SEDIMENTATION AND WATER QUALITY IN THE WEST BRANCH SHADE RIVER BASIN, OHIO, 1983-85

By Carolyn J. Oblinger Childress and Rick L. Jones

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4262

Prepared in cooperation with the

OHIO DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF RECLAMATION

Columbus, Ohio

1988

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
975 W. Third Avenue
Columbus, OH 43212-3192

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Box 25425, Federal Center
Denver, CO 80225

CONTENTS

	Page
Abstract	1
Introduction	2
Background	2
Purpose and scope	3
Description of the Shade River basin	7
Location and physical setting	7
Mining history	8
Reclamation	8
Methods of study	10
Sedimentation	12
Mean suspended-sediment concentration	13
Channel scour and fill	16
Water quality	19
Summary and conclusions	27
Selected references	28

ILLUSTRATIONS

		Page
Figure 1.	Map of the lower reach of an unnamed tributary to the West Branch Shade River near Harisonville showing the active channel in 1951 and 1982	4
2.	Map showing the location of gages, stream-channel cross sections, and water-quality sites in the Shade River basin	5
3.	Photograph of an old fence line buried by sediment from runoff from an abandoned mine in the West Branch Shade River basin	6
4.	Map showing the approximate location of abandoned and reclaimed surface coal mines in the West Branch Shade River basin, October 1984	9
5-8.	Graphs showing the distribution of water-quality data at mined and unmined sites on West and East West Branches of Shade River from samples collected from 1983 through 1986:	
	5. Alkalinity concentrations and pH values	20
	6. Acidity and sulfate concentrations	21
	7. Dissolved-iron and manganese concentrations	22
	8. Dissolved-aluminum concentrations and specific-conductance values	24

TABLES

Table 1. Annual total precipitation and departure normal at Carpenter, Ohio, for water years 1983 through 1985 7

2. Total suspended-sediment load, total stream discharge, and mean suspended-sediment concentration for West Branch Shade River near Harrisonville and near Burlingham and East Branch Shade River near Tuppers Plains, Ohio 14

3. Cross-sectional area, normalized area, and positive or negative change in area between measurements from surveys made at 10 locations in the Shade River basin 17

4. Results of water-quality analyses for West Branch Shade River near Harrisonville, at Snowville, and near Burlingham; for the tributary to West Branch Shade River near Burlingham; and for East Branch Shade River near Tuppers Plains, Ohio, from June 1983 through July 1986 25

5-7. Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge during water years 1983 through 1985:

5. East Branch Shade River near Tuppers Plains, Ohio 30
6. West Branch Shade River near Burlingham, Ohio 40
7. West Branch Shade River near Harrisonville, Ohio 50

CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	square hectometer
cubic foot per second-day (cfs-day)	0.2447	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton	0.9072	megagram (Mg)
ton per acre-foot (ton/acre-ft)	0.07358	megagram per cubic hectometer (Mg/hm^3)

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by the following equation:

$$F = 1.8(^{\circ}C) + 32$$

SEDIMENTATION AND WATER QUALITY IN THE WEST BRANCH SHADE RIVER BASIN, OHIO, 1983-85

By C. J. Oblinger Childress and Rick L. Jones

ABSTRACT

Loss of channel conveyance from deposition of sediment from abandoned surface mines in the West Branch Shade River basin has resulted in frequent flooding. In addition, water quality in the West Branch Shade River and some of its tributaries is typical of streams affected by acid mine drainage. About 938 acres were surfaced mined and abandoned in West Branch Shade River basin. By the end of 1984, about 450 acres were reclaimed. The purpose of this study was to measure the effects of abandoned surface mines and their reclamation on suspended-sediment load, channel cross-section profile, and water quality of West Branch Shade River.

Sediment data were collected from June 1983 through September 1985. Daily suspended-sediment samples were collected and continuous streamflow data were recorded at two locations in West Branch Shade River basin and one location in the unmined, East Branch Shade River basin. Water-quality samples were collected three times per year, from June 1983 through July 1986, at four locations in the West Branch Shade River basin and at one location in East Branch Shade River basin. Stream-channel cross sections were surveyed at least twice per year at 10 locations.

During the period of study, annual mean suspended-sediment concentration was unchanged for the unmined, East Branch Shade River basin; 0.28 ton per acre-foot of runoff in 1984 and 1985 water years. Annual suspended-sediment concentration, in tons per acre foot, in West Branch Shade River near Harrisonville, which was 100 percent reclaimed by the end of 1984, decreased from 8.6 in 1984 water year to 0.15 in 1985 water year. In West Branch Shade River near Burlingham, where 48 percent of the abandoned mines were reclaimed by the end of 1984, annual mean suspended-sediment concentration was unchanged (0.5 ton per acre-foot of runoff) in 1984 and 1985 water years and was twice that of the unmined basin.

Channel profiles, surveyed at each of the 10 cross sections, indicated scouring at two locations and filling at one location. West Branch Shade River near Harrisonville was scouring, whereas West Branch Shade River near Burlingham was filling. Although the source of sediment in the headwaters has been greatly reduced with reclamation, the sediments previously deposited and stored in the channel of West Branch Shade River most likely will continue to provide a suspended-sediment supply and contribute to channel filling farther downstream. In addition, part of West Branch Shade River basin is still largely unreclaimed and continues as a suspended-sediment source.

On the basis of successive cross-section profiles, the downstream-most cross section surveyed in Kingsbury Creek, a tributary to West Branch Shade River, also appeared to be scouring. The cause of the scouring is unknown, as no reclamation activities have occurred in that part of the basin.

The quality of West Branch Shade River was characteristic of streams draining abandoned or improperly reclaimed surface mines in southeastern Ohio. Median alkalinity was less than 25 mg/L (milligrams per liter) as $CaCO_3$ at the three mined sites. Median sulfate concentration was 44 mg/L at the unmined site compared to 128 mg/L at the mined sites. Median manganese concentration was 10 times higher at the mined sites than the unmined sites. Both sulfate and manganese are indicators of the presence of acid mine drainage.

The greatest change in water quality during the study period was observed in West Branch Shade River near Harrisonville, above which all abandoned mine lands were reclaimed. The pH at that site increased to neutral by the end of the study. In addition, alkalinity concentration increased, and acidity concentration decreased. As has been observed in previous studies of abandoned surface mines that have been reclaimed, manganese and sulfate concentrations did not change following reclamation. No change in water quality was observed at the two downstream sites during the period of study. However, the percentage of abandoned mined lands that were reclaimed was much smaller above these sites (48 percent).

INTRODUCTION

Background

West Branch Shade River basin was surface mined for coal from the mid-1940's through the early 1960's. Although mine operators were required under Ohio law to reclaim surface mines, reclamation, at that time, generally consisted of only regrading and seeding. Mine spoils in this area typically are too acid and too erodible to support new vegetation and the law did not require that spoils be chemically treated to enhance the likelihood of plant survival. Barren slopes with no vegetation for protection against erosion redeveloped in many areas after reclamation. As a result, much of the area in the headwaters of West Branch Shade River basin is marked by disturbed land, highwalls, and spoil piles that are devoid of vegetation. Soils from these unvegetated areas are subject to erosion. During periods of storm runoff, soils are transported to the stream channel.

Loss of channel conveyance caused by this deposition of sediment has resulted in frequent flooding. Dredging at bridge crossings has been necessary to reduce flooding of roadways. The filling of West Branch Shade River channel following mining activities is evident from aerial photographs taken in 1951 and in

1981. Figure 1 shows the channel width of the unnamed tributary to West Branch Shade River as seen from these aerial photographs (the cross-section location shown in fig. 1 corresponds to cross section 3 in fig. 2). In 1951, the active channel was narrow and well defined and riparian land was typically under cultivation. In 1981, nearly 30 years after the most active period of surface mining, the channel had widened considerably. Excessive sediment loads from abandoned mines had been deposited in the river valley and alluvial fans had developed at the mouths of each tributary. Thus, much of the riparian land under cultivation in 1951 had become swamp by 1981 and remains so today. In many areas, the depth of deposited sediments also can be clearly gauged. For example, in a photograph taken downslope from abandoned mines in 1984 (fig. 3) the tops of fence posts are all that remain exposed of a fence line that has been buried by the accumulation of sediment.

In addition to excessive sediment transport and deposition, water quality in West Branch Shade River and some of its tributaries is of concern (Ohio Board of Unreclaimed Strip Mine Lands, 1974). The quality of the headwaters of West Branch Shade River basin generally are degraded, typical of streams affected by acid mine drainage.

In 1978, the U.S. Department of Agriculture, Soil Conservation Service and the Ohio Department of Natural Resources, Division of Reclamation began reclaiming some of these abandoned surface mines with funds made available through the Surface Mining Reclamation and Control Act (PL 95-87). Reclamation is expected to reduce sediment loads from source areas and, ultimately, should increase channel conveyance. In addition, reclamation is expected to result in improved water quality.

A study was begun in 1983 in cooperation with the Ohio Department of Natural Resources, Divison of Reclamation, to measure the effects of reclamation of abandoned surface mines in West Branch Shade River basin on sedimentation and water quality.

Purpose and Scope

This report presents a summary and analysis of data on suspended-sediment load, channel conveyance, and water quality that were collected between June 1983 and July 1986. Comparisons are made between data from the mined West Branch Shade River basin and the unmined East Branch Shade River basin.

Daily suspended-sediment and streamflow data were collected at three streamflow-gaging stations located on West and East Branches of the Shade River (fig. 2). Water-quality data were collected at five locations on West and East Branches of the Shade River, and stream-channel cross-section elevations were surveyed at 10 locations on East and West Branch Shade River and West Branch Shade River tributaries.

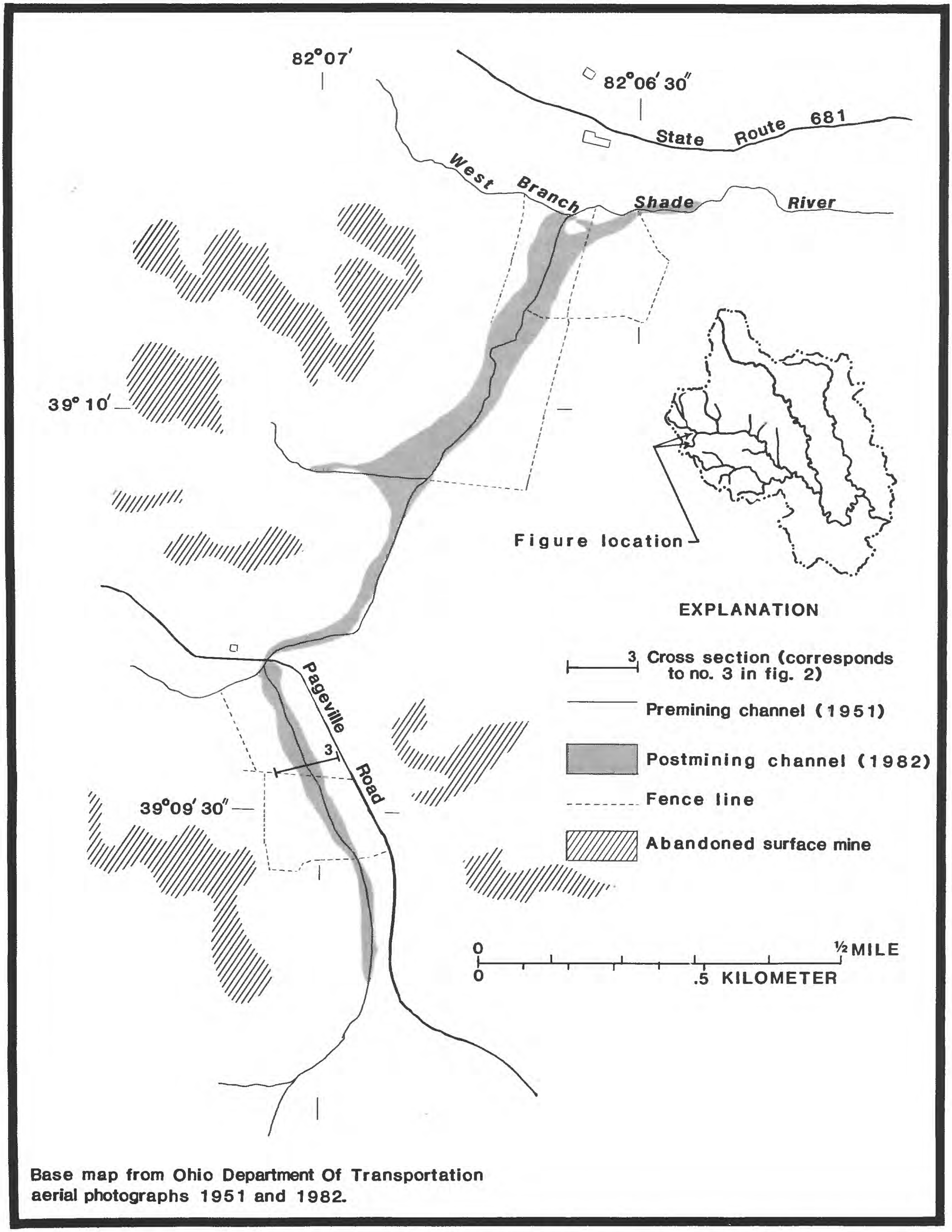

Figure 1.--Lower reach of the unnamed tributary to West Branch Shade River near Harrisonville showing the active channel in 1951 and 1982.

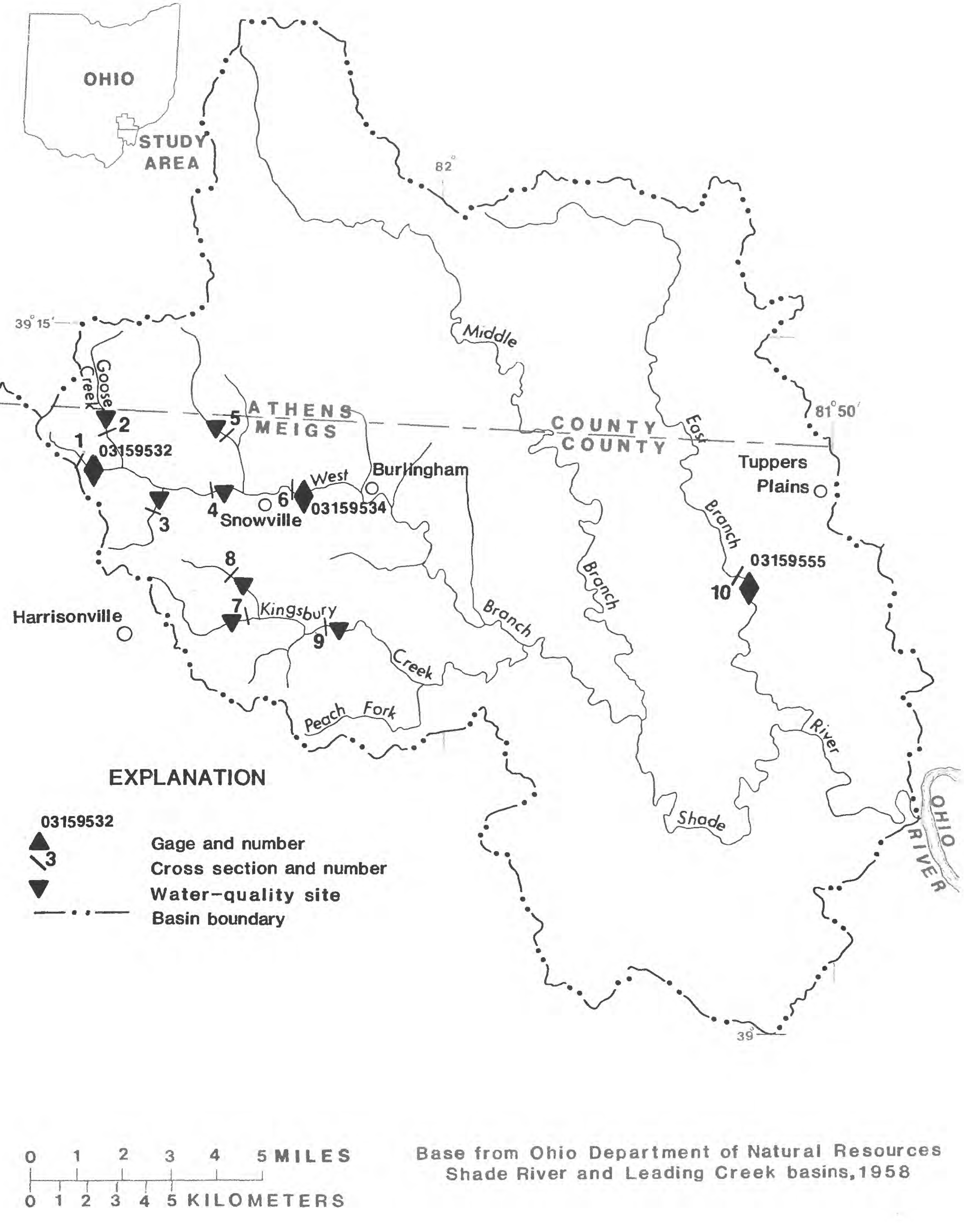

Figure 2.--Locations of gages, stream-channel cross sections, and water-quality sites in the Shade River basin.

