TRAP EFFICIENCY OF A SEDIMENT-CONTROL POND BELOW A BLOCK-CUT COAL MINE IN FAYETTE COUNTY, PENNSYLVANIA

By Lloyd A. Reed, Lou Dilissio, and Donald E. Stump, Jr.

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

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
pound, avoirdupois (lb)	453.6	gram (g)
ton, short	0.9072	megagram (Mg)
ton per acre	2.242	megagram per hectare (Mg/ha)

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ABSTRACT

The efficiency of a pond constructed to control sediment from a surface coal mine site was determined by measuring runoff and sediment loads at the inlet to and discharge from the pond during storms. The pond is below a 17.9-acre block-cut coal mine in Fayette County, Pennsylvania and has a permanent pool capacity of 60,200 cubic feet. The capacities at the principal spillway and the emergency spillway are 128,900 and 175,500 cubic feet, respectively. The pond is equipped with a 3-inch flow control valve, used by the mine operator to regulate the pond stage between the permanent pool and the principal spillway. Data were collected during five moderate storms when the 3-inch control valve was intentionally opened. The ratio between the quantity of water in the pond at the start of the storm and the quantity of runoff to the pond was calculated for each storm. The ratios were 3.6, 2.5, 8.6, 2.9, and 1.5, for the five storms. The measured trap efficiencies were 98.1, 92.8, 99.6, 99.1, and 98.2 percent, for the five storms.

INTRODUCTION

Background

All active surface-mining sites in Pennsylvania must have erosion control facilities to prevent excessive sediment discharge during mining and reclamation. Sediment-control ponds are required to have a permanent pool capacity large enough to receive 3,000 ft^3/acre of stream discharge from the basin drainage area, and a stream discharge capacity at the principal spillway of 7,000 ft^3/acre from the disturbed drainage area. They are also required to have an outlet, with or without a valve, at the permanent pool-overflow altitude large enough to discharge at a rate of 4,000 ft^3/acre per day. The ponds are left in place until reclamation has been completed and the area has stabilized.

The efficiency of a pond constructed to control sediment from a surface mine site was determined by measuring runoff and sediment loads at the inlet to and discharge from the pond during storms. The pond is below a block-cut coal mine in Fayette County, Pennsylvania and has a permanent pool capacity large enough to receive 3,400 ft^3/acre of stream discharge from the basin drainage area, and a discharge capacity at the principal spillway of 7,200 ft^3/acre. The area and volume of the pond at the principal spillway are 0.3 acres and 128,900 ft^3, respectively. The pond is equipped with a 3 in. valve, used by the mine operator to regulate the pond stage between the permanent pool and the principal spillway. The valve is large enough to discharge 3,800 ft^3/acre in 1.85 days.

Purpose and Scope

This report presents data collected from July 1981 through September 1982 to evaluate the sediment-removal (trap) efficiency of the sediment-control pond. Water discharge and suspended-sediment data were collected at the inflow and at the outlet from the sediment-control pond during five storms. Precipitation and changes in pond stage were also recorded during the five storms. Data were collected when the flow control valve was open; actual trap efficiencies were measured.

Description of Study Area

The study area is a block-cut surface coal mine in Fayette County, about 2 miles south of Farmington, Pennsylvania (fig. 1). The area is underlain by rocks of the Allegheny group of Pennsylvania age (Pennsylvania Geological Survey, 1960), and includes sandstone, shale, clay, and in some areas the Freeport, Kittanning, and Brookville-Clarion coals. Figure 2 is a map of the area prior to mining showing the contours and the soil types. Prior to mining the area was forested, and slopes in the area ranged from 5 to 17 percent.

The soils are classified as Gilpin very stony loams and belong to the Gilpin-Wharton-Ernest association and are moderately erodible (U.S. Department of Agriculture, 1973). Before mining, most of the soils had an organic layer of leaf litter and humus over the surface. The top soils were dark grayish brown channery silt loams and were up to 7 in. thick. The subsoils were yellowish brown silty clay loams and channery silty clay loams, and were from 24 to 36 in. thick. The particle-size composition of soil samples collected at the mine was about 38 percent sand or larger particles, 36 percent silt, and 26 percent clay (table 1).

Surface mining at the Fayette County site began in April 1979, after the installation of the sediment-control pond and two diversion channels (fig. 2). Most timber had been removed from the area the previous year. The south diversion channels occupied 0.4 acres and drained an additional 3.8 acres; the total area was 4.2 acres. The north diversion occupied 0.6 acres and drained an additional 10.5 acres; the total area was 11.1 acres. During the period of data collection the north diversion terrace drained an area of 3.7 acres that had been disturbed by mining, 0.3 acres were still wooded, and 6.5 acres drained to the pit. The sediment-control pond received drainage directly from 2.3 acres, and the pond surface occupied an additional 0.3 acres at the altitude of the principal spillway.

