WATER QUALITY OF LAKE TUSCALOOSA AND STREAMFLOW AND WATER QUALITY OF SELECTED TRIBUTARIES TO LAKE TUSCALOOSA, ALABAMA, 1982-86

By Larry J. Slack

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 87-4002

Prepared in cooperation with the

CITY OF TUSCALOOSA

Tuscaloosa, Alabama

1987

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
520 19th Avenue
Tuscaloosa, Alabama 35401

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports
Box 25425, Federal Center
Building 41
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

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 units	By	To obtain SI units
inches (in.)	25.4	millimeters
feet (ft)	0.3048	meters
miles (mi)	1.609	kilometers
feet per mile (ft/mi)	0.1894	meter per kilometers
square miles (mi^2)	2.590	square kilometers
acres	4,047	square meters
acre-feet (acre-ft)	1,233	cubic meters
million gallons per day (Mgal/d)	0.04381	cubic meters per second
cubic feet per second (ft^3/s)	0.02832	cubic meters per second
tons per square mile per year ($(tons/mi^2)/yr$)	0.3503	metric tons per square kilometer per year
feet per year (ft/yr)	0.3048	meters per year

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: $°F = (1.8)°C + 32$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly referred to as "Mean Sea Level."

WATER QUALITY OF LAKE TUSCALOOSA AND STREAMFLOW AND WATER QUALITY OF SELECTED TRIBUTARIES TO LAKE TUSCALOOSA, ALABAMA, 1982-86

by Larry J. Slack

ABSTRACT

Lake Tuscaloosa, created in 1969 by the impoundment of North River, provides the primary water supply for Tuscaloosa, Alabama, and surrounding areas. This report describes the percent contribution of major tributaries to the mean inflow to the lake; water quality; and changes in water quality in the lake and selected tributaries.

During base flow, about 60 percent of the total flow into Lake Tuscaloosa is contributed by Binion and Carroll Creeks, which drain only 22 percent of the Lake Tuscaloosa basin. Binion and Carroll Creek basins are underlain primarily by sand and gravel deposits of the Coker Formation.

Mean inflow to the lake was 1,150 cubic feet per second during 1983, a wet year, and 450 cubic feet per second during 1985, a relatively dry year. More than 80 percent of the total inflow during both years was contributed by North River and Binion, Cripple, and Carroll Creeks. About 59 percent was contributed by North River during those years.

Except for pH, sulfate, and dissolved and total recoverable iron and manganese, the water quality of the tributaries is generally within drinking water limits and acceptable for most uses. The minimum pH of 4.4 occurred in Brush Creek, an unmined basin, and is nearly the same as the minimum reported for other streams that drain undisturbed basins in the area.

During both low and high flow, sulfate was the primary anion for streams that drain areas with significant surface mining--North River and Little, Cripple, and Turkey Creeks. Increases in specific conductance values, sulfate, and dissolved and total recoverable iron and manganese concentrations occurred during mining (1977-86) at each of these sites but were greatest for the Cripple Creek basin because a larger percentage of its drainage area has been disturbed by mining.

The water quality of Lake Tuscaloosa is generally within drinking water limits and acceptable for most uses. The trend of increasing mineralization of Lake Tuscaloosa was similar to, and largely caused by, the trend of increasing mineralization of the water at North River. The maximum and median concentrations of sulfate increased every year at the dam from 1979 to 1985 (7.2 to 18 mg/L [milligrams per liter] and 6.2 to 14 mg/L, respectively).

The dissolved-solids concentrations for water at the dam have varied (1979-86) from 27 to 43 mg/L; the sulfate, 5.2 to 18 mg/L; and the dissolved iron, 10 to 250 micrograms per liter--all within the recommended drinking-water limits. However, concentrations of dissolved manganese and total recoverable iron and manganese at the dam commonly exceeded the recommended drinking-water limits.

In November 1985, after the summer warmup and increase in biological activity, the water quality at five depth profile sites on Lake Tuscaloosa was acceptable for most uses, generally. However, a dissolved oxygen concentration of 1 mg/L or less was observed within 5 to 10 feet of the bottom for several depth profiles. At depths greater than about 35 to 40 feet (out of a total depth of about 50 to 100 feet) the dissolved oxygen concentration was less than 5 mg/L at several sites.

By mid-January 1986, the temperature and dissolved oxygen depth profiles were virtually constant from top to bottom of the lake at all five sites; this indicated that lake turnover was complete. However, significant variation existed in pH depth profiles.

INTRODUCTION

Lake Tuscaloosa (fig. 1), created in 1969 by the impoundment of North River, provides the primary water supply for Tuscaloosa, Alabama, and surrounding areas. The lake also is used for recreation and shoreline residential development. Changes in land use, such as coal mining, agriculture, timber clear-cutting, and residential development in basins that drain into the lake have caused concern about possible changes in the water quality of the reservoir. The lack of data for streamflow to the lake from its tributaries also is of concern.

Purpose and Scope

The purpose of this report is to describe as of September 1986 the flow, water quality, and changes in the water quality in Lake Tuscaloosa and selected tributaries in the North River basin. The study began in October 1982 with the collection of streamflow and water-quality data at 12 sites on streams that drain to Lake Tuscaloosa and at 2 sites on the lake. Data collected previously for other studies also were compiled. In the continuing study, some of the sites have been changed and new sites added. Currently (September 1986) water-quality and (or) streamflow data are collected at 10 of the original 14 sites plus 7 new sites.

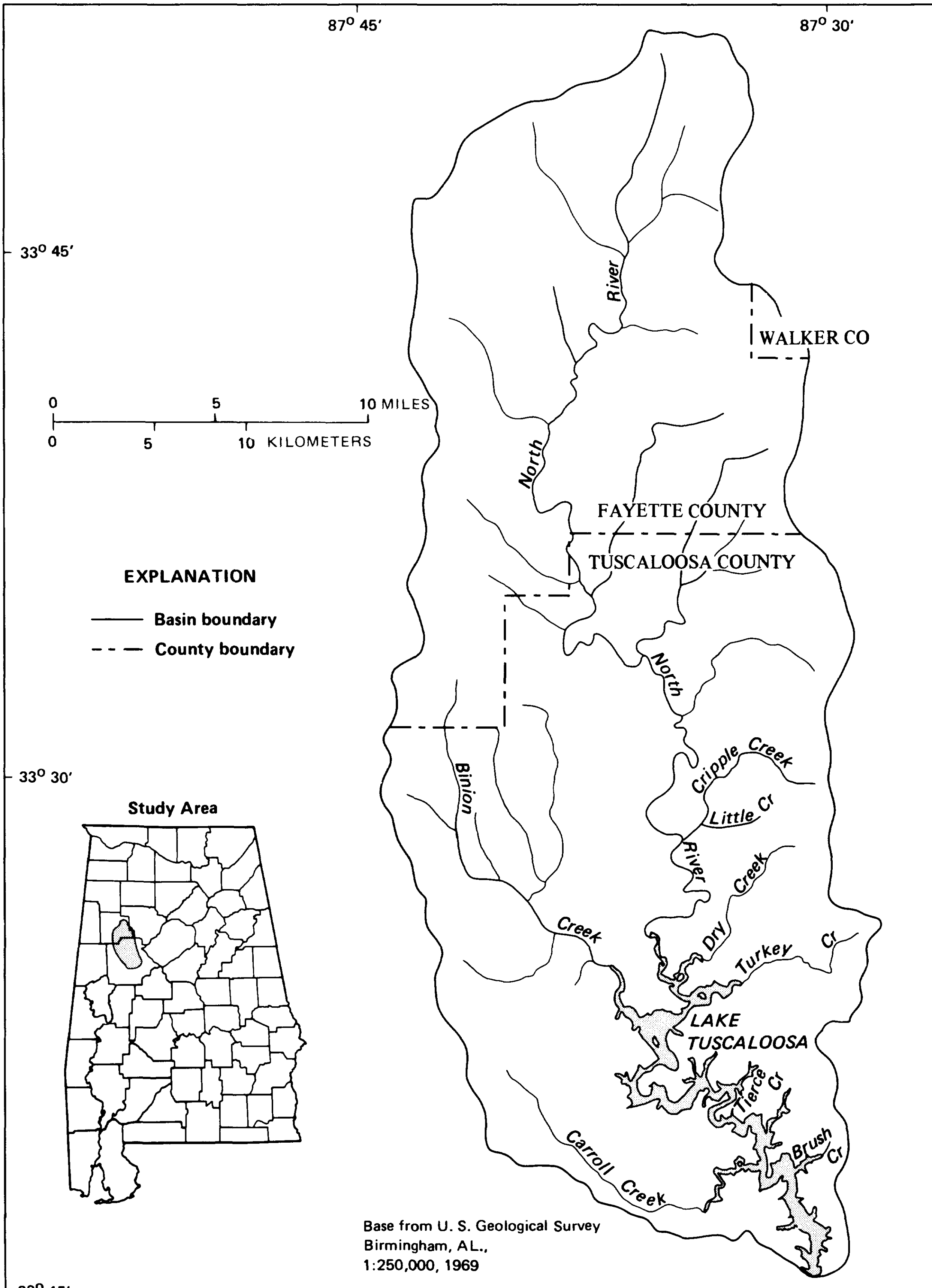

Figure 1.--Study area.