Figure 3.--An old fence line buried by sediment from runoff from an abandoned surface mine in the West Branch Shade River basin. (View to south)

DESCRIPTION OF THE SHADE RIVER BASIN

Location and Physical Setting

Shade River is a tributary to the Ohio River and drains 221 mi^2 (square miles), most of which is in eastern and north-central Meigs County in southeastern Ohio. There are three main branches: West (drainage area, 71.3 mi^2), Middle (57.6 mi^2), and East (54.9 mi^2).

The Shade River basin is located in the unglaciated Appalachian Plateaus physiographic province, which is characterized by eastward dipping strata dissected by steep, narrow valleys. Rocks of the Conemaugh and Monongahela Formations of Pennsylvanian age crop out in the central and western coal-producing part of Meigs County, and rocks of the Dunkard group of Pennsylvanian and Permian age crop out in the eastern third of the county (Brant and DeLong, 1960). Bedrock is primarily sandstone and shale. Limestone strata are not well developed. The main coal-producing seams are the Lower Kittaning, Upper Freeport, Pittsburgh, Pomeroy, and Meigs Creek.

The mean annual temperature was 53.2 degrees Fahrenheit over an 18-year period at Carpenter, Ohio, located 4 miles west-southwest of the West Branch Shade River gage near Harrisonville (U.S. Department of Commerce 1982). Annual precipitation has averaged 40.4 inches over the same period (U.S. Department of Commerce, 1983). Annual total precipitation and departure from normal for each year of the study are shown in table 1.

Table 1.--Annual total precipitation and departure from normal at Carpenter, Ohio, for water years 1983 through 1985

Water year[1]	Total precipitation, in inches	Departure from the mean for the period, in inches
1983[2]	[3]15.6	-4.2
1984	[3]40.4	0
1985	42.7	+2.3

[1] Water year extends from October 1 of the previous year through September 30.
[2] Total is for the partial water year, from May through September, during which data were collected.
[3] Estimated with record from a nearby station (McArthur, Ohio) for months with missing record.

The channel of East Branch Shade River is characterized by series of pools and riffles typical of Ohio streams. Streambed material is primarily cobbles and sand. Streamflow at the gage (fig. 1) is intermittent during the driest months of the year.

The channel of West Branch Shade River lacks pool-and-riffle sequences and is braided above Snowville (fig. 1). Bed material is primarily composed of sand and silt. A braided channel can be a response to a sediment load that is too large to be handled by a single channel and often is associated with an aggrading stream (Leopold and others, 1964, p. 294). Flow at the two West Branch Shade River gages is intermittent during all but the wettest months of the year.

Mining History

Although coal mining was first reported in Meigs County in 1806, the first report of surface mining was not until 1940. Most coal was extracted from the basin through the 1950's and into the 1960's. By the mid-1960's, almost all mining activity had ended. Today there are no active surface coal mines in the basin.

About 938 acres have been surface mined in the Shade River basin (U.S. Department of Agriculture, 1985); most were unreclaimed or inadequately reclaimed after mining. Mining was most intense in the upper part of West Branch basin; approximately 19 percent of the drainage area above the West Branch Shade River gage near Harrisonville (station 03159532) and 8 percent of the drainage area above the West Branch Shade River gage near Burlingham (station 03159534) had been surface mined (fig. 4). East Branch Shade River basin was not surface mined and serves as a control site for this study.

Reclamation

Reclamation of abandoned or unsuccessfully reclaimed mines in West Branch Shade River basin was begun in 1978 by the U.S. Department of Agriculture, Soil Conservation Service, and the Ohio Department of Natural Resources, Division of Reclamation. These agencies had reclaimed approximately 450 acres of abandoned surface mines in the West Branch Shade River basin by the end of 1984 (fig. 4). The reclamation process included regrading the land surface to reduce slopes and provide surface or subsurface drainage, addition of a layer of top soil, incorporation of fertilizer and (or) lime, and finally seeding and mulching. During reclamation, sediment ponds were constructed and used to prevent sediment from reaching the receiving stream.

The Ohio Department of Natural Resources funded reclamation of 100 acres (area A, fig. 4) in 1978, and 235 acres (area B, fig. 4) in the summer of 1984 (M. Farley, Ohio Department of Natural Resources, oral commun., 1984). The U.S. Department of

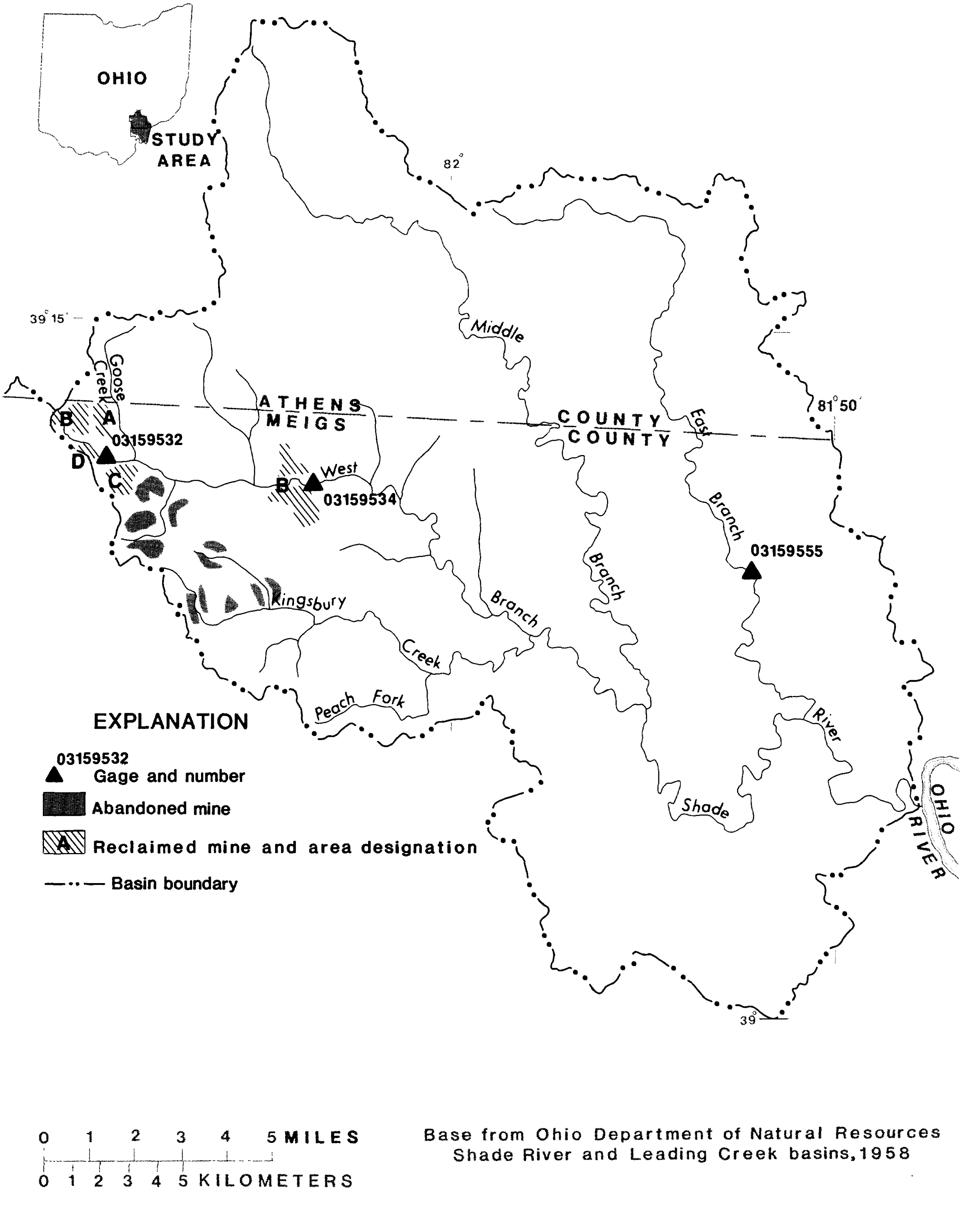

Figure 4.--Approximate location of abandoned and reclaimed surface coal mines in the West Branch Shade River basin, October 1984.

Agriculture, Soil Conservation Service, funded reclamation of about 88 acres (area C, fig. 4) in 1982 and 30 acres (area D, fig. 4) in 1983 (D. Hire, U.S. Department of Agriculture, oral commun., 1984). In all, 188 acres were reclaimed before the beginning of data collection. These areas comprise only 1 percent of the basin above the Burlingham gage.

METHODS OF STUDY

Three continuous-record streamflow-gaging stations were constructed. Two were located on the West Branch Shade River, near Harrisonville (03159532) and near Burlingham (03159534, fig. 2). The third, on East Branch Shade River near Tuppers Plains (03159555, fig. 2), was a control site. East Branch Shade River basin was selected as a control for this study because of the physiographic, topographic, and lithologic similarity to West Branch Shade River basin. (See the section on Location and Physical Setting.) With the exception of coal mining (there has been no mining in the East Branch basin), land use also is similar--primarily agriculture, forest, and rural residential.

The West Branch Shade River gaging station near Burlingham and the East Branch Shade River gaging station were equipped with manometers to measure stream stage, U.S. Geological Survey PS-69 automatic sediment samplers, and data loggers to record stage at 15-minute to 1-hour intervals, depending on flow conditions. The West Branch station near Harrisonville was equipped with a stilling well and float to measure stage, an automatic sampler, and a digital recorder to record stage at 5-minute intervals. Data collection began in June 1983.

Suspended-sediment samples, collected manually using the equal-transit-rate method (U.S. Geological Survey, 1977), were used to establish sediment concentration during base-flow periods.

Suspended-sediment samples were collected during periods of runoff by the automatic samplers. At the stations on East Branch Shade River and West Branch Shade River near Burlingham, the automatic sampler was activated when the stage rose above pre-set thresholds of 7.0 and 3.5 feet, respectively. When the automatic sampler was activated, samples were collected at 15-minute intervals or when a change in stage of 0.5 foot or more occurred. At the station on West Branch Shade River near Harrisonville, the sampler was activated when the stage rose 0.5 foot above base-flow stage. Samples were collected at 5-minute intervals until the stage dropped below the level at which the sampler was activated.

The automatic suspended-sediment sampler withdrew a water sample from a fixed point in the cross section; thus, the point concentration needed to be adjusted to the average suspended-sediment concentration for the cross section. This cross-section average was determined empirically by collecting a manual sample simultaneously with a sample collected by the automatic sampler.

The manual sample was collected using an integrating method that yields a sample that represents the average suspended-sediment concentration within the cross section. The relation between point sample and integrated sample was used to calculate a correction coefficient. This coefficient was used to adjust point-sample concentration to the average concentration in the cross section (Porterfield, 1972, p. 12). For East Branch Shade River near Tuppers Plains, the coefficient was 1.0. For West Branch Shade River near Burlingham, the coefficient was 0.84. For West Branch Shade River near Harrisonville, the coefficient was 1.0.

Sediment samples were analyzed at the U.S. Geological Survey District office in Columbus, Ohio, from May through September 1983 using a method for suspended sediment (Guy, 1969). Heidelberg College Water Quality Laboratory in Tiffin, Ohio, analyzed samples thereafter. The Heidelberg College Laboratory used a method for suspended solids (American Public Health Association and others, 1975) for analyses of samples. To compare the equivalency of the two methods for analysis of sediments in the Shade River, duplicate suspended-sediment samples were collected. One duplicate was analyzed in Heidelberg College Laboratory using the suspended-solids method and the other was analyzed in the U.S. Geological Survey Ohio District office using the suspended-sediment method. Results indicate that there was no significant difference in concentration because of analytical method for suspended-sediment samples from West Branch Shade River.

Daily suspended-sediment load was calculated using one of several methods depending on the completeness of data. For East Branch Shade River near Tuppers Plains, data collection was uncomplicated because of a relatively stable streambed and fairly continuous streamflow. As a result, few data were missing and daily suspended-sediment load was calculated from measured concentrations of suspended sediment and measured streamflow. For days with suspended-sediment concentration missing, loads were estimated from suspended-sediment concentration for comparable streamflow conditions (Porterfield, 1972, p. 20). For West Branch Shade River near Burlingham, record was less complete because the equipment used to measure stage was not sensitive to discontinuous or low streamflow. In addition, extreme shifts in the streambed generally caused the equipment to fail. For days when suspended-sediment concentration was missing, the concentration was assumed to be the same as the suspended-sediment concentration measured under the most recent similar streamflow and antecedent-weather conditions (Porterfield, 1972, p. 20). For days with missing stage record, daily streamflow was determined from record of rainfall and stage on days preceding and following the missing record or was estimated from a nearby gage.

For West Branch Shade River near Harrisonville, data were the least complete because of the same equipment and stream conditions described for the Burlingham gage. For days with missing stage record, streamflow was determined as described above. Furthermore, because of the small drainage-basin size, it was very difficult to reach the site and collect a suspended-sediment sample in the short time between initial rainfall and peak runoff. As a result, daily suspended-sediment loads were calculated from suspended-sediment rating curves. Instantaneous streamflow data, in cubic feet per second, were related to the corresponding instantaneous suspended-sediment discharge, in tons per day, on logarithmic graph paper. S-shaped curves were manually fit to the data (Colby, 1956). Four suspended-sediment rating curves were developed, each describing a different time period and representing a change in the relation between streamflow and suspended-sediment. These ratings were used with record of daily streamflow to calculate daily suspended-sediment loads.

Stream cross sections were surveyed at nine locations in West Branch Shade River basin and one location in East Branch Shade River basin (fig. 2). The cross sections were surveyed quarterly from July 1983 until September 1984 and twice a year thereafter. Elevations at each point in the cross section were measured relative to an arbitrary datum of 50 feet established on the left bank of each cross section. Elevations were recorded to the nearest 0.1 foot. At least two reference points also were established at each cross section and measured with each survey to cross check the accuracy of the primary reference mark.

Water-quality samples were collected at each of the three gaging stations and at two other locations in West Branch Shade River basin (fig. 2) in the winter, spring, and early summer during the study period. Samples were analyzed by U.S. Geological Survey Central Laboratory for concentrations of total and dissolved aluminum, iron, and manganese, and dissolved sulfate using methods described in Skougstad and others (1979). Water discharge, pH, water temperature, and concentrations of alkalinity and acidity were determined on site at the time of sample collection. Alkalinity concentration was determined as described in Skougstad and others (1979, p. 517). Acidity concentration was determined as described in American Public Health Association and others (1975, p. 275).

SEDIMENTATION

During surface mining, overburden that is removed to expose the coal-bearing strata is accumulated in spoil piles. Spoil piles typically have steep slopes and are lacking topsoil to help support vegetation. As a result, erosion rates from these areas are higher than for any other land use in Ohio (U.S. Department of Agriculture, 1985). The U.S. Department of Agriculture (1985) measured soil-loss rates in excess of 200 tons per acre per year from spoil piles in Meigs County. Most material eroded from the land surface is deposited downslope or in the channel of the receiving water; however, only about 5 to 10 percent is exported from the basin by receiving waters (Trimble, 1975).

When the suspended-sediment load exceeds the transport capacity of stream-water discharge, the channel typically begins to fill with sediment (Foster and Meyer, 1977). The West Branch Shade River basin is typical of much of southeastern Ohio, where surface mining usually occurs on hillsides and transport capacity decreases as runoff from hillsides reaches the receiving stream in the flat, valley area. Under these conditions, deposited material may form alluvial fans at the confluence of receiving streams and tributaries. Subsequent backfilling of the tributary and main channels further reduces channel capacity and may result in more frequent out-of-bank flooding. These channel overflows may, in turn, lead to deposition of suspended sediment in the flood plain adjacent to the filled channel (Happ and others, 1940, p. 71) and to the formation of elevated natural levees.

However, when suspended-sediment loading decreases so that the stream has the capacity to carry a greater quantity of suspended sediment than is received by the stream from runoff, scouring of the stream channel will occur. This has often been observed below newly built reservoirs because the reservoir acts as a sediment trap. The clear water released below the reservoir in place of the once sediment-laden water causes the channel to scour. Eventually, scouring causes the slope of the streambed to flatten so that the sediment-carrying capacity decreases and a new equilibrium is achieved (Leopold and others, 1964, p. 454-5). A significant reduction in suspended-sediment loading resulting from abandoned surface mine reclamation would be expected to have the same effect on the receiving stream channel.

