continued

	i	Log_{10} Q_{wp}	T	Log_{10} Q_s	Log_{10} C	Log_{10} Q_w	Y
			ELK RUN NEAR MAINESBURG, PA.				
			Growing season				
M	a/-0.2012	-0.09604	b/0.1950	b/0.1802	a/0.2367	c/0.1331	a/-0.2726
Y	a/.9972	c/.1192	a/-.4017	-0.02073	.0009311	.09970	
Log_{10} Q_w	d/.1101	a/.2917	a/-.2039	a/.8024	a/.5987		
Log_{10} C	.01864	a/-.2042	b/.1515	a/.9028			
Log_{10} Q_s	-.008495	-.04686	.06657				
T	a/-.3920	a/ -.3137					
Log_{10} Q_{wp}	c/.1137						

Table 6 .--Simple correlation coefficients and level of significance for daily water discharge of 10 cfs or greater, Corey Creek near Mainesburg, Pa., and Elk Run near Mainesburg, Pa., 1954-60--Continued

	i	Log_{10} Q_{wp}	T	Log_{10} Q_s	Log_{10} C	Log_{10} Q_w	Y
ELK RUN NEAR MAINESBURG--Continued							
Dormant season							
M	a/-0.1424	-0.02879	a/0.1574	-0.05645	-0.007384	-0.03485	a/-0.3461
Y	a/.9777	a/.1229	b/-.1093	a/.1394	b/.08864	a/.2009	
Log_{10} Q_w	a/.2003	a/.5007	-.005353	a/.8781	a/.6785		
Log_{10} C	b/.09110	a/.2356	.05832	a/.8390			
Log_{10} Q_s	a/.1320	a/.3002	-.007093				
T	c/-.07878	.02295					
Log_{10} Q_{wp}	a/.1185						

a/ Significant at 0.01 level.
b/ Significant at 0.05 level.
c/ Significant at 0.10 level.
d/ Absence of a qualifying note indicates level of significance at greater than 0.10.

Analysis of storm data - 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 storm events. These analyses were performed on data representing 21 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:

Dependent variable

$\log_{10} C_w$ and $\log_{10} C_{w_1}$ = Logarithm of mean water-weighted sediment concentration for daily and intermittent stations respectively, computed as

$$C_w = \frac{Q_s}{Q_{w_t} \cdot K}$$

where

Q_s = storm sediment load, in tons

Q_{w_t} = total storm runoff, in cfs-days

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

Independent variables

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

$Log_{10}Q_{wd}$ and $Log_{10}Q_{wd_1}$ = logarithm of direct storm runoff ($Q_m - Q_b$) for daily and intermittent stations respectively, in cfs-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.)

$Log_{10}R_q$ = logarithm of rainfall quantity during storm period, in inches

$Log_{10}R_i$ = 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 $\frac{Q_p - Q_b}{Q_m - Q_b}$

where

Q_m = time-weighted mean storm runoff, in cfs

Q_b = base flow, in cfs

Q_p = instantaneous peak runoff, in cfs

Suspended-sediment concentration, rather than discharge was used because the length of storms varied. Water-weighted sediment concentration provided a more direct comparison between storms, 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 antecedent temperature conditions prior to a storm runoff were significant. Two periods of antecedent air temperature were considered, to determine how long before the storm the temperature conditions were related to the sediment discharge. 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 computer operations.

The most efficient equations are shown in the following table:

Station	Standard error (Log_{10} units)	Equation
Corey Creek near Mainesburg, Pa.	0.3883	$Log_{10}C_w = 0.5129\ Log_{10}Q_{wd} + 0.00701\ T_{a_1} + 0.8542$
Corey Creek at Mainesburg, Pa.	.3699	$Log_{10}C_{w_1} = 0.3197\ Log_{10}Q_{wd_1} - 0.008204\ M_t + 0.9374\ Log_{10}(100R_q) + 0.1017\ P_1 + 0.5439$

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 a more significant measure of season than was the antecedent air temperature, 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; the average peakedness factor being 4.3, while the average was 3.5 at the downstream (daily) station.

The simple correlation coefficients between all variables and the levels of significance are shown in table 3.

Table 7.--Simple correlation coefficients and level of significance for storm data, Corey Creek near Mainesburg, Pa., and Corey Creek at Mainesburg, Pa., 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	$Log_{10}Q_{wd}$
$Log_{10}C_w$	d/-0.0008376	a/0.5963	b/0.4524	0.1822	0.3469	0.2173	-0.1886	-0.1391	0.2464	a/0.5681
$Log_{10}Q_{wd}$	-.2434	a/.9311	c/.3921	-.03131	c/.3713	-.003887	a/-.5878	a/-.5625	.06269	
M_t	.1068	-.08262	-.1682	.08567	.05005	-.2625	-.02669	-.04828		
T_{a_1}	.3245	b/-.4571	.1641	.2218	.2792	c/.3930	a/.9563			
T_{a_2}	.2869	b/-.4695	.1305	.2142	.3131	b/.4340				
$Log_{10}(100R_i)$	.1719	.03321	b/.4684	c/.4214	a/.5510					
$Log_{10}(100R_q)$	.03058	c/.3951	a/.6881	.1569						
P	a/.8126	-.07281	b/.4501							
$Log_{10}C_{w_1}$	.2718	c/.4129								
$Log_{10}Q_{wd_1}$	-.3262									

a/ Significant at 0.01 level.
b/ Significant at 0.05 level.
c/ Significant at 0.10 level.
d/ Absence of a qualifying rate indicates significance at a lever greater than 0.10.

Size Distribution of Suspended Sediment

Size distribution of the suspended sediment is an important characteristic measured during the study. The proportion of sand, silt, and clay being carried by the stream gives some indication of the type of soil being eroded. Significant changes in these proportions might also be indicative of changing basin conditions. Figure 11 shows the proportion of sand, silt, and clay as percent of the total sediment weight in samples from the two basins. Most of the suspended samples contain more than 50 percent silt. The dashed line in figure 11 indicates the boundaries of 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 analyses correspond to this soil class.

Differences between the two basins appear in 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 relationships can be developed by combining the analyses from the two basins.

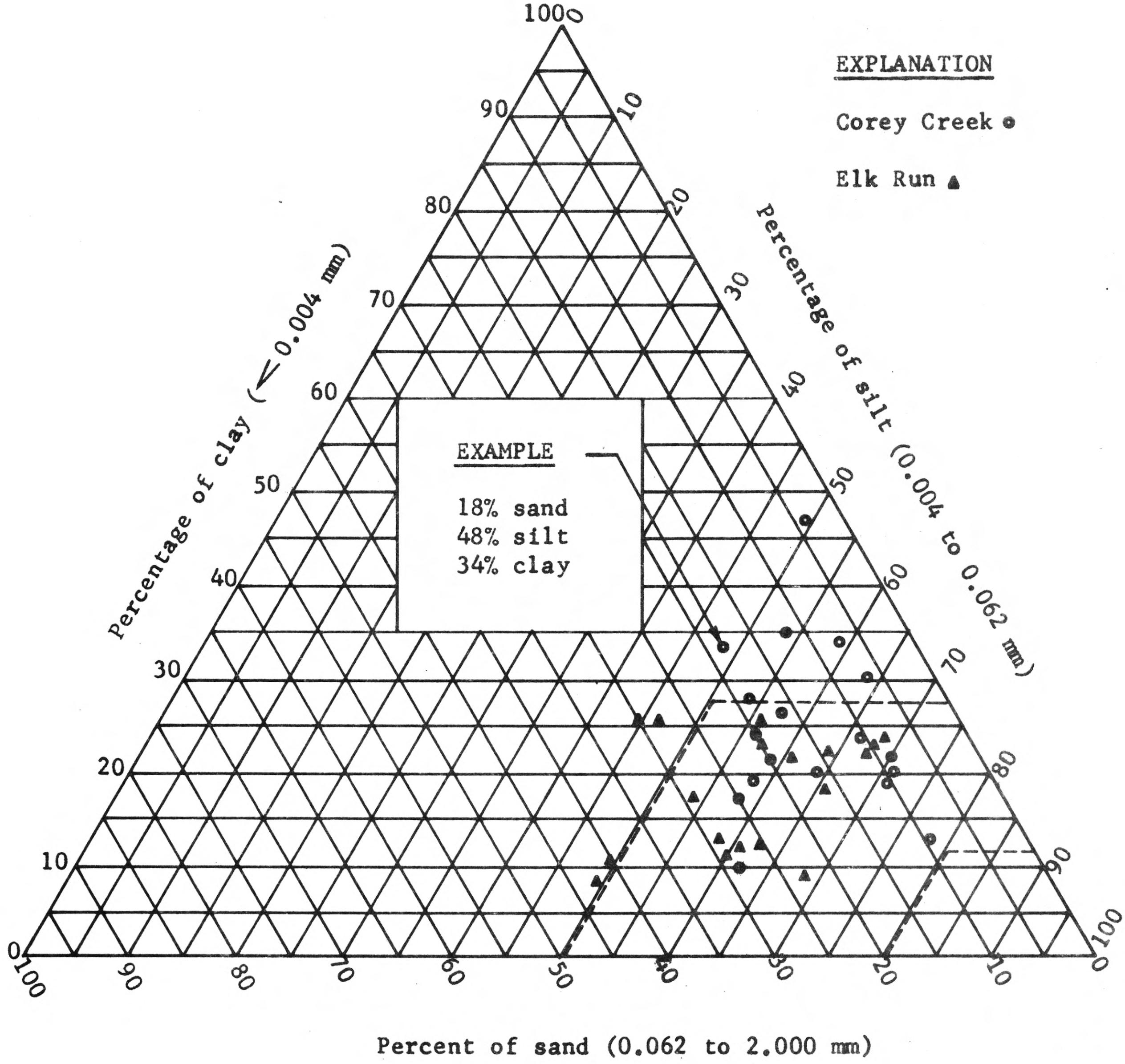


Figure 11.--Percentages of sand, silt, and clay in suspended-sediment samples, Corey Creek and Elk Run near Mainesburg, Pa., 1955-60.

The minimum water discharge represented by the data is relatively high, being a factor of about 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 12 shows the 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 sand sediment-transport curve may be caused by the immediate availability of sand-size sediment in the stream channel, or it may be a result of sand being deposited near the stream channel during the smaller runoff events.