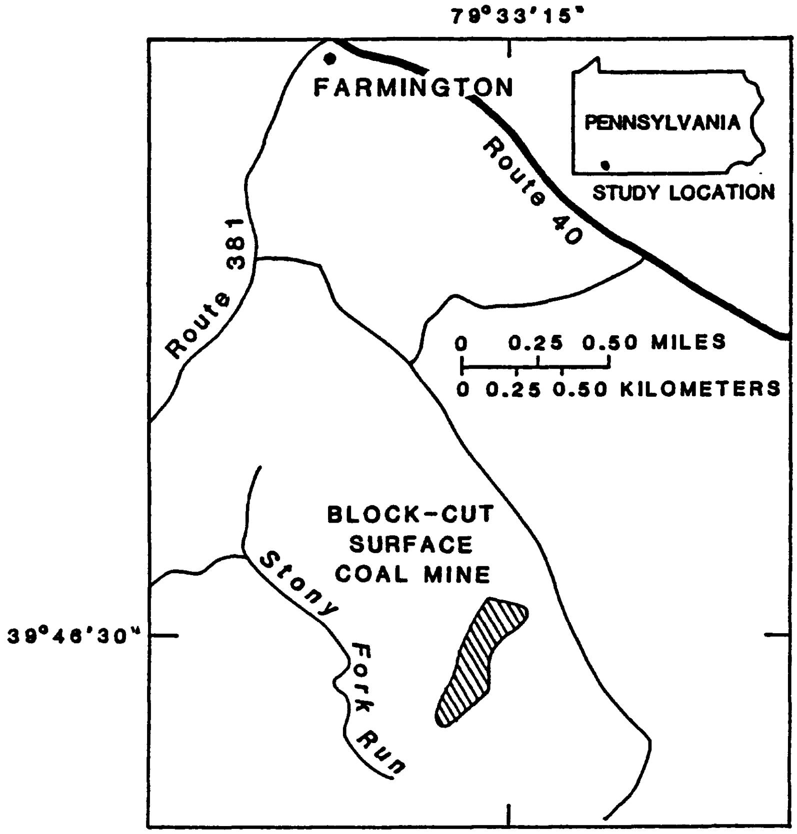

Figure 1.--Location of block-cut coal mine in Fayette County, Pennsylvania.

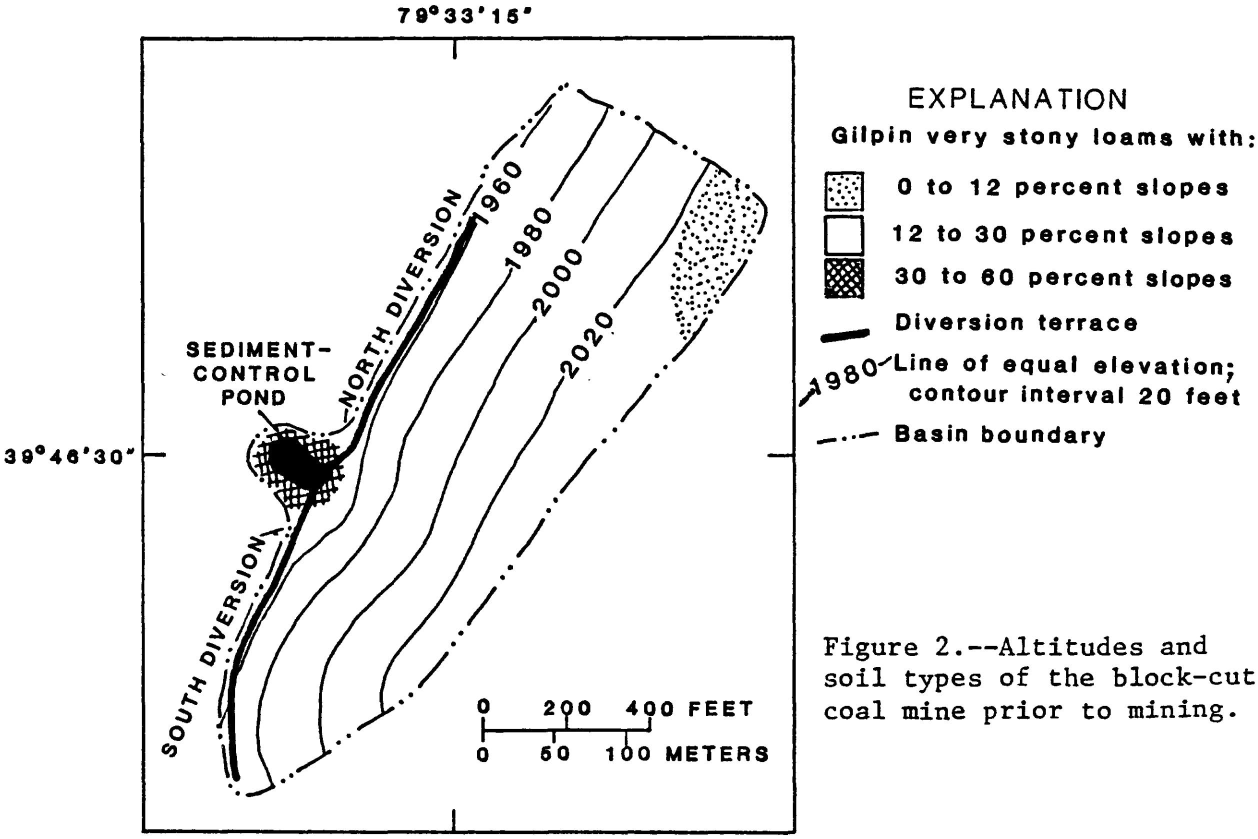

Figure 2.--Altitudes and soil types of the block-cut coal mine prior to mining.