Mean Suspended-Sediment Concentration

Mean suspended-sediment concentrations were used to assess whether reclamation in the West Branch Shade River basin was resulting in a decrease in the quantity of suspended sediment carried by the West Branch Shade River. Mean suspended-sediment concentration for a specific period was calculated from total suspended-sediment load and total streamflow for that period. Sediment load is, in part, a function of total annual runoff; thus, total annual load varies due to natural annual variation in rainfall and runoff at each site and varies from site to site due to differences in drainage basin size. Suspended sediment is expressed in this report as total mean concentration, in tons per acre-foot of runoff, in an effort to account for these variations. These data are shown in table 2 for the 1983 through 1985 water years. Because data collection began in the summer of 1983, only 4 months of data were collected in the 1983 water year. Data for the same 4-month period in the 1984 and 1985 water years are presented so that the 1983 partial year may be compared to the same period in following years.

Table 2.--Total suspended-sediment load, total stream discharge, and mean suspended-sediment concentration for West Branch Shade River near Harrisonville and near Burlingham, and East Branch Shade River near Tuppers Plains, Ohio

[CFS-days, cubic foot per second-days; Dash indicates data were not collected for the period]

Station	Water year	Period					
		June through September			October through September		
		Total suspended-sediment load for the period (tons)	Total stream discharge for the period (CFS-days)	Mean Suspended-sediment concentration for the period (tons per acre-foot)	Total suspended-sediment load for the period (tons)	Total stream discharge for the period (CFS-days)	Mean Suspended-sediment concentration for the year (tons per acre-foot)
West Branch Shade River near Harrisonville	1983	34	9	1.9	--	--	--
	1984	70	13	2.7	13,600	796	8.6
	1985	2	34	.03	111	380	.15
West Branch Shade River near Burlingham	1983	4,830	474	5.1	--	--	--
	1984	794	266	1.5	8,420	8,330	.51
	1985	62	247	.13	9,960	10,200	.49
East Branch Shade River near Tuppers Plains	1983	460	655	.35	--	--	--
	1984	123	389	.16	7,700	14,000	.28
	1985	66	276	.12	6,680	12,100	.28

East Branch Shade River basin above the sampling location is unmined and no major land-use changes occurred during the study period. Mean suspended-sediment concentration at East Branch Shade River was 0.28 ton per acre-foot of runoff per year during 1984 and 1985 water years (table 2). More than 70 percent of the annual-suspended-sediment load was transported from February through May (table 5, at back of report).

Mean suspended-sediment concentration for the period June through September for the East Branch site was 0.35 ton per acre-foot of runoff in 1983, 0.16 in 1984, and 0.12 in 1985. However, less than about 2 percent of the total annual suspended-sediment load was transported from June through September (table 5). The relatively high concentration for the period in 1983 compared with the same period for 1984 and 1985 is due to one storm that occurred in July 1983, runoff from which transported 364 tons of suspended sediment or 79 percent of the load measured in the 1983 water year (table 5). In Ohio, summer thunderstorms are common, and a single thunderstorm with high rainfall intensity can produce high suspended-sediment concentrations in runoff.

Mean suspended-sediment concentration in West Branch Shade River near Burlingham was about 0.5 ton per acre-foot of runoff during 1984 and 1985 water years (table 2)--nearly twice that for East Branch Shade River basin. No decrease in mean concentration was observed following reclamation of 46 percent of the abandoned-mine lands in 1983 and 1984. The seasonal distribution of suspended-sediment transport was similar to East Branch; more than 60 percent of the annual load was transported from February through May and less than 9 percent was transported from June through September (table 6, at back of report).

Mean suspended-sediment concentration for the period June through September at the Burlingham site, in tons per acre foot of runoff, was 5.1 in 1983, 1.5 in 1984, and 0.13 in 1985. The extremely high suspended-sediment load in June and July of 1983 (table 6) may be due to a combination of factors--erosion from unreclaimed surface mines just upstream from the site and greater total streamflow for the period June through September compared with the same period in 1984 and 1985. In the summer of 1983, none of the abandoned-mine lands immediately upstream of this site had been reclaimed (area B, fig. 4). Reclamation activities began in this area in March 1984 and ended in October 1984.

Mean suspended-sediment concentration for the headwaters of West Branch Shade River near Harrisonville was 8.6 and 0.15 tons per acre-foot of runoff in the 1984 and 1985 water years, respectively (table 2). The pronounced decrease in mean suspended-sediment concentration corresponds to completion of reclamation activities. By the autumn of 1984, 100 percent of the abandoned-mine lands above this site had been reclaimed. Construction of a retention pond (area B, fig. 4) in part accounts for the extremely low annual mean suspended-sediment concentration in 1985. More than 50 percent of the annual load was transported in February through May and less than 2 percent from June through September (table 7, at back of report).

Mean suspended-sediment concentration, in tons per acre-foot of runoff, for the period June through September for the Harrisonville site was 1.9 in 1983, 2.7 in 1984, and 0.03 in 1985 (table 2). Reclamation activities were ongoing during the summers of 1983 and 1984. In a 1-week period in March, during which access roads and retention ponds were constructed as the initial phase of reclamation, 5,810 tons of suspended-sediment (41 percent of the annual suspended-sediment load) was transported past the Harrisonville gage in runoff from two storms (table 7). By October 1984, all abandoned surface mines above the Harrisonville gage had been reclaimed.

Channel Scour and Fill

Successive surveys of cross-section profile were used to assess channel scour or fill following reclamation. The following data were calculated from these surveys (table 3): Cross-section area, normalized cross-section area, whether the difference between successive measurements was positive or negative, and the average difference in normalized area between measurements. Normalized area was calculated by dividing each cross-section area by the initial cross-section area. Thus, each area was expressed as a proportion of the initial cross-section area and comparison could be made between streams of differing total area.

No long-term net fill or scour of the stream channel is expected under conditions of equilibrium, although some short-term variation in channel configuration is typical. A long-term net scour or long-term net fill of the channel may indicate a change in the sediment-carrying capacity of the stream (that is, a change in channel conveyance). A positive change in area indicates channel scour, whereas a negative change in area indicates filling of the channel.

For the two cross sections measured in areas with no abandoned surface mines, East Branch Shade River (site 10) and tributary to West Branch Shade River (site 5), cross-section area fluctuated so that the number of times the channel was observed to have filled (that is, there was a negative difference in area between measurements) approximately equalled the number of times the channel was observed to have scoured (table 3). Furthermore, the average change in normalized area was small, -0.1 and 0, respectively.

Five of the cross sections measured in areas with abandoned surface mines also appeared to be in equilibrium--two sites in the headwaters of Kingsbury Creek (sites 7 and 8); Goose Creek (site 2); a tributary to West Branch Shade River (site 3); and West Branch Shade River at Snowville (site 4). Like the cross sections in the two unmined basins, the cross-section area at these five sites flucuated, and average change in normalized areas was near zero.

Table 3.--Cross-sectional area, normalized area, and positive or negative change in area between measurements from surveys made at 10 locations in the Shade River basin

[Site numbers refer to figure 1. Dash indicates no data or not applicable. (+) indicates channel scour. (-) indicates channel fill. N indicates no change.]

Site number	Site name	Area, in square feet Normalized area (Positive or negative change in area between measurement and previous measurement)								Average change in normalized area between measurements
		1983	1984			1985			1986	
		July	October	January	June	October	March	September	July	
1	West Branch Shade River near Harrisonville	13.0 1.0 --	11.3 .87 (-)	13.1 1.01 (+)	15.5 1.19 (+)	16.9 1.30 (+)	17.7 1.36 (+)	19.7 1.52 (+)	-- -- --	09
2	Goose Creek near Harrisonville	39.4 1.0 --	37.1 .94 (-)	36.0 .91 (-)	37.8 .96 (+)	39.0 .99 (+)	36.2 .92 (-)	37.8 .96 (+)	-- -- --	-.01
3	Tributary to West Branch Shade River near Harrisonville	124.5 1.0 --	114.6 .92 (-)	133.3 1.07 (+)	117.3 .94 (-)	93.9 .75 (-)	127.5 1.02 (+)	-- -- --	-- -- --	.00
4	West Branch Shade River at Snowville	150.0 1.0 --	146.6 .98 (-)	127.8 .85 (-)	137.3 .92 (+)	137.6 .92 (+)	136.5 .91 (-)	132.7 .88 (-)	148.2 .99 (+)	.00
5	Tributary to West Branch Shade River near Burlingham	57.3 1.0 --	62.3 1.09 (+)	60.2 1.05 (-)	62.0 1.08 (+)	57.4 1.00 (-)	53.5 .93 (-)	56.7 .99 (+)	56.7 .99 N	.00
6	West Branch Shade near Burlingham	169.4 1.0 --	166.6 .98 (-)	161.9 .96 (-)	167.0 .98 (+)	165.7 .98 (-)	164.5 .97 (-)	159.6 .94 (-)	159.4 .94 (-)	-.01
7	Kingsbury Creek near Harrisonville	26.1 1.0 --	24.0 .92 (-)	23.2 .89 (-)	25.7 .98 (+)	24.6 .94 (-)	22.8 .87 (-)	25.2 .96 (+)	-- -- --	-.01
8	Tributary to Kingsbury Creek near Harrisonville	24.8 1.0 --	25.0 1.01 (+)	23.1 .93 (-)	23.5 .95 (+)	20.8 .84 (-)	21.0 .85 (+)	21.2 .85 (+)	-- -- --	-.02
9	Kingsbury Creek near Burlingham	37.7 1.0 --	40.0 1.06 (+)	37.8 1.0 (-)	39.2 1.04 (+)	39.4 1.04 (+)	39.6 1.05 (+)	41.7 1.11 (+)	48.3 1.28 (+)	.04
10	East Branch Shade Shade River near Tuppers Plains	-- -- --	-- -- --	140.4 1.0 --	134.7 .96 (-)	131.6 .94 (-)	132.0 .94 (+)	133.9 .95 (+)	135.2 .96 (+)	-.01

Three sites do not appear to be in equilibrium: West Branch Shade River near Harrisonville and near Burlingham and Kingsbury Creek near Burlingham. Scour of the channel of West Branch Shade River near Harrisonville is evident from consistent positive change between successive measurement of cross-section area (table 3), from the relatively large average change in normalized area, and from visual observations of the streambed. Each successive measurement after the first period of reclamation in 1983 indicated scour. In addition, over the course of the study, the water intake for the streamflow gage needed to be lowered repeatedly because of a drop in the streambed elevation. The change in composition of the bed material also provides evidence that the bed was scouring. By the end of the study period, streambed materials had changed from predominantly sands and silts to predominantly sands and gravels. This change in composition of the bed material was visible from the headwaters to the confluence with Goose Creek. Below the confluence with Goose Creek, the West Branch Shade River widens considerably and the active channel is poorly defined. Much of the river valley from this point to the confluence with the next major tributary is swampland, which acts as a sediment trap.

The channel of West Branch Shade River near Burlingham appears to be filling, based on change in area between measurements. Except for one period, between January and June 1984, cross-section area decreased (negative change in area) with each successive measurement (table 3). This indicates that the channel was filling even after reclamation, in 1984, of about 168 acre of abandoned-mine lands immediately upstream of the cross section. Indeed, this is supported by the computed annual suspended-sediment loads; loads did not decrease during the study. However, the magnitude of fill was small; average change in cross section area was only -0.1, the same as at the control site. More data are needed to confirm if the channel will continue to fill.

Although the source of sediment near the headwaters has been greatly reduced because of reclamation of abandoned-mine lands, sediment previously deposited and stored in the channel of the West Branch Shade River most likely continues to provide a supply of suspended sediment (Foster and Meyer, 1977). In addition, unreclaimed mines in the basin (fig. 4) continue to provide a source of suspended sediment. These two factors, no doubt, account for the continuing high suspended-sediment load near Burlingham and to possible channel filling.

Although bed elevations in the headwaters of Kingsbury Creek appeared to be in equilibrium, a cross section (site 9, fig. 2) in the lower part of the basin appeared to be scouring. No reclamation activities have occurred in the Kingsbury Creek basin to reduce suspended-sediment load, and the reason for the scouring is unknown.

WATER QUALITY

Weathering and oxidation of pyrite, which is found in bedrock in southeastern Ohio, produces acidity and sulfate. This weathering process is intensified as a result of surface coal mining because of the increased surface area of bedrock exposed when coal is extracted. Furthermore, streams draining abandoned surface mines in areas where local bedrock is composed of few limestone-bearing members have relatively low buffering capacity (that is, contain low concentrations of alkalinity); therefore, pH typically is well below neutral. Streams with low pH and high acidity concentrations also typically have high concentrations of dissolved metals as a result of dissolution of minerals in soils and bedrock. These metals remain in solution in accordance with the pH-solubility relationship for each metal.

Streams draining unmined basins in southeastern Ohio typically have relatively high alkalinity and low acidity concentration, near-neutral pH values, and relatively low concentrations of dissolved metals compared with streams draining abandoned-mine lands (Childress, 1984). Comparison of selected chemical constituents in the mined area of West Branch Shade River basin with unmined areas illustrates the significant effect that abandoned mines can have on the water quality of the receiving stream.

pH is a measure of the hydrogen-ion concentration expressed as a negative logarithm to base 10. Medians of pH at the mined sites were less than neutral (7.0), whereas medians of pH were greater than neutral at the unmined sites (fig. 5). Alkalinity concentration is a measure of the capacity of stream water to neutralize acids. Median alkalinity concentration for the unnamed tributary to West Branch Shade River near Burlingham that drains an unmined area of the basin was 67 mg/L (milligrams per liter) as $CaCO_3$ (fig. 5). The median concentration for the East Branch, which drains the more calcareous bedrock formations in the eastern part of the county and which also is unmined, was 120 mg/L. In contrast, median alkalinity concentrations were less than 25 mg/L at the mined sites (fig. 5). Acidity concentration is a measure of the capacity of the stream water to react with hydroxyl ions. For streams with pH above 7.0, acidity was assumed to be equal to zero and therefore was not measured. Concentrations of acidity were assumed to be 0 mg/L at the two unmined sites based on pH. Median concentrations at the mined sites ranged from 5 to 50 mg/L (fig. 6).

Median sulfate concentrations were 3 times higher at the mined sites than at the unmined sites (fig. 6). Median dissolved-manganese concentrations were at least an order of magnitude higher at mined sites than at unmined sites (fig. 7). Both dissolved sulfate and dissolved manganese concentrations were highest in the headwaters of West Branch Shade River where a greater proportion of the basin was mined. Dissolved-iron concentrations fluctuated seasonally, but median concentrations generally were also higher at the mined sites (fig. 7).

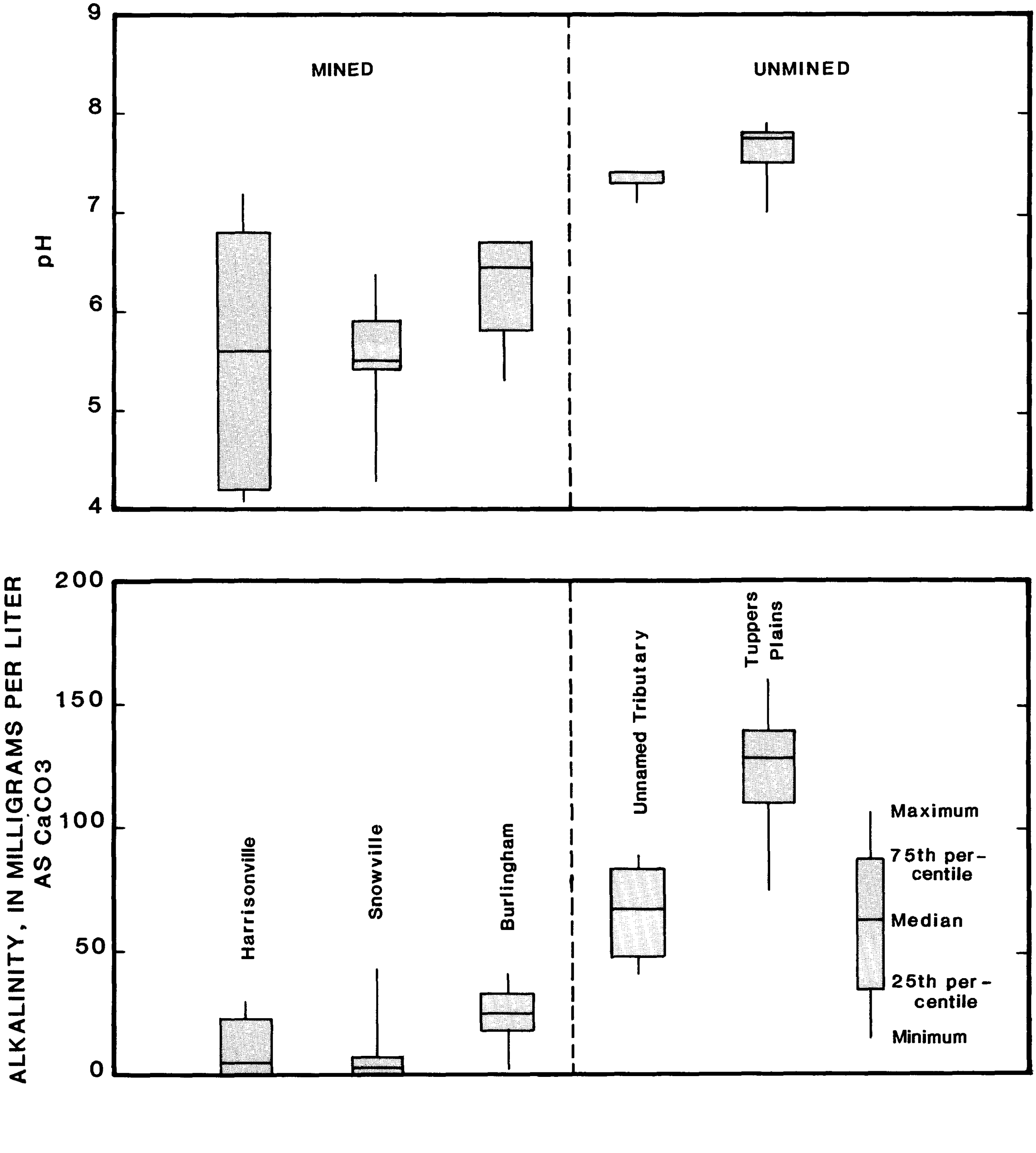

Figure 5.--Distribution of pH values and alkalinity concentrations at mined and unmined sites on West and East Branches of Shade River from samples collected from 1983 through 1986.

