EFFECTS OF SURFACE COAL MINING ON SUSPENDED-SEDIMENT DISCHARGE IN A SMALL MOUNTAIN WATERSHED, FAYETTE COUNTY, PENNSYLVANIA

By Thomas M. Mastrilli and Donald E. Stump, Jr.

U.S. Geological Survey

Water-Resources Investigations Report 85-4093

Harrisburg, Pennsylvania

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC (INTERNATIONAL SYSTEM) UNITS

Multiply inch-pound units	by	To obtain metric units
inch (in.)	25.40	millimeters (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometeres (km)
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometers (km^2)
acre-foot (acre-ft)	1.233×10^{-3}	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

EFFECTS OF SURFACE COAL MINING ON SUSPENDED-SEDIMENT DISCHARGE IN A SMALL MOUNTAIN WATERSHED, FAYETTE COUNTY, PENNSYLVANIA

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ABSTRACT

Data collected in the upper Stony Fork basin from July 1980 to November 1981 indicate that logging operations associated with block-cut surface coal mining temporarily increased the suspended-sediment discharge of Stony Fork. However, the strip-mining operation did not increase the suspended-sediment discharge of Stony Fork because of effective sediment-control measures. These controls include diversion terraces and a large sediment-control pond. The 50-acre mine site yielded an average of 6.9 tons of sediment per acre, whereas the sediment yield of the 2.5-square-mile study area was 0.13 tons per acre. During most storms, sharp increases in streamflow were accompanied by corresponding increases in suspended-sediment concentrations. At the end of a storm, suspended-sediment concentrations quickly returned to base-flow levels.

Instantaneous water discharge ranged from 0.02 to 146 cubic feet per second. Average monthly water discharges ranged from 0.30 to 14.3 cubic feet per second. Suspended-sediment concentration ranged from less than 10 to 905 milligrams per liter. The highest daily mean suspended-sediment concentration was 176 milligrams per liter.

INTRODUCTION

The Pennsylvania Department of Environmental Resources (PaDER) has received numerous permit applications for strip-mining the coal deposits in the Stony Fork basin of Fayette County, Pennsylvania. To provide data that would aid PaDER in permit evaluation, the U.S. Geological Survey investigated the effects of surface coal mining on suspended-sediment discharge and on streamflow in the upper Stony Fork basin from July 1980 through November 1981.

Purpose and Scope

The purpose of this report is to describe the effects of surface coal mining on suspended-sediment discharge in the Stony Fork basin. A gaging station was established downstream of the mine area to collect suspended-sediment and streamflow data. Statistical analysis was used to measure the cause-effect relation of surface coal-mining activities within the study area. Analyses of individual storms and base-flow periods are also included.

Physical Setting

The study area comprises 2.5 mi^2 in the headwaters of the Stony Fork basin in Wharton Township, Fayette County, Pennsylvania (fig. 1). Stony Fork is southeast of State Route 381 between Farmington and Elliottsville Pennsylvania. The PaDER classifies Stony Fork as a high quality cold-water fishery.

The Stony Fork basin is between the Chestnut and Laurel Ridges in the Ohiopyle Valley of the Allegheny Mountain section of the Appalachian Plateau Province (Hickok and Moyer, 1971). The study area is predominantly forested with relatively flat-topped, steep-sided, ridges ranging in altitude from 1,700 to 2,200 feet. The remaining areas within the basin are used mainly for farming and pasture. Table 1 shows recent land use evolution in a chronological sequence.

Table 1.--Land use in the study area from July 1980 to November 1981

Date	Forested		Farmland and Pasture		Logging and Mining	
	Acres	Percent of total	Acres	Percent of total	Acres	Percent of total
July 1980	1164	72.8	424	26.5	12	0.75
October 1980	1156	72.2	424	26.5	20	1.2
November 1981	1126	70.4	424	26.5	50	3.1

TOTAL ACRES IN STUDY AREA = 1,600

The climate is humid continental with warm summers and cold winters. Maximum temperatures of about 95°F occur in July and minimum temperatures of about 0°F occur in January; precipitation is well distributed throughout the year.

A recording rain gage was used to collect precipitation data in the basin. The total precipitation between July 1980 and November 1981 was 60.1 in. The highest monthly precipitation was 8.31 in. during April 1981 and the lowest was 1.29 in. during November 1981.