Table 1.--Particle-size composition of soil and sediment in samples collected at the block-cut coal mine

Date	Time	Water discharge (ft^3/s)	Sediment concentration (mg/L)	Particle-size composition (percent) Sand	Silt	Clay
			Soil on reclaimed area			
May 21, 1982				38	36	26
			Sediment in storm-water discharge from south diversion			
September 2, 1981	1900	2.3	8,370	11	50	39
August 8, 1982	1900	2.2	14,720	2	56	42
August 8, 1982	1905	7.0	13,500	4	52	44
August 8, 1982	2030	.90	1,570	1	31	68
			Sediment in storm-water discharge from north diversion			
September 2, 1981	1902	2.5	8,590	6	49	45
			Sediment in storm-water discharge from sediment-control pond			
September 2, 1981	1915	.39	1,080	0	38	62
August 8, 1982	1909	.23	8,340	0	54	46
August 8, 1982	1917	.23	7,560	0	49	51

Surface Mining and Sediment Control

The area was surface mined by the block-cut method. The first step in block-cut mining is to establish locations for diversion channels along the downslope side of the site, and to construct sediment-control ponds to collect the drainage from the diversion channels. The diversion channels are constructed after the sediment-control pond has been installed. At this site, mining began shortly after the sediment-control pond and diversion channels had been constructed. In block-cut mining, the first cut is made at one end of the job, perpendicular to the contour. The top soil and rock from the first cut are hauled to a site adjacent to the location of the last planned cut. After the coal has been removed from the first cut, the second cut is started. Once again the soil is hauled to the approximate location of the last planned cut, but the rock overburden is turned into the first cut and graded to approximately the original contour, and coal is removed from the second cut. Soil from the third cut is placed on the area of the first cut, graded, and seeded. This process continues until the area has been mined. In areas being mined by the block-cut method, reclamation can be concurrent with mining. Mining of the study site progressed rapidly until October 1980. From October 1980 through September 1982, coal was sold from a stockpile and no new cuts were made because of a reduced demand for coal.

Water that reaches the sediment-control pond comes from rain falling directly on the diversions, the reclaimed area, and the unmined areas that drain to the diversions. Most of the rain falling on the pit and on the rock overburden drains internally or it ends up as pit water and must be pumped from the pit to special ponds where it is treated to meet acid- and iron-discharge specifications of the Commonwealth of Pennsylvania.

Sediment-Control Pond

The sediment-control pond was constructed in April 1979, with a 3-in. valve to control water levels between the permanent pool altitude and the altitude of the principal spillway. The principal spillway is a drop inlet with a diameter of 24 in. located 5.3 ft above the 3-in. valve. An emergency spillway is built at an altitude 3 ft above the top of the principal spillway, and 8.3 ft above the 3-in. valve. A detailed sketch of the pond is shown on figure 3, and figure 4 is a photograph of the pond taken when the water level was at the altitude of the 3-in. valve.

The initial storage capacity of the pond at the altitude of the 3-in. valve was 60,200 ft^3. The storage capacity at the top of the principal spillway was 128,900 ft^3, and the storage capacity at the top of the emergency spillway was 175,500 ft^3. From the time the pond was completed until March 17, 1982, all discharge from the pond was regulated by the 3-in. valve. During a storm in March 1982, water in the pond reached the level of the principal spillway for the first time. The 3-in. valve had been closed for several weeks but was opened at the start of the storm; however, the pond was nearly full. Generally, the operator kept the valve closed, opening it only after the pond had cleared, and closing it before the next storm. The emergency spillway was never used. Data were collected during five moderate storms when the flow control valve was intentionally opened. The pond was surveyed in December 1980, and again in September 1982, and its capacity at

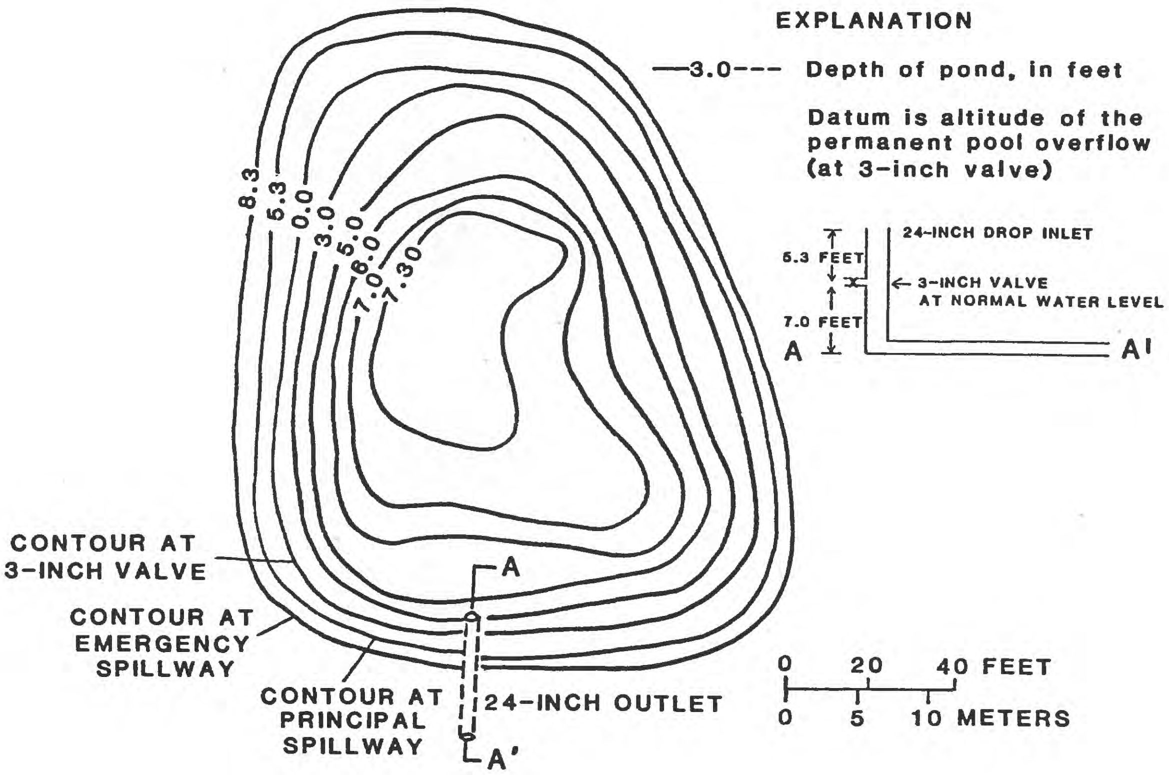

Figure 3.--Depth contours and bottom configuration of the outlet system in the sediment-control pond, April 1979.