Previous Investigations

Previous investigations generally have been reconnaissance in nature. The most important ones are the following: Keener and others (1975), Almon and Associates (1976), Hubbard (1976a and 1976b), West Alabama Planning and Development Council (1979), Harkins and others (1980), Puente and Newton (1979 and 1982), Puente and others (1980 and 1982), and Cole (1985). The report by Cole (1985) discusses several of these reports and gives the results of the first year of this study.

Data-Collection Methods

From October 1982 to September 1986, streamflow and water-quality data were collected at 21 sites in the North River basin (fig. 2) to determine the changes in surface-water quality in the study area. Streamflow, specific conductance, pH, water temperature, and dissolved oxygen were measured at the time of sampling. Major chemical constituents, selected nutrients, and trace constituents were analyzed by U.S. Geological Survey laboratories. Because they are published in annual data reports, not all the data are presented in this report. As indicated in table 1, water-quality data from as early as 1966 are available for North River near Samantha and from the 1970's for a few of the sites.

Specific conductance, pH, temperature, and dissolved oxygen profile data were collected at five sites on the lake beginning in March 1985. These are sites A to E in figure 2 and table 1. Measurements were made at three to five verticals (left quarter, center, and right quarter; or left eighth, left quarter, center, right quarter, and right eighth) from surface to bottom in 5-ft intervals.

Acknowledgments

Much of the field work and sample collection was performed by William A. Hard. Appreciation is also extended to Ira A. Giles, Brian L. Moore, Will S. Mooty, and others who have performed fieldwork or otherwise assisted this project.

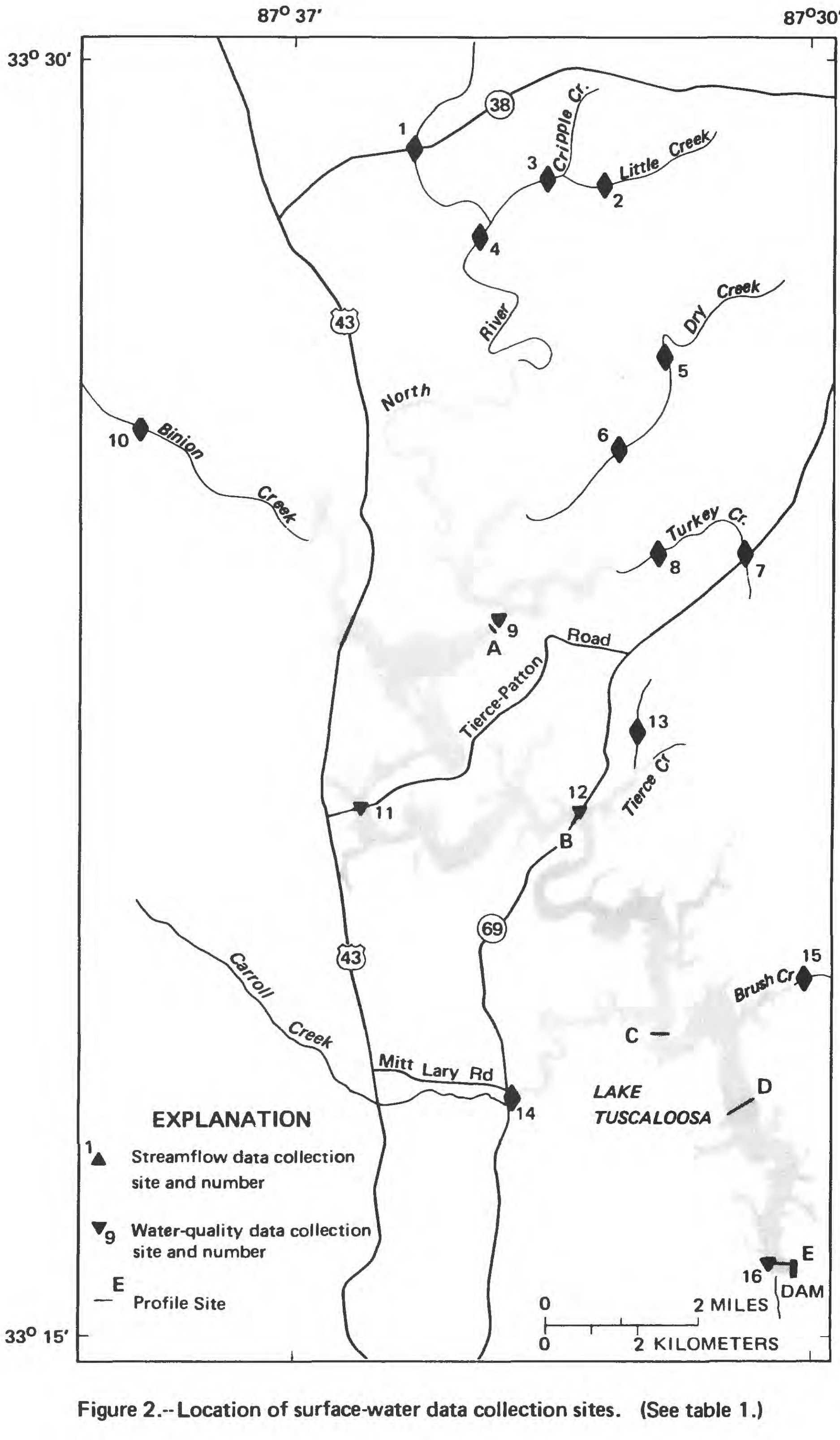

Figure 2.--Location of surface-water data collection sites. (See table 1.)

Table 1. Summary of surface-water data-collection network
[Site numbers correspond to those in figure 2]

Site number	USGS station number	Name	Drainage area (mi^2)	Period and type of record: Streamflow	Water quality	Suspended sediment
1	02464000	North River near Samantha	223[R]	1938-54, 1968-86	1966-68, 1971-86	1979-83
2	02464032	Little Creek east of Samantha	2.47	1980, 1982-83	1980, 1982-83	--
3	02464035	Cripple Creek east of Samantha	16.4	1977-86	1977-86	1979-83
4	02464040	North River, 1,500 feet below Cripple Creek	241	1982-83	1982-83	--
5	02464100	Dry Creek near Samantha	7.56	1981-86	1981-86	1982
6	02464110	Dry Creek near Northport	9.45	1982-83	1982-83	1982
7	02464146	Turkey Creek near Tuscaloosa	6.16	1977-83	1977-83	1981-83
8	02464149	Turkey Creek near Patterson Chapel	10.6	1982-85	1982-86	1982-83
9	02464155	Lake Tuscaloosa at Hilltop Estates Landing	282	--	1975,1983	1975
10	02464360	Binion Creek below Gin Creek near Samantha	57.0	1982-86	1982-86	1982-83
11	02464400	Lake Tuscaloosa at Tierce Patton Road	--	--	1984-86	--
12	02464500	Lake Tuscaloosa at State Highway 69	372	--	1984-86	--
13	02464505	Tierce Creek near Northport	2.17	1983-86	1983-86	1983
14	02464660	Carroll Creek at State Highway 69 near Northport	20.9	1983-86	1983-86	1983
15	02464680	Brush Creek near Northport	0.92	1983-86	1983-86	1983
16	02464800	Lake Tuscaloosa Reservoir near Tuscaloosa	423[R]	1983-86	1975, 1983-86	1975
A		Lake Tuscaloosa site A	--	--	1986	--
B		Lake Tuscaloosa site B	--	--	1986	--
C		Lake Tuscaloosa site C	--	--	1986	--
D		Lake Tuscaloosa site D	--	--	1986	--
E		Lake Tuscaloosa site E	--	--	1986	--

[R] Revised 1985.

DESCRIPTION OF THE STUDY AREA

Lake Tuscaloosa, in north-central Tuscaloosa County, Alabama, receives surface runoff from a drainage area of 423 mi^2 (fig. 1). The eight largest streams discharging to Lake Tuscaloosa (North River basin) are: North River and Binion, Carroll, Cripple, Turkey, Dry, Tierce, and Brush Creeks. However, Cripple Creek actually discharges to North River about 5 river miles before North River discharges to Lake Tuscaloosa. The lake is about 25 tortuous miles long and has a surface area at normal pool of 5,885 acres. In 1975, Keener and others estimated the reservoir capacity to be about 123,000 acre-ft and the safe yield about 200 Mgal/d.

The Lake Tuscaloosa (North River) basin has a subtropical climate characterized by warm, humid weather. The mean annual temperature is about 62 °F (Frentz and Lynott, 1978). Precipitation is usually rain, with little or no snowfall.

Generally, March is the wettest month; October, the driest. Annual precipitation data for October 1981-September 1985 at Winfield 2 SW, Bankhead Lock and Dam, and Tuscaloosa Oliver Dam are shown in figure 3. Annual precipitation for the three stations ranged from a low of 50.70 in. at Oliver Dam (1985) to a high of 81.42 in. at Bankhead Lock and Dam (1984) during this period (U.S. Department of Commerce, 1981-85). The annual discharge of North River near Samantha most nearly paralleled the annual precipitation at Oliver Dam. The mean annual precipitation at Oliver Dam (October 1981-September 1985) was 58.59 in. or 3.19 in. above the long-term average, based on 1951-80 U.S. Department of Commerce Data.