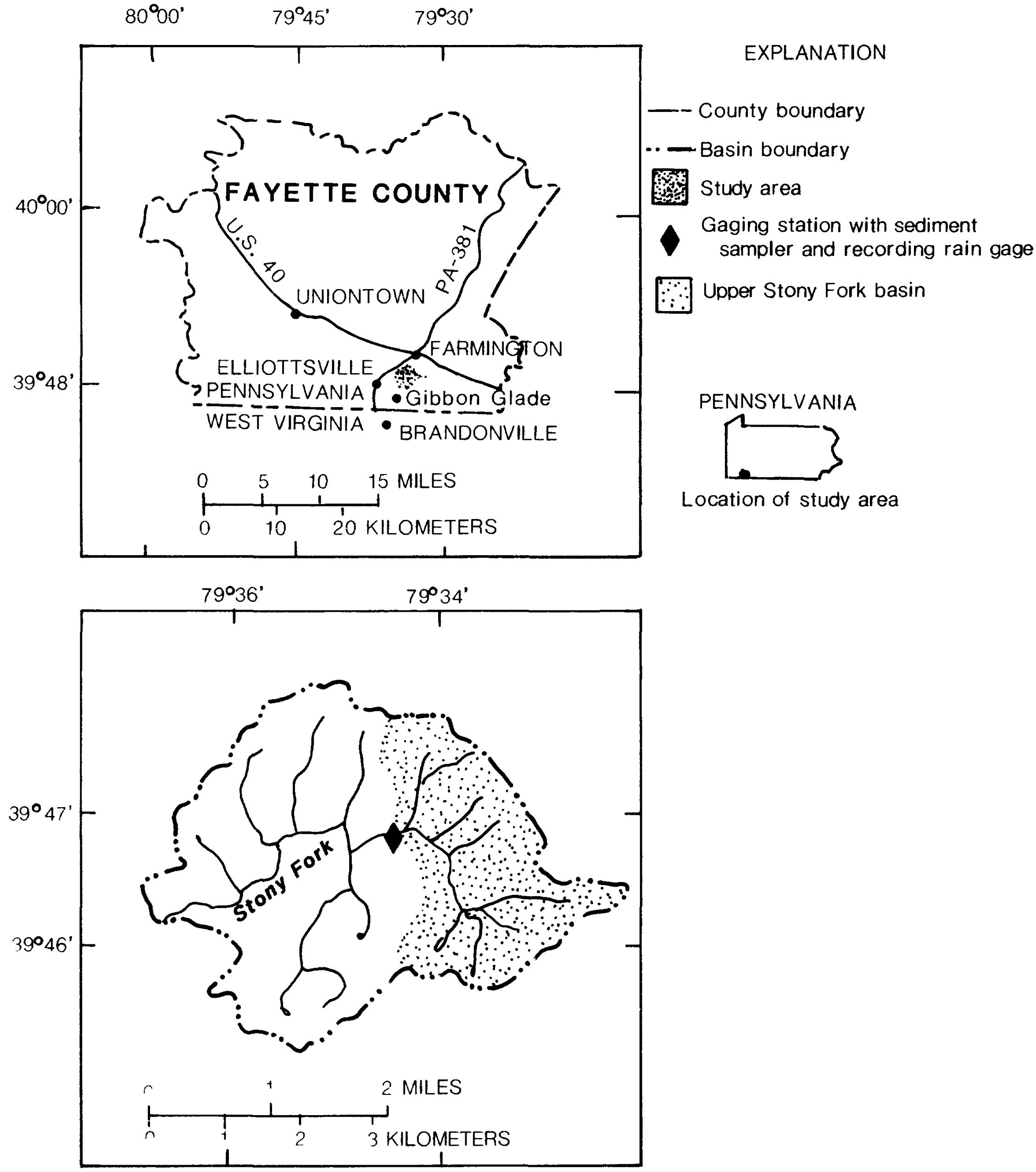

Figure 1.--Location of study area and data-collection site in the Stony Fork basin.

Monthly precipitation data for Brandonville, West Virginia (a National Weather Service station 7 miles south of the study area) and the Stony Fork gage are shown in figure 2. Data collected at Brandonville is used to verify the Stony Fork data.

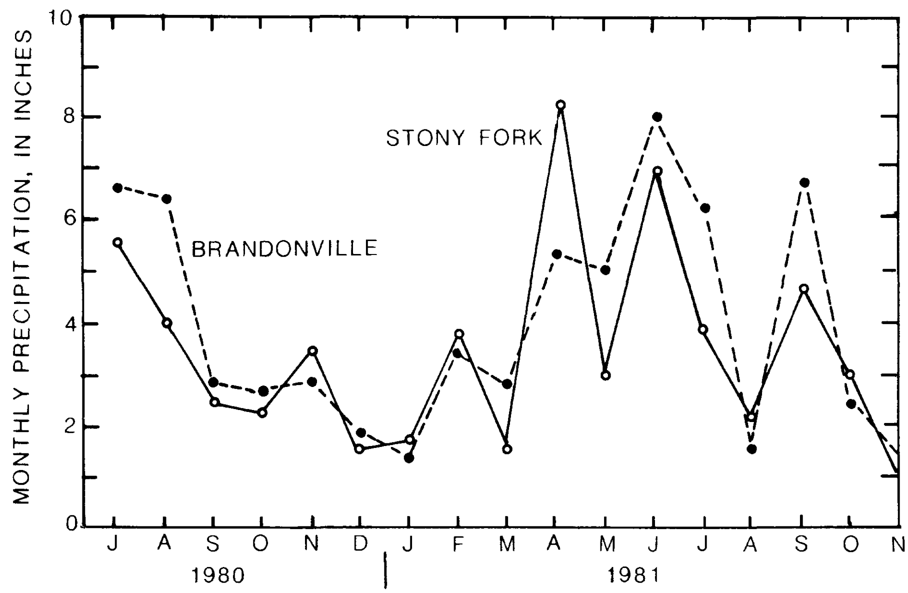

Figure 2.--Monthly precipitation in the Stony Fork study area and at Brandonville, West Virginia (seven miles south of Stony Fork).

Bedrock formations that crop out in the Stony Fork basin belong to the Allegheny Group and the overlying Conemaugh Group, and are of Pennsylvania age (Hickok and Moyer, 1971). Structurally, the basin is on the Preston anticline about midway between the Chestnut Ridge and Laurel Hill anticlines (Hickok and Moyer, 1971, p. 23-26). The bituminous coal seam being mined in the study area is the Upper Kittanning of the Allegheny Group. The seam is from one to five feet thick and irregular in thickness and extent. It is generally overlain by a sandy shale or thin-bedded sandstone, and overlies a black shale or clay (Hickok and Moyer, 1971).

Surface Coal-Mining Activities

Mining Methods

Surface mining disturbs vegetation, soils, and bedrock units. As a result, the hydrologic characteristics within the mined area are generally altered (table 2).

In preparation for mining, the technique of "clear-cutting" timber (the cutting down of all trees and vegetation in a stand) increases the availability of sediment for erosion by exposing more soil to rain impact. Surface mining also increases erosion by making more sediment available for transport.

Surface mining was done by the block-cut method because the coal reserves are under relatively flat ridge tops. In block-cut mining, excavation is made perpendicular to topographic contour lines. The soil and rock material overlying the coal seam (overburden) is removed from a new cut and placed in the pit of the previous cut. This overburden is placed along the edge of the mined area, and is integrated into the reclamation part of the mining schedule. When the overburden material is only moved once, erosion, landslide, and mineral decomposition problems are reduced, and reclamation costs less. A diversion ditch is constructed at the base of the mine to divert surface-water runoff into a settling pond. This sedimentation pond is designed to detain the runoff until suspended particles settle out.

Table 2.--Surface mining land disturbances and associated hydrologic impacts

Surface mine disturbance	Hydrologic impacts
Topsoil and vegetation removal	Increased erosion potential
	Decreased infiltration rate
	Increased runoff rates
Overburden removal	Increased bedrock infiltration due to blasting
	Changes in ground-water movement patterns
	Increased weathering potential
	Decreased runoff
	Potential for large amount of ground-water storage in bedrock and or spoil-piles

Description of the Mine in the Study Area

One surface mine was active during the study period (fig. 3). The area mined was forested with slopes ranging from 0 to 60 percent. The area disturbed by surface mining increased from 12 acres to about 50 acres from July 1980 to November 1981. A mining permit was issued on April 20, 1979, and mining began shortly thereafter. The original permit application was for 64.2 acres; however, not all of this area was mined. The PaDER reported that 16,819 tons of coal were produced from this mine during 1979. Production increased to 87,150 tons for 1980, but decreased to almost zero in 1981.