Figure 4.--The sediment-control pond from the mine site (view looking west).

the level of the 3-in. valve was determined to be 57,300 and 33,800 ft^3, respectively (indicating that 23,500 ft^3 of sediment had been trapped by the pond between the two surveys).

DATA COLLECTION

Data collection began in July 1981. A rain gage, flow-control weir, stage recorder, and an automatic suspended-sediment sampler were installed at the point where the south diversion channel enters the sediment-control pond. At the outflow of the sediment-control pond, a weir, stage recorder, and an automatic sediment sampler were installed. A water-level recorder was installed in the pond to record changes in water level in response to rainfall and the operation of the 3-in. valve. A weir was installed in the north diversion channel and hand samples were collected during one storm to compare the sediment loads from the north diversion with those from the south diversion. Figure 5 is a sketch of the coal mine at the time the data-collection equipment was installed, and figure 6 is a photograph of the coal mine taken shortly after mining was discontinued in October 1980.

Although active mining at the site ceased in the fall of 1980, reclamation work on the area drained by the south diversion continued. Soil had been spread on the entire 4.2-acre area when data collection began in July 1981, but the area was not seeded until October 1981. The October seeding did not germinate and only about 10 percent of the surface area was covered with vegetation in the spring of 1982. On July 1, 1982, the area was reseeded and, by September 1982, about 70 percent of the area was covered with vegetation.

TRAP EFFICIENCY OF THE SEDIMENT-CONTROL POND

Suspended-sediment data collected during five moderate storms that occurred when the 3-in. valve was open were used to evaluate trap efficiency. These storms were on September 2, 1981; March 15 and 16; June 16, (two storms); and August 8, 1982. During the March 15 and 16, 1982 storm, water was discharged through the 24-in. principal spillway because the pond was nearly full when the storm occurred. The other four storms occurred when the pond level was less than 2 ft above the level of the 3-in. valve and all discharge was through the 3-in. valve. Precipitation during the storms ranged from 0.30 to 1.30 in. and the maximum intensities ranged from 0.80 to 6.00 in./h (inches per hour). Runoff from the August 8, 1982 storm, raised the pond stage 0.70 ft in 7.5 minutes; the water discharge to the pond during the 7.5-minute period averaged 20 ft^3/s. This was the most intense storm that occurred when the flow control valve was open.

On September 2, 1981, 0.68 in. of precipitation fell over a period of one hour. Data were collected from both diversion channels and from the outflow of the sediment control pond. The rainfall and sediment-concentration data are shown on figure 7. The sediment load measured from the south diversion terrace (4.2 acres) was 1.3 tons. The sediment load measured from the north diversion terrace (3.7 acres) was 1.8 tons. The total sediment load to the pond was about 3.9 tons, including 0.8 ton of sediment estimated for the 2.3-acre area that drains directly to the sediment-control pond.

EXPLANATION

- **A** Reclaimed slope
- **B** South diversion
- **C** Ponds for treating acid water
- **D** Gaging station
- **E** Sediment-control pond

Figure 5.--The mine site at the time data-collection equipment was installed in July 1981 (view looking south).

Figure 6.--The mine after mining had ceased in October 1980 (view looking west).