Water year 1983 was a wet year; precipitation at Oliver Dam exceeded the long-term average by 18.83 in., or 35 percent. In contrast, water year 1985 was a relatively dry year; precipitation at Oliver Dam was 3.19 in., or 6 percent, below the long-term average.

The free water surface evaporation for the study area is about 30 in. per year based on data from Farnsworth and others (1982) and Cole (1985). Due to changes in heat storage in reservoir water, however, actual evaporation from the lake may differ significantly from estimates.

About 75 percent of the land in the Lake Tuscaloosa basin is forested (fig. 4). Some of the cleared areas are used to produce crops. Several small areas in the basin have been disturbed by surface coal mining. However, they are estimated to be less than 5 percent of the total drainage area of the basin. The locations of surface mines shown in figure 4 were taken by Cole (1985) from aerial photographs and unpublished information from previous investigations in the North River basin. Although the study area is sparsely populated, residential development near the lake has been practically continuous since the lake was formed.

Although the relatively impermeable Pottsville Formation of Pennsylvanian age underlies all of the Lake Tuscaloosa basin, it is exposed mainly in the northeastern part. The more permeable Coker Formation of Cretaceous age crops out in the southern and western parts of the basin. Strata in the Pottsville

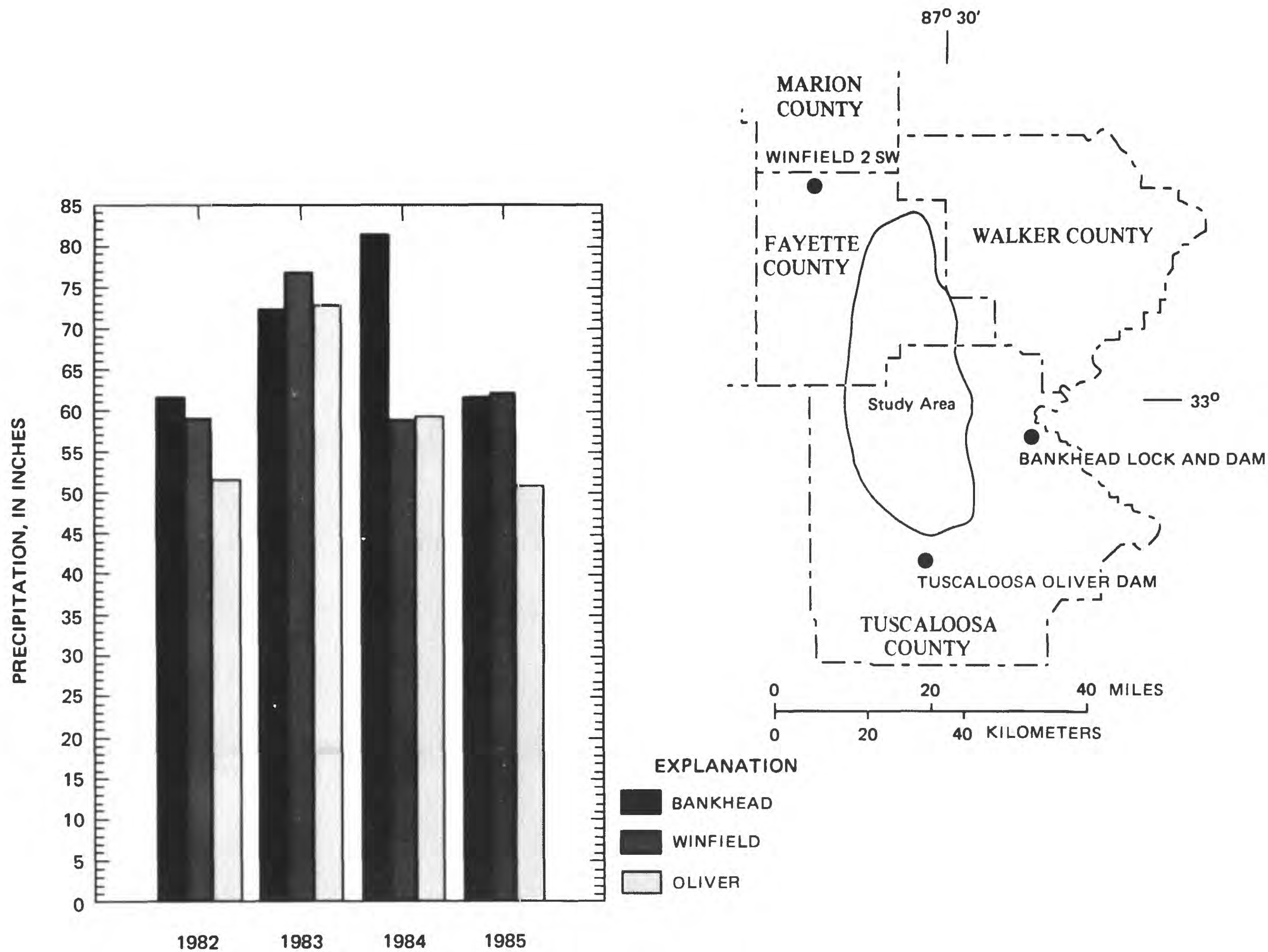

Figure 3. - - Annual precipitation at Winfield 2 SW, Bankhead Lock and Dam, and Tuscaloosa Oliver Dam.

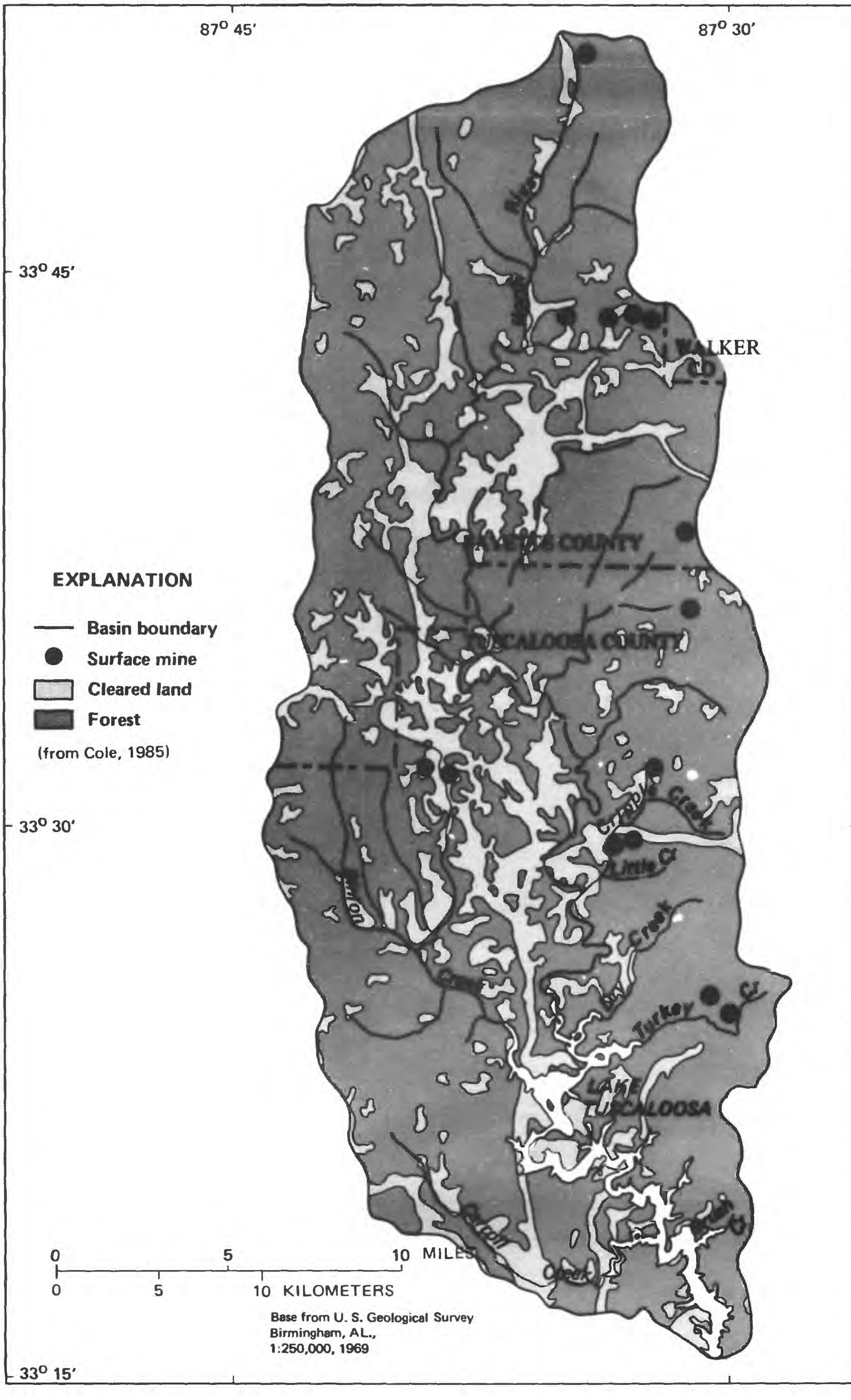

Figure 4.--Land use in study area.

