SEDIMENT DISCHARGE FROM AN AREA OF HIGHWAY CONSTRUCTION, APPLEMANS RUN BASIN, COLUMBIA COUNTY, PENNSYLVANIA

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CONVERSION FACTORS

Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric*
inches (in)	25.4	millimeters (mm)
acres	.4047	hectares (ha)
square miles (mi^2)	2.590	square kilometers (km^2)
tons (short)	.9072	tonnes (t)
cubic feet per second (ft^3/s)	.0283	cubic meters per second (m^3/s)

SEDIMENT DISCHARGE FROM AN AREA OF HIGHWAY CONSTRUCTION,

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COLUMBIA COUNTY, PENNSYLVANIA

By David A. V. Eckhardt

ABSTRACT

The effects of highway construction on stream sediment loads were studied in Applemans Run basin, Columbia County, Pa., from October 1971 to May 1974. From September 1971 to August 1973, a two-lane roadway was constructed across the lower reaches of the basin, a rural watershed with a drainage area of 1.99 mi^2 (5.15 km^2).

During the investigation, about 5,200 tons (4,700 tonnes) of suspended-sediment were discharged from the basin. Of this amount, about 2,700 tons (2,500 tonnes), or about half the total sediment discharge, was derived from the highway construction area. The remainder came from other land-use areas within the basin, such as cropland and localized private construction near Applemans Run. Annual suspended-sediment yields from 17.5 acres (7.08 hectares) under construction ranged from 40,000 to 66,000 tons/mi^2 (62 to 100 tons/acre) in the 1972 and 1973 water years, respectively.

In the 1972 and 1973 water years of active construction, 83 percent of the sediment transported from the construction site was eroded each year in storms from January to June. Seasonal trends in sediment discharge for 1972 show that 69 percent of that year's suspended-load was transported in April to June, whereas less than 1 percent was transported in July to September.

High sediment yields from the construction area continued after the completion of the highway in August 1973, even though seeding and mulching had reduced the erodibility of the steep embankment slopes. Those operations did not fully take effect until spring of 1974, when a protective cover of crown vetch matured and measured sediment yields from the basin returned to normal.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the Pennsylvania Department of Transportation, has made several surveys of stream sedimentation in various locations throughout Pennsylvania. The investigation reported here was made in Applemans Run basin, a small catchment of 1.99 mi^2 (5.15 km^2) in west-central Columbia County near Bloomsburg, Pa. From September 1971 to August 1973, the Department of Transportation relocated State Highway 487 through the lower areas of the basin near the village of Light Street, as shown in figure 1.

The investigation was undertaken to evaluate the effects of highway construction on suspended-sediment discharge in a small basin underlain by thick deposits of periglacial sediments. In order to evaluate properly what impact the highway relocation would have within the basin, streamflow and sediment data were collected from Applemans Run above and below the new highway during and after active construction. This report documents the changes and trends in suspended-sediment discharge and turbidity that were observed during that period.

DATA COLLECTION

Two gaging stations were established on Applemans Run near Light Street during September 1971. One station was installed downstream from the construction site to monitor sediment discharge during the different highway construction stages. A control station was installed immediately upstream from the construction area to monitor natural sediment discharge. Data were collected from the beginning of construction (October 1971) until its completion and stabilization of the area (May 1974), a period of 32 months.

At each station, water-stage recorders were used to provide a continuous record of the stream's stage (height). The stage was then converted to water discharge with a stage-discharge relation, which was defined by water discharge measurements at various stages. Suspended-sediment samples were collected with automatic pendulum samplers at predetermined stages during storms, and intermittently by hand with a U.S. DH-48 sampler. The concentrations of the sediment samples were determined in the laboratory using the filtered dry-weight method, as outlined by Guy (1969). Daily mean water discharge, sediment concentration, and sediment discharge were calculated for each station according to the techniques described by Porterfield (1972). The turbidity of all sediment samples was measured nephelometrically in the laboratory. Turbidity was also monitored continuously in the field with surface-scatter instrumentation at each station.

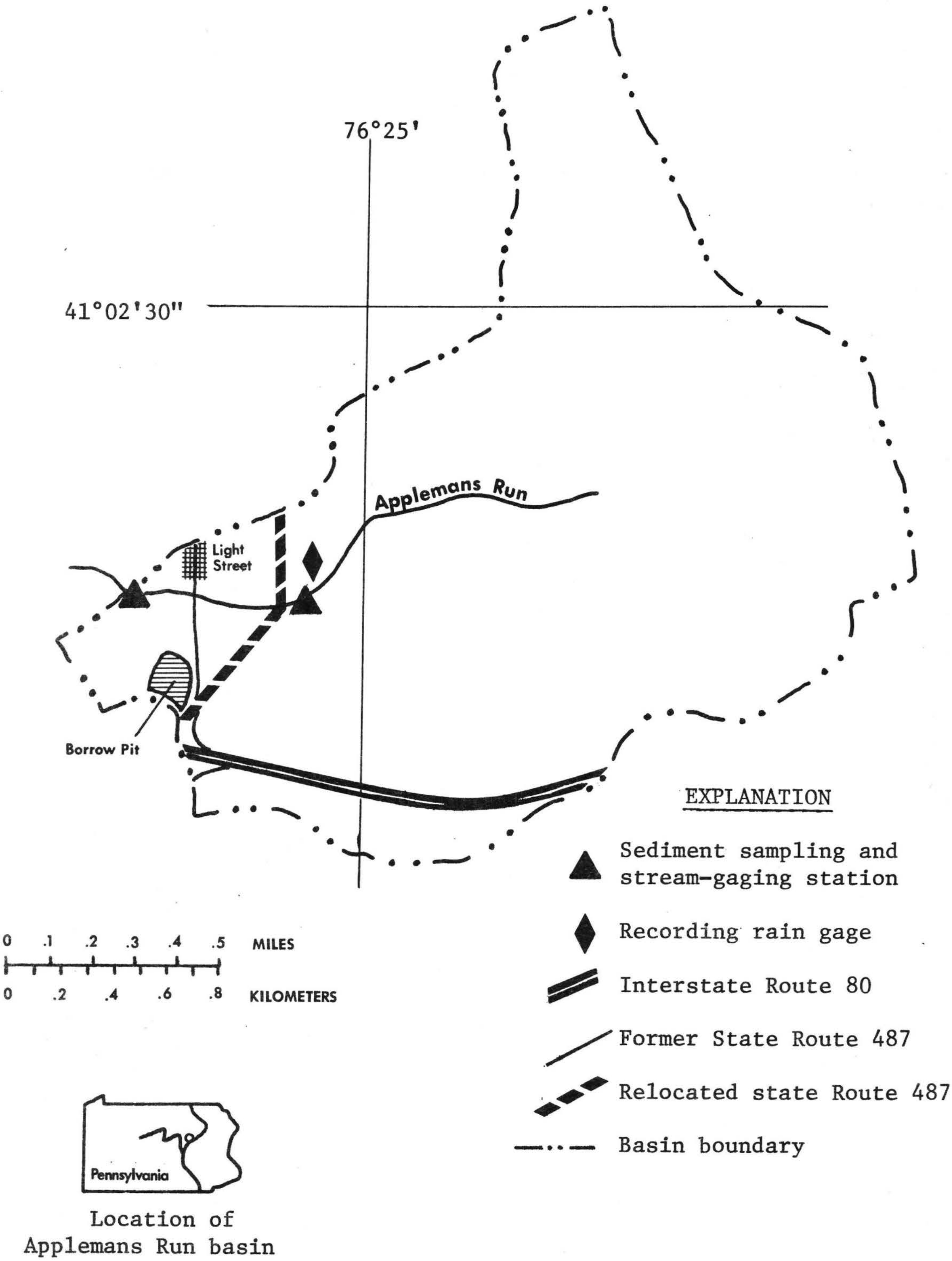

Figure 1.--*Applemans Run basin showing highway relocation near Light Street and data-collection sites.*