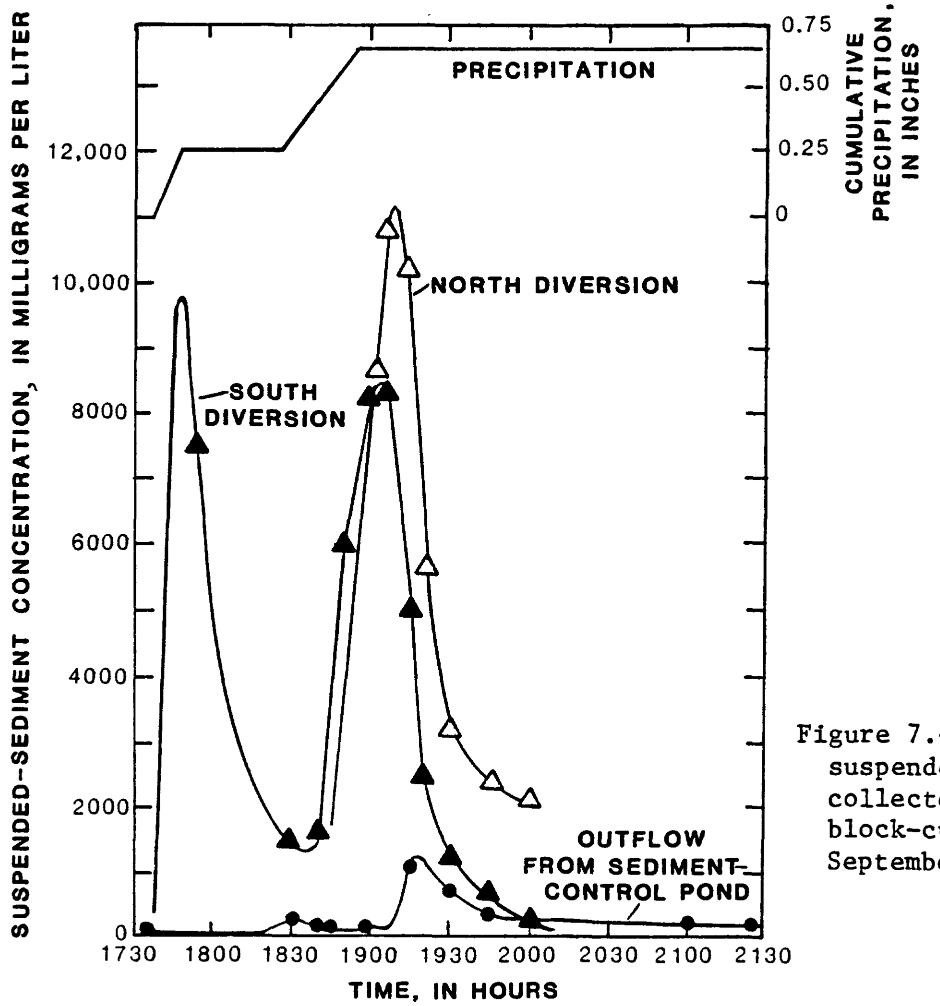

Figure 7.--Rainfall and suspended-sediment data collected from the block-cut coal mine on September 2, 1981.

Sediment discharge through the 3-in. valve was 0.074 ton, and the trap efficiency was 98.1 percent. The maximum sediment concentration of the inflow was 11,200 mg/L, and the maximum concentration of the outflow was 1,080 mg/L. The suspended-sediment and precipitation data for this and the other four reported storms are listed in table 2.

Runoff from the entire 11.1-acre drainage area during the September 2, 1981 storm was 16,100 ft^3, and the mean water-discharge-weighted sediment concentration was 7,750 mg/L. Peak water discharge to the pond from the south diversion channel was 2.25 ft^3/s. During the storm, water discharge through the 3-in. valve averaged 0.40 ft^3/s and ranged from 0.37 to 0.43 ft^3/s. At the start of the storm, the pond contained 58,200 ft^3 of water, and the maximum volume contained in the pond during the storm was 68,700 ft^3. The contents of the pond were adjusted based on the sediment-deposition surveys made during December 1980 and September 1982. The maximum stage reached by the pond was 2 ft above the 3-in. valve, and 3.3 ft below the principal spillway. The capacity-inflow ratio (Brune, 1953)--the ratio between water stored in the pond at the start of the storm and runoff from the storm--was 3.60.

Table 2.—Data collected from the sediment-control pond during the five storms used to compute trap efficiency

Date	Initial contents (ft^3)	Runoff from mine site (ft^3)	Capacity-inflow ratio contents/inflow	Suspended-sediment discharge, in tons: From mine site	Suspended-sediment discharge, in tons: From sediment-control pond	Trap efficiency (percent)
September 2, 1981	58,200	16,100	3.6	3.9	0.074	98.1
March 15-16, 1982	101,000	40,000	2.5	32.0	2.3	92.8
June 16, 1982 (3:00 p.m.)	49,700	5,800	8.6	6.4	.025	99.6
(6:00 p.m.)	52,100	18,000	2.9	15.0	.13	99.1
August 8, 1982	34,200	22,700	1.5	7.8	.14	98.2

One suspended-sediment sample was collected from each diversion channel at the time of peak water discharge on September 2, 1981; the average particle-size composition of the sediment in the samples (table 1) was 8.5 percent sand, 49.5 percent silt, and 42.0 percent clay. A sample of the discharge from the sediment-control pond, collected when the concentration of suspended sediment was 1,080 mg/L, had a particle-size distribution of 38.0 percent silt and 62.0 percent clay. Although the length of the pond from the inflow to the outflow was 125 ft, the lag time (fig. 7) between the peak inflow and outflow sediment concentration was only 10 to 15 minutes. From figure 7, it can be seen that suspended-sediment concentrations of the discharge into and from the sediment-control pond changed rapidly.

On March 15 and 16, 1982, a storm produced 1.30 in. of precipitation, nearly half of which fell in a 10-minute period near the end of the storm. The heavy rainfall near the end of the storm caused water in the sediment-control pond to rise above the altitude of the 24-in. drop inlet for the first time since the pond was constructed. Sediment data were collected at the discharge from the sediment-control pond for the entire storm, and samples were collected from the south diversion terrace for the first half of the storm, but not during the heavy runoff at the end of the storm, because debris plugged the intake of the sediment sampler.

Water discharge and suspended-sediment concentration data from the sediment-control pond are shown on figure 8 for the period when the intense precipitation occurred. Total water discharge to the sediment-control pond was 40,000 ft^3. The contents of the pond at the start of the storm was 101,000 ft^3, and the pond stage was 0.5 ft below the 24-in. drop inlet. The maximum contents during the storm was 116,000 ft^3. Sediment discharge to the pond was estimated to be 32 tons; the estimate was based on the samples collected during the first part of the storm and the discharge samples collected from the pond. Water discharge from the sediment-control pond peaked at 2.0 ft^3/s, and the suspended-sediment concentration peaked 1 hour later at 8,800 mg/L. Sediment discharge from the pond during the entire storm was 2.3 tons, and