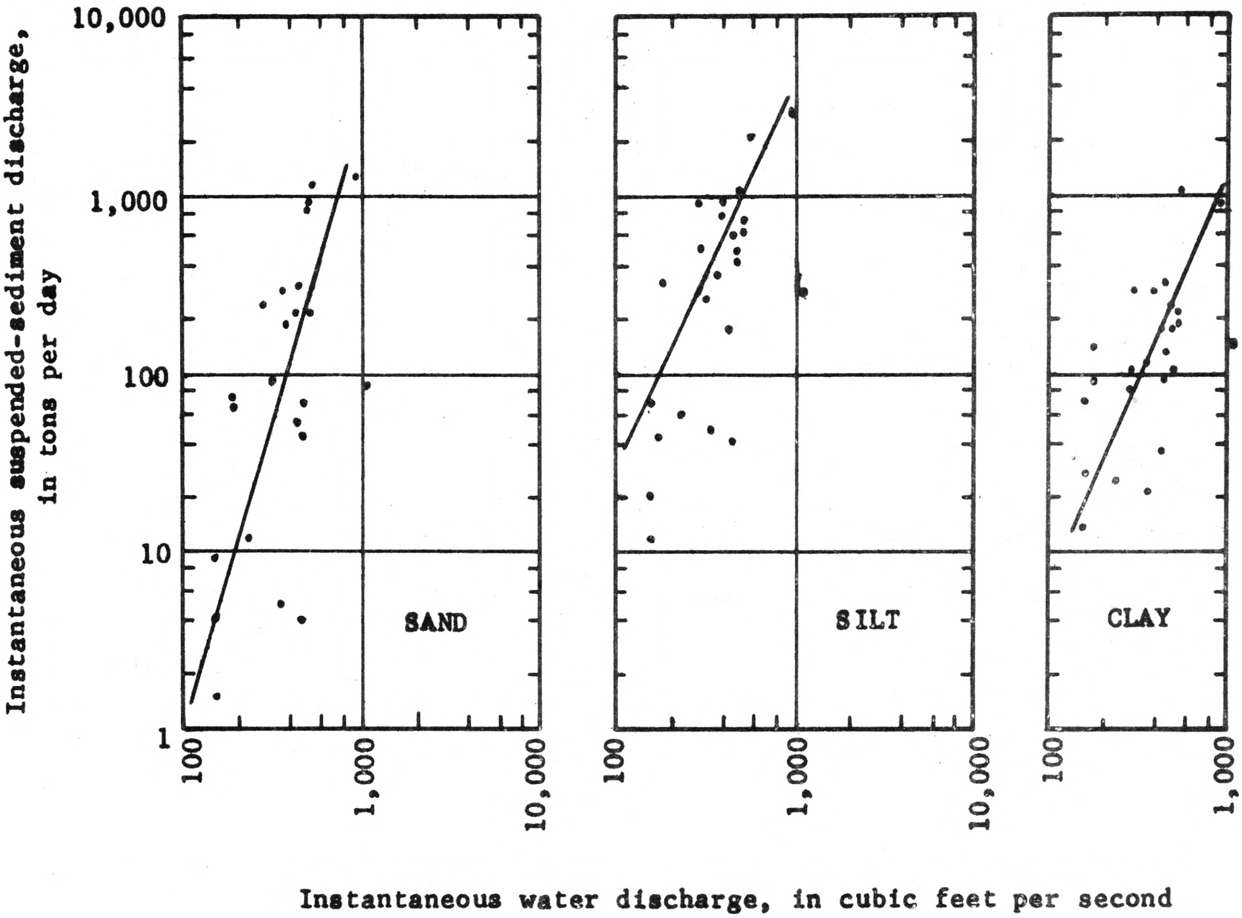


Figure 12.--Relation of the sand, silt, and clay discharge to instantaneous water discharge for Corey Creek and Elk Run near Mainesburg, Pa., 1955-60.

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 stream banks, with the addition or removal of material of sand size or finer. Undercutting and slumping of stream banks are commonly observed in both basins. Changes in bed elevation generally have been very slight, and in those cases where the bed elevation has changed, it usually has been as a result of filling rather than scouring.

In Elk Run, changes at the cross sections were almost evenly divided between scour and fill. Table 8 summarizes the results of the surveys for both basins. The locations of these ranges are shown in figure 1. Range No. 5 in Elk Run basin is located 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 13.

In both stream channels, the bed is composed mostly of material gravel size (2.0 - 64 mm) or larger. (Fig. 14.) The range data indicate that there has been very little redistribution of this material within the measured cross sections.

Table 8.--Changes in cross-sectional area of aggradation-degradation ranges, Corey Creek and Elk Run, 1954-60

Range No.	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

Table 8 .--Changes in cross-sectional area of aggradation-degradation ranges, Corey Creek and Elk Run, 1954-60--Continued

Range No.	Scour (sq ft)		Fill (sq ft)	
	Net change	Average annual change	Net change	Average annual change
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

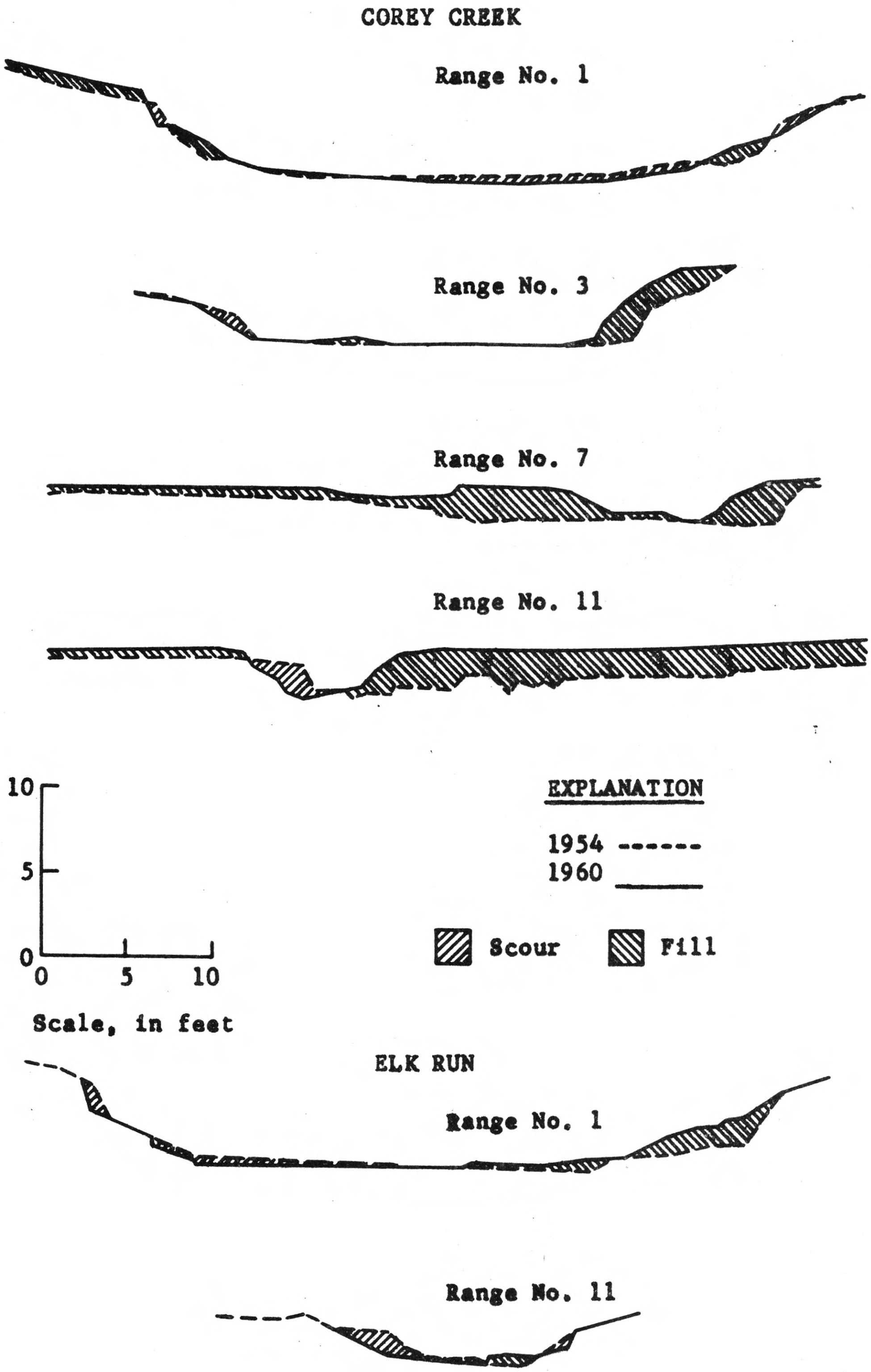


Figure 13.--Changes in stream cross sections at selected ranges in the Corey Creek and Elk Run basins, 1954-60.

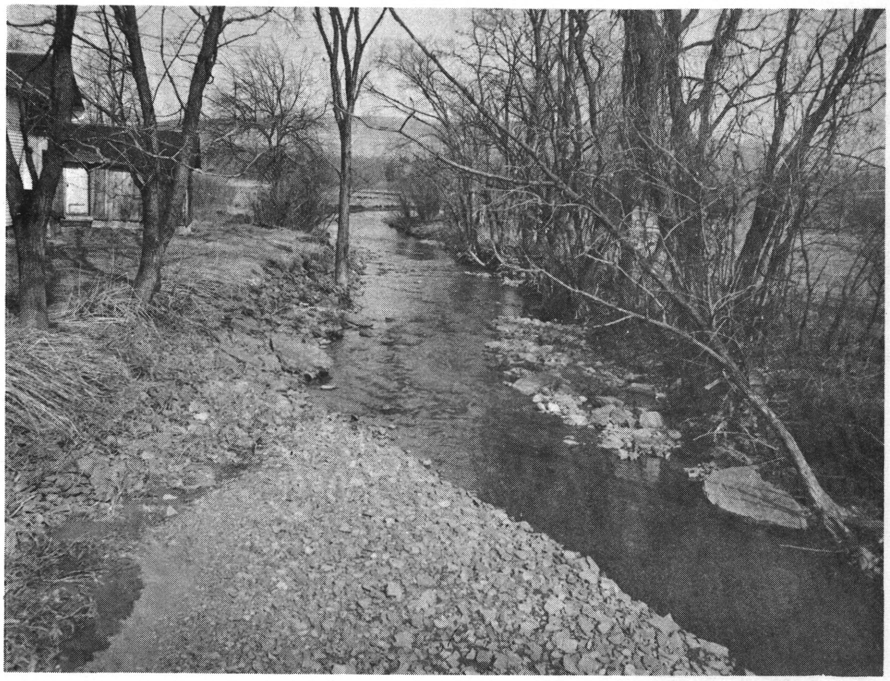


Figure 14.--Elk Run, showing bed material typical of both stream channels. Note undercutting of trees on right bank.

Figure 15 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 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 - Corey Creek Basin

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

Two different 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. 16). 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. 17) then was used with a cumulative sediment discharge frequency curve (fig. 18) to compute an average-annual sediment discharge.