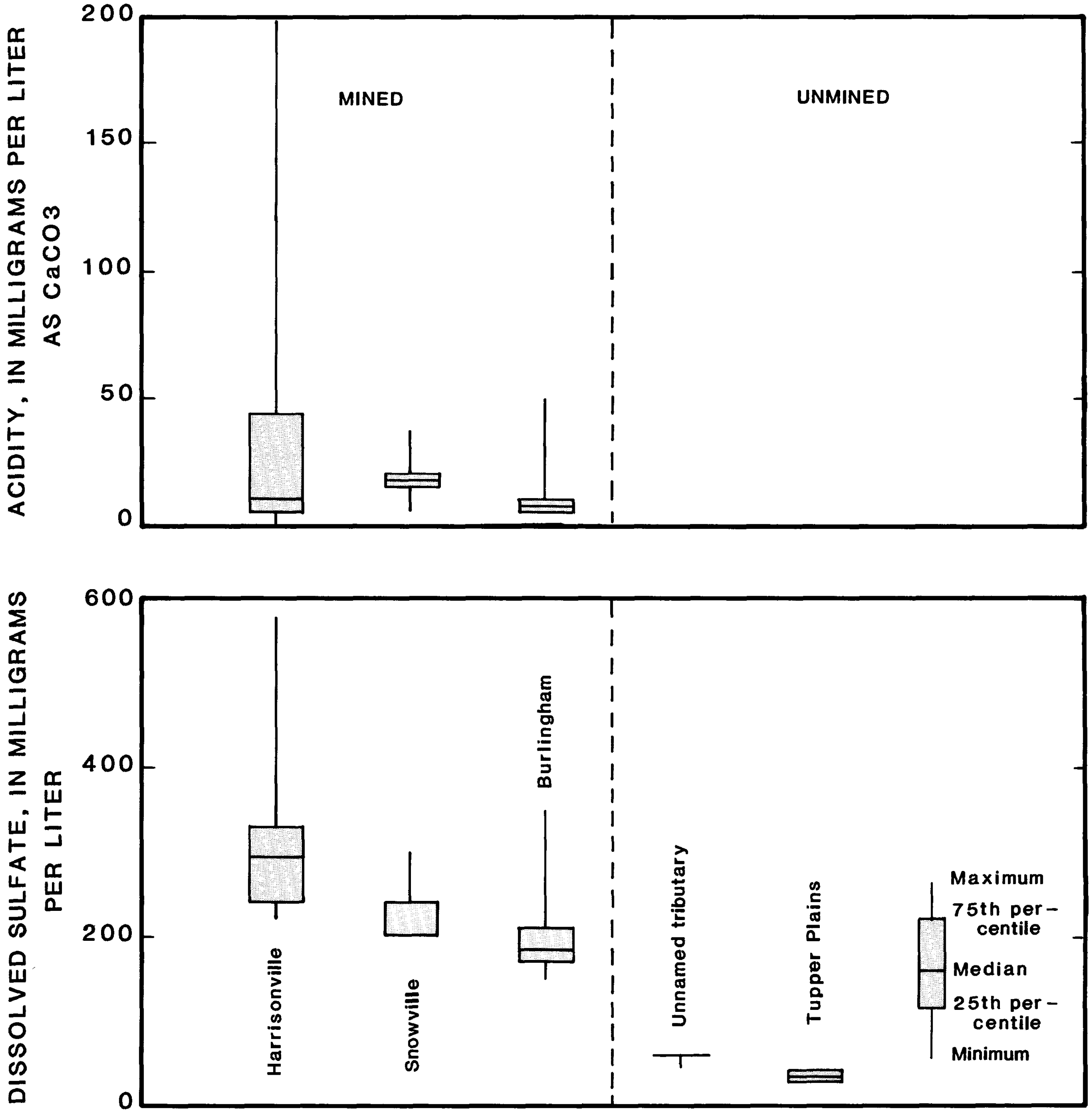

Figure 6.--Distribution of acidity and sulfate concentrations at mined and unmined sites on West and East Branches of Shade River from samples collected from 1983 through 1986.

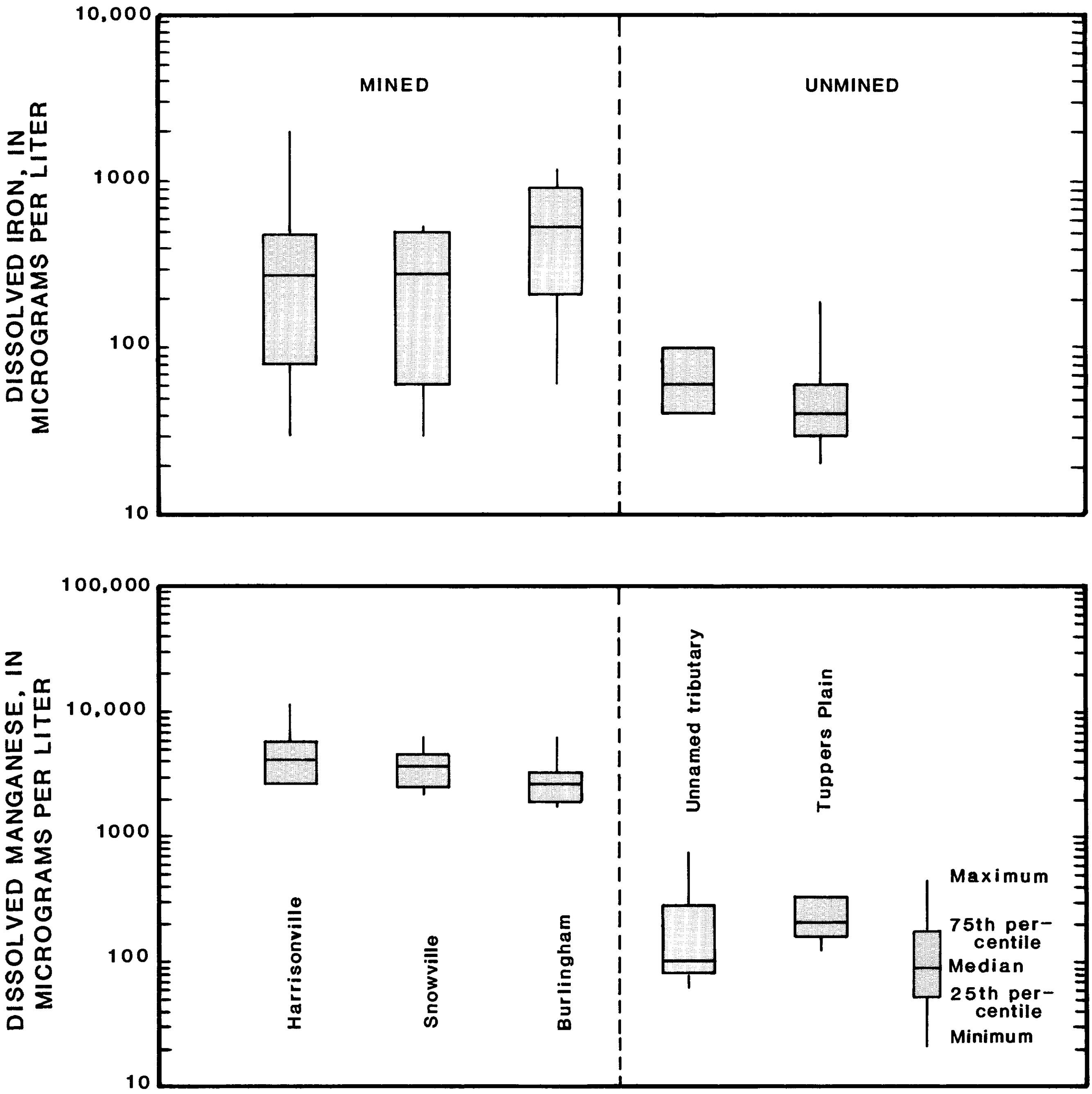

Figure 7.—Distribution of dissolved -iron and -manganese concentrations at mined and unmined sites on West and East Branches of Shade River from samples collected from 1983 through 1986.

Dissolved-aluminum concentration is related to pH and is rarely found in natural waters at concentrations above 100-200 ug/L, except in waters of very low pH (Hem, 1985, p. 73). Median dissolved-aluminum concentrations were near 900 ug/L at the two upstream stations on West Branch Shade River and less than 200 ug/L at the unmined sites (fig. 8). Specific conductance is a general indicator of the concentration of dissolved minerals. Median values were highest progressing upstream in West Branch Shade River basin and lowest in the streams draining unmined areas (fig. 8).

The period over which data were collected was insufficient to perform valid statistical tests of water-quality trends. The Seasonal Kendall test (Hirsch and others, 1982) is most suitable for application to water-quality data that are typically not normally distributed and that vary seasonally. However, because the period of study was relatively short, there were, at most, two samples per season for trend analysis. Additional data are needed over several more years to test whether there are statistically significant trends in water-quality constituents at any of the sites.

However, changes in concentrations and values of constituents analyzed during the study period suggest that some water-quality improvements are occurring at some sites. All water samples were collected during periods of base flow when drainage from the abandoned mines was not diluted with surface runoff.

Alkalinity concentrations appear to have increased at the West Branch Shade River near Harrisonville, where all abandoned surface mines have been reclaimed. Alkalinity was 0 mg/L in 1983 and 30 mg/L in 1986 at approximately the same streamflow. Despite that increase, the alkalinity concentration in 1986 was still less than the concentrations at either unmined site (table 4). Likewise, pH, which in 1983 was lower in the headwaters than anywhere else in the basin, was neutral when measured in 1986. The fact that pH is neutral, yet alkalinity concentration is lower than found in unmined areas of the West Shade River basin, may indicate that there is some continuing acid production but that it is buffered. In contrast, there was no apparent change in alkalinity or pH at Snowville or Burlingham during the study period (table 4).

Dissolved-manganese concentration decreased from 1983 to 1986 at the Harrisonville site. At the sites near Burlingham and Snowville, the concentrations did not change appreciably. The concentration of dissolved manganese at all three mined sites remained well above the concentrations at the two unmined sites (table 4). Dissolved-sulfate concentration did not change appreciably at any of the mined sites and the concentrations remained well above the concentrations at the two unmined sites (table 4).

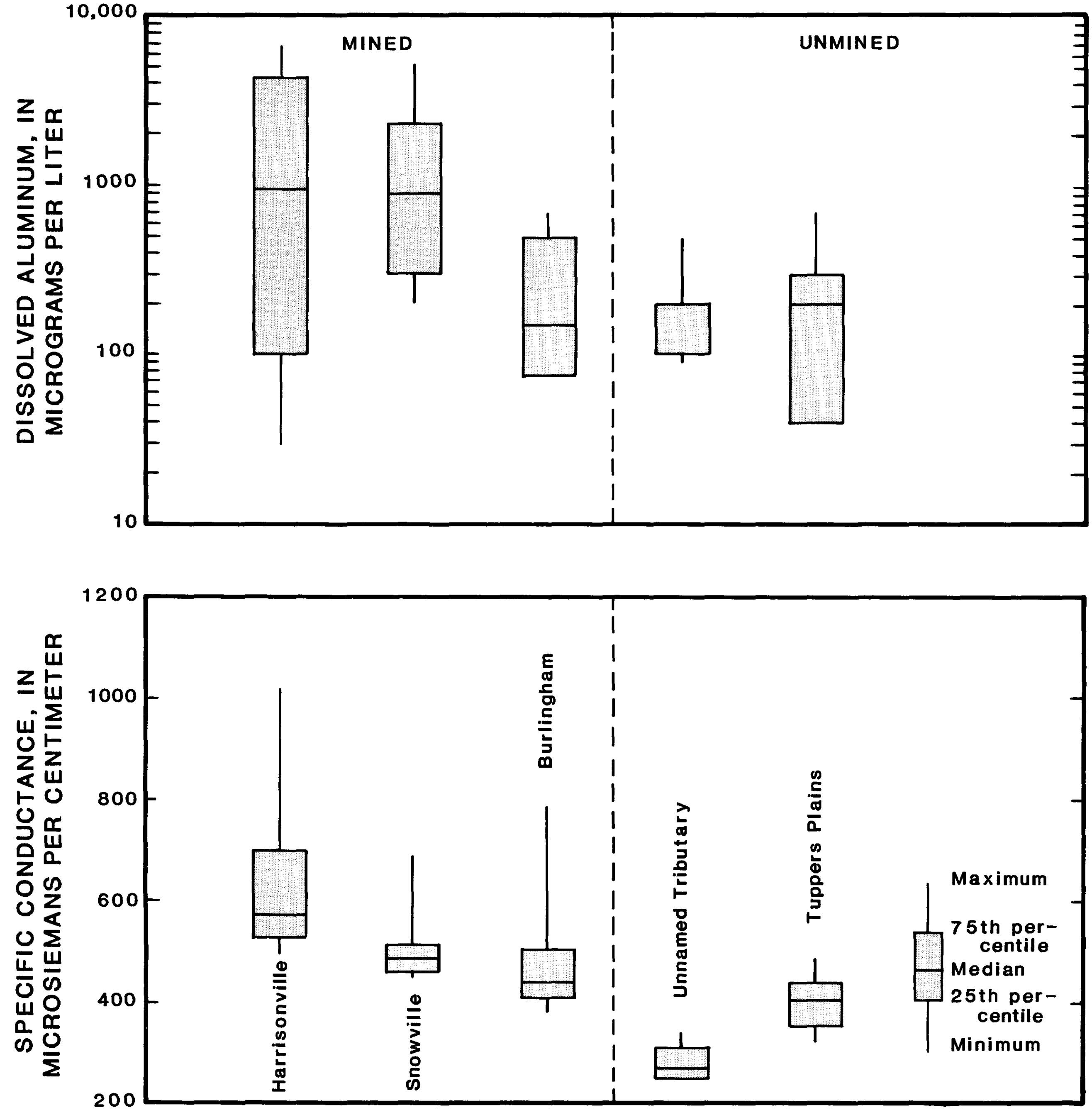

Figure 8.--Distribution of dissolved-aluminium concentrations and specfic conductance values at mined and unmined sites on West and East Branches of Shade River from samples collected from 1983 through 1986.