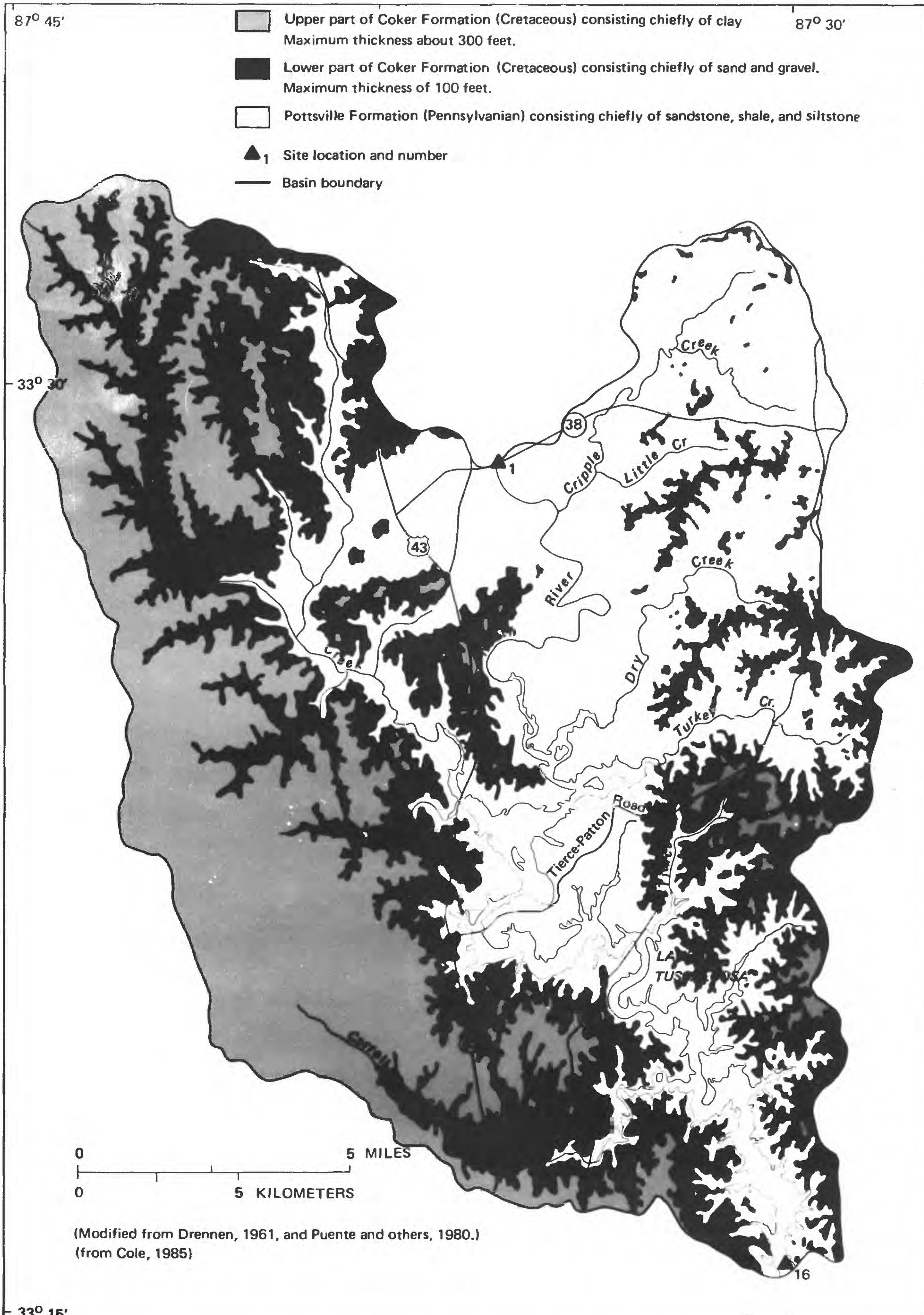

Figure 5.--Geohydrologic units in North River basin between North River (site 1) and Lake Tuscaloosa (site 16). (Site numbers correspond to those in figure 2 and table 1.)

and Coker strike northwestward and dip southwestward, 30 to 200 ft/mi and 30 to 50 ft/mi, respectively (Culbertson, 1964, Puente and others, 1982). The geohydrologic units in the southern part of the Lake Tuscaloosa basin (fig. 5) were mapped by Cole (1985).

The Pottsville Formation consists mainly of sandstone, shale, and siltstone with shale being dominant (Metzger, 1965). Beds of coal and underclay are present in some parts of the formation. Ground water usually occurs in openings along joints, fractures, and bedding planes (Culbertson, 1964).

Although the upper 300 ft of the Coker Formation consists chiefly of clay (Metzger, 1965), the permeable sand and gravel beds in the lower 100 ft provide significant quantities of base flow to streams and are the principal source of water obtained by wells in much of the Lake Tuscaloosa area (Cole, 1985).

STREAMFLOW

Streams in areas having similar climate, topography, geology, and land use generally have similar flow (discharge) characteristics. Streamflow in the North River basin usually is highest during December through April when precipitation is greatest and transpiration from vegetation is lowest. In contrast, streamflow usually is lowest during June through November when precipitation is least and evapotranspiration is greatest.

Poorly sustained base flows during June through November are characteristic of North River and Little, Cripple, Dry, Tierce, and Brush Creeks. All these streams drain basins that are underlain primarily by the relatively impermeable Pottsville Formation, which contributes little base flow.

Binion and Carroll Creek basins are underlain primarily by the sand and gravel deposits in the Coker Formation. Well-sustained base flows of Binion and Carroll Creeks during dry periods contrast with poorly sustained base flow at site 1 on North River during the same periods. During base-flow conditions, based on 1982-86 data, about 45 percent of the total flow into Lake Tuscaloosa is contributed by Binion Creek and about 60 percent is contributed by Binion and Carroll Creeks. Together, Binion and Carroll Creeks (at their mouths) drain less than 22 percent of the Lake Tuscaloosa basin.

The discharges (inflows) for the streams between North River near Samantha and Lake Tuscaloosa at the dam were calculated by substituting the mean annual discharge at a gaged site into a general linear model regression equation that relates monthly measurements at the ungaged site and daily mean discharge for the same day at the gaged site. Riggs (1969) has shown that discharge at a gaged site may be related to discharge at an ungaged site to provide accurate estimates of mean annual flow from the ungaged site. Individual general linear model equations were developed for each year. Discharge for areas below measured sites were then calculated on the basis of prorated drainage areas.

Outflow from the lake (table 2) was calculated by adding (1) discharge over the spillway calculated from a theoretical weir-rating, (2) pumpage from the lake (figures supplied by the city of Tuscaloosa), (3) aerated unregulated discharge from the lake (through pipes near the bottom of the lake) to North River below the dam, and (4) estimates of mean annual evaporation (30 inches per year). Plots of daily mean water-surface elevations and discharge for Lake Tuscaloosa at the dam (site 16), for November 1982 to September 1986, are shown in figure 6. The flat portion of the discharge hydrograph shown in figure 6 occurs when the lake surface is below the bottom of the spillway and the only "discharge" is from a pipe at the lake bottom.

Discharge of North River near Samantha during water year 1983, a wet year, was 684 ft^3/s and exceeded the average annual discharge (401 ft^3/s, 31 years) by 283 ft^3/s or 71 percent. Total mean inflow to the lake in water year 1983 was 1,150 ft^3/s. About 59 percent of the total inflow to Lake Tuscaloosa was from North River; about 13 percent was from Binion Creek; Cripple Creek contributed about 6 percent and Carroll Creek 4 percent (table 3). Drainage from North River and Binion Creek basins contributed almost three-fourths of the total inflow to the reservoir; North River and Binion, Cripple, and Carroll Creeks together contributed over 82 percent.

Discharge of North River near Samantha during water year 1985, a relatively dry year, was 265 ft^3/s or 34 percent below the average annual discharge (table 2). Mean inflow to Lake Tuscaloosa in water year 1985 was about 450 ft^3/s (table 2). About 59 percent of the total flow was from North River at Samantha; about 20 percent was from Binion Creek; Cripple and Carroll Creeks contributed about 3 percent each (table 3). During a relatively dry year, North River and Binion, Cripple, and Carroll Creeks together contributed about 85 percent of the total inflow to the lake or roughly the same as during a wet year.

Table 2.--Annual mean flow of North River near Samantha (site 1) and Lake Tuscaloosa, water years 1983-86

	Mean flow in cubic feet per second	
Water year	North River near Samantha	Lake Tuscaloosa[1/] (Total outflow)
1983	684	1,150
1984	559	960
1985	265	450
1986	133	247

1/ Discharge at spillway plus pumpage plus unregulated discharge plus evaporation.