Using the water discharge data for Applemans Run upstream and downstream from Light Street with sediment discharge data for the upper station, a normally expected sediment discharge was calculated for the lower station. The calculated sediment discharge indicates the quantity of sediment in transport at the lower station under nonconstruction conditions. It was compared with the measured load at the lower station to help evaluate the changes in sediment transport in Applemans Run caused by the relocation of Route 487.

BASIN DESCRIPTION

Applemans Run basin at Light Street drains a small area of glacial outwash sediments (Higbee, 1967) in the Appalachian Valley and Ridge province, 3 mi (4.8 km) northeast of Bloomsburg, Columbia County, in east-central Pennsylvania. The run flows westward into Fishing Creek, which empties into the North Branch Susquehanna River at Bloomsburg.

The gaging station, Applemans Run above Light Street, at 555 ft (169 m) above sea level, was located 0.8 mi (1.3 km) from the run's origin, 650 ft (198 m) above sea level (figure 1). This gage was immediately upstream from the highway construction site. Drainage area above the gage was 1.72 mi^2 (4.45 km^2). The gage below Light Street, at 535 ft (163 m) above sea level, was located 0.4 mi (0.6 km) farther downstream. The drainage area of the study basin above this gage was 1.99 mi^2 (5.15 km^2), which included 17.5 acres (7.08 ha) exposed during construction. The confluence of the run with Fishing Creek was 1.4 mi (2.3 km) downstream from the lower gage.

The eastern upland area of the watershed is gently rolling, and ground slopes average about 4 percent. The western part of the basin near Light Street drops sharply to the flood plain of Fishing Creek, with slopes averaging about 9 percent. The southern and eastern basin divide is close to 700 ft (213 m) above sea level, although a small ridge along the northern divide reaches 1,000 ft (305 m). Maximum local relief within the basin is about 465 ft (142 m).

Climate

Applemans Run basin lies within the main stem Susquehanna River valley, where climate is characterized as continental inland. Warm, humid summers and moderately long winters are typical, with prevailing winds from the west and northwest. Climatological records at Millville, Pa., 6 mi (1.5 km) northwest of Light Street, show that January average daily temperatures ranged from 10° to 38°F (-12.2° to 3.3°C), whereas July average daily temperatures ranged from 56° to 83°F (13.5° to 28°C) from 1971 to 1974. The average frost-free season is about 130 days, from mid-May to mid-September.

Precipitation was recorded continuously near the upper gaging station (fig. 1) and is reported in table 1 and graphically in figure 2. The average rainfall for the 1972-73 calendar years was 44.1 in (1,120 mm), excluding the rainfall of tropical storm Agnes on June 22, 1972. Average annual precipitation, as determined from 25 years of record at nearby Millville, Pa., was 42.6 in (1,080 mm). Except for a brief discussion of tropical storm Agnes and its significance in the basin on page 18, all data for June 22 have been deleted from this report due to their overwhelming proportions.

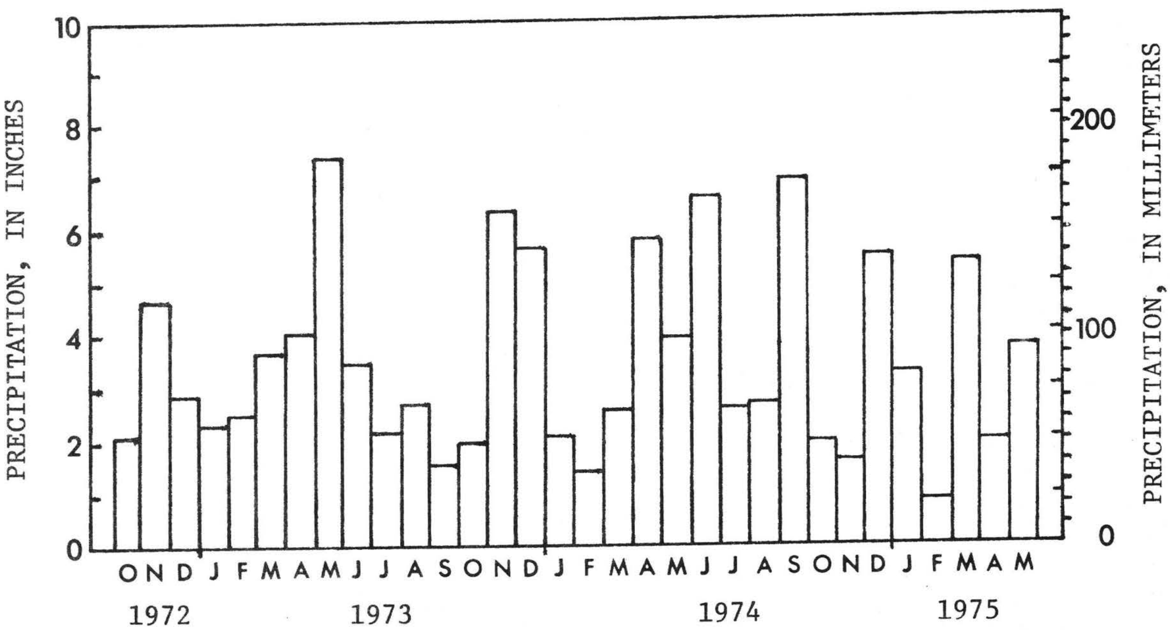

Figure 2.--*Monthly precipitation in Applemans Run basin for period October 1971 to May 1974. Precipitation for June 1972 does not include that during tropical storm Agnes, June 22.*

Table 1.--*Summary of water discharge, suspended-sediment discharge, and precipitation by months for Applemans Run above and below Light Street*