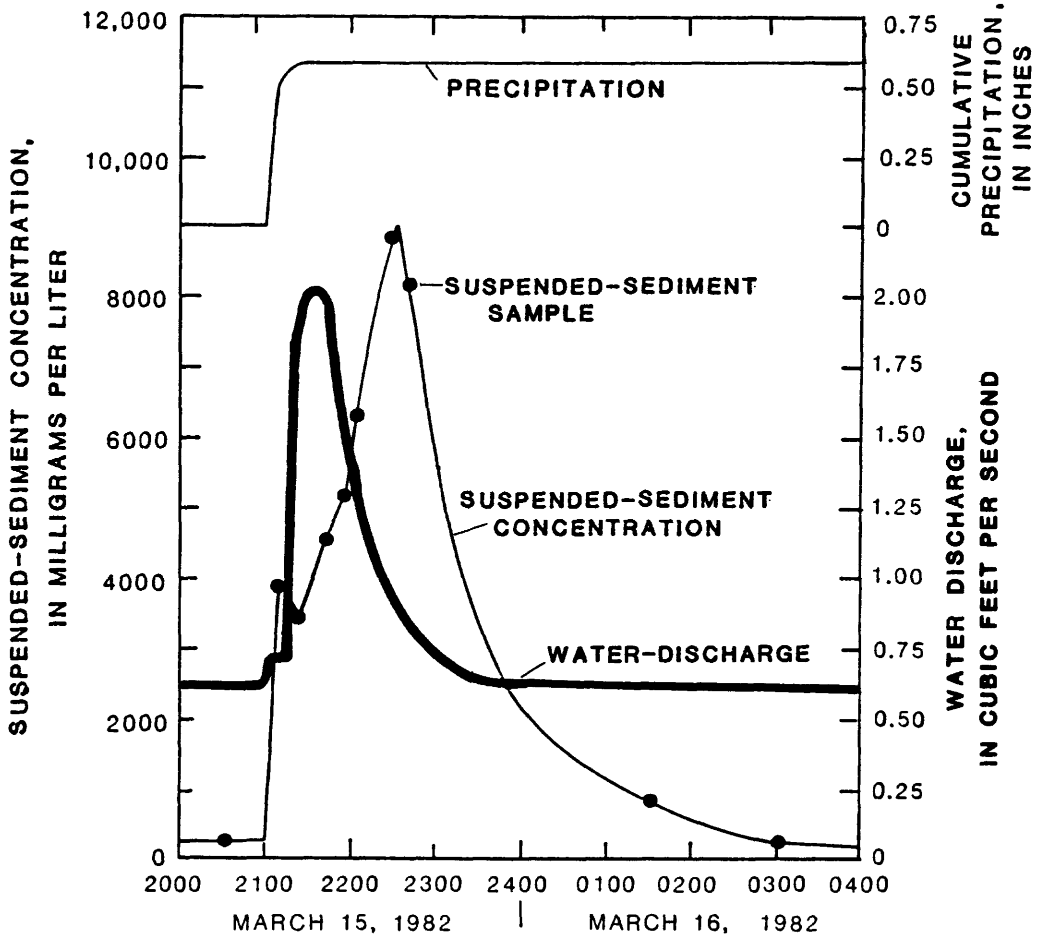

Figure 8.--Rainfall, suspended-sediment, and water-discharge data collected at the sediment-control pond on March 15 and 16, 1982.

the trap efficiency was 92.8 percent. If the storm had occurred when the stage in the pond was low enough to prevent flow out of the 24-in. drop inlet, sediment discharge would have been about 0.8 ton less, or about 1.5 tons. Suspended-sediment and precipitation data from this storm are in table 2; figure 9 is a photograph that shows runoff from the south diversion during the early part of the storm.

On June 16, 1982, a storm produced 0.80 in. of precipitation. The storm occurred in two separate periods, the first, at 3 p.m., produced 0.30 in. of rainfall in less than 5 minutes, and the second, at 6 p.m., produced 0.50 in. during the first 5 minutes and an additional 0.15 in. during the next 25 minutes. Suspended-sediment data were collected from the south diversion and from the discharge from the 3-in. flow control valve on the sediment-control pond during both segments of the storm. The data are shown in figure 10 and are listed in table 2.

Figure 9.--Runoff from the coal mine on March 15, 1982 (view looking south).

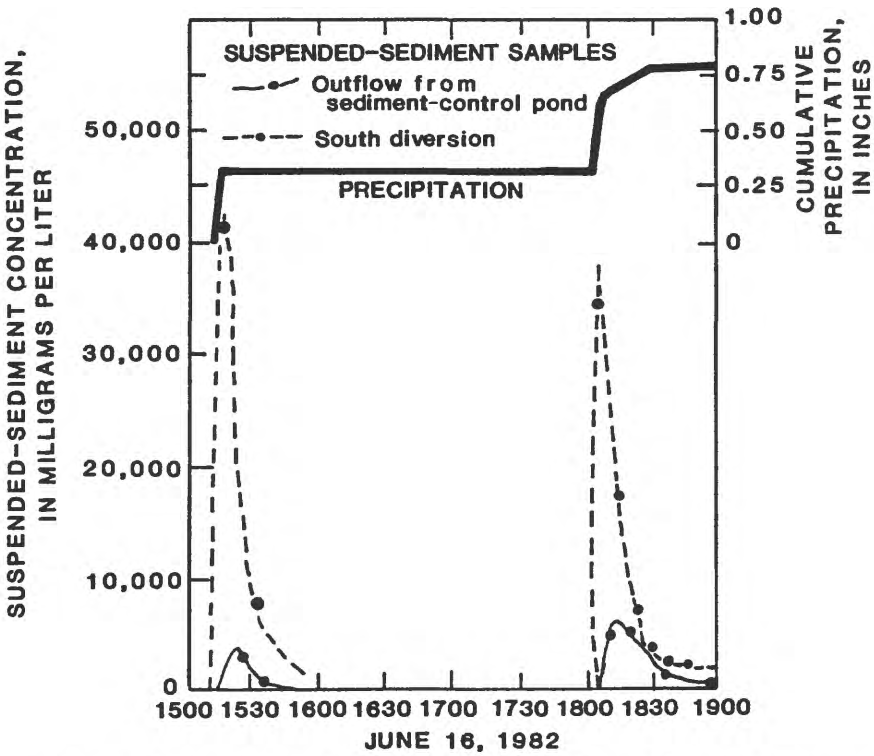

Figure 10.--Rainfall and suspended-sediment data collected from the coal mine during the storm on June 16, 1982.