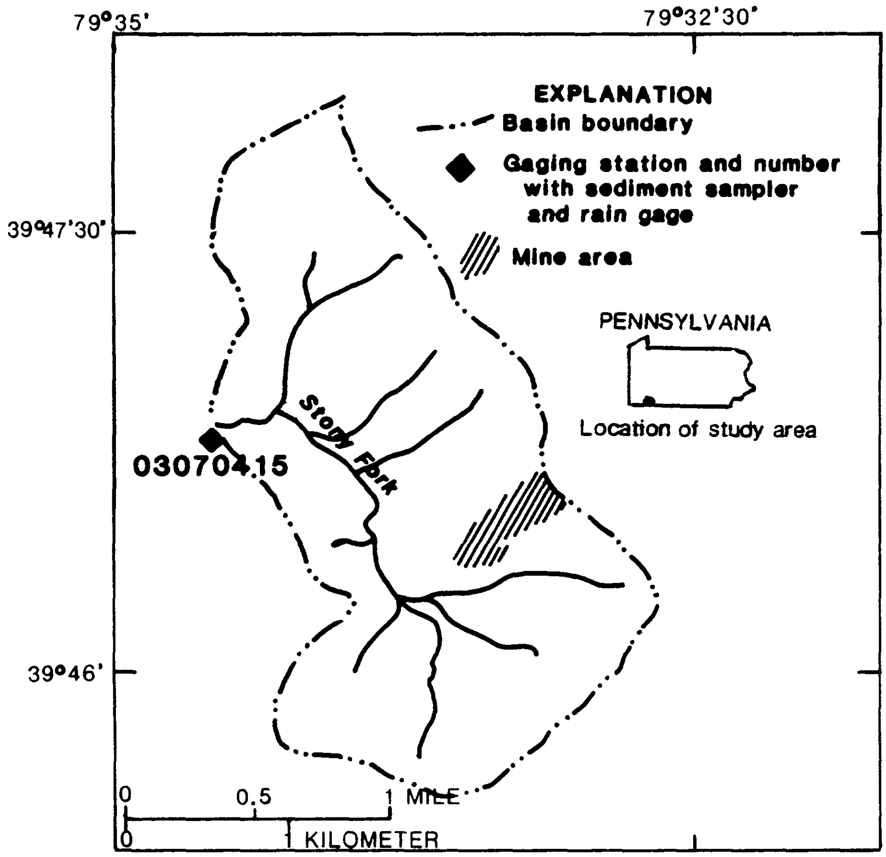

Figure 3.--Mine area within the upper Stony Fork drainage basin.

DATA COLLECTION

Hydrologic data were collected on streamflow, suspended-sediment discharge, and precipitation. A data-collection station was operated from July 1980 through November 1981 to record stream stage and precipitation continually, and to obtain storm samples for suspended-sediment concentration analysis.

Stream discharge measurements were made periodically to define the stage-discharge relation at the station. A PS-69 automatic sediment sampler was used to collect suspended-sediment samples. The sampler was set to take samples at predetermined intervals during high-flow periods (fig. 4). Depth-integrated samples were taken manually during periods of high and medium flow and the results were compared with samples taken by the PS-69 sampler to determine if the PS-69 point-sample concentration data were representative of the average concentrations for the stream cross section. The results of this comparison were similar, indicating that samples taken by the PS-69 sampler were valid. Suspended-sediment concentrations were determined in the U.S. Geological Survey Harrisburg District sediment laboratory using the filtered dry-weight method. Sediment discharges were determined using techniques described by Porterfield (1972).

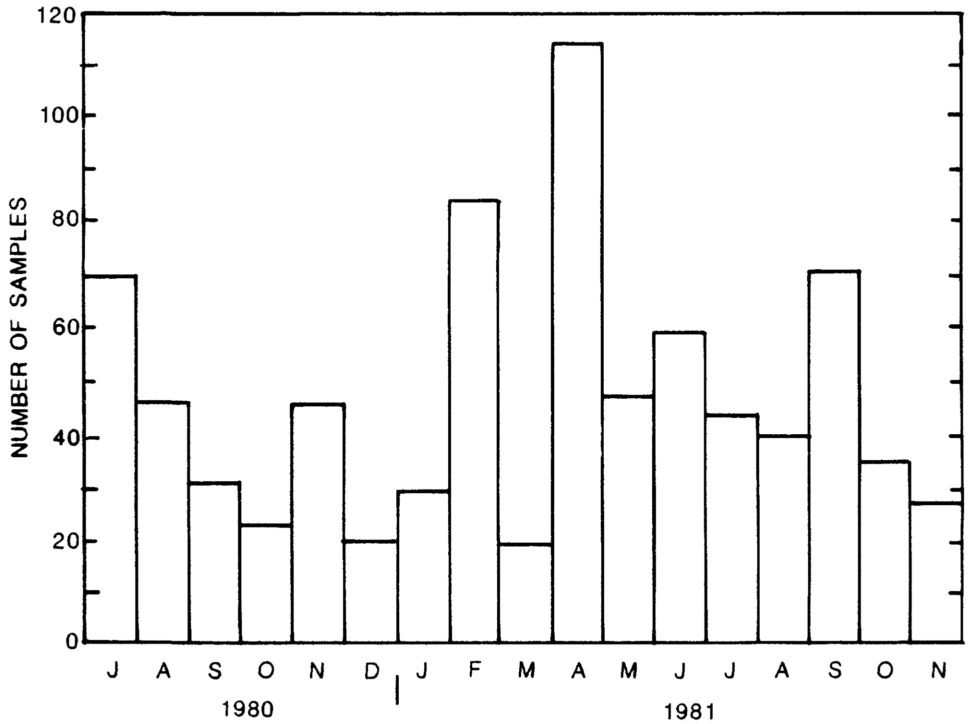

Figure 4.--Number of suspended-sediment samples.

STREAMFLOW

Streamflow is the water discharge in a channel. The amount of type of vegetative cover and soil composition are major influences on the amount of runoff, especially during small and moderate storms. Rainfall intensity may affect the rate of runoff more than the volume of runoff. Accumulated runoff and precipitation are compared in figure 5.