Date	Applemans Run above Light Street: Water discharge (ft^3/s-days)	Applemans Run above Light Street: Suspended-sediment discharge (tons)	Precipitation (inches)	Applemans Run below Light Street: Water discharge (ft^3/s-days)	Applemans Run below Light Street: Suspended-sediment discharge: Measured (tons)	Applemans Run below Light Street: Suspended-sediment discharge: Estimated normal discharge (tons)
1971						
October-----	8.8	0.4	2.09	[a]10	[a]1.0	0.5
November----	21	10	4.70	34	52	16
December	78	12	2.91	100	45	15
1972						
January-----	45	4.2	2.32	51	15	5
February----	34	21	2.56	41	55	25
March-------	116	273	3.72	134	507	315
April-------	64	131	4.10	73	188	149
May---------	80	111	7.45	92	724	128
June[b]------	70	25	3.51	91	59	32
July--------	31	3.9	2.20	42	8.3	5
August------	19	97	2.75	27	125	138
September---	8.6	0.1	1.58	9.3	0.9	0.1
October-----	6.1	0.8	2.01	12	2.2	2
November----	50	25	6.39	82	64	41
December----	127	67	5.70	139	176	73

1973						
January-----	48	30	2.14	62	37	39
February----	48	66	1.46	65	307	89
March-------	48	201	2.65	63	507	264
April-------	78	78	5.86	108	747	108
May---------	41	8.0	3.94	59	27	12
June--------	60	275	6.66	87	995	399
July--------	26	9.8	2.65	39	63	15
August------	12	11	2.78	22	37	20
September---	32	56	6.99	60	253	105
October-----	20	3.3	2.02	28	15	5
November----	17	2.1	1.65	23	6.4	3
December----	105	183	5.54	151	509	263
1974						
January-----	84	30	3.35	102	72	36
February----	29	16	0.91	32	21	18
March-------	76	106	5.45	98	149	137
April-------	70	18	2.02	79	22	20
May---------	29	25	3.83	35	32	30
TOTAL	1,582	1,900	113.89	2,050	5,220	2,508

a/ Estimated.

b/ Excluding June 22, 1972, flood.

Geology and Soils

A thick overburden of pre-Wisconsin glacial outwash consisting mostly of stratified sand and gravel but including some large cobbles covers most of the bedrock in this area. The glacial sediments have been derived from Paleozoic sandstone and shale and in many places are more than 30 ft (9.1 m) thick (U.S. Department of Agriculture, 1967). Few rock outcrops occur in the gently sloping surface of the basin. The underlying bedrock is thinly bedded sandstone and shale of Middle Devonian age in the northern parts of the basin and fissile shale and siltstone and some red beds of Silurian age in the southern areas.

Most of the soils in the basin are silty loams formed in the glacial sediments and in fine-grained windblown deposits (Higbee, 1967). The soils are 3 to 6 ft (0.9 to 1.8 m) thick in most places. They are moderately well-drained and have high permeability, with a high moisture holding capacity (U.S. Department of Agriculture, 1967). Topsoil is generally about 50 percent sand, 44 percent silt, and 6 percent clay. Most of the forest cover has been cleared and the soils are extensively cultivated. The soils and gravel substratum in the basin were judged to be very erodible.

Land-Use

Table 2 summarizes land-use in Applemans Run basin from October 1971 to August 1973. Much of the land was cropland or pasture and grassland, and only small, isolated areas have remained under forest cover. The area of the basin below the upstream gaging station was more urbanized than the upper area of the basin, as it contained the buildings and streets of the village of Light Street. As much as 17.5 acres (7.08 hectares) of this lower drainage area was disturbed by highway construction from September 1971 to August 1973. This construction area amounted to about 1 percent of the total basin area.

Table 2.--*Land-use in Applemans Run basin, October 1971 to August 1973.*

	Upper area ($1.72\ mi^2$)	Lower area ($0.27\ mi^2$)	Total basin ($1.99\ mi^2$)
Forest	10%	0%	9%
Grassland	50%	60%	51%
Cultivated	40%	20%	38%
Residential	0%	10%	1%
Construction	0%	10%	1%

Runoff

Average runoff from Applemans Run basin was about 14.0 in (356 mm) for each of the 1972-74 water years[1/]. Runoff at each gage and precipitation in the catchment, was as follows:

Water year	Precipitation (inches)	Applemans Run above Light Street runoff (inches)	Applemans Run below Light Street runoff (inches)
1972------	39.9	12.4	13.1
1973------	49.2	12.5	14.9
1974[a/]----	24.8	9.3	10.2

a/ The 1974 water year only indicates data from October 1973 to May 1974.

About one-third of the precipitation on the basin during this period was discharged as runoff past the lower gage; the remainder was either transpired by the basin's vegetation, evaporated directly into the atmosphere, or lost by seepage. Daily records of water discharge from Applemans Run above and below Light Street are published in the U.S. Geological Survey reports titled "Water Resources Data for Pennsylvania--Part 2" (1973 and 1974).

Data from the 32-month study period indicate that runoff from the study basin, measured at the gage below Light Street, could be as much as 10 percent greater than runoff from the upper basin area, measured at the gage above Light Street. This larger volume of water per unit area at the lower station is notable considering that the difference in drainage areas for the gaging stations is only 0.27 mi^2 (0.70 km^2). Greater runoff at the lower station may be partly attributed to increased imperviousness of the lower basin area due to the buildings and paved areas of Light Street and to storm-sewer drainage from Interstate Highway 80. Increased runoff at the lower station may also be attributed to the steep slopes and decreased permeability of the compacted embankment material in the areas of highway construction.

Monthly runoff at the downstream station ranged from 2.82 in (71.6 mm) in December 1973 to 0.17 in (4.3 mm) in September 1972 (table 1). However, months of maximum runoff did not necessarily correspond to months of maximum sediment discharge, due to the varying influences of other erosion controlling factors.

1/ A water year is a year beginning October 1 and ending September 30 and is designated by the year in which it ends.

HIGHWAY CONSTRUCTION

From September 1971 to August 1973, the Pennsylvania Department of Transportation relocated State Route 487 through Applemans Run basin. The new two-lane highway connects with the old Route 487 at interchange 35 of Interstate Highway 80 in the southwest corner of Applemans Run basin. It runs 0.5 mi (0.8 km) across Applemans Run to the northwestern divide of the basin and then rejoins existing Route 487, bypassing the village of Light Street (fig. 1).

Because the highway was built directly across the lower part of the basin, large quantities of fill material were used to bring the roadway up to grade. In the early stages of construction, the channel of Applemans Run was diverted, and a concrete box culvert was constructed. Flow was diverted through the new culvert in January 1972, and fill material was placed across the basin. Most of the material was glacial outwash from two borrow pits, the largest of which was located within the lower area of the study basin. Average particle-size percentages of the fill material were as follows:

	Clay (0.002-0.004 mm)	Silt (0.004-0.062 mm)	Sand (0.062-2.0 mm)	Gravel (2.0-64 mm)
Borrow pit 1	9%	7%	28%	56%
Borrow pit 2	34%	27%	21%	18%

The coarser sediment from borrow pit 1, which was located outside the basin, was used only in the early stages of construction. The construction area exposed in the basin, including borrow pit 2, during the relocation project was about 17.5 acres (7.08 ha), or about 1 percent of the total basin area.