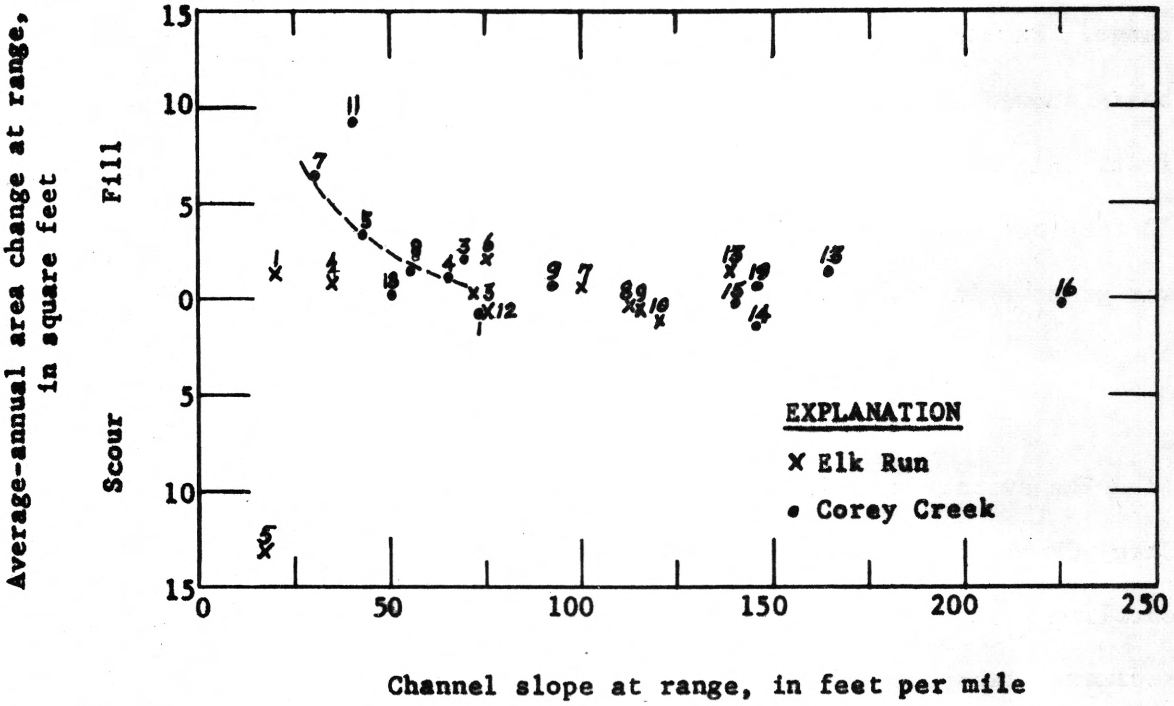


Figure 15.--Relation between average-annual scouring or filling and stream slope at Corey Creek and Elk Run aggradation-degradation ranges, 1954-60.

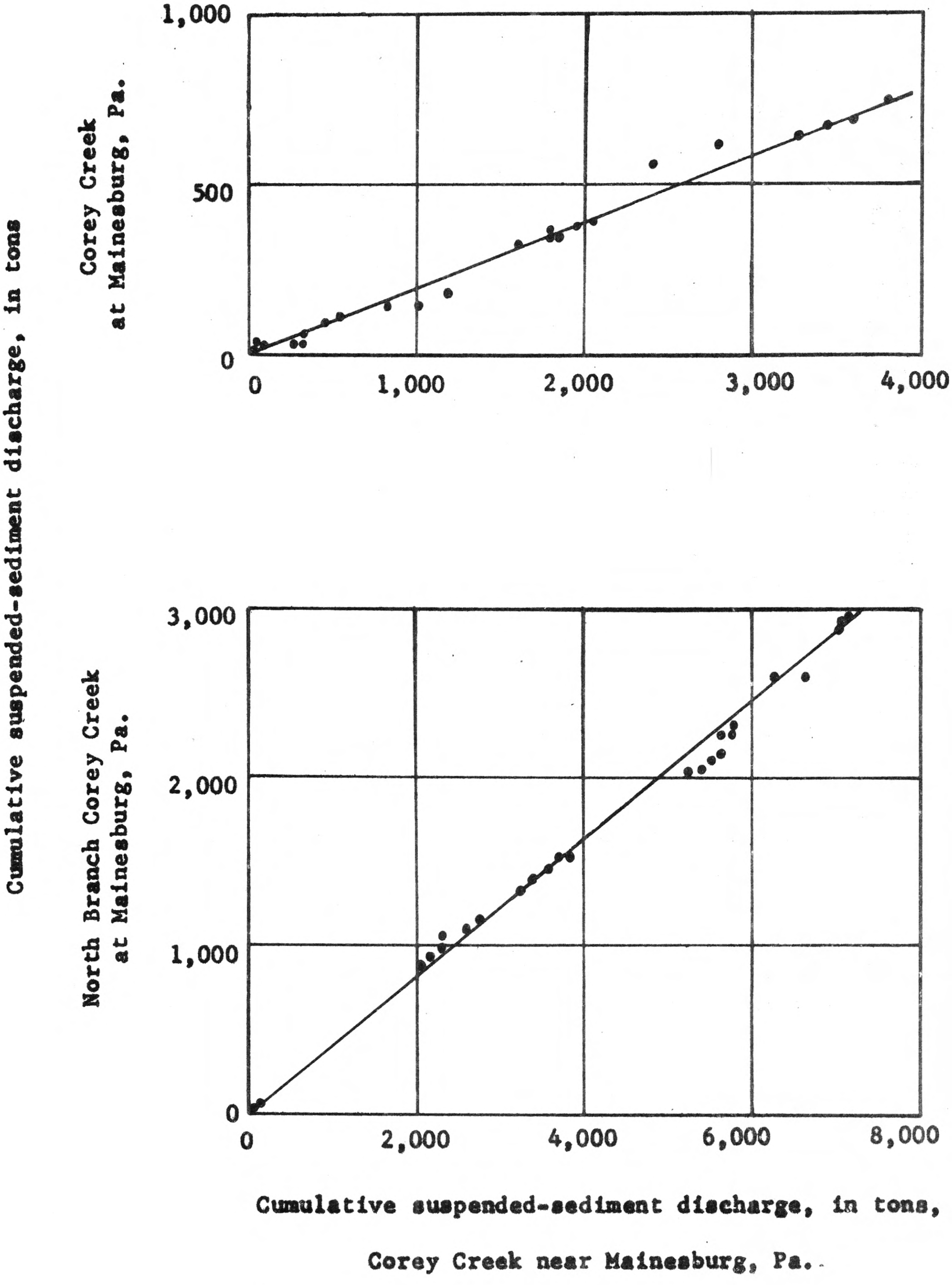


Figure 16.--Double-mass comparisons of storm suspended-sediment discharges from the Corey Creek basin with storm suspended-sediment discharges from the Corey Creek subbasins.

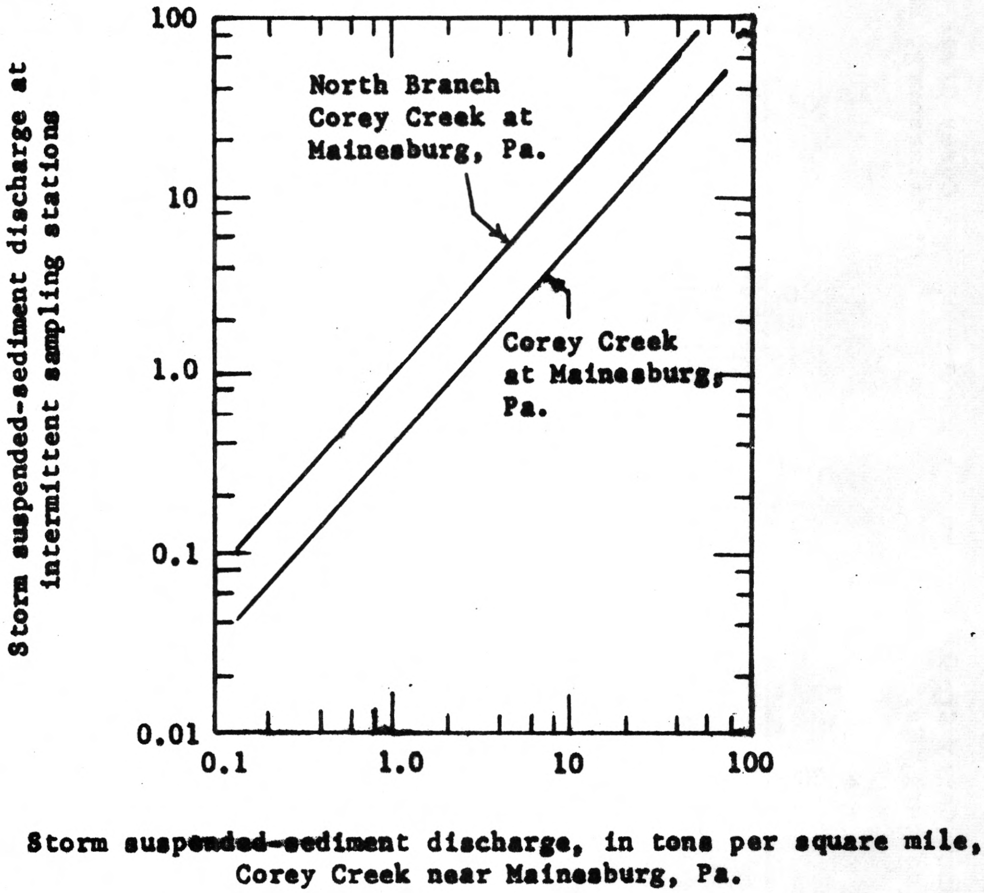


Figure 17.--Relation between storm-suspended-sediment loads for daily station and intermittent stations, Corey Creek basin, 1954-60.