The maximum instantaneous discharge for the study period was 146 ft^3/s and occurred in conjunction with a recorded rainfall of 1.76 inches on April 12, 1981. The minimum instantaneous discharge was 0.02 ft^3/s on July 21, 1980. The maximum monthly mean discharge occurred in April 1981 (14.3 ft^3/s). The minimum monthly mean discharge occurred in August 1981 (0.30 ft^3/s).

Table 3 estimates the percentage of precipitation that contributed to runoff. Precipitation in the study area was highly variable, resulting in a wide range of values for percent of runoff. Periods of low evapotranspiration and air temperature generally have greater amounts of runoff relative to precipitation. The highest runoff, in percentage of precipitation, occurred during March 1981 (203 percent) and was primarily the result of snowmelt.

During periods of minimal precipitation, streamflow is predominantly ground-water discharge, or base flow. During high base-flow periods (spring), daily mean discharges ranged from 1.0 ft^3/s to 15 ft^3/s. During low base-flow periods (late summer and early fall), daily mean discharges ranged from 0.1 ft^3/s to 1.0 ft^3/s. Normally, streamflow within the study area would return to seasonal base-flow levels within several days of a storm providing no additional precipitation occurred.

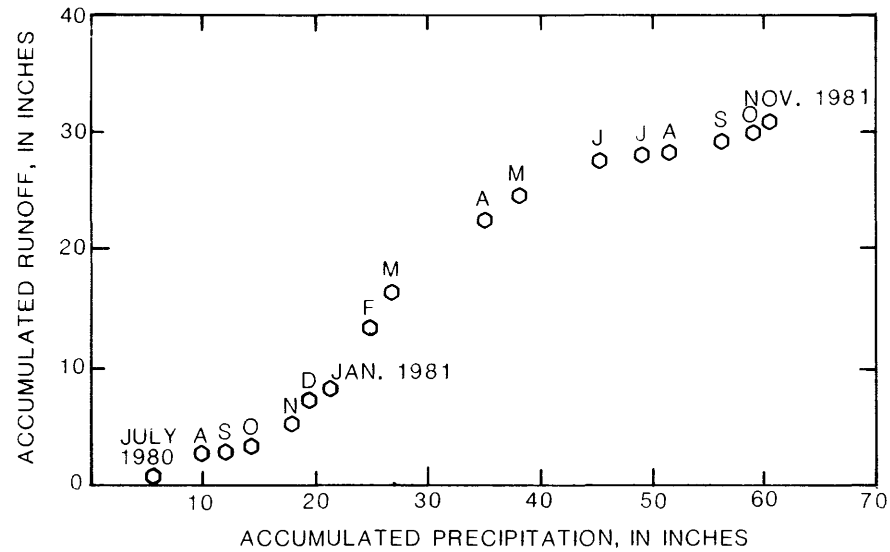

Figure 5.--Accumulated monthly runoff and precipitation from July 1980 to November 1981.

Table 3.--Monthly precipitation and percentage as runoff for Stony Fork near Farmington from July 1980 to November 1981

Month		Precip.	Runoff inches	Runoff percent of precipitation
1980	July	5.58	0.62	11.1
	August	4.02	2.48	61.7
	September	2.47	.23	9.3
	October	2.27	.31	13.7
	November	3.55	1.97	55.5
	December	1.57	1.91	122
1981	January	1.78	1.01	56.7
	February	3.81	4.87	128
	March	1.50	3.05	203
	April	8.31	6.37	76.6
	May	3.13	1.76	56.2
	June	6.98	3.10	44.4
	July	3.88	.34	8.8
	August	2.23	.14	6.3
	September	4.70	.91	19.4
	October	3.03	.79	26.1
	November	1.29	.85	65.9

EFFECTS OF SURFACE COAL MINING ON SUSPENDED-SEDIMENT DISCHARGE

Soil erosion and deposition involves the detachment, transport and subsequent deposition of soil particles. The soil particles are generally detached from the ground by raindrop impact and water movement and transported down slope by flowing water. Soil erosion is influenced by the soil properties, land slope, length of slope, climate, amount and rate of rainfall, and the type and percentage of vegetative ground cover. Surface mining greatly affects soil erosion and deposition.

During mining, the area consisting of pits and rock overburden piles may not produce suspended-sediment because these areas may drain internally with runoff water accumulating in the pit. Finally, soil placed on the reclaimed overburden, is highly susceptible to erosion, especially before new vegetation is established.

Sediment particles are deposited at variable distances below their sources, depending on water velocity, land slope, vegetation, and soil properties. Some problems caused by sediment deposition are: (1) decreasing the conveyance of natural stream channels, thereby increasing flooding; (2) filling of lakes and reservoirs; (3) impairing surface drainage; (4) burying of crops and fence lines; and (5) raising the water table. In addition, increases in sediment concentrations decrease stream suitability as a water-supply source or as a recreational facility.

The most important variables that affect suspended-sediment yields include land use, rainfall amounts and intensities, initial soil-moisture content, season, slope, and vegetative cover. Sediment yields from small drainage areas can be quite variable, especially if the areas are undergoing land use changes.

Monthly suspended-sediment discharge at the Stony Fork sampling site, averaged 12.5 tons, and ranged from 97.1 tons in April 1981 to 0.15 tons in August 1981 (fig. 6). A total of 214 tons of suspended-sediment were discharged past the gaging station during the study period. A maximum instantaneous suspended-sediment concentration of 905 mg/L (milligrams per liter) occurred on April 18, 1981. The highest daily mean suspended-sediment concentration of 176 mg/L occurred on April 12, 1981. On that date, 42 tons of sediment was discharged past the sampling site.

The data in figure 7 were plotted according to season. A considerable amount of scatter is seen in the figure; the scatter can be explained by examining specific sediment data more closely, as shown in figure 4.

For almost equal discharges, suspended-sediment concentrations in Stony Fork were from 3.6 to 12 times greater as a result of summer storms than as a result of high base flow.

Statistical regression analyses defined sediment transport curves for July and August 1980 and June through August 1981. As seen in figure 8, the coefficients of determination (r^2) are the same for both periods. These values indicate the quality of fit for the regression. Values of r^2 closer to 1.0 suggest a better relationship between sediment discharge and stream discharge. Figure 8 suggests a decrease in suspended-sediment discharge between the summers of 1980 and 1981. Thus, an equivalent streamflow would produce less suspended-sediment discharge in 1981 than the same period in 1980. The higher suspended-sediment discharges, shown in figure 8 during July and August 1980, probably result from logging operations during this period.