As filling progressed, the exposed embankments were continually seeded and mulched to help control erosion on the slopes. A mixture of straw mulch, rye grass seed, crown vetch seed, fertilizers, lime, and a binding emulsifier was used in the seeding and mulching operations. The mulch temporarily protected the steep embankments until the fast-growing rye grass was able to root. By April 1973 the highway embankment was up to grade and the sub-base was laid. Paving was completed by August 1973. Because it is a slow-grower, the full growth of the crown vetch protective cover was not seen until the spring of 1974.

SUSPENDED-SEDIMENT DISCHARGE

Suspended-sediment discharges were computed for Applemans Run above and below the areas exposed by construction of the two-lane highway. Because of other sediment sources within the basin, which include croplands and localized private construction near the run, it was necessary to determine how much of the total suspended-sediment load measured at the lower station was derived only from the highway construction site. Using flow and sediment-discharge values from the control station above the construction, normal sediment discharge was estimated for the lower station, allowing for the added increase of runoff from the additional basin area, as follows:

$$\text{estimated normal } Q_{sb} = \frac{Q_{wb}}{Q_{wa}} \times Q_{sa}$$

where:

Q_{wa} = water discharge (ft^3/s-days) above Light Street.
Q_{wb} = water discharge (ft^3/s-days) below Light Street.
Q_{sa} = sediment discharge (tons) above Light Street.
Q_{sb} = sediment discharge (tons) below Light Street.

The estimated sediment discharge is an indication of normal sediment yield from the watershed based on measured yields from the unaffected upper area of the basin. The difference between the measured load at the lower station and the estimated normally expected load is the measurement of suspended-sediment transport in the basin that can be directly attributed to the highway construction.

In the 32 months of data collection, about 5,200 tons (4,700 tonnes) of suspended-sediment were discharged past the lower gage, as reported in table 1 (see page 6). Of this load, about 2,500 tons (2,300 tonnes) was estimated to be the normally expected discharge. Therefore, about 2,700 tons (2,400 tonnes), or slightly more than 50 percent of the total suspended-sediment transported from the basin during this investigation, was derived from the highway construction area. The remainder of the sediment was eroded and transported from other source areas in the basin.

Trends in Suspended-Sediment Discharge

Many investigators have observed that a major part of a stream's annual load is transported during relatively short periods of time. Table 3 shows the flow and suspended-sediment discharge for Applemans Run produced by storms on 55 days during the 32 months (974 days) of data collection.

Table 3.--*Flow and suspended-sediment discharge values for 55 storm days*[a/].

Date	Applemans Run above Light Street: Water discharge (ft^3/s-days)	Applemans Run above Light Street: Suspended-sediment discharge (tons)	Applemans Run below Light Street: Water discharge (ft^3/s-days)	Applemans Run below Light Street: Suspended-sediment discharge: Measured (tons)	Applemans Run below Light Street: Suspended-sediment discharge: Estimated normal (tons)	Applemans Run below Light Street: Suspended-sediment discharge: Ratio measured (tons) to estimated normal (tons)
1971						
Nov. 29---	5.4	9.8	9.4	48	17	2.8
Dec. 06---	8.7	7.0	12	26	9.7	2.6
Dec. 07---	12	2.9	17	15	4.1	3.6
1972						
Feb. 13---	6.4	14	7.5	28	16	1.8
Feb. 28---	4.2	5.3	5.9	23	7.4	3.1
Mar. 01---	7.5	15	10	33	20	1.6
Mar. 02---	13	69	15	112	80	1.4
Mar. 03---	16	128	19	272	152	1.8
Mar. 16---	6.3	29	7.6	38	34	1.1
Mar. 22---	7.8	15	9.1	33	17	1.9
Apr. 16---	11	109	13	149	129	1.2
Apr. 20---	8.1	17	9.4	27	20	1.4
May 04---	15	54	17	89	61	1.5
May 30---	5.0	10	5.8	272	12	23
May 31---	11	42	13	350	50	7.0
June 21---	6.3	10	9.7	25	15	1.7
June 23---	12	7.0	16	18	9.3	1.9
Aug. 03---	1.9	19	2.6	24	24	1.0
Aug. 07---	5.5	78	7.5	100	100	1.0
Nov. 08---	5.3	5.2	9.0	20	8.8	2.3
Nov. 14---	9.1	11	16	23	19	1.2
Dec. 06---	9.8	30	12	44	37	1.2
Dec. 22---	14	16	20	100	23	4.3

1973						
Jan. 22---	2.0	14	2.8	14	14	1.0
Jan. 27---	3.7	13	5.0	14	14	1.0
Feb. 02---	9.7	62	13	300	91	3.3
Mar. 17---	8.2	195	15	502	375	1.4
Apr. 04---	9.5	54	16	114	91	1.3
Apr. 10---	6.7	11	9.3	15	5.0	1.0
May 10---	2.0	4.5	2.9	18	6.5	2.8
June 04---	1.8	2.5	2.5	15	3.5	4.3
June 28---	25	220	35	720	308	2.3
June 29---	7.5	28	11	130	41	3.2
June 30---	6.0	19	9.8	110	31	3.5
July 05---	3.4	7.2	5.9	52	12	4.3
Aug. 12---	1.5	8.3	3.0	29	17	1.7
Sep. 06---	0.88	3.4	1.7	19	6.6	2.9
Sep. 14---	4.5	13	11	73	32	2.3
Sep. 18---	6.4	19	12	77	36	2.1
Sep. 22---	1.2	5.5	2.5	22	11	2.0
Sep. 23---	4.5	12	8.8	31	23	1.3
Sep. 29---	2.0	3.0	3.5	30	5.2	5.8
Dec. 05---	3.5	2.0	6.2	12	3.5	3.4
Dec. 09---	9.4	70	17	180	127	1.4
Dec. 20---	7.4	64	14	150	121	1.2
Dec. 21---	12	28	23	120	54	2.2
Dec. 26---	9.2	7.4	15	25	12	2.1
Dec. 27---	8.6	5.8	12	11	8.1	1.4
1974						
Jan. 21---	8.4	14	15	42	25	1.7
Jan. 28---	5.2	12	7.2	24	17	1.4
Feb. 22---	3.9	15	4.9	20	19	1.1
Mar. 09---	11	70	14	90	89	1.0
Mar. 21---	6.2	21	7.9	32	27	1.2
Apr. 01---	10	9.3	12	10	10	1.0
May 12---	5.8	22	7.0	29	27	1.1
TOTAL	408	1,738	589	4,899	2,520	

a/ Suspended-sediment discharge at lower station greater than 10 tons per day.

The 55 days represent less than 6 percent of the time period, but account for 95 percent of the suspended-sediment transported past the lower gage and 30 percent of the total flow. Correspondingly, in the other 919 days, the remaining 70 percent of flow transported only 5 percent of the total suspended-sediment discharged. The percentages compare favorably with the upper part of the basin, which was unaffected by the highway construction. During the same 55 storm days there, 90 percent of the total suspended-sediment was transported by only 25 percent of the water. The data suggest similar trends in sediment transport at each station.