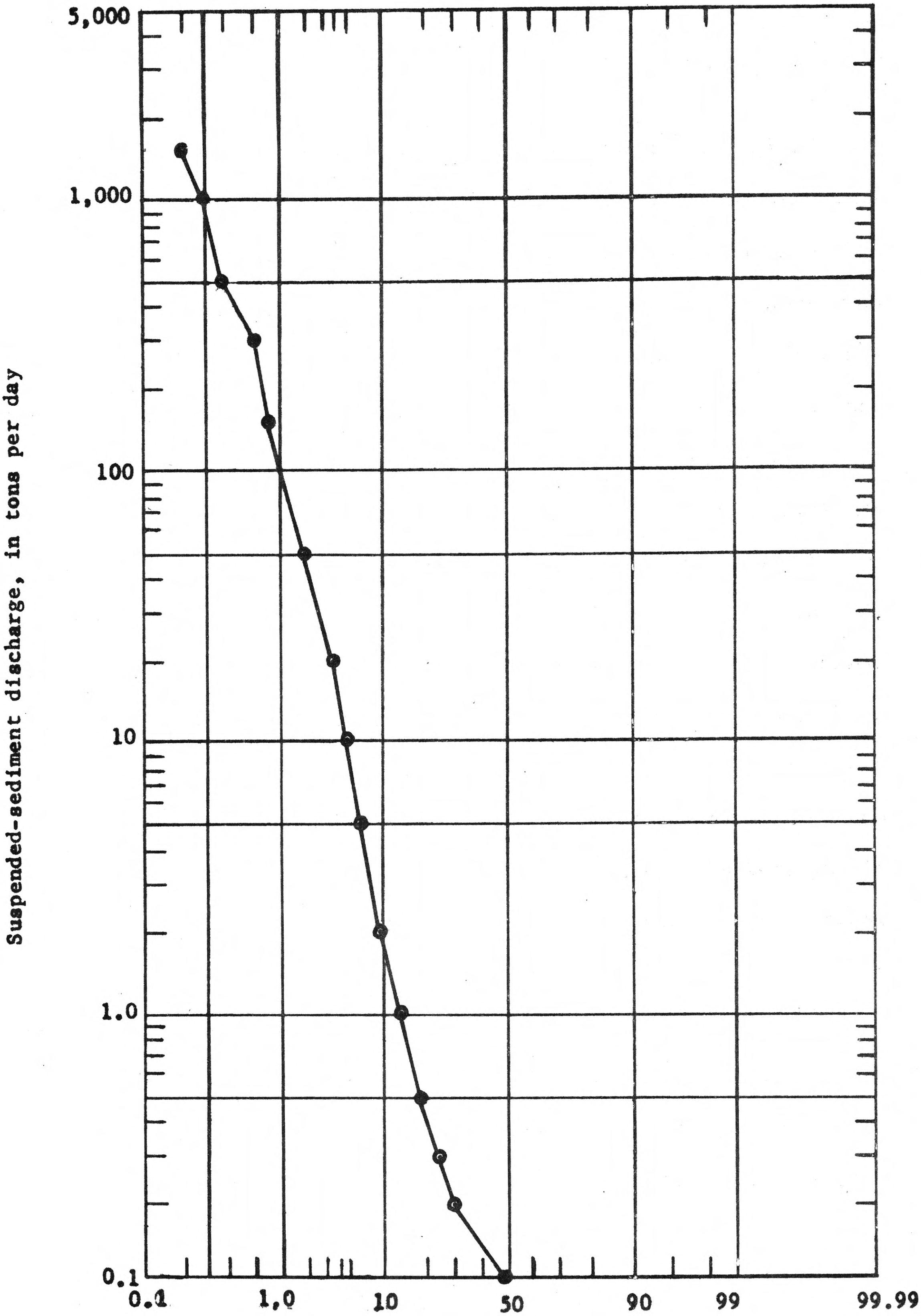


Figure 18.--Cumulative frequency curve of daily suspended-sediment discharge, Corey Creek near Mainesburg, Pa., October 1954-September 1960.

Table 9 shows this method of calculation. Percent intervals were selected from figure 18 and the sediment discharges corresponding to the mid-ordinate of the percent intervals were tabulated. The corresponding values of sediment discharge for the intermittent stations were then read from the curves in figure 17 and tabulated. Each of these was then multiplied by the percent interval. The sum of the products was the mean daily sediment discharge, which was multiplied by 365 to obtain the annual sediment discharge.

Table 10 compares the suspended-sediment discharges computed by the two methods. Results compare within a few percent. The computed sediment discharge from the remaining portion of the basin is the difference between the measured basin discharge and the sum of the computed subbasin discharges. This portion of the basin includes most of the urban land in the basin, 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, Pa.) were not used in this preliminary evaluation, but its drainage area is included in the area of the largest intermittent station (Corey Creek at Mainesburg, Pa.).

Table 9.--Computation of average-annual suspended sediment discharges, Corey Creek near Mainesburg, Pa., Corey Creek at Mainesburg, Pa., and North Branch Corey Creek at Mainesburg, Pa., 1954-60

Percent limits	Percent interval	Percent mid-ordinate	Suspended-sediment discharge (tons/day)			Suspended-sediment discharge (tons/day) x percent interval		
			Corey Creek near Mainesburg, Pa.	Corey Creek at Mainesburg, Pa.	North Branch Corey Creek at Mainesburg, Pa.	Corey Creek near Mainesburg, Pa.	Corey Creek at Mainesburg, Pa.	North Branch Corey Creek at Mainesburg, Pa.
0 - 0.1	0.1	0.05	1,450	710	345	1.45	0.71	0.34
.1 - .2	.1	.15	740	330	165	.74	.33	.16
.2 - .3	.1	.25	430	180	90	.43	.18	.09
.3 - .5	.2	.4	330	135	70	.66	.27	.14
.5 - .7	.2	.6	200	77	41	.40	.15	.08
.7 - 1.0	.3	.85	130	48	26	.39	.14	.08
1.0 - 3.0	2.0	2	44	14	8	.88	.28	.16
3.0 - 5.0	2.0	4	14	5.5	2.4	.28	.11	.05
5.0 - 7.0	2.0	6	6.4	1.2	1.0	.13	.02	.02
7.0 - 10.0	3.0	8.5	2.7	.6	.4	.08	.02	.01
10.0 - 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, in tons						5.57	2.22	1.14
Mean annual discharge, in tons (daily x 365)						2,030	806	416

Table 10.--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/sq.mi.)	
		Double-mass curve method	Suspended-sediment duration curve method	Double-mass curve method	Suspended-sediment duration curve method
Corey Creek near Mainesburg, Pa.	12.2	--	1,990	--	163
Corey Creek at Mainesburg, Pa.	8.44	800	810	95	96
North Branch Corey Creek at Mainesburg, Pa.	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. Because of this, 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.

Elk Run basin received considerably less conservation treatment. Suspended-sediment data from this basin provide the best available estimate of the sediment-discharge rate under relatively undisturbed conditions. In the following trend analyses the Elk Run data were used to adjust the Corey Creek data.

Double-mass curves were developed in order to detect any change in the rate of suspended-sediment discharge from the two basins. Figure 19 is a double-mass plot of runoff and suspended-sediment discharge at both stations. The curves indicate a higher suspended-sediment discharge per unit water discharge for Corey Creek than for Elk Run during the first half of the record. During the last half of the record, the suspended-sediment discharge bore about the same relation to water discharge in both basins.

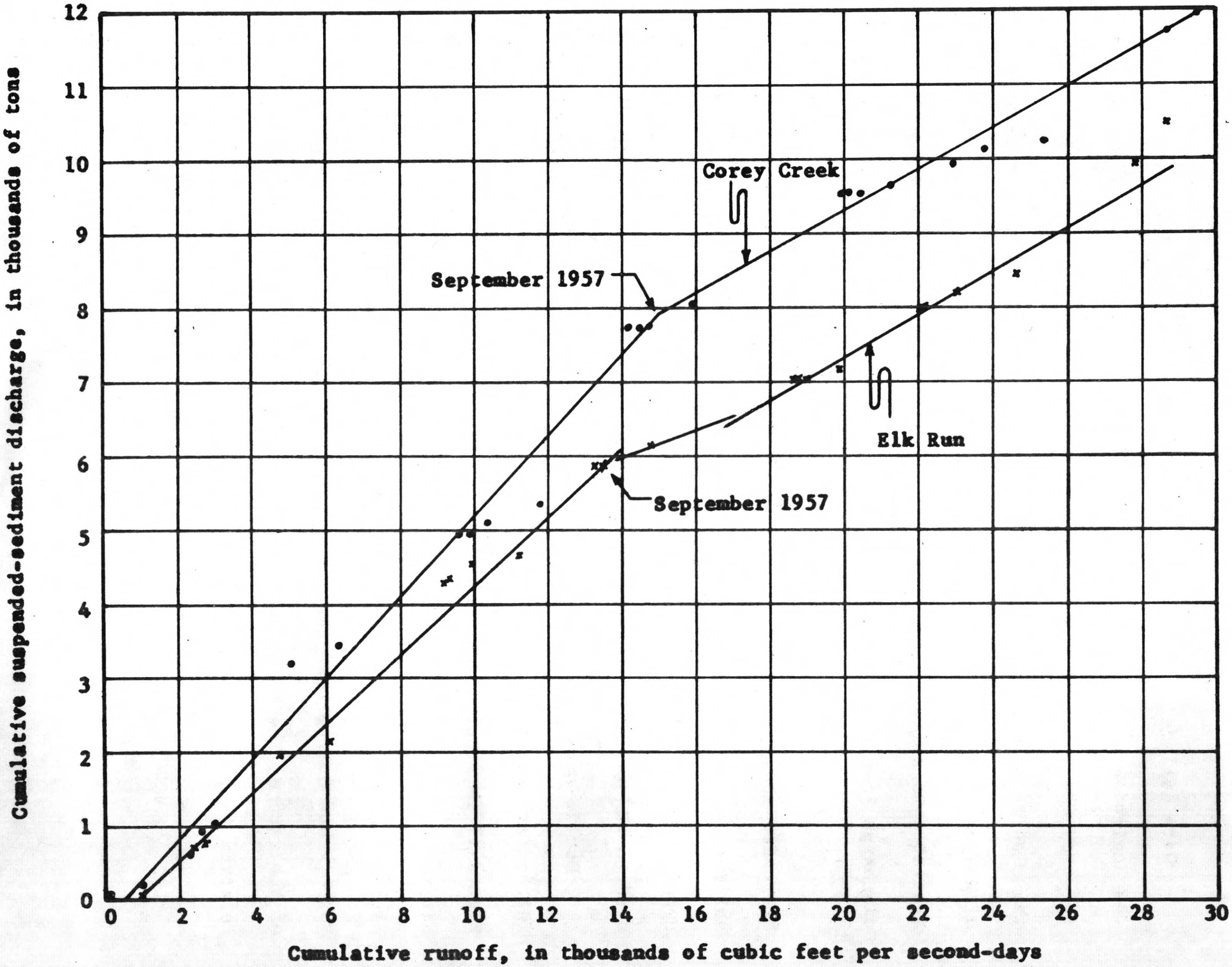


Figure 19.--Double-mass relations of runoff and suspended-sediment discharge for Corey Creek and Elk Run near Mainesburg, Pa., October 1954-September 1960.