The transport curves for September through November in both 1980 and 1981 show the relation between water discharge and suspended-sediment load are similar for both periods (fig. 9). The relation between water discharge and suspended-sediment load from June through August 1981 shown in figure 8, is similar to the relations shown on figure 9. This suggests that sediment yields declined in the late summer and early fall of 1980, when vegetation became reestablished on the logging area. Also, only very small amounts of sediment were discharged from the mine during 1980 and 1981. Diversion terraces collected runoff and transported it to a large sediment control pond. All discharges from the sediment-control pond were manually controlled by an outlet valve. Unregulated discharges did not occur during this period. The capacity of the sediment pond was calculated to be about 174,000 ft^3 when the mine was opened; in November 1982, the capacity of the pond was determined to be nearly 160,000 ft^3, a reduction of 14,000 ft^3 (346 tons). This reduction in storage capacity reflects the amount of sediment trapped in the pond from the mine area. The mine site yielded an average of 6.9 tons per acre, whereas, the entire study area yielded an average of only 0.13 tons per acre. These data suggest the sediment-control measures used on the mine were effective.

Suspended-sediment discharge data can be examined more closely by analyzing individual storm hydrographs. Overall, the sediment concentration and streamflow hydrographs were in phase, or nearly in phase, and peaked at approximately the same time. Storm events were selected for analysis primarily according to similarities in rainfall amounts and intensity characteristics. The two storms shown in figure 10 had average precipitation intensities of 0.2 in./hr. (inches per hour). The shapes of the sediment hydrographs are similar during the rising and falling segments, whereas the peak values differ. The streamflow hydrographs also exhibit similar configurations.

The average rainfall intensities were 0.1 in./hr. for the two storms shown in figure 11. The discharge hydrographs have similar rising and falling limbs but the peak values differ. The suspended-sediment hydrographs also have similar rising and falling segments.

Average rainfall intensities for the two storms shown in figure 12 was 0.1 in./hr. The discharge and sediment hydrographs in figure 12 differ from those in figures 10 and 11. Figure 12 shows multiple sediment peaks for both storm events. When comparing figures 10 and 11 to figure 12, the range of values may be an important factor. Figures 10 and 11 show similar shapes for both the sediment and discharge hydrographs, whereas figure 12 shows lower discharge peaks and higher sediment peaks. Table 5 shows that the data from figure 10 appears to agree with that in figure 8. The temporary runoff increase produced by vegetation removal prior to mining, subsequently produces higher suspended-sediment concentrations as seen in figure 10. After the increase in suspended-sediment concentrations seen in the late summer of 1980, figures 9, 11, and 12 show a decline in suspended-sediment concentrations.

Analyses of individual storm hydrographs indicate that suspended-sediment discharge temporarily increased during logging and then returned to previous levels. Regulated discharges from the mine site make a direct cause and effect relationship between surface mining and increased sediment discharge difficult to establish.

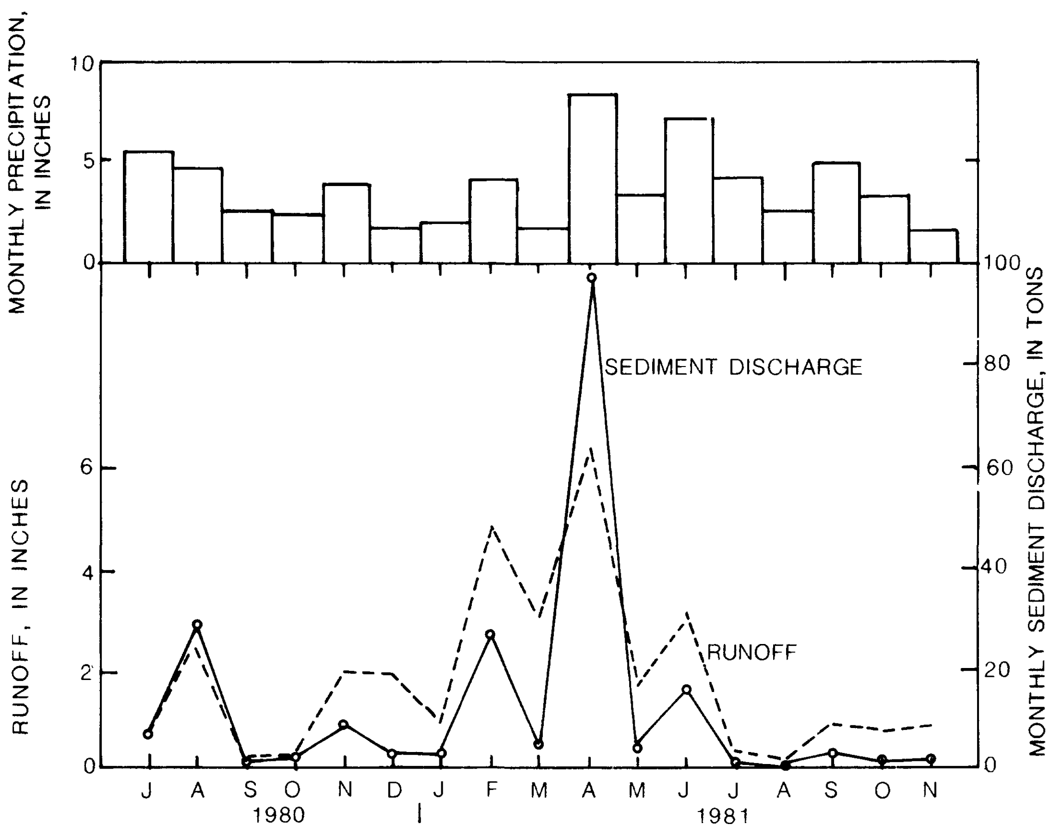

Figure 6.--Monthly runoff, sediment discharge and precipitation from July 1980 to November 1981 at Stony Fork near Farmington.