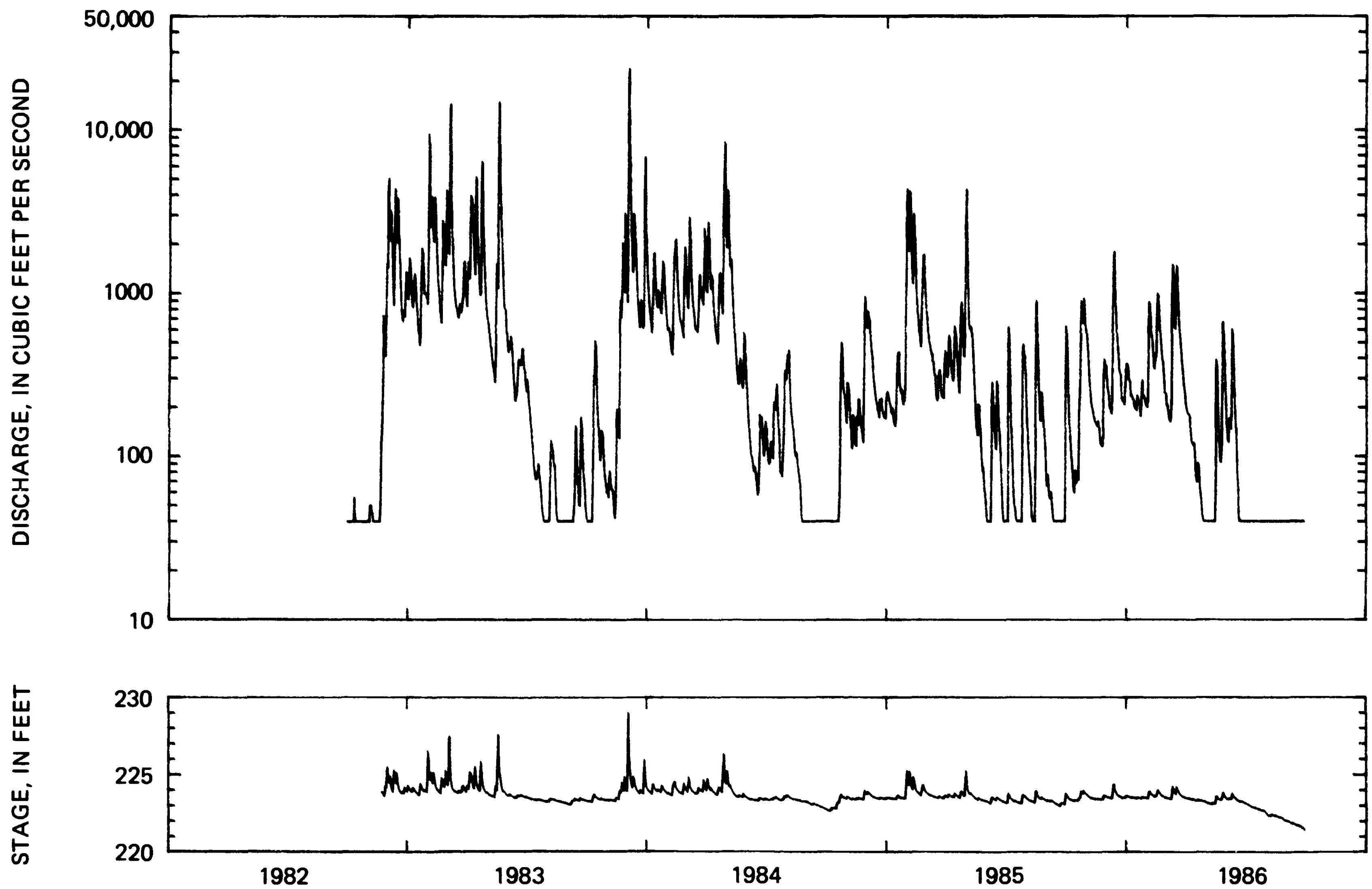

Figure 6.-- Daily mean water-surface elevation and discharge at Lake Tuscaloosa (site 16), November 1982-September 1986.

Table 3.--Percent contribution of major tributaries to mean inflow to Lake Tuscaloosa, water years 1983 and 1985

Tributary	Percent contribution to mean inflow to Lake Tuscaloosa	
	Water year 1983 (wet year)	Water year 1985 (dry year)
North River	59	59
Cripple Creek	6	3
Dry Creek	2	2
Turkey Creek	3	2
Binion Creek	13	20
Tierce Creek	<1	1
Carroll Creek	4	3
Brush Creek	<1	<1
Ungaged tributaries	approximately 13	approximately 10

WATER QUALITY OF SELECTED TRIBUTARIES

All natural waters contain mineral constituents dissolved from the rock and soil with which the water has been in contact. The concentration of dissolved constituents primarily depends on the type of rock or soil, the length of contact time, atmospheric pressure, water temperature, and mixing conditions. Daily, weekly, monthly, or seasonal variations in temperature, precipitation and, subsequently, streamflow can result in major changes in water quality.

In addition to natural conditions, man's activities, such as those associated with coal mining, timber clear-cutting, residential development, disposal of wastes, and agricultural practices can have a significant effect on the chemical quality of water. However, coal mining in the Lake Tuscaloosa basin is the only land use change that has significantly affected the water quality of the lake at the present time.

Minerals in the overburden and coal are in equilibrium with the environment as long as that environment is not changed. Mining and subsequent reclamation disturb that equilibrium and the minerals react with various chemical components of their new environment such as water, oxygen, and plant acids.

Sulfate commonly is the best indicator of coal-mine drainage. Once exposed to oxygen (O_2) and water (H_2O), iron sulfides (FeS_2) can be oxidized to release sulfuric acid (H_2SO_4) and ferrous sulfate ($FeSO_4$), with a corresponding decrease in pH of the solution (or increase in H+ ions):

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{+2} + 2\ H^+ + 2\ SO_4^{-2}.$$

The variability of sulfate concentrations in streams that drain mining areas primarily is due to the quantities of iron sulfide and calcium sulfate minerals in the spoil material, the length of time of exposure of these materials to weathering, the length of time water is in contact with the spoils, and the quantity of water leaving the mined areas.

In natural waters, the major cations--calcium, magnesium, sodium, and potassium--and the major anions--carbonate/bicarbonate (alkalinity), chloride, and sulfate--generally constitute more than 95 percent of the total ions in solution. Water can be categorized, or typed, according to the milliequivalents per liter (meq/L) of each of the major ions. The primary water type is the largest cation and the largest anion (in milliequivalents per liter) in solution. The secondary water type is the next largest cation and anion. If none of the cations or anions is predominant, the water is described as a mixed type.

Commonly, as in this report, concentrations of dissolved and total recoverable metals are compared to U.S. Environmental Protection Agency (1986a and 1986b) drinking-water standards. These comparisons are made for illustrative purposes only. The analytical techniques associated with the drinking-water standards for these constituents generally are for dissolved rather than total recoverable metals.

Concentrations for most chemical constituents in this report are given in milligrams per liter (mg/L) and micrograms per liter (ug/L). Specific conductance is given in microsiemens per centimeter at 25 °C (uS/cm); pH is given in standard pH units.

Minimum values for many water-quality constituents represent natural or background conditions. Dissolved oxygen and pH values are exceptions in which minimum values generally represent degraded water-quality conditions. Maximum values for most water-quality constituents generally represent periods in which the water quality in a stream is most adversely affected by man's activities--usually during low-flow conditions. Mean values are arithmetic averages of all the data. Annual streamflow data generally are reported as means. Because mean values are easily understood and historically have been used in water-quality data interpretation, they are reported in table 4.

The median value is the middle observation when all the observations are ordered (ranked) from smallest to largest. The median is the central value of the distribution. If there are an even number of observations, the median is the average of the two middle observations. The median is preferred by many hydrologists and statisticians because it is "robust"--that is, it is insensitive to outliers (extreme values)--and it represents a typical value--one that actually occurs.

Water-quality analyses for 12 stream and 4 lake sites are summarized in table 4. Except for pH, sulfate, and dissolved and total recoverable iron and manganese, the water quality of the tributaries is generally within drinking water limits and acceptable for most uses. However, the water quality of some streams that receive drainage from mined areas--North River, Little, Cripple, and Turkey Creeks--is deteriorating. Although its basin has also been disturbed by mining, Binion Creek's water quality has not been affected significantly.