The change in slope of the curves indicates a 49 percent decrease in suspended-sediment discharge from Corey Creek basin and a 38 percent decrease from Elk Run basin. Using the Elk Run basin as the standard for comparison, the net relative decrease in sediment discharge for Corey Creek was 11 percent.

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

The curves in figure 20 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.

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.

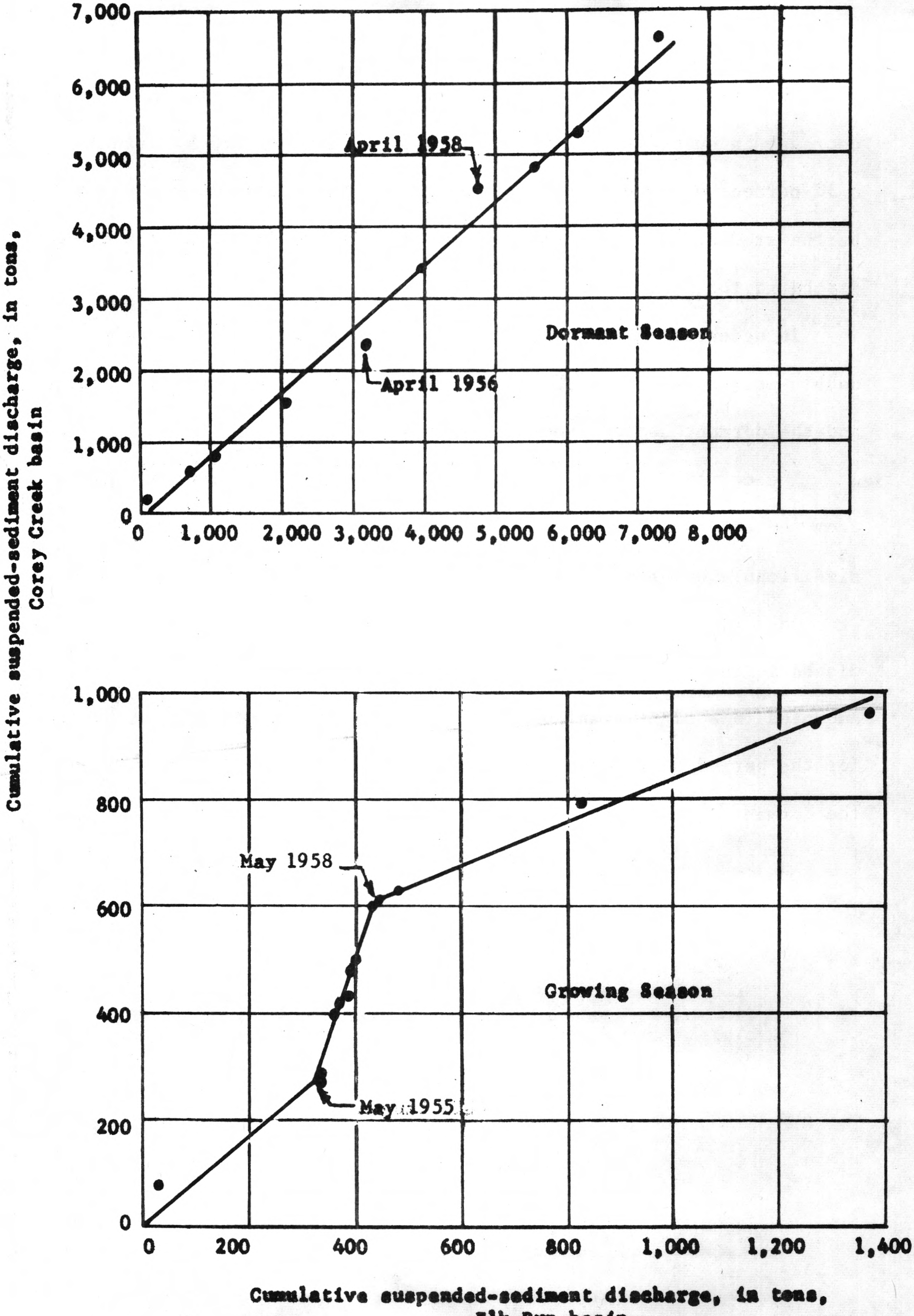


Figure 20.--Double-mass comparisons of monthly sediment discharge for growing and dormant seasons, Corey Creek near Mainesburg, Pa., versus Elk Run near Mainesburg, Pa., May 1954-September 1960.

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

Period	Average slope of double-mass curve (percent)
May 1954-May 1955	83
June 1955-May 1958	290
June 1958-September 1960	41

Comparison of the slope of the curve for the May 1954-May 1955 period with the slope for the June 1958-September 1960 period indicates a relative decrease in sediment discharge from the Corey Creek basin of 51 percent. Approximately 25 percent of the total suspended-sediment discharge from 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, 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 of these techniques required a numerical evaluation of the effects of changing land use and agronomic practices.

The changes taking place in the basins are of two general kinds: (1) changes in the type and density of soil cover, and (2) changes in the physical or topographic characteristics of the land.

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

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:

$$E_R = F_e \times \frac{\%}{100}$$

where E_R is the relative erosion potential, F_e is the relative erosion factor, and % 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:

Year	Relative erosion potential	
	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 would theoretically occur if the forces causing erosion were constant with time. But 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 during the same period. This is another way of expressing the mean annual slope of the growing season double-mass curve. These factors are given in the following table:

Year	Growing season suspended sediment discharge ratio $\frac{\text{Corey Creek basin}}{\text{Elk Run basin}}$
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 effect both the cover conditions and the relations between precipitation, runoff, and sediment discharge.

Figure 21 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 were also considered.

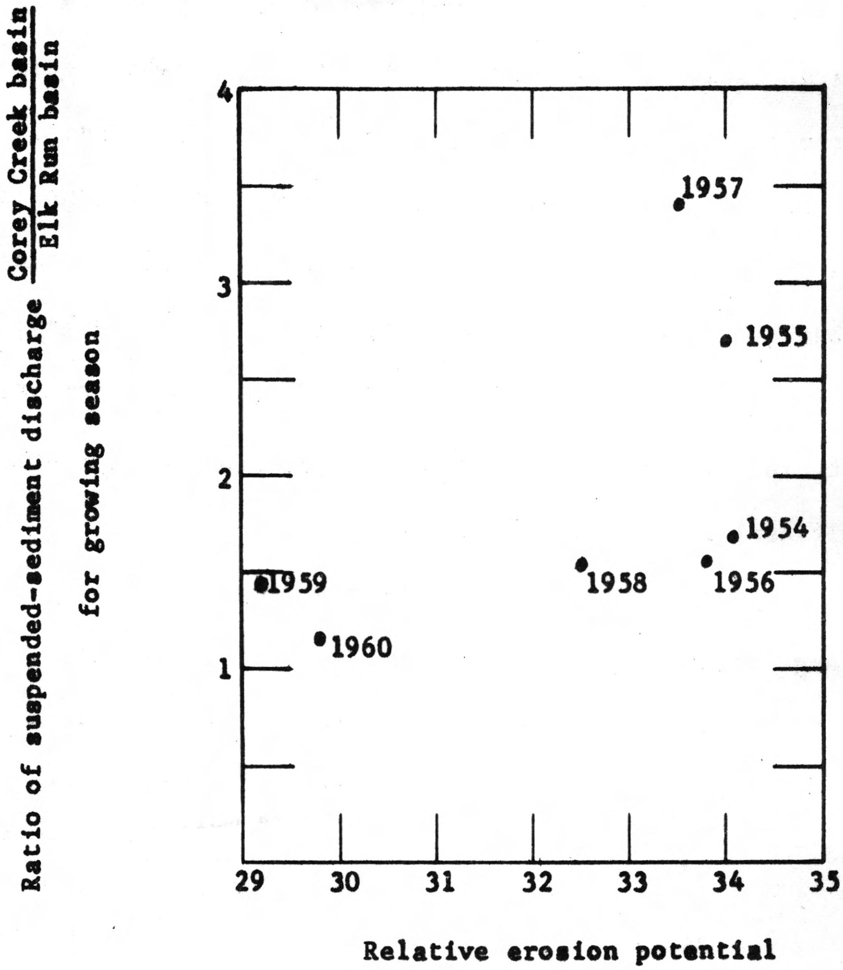


Figure 21.--Relation of relative erosion potential to Corey Creek/Elk Run sediment-discharge ratio, 1954-60 growing seasons.

Effects of Diversion Terrace Construction

The changes next considered were those associated with engineering practices. More diversion terraces were installed than any other engineering practice. In the Corey Creek basin, 163,000 feet of diversion terraces were constructed between 1953 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 of them were constructed for the purpose of improving the drainage characteristics of those soils having impermeable substrata. By constructing the terrace so as to intersect these substrata, drainage of the surface soil above the terrace is more rapid. Interception of the water by the terraces also decreases the amount of water reaching the lower portions of the slope. The area immediately below each terrace receives the most benefit from this treatment, and often the effect extends for one-third of the way down the slope. The improved drainage may allow a more deeply-rooted type of vegetation to be grown on this portion of the slope, and this, 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. In most cases, 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 disturbed during terrace construction. (Fig. 22.)

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 portion the erosion factor became 100. The increase in erosion potential caused by this soil disturbance was:

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

or approximately 50 percent.

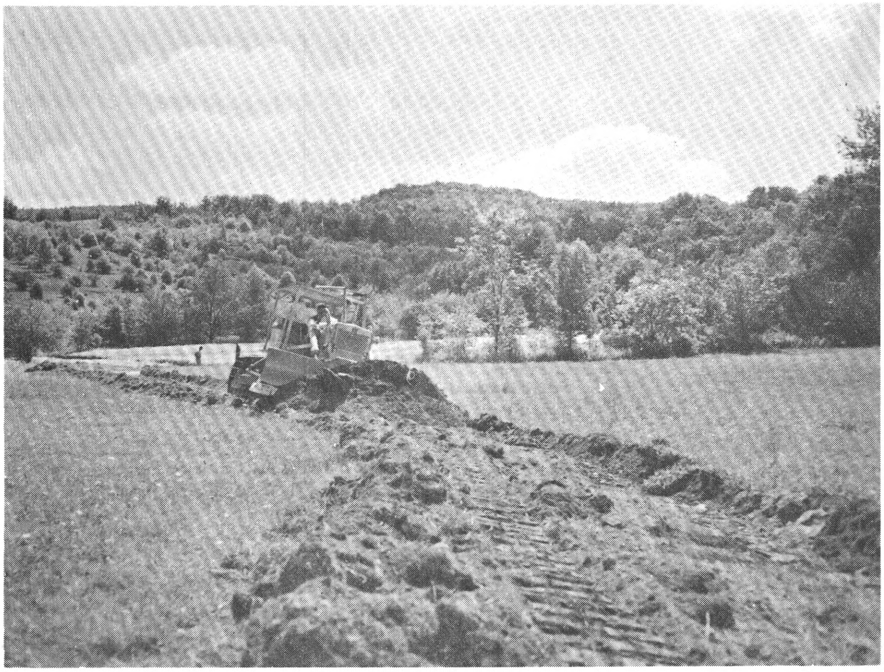


Figure 22.--Construction of a diversion terrace in the Corey Creek basin.