Table 4.--Comparison of high base-flow suspended-sediment discharge (upper) with storm suspended-sediment discharge (lower) for selected dates at Stony Fork near Farmington

Date	Daily mean water discharge in cubic feet per second	Daily mean suspended-sediment discharge in tons
4/15/81	27	1.8
8/18/80	30	15
4/25/81	18	1.0
6/6/81	19	3.6
4/27/81	10	.30
8/11/80	10	1.9
4/28/81	7.3	.20
7/22/80	7.4	2.4

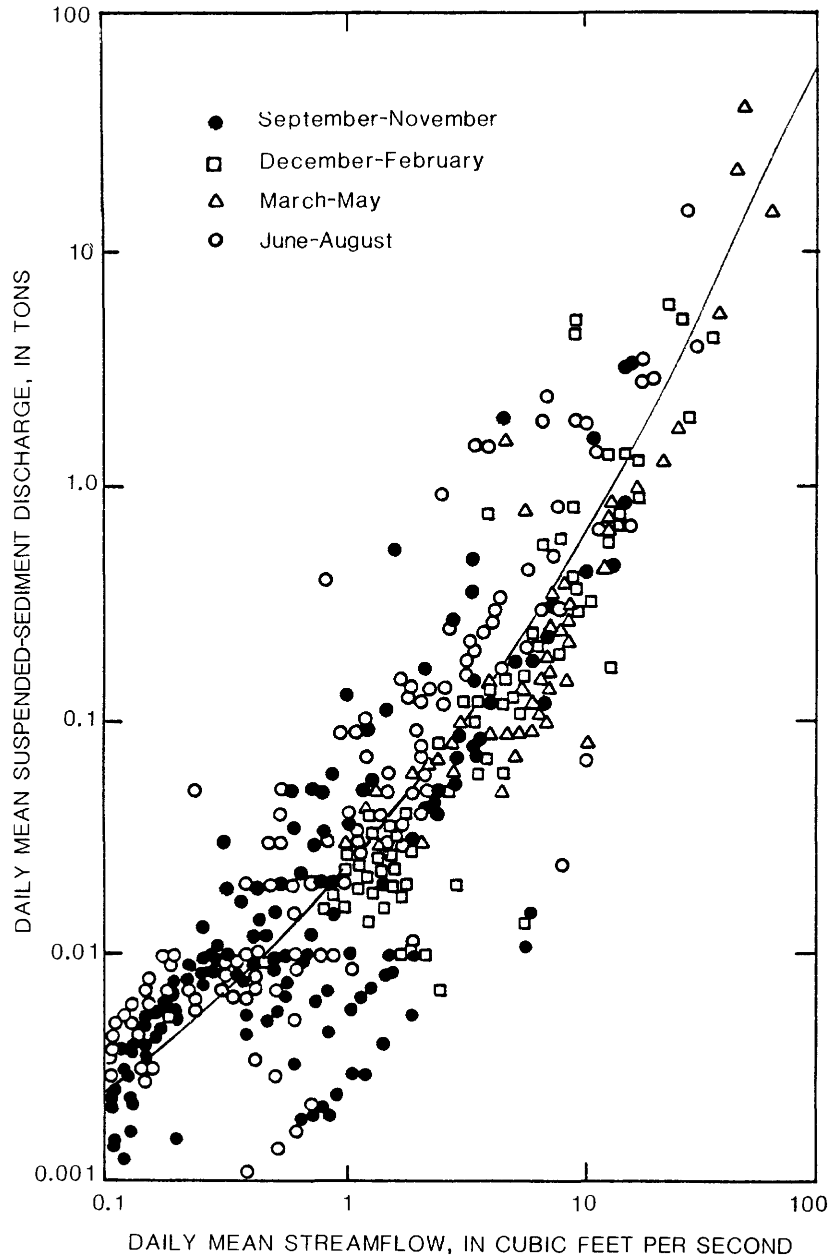

Figure 7.--Relation between daily mean suspended-sediment discharge and streamflow from July 1980 to November 1981 at Stony Fork near Farmington.

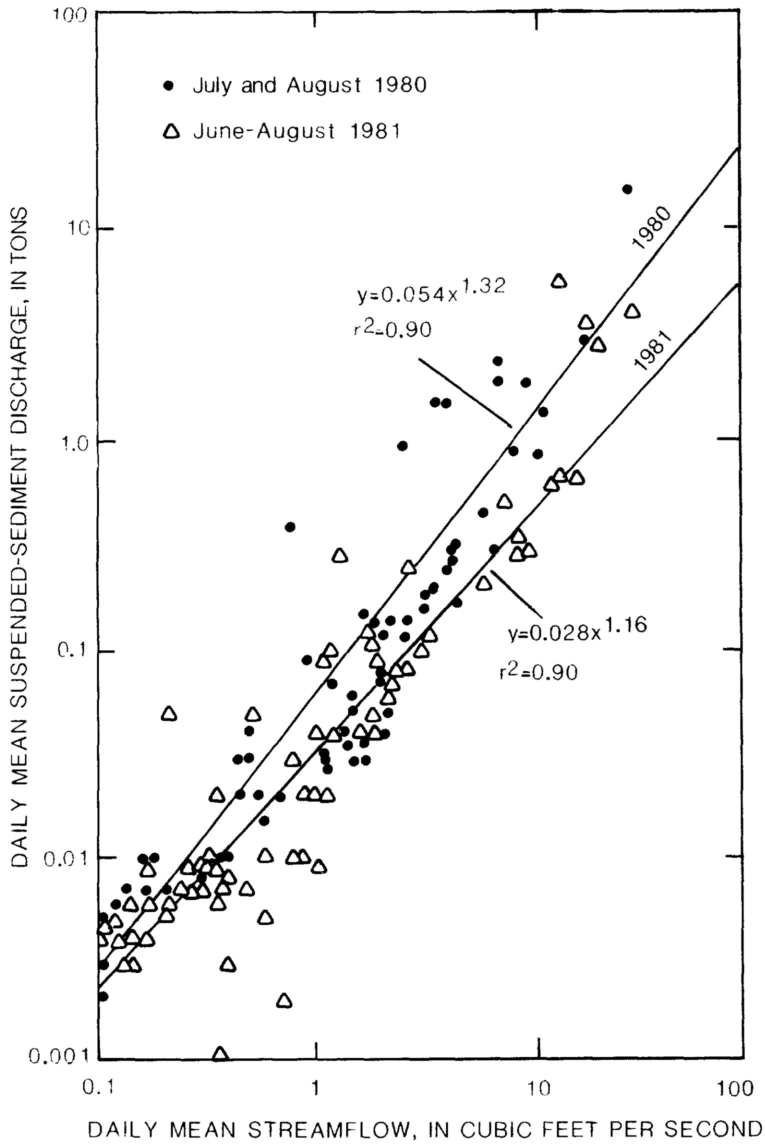

Figure 8.--Comparison of suspended-sediment transport curves for July and August 1980, and June through August 1981.