Water discharge to the pond during the first segment of the storm was 5,800 ft^3, sediment discharged to the pond was 6.4 tons, the sediment discharge from the pond was 0.025 ton, and the trap efficiency was 99.6 percent. During the second segment of the storm, water discharge to the pond was 18,000 ft^3, the suspended-sediment inflow was 15 tons, sediment discharge from the pond was 0.13 ton, and the trap efficiency was 99.1 percent.

On August 8, 1982, a storm produced 0.90 in. of precipitation, of which 0.65 in. fell within the first 7 minutes of the storm. Water-discharge and suspended-sediment data were collected from the south diversion and at the discharge from the sediment-control pond, the rainfall and suspended-sediment data are shown on figure 11.

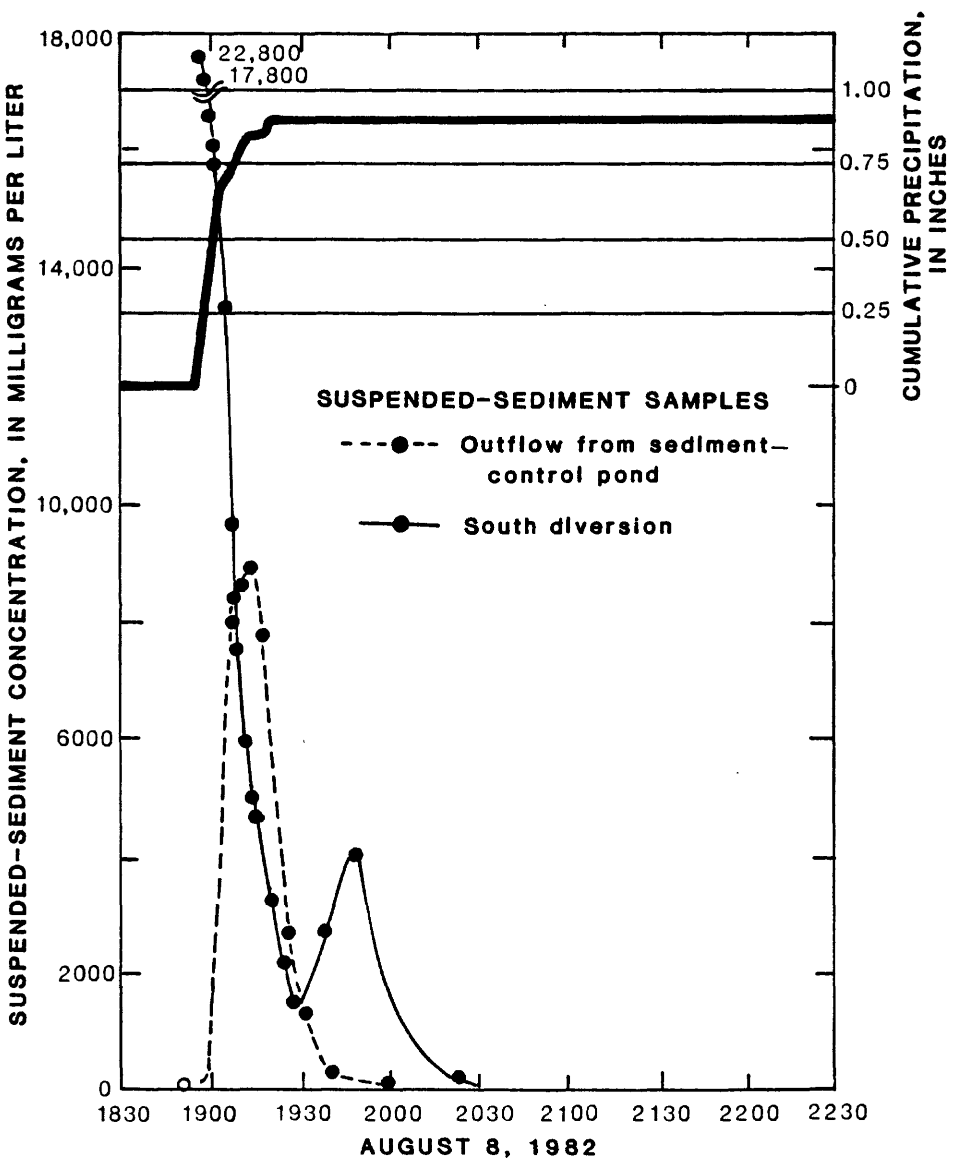

Figure 11.--Rainfall and suspended-sediment data collected from the coal mine on August 8, 1982.

The pond contained 34,200 ft^3 of water when the storm started; the volume of runoff from the 11.1-acre area was 22,700 ft^3. Sediment discharge to the pond during the storm from the south diversion was 3.0 tons, and the sediment load from the entire area was about 7.8 tons. Sediment deposition in the pond averaged about 2.8 ft at the time of the August 8 storm. The high suspended-sediment concentration of the discharge from the pond, 9,000 mg/L, could have been caused by sediment becoming resuspended by the turbulent inflow. Sediment discharge from the pond was 0.14 ton and the trap efficiency was 98.2 percent.

Three samples of the inflow from the south diversion terrace and two samples of the outflow from the sediment-control pond were analyzed for particle-size composition. Table 1 lists the results of the analyses. The average discharge-weighted particle-size composition of the sediment discharge from the south diversion channel was 3 percent sand, 53 percent silt, and 44 percent clay. The average particle-size composition of the sediment being discharged from the sediment-control pond was 52 percent silt, 48 percent clay, and no measureable sand.