Daily storm data listed in Table 3 are arranged seasonally in figure 3 to illustrate the relation of variations in suspended-sediment discharge from the construction site (measured discharge minus estimated normal discharge) to storm-water discharge measured at Applemans Run below Light Street. Factors controlling erosion of sediment from the construction area changed considerably during the course of the investigation, and suspended-sediment discharges for each storm varied accordingly in relation to water discharge.

During any given storm, sediment erosion and transport is dependent upon many factors, several of which are closely interrelated. Foremost among these factors is the individual storm intensity and duration, which partly determines the erosiveness of raindrops and of overland runoff (Johnson, 1961). Soil character, which includes particle size, cohesiveness, porosity, and moisture content (from antecedent conditions) also directly affects the amount of runoff. Slopes and slope lengths are other important factors in determining amount and velocity of storm runoff. Erodibility of source material in some seasons is dependent upon whether the soil is frozen as well as on soil character. Sediment erosion is also partly dependent upon soil cover, as determined from land-use within an area; vegetation protects the land surface by interception of raindrops and minimizes erosion and transport by retarding overland runoff. The amount of fine material that is available for erosion is another important factor; material available from construction areas is often relatively limited to a layer of fine particles that overlies compacted fill material.

Guy (1964) and others have reported a definite increase from minimum to maximum erodibility during the early spring in the Eastern United States, as temperatures increase. Correspondingly, the amount of suspended-sediment transported from construction areas during this study was highest in the spring, as seen in figure 3. Several storms during February and March also produced significant sediment discharges, which may be attributed to freezing and thawing that markedly increased soil erodibility during these storms. During the summer, the amount of precipitation becomes the most important factor affecting sediment discharge. The relatively minor amounts of suspended-sediment discharged from construction areas during the summer in Applemans Run basin is directly attributed to less rainfall then.

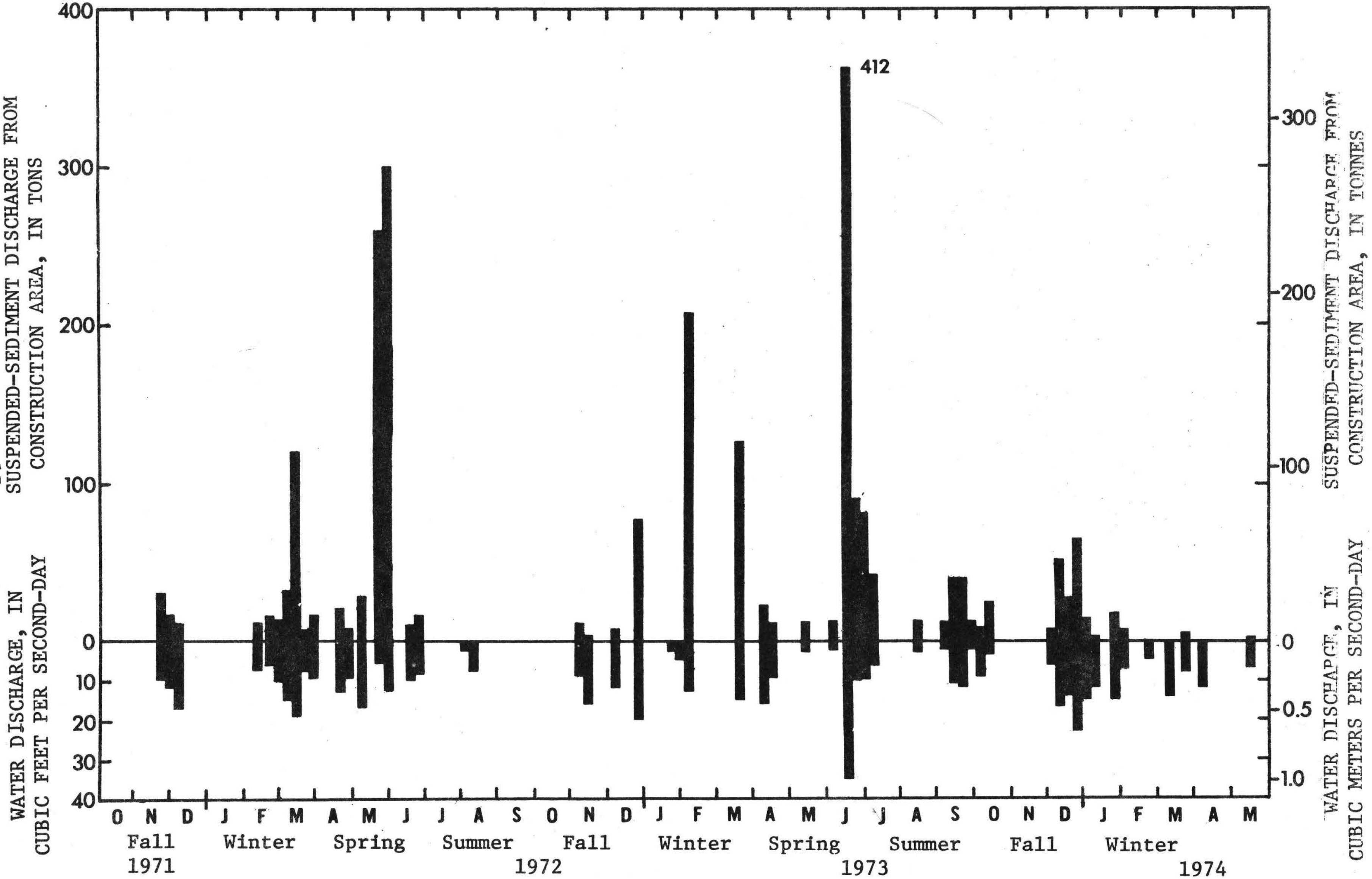

Figure 3.--*The relation of variations in suspended-sediment discharge from construction site to storm-water discharge in Applemans Run basin for 55 storm days, October 1971 to May 1974. Data from tropical storm Agnes, June 22, 1972, have been deleted.*

Data from this study directly support the statement by Vice and others (1969) that erosion can be significantly reduced by scheduling construction during the summer, when yields are lowest, and avoiding or minimizing construction during the spring, when yields are highest. During the 1972 to 1973 water years of active construction, 83 percent of the sediment transported from construction areas was eroded each year from January to June. Additionally, 69 percent of the total amount of sediment discharged from the construction site in 1972 was transported in April to June, whereas less than 1 percent of the year's load was transported in July to September. This indicates that soil losses due to erosion and the subsequent effects of sedimentation in nearby streams in this area may be greatest in the first half of each year and especially during the late spring months.

Suspended-sediment discharges from the construction area in Applemans Run basin were considerably lower in the first five months of 1974 than they were in the same months in 1972 and 1973, despite nearly average runoff, as seen in figure 3. Most of the storm runoff in early 1974 occurred during the winter, although two spring storms were notable. Suspended-sediment discharges from Applemans Run basin during these spring storms were nearly normal, reflecting the completion of the highway in late 1973.