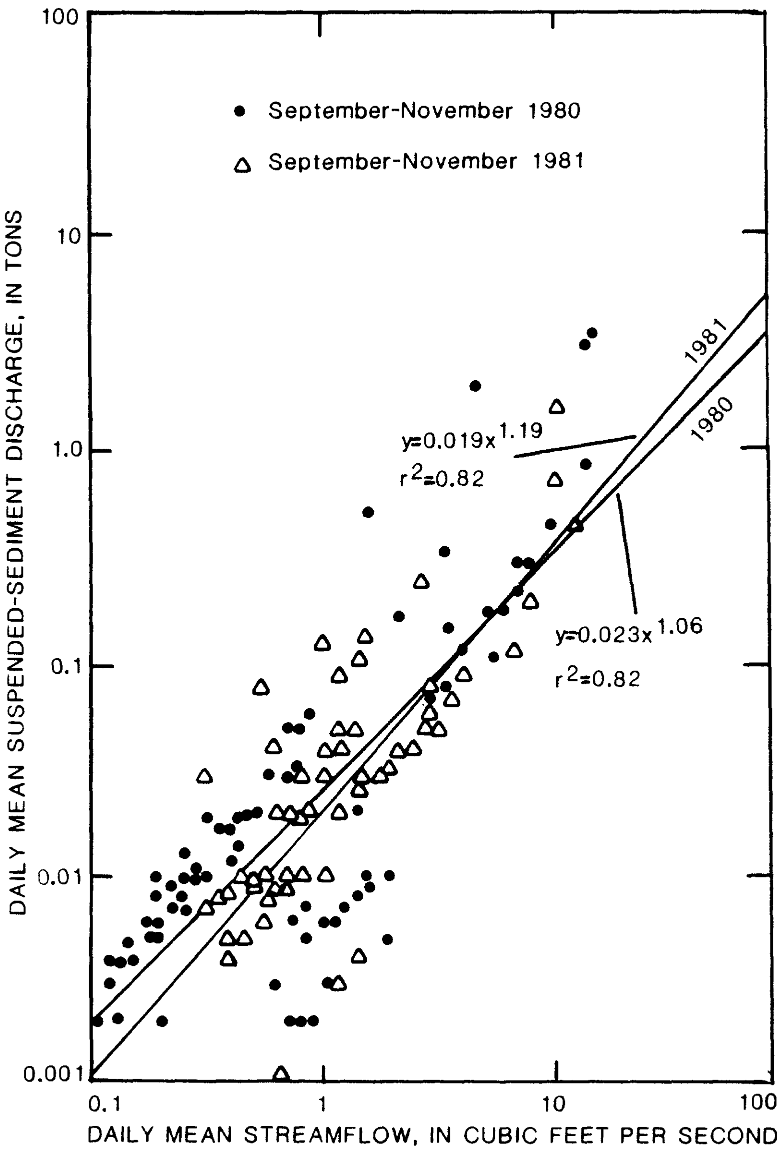

Figure 9.--Comparison of suspended-sediment transport curves between September through November 1980, and September through November 1981.

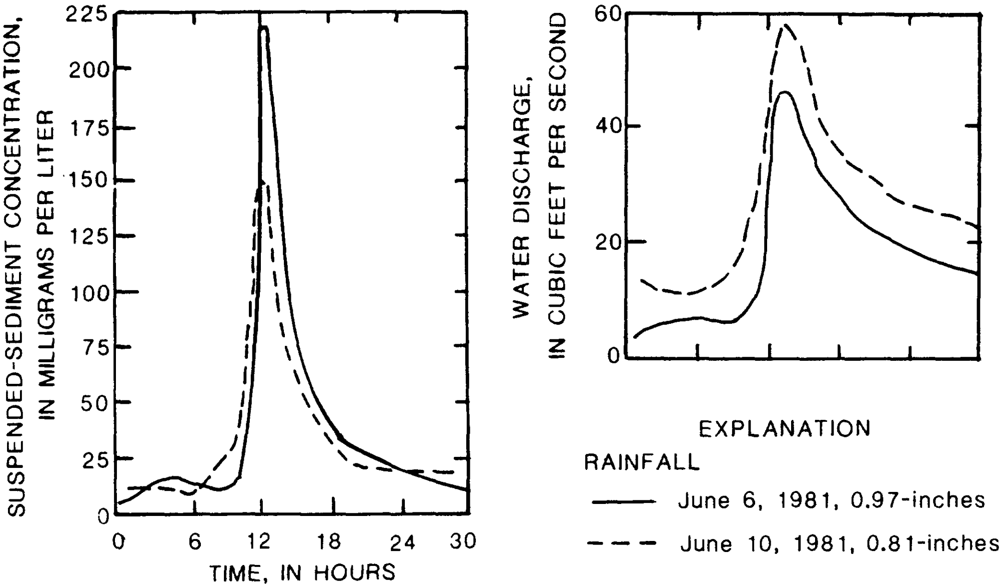

Figure 10.--Suspended-sediment concentration and water discharge hydrographs for June 6, 1981 and June 10, 1981 at Stony Fork near Farmington.

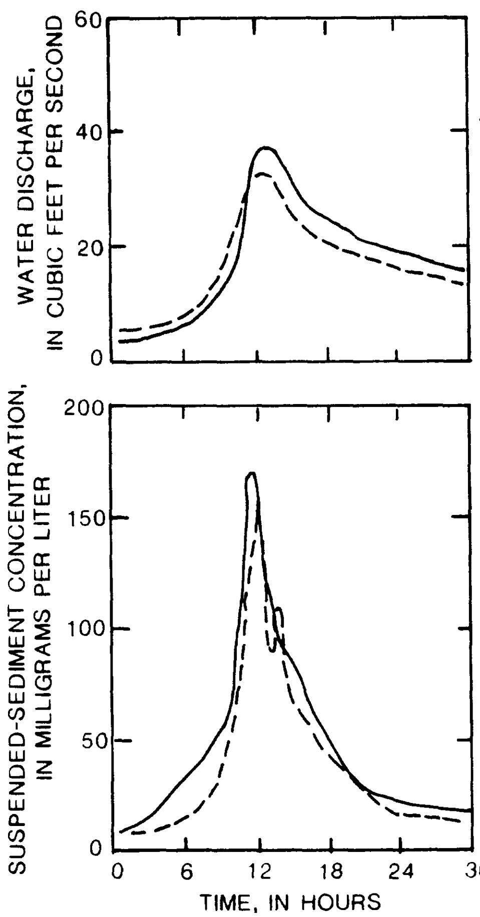

Figure 11.--Suspended-sediment concentration and water discharge hydrographs for November 24, 1980 and February 28, 1981 at Stony Fork near Farmington.