Table 4.--Summary of water-quality analyses at 16 sites in North River basin

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464000 North River near Samantha (site 1)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	2	19	10
Calcium, dissolved (mg/L as Ca)	1.2	8.9	3.6
Chloride, dissolved (mg/L as Cl)	.0	66	4.9
Fluoride, dissolved (mg/L as F)	.0	1.0	.1
Hardness (mg/L as CaCO3)	9	45	19
Magnesium, dissolved (mg/L as Mg)	.9	6.0	2.6
Potassium, dissolved (mg/L as K)	.6	3.0	1.3
Silica, dissolved (mg/L as SiO2)	2.0	9.3	6.8
Sodium, dissolved (mg/L as Na)	.8	39	6.0
Solids, residue at 180 °C, dissolved (mg/L)	24	559	61
Solids, sum of constituents, dissolved (mg/L)	18	150	48
Sulfate, dissolved (mg/L as SO4)	3.0	180	16
pH (standard units)	4.8	7.4	--
Specific conductance (uS/cm)	24	725	73
Arsenic, dissolved (ug/L as As)	<1	3	1
Cadmium, dissolved (ug/L as Cd)	<1	4	2
Chromium, dissolved (ug/L as Cr)	<1	7	1
Iron, dissolved (ug/L as Fe)	<10	710	240
Lead, dissolved (ug/L as Pb)	<1	17	2
Manganese, dissolved (ug/L as Mn)	9	820	108
Mercury, dissolved (ug/L as Hg)	<.1	1.4	.3
Selenium, dissolved (ug/L as Se)	<1	1	1
Silver, dissolved (ug/L as Ag)	<1	2	2
Arsenic, total recoverable (ug/L as As)	1	2	1
Cadmium, total recoverable (ug/L as Cd)	<1	1	<1
Chromium, total recoverable (ug/L as Cr)	1	10	6
Iron, total recoverable (ug/L as Fe)	50	12,000	1,200
Lead, total recoverable (ug/L as Pb)	<1	10	4
Manganese, total recoverable (ug/L as Mn)	60	1,000	160
Mercury, total recoverable (ug/L as Hg)	.1	.2	.1
Selenium, total recoverable (ug/L as Se)	<1	1	.7
Silver, total recoverable (ug/L as Ag)	<1	1	.5
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.03	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	<.01	.30	.12
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	1.2	.44
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.04	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.56	.04

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464032 Little Creek east of Samantha (site 2)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	5	72	29
Calcium, dissolved (mg/L as Ca)	12	88	38
Chloride, dissolved (mg/L as Cl)	1.4	2.6	1.9
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	70	580	240
Magnesium, dissolved (mg/L as Mg)	9.7	69	30
Potassium, dissolved (mg/L as K)	1.3	3.0	2.1
Silica, dissolved (mg/L as SiO2)	5.4	9.3	7.7
Sodium, dissolved (mg/L as Na)	2.2	11	6.1
Solids, residue at 180 °C, dissolved (mg/L)	204	904	402
Solids, sum of constituents, dissolved (mg/L)	100	460	282
Sulfate, dissolved (mg/L as SO4)	58	550	235
pH (standard units)	5.8	7.4	--
Specific conductance (uS/cm)	158	1,420	645
Arsenic, dissolved (ug/L as As)	1	1	1
Iron, dissolved (ug/L as Fe)	86	280	195
Lead, dissolved (ug/L as Pb)	2	2	2
Manganese, dissolved (ug/L as Mn)	10	4,100	2,280
Arsenic, total recoverable (ug/L as As)	1	1	1
Iron, total recoverable (ug/L as Fe)	240	1,300	620
Lead, total recoverable (ug/L as Pb)	6	6	6
Manganese, total recoverable (ug/L as Mn)	390	6,600	2,600
Mercury, total recoverable (ug/L as Hg)	.1	.1	.1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.01	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	1.1	.60
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.40	.40	.40
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.01	.01
Phosphorus, total recoverable (mg/L as P)	.05	.05	.05

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464035 Cripple Creek east of Samantha (site 3)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	0	150	24
Calcium, dissolved (mg/L as Ca)	1.1	91	23
Chloride, dissolved (mg/L as Cl)	.0	66	5.8
Fluoride, dissolved (mg/L as F)	.0	.1	.1
Hardness (mg/L as CaCO3)	0	1,100	160
Magnesium, dissolved (mg/L as Mg)	1.1	110	19
Potassium, dissolved (mg/L as K)	.3	7.5	1.9
Silica, dissolved (mg/L as SiO2)	2.6	10	7.3
Sodium, dissolved (mg/L as Na)	1.0	48	9.7
Solids, residue at 180 °C, dissolved (mg/L)	25	1,550	316
Solids, sum of constituents, dissolved (mg/L)	19	1,400	240
Sulfate, dissolved (mg/L as SO4)	4.7	960	124
pH (standard units)	4.5	8.2	--
Specific conductance (uS/cm)	24	1,840	310
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	<1	9	1
Chromium, dissolved (ug/L as Cr)	<1	20	6
Iron, dissolved (ug/L as Fe)	<10	810	100
Lead, dissolved (ug/L as Pb)	<1	10	2
Manganese, dissolved (ug/L as Mn)	30	3,300	760
Mercury, dissolved (ug/L as Hg)	.1	.5	.3
Selenium, dissolved (ug/L as Se)	<1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	2	1
Cadmium, total recoverable (ug/L as Cd)	<1	9	1
Chromium, total recoverable (ug/L as Cr)	5	20	14
Iron, total recoverable (ug/L as Fe)	160	17,000	1,900
Lead, total recoverable (ug/L as Pb)	<1	15	4
Manganese, total recoverable (ug/L as Mn)	50	3,300	860
Mercury, total recoverable (ug/L as Hg)	.1	.7	.3
Selenium, total recoverable (ug/L as Se)	<1	1	1
Silver, total recoverable (ug/L as Ag)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.05	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.09	2.7	.29
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.05	.70	.26
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.06	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.05	.02

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464040 North River 1500 ft below confluence of Cripple Creek (site 4)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	10	13	12
Calcium, dissolved (mg/L as Ca)	8.0	8.6	8.3
Chloride, dissolved (mg/L as Cl)	2.9	4.4	3.6
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	43	45	44
Magnesium, dissolved (mg/L as Mg)	5.5	5.8	5.6
Potassium, dissolved (mg/L as K)	1.0	1.1	1.0
Silica, dissolved (mg/L as SiO2)	8.8	8.8	8.8
Sodium, dissolved (mg/L as Na)	4.3	6.9	5.6
Solids, sum of constituents, dissolved (mg/L)	78	80	79
Sulfate, dissolved (mg/L as SO4)	35	42	38
pH (standard units)	6.6	6.7	--
Specific conductance (uS/cm)	134	134	134
Iron, dissolved (ug/L as Fe)	44	510	280
Manganese, dissolved (ug/L as Mn)	360	360	360
Iron, total recoverable (ug/L as Fe)	690	1,000	840
Manganese, total recoverable (ug/L as Mn)	120	360	240

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens er centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464100 Dry Creek near Samantha (site 5)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	2	28	9
Calcium, dissolved (mg/L as Ca)	.6	3.4	1.8
Chloride, dissolved (mg/L as Cl)	.0	1.9	1.3
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	4	23	10
Magnesium, dissolved (mg/L as Mg)	.6	2.1	1.2
Potassium, dissolved (mg/L as K)	.5	1.4	.7
Silica, dissolved (mg/L as SiO2)	5.6	9.8	7.7
Sodium, dissolved (mg/L as Na)	.8	1.9	1.5
Solids, residue at 180 °C, dissolved (mg/L)	15	52	27
Solids, sum of constituents, dissolved (mg/L)	21	37	26
Sulfate, dissolved (mg/L as SO4)	.0	10	4.6
pH (standard units)	4.8	7.1	--
Specific conductance (uS/cm)	22	54	31
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	2	2	2
Iron, dissolved (ug/L as Fe)	3	720	160
Lead, dissolved (ug/L as Pb)	3	5	4
Manganese, dissolved (ug/L as Mn)	17	470	81
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	1	1
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	6	6	6
Iron, total recoverable (ug/L as Fe)	270	5,600	1,060
Lead, total recoverable (ug/L as Pb)	6	7	6
Manganese, total recoverable (ug/L as Mn)	20	520	100
Mercury, total recoverable (ug/L as Hg)	.1	.1	.1
Silver, total recoverable (ug/L as Ag)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.01	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	<.01	.10	.09
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.08	.60	.37
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.02	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.03	.02

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464110 Dry Creek near Northport (site 6)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	5	13	8
Calcium, dissolved (mg/L as Ca)	1.0	2.5	1.8
Chloride, dissolved (mg/L as Cl)	1.2	2.0	1.6
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	6	13	10
Magnesium, dissolved (mg/L as Mg)	1.0	1.7	1.4
Potassium, dissolved (mg/L as K)	.5	1.4	.9
Silica, dissolved (mg/L as SiO2)	7.8	8.9	8.2
Sodium, dissolved (mg/L as Na)	1.3	1.9	1.6
Solids, residue at 180 °C, dissolved (mg/L)	22	22	22
Solids, sum of constituents, dissolved (mg/L)	20	28	24
Sulfate, dissolved (mg/L as SO4)	3.0	4.4	3.3
pH (standard units)	5.2	7.3	--
Specific conductance (uS/cm)	22	40	34
Arsenic, dissolved (ug/L as As)	1	1	1
Iron, dissolved (ug/L as Fe)	210	510	360
Manganese, dissolved (ug/L as Mn)	15	32	24
Selenium, dissolved (ug/L as Se)	1	1	1
Iron, total recoverable (ug/L as Fe)	430	1,500	980
Manganese, total recoverable (ug/L as Mn)	10	100	40