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

$$E_R = 1 - 0.65\left(\frac{1{,}600^{.6} - 400^{.6}}{1{,}600^{.6}}\right) = 0.72$$

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 23 represents 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 it is 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, continued decreases are shown as taking place only during the growing seasons. In the figure, it is assumed that the terraces were constructed during May, the beginning of the growing season. In order to use the curve for June, it must be shifted so that the curve intersects the vertical line representing June at the 1.50 line.

An example (page 87) will show 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; and that the average drainage area is 9 acres per 1,000 linear feet of terrace, with a total basin area of 12.2 square miles, or 7,808 acres.

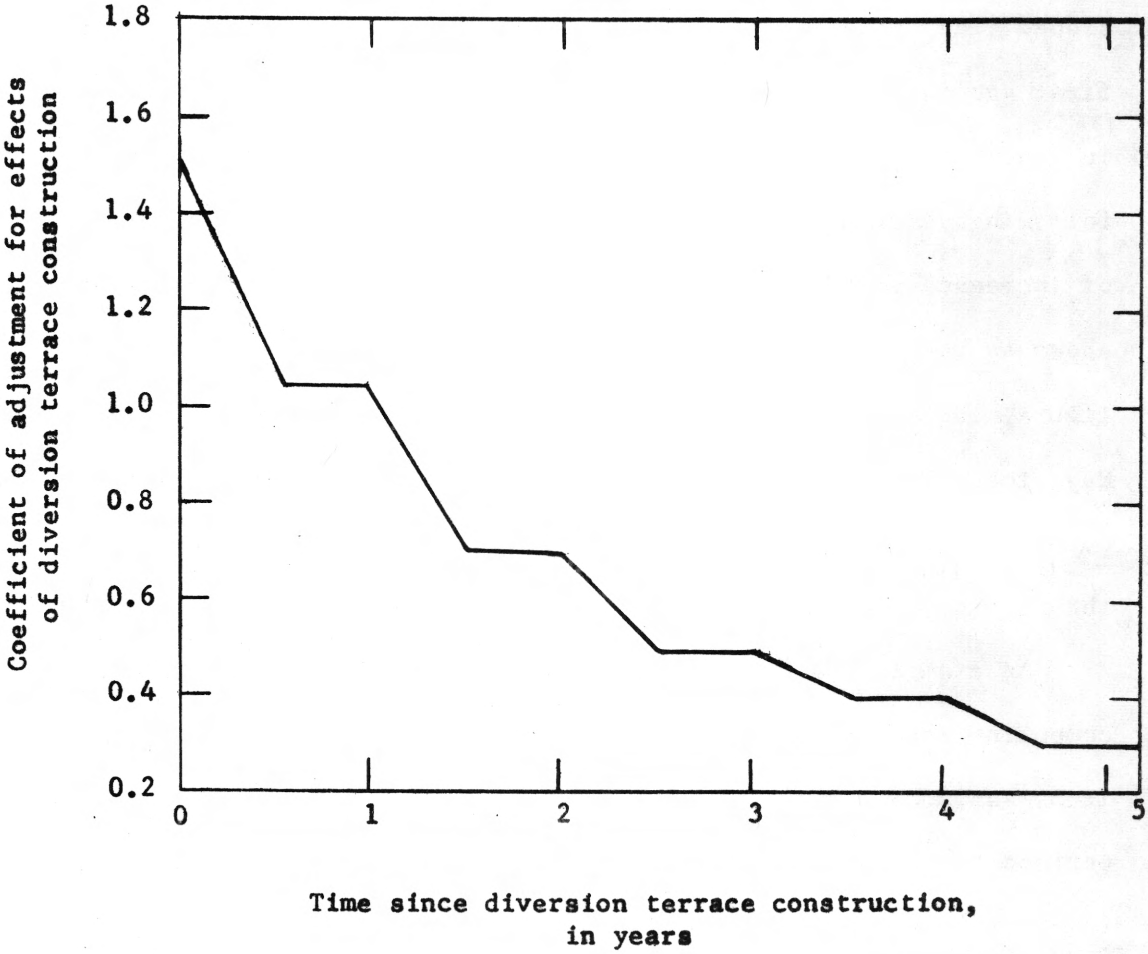


Figure 23.--Adjustment for the change in erosion potential produced by diversion terrace construction.

Date of construction	Terraces constructed (ft.)	Basin area affected		Adjustment coefficient	Adjustment coefficient times percent of basin affected
		Acres	Percent		
May, 1st year	10,000	90	1.2	1.50	1.8
May, 2nd year	14,000	126	1.6	1.50	2.4
May, 3rd year	9,000	81	1.0	1.50	1.5

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:

		Terrace construction during: 1st year	2nd year	3rd year	Σ Percent of basin X coefficient	Cumulative percent of basin affected
Values of coefficients	1st year	1.8	--	--	1.8	1.2
	2nd year	1.3	2.4	--	3.7	2.8
	3rd 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. For example: If, for the third year, the relative erosion potential were 35.0, the adjustment applied would be

$$35\left(\frac{4.0 - 3.8}{100}\right) = 0.12$$

and the adjusted value would be 35.1.

Figure 24 presents the results of such computations for the Corey Creek basin. The vertical distance between the two curves in the figure is the adjustment to be applied to the relative erosion potential, in percent. 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 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 became negative, causing a progressive decrease in the erosion potential. The adjustment factor is projected through 1964 based on the average construction rate in 1959-60.

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

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

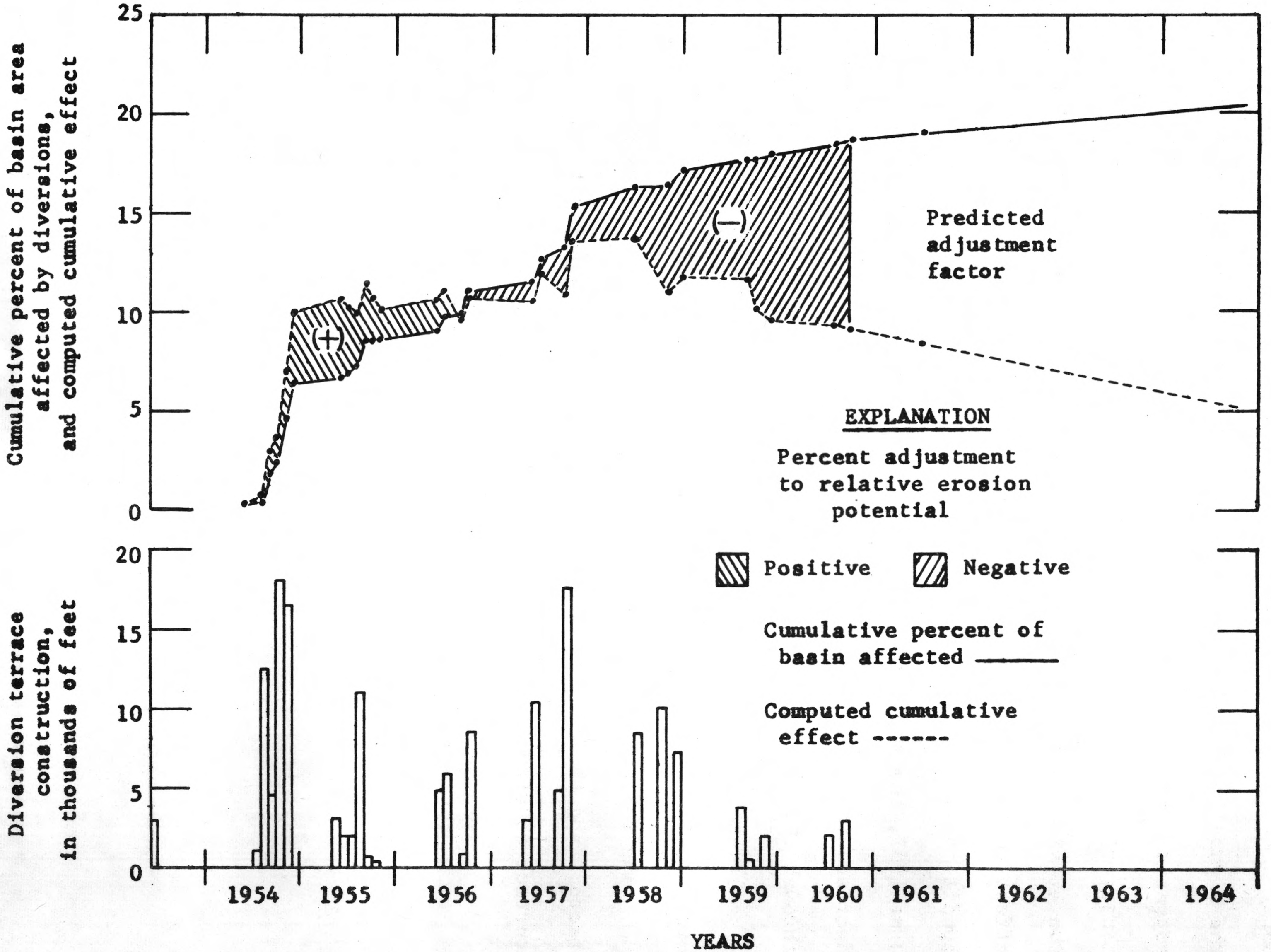


Figure 24.--Time distribution of diversion terrace construction and the computed effect of diversion terrace construction for Corey Creek basin, 1953-60.

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	-0.56	33.3
1958	-1.86	32.9
1959	-5.59	27.6
1960	-7.76	27.5

Figure 25 is a plot of the adjusted relative erosion potential against the Corey Creek/Elk Run sediment ratio. The rank-correlation coefficient is 0.71, and it 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 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 25 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.