Paving of the highway was completed in August 1973, and by that time most of the embankment slope was covered with quick-growing rye grass. By spring in 1974, a thick protective cover of crown vetch, a leguminous plant that matures more slowly than rye grass, had grown over most of the exposed construction area. Correspondingly, suspended-sediment discharges from the construction site showed marked decreases in 1974, once the vetch matured. Despite significant storms during the spring, suspended-sediment discharges from the construction site were minimal compared with sediment discharges of previous spring months of active construction. This indicates a stabilization of the exposed areas within the basin during a season when suspended-sediment discharge might have potentially been highest.

Suspended-Sediment Yield

Annual suspended-sediment yields, expressed as tons/mi^2, were computed for Applemans Run above and below Light Street and for the construction areas within the basin for the water years 1972-74 (Table 4). The values for Applemans Run above Light Street (1.72 mi^2 [4.45 km^2]) were used as an indication of yields from nonconstruction areas within the basin. These normal yields were compared to yields at the lower station to determine the yields from highway construction areas. The significantly higher yields from construction areas in 1973 may be attributed to an increase in both precipitation and construction activity in that water year. Embankment slopes were steeper and longer in 1973, as filling progressed. Also, the material used in 1973 was finer in size than material initially used in 1972 (see page 10) and thus was more susceptible for erosion and transport.

Table 4.--*Suspended-sediment yields from Applemans Run basin for 1972-74 water years.*

Water year	Precipitation (inches)	Annual suspended-sediment yields, in tons/mi^2		
		Applemans Run above Light Street	Applemans Run below Light Street	Highway construction area
1972	39.9	401	896	40,000
1973	49.2	481	1,315	66,000
1974[a/]	24.8	222	416	14,000

a/ The 1974 water year indicates data from October 1973 to May 1974.

Annual sediment yields from the part of the basin unaffected by highway construction were considerably larger than average-annual sediment yields for larger basins in this area, as reported by Williams and Reed (1972). Applemans Run basin is within the low yielding area of the Valley and Ridge province in the Susquehanna River basin, where average-annual yields were described to be generally less than 100 tons/mi^2 (0.16 tons/acre). Although precipitation during this investigation was near normal, the upper areas of Applemans Run basin yielded more than four times the expected average-annual yield for this area.

Several studies, notably Brune (1948), have shown that sediment yields decrease with increased drainage area. Furthermore, rates of sediment yield for small basins are more dependent on land-use and individual basin characteristics than larger basins (Brown, 1950). The high yield from Applemans Run basin may be attributed to the fact that it is a much smaller first-order stream basin than the larger and more complex basins studied in this area by Williams and Reed (1972). Within this small basin, extensive cultivation increases the erodibility of the soils and contributes to high suspended-sediment yields. A high rate of erosion in this small area of cultivated soils and unconsolidated glacial deposits must be supplying more sediment than the downstream system can efficiently transport, resulting in loss of sediment by deposition. Thus, as drainage area increases, sediment yields decrease due to aggradation, possibly along downstream flood plains and at tributary mouths, where stream gradients decrease.

Turbidity and Suspended-Sediment Concentration

Turbidity may be defined as an optical indication of a water's cloudiness or muddiness due to the amount, size, shape, refractive index, and other characteristics of its suspended material (Brown and Ritter, 1971). Turbidity measurements on all sediment samples were made in the laboratory with a Hach 2100 nephelometric turbidimeter[2/] and the values were used to compute a daily mean discharge-weighted turbidity value. Those values, with the daily sediment data from Applemans Run above and below Light Street, may be found in the U.S. Geological Survey publications titled "Water Resources Data for Pennsylvania--Part 2" (1973, 1974). Turbidity was also monitored continuously at each station with a Hach surface-scatter turbidimeter. The field turbidity record was used as an aid in defining the daily sediment-concentration graph used in determining daily sediment discharge values, as described by Truhlar (1976).

The relation of turbidity to suspended-sediment concentration at the station below Light Street for three sucessive water years is indicated in figures 4, 5, and 6. The data, plotted from laboratory measurements of individual samples, show a good degree of correlation, although slight changes were observed in the relations as construction progressed. This may be due to the fact that finer particles have a greater surface area per unit weight than coarser particles and thus scatter more light. Accordingly, samples with more clay would have a greater turbidity than samples of an equal concentration with less clay and more sand (Ritter and Brown, 1971). The shifts in the curve for each water year may, therefore, reflect changes over the years in the size distribution of the sediment eroded and transported from the construction area.

THE FLOOD OF JUNE 1972

From June 22-24, 1972, the most severe flooding ever to occur in Pennsylvania took place as the result of tropical storm Agnes. During the flood, it was estimated that many streams in the State carried as much suspended-sediment as they usually carry in 2-7 years (Ritter, 1974). On June 22, 8.6 in (218 mm) of rain fell in Millville, northwest of Light Street, and flooding was severe in Applemans Run basin. Much of the data for that event were lost, as the gaging stations were inundated, although good indications of the floodwater stages were recovered from partly intact stage recordings. The peak water discharge at the new concrete box culvert immediately downstream from the upper gage was indirectly measured using methods described by Bodhaine (1968) and used in computing the daily mean water discharges for June 22. Sediment discharges were estimated using sediment-transport curves.

Because of the overwhelming magnitude of the June 22 flood in Applemans Run, all data for that day were excluded in the foregoing analyses. At the lower gaging station, it was estimated that in 1 day 350 ft^3/s-day (9.91 m^3/s-day) of water was discharged carrying about 12,000 tons (10,900 tonnes) of suspended-sediment. It was estimated that the basin yielded in 1 day almost as much sediment as it would normally yield in 15 years, based on an average annual yield of 400 $tons/mi^2$.