Table 4.--Results of water-quality analyses for West Branch Shade River near Harrisonville, at Snowville, and near Burlingham; for the tributary to West Branch Shade River near Burlingham; and for East Branch Shade River near Tuppers Plains, Ohio, from June 1983 through July 1986

[°C, degrees Celsius; ft^3/s, cubic feet per second; ug/L, micrograms per liter; uS/cm, microsiemens per centimeter at 25 degrees Celsius. Dash indicates no data available]

Station	Date	Time	Temperature (°C)	Temperature, air (°C)	Streamflow, instantaneous (ft^3/s)	Specific conductance (uS/cm)	pH	Alkalinity[1] (mg/L as $CaCO_3$)	Acidity[2] (mg/L as $CaCO_3$)
Mined sites:									
West Branch Shade River near Harrisonville	06-28-83	1230	27.0	--	0.07	1020	4.2	0	200
	01-16-84	1600	0.0	-1.0	0.33	560	5.1	3	94
	05-22-84	0800	16.5	--	0.2	572	4.1	0	50
	01-10-85	0915	0.0	5.5	0.32	495	6.1	7	9.9
	06-03-85	1510	34.5	32.0	0.1	580	6.8	23	--
	07-09-86	1215	30.0	32.0	0.08	815	7.2	30	0
West Branch Shade River at Snowville	01-16-84	1500	0.0	-1.0	2.8	513	5.4	3	20
	05-22-84	0900	18.5	21.5	1.9	451	5.5	7	15
	01-09-85	1500	0.5	5.5	5.0	460	5.9	1	5.0
	06-03-85	1200	26.5	24.0	0.95	485	6.4	43	--
	07-09-86	1400	26.5	27.0	0.18	685	4.3	0	37
West Branch Shade River near Burlingham	06-28-83	1400	25.0	--	2.4	502	6.5	33	50
	01-16-84	1200	0.5	2.5	6.7	455	5.8	18	5.0
	05-21-84	1450	24.5	27.0	5.4	411	6.7	30	5.0
	01-09-85	1630	0.0	7.5	13.0	380	6.4	20	--
	06-03-85	1300	24.5	30.0	2.8	420	6.7	41	--
	07-10-86	0845	22.0	25.0	0.10	788	5.3	2	10
Unmined sites:									
Unnamed tributary to West Branch Shade River near Burlingham	02-02-84	1300	0.0	8.0	7.8	247	7.1	48	0
	05-21-84	1615	22.0	27.5	1.4	270	7.3	67	0
	01-10-85	1155	0.5	6.0	2.6	250	7.4	41	0
	06-04-85	0840	18.5	16.0	0.62	310	7.4	83	0
	07-09-86	1500	25.0	32.0	0.01	340	7.4	89	0
East Branch Shade River near Tuppers Plains	07-05-83	1215	25.5	25.0	3.5	441	7.0	140	0
	01-17-84	0930	0.0	1.0	11.0	355	7.8	110	0
	05-21-84	1245	20.0	--	11.0	392	7.8	130	0
	01-09-85	1210	1.0	6.0	22.0	325	7.7	74	0
	06-04-85	1000	21.0	16.0	3.6	420	7.5	160	0
	07-10-86	1045	24.5	26.5	0.83	490	7.9	120	0

Table 4.--Results of water-quality analyses for West Branch Shade River near Harrisonville, at Snowville, and near Burlingham; for the tributary to West Branch Shade River near Burlingham; and for East Branch Shade River near Tuppers Plains, Ohio, from June 1983 through July 1986--Continued

Station	Date	Sulfate dis-solved (mg/L)	Iron, total recov-erable (ug/L)	Iron, dis-solved (ug/L)	Manga-nese, total recov-erable (ug/L)	Manga-nese, dis-solved (ug/L)	Alum-inum, total recov-erable (ug/L)	Alum-inum, dis-solved (ug/L)
Mined sites:								
West Branch Shade River near Harrisonville	06-28-83	580	640	480	12,000	12,000	1,000	1,000
	01-16-84	300	2,900	2,000	5,800	5,800	7,000	6,900
	05-22-84	290	1,400	30	5,300	5,200	4,600	4,300
	01-10-85	220	710	470	3,400	3,100	1,800	100
	06-03-85	240	1,300	80	2,800	2,600	1,000	900
	07-09-86	330	2,400	80	2,900	2,700	550	30
West Branch Shade River at Snowville	01-16-84	240	960	540	4,600	4,600	2,900	2,300
	05-22-84	200	550	60	3,800	2,200	1,600	300
	01-09-85	200	1,600	280	2,800	2,500	3,200	200
	06-03-85	240	750	30	3,900	3,700	1,400	900
	07-09-86	300	910	500	6,400	6,500	5,100	5,200
West Branch Shade River near Burlingham	06-28-83	210	1,700	210	3,300	3,300	1,000	<100
	01-16-84	200	1,400	1,200	3,300	3,300	1,000	<100
	05-21-84	170	670	650	2,200	2,000	400	100
	01-09-85	150	1,400	410	2,000	1,800	1,200	200
	06-03-85	170	760	60	1,900	1,900	700	700
	07-10-86	350	1,300	910	6,300	6,400	780	500
Unmined sites:								
Unnamed tributary to West Branch Shade River near Burlingham	02-02-84	64	90	60	150	100	200	200
	05-21-84	61	250	40	70	60	100	100
	01-10-85	61	440	100	340	280	300	100
	06-04-85	62	380	40	110	80	800	500
	07-09-86	49	3,000	100	1,500	770	1,600	90
East Branch Shade River near Tuppers Plains	07-05-83	28	1,200	30	400	340	700	300
	01-17-84	44	130	60	160	160	<100	<100
	05-21-84	40	760	50	230	160	200	100
	01-09-85	42	440	190	130	120	400	300
	06-04-85	32	1,100	20	300	250	1,100	700
	07-10-86	29	2,500	30	920	330	1,500	40

[1]Alkalinity is assumed to be zero when pH is less than 5.0.

[2]Acidity is assumed to be zero when pH is greater than 7.0.

Previous studies have shown that, in southeastern Ohio, concentrations of manganese and sulfate typically remain at prereclamation levels even after reclamation (Childress, 1984; Pfaff and others, 1981). In fact, sulfate and manganese concentrations are typically reliable indicators of past disturbance from surface mining.

SUMMARY AND CONCLUSIONS

Daily mean streamflow and suspended-sediment concentrations were measured from June 1983 through October 1985 at three streamflow gages located in the Shade River basin--East Branch Shade River near Tuppers Plains and West Branch Shade River near Harrisonville and Burlingham. In addition, water samples for chemical-quality analyses were collected at five locations on East and West Branches, and channel cross sections were surveyed at 10 locations from June 1983 through September 1986. East Branch Shade River basin has never been mined for coal, whereas there are more than 900 acres of abandoned-mine lands in West Branch Shade River basin.

During the study period, about 450 acres of abandoned-mine lands were reclaimed, including all of the abandoned-mine lands above the Harrisonville site and 41 percent of the abandoned-mine lands above the Burlingham site. The mean annual suspended-sediment concentrations at the two sites in West Branch basin were more than twice as high (0.51 and 8.6 ton per acre-foot of runoff) in the 1984 water year (before the completion of reclamation activities) as the mean annual suspended-sediment concentrations for the unmined East Branch basin (0.28 ton per acre-foot of runoff). In the 1985 water year, after the completion of reclamation activities, mean annual suspended-sediment concentration decreased at Harrisonville to 0.15 ton per acre-foot of runoff and was unchanged near Burlingham (0.49 ton per acre-foot of runoff). Mean annual suspended-sediment concentration also was unchanged for the unmined East Branch basin in 1985.

Surveys of stream cross sections were made at least twice a year and were used to calculate a cross-section area. The cross section surveyed in the headwaters of West Branch Shade River basin near Harrisonville had scoured. This was confirmed by visual observation of the streambed and by changes in the stage-discharge relation over the study period. The cross section surveyed near Burlingham, however, appeared to be filling. The cross section surveyed at Snowville appeared to be in equilibrium, neither filling nor scouring consistently over the period of study. Although the source of sediment from the headwaters has been greatly reduced because of reclamation, the sediment previously deposited in the channel continues to provide a sediment supply. In addition, there is a continuing supply from the remaining abandoned mines.

Of the tributaries to West Branch Shade River that were surveyed, only one series of cross sections, on Kingsbury Creek, indicated a change in channel configuration. This cross section was scouring over the study period. The channel configuration of two cross sections in the headwaters of Kingsbury Creek and nearest to the abandoned-mine lands appear to be in equilibrium over the study period.

Water quality for the West Branch Shade River basin was characteristic of streams draining abandoned-mine lands. In general, pH and alkalinity concentrations were low and acidity, dissolved-sulfate, and dissolved-manganese concentrations were high compared with East Branch Shade River and the tributary draining an unmined part of West Branch Shade River basin.

Improvements in water quality at West Branch Shade River near Harrisonville were observed following a significant amount of reclamation. All abandoned mines in the headwaters of West Branch Shade River basin were reclaimed by the end of the study period. Alkalinity concentrations and pH values in the headwaters were higher at the end of the study than at the beginning of the study at nearly identical streamflow. Dissolved-manganese concentrations were lower at the end of the study compared with the beginning of the study, although concentrations were still an order of magnitude higher than at the unmined sites.

SELECTED REFERENCES

American Public Health Association, 1975, Standard methods for the analysis of water and wastewater, 14th edition: p. 275-277.

Brant, R. A., and Delong, R. M., 1960, Coal resources of Ohio: Ohio Division of Geological Survey Bulletin 58, 245 p.

Childress, C. J. O., 1984, Classification of stream basins in southeastern Ohio according to extent of surface coal mining: U.S. Geological Survey Water-Resources Investigations Report 84-4212, 83 p.

Childress, C. J. O., and Jones, R. L., 1985a, Sediment and water-quality data for the West Branch and East Branch Shade River basins, Ohio, 1983 water year: U.S. Geological Survey Open-File Report 85-187, 16 p.

----- 1985b, Sedimentation and water quality in the West Branch Shade River Basin, Ohio, 1984 water year: U.S. Geological Survey Water-Resources Investigations Report 85-552, 26 p.

Colby, B. R., 1956, Relationship of sediment discharge to streamflow: U.S. Geological Survey Open-File Report, 170 p.

Fenneman, N. M., 1938, Physiography of eastern United States: New York, McGraw-Hill, 691 p.

Foster, G. R., and Meyer, L. D., 1977, Soil erosion and sedimentation by water--An overview, in National Symposium on Soil Erosion and Sedimentation by Water: Chicago, IL, p. 1-13.

Guy, H. P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. Cl, 58 p.

Happ, S. C., Rittenhouse, G., and Dobson, G. C., 1940, Some principles of accelerated stream and valley sedimentation: U.S. Department of Agriculture Technical Bulletin 695, 133 p.

Hirsch, R. M., Slack, J. R., Smith, R. A., 1982, Techniques of trend analysis for monthly water-quality data: Water Resources Research, v. 18, no. 1, p. 107-21

Leopold, L. B., Wolman, M. G., Miller, J. P., 1964a, Fluvial Processes in geomorphology: W. H. Freeman and Company, San Francisco, 522 p.

Ohio Board of Unreclaimed Strip Mine Lands, 1974, Land reborn: Ohio Department of Natural Resources, 91 p.

Pfaff, C. L., Helsel, D. R., Johnson, D. P., and Angelo, C. G., 1981, Assessment of water quality in streams draining coal-producing areas in Ohio: U.S. Geological Survey Water Resources Investigations/Open-File Report 81-409, 98 p.

Porterfield, G., 1972, Computation of fluvial-sediment discharge: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C3, 66 p.

Skougstad, M. W., and others, 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. Al, 626 p.

Trimble, S. W., 1975, Denudation studies--Can we assume stream study state: Science, v. 188, p. 1207-1208.

U.S. Department of Commerce, 1982, Climatological Data, Annual Summary, Ohio.

----- 1983, Climatological Data, Annual Summary, Ohio.

U.S. Department of Agriculture, 1985, Assessment and Treatment of Areas in Ohio Impacted by Abandoned Mines: 73 p.

U.S. Geological Survey, 1977, Sediment, in National handbook of recommended methods for water-data acquisition.

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; tons/d, tons per day. Dash indicates no data available.]

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)
	Water year 1983					
	June			July		
1	24	17	1.1	3.0	13	0.11
2	21	11	.62	3.4	10	.09
3	30	41	7.1	1.3	10	.04
4	84	37	9.8	2.2	14	.08
5	48	25	3.2	3.4	27	.25
6	30	25	2.0	2.7	25	.18
7	47	50	6.3	1.6	16	.07
8	26	13	.91	1.2	18	.06
9	18	10	.49	.97	15	.04
10	14	10	.38	.73	17	.03
11	11	10	.30	.73	20	.04
12	8.8	10	.24	.54	18	.03
13	7.1	10	.19	.22	19	.01
14	6.1	10	.16	.22	15	.00
15	5.2	10	.14	.19	15	.00
16	4.7	10	.13	.12	16	.00
17	4.5	10	.12	.10	14	.00
18	4.3	10	.12	.22	21	.01
19	15	50	4.6	.47	26	.03
20	22	41	2.4	.47	17	.02
21	8.8	10	.24	.47	20	.03
22	6.6	10	.18	.47	16	.02
23	5.2	10	.14	2.8	681	21
24	4.1	10	.11	83	1590	364
25	3.4	10	.09	8.2	135	3.0
26	2.8	10	.08	4.4	68	.81
27	2.3	10	.06	2.3	65	.40
28	2.7	10	.07	1.8	42	.20
29	2.8	10	.08	1.3	34	.12
30	2.8	10	.08	1.1	28	.08
31	---	---	---	.84	22	.05
Total	472	---	41.00	130	---	391

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concen-tration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concen-tration (mg/L)	Daily suspended-sediment discharge (tons/d)
			Water year 1983--Continued			
		August			September	
1	2.1	62	0.35	0.00	0	0.00
2	4.5	28	.34	.00	0	.00
3	1.8	25	.12	.00	0	.00
4	1.2	14	.05	.00	0	.00
5	1.0	25	.07	.00	0	.00
6	27	301	24	.00	0	.00
7	5.0	156	2.1	.00	0	.00
8	2.7	95	.69	.00	0	.00
9	1.8	50	.24	.00	0	.00
10	1.2	30	.10	.00	0	.00
11	.84	46	.10	.00	0	.00
12	.54	25	.04	.00	0	.00
13	1.1	57	.17	.00	0	.00
14	.63	55	.09	.00	0	.00
15	.30	32	.03	.00	0	.00
16	.19	34	.02	.00	0	.00
17	.14	20	.00	.00	0	.00
18	.10	19	.00	.00	0	.00
19	.10	16	.00	.00	0	.00
20	.14	20	.00	.00	0	.00
21	.26	25	.02	.00	0	.00
22	.16	21	.00	.00	0	.00
23	.00	0	.00	.00	0	.00
24	.00	0	.00	.00	0	.00
25	.03	24	.00	.00	0	.00
26	.02	23	.00	.00	0	.00
27	.00	0	.00	.00	0	.00
28	.00	0	.00	.00	0	.00
29	.00	0	.00	.00	0	.00
30	.00	0	.00	.00	0	.00
31	.00	0	.00	---	---	---
Total	52.8	---	28.5	0.00	---	0.00
June through September:	655	460				

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1984					
		October			November			December	
1	0.00	0	0.00	5.0	21	0.28	31	4	0.33
2	.00	0	.00	4.8	30	.39	24	3	.19
3	.00	0	.00	5.0	27	.36	22	3	.18
4	.00	0	.00	7.4	23	.46	180	91	49
5	.00	0	.00	6.4	14	.24	110	33	10
6	.00	0	.00	5.5	10	.15	131	61	24
7	.00	0	.00	4.6	10	.12	103	29	8.7
8	.00	0	.00	3.8	10	.10	65	12	2.1
9	.00	0	.00	3.3	11	.10	74	25	8.1
10	.00	0	.00	238	239	200	198	89	51
11	.00	0	.00	408	158	115	93	25	6.2
12	.00	0	.00	76	31	6.7	437	248	297
13	.00	0	.00	41	14	1.5	144	45	18
14	.40	24	.03	28	9	.68	90	23	5.6
15	.11	11	.00	118	75	36	92	30	7.4
16	1.0	13	.04	128	55	19	66	6	1.1
17	.84	16	.04	94	25	6.3	49	2	.26
18	.63	16	.03	57	14	2.2	40	2	.22
19	.63	18	.03	40	20	2.2	34	2	.18
20	.63	20	.03	32	20	1.7	26	2	.14
21	31	53	5.5	29	12	.94	25	3	.20
22	39	51	7.2	24	5	.32	306	254	211
23	254	480	393	21	3	.17	128	48	18
24	228	185	140	21	7	.40	70	9	1.7
25	118	68	26	19	8	.41	44	7	.83
26	27	22	1.6	16	5	.22	31	7	.59
27	19	15	.77	14	6	.23	26	13	.91
28	12	17	.55	155	106	48	22	27	1.6
29	9.1	20	.49	79	27	5.8	20	24	1.3
30	7.1	20	.38	47	7	.89	18	13	.63
31	5.5	18	.27	---	---	---	16	5	.22
Total	754	---	576	1,730	---	451	2,720	---	727