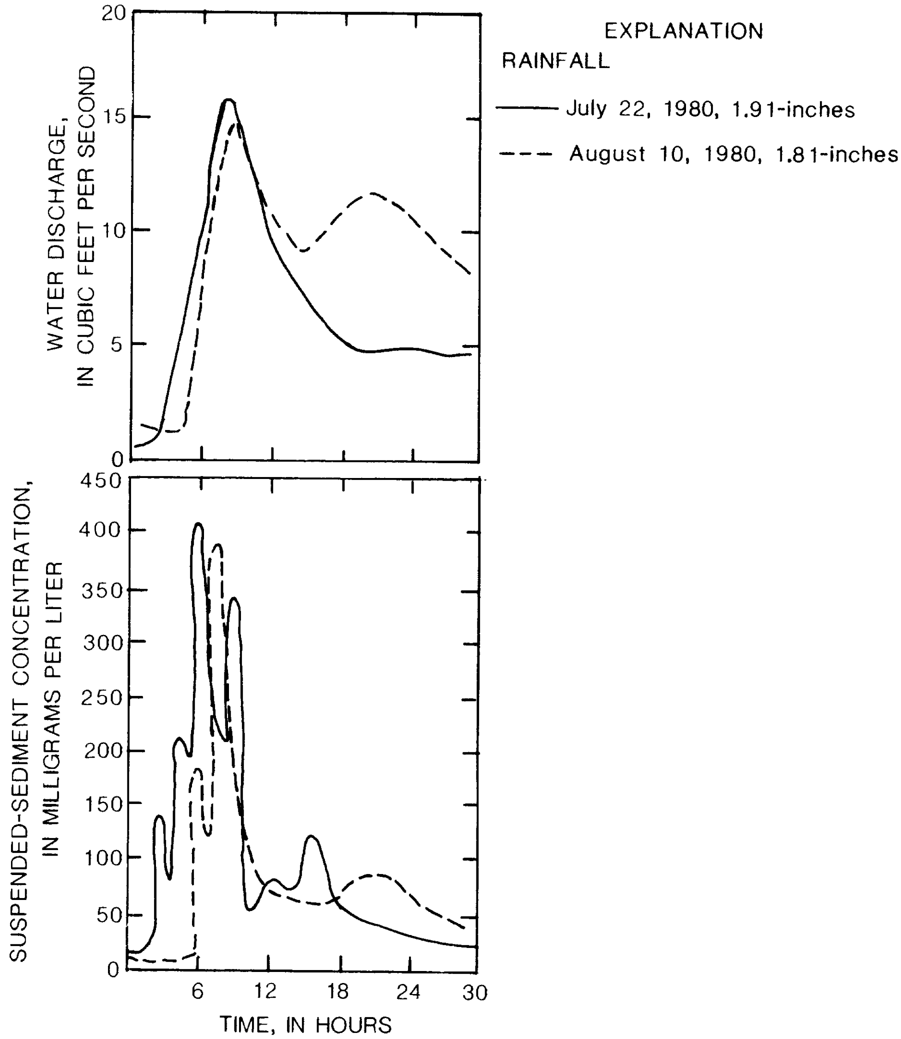

Figure 12.--Suspended-sediment concentration and water discharge hydrographs for July 22, and August 10, 1980 at Stony Fork near Farmington.

Table 5.--Tabulation of indicated data for figures 10, 11, and 12

Figure	Date	Precipitation (in inches)	Runoff (in inches)	Daily Mean Suspended-Sediment (in tons)	Suspended-sediment concentration (in milligrams per liter)		Streamflow (in cubic feet per second)	
					Max.	Min.	Max.	Min.
10	6/6/81	0.97	0.29	3.60	245	10	46.2	5.20
10	6/10/81	.81	.46	4.00	145	12	57.4	13.8
11	11/24/80	1.04	.27	3.40	165	10	36.8	4.70
11	2/28/81	1.05	.21	2.30	145	10	32.4	6.00
12	8/22/80	1.91	.11	2.40	410	28	14.9	4.90
12	8/10/81	1.81	.07	1.50	390	10	13.0	1.40

(p. 19 follows)

SUMMARY

The U.S. Geological Survey investigated streamflow, precipitation, and suspended-sediment discharge in the upper Stony Fork watershed during 1980 and 1981 to determine the effects of surface coal mining on the suspended-sediment discharge in the headwaters of the Stony Fork drainage basin. The 2.5-mi^2 (1,600 acres) study area is located between the Chestnut and Laurel Ridges of the Appalachian Mountains. A surface mine was in operation during the study; previously, there had been little mining in the basin.

Instantaneous stream discharge ranged from 0.02 to 146 ft^3/s. The highest monthly mean discharge (14.3 ft^3/s) was in April 1981; the lowest monthly mean discharge (0.30 ft^3/s) was in August 1981.

During most storms, a sharp rise in streamflow was accompanied by a corresponding rise in suspended-sediment concentration. At the end of the storm, suspended-sediment concentrations quickly returned to base-flow levels. Monthly suspended-sediment discharges ranged from 97.1 tons in April 1981 to 0.15 tons in August 1981. The maximum instantaneous suspended-sediment concentration was 905 mg/L, whereas, the maximum daily mean suspended-sediment concentration was 176 mg/L. Statistical analyses suggested that mean suspended-sediment concentrations increased temporarily during July and August of 1980, and then returned to previous levels. Logging operations were taking place during this period. Individual storm hydrograph analyses also showed a temporary increase in suspended-sediment concentrations during the late summer of 1980.

Although logging increased suspended-sediment yields temporarily, there is no indication surface mining activities increased fluvial suspended-sediment transport in the basin during the period of investigation. This is primarily because of the effective sediment control techniques used at the mining site.

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