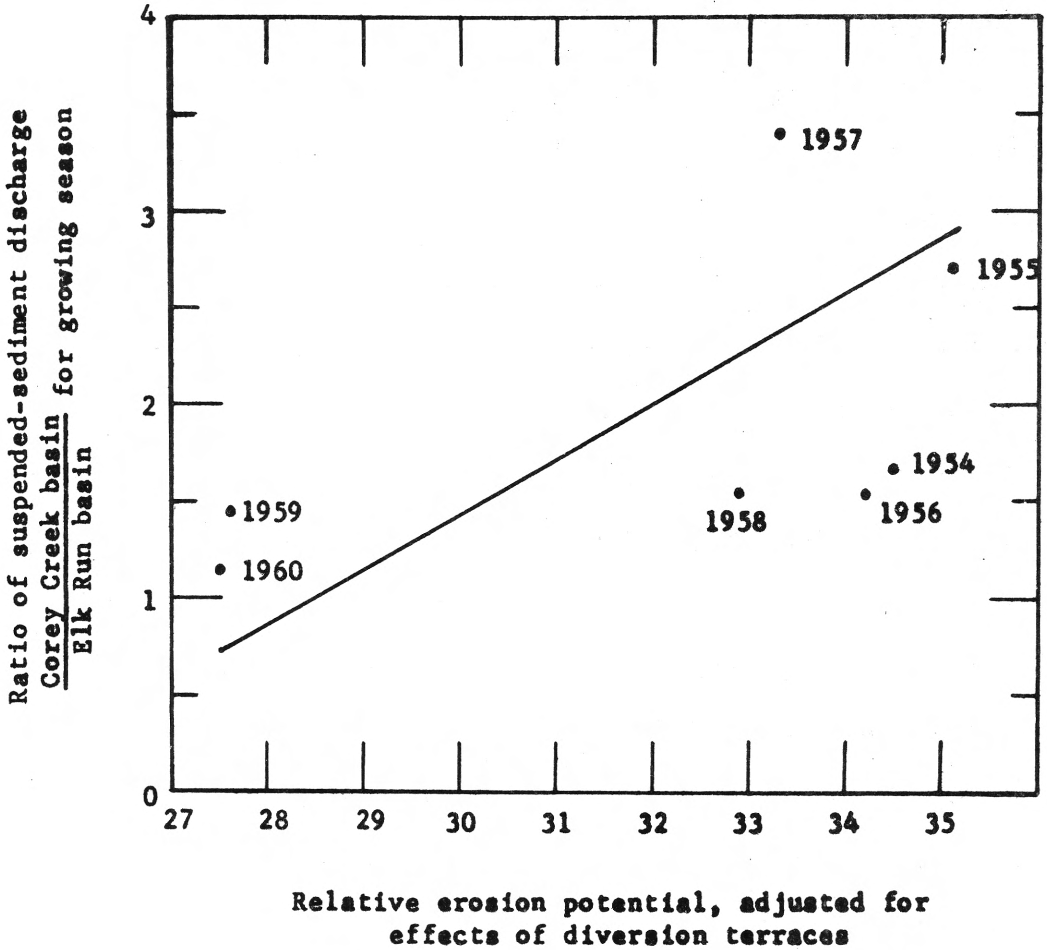


Figure 25.--Adjusted relative erosion potential versus the ratio of Corey Creek suspended-sediment discharge to Elk Run suspended-sediment discharge, 1954-60 growing seasons.

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 above equation, 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 necessary to (1) evaluate the suitability of the water for various uses, (2) estimate the behavior of the sediment under different hydrologic conditions, and (3) estimate the magnitude of the chemical weathering and erosion.

The waters of Corey Creek and Elk Run are similar in chemical composition and in total amount of dissolved solids (see table 11). 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 derived from precipitation is normally low in dissolved solids, and it dilutes the water in the stream to a lower dissolved-solids concentration.

Table 11.--Chemical analyses of water, Corey Creek and Elk Run near Mainesburg, Pa., 1956-61

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2) (ppm)	Iron (Fe) (ppm)	Calcium (Ca) (ppm)	Magnesium (Mg) (ppm)	Sodium (Na) (ppm)	Potassium (K) (ppm)	Bicarbonate (HCO_3) (ppm)	Sulfate (SO_4) (ppm)	Chloride (Cl) (ppm)	Fluoride (F) (ppm)	Nitrate (NO_3) (ppm)	Dissolved solids (residue on evaporation at 180°C) (ppm)	Hardness as $CaCO_3$: Calcium, magnesium (ppm)	Hardness as $CaCO_3$: Noncarbonate (ppm)	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

Table 11.--Chemical analyses of water, Corey Creek and Elk Run near Mainesburg, Pa., 1956-61--Continued

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2) (ppm)	Iron (Fe) (ppm)	Calcium (Ca) (ppm)	Magnesium (Mg) (ppm)	Sodium (Na) (ppm)	Potassium (K) (ppm)	Bicarbonate (HCO_3) (ppm)	Sulfate (SO_4) (ppm)	Chloride (Cl) (ppm)	Fluoride (F) (ppm)	Nitrate (NO_3) (ppm)	Dissolved solids (residue on evaporation at 180°C) (ppm)	Hardness as $CaCO_3$: Calcium, magnesium (ppm)	Hardness as $CaCO_3$: Noncarbonate (ppm)	Specific conductance (micromhos at 25°C)	pH	Color
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 26. The average curve has a negative slope, showing that dissolved-solids concentration decreases as water discharge increases.

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 26. These curves and flow-duration curves were used to compute the average-annual discharge of dissolved solids and the data in the following table. The results indicate that the average-annual

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

dissolved solids discharge is approximately one-half the average-annual suspended sediment discharge.

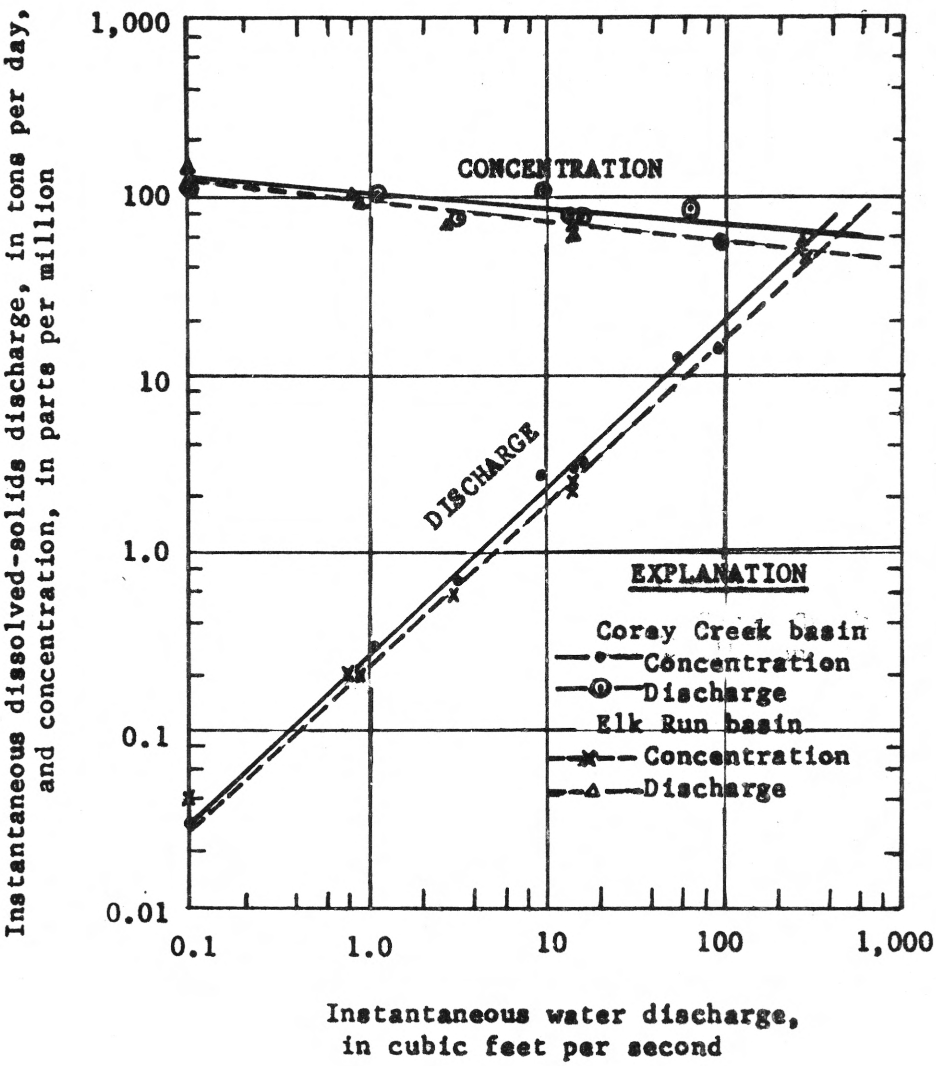


Figure 26.--Relation of instantaneous water discharge to concentration and discharge of dissolved solids, Corey Creek and Elk Run near Mainesburg, Pa., June 1956-October 1961.

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 a current is dependent upon the concentration of dissolved solids present in the water; therefore, specific conductance can be used as an indirect method of determining dissolved-solids content. Figure 27 is the relation of specific conductance to dissolved-solids concentration, and to hardness. Dissolved-solids content or 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 28 can be used to estimate the specific conductance (and thus, the dissolved-solids concentration) for any given rate of water discharge.