2/ The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

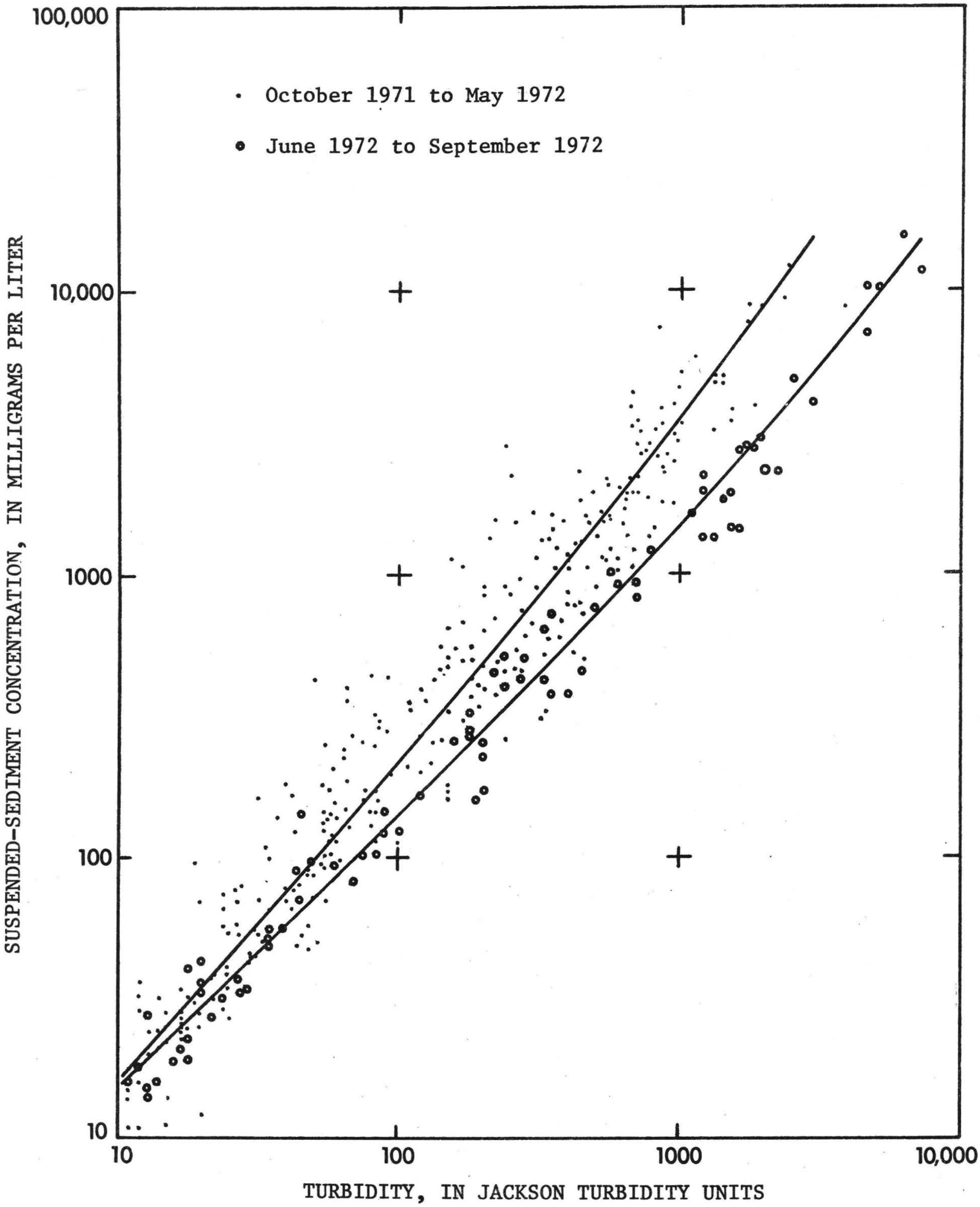

Figure 4.--*Relation between turbidity and suspended-sediment concentration in Applemans Run below Light Street for the 1972 water year.*

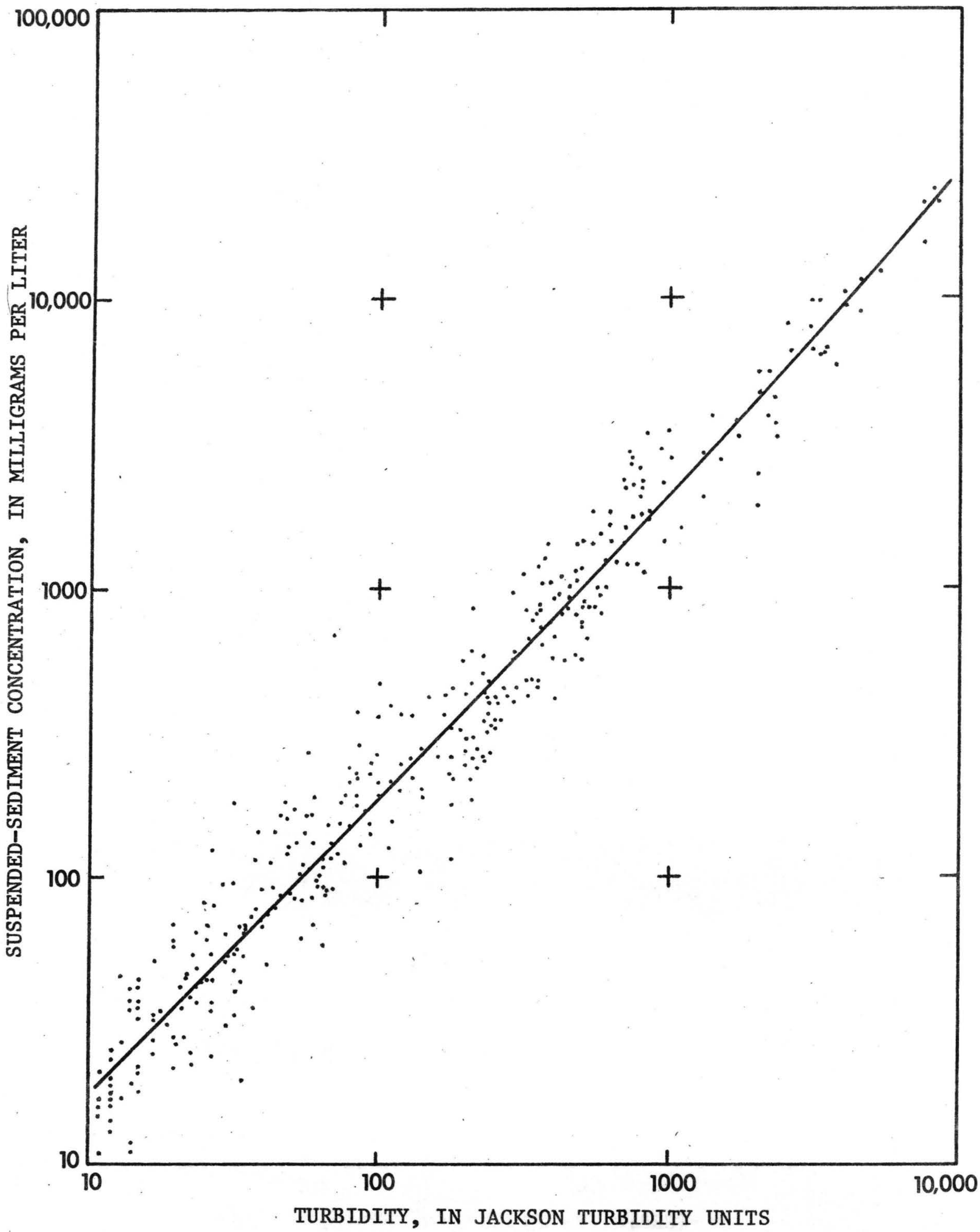

Figure 5.--*Relation between turbidity and suspended-sediment concentration in Applemans Run below Light Street for the 1973 water year.*