AMOUNT OF SEDIMENT TRAPPED

The pond was surveyed on December 30, 1980, and again on September 30, 1982, to determine the decrease in storage capacity due to sedimentation. On December 30, 1980, the average thickness of the sediment in the pond was 0.4 ft. Thickness of accumulated sediment in the pond on September 30, 1982 is shown on figure 12. The decrease in storage capacity between April 1979, when the pond was constructed, and December 30, 1980, was 2,900 ft^3 and the decrease between December 30, 1980, and September 30, 1982 was 23,500 ft^3. Precipitation between April 1979, and December 30, 1980 was 80.43 in. and precipitation between December 30, 1980 and September 30, 1982 was 74.30 in. A core sample of the material deposited near the center of the sediment control pond was collected on September 30, 1982 and analyzed for particle size and density. The depth of sediment at the site where the core was collected was 3.4 ft, and the core was 1 percent sand, 47 percent silt, and 52 percent clay. The density of the deposited sediment was 49.5 lb/ft^3. If the core is assumed to be representative of the entire pond, the weight of the sediment deposited in the pond from December 30, 1980, through September 30, 1982, was 580 tons. The average annual sediment yield for the 21-month period was 31 tons/acre (average disturbed area was 10.8 acres). This high yield is partly the result of the extensive time between reclamation and the establishment of vegetation.

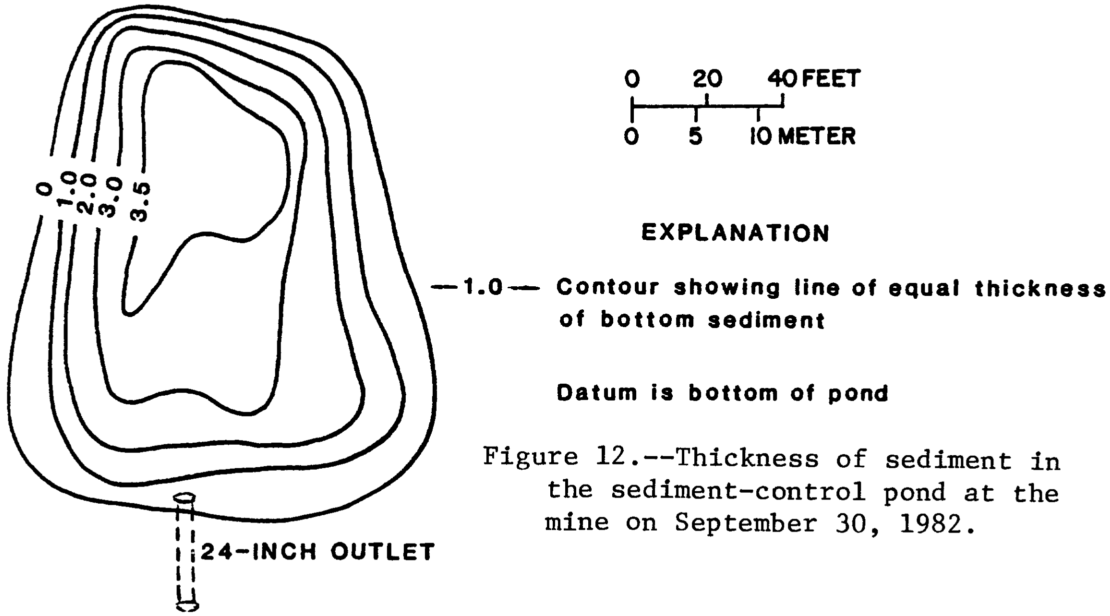

Figure 12.--Thickness of sediment in the sediment-control pond at the mine on September 30, 1982.

SUMMARY AND CONCLUSIONS

The efficiency of a pond constructed to control sediment from a surface coal mine site was determined by measuring runoff and sediment loads at the inlet to and discharge from the pond during storms. The pond is below a 17.9-acre block-cut coal mine in Fayette County, Pennsylvania and has a permanent pool capacity of 60,200 ft^3, a principal spillway capacity of 128,900 ft^3, and an emergency spillway capacity of 175,500 ft^3.

The pond was equipped with a 3-in. valve, used by the mine operator to regulate the pond stage between the permanent pool and the principal spillway levels. The valve is large enough to discharge 3,800 ft^3/acre in 1.85 days. The principal spillway is a 24-in. drop inlet 5.3 ft above the 3.0-in. valve and 3.0 ft below the altitude of the emergency spillway. The original storage capacity at the top of the 24-in. drop inlet was 128,900 ft^3, and the storage capacity at the crest of the emergency spillway was 175,500 ft^3. From the time the pond was completed until March 17, 1982, all discharge from the pond was regulated by the 3-in. valve. During a storm in March 1982, water in the pond reached the level of the principal spillway for the first time. The emergency spillway was never used.

Data were collected during five moderate storms when the flow control valve was intentionally opened. Precipitation during the five storms ranged from 0.30 to 1.30 in., and the maximum intensities ranged from 0.80 to 6.00 in./hour. Runoff from one storm, August 8, 1982, raised the pond stage 0.70 ft in 7.5 minutes; the water discharge to the pond during the 7.5 minutes averaged 20 ft^3/s. This was the most intense storm that occurred when the flow control valve was open. The suspended-sediment-trap efficiencies measured during the five storms were 98.1, 92.8, 99.6, 99.1, and 98.2 percent. The ratio between the quantity of water in the sediment-control pond at the start of the storms and the quantity of runoff from the disturbed area was 3.6, 2.5, 8.6, 2.9, and 1.5, respectively.

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