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464146 Turkey Creek near Tuscaloosa (site 7)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	2	7	3.6
Calcium, dissolved (mg/L as Ca)	1.1	4.5	2.5
Chloride, dissolved (mg/L as Cl)	1.2	1.7	1.4
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	7	29	15
Magnesium, dissolved (mg/L as Mg)	.9	4.2	2.1
Potassium, dissolved (mg/L as K)	.4	.8	.6
Silica, dissolved (mg/L as SiO2)	5.9	8.1	6.7
Sodium, dissolved (mg/L as Na)	1.1	1.7	1.3
Solids, residue at 180 °C, dissolved (mg/L)	14	70	37
Solids, sum of constituents, dissolved (mg/L)	19	32	27
Sulfate, dissolved (mg/L as SO4)	3.8	21	11
pH (standard units)	4.9	6.9	--
Specific conductance (uS/cm)	13	81	39
Arsenic, dissolved (ug/L as As)	<1	1	1
Cadmium, dissolved (ug/L as Cd)	2	2	2
Chromium, dissolved (ug/L as Cr)	10	10	10
Iron, dissolved (ug/L as Fe)	<10	240	110
Lead, dissolved (ug/L as Pb)	1	560	190
Manganese, dissolved (ug/L as Mn)	20	300	120
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	2	1
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	10	10	10
Iron, total recoverable (ug/L as Fe)	140	980	390
Lead, total recoverable (ug/L as Pb)	1	2	2
Manganese, total recoverable (ug/L as Mn)	20	340	120
Mercury, total recoverable (ug/L as Hg)	.1	.2	.1
Selenium, total recoverable (ug/L as Se)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.01	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.15	.12
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.20	.34	.25
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.01	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.01	.01

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464149 Turkey Creek near Patterson Chapel (site 8)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	2	20	7
Calcium, dissolved (mg/L as Ca)	1.1	10	3.5
Chloride, dissolved (mg/L as Cl)	.0	2.6	1.5
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	6	48	19
Magnesium, dissolved (mg/L as Mg)	.9	5.7	2.5
Potassium, dissolved (mg/L as K)	.5	1.4	.8
Silica, dissolved (mg/L as SiO2)	6.1	8.6	7.0
Sodium, dissolved (mg/L as Na)	1.1	2.4	1.6
Solids, residue at 180 °C, dissolved (mg/L)	1	75	43
Solids, sum of constituents, dissolved (mg/L)	13	70	36
Sulfate, dissolved (mg/L as SO4)	3.6	31	14
pH (standard units)	5.3	7.0	--
Specific conductance (uS/cm)	35	130	62
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	2	2	2
Iron, dissolved (ug/L as Fe)	43	230	100
Lead, dissolved (ug/L as Pb)	1	3	2
Manganese, dissolved (ug/L as Mn)	34	900	210
Mercury, dissolved (ug/L as Hg)	.5	.5	.5
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	2	2
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	6	6	6
Iron, total recoverable (ug/L as Fe)	230	6,900	800
Lead, total recoverable (ug/L as Pb)	5	7	6
Manganese, total recoverable (ug/L as Mn)	30	940	240
Mercury, total recoverable (ug/L as Hg)	<.1	<1	.1
Silver, total recoverable (ug/L as Ag)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.02	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.70	.17
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	1.7	.50
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.01	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.05	.02

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464155 Lake Tuscaloosa at Hilltop Estates Landing near Northport (site 9)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	2	17	9
Calcium, dissolved (mg/L as Ca)	1.7	5.3	3.9
Chloride, dissolved (mg/L as Cl)	.0	5.5	2.8
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	9	29	21
Magnesium, dissolved (mg/L as Mg)	1.1	4.0	2.8
Potassium, dissolved (mg/L as K)	.7	1.5	1.0
Silica, dissolved (mg/L as SiO2)	4.8	7.7	6.6
Sodium, dissolved (mg/L as Na)	1.0	8.6	3.7
Solids, residue at 180 °C, dissolved (mg/L)	28	86	51
Solids, sum of constituents, dissolved (mg/L)	21	64	44
Sulfate, dissolved (mg/L as SO4)	9.0	26	28
pH (standard units)	5.7	6.9	---
Specific conductance (uS/cm)	33	115	72
Arsenic, dissolved (ug/L as As)	1	2	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	1	3	1
Iron, dissolved (ug/L as Fe)	10	2,100	360
Lead, dissolved (ug/L as Pb)	2	7	4
Manganese, dissolved (ug/L as Mn)	10	1,200	390
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	2	1
Arsenic, total recoverable (ug/L as As)	2	2	2
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	1	5	3
Iron, total recoverable (ug/L as Fe)	50	5,100	1,340
Lead, total recoverable (ug/L as Pb)	2	9	5
Manganese, total recoverable (ug/L as Mn)	80	1,300	410
Mercury, total recoverable (ug/L as Hg)	.1	.1	.1
Selenium, total recoverable (ug/L as Se)	1	1	1
Silver, total recoverable (ug/L as Ag)	1	2	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.15	.02
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.20	.11
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	1.8	.44
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.10	.02
Phosphorus, total recoverable (mg/L as P)	<.01	.19	.03

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464360 Binion Creek below Gin Creek near Samantha (site 10)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	1	49	8
Calcium, dissolved (mg/L as Ca)	2.0	4.4	2.7
Chloride, dissolved (mg/L as Cl)	.0	3.3	2.1
Fluoride, dissolved (mg/L as F)	.1	.2	.1
Hardness (mg/L as CaCO3)	10	20	13
Magnesium, dissolved (mg/L as Mg)	1.1	2.6	1.5
Potassium, dissolved (mg/L as K)	.7	1.3	.9
Silica, dissolved (mg/L as SiO2)	4.4	9.8	7.7
Sodium, dissolved (mg/L as Na)	1.0	2.2	1.4
Solids, residue at 180 °C, dissolved (mg/L)	21	50	33
Solids, sum of constituents, dissolved (mg/L)	22	42	28
Sulfate, dissolved (mg/L as SO4)	3.0	15	7.3
pH (standard units)	5.2	6.8	--
Specific conductance (uS/cm)	22	69	41
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	1	2	1
Iron, dissolved (ug/L as Fe)	10	570	230
Lead, dissolved (ug/L as Pb)	1	5	3
Manganese, dissolved (ug/L as Mn)	10	380	190
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	1	1
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	3	10	6
Iron, total recoverable (ug/L as Fe)	50	9,600	1,980
Lead, total recoverable (ug/L as Pb)	1	6	4
Manganese, total recoverable (ug/L as Mn)	10	650	260
Mercury, total recoverable (ug/L as Hg)	.1	.1	.1
Selenium, total recoverable (ug/L as Se)	1	1	1
Silver, total recoverable (ug/L as Ag)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.03	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.20	.11
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	1.2	.41
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.06	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.31	.04

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464400 Lake Tuscaloosa at Tierce Patton Road (site 11)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	5	12	9
pH (standard units)	6.0	6.9	--
Specific conductance (uS/cm)	44	87	67
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.03	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.10	.10
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	.60	.36
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.02	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.03	.02

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464500 Lake Tuscaloosa at State Highway 69 (site 12)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	7	15	11
Calcium, dissolved (mg/L as Ca)	1.6	4.4	2.8
Chloride, dissolved (mg/L as Cl)	.0	4.4	2.7
Fluoride, dissolved (mg/L as F)	.0	.1	.1
Hardness (mg/L as CaCO3)	8	30	14
Magnesium, dissolved (mg/L as Mg)	1.0	2.9	1.8
Potassium, dissolved (mg/L as K)	.6	1.2	1.0
Silica, dissolved (mg/L as SiO2)	7.1	8.9	7.9
Sodium, dissolved (mg/L as Na)	1.5	4.2	2.8
Solids, residue at 180 °C, dissolved (mg/L)	32	44	37
Solids, sum of constituents, dissolved (mg/L)	20	47	32
Sulfate, dissolved (mg/L as SO4)	.0	15	6.6
pH (standard units)	6.2	7.8	--
Specific conductance (uS/cm)	27	79	40
Iron, total recoverable (ug/L as Fe)	50	340	150
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.01	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.10	.10
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.30	.40	.35
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.02	.02
Phosphorus, total recoverable (mg/L as P)	<.01	.01	.01

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464505 Tierce Creek near Northport (site 13)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	0	5	2
Calcium, dissolved (mg/L as Ca)	.4	1.0	.7
Chloride, dissolved (mg/L as Cl)	.0	2.2	1.6
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	2	5	4
Magnesium, dissolved (mg/L as Mg)	.3	.7	.5
Potassium, dissolved (mg/L as K)	.1	.7	.4
Silica, dissolved (mg/L as SiO2)	6.0	7.8	6.8
Sodium, dissolved (mg/L as Na)	.1	2.0	1.1
Solids, residue at 180 °C, dissolved (mg/L)	11	29	18
Solids, sum of constituents, dissolved (mg/L)	12	17	15
Sulfate, dissolved (mg/L as SO4)	.1	5.0	1.9
pH (standard units)	4.5	6.8	--
Specific conductance (uS/cm)	6.0	27	16
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	1	12	6
Iron, dissolved (ug/L as Fe)	29	210	84
Lead, dissolved (ug/L as Pb)	1	2	2
Manganese, dissolved (ug/L as Mn)	9	86	31
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	1	1
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	5	10	8
Iron, total recoverable (ug/L as Fe)	130	690	390
Lead, total recoverable (ug/L as Pb)	1	7	4
Manganese, total recoverable (ug/L as Mn)	20	90	40
Mercury, total recoverable (ug/L as Hg)	.1	.1	.1
Selenium, total recoverable (ug/L as Se)	1	1	1
Silver, total recoverable (ug/L as Ag)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.02	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.08	.20	.10
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.08	1.2	.37
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.04	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.47	.03