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
	Water year 1984--Continued								
	January			February			March		
1	15	4	0.16	42	14	1.6	83	30	6.7
2	14	3	.11	36	13	1.3	69	21	3.9
3	14	2	.08	36	17	1.7	59	19	3.0
4	14	2	.08	48	25	3.2	54	23	3.4
5	14	2	.08	40	18	1.9	95	95	24
6	14	3	.11	34	8	.73	119	119	39
7	14	2	.08	23	6	.37	76	23	4.7
8	14	3	.11	25	7	.47	60	8	1.3
9	15	3	.12	18	5	.24	38	19	2.0
10	14	3	.11	17	5	.23	33	23	1.9
11	14	3	.11	19	8	.41	35	15	1.4
12	13	5	.18	27	17	1.2	24	13	.84
13	13	4	.14	34	36	4.7	25	13	.88
14	13	3	.11	119	179	63	24	8	.52
15	12	4	.13	80	45	9.9	23	9	.56
16	12	4	.13	55	18	2.7	22	16	.95
17	11	5	.15	44	16	1.9	21	12	.68
18	10	7	.19	38	17	1.7	20	12	.65
19	8.0	7	.15	36	21	2.0	19	15	.77
20	7.0	7	.13	38	14	1.4	18	36	2.0
21	6.6	8	.14	33	7	.62	410	905	1040
22	6.2	6	.10	29	6	.47	172	128	61
23	6.0	6	.10	27	6	.44	116	50	16
24	172	139	96	24	9	.58	79	31	6.6
25	196	125	74	23	10	.62	66	28	5.0
26	101	58	16	20	10	.54	82	45	10
27	66	31	5.5	18	10	.49	76	32	6.6
28	51	18	2.5	178	512	350	167	176	139
29	43	13	1.5	154	138	63	262	305	234
30	38	11	1.1	---	---	---	119	63	20
31	43	13	1.5	---	---	---	80	30	6.5
Total	984	---	201	1320	---	517	2,550	---	1,640

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1984--Continued					
		April			May			June	
1	60	20	3.2	26	20	1.4	26	22	1.5
2	47	15	1.9	22	20	1.2	19	28	1.4
3	53	36	6.8	26	35	2.8	15	27	1.1
4	414	531	572	45	80	11	12	22	.71
5	274	229	181	31	20	1.7	9.5	17	.44
6	126	65	22	32	23	2.0	7.9	14	.30
7	94	33	8.4	36	22	2.1	6.6	13	.23
8	67	22	4.0	36	32	3.6	5.7	19	.29
9	53	21	3.0	58	55	13	5.0	24	.32
10	43	20	2.3	39	16	1.7	4.3	19	.22
11	37	20	2.0	31	11	.92	3.7	17	.17
12	33	16	1.4	49	76	26	3.1	23	.19
13	31	12	1.0	41	27	3.0	2.8	23	.17
14	28	13	.98	31	15	1.3	2.3	27	.17
15	28	17	1.3	25	15	1.0	2.0	25	.14
16	29	14	1.1	20	17	.92	1.5	27	.11
17	29	22	1.7	18	18	.87	1.5	34	.14
18	48	26	3.4	15	19	.77	1.5	33	.13
19	57	24	3.7	14	20	.76	2.0	32	.17
20	42	17	1.9	12	20	.65	1.7	25	.11
21	35	10	.95	10	21	.57	1.7	16	.07
22	216	371	384	9.1	23	.57	1.4	17	.06
23	217	208	136	13	30	1.1	1.4	22	.08
24	158	66	28	12	39	1.3	1.5	30	.12
25	93	30	7.5	8.2	25	.55	3.4	40	.37
26	64	20	3.5	7.1	25	.48	2.1	19	.11
27	51	20	2.8	6.6	25	.45	1.5	28	.11
28	45	20	2.4	33	933	1350	1.2	20	.06
29	36	17	1.7	161	344	634	1.7	45	.26
30	32	20	1.7	76	57	13	1.3	46	.15
31	---	---	---	40	27	2.9	---	---	---
Total	2,540	---	1,390	983	---	2,080	150	---	9.40

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1984--Continued					
		July			August			September	
1	9.8	74	1.7	1.2	18	0.06	0.35	18	0.02
2	5.7	38	.58	1.2	24	.10	.35	19	.02
3	3.0	30	.24	9.1	83	2.1	.30	23	.02
4	2.0	18	.10	34	260	53	.30	23	.02
5	1.8	12	.06	45	323	41	.26	22	.02
6	7.4	54	.85	15	63	2.6	.22	22	.01
7	4.1	19	.21	7.1	75	1.4	.19	22	.01
8	2.8	15	.11	7.6	66	1.4	.19	21	.01
9	1.9	13	.07	5.0	41	.55	.19	21	.01
10	1.4	12	.05	3.3	30	.27	.16	21	.00
11	2.4	33	.33	3.9	31	.33	.16	20	.00
12	4.8	64	.83	3.1	22	.18	.16	20	.00
13	2.2	42	.25	2.2	18	.11	.14	20	.00
14	1.4	33	.12	1.9	15	.08	.12	19	.00
15	1.1	25	.07	1.6	14	.06	.30	19	.02
16	.97	20	.05	1.4	16	.06	.26	19	.01
17	.84	16	.04	1.2	20	.06	.22	19	.01
18	.54	14	.02	1.0	18	.05	.19	19	.00
19	.54	12	.02	3.3	39	.28	.16	18	.00
20	.47	11	.01	2.0	20	.11	.16	18	.00
21	.47	10	.01	1.4	20	.08	.16	18	.00
22	.47	11	.01	1.2	20	.06	.14	18	.00
23	.40	11	.01	1.2	20	.06	.12	18	.00
24	.40	11	.01	1.1	19	.06	.12	17	.00
25	.40	10	.01	1.4	16	.06	.12	17	.00
26	.40	10	.01	1.2	18	.06	.12	17	.00
27	1.2	11	.04	1.0	21	.06	.06	17	.00
28	1.7	11	.05	.63	18	.03	.06	17	.00
29	9.1	137	3.3	.54	21	.03	.06	17	.00
30	2.8	24	.18	.30	25	.02	.06	16	.00
31	1.5	17	.07	.35	21	.02	---	---	---
Total	74.0	---	9.41	160	---	104	5.40	---	0.18
Year	14,000		7,700						

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
	Water year 1985								
	October			November			December		
1	0.06	3	0.00	4.5	32	0.39	51	31	4.9
2	.13	14	.00	3.6	28	.27	39	16	1.7
3	.14	14	.00	3.2	22	.19	31	11	.92
4	.16	14	.00	3.0	18	.15	23	9	.56
5	.17	13	.00	8.4	30	.80	18	7	.34
6	.17	13	.00	10	28	.76	18	6	.29
7	.17	12	.00	7.0	18	.34	13	6	.21
8	.17	12	.00	5.5	12	.18	13	6	.21
9	.17	12	.00	54	98	29	15	5	.20
10	.17	11	.00	129	184	66	122	116	64
11	.17	10	.00	173	168	78	125	100	34
12	.17	10	.00	51	45	6.2	66	23	4.1
13	.17	11	.00	25	16	1.1	45	14	1.7
14	.17	11	.00	17	11	.50	35	12	1.1
15	.18	10	.00	13	8	.28	34	12	1.1
16	.25	9	.00	13	7	.25	31	12	1.0
17	.25	9	.00	9.9	9	.24	26	11	.77
18	.25	10	.00	27	45	8.5	25	10	.68
19	.46	14	.02	135	63	23	29	21	2.0
20	.60	17	.03	78	24	5.1	46	115	14
21	.65	16	.03	37	19	1.9	288	417	485
22	1.5	35	.22	24	15	.97	394	130	138
23	5.8	34	.57	19	13	.67	104	70	20
24	5.0	22	.30	16	12	.52	70	53	10
25	3.2	20	.17	13	11	.39	75	38	7.7
26	2.6	19	.13	12	11	.36	54	25	3.6
27	2.0	21	.11	10	9	.24	45	17	2.1
28	4.2	31	.47	43	38	7.9	37	14	1.4
29	27	75	8.2	66	45	8.0	32	11	.95
30	19	65	3.3	36	17	1.7	47	64	11
31	6.9	38	.71	---	---	---	67	420	76
Total	82.0	---	14.3	1,050	---	244	2,020	---	890

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1985--Continued					
		January			February			March	
1	60	290	47	9.2	49	14	44	16	1.9
2	56	190	29	9.2	17	.42	37	13	1.3
3	43	109	13	9.2	11	.27	30	11	.89
4	40	70	7.6	9.2	8	.20	27	10	.73
5	36	60	5.8	9.2	8	.20	29	60	4.7
6	32	57	4.9	9.2	8	.20	27	18	1.3
7	29	54	4.2	9.2	8	.20	24	17	1.1
8	26	56	3.9	9.2	7	.17	25	17	1.1
9	23	56	3.5	9.2	7	.17	27	17	1.2
10	22	55	3.3	9.2	7	.17	25	17	1.1
11	20	55	3.0	13	8	.28	145	248	217
12	19	54	2.8	21	80	81	634	500	977
13	17	115	5.3	23	55	3.4	144	85	33
14	16	115	5.0	60	31	5.0	101	41	11
15	15	100	4.1	63	24	4.1	73	28	5.5
16	14	94	3.6	58	19	3.0	56	23	3.5
17	13	92	3.2	57	15	2.3	48	22	2.9
18	12	90	2.9	58	15	2.3	37	20	2.0
19	12	88	2.9	60	28	7.1	31	18	1.5
20	11	86	2.6	81	81	25	29	17	1.3
21	10	84	2.3	158	159	82	24	17	1.1
22	10	81	2.2	453	470	679	24	16	1.0
23	9.7	80	2.1	633	320	583	48	43	5.3
24	9.6	78	2.0	362	160	156	46	9	1.1
25	9.4	76	1.9	111	100	30	37	7	.70
26	9.3	75	1.9	92	55	14	30	6	.49
27	9.2	74	1.8	68	30	5.5	28	6	.45
28	9.2	67	1.7	52	22	3.1	26	6	.42
29	9.2	57	1.4	---	---	---	25	6	.41
30	9.2	48	1.2	---	---	---	523	608	947
31	9.2	53	8.4	---	---	---	632	236	426
Total	620	---	184	2,520	---	1,700	3,040	---	2,650

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1985--Continued					
		April			May			June	
1	216	122	77	5.2	17	0.24	5.2	45	0.63
2	111	40	12	227	232	229	4.4	52	.62
3	79	27	5.8	286	150	139	3.9	52	.55
4	59	21	3.3	66	35	6.2	3.8	52	.53
5	47	19	2.4	37	22	2.2	3.8	52	.53
6	43	16	1.9	27	21	1.5	3.8	47	.48
7	45	50	6.1	23	23	1.4	3.4	45	.41
8	63	60	10	18	23	1.1	3.4	41	.38
9	55	23	3.4	15	22	.89	3.4	38	.35
10	45	13	1.6	13	22	.77	3.2	34	.29
11	40	12	1.3	12	19	.62	3.1	31	.26
12	34	16	1.5	11	16	.48	6.6	70	1.2
13	30	17	1.4	12	18	.58	6.3	75	1.3
14	27	18	1.3	12	24	.78	4.1	61	.68
15	25	19	1.3	61	232	229	3.1	58	.49
16	23	20	1.2	230	150	139	2.8	54	.41
17	22	18	1.1	92	35	8.7	2.5	57	.38
18	18	19	.92	39	29	2.8	2.2	52	.31
19	17	19	.87	47	80	10	2.1	47	.27
20	15	17	.69	26	37	2.6	2.0	44	.24
21	13	17	.60	18	26	1.3	1.8	40	.19
22	11	18	.53	15	32	1.3	1.7	36	.17
23	10	17	.46	14	50	1.9	1.7	36	.17
24	8.7	16	.38	13	56	2.0	2.0	35	.19
25	8.5	15	.34	10	54	1.5	2.0	34	.18
26	7.9	13	.28	8.5	51	1.2	1.6	32	.14
27	7.2	14	.27	7.3	48	.95	1.3	31	.11
28	7.1	16	.31	9.2	46	1.1	1.1	27	.08
29	6.4	19	.33	8.7	42	.99	.94	25	.06
30	5.4	18	.26	6.7	37	.67	.94	24	.06
31	---	---	---	5.7	34	.52	---	---	---
Total	1,100	---	139	1,380	---	790	88.2	---	11.7

Table 5.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for East Branch Shade River near Tuppers Plains, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
Water year 1985--Continued									
	July			August			September		
1	0.93	23	0.06	0.93	16	0.04	2.4	35	0.23
2	1.0	23	.06	.75	19	.04	1.4	29	.11
3	2.4	38	.16	.62	18	.03	1.0	23	.06
4	2.8	23	.17	.56	15	.02	.62	16	.03
5	2.1	21	.12	.50	12	.02	.50	15	.02
6	1.7	21	.10	.50	10	.01	.34	15	.01
7	2.4	21	.14	.46	10	.01	.34	14	.01
8	2.6	21	.15	.44	9	.01	.30	10	.00
9	1.8	20	.10	.44	8	.00	.25	8	.00
10	1.7	21	.10	.43	7	.00	.24	5	.00
11	4.4	20	.24	.41	7	.00	.21	3	.00
12	2.6	21	.15	.33	7	.00	.17	2	.00
13	1.7	20	.09	.29	7	.00	.03	0	.00
14	1.3	20	.07	.26	7	.00	.00	0	.00
15	40	174	30	.25	6	.00	.00	0	.00
16	8.4	107	2.5	.25	5	.00	.00	0	.00
17	3.6	71	.69	.46	5	.00	.00	0	.00
18	2.3	55	.34	.68	5	.00	.00	0	.00
19	1.6	44	.19	.85	5	.01	.00	0	.00
20	1.3	34	.12	1.0	5	.01	.00	0	.00
21	12	72	2.4	.72	5	.00	.00	0	.00
22	9.1	83	2.0	.48	6	.00	.00	0	.00
23	3.6	41	.40	.62	6	.01	.00	0	.00
24	2.2	30	.18	.82	6	.01	.00	0	.00
25	1.6	27	.12	23	69	8.2	.00	0	.00
26	1.3	23	.08	8.8	111	2.6	.00	0	.00
27	2.0	20	.11	2.4	58	.38	.00	0	.00
28	2.0	16	.09	1.4	41	.15	.00	0	.00
29	1.4	14	.05	1.0	37	.10	.00	0	.00
30	1.1	15	.04	1.2	36	.12	.00	0	.00
31	.95	15	.04	5.0	60	.81	---	---	---
Total	124	---	41.1	55.8	---	12.6	7.80	---	0.47
Year	12,100		6,680						

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio

[ft^3/s, cubic feet per second; mg/L, milligrams per liter. Dash indicates no data available.]