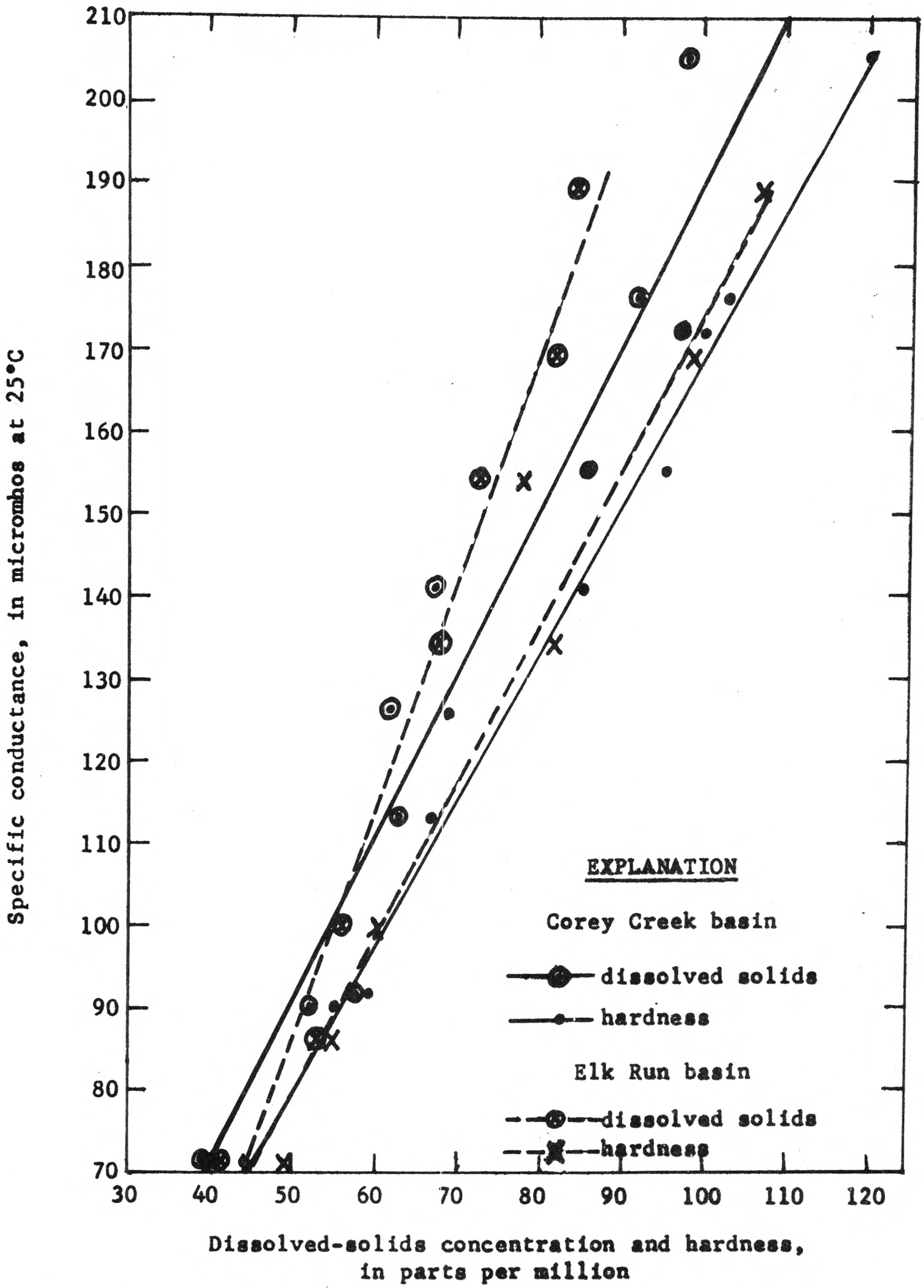


Figure 27.--Relation of dissolved-solids concentration and hardness to specific conductance, Corey Creek and Elk Run near Mainesburg, Pa., June 1956-October 1961.

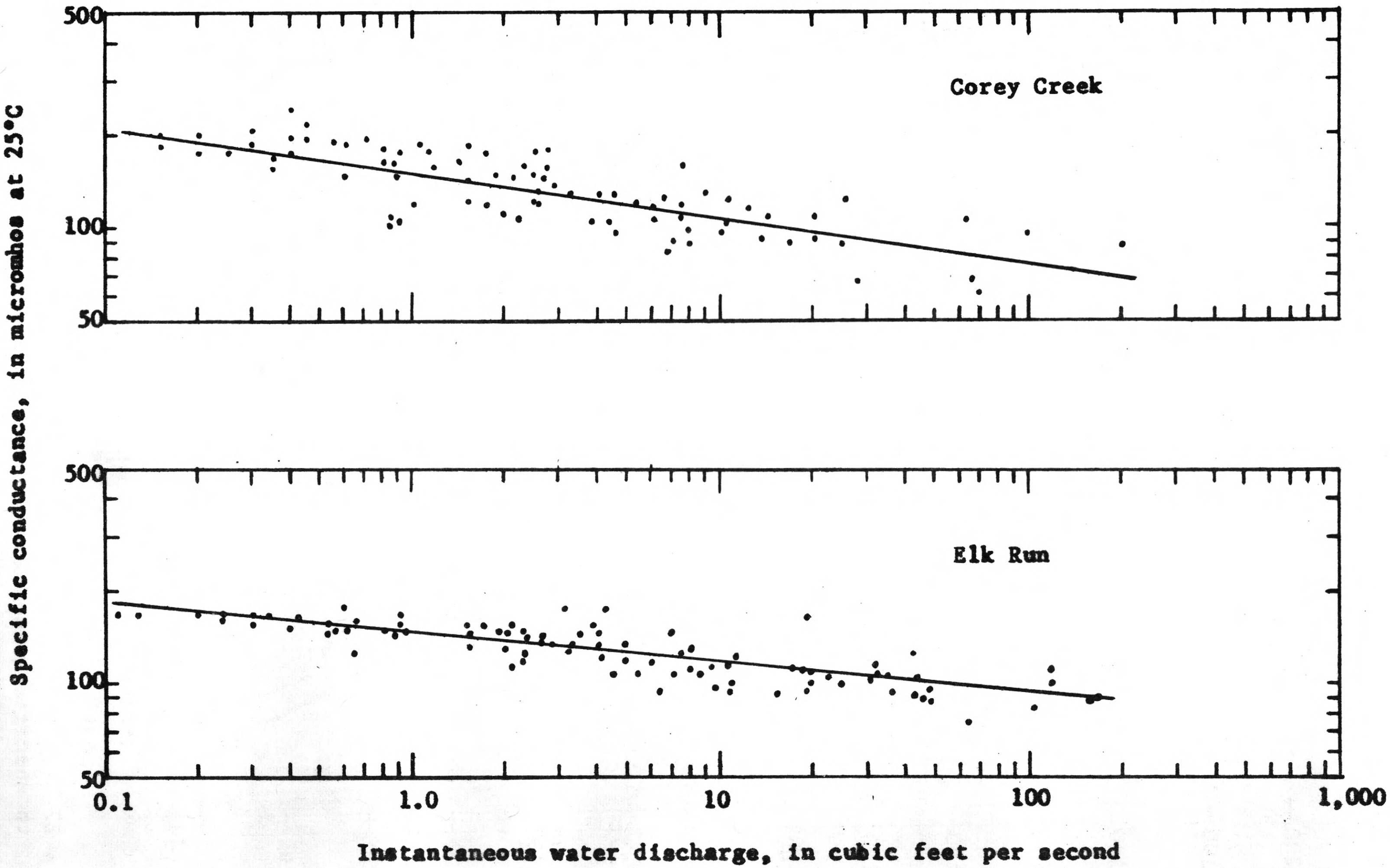


Figure 28.--Relation of specific conductance to instantaneous water discharge, Corey Creek and Elk Run near Mainesburg, Pa., May 1954-September 1960.

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.

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.

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.

Data from the aggradation-degradation ranges in both basins indicate an average change in cross-sectional area of less than ± 2.5 square feet for ranges located 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 stream beds.

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, Pa.

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 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. Apparently the most important change 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 area in 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 developing 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 activity in the basins has ceased. Data collection should, therefore, continue until it has been determined that a relatively stable condition exists. New data, along with that presently available, could be analyzed by other techniques, such as that suggested by Van Doren and Bartelli (1956) in order to obtain a more quantitative solution of the erosion-sedimentation relationship.

During the period 1954 through 1958, there was a very 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 accomplished was not directly proportional to the intensity of conservation activity. Elk Run basin showed a reduction in sediment yield more than half that of 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 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.

DEFINITIONS OF TERMS

Aggradation.--The process of building up of a stream channel by deposition of material in the channel.

Base flow or base runoff.--Sustained or fair weather streamflow. In most streams, base flow is composed largely of ground-water effluent.

Correlation.--A measure of the degree of relationship between variables or groups of variables.

Correlation coefficient.--A mathematical expression that gives the proportion of the variation in one variable that is associated with variations in another variable, or group of variables. A perfect positive correlation is designated at +1, a perfect negative correlation as -1, and no correlation as 0.

Degradation.--The process by which stream channel is lowered by wearing away of the channel material.

Dependent variable.--A variable quantity, with a value that depends on the value of another related variable, termed the independent variable.

Direct runoff.--The runoff entering stream channels promptly after rainfall or snowmelt.

Dissolved solids.--Materials that are solids in their natural state, but which are dissolved in water.

Double-mass curve.--A plot of the cumulative values of one variable against cumulative values of another variable or the computed values of the same variable, for a concurrent period of time.

Erosion.--The wearing away of the land surface. As used in this report, it includes only the mechanical wearing away of soil materials by water.

Hardness.--The property of water caused by the presence of alkaline earths (especially the salts of calcium and magnesium). Usually it is expressed as parts per million of calcium carbonate.

Hydrograph.--A graph showing stage, flow, velocity, or other property of water with respect to time.

Hydrology.--The science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground, and underground.

Independent variable.--A variable quantity, the values of which determines the values of a dependent related quantity. See dependent variable.

pH.--The negative logarithm of the hydrogen ion activity. A pH of 7.0 indicates an activity of 10^{-7} mole/liter.

Precipitation.--A general term for all forms of moisture discharged from the atmosphere.

Rank correlation.--A method of measuring the degree of correlation between the rank orders of two simultaneously observed variables. See correlation.

Regression.--A method of deriving a curve or equation from which the values of a dependent variable may be estimated, using measured values of a related independent variable. Multiple regression is a regression in which more than one independent variable is used to determine the dependent variable.

Regression coefficient.--A coefficient in a regression equation that shows the average number of units change in the dependent variable which occurs with a unit change in the independent variable. This coefficient determines the slope of the regression line.

Regression equation.--An equation that mathematically defines the average relation between a dependent variable and one or more dependent variables.

Runoff.--That part of the precipitation that appears in surface streams.

Runoff peakedness.--The ratio of the peak direct runoff to the mean direct runoff for a storm period.

Sediment.--Fragmental material that originates largely from weathering of rocks and is transported by, suspended in, or deposited by air, water, or other natural agencies. It may contain varying amounts of organic particles.

Sedimentation.--The process which includes the weathering, erosion, transportation, deposition, and consolidation of sediments.

Sediment concentration.--Ratio of the weight of sediment in a water-sediment mixture to the total weight of the mixture. It is expressed in this report in parts per million (ppm).

Sediment discharge.--The rate at which a dry weight of stream-transported sediment passes a section of stream. It is usually expressed in tons/day.

Sediment load.--The weight of sediment transported by a stream.

Sediment-transport curves.--A curve which expresses the average relation between sediment discharge and water discharge.

Sediment-transport equation.--An equation which mathematically describes a sediment-transport curve.

Specific electrical conductance.--Electrical conductance is ability of a substance to conduct an electric current. Specific electrical conductance is the conductance of a cube of the conductance 1 centimeter on a side.

Standard error of estimate.--A measure of the variance of data about a regression line.

Suspended sediment.--Sediment which remains in suspension in the water for a considerable period of time without contacting the stream bottom.

Water discharge.--The rate at which water flows in a channel, or the volume of flow. In this report, it is synonymous to streamflow. Units are either rates of flow, as cubic feet per second (cfs) or the volume of water, as cubic feet per second-day (cfs-day).

Watershed or drainage basin.--A part of the surface of the earth occupied by a drainage system, which consists of a surface stream together with all its tributaries. This system is separated from other systems by a drainage divide.

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