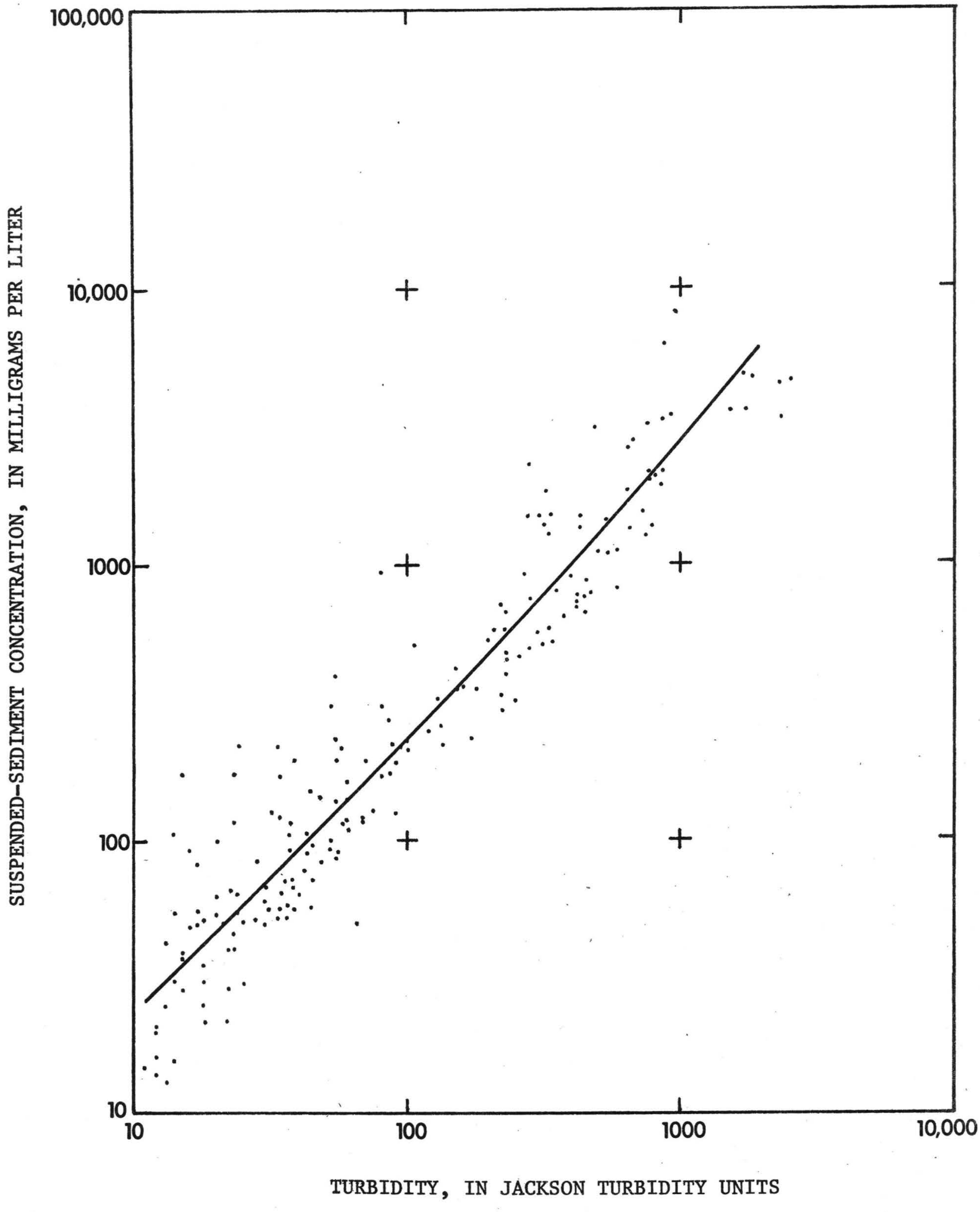

Figure 6.--*Relation between turbidity and suspended-sediment concentration in Applemans Run below Light Street for the 1974 water year. Data include samples from October 1973 to May 1974.*

Of the 12,000 tons (11,000 tonnes) transported past the lower gage on June 22, only 2,400 tons (2,200 tonnes) was estimated to have been derived from the construction site. This 2,400 tons (2,200 tonnes) was calculated by deducting the normally expected sediment discharge from the day's estimated actual sediment discharge.

The suspended-sediment discharge of 2,400 tons (2,200 tonnes) on June 22 indicates that only one-fifth of the basin's yield on that day was derived from the construction area. In comparison, about one-half of the total sediment discharged from the basin in 32 months was derived from the construction area. This difference suggests that during large storms the supply of readily available sediment from highway construction areas may be limited to the uppermost layers of fine particles, which accumulate as dust on the construction surfaces. This uppermost layer of dust is quickly removed by sheet erosion in the early stages of most storms, while the entire basin continues to supply sediment through channel and gully erosion during continuation of very large storms (L. A. Reed, oral commun., 1975). The supply of fine sediment available for erosion from construction sites, however, quickly accumulates again due to construction activity after each storm. This supply of fine sediment, once replaced, is continually washed off by small storms, accounting for the overall high sediment yields from areas of highway construction.

SUMMARY AND CONCLUSIONS

Shortly after relocation of State Highway 487 began in Applemans Run basin near Bloomsburg, Pa., two gaging stations were established, one above and one below the construction area, to measure suspended-sediment discharge in the basin. Normally expected sediment discharges were computed using data from the control station on Applemans Run above the new highway and were compared with discharges measured at the station below the construction area in order to evaluate and summarize the sediment transport within the basin that was directly attributable to highway construction activities.

In 32 months of data collection, from October 1971 to May 1974, about 5,200 tons (4,700 tonnes) of suspended-sediment were discharged from the 1.99-mi^2 (5.15-km^2) drainage basin. About 50 percent of this sediment was derived from 0.027 mi^2 (0.071 km^2) of the basin area exposed during construction, while the remaining sediment came from other land-use areas. Annual suspended-sediment yields from the construction area were 40,000 and 66,000 tons/mi^2 (62 - 100 tons/acre) in the 1972 and 1973 water years, respectively. The larger yield in 1973 is attributed to an increase in both precipitation and construction activity in that water year.

During the study, the upper basin areas of Applemans Run unaffected by highway construction yielded more than four times the average-annual sediment yield expected for such basins in this area of the Susquehanna River basin. The unusually high yields from this basin were attributed to its small drainage area as compared to the larger basins previously studied in the area, to the overall availability of the basin's thick mantle of periglacial sediment, and to the high erodibility of the basin's soils due to extensive cultivation.

During the 1972 and 1973 water years of active highway construction, 83 percent of the sediment transported from the construction site was eroded each year in storms from January to June, corresponding to seasonal increases in runoff and soil erodibility. Sixty-nine percent of the 1972 water year's suspended-sediment discharge was transported in April to June, whereas less than one percent was transported in July to September. This indicates that soil losses due to erosion and the subsequent effects of sedimentation in nearby streams in this area is greatest in the first half of each calendar year, and especially during the late spring months.

Suspended-sediment discharges from the construction area in Applemans Run basin were considerably lower in the first 5 months of 1974 than they were in the same months in 1972 and 1973, despite nearly average runoff during that period. Paving of the highway had been completed in August 1973 and most of the slopes were covered with quick-growing rye grass. Complete stabilization of the area was not noticed, however, until the spring of 1974, when a protective cover of crown vetch matured on the embankment slopes and suspended-sediment discharge from Applemans Run basin returned to normal.

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