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)
			Water year 1983			
		June			July	
1	15	5	0.20	45	8,130	1,510
2	11	5	.15	6.4	353	8.8
3	18	2,300	334	3.7	30	.30
4	60	6,050	1,100	3.9	219	5.9
5	22	413	29	5.8	134	2.2
6	15	1130	59	1.7	30	.14
7	12	275	11	1.3	30	.11
8	7.6	10	.21	1.0	28	.08
9	5.6	5	.08	.82	20	.04
10	5.2	5	.07	.73	20	.04
11	4.6	5	.06	.61	20	.03
12	4.5	5	.06	.55	20	.03
13	4.2	5	.06	.50	16	.02
14	4.1	5	.06	.51	15	.02
15	3.9	5	.05	.50	14	.02
16	3.8	5	.05	.49	12	.02
17	3.9	5	.05	.49	10	.01
18	4.7	5	.06	7.6	2,170	93
19	18	2,030	231	1.9	80	.48
20	15	820	38	1.2	20	.06
21	8.7	25	.59	1.0	15	.04
22	4.5	5	.06	.94	15	.04
23	3.4	5	.05	.91	10	.02
24	3.1	5	.04	42	4,290	826
25	3.0	5	.04	9.3	1,830	147
26	3.0	5	.04	7.0	1,090	30
27	3.0	5	.04	2.3	15	.09
28	3.3	5	.04	1.4	15	.06
29	4.3	10	.12	.97	10	.03
30	13	1,820	242	.76	10	.02
31	---	---	---	.60	10	.02
Total	287	---	2,050	152	---	2,620

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)
			Water year 1983--Continued			
		August			September	
1	21	7,340	156	0.00	0	0.00
2	3.2	60	.60	.00	0	.00
3	1.6	10	.04	.00	0	.00
4	.97	10	.30	.00	0	.00
5	.68	5	.00	.00	0	.00
6	1.7	5	.02	.00	0	.00
7	.76	5	.01	.00	0	.00
8	.55	5	.00	.00	0	.00
9	.55	5	.00	.00	0	.00
10	.21	5	.00	.00	0	.00
11	.33	5	.00	.00	0	.00
12	1.1	5	.01	.00	0	.00
13	.38	5	.00	.00	0	.00
14	.21	5	.00	.00	0	.00
15	.18	5	.00	.05	5	.00
16	.14	5	.00	.10	5	.00
17	.12	5	.00	.15	5	.00
18	.12	5	.00	.06	5	.00
19	.10	5	.00	.05	5	.00
20	.03	5	.00	.05	5	.00
21	.02	5	.00	.21	5	.00
22	.02	5	.00	.14	5	.00
23	.00	0	.00	.06	5	.00
24	.00	0	.00	.04	5	.00
25	.00	0	.00	.04	5	.00
26	.00	0	.00	.00	0	.00
27	.00	0	.00	.00	0	.00
28	.00	0	.00	.00	0	.00
29	.00	0	.00	.00	0	.00
30	.00	0	.00	.00	0	.00
31	.00	0	.00	---	---	---
Total	34.0	---	157	0.95	---	0.00
June through September	474		4,830			

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
	Water year 1984								
	October			November			December		
1	0.00	0	0.00	2.0	8	0.04	14	55	2.1
2	.00	0	.00	1.7	8	.04	13	49	1.7
3	.00	0	.00	5.0	8	.11	14	44	1.7
4	.00	0	.00	6.6	8	.14	121	364	120
5	.00	0	.00	6.0	8	.13	51	121	17
6	.00	0	.00	4.8	8	.10	80	196	48
7	.00	0	.00	3.1	8	.07	51	112	110
8	.00	0	.00	2.8	8	.06	30	47	3.8
9	.00	0	.00	2.6	8	.06	41	85	19
10	.00	0	.00	140	552	318	96	221	55
11	.04	4	.00	128	346	150	46	169	20
12	.18	4	.00	31	42	3.5	170	389	180
13	.18	1,120	.88	17	10	.46	73	247	59
14	.08	71	.02	12	8	.26	47	117	14
15	.05	8	.00	36	110	15	42	69	7.7
16	.04	4	.00	50	128	17	29	27	2.1
17	.04	4	.00	37	76	7.6	23	17	1.1
18	.10	4	.00	21	59	3.3	17	15	.69
19	.10	4	.00	17	49	2.2	15	14	.57
20	.50	4	.00	15	45	1.8	13	13	.46
21	14	89	3.5	17	41	1.9	20	70	3.8
22	27	313	47	14	33	1.2	110	168	50
23	136	903	414	12	29	.94	90	55	13
24	107	416	191	12	25	.81	33	28	2.5
25	52	372	63	10	22	.59	21	20	1.1
26	15	67	2.7	8.2	18	.40	16	17	.73
27	9.2	17	.42	7.2	22	.43	14	16	.60
28	6.6	8	.14	107	288	90	12	16	.52
29	5.2	8	.11	35	101	9.5	11	16	.48
30	3.5	8	.08	19	67	3.4	11	15	.45
31	2.5	8	.05	---	---	---	11	14	.42
Total	379	---	723	780	---	629	1340	---	738

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
Water year 1984--Continued									
	January			February			March		
1	11	12	0.36	42	47	5.3	14	10	0.38
2	10	12	.32	44	26	3.1	14	10	.38
3	10	13	.35	42	60	6.8	26	11	.77
4	9.6	12	.31	33	39	3.5	34	17	1.6
5	9.4	12	.30	23	25	1.6	84	109	25
6	9.0	12	.29	19	22	1.1	75	25	5.1
7	8.6	12	.28	20	60	3.2	37	14	1.4
8	8.2	12	.27	23	63	3.9	29	13	1.0
9	7.8	12	.25	19	31	1.6	27	13	.95
10	7.6	11	.23	16	27	1.2	24	13	.84
11	7.4	13	.26	20	42	2.3	19	12	.62
12	7.2	15	.29	23	50	3.1	17	12	.55
13	7.0	15	.28	30	94	9.0	18	12	.58
14	6.8	16	.29	75	235	50	17	12	.55
15	6.8	16	.29	42	98	11	10	18	.49
16	6.6	18	.32	29	46	3.6	15	13	.53
17	6.2	16	.27	26	25	1.8	15	12	.49
18	5.8	16	.25	23	17	1.1	14	17	.64
19	5.2	16	.22	25	15	1.0	13	23	.81
20	4.7	14	.18	24	15	.97	15	23	.93
21	4.3	14	.16	20	13	.70	171	1,150	565
22	4.0	14	.15	15	13	.53	75	356	74
23	50	13	1.8	17	14	.64	50	185	25
24	277	156	117	15	13	.53	28	42	3.2
25	157	84	36	16	13	.56	28	29	2.2
26	93	59	15	15	12	.49	30	24	1.9
27	70	57	11	14	12	.45	25	24	1.6
28	55	38	5.6	14	11	.42	234	755	545
29	45	24	2.9	14	11	.42	218	1,030	649
30	41	20	2.2	---	---	---	74	332	69
31	39	19	2.0	---	---	---	44	157	19
Total	990	---	199	738	---	120	1,490	---	2,000

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1984--Continued					
		April			May			June	
1	33	60	5.4	20	59	3.1	21	320	17
2	26	48	3.4	18	46	2.2	16	99	4.0
3	40	210	52	38	417	42	12	29	.94
4	232	1080	706	42	143	19	7.8	15	.32
5	160	621	270	27	67	5.1	6.3	18	.31
6	98	466	99	33	153	15	4.8	21	.27
7	57	185	28	34	70	6.4	3.7	11	.11
8	40	88	9.5	35	92	11	3.5	53	4.7
9	32	67	5.8	37	152	15	3.0	8	.06
10	27	53	3.9	27	145	11	2.8	6	.05
11	22	39	2.3	21	44	2.5	2.8	7	.05
12	19	34	1.7	29	158	14	3.0	69	.77
13	20	34	1.8	22	43	2.6	1.8	17	.08
14	17	24	1.1	18	67	3.4	1.6	35	.15
15	16	24	1.0	16	95	4.3	1.7	37	.17
16	14	22	.83	15	77	2.5	1.6	13	.06
17	14	55	2.1	10	30	.81	1.4	13	.05
18	19	124	6.5	9.6	150	4.3	2.0	---	---
19	18	70	3.5	6.9	35	.69	3.3	73	.88
20	16	24	1.0	5.2	10	.14	1.6	17	.07
21	14	17	.64	5.8	73	1.6	1.8	40	.25
22	117	692	410	6.0	69	1.6	1.4	21	.08
23	107	399	126	13	132	5.9	1.4	15	.06
24	100	379	106	7.8	27	.57	14	203	9.3
25	55	158	25	8.5	88	2.7	3.3	241	2.1
26	40	52	5.6	4.3	11	.13	1.3	108	.38
27	44	118	13	3.9	8	.08	1.1	21	.06
28	35	116	11	103	2,820	868	1.6	7	.03
29	27	42	3.1	184	397	204	2.8	76	1.6
30	26	42	2.9	41	189	21	3.0	169	1.4
31	---	---	---	29	569	42	---	---	---
Total	1480	---	1,910	870	---	1,310	133	---	45.3

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1984--Continued					
		July			August			September	
1	23	237	13	1.0	27	0.07	0.00	0	0.00
2	5.2	88	1.3	1.0	13	.04	.00	0	.00
3	2.0	19	.10	1.0	8	.02	.00	0	.00
4	1.6	13	.06	1.7	7	.03	.00	0	.00
5	23	2,120	257	4.6	6	.07	.00	0	.00
6	16	688	37	2.2	3	.02	.00	0	.00
7	4.3	106	1.2	2.0	3	.02	.00	0	.00
8	1.4	34	.13	1.8	3	.01	.00	0	.00
9	.68	13	.02	1.7	2	.00	.00	0	.00
10	.62	6	.01	1.8	2	.00	.00	0	.00
11	5.7	2,990	123	3.5	2	.02	.00	0	.00
12	3.2	1,600	21	1.8	2	.00	.00	0	.00
13	.45	6	.00	.89	2	.00	.00	0	.00
14	.04	3	.00	.40	2	.00	.00	0	.00
15	.01	2	.00	.21	2	.00	.00	0	.00
16	.00	0	.00	.08	2	.00	.00	0	.00
17	.00	0	.00	.02	2	.00	.00	0	.00
18	.00	0	.00	.01	2	.00	.00	0	.00
19	.00	0	.00	.01	0	.00	.00	0	.00
20	.00	0	.00	.00	0	.00	.00	0	.00
21	.00	0	.00	.00	0	.00	.00	0	.00
22	.00	0	.00	.00	0	.00	.00	0	.00
23	.00	0	.00	.00	0	.00	.00	0	.00
24	.00	0	.00	.00	0	.00	.00	0	.00
25	.01	0	.00	.00	0	.00	.00	0	.00
26	.21	6	.00	.00	0	.00	.00	0	.00
27	2.1	8	.05	.00	0	.00	.00	0	.00
28	10	2,280	257	.00	0	.00	.00	0	.00
29	5.0	1,590	37	.00	0	.00	.00	0	.00
30	1.1	95	.28	.00	0	.00	.00	0	.00
31	1.1	59	.18	.00	0	.00	---	---	---
Total	107	---	748	25.7	---	0.30	0.00	---	0.00
Year	8,330		8,420						

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
					Water year 1985				
		October			November			December	
1	0.00	0	0.00	4.2	19	0.22	35	68	6.4
2	.00	0	.00	2.7	14	.10	21	30	1.7
3	.00	0	.00	1.9	17	.09	18	25	1.2
4	.00	0	.00	4.2	32	.42	14	20	.76
5	.00	0	.00	7.5	54	.91	13	15	.53
6	.00	0	.00	3.8	23	.24	14	12	.45
7	.00	0	.00	2.4	19	.12	17	71	4.1
8	.00	0	.00	1.9	15	.08	14	27	1.0
9	.00	0	.00	33	747	135	17	17	.78
10	.00	0	.00	87	906	234	82	194	67
11	.00	0	.00	78	1,770	381	70	200	38
12	.00	0	.00	21	440	25	32	68	5.9
13	.00	0	.00	13	52	1.8	24	41	2.7
14	.00	0	.00	9.8	28	.74	22	30	1.8
15	.00	0	.00	9.2	19	.47	21	24	1.4
16	.13	4	.00	8.5	17	.39	18	20	.97
17	.06	5	.00	6.0	17	.28	16	19	.82
18	.06	5	.00	23	856	118	16	17	.73
19	.05	5	.00	83	1,650	370	22	51	3.5
20	.05	3	.00	39	500	53	26	33	2.3
21	.25	2	.00	20	48	2.6	154	448	367
22	5.8	62	1.7	17	34	1.6	225	983	793
23	3.2	45	.39	14	29	1.1	74	148	30
24	1.7	25	.11	11	8	.24	55	99	20
25	.90	18	.04	8.8	6	.14	65	96	16
26	.66	12	.02	7.2	6	.12	45	31	3.8
27	.42	8	.00	6.5	6	.11	43	19	2.2
28	2.6	30	.61	34	230	34	36	15	1.5
29	22	604	54	29	200	16	33	14	1.2
30	8.0	179	4.3	21	67	5.5	53	20	2.4
31	4.5	65	.79	---	---	---	58	66	10
Total	50.4	---	62.0	608	---	1,380	1,350	---	1,390

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft³/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft³/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft³/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1985--Continued					
		January			February			March	
1	51	42	5.4	6.4	8	0.14	50	46	6.2
2	45	28	3.4	6.4	8	.14	48	39	5.1
3	36	17	1.7	6.4	7	.12	40	37	4.0
4	32	24	3.0	6.4	7	.12	42	36	4.1
5	27	45	3.3	6.4	6	.10	58	84	13
6	24	30	1.9	6.4	6	.10	39	53	5.6
7	21	26	1.5	6.4	6	.10	38	45	4.6
8	19	25	1.3	6.4	5	.09	53	51	7.3
9	17	77	9.6	6.4	5	.09	50	40	5.4
10	15	28	1.1	6.4	4	.07	47	36	4.6
11	14	16	.60	11	4	.12	146	130	79
12	13	13	.46	19	125	6.4	440	381	482
13	12	12	.39	30	255	21	143	150	58
14	11	12	.36	48	155	20	118	73	23
15	11	11	.33	42	128	15	86	39	9.1
16	10	11	.30	40	111	12	77	37	7.7
17	9.6	11	.29	40	98	11	62	36	6.0
18	9.2	10	.25	40	91	9.8	47	35	4.4
19	8.8	10	.24	40	84	9.1	38	37	3.8
20	8.4	9	.20	40	82	8.9	35	39	3.7
21	8.1	9	.20	100	205	90	29	38	3.0
22	7.8	9	.19	316	655	650	42	37	4.2
23	7.6	9	.18	469	551	697	71	70	13
24	7.4	9	.18	257	330	229	61	42	6.9
25	7.2	8	.16	125	160	54	52	35	4.9
26	7.0	8	.15	88	95	23	45	30	3.6
27	6.8	8	.15	71	74	14	39	28	2.9
28	6.7	8	.14	54	60	8.7	32	23	2.0
29	6.6	8	.14	---	---	---	34	19	1.7
30	6.5	8	.14	---	---	---	370	1130	1370
31	6.4	8	.14	---	---	---	536	850	1420
Total	472	---	37.4	1,890	---	1,880	2,970	---	3,570

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concentration (mg/L)	Daily suspended sediment discharge (tons/d)
				Water year 1985--Continued					
		April			May			June	
1	188	280	142	4.5	80	0.97	4.5	45	0.55
2	112	105	32	100	1070	289	3.5	45	.43
3	90	77	19	170	290	133	3.3	44	.39
4	73	76	15	110	80	24	3.0	43	.35
5	63	76	13	60	41	6.6	3.1	42	.35
6	80	136	29	35	40	3.8	3.1	42	.35
7	85	175	40	20	39	2.1	4.0	41	.44
8	96	80	21	14	37	1.4	4.4	39	.46
9	73	46	9.1	11	36	1.1	3.1	36	.30
10	57	34	5.2	9.2	35	.87	2.6	34	.24
11	53	34	4.9	7.8	34	.72	4.3	48	.75
12	46	33	4.1	9.6	43	1.1	13	72	2.9
13	41	35	3.9	12	51	1.7	5.1	49	.67
14	39	34	3.6	7.5	25	.51	3.1	47	.39
15	35	34	3.2	81	380	151	2.8	46	.35
16	29	33	2.6	156	360	152	2.7	45	.33
17	23	33	2.0	148	230	92	2.3	45	.28
18	19	32	1.6	78	498	144	2.3	44	.27
19	16	32	1.4	82	700	155	2.6	43	.30
20	15	31	1.3	38	260	27	3.1	41	.34
21	13	31	1.1	22	148	8.8	2.4	40	.26
22	12	30	.97	15	95	3.8	2.4	39	.25
23	10	30	.81	21	70	4.0	3.1	38	.32
24	11	28	.83	15	45	1.8	2.3	37	.23
25	9.4	28	.71	10	46	1.2	2.2	34	.20
26	8.2	28	.62	7.5	44	.89	2.1	32	.18
27	7.4	29	.58	13	101	4.5	2.1	31	.18
28	6.4	28	.48	12	78	2.5	1.9	30	.15
29	5.6	27	.41	11	56	1.7	1.9	27	.14
30	5.0	26	.35	7.5	50	1.0	1.8	25	.12
31	---	---	---	5.2	46	.65	---	---	---
Total	1,320	---	361	1,290	---	1,220	98.1	---	12.5

Table 6.--Daily mean streamflow, daily mean suspended-sediment concentration, and daily suspended-sediment discharge for West Branch Shade River near Burlingham, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concen-tration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concen-tration (mg/L)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily mean suspended-sediment concen-tration (mg/L)	Daily suspended sediment discharge (tons/d)
Water year 1985--Continued									
		July			August			September	
1	2.5	24	0.16	0.00	0	0.00	1.5	17	0.07
2	3.0	23	.19	.00	0	.00	.84	17	.04
3	4.8	40	.52	.00	0	.00	.60	15	.02
4	3.1	26	.22	.00	0	.00	.37	15	.01
5	3.1	25	.21	.00	0	.00	.28	12	.00
6	3.1	25	.21	.00	0	.00	.22	11	.00
7	2.8	24	.18	.00	0	.00	.15	8	.00
8	1.8	22	.11	.00	0	.00	.10	7	.00
9	1.8	22	.11	.00	0	.00	.06	5	.00
10	1.8	21	.10	.00	0	.00	.04	2	.00
11	2.1	20	.11	.00	0	.00	.02	0	.00
12	1.8	19	.09	.00	0	.00	.01	0	.00
13	1.7	18	.08	.00	0	.00	.00	0	.00
14	1.7	18	.08	.00	0	.00	.00	0	.00
15	13	55	1.4	.00	0	.00	.00	0	.00
16	2.8	27	.20	.00	0	.00	.00	0	.00
17	1.4	24	.09	.00	0	.00	.00	0	.00
18	.81	21	.05	.00	0	.00	.00	0	.00
19	.65	21	.04	.00	0	.00	.00	0	.00
20	.64	20	.03	.00	0	.00	.00	0	.00
21	35	374	35	.00	0	.00	.00	0	.00
22	6.3	115	2.0	.00	0	.00	.00	0	.00
23	2.9	68	.53	.05	25	.00	.00	0	.00
24	1.9	60	.31	.50	30	.04	.00	0	.00
25	1.3	49	.17	14	63	2.4	.00	0	.00
26	8.9	95	2.3	4.5	35	.43	.00	0	.00
27	5.4	110	1.6	1.5	20	.08	.00	0	.00
28	3.1	32	.27	.88	18	.04	.00	0	.00
29	.30	9	.00	.64	14	.02	.00	0	.00
30	.02	0	.00	.70	9	.02	.00	0	.00
31	.00	0	.00	3.0	35	.28	---	---	---
Total	119	---	46.4	25.8	---	3.31	4.19	---	0.14
Year	10,200		9,960						

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio

[ft^3/s, cubic feet per second. Dash indicates no data available.]

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
Water year 1983								
	June		July		August		September	
1	---	---	0.03	0.06	0.94	5.0	0.00	0.00
2	---	---	.03	.06	.15	3.9	.00	.00
3	---	---	.03	.06	.07	.16	.00	.00
4	---	---	.02	.04	.50	1.9	.00	.00
5	---	---	.04	.08	.12	.30	.00	.00
6	---	---	.06	.13	.04	.08	.00	.00
7	.54	2.1	.06	.13	.05	.11	.00	.00
8	.35	1.2	.08	.18	.00	.00	.00	.00
9	.25	.75	.08	.18	.00	.00	.00	.00
10	.22	.64	.08	.18	.00	.00	.00	.00
11	.20	.56	.08	.18	.00	.00	.00	.00
12	.20	.56	.08	.18	.00	.00	.00	.00
13	.19	.52	.07	.16	.00	.00	.00	.00
14	.18	.49	.07	.16	.00	.00	.00	.00
15	.18	.49	.07	.16	.00	.00	.00	.00
16	.17	.46	.06	.13	.00	.00	.06	.13
17	.19	.52	.06	.13	.00	.00	.04	.08
18	.21	.60	.23	.67	.00	.00	.02	.04
19	.40	1.4	.08	.18	.00	.00	.00	.00
20	.81	3.9	.07	.16	.00	.00	.00	.00
21	.08	.18	.07	.16	.00	.00	.00	.00
22	.07	.16	.06	.13	.00	.00	.00	.00
23	.06	.13	.06	.13	.00	.00	.00	.00
24	.06	.13	.58	2.4	.00	.00	.00	.00
25	.05	.11	.06	.13	.00	.00	.00	.00
26	.05	.11	.05	.11	.00	.00	.01	.02
27	.05	.11	.04	.08	.00	.00	.02	.04
28	.04	.08	.04	.08	.00	.00	.03	.06
29	.04	.08	.03	.06	.00	.00	.04	.08
30	.04	.08	.03	.06	.00	.00	.05	.11
31	---	.03	.06	.00	.00	---	---	---
Total	4.63	15.4	2.43	6.61	1.87	11.4	0.27	0.56
June through September	9.20	34.0						

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Mean daily streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
	Water year 1984							
	October		November		December		January	
1	0.00	0.00	0.65	2.8	7.6	100	0.71	3.2
2	.00	.00	.81	4.0	8.4	110	.65	2.8
3	.00	.00	1.4	9.5	9.6	130	.61	2.6
4	.00	.00	1.2	7.5	17	237	.56	2.3
5	.00	.00	.51	2.0	12	165	.52	2.1
6	.00	.00	.24	.70	16	220	.49	1.8
7	.00	.00	1.2	7.5	12	165	.47	1.7
8	.00	.00	1.1	6.5	12	165	.44	1.6
9	.00	.00	1.5	11	15	208	.42	1.5
10	.00	.00	16	220	16	220	.40	1.4
11	.00	.00	7.9	104	17	237	.39	1.4
12	.00	.00	4.9	58	22	300	.37	1.3
13	.00	.00	4.4	50	17	237	.36	1.2
14	.00	.00	4.2	48	11	150	.35	1.2
15	.00	.00	8.4	110	8.9	120	.34	1.2
16	.00	.00	9.4	125	7.6	98	.33	1.1
17	.00	.00	8.0	105	6.7	86	.32	1.0
18	.00	.00	7.2	94	5.9	74	.31	.98
19	.00	.00	6.6	84	5.4	66	.30	.94
20	.00	.00	7.5	97	4.8	57	.29	.90
21	.00	.00	7.4	95	15	210	.28	.88
22	.00	.00	6.5	84	22	300	.28	.88
23	.00	.00	6.3	80	8.8	118	1.5	11
24	8.4	110	6.6	84	4.5	53	7.1	92
25	1.6	12	6.5	83	2.8	28	4.8	58
26	.90	4.7	6.3	80	1.6	12	3.3	34
27	.70	3.2	7.3	95	1.3	8.5	2.7	26
28	.68	3.0	14	195	1.1	6.5	2.4	22
29	.68	3.0	9.9	135	.96	51	2.1	18
30	.68	3.0	8.0	107	.85	42	2.0	17
31	.68	3.0	---		.77	34	1.9	15
Total	14.3	142	172	2,180	292	4,010	37.0	327

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Mean daily streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
	Water year 1984--Continued							
	February		March		April		May	
1	1.8	14	2.1	18	4.2	3.7	0.90	0.22
2	2.0	17	1.0	5.3	4.1	3.6	.80	.18
3	1.6	12	1.0	5.3	4.7	4.7	3.4	2.4
4	1.3	8.6	.94	5.0	13	48	2.0	.83
5	1.1	6.5	5.3	64	11	32	1.3	.39
6	.88	4.6	2.5	23	9.0	20	1.6	.55
7	.96	5.2	1.9	16	7.9	15	1.7	.61
8	1.1	6.5	1.8	14	5.5	6.6	1.7	.61
9	.86	4.4	1.8	14	3.5	2.5	1.8	.68
10	.71	3.2	1.8	14	2.2	.97	1.3	.39
11	.91	4.8	1.7	13	1.5	.51	1.0	.26
12	1.1	6.5	1.5	11	1.0	.26	1.4	.44
13	1.3	8.7	1.3	8.5	.78	.18	1.1	.30
14	9.9	132	1.1	6.6	.72	.16	.89	.22
15	8.6	114	.84	4.1	.67	.14	.71	.15
16	5.0	59	1.0	5.5	.64	.13	.58	.11
17	1.4	9.6	.91	4.8	.72	.16	.47	.08
18	1.2	7.5	.75	3.5	.91	.22	.38	.06
19	1.4	9.6	1.6	12	.82	.19	.31	.05
20	1.2	7.5	2.3	20	.75	.17	.24	.03
21	1.2	7.5	8.6	1,530	.70	.15	.22	.03
22	1.1	6.5	1.2	7.5	5.2	5.9	.40	.07
23	1.0	5.6	.92	4.9	4.9	5.2	.59	.12
24	.95	5.0	.70	3.2	4.7	4.7	.39	.07
25	.92	4.8	.68	3.0	3.0	1.8	.26	.04
26	.92	4.8	.68	3.0	1.8	.68	.20	.03
27	1.0	5.6	.68	3.0	1.5	.50	.29	.04
28	4.1	47	7.6	4,280	1.4	.44	5.3	6.1
29	3.2	31	6.1	8.3	1.2	.34	5.8	7.4
30	---		4.5	4.3	1.0	.26	1.8	.68
31	---		4.3	3.9	---		1.3	.39
Total	58.7	559	69.1	6,120	99.0	159	40.1	23.5

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Mean daily streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
	Water year 1984--Continued							
	June		July		August		September	
1	0.90	0.22	0.25	0.37	0.00	0.00	0.00	0.00
2	.66	.14	.09	.01	.00	.00	.00	.00
3	.48	.09	.07	.01	.00	.00	.00	.00
4	.34	.05	1.0	.26	.01	.00	.00	.00
5	.25	.04	6.2	8.6	.02	.00	.00	.00
6	.10	.01	.32	.02	.02	.00	.00	.00
7	.04	.01	.12	.00	.01	.00	.00	.00
8	.00	.00	.03	.00	.01	.00	.00	.00
9	.00	.00	.02	.00	.01	.00	.00	.00
10	.00	.00	.01	.00	.01	.00	.00	.00
11	.00	.00	.02	.58	.03	.00	.00	.00
12	.00	.00	.04	.00	.00	.00	.00	.00
13	.00	.00	.01	.00	.00	.00	.00	.00
14	.00	.00	.01	.00	.00	.00	.00	.00
15	.00	.00	.02	3.5	.00	.00	.00	.00
16	.00	.00	.05	.00	.00	.00	.00	.00
17	.00	.00	.01	.00	.00	.00	.00	.00
18	.65	.14	.01	.00	.00	.00	.00	.00
19	.04	.01	.00	.00	.00	.00	.00	.00
20	.01	.00	.00	.00	.00	.00	.00	.00
21	.01	.00	.00	.00	.00	.00	.00	.00
22	.00	.00	.00	.00	.00	.00	.00	.00
23	.01	.00	.00	.00	.00	.00	.00	.00
24	.10	16	.00	.00	.01	.00	.00	.00
25	.02	.00	.02	6.7	.00	.00	.00	.00
26	.02	.00	.02	33	.00	.00	.00	.00
27	.08	.01	.06	.00	.00	.00	.00	.00
28	.10	.01	.01	.00	.00	.00	.00	.00
29	.14	.02	.01	.00	.00	.00	.00	.00
30	.96	.24	.00	.00	.00	.00	.00	.00
31	---	.00	.00	.00	.00	---		
Total	4.91	17.0	8.40	53.0	0.13	0.00	0.00	0.00
Year	796	13,600						

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Mean daily streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
	Water year 1985							
	October		November		December		January	
1	0.00	0.00	0.21	0.01	0.95	0.07	1.3	0.13
2	.00	.00	.21	.01	.52	.03	.98	.08
3	.00	.00	.16	.01	.44	.02	.82	.06
4	.00	.00	.58	.04	.43	.02	.71	.05
5	.00	.00	.61	.04	.31	.01	.62	.04
6	.00	.00	.19	.01	.54	.03	.55	.03
7	.00	.00	.12	.00	.28	.01	.50	.03
8	.00	.00	.12	.00	.38	.02	.45	.02
9	.00	.00	.13	.00	.62	.04	.41	.02
10	.00	.00	3.6	.60	5.8	1.4	.38	.02
11	.00	.00	1.9	.22	1.7	.16	.35	.02
12	.00	.00	1.0	.08	.75	.05	.33	.02
13	.00	.00	.59	.04	.61	.04	.31	.01
14	.00	.00	.35	.02	.61	.04	.29	.01
15	.00	.00	.35	.02	.61	.04	.28	.01
16	.00	.00	.35	.02	.61	.04	.27	.01
17	.00	.00	.25	.01	.61	.04	.25	.01
18	.00	.00	1.3	.12	.60	.04	.24	.01
19	.00	.00	3.7	.64	.55	.03	.24	.01
20	.00	.00	1.5	.10	.60	.04	.23	.01
21	.00	.00	.92	.07	11	5.0	.23	.01
22	.26	.01	.72	.05	2.8	.40	.22	.01
23	.13	.00	.58	.04	.37	.02	.21	.01
24	.07	.00	.48	.03	.17	.01	.21	.01
25	.05	.00	.38	.02	2.8	.40	.20	.01
26	.03	.00	.30	.01	2.0	.23	.20	.01
27	.02	.00	.30	.01	1.4	.13	.19	.00
28	.17	.01	1.7	.18	.92	.07	.19	.00
29	1.1	.09	.60	.04	.66	.04	.19	.00
30	.35	.02	1.1	.09	2.4	.32	.18	.00
31	.26	.01	---		1.6	.16	.18	.00
Total	2.44	0.14	24.3	2.53	43.6	8.95	11.7	0.66

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Mean daily streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
	Water year 1985--Continued							
	February		March		April		May	
1	0.18	0.00	1.5	0.15	2.4	0.03	0.32	0.00
2	.18	.00	1.5	.15	2.2	.03	11	1.4
3	.17	.00	1.5	.01	2.0	.02	9.0	.76
4	.17	.00	1.4	.01	1.9	.02	8.5	.64
5	.17	.00	1.4	.01	1.7	.02	8.3	.59
6	.17	.00	1.4	.01	1.7	.01	5.6	.21
7	.17	.00	1.4	.01	1.5	.01	1.1	.00
8	.17	.00	1.4	.01	1.4	.01	1.1	.00
9	.16	.00	1.4	.01	1.3	.00	1.0	.00
10	.16	.00	2.7	.04	1.2	.00	.94	.00
11	.16	.00	6.9	.36	1.1	.00	.87	.00
12	.16	.00	14	3.0	1.1	.00	.93	.00
13	.16	.00	5.5	.20	.97	.00	1.1	.00
14	.16	.00	4.6	.13	.91	.00	.98	.00
15	.16	.00	3.7	.08	.85	.00	3.6	.07
16	.16	.00	2.9	.05	.79	.00	4.2	.11
17	.16	.00	2.3	.03	.72	.00	4.4	.12
18	.16	.00	1.8	.02	.78	.00	1.9	.02
19	.23	.01	1.4	.01	.87	.00	.92	.00
20	2.2	.27	1.1	.00	.80	.00	.71	.00
21	7.0	2.0	1.5	.01	.73	.00	.62	.00
22	18	68	2.5	.03	.66	.00	.51	.00
23	15	10	4.8	.14	.60	.00	.17	.00
24	5.1	1.1	2.3	.03	.54	.00	.08	.00
25	2.5	.34	1.9	.02	.48	.00	.07	.00
26	1.8	.20	1.7	.02	.44	.00	.07	.00
27	1.6	.16	1.5	.01	.39	.00	.18	.00
28	1.7	.18	1.3	.01	.34	.00	.19	.00
29	---		4.5	.12	.61	.00	.12	.00
30	---		17	5.6	.73	.00	.11	.00
31	---		6.8	.34	---		.11	.00
Total	58.1	82.3	106	10.6	31.7	0.15	68.7	3.92

Table 7.--Daily mean streamflow and daily suspended-sediment discharge for West Branch Shade River near Harrisonville, Ohio--Continued

Day	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended-sediment discharge (tons/d)	Daily mean streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)	Mean daily streamflow (ft^3/s)	Daily suspended sediment discharge (tons/d)
Water year 1985--Continued								
	June		July		August		September	
1	0.11	0.00	0.11	0.00	0.00	0.00	0.06	0.00
2	.12	.00	.16	.00	.00	.00	.04	.00
3	.14	.00	.24	.00	.00	.00	.03	.00
4	.20	.00	.15	.00	.00	.00	.02	.00
5	.20	.00	.14	.00	.00	.00	.00	.00
6	.19	.00	.14	.00	.00	.00	.00	.00
7	.35	.00	.13	.00	.00	.00	.00	.00
8	.25	.00	.06	.00	.00	.00	.00	.00
9	.20	.00	.05	.00	.00	.00	.00	.00
10	.18	.00	.06	.00	.00	.00	.00	.00
11	.31	.00	.08	.00	.00	.00	.00	.00
12	.49	.00	.06	.00	.00	.00	.00	.00
13	.23	.00	.05	.00	.00	.00	.00	.00
14	.20	.00	.05	.00	.00	.00	.00	.00
15	.18	.00	.58	.00	.00	.00	.00	.00
16	.17	.00	.33	.00	.00	.00	.00	.00
17	.16	.00	.30	.00	.00	.00	.00	.00
18	.14	.00	.28	.00	.00	.00	.00	.00
19	.21	.00	.28	.00	.00	.00	.00	.00
20	.18	.00	.27	.00	.00	.00	.00	.00
21	.13	.00	3.6	.07	.00	.00	.00	.00
22	.30	.00	1.9	.02	.00	.00	.00	.00
23	.22	.00	.00	.00	.00	.00	.00	.00
24	.09	.00	.00	.00	1.1	.00	.00	.00
25	.08	.00	.00	.00	11	1.4	.00	.00
26	.08	.00	.00	.00	6.6	.32	.00	.00
27	.07	.00	.00	.00	.41	.00	.00	.00
28	.06	.00	.00	.00	.04	.00	.00	.00
29	.06	.00	.00	.00	.02	.00	.00	.00
30	.06	.00	.00	.00	.05	.00	.00	.00
31	---		.00	.00	.11	.00	---	
Total	5.36	0.00	9.02	0.09	19.3	1.72	0.15	0.00
Year	380	111						

* GOVERNMENT PRINTING OFFICE: 1988 - 550302 / 62073