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464660 Carroll Creek at State Highway 69 near Northport (site 14)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	0	8	4
Calcium, dissolved (mg/L as Ca)	.8	2.0	1.2
Chloride, dissolved (mg/L as Cl)	.0	4.0	2.4
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	4	9	6
Magnesium, dissolved (mg/L as Mg)	.5	1.0	.7
Potassium, dissolved (mg/L as K)	.2	1.3	.8
Silica, dissolved (mg/L as SiO2)	5.4	9.4	7.3
Sodium, dissolved (mg/L as Na)	1.0	2.4	1.6
Solids, residue at 180 °C, dissolved (mg/L)	14	35	24
Solids, sum of constituents, dissolved (mg/L)	16	27	20
Sulfate, dissolved (mg/L as SO4)	.1	7.7	2.9
pH (standard units)	4.6	6.8	--
Specific conductance (uS/cm)	20	33	25
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	1	2	1
Chromium, dissolved (ug/L as Cr)	1	4	2
Iron, dissolved (ug/L as Fe)	10	780	250
Lead, dissolved (ug/L as Pb)	1	5	3
Manganese, dissolved (ug/L as Mn)	23	260	110
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	2	1
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	1	10	6
Iron, total recoverable (ug/L as Fe)	510	4,100	1,570
Lead, total recoverable (ug/L as Pb)	2	3	2
Manganese, total recoverable (ug/L as Mn)	30	500	160
Mercury, total recoverable (ug/L as Hg)	.1	2.0	.7
Selenium, total recoverable (ug/L as Se)	1	1	1
Silver, total recoverable (ug/L as Ag)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.02	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.30	.15
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	.90	.49
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.04	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.11	.03

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464680 Brush Creek near Northport (site 15)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	0	4	2
Calcium, dissolved (mg/L as Ca)	.3	.8	.5
Chloride, dissolved (mg/L as Cl)	.0	1.9	1.4
Fluoride, dissolved (mg/L as F)	.1	.2	.1
Hardness (mg/L as CaCO3)	2	4	3
Magnesium, dissolved (mg/L as Mg)	.3	.5	.4
Potassium, dissolved (mg/L as K)	.1	.5	.3
Silica, dissolved (mg/L as SiO2)	6.4	7.5	6.8
Sodium, dissolved (mg/L as Na)	.9	2.1	1.2
Solids, residue at 180 °C, dissolved (mg/L)	8	27	17
Solids, sum of constituents, dissolved (mg/L)	12	16	14
Sulfate, dissolved (mg/L as SO4)	.1	5.0	2.1
pH (standard units)	4.4	6.4	--
Specific conductance (uS/cm)	11	19	14
Arsenic, dissolved (ug/L as As)	1	1	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	6	6	6
Iron, dissolved (ug/L as Fe)	30	190	100
Lead, dissolved (ug/L as Pb)	1	1	1
Manganese, dissolved (ug/L as Mn)	10	43	26
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	1	1
Arsenic, total recoverable (ug/L as As)	1	1	1
Cadmium, total recoverable (ug/L as Cd)	1	1	1
Chromium, total recoverable (ug/L as Cr)	10	10	10
Iron, total recoverable (ug/L as Fe)	180	650	330
Lead, total recoverable (ug/L as Pb)	1	1	1
Manganese, total recoverable (ug/L as Mn)	10	70	34
Mercury, total recoverable (ug/L as Hg)	.1	.1	.1
Selenium, total recoverable (ug/L as Se)	1	1	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.01	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.05	.10	.10
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.05	.60	.24
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.04	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.15	.02

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

02464800 Lake Tuscaloosa Reservoir near Tuscaloosa (site 16)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	2	12	6
Calcium, dissolved (mg/L as Ca)	2.0	4.0	2.8
Chloride, dissolved (mg/L as Cl)	1.0	3.7	2.2
Fluoride, dissolved (mg/L as F)	.1	.1	.1
Hardness (mg/L as CaCO3)	11	22	15
Magnesium, dissolved (mg/L as Mg)	1.4	2.8	2.0
Potassium, dissolved (mg/L as K)	.5	1.3	1.0
Silica, dissolved (mg/L as SiO2)	4.2	7.1	6.0
Sodium, dissolved (mg/L as Na)	1.5	3.9	2.3
Solids, residue at 180 °C, dissolved (mg/L)	29	68	41
Solids, sum of constituents, dissolved (mg/L)	27	43	33
Sulfate, dissolved (mg/L as SO4)	5.2	18	12
pH (standard units)	5.2	7.0	--
Specific conductance (uS/cm)	29	75	52
Arsenic, dissolved (ug/L as As)	1	2	1
Cadmium, dissolved (ug/L as Cd)	1	1	1
Chromium, dissolved (ug/L as Cr)	1	3	2
Iron, dissolved (ug/L as Fe)	10	250	110
Lead, dissolved (ug/L as Pb)	2	7	4
Manganese, dissolved (ug/L as Mn)	10	610	152
Mercury, dissolved (ug/L as Hg)	.1	.1	.1
Selenium, dissolved (ug/L as Se)	1	1	1
Silver, dissolved (ug/L as Ag)	1	2	1
Arsenic, total recoverable (ug/L as As)	1	2	1
Cadmium, total recoverable (ug/L as Cd)	0	1	1
Chromium, total recoverable (ug/L as Cr)	1	10	5
Iron, total recoverable (ug/L as Fe)	60	1,200	463
Lead, total recoverable (ug/L as Pb)	2	8	5
Manganese, total recoverable (ug/L as Mn)	20	1,100	202
Mercury, total recoverable (ug/L as Hg)	.1	.8	.3
Selenium, total recoverable (ug/L as Se)	0	1	.5
Silver, total recoverable (ug/L as Ag)	0	2	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.04	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	.10	.20	.11
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.10	5.0	.43
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.04	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.27	.03

Table 4.--Summary of water-quality analyses at 16 sites in North River basin--continued

[mg/L = milligrams per liter; °C = degrees Celsius; uS/cm = microsiemens per centimeter at 25 °C; ug/L = micrograms per liter; site numbers correspond to those in table 1 and figure 2]

(sites 1-16)

Constituent or property	Minimum	Maximum	Mean
Alkalinity, field (mg/L as CaCO3)	0	150	11
Calcium, dissolved (mg/L as Ca)	.3	91	6.5
Chloride, dissolved (mg/L as Cl)	.0	66	3.1
Fluoride, dissolved (mg/L as F)	.0	1.0	.1
Hardness (mg/L as CaCO3)	0	1,100	40
Magnesium, dissolved (mg/L as Mg)	.3	110	5.1
Potassium, dissolved (mg/L as K)	.1	7.5	1.0
Silica, dissolved (mg/L as SiO2)	2.0	10	7.0
Sodium, dissolved (mg/L as Na)	.1	48	3.8
Solids, residue at 180 °C, dissolved (mg/L)	8	1,550	74
Solids, sum of constituents, dissolved (mg/L)	12	1,400	67
Sulfate, dissolved (mg/L as SO4)	.0	960	38
pH (standard units)	4.4	8.2	--
Specific conductance (uS/cm)	6	1,840	112
Arsenic, dissolved (ug/L as As)	<1	3	<1
Cadmium, dissolved (ug/L as Cd)	<1	9	1
Chromium, dissolved (ug/L as Cr)	<1	20	2
Iron, dissolved (ug/L as Fe)	<10	2,100	190
Lead, dissolved (ug/L as Pb)	<1	560	8
Manganese, dissolved (ug/L as Mn)	9	4,100	290
Mercury, dissolved (ug/L as Hg)	<.1	1.4	.2
Selenium, dissolved (ug/L as Se)	<1	1	<1
Silver, dissolved (ug/L as Ag)	<1	2	1
Arsenic, total recoverable (ug/L as As)	1	2	1
Cadmium, total recoverable (ug/L as Cd)	<1	9	1
Chromium, total recoverable (ug/L as Cr)	1	20	9
Iron, total recoverable (ug/L as Fe)	50	17,000	1,120
Lead, total recoverable (ug/L as Pb)	<1	15	4
Manganese, total recoverable (ug/L as Mn)	10	6,600	360
Mercury, total recoverable (ug/L as Hg)	.1	2.0	.3
Selenium, total recoverable (ug/L as Se)	<1	1	.9
Silver, total recoverable (ug/L as Ag)	<1	2	1
Nitrogen, NO2, total recoverable (mg/L as N)	<.01	.15	.01
Nitrogen, NO2+NO3, total recoverable (mg/L as N)	<.01	2.7	.15
Nitrogen, NH3 + Org, total recoverable (mg/L as N)	.05	5.0	.40
Phosphorus, ortho, total recoverable (mg/L as P)	<.01	.10	.01
Phosphorus, total recoverable (mg/L as P)	<.01	.56	.03

The median pH for most streams draining mined and unmined areas was less than the 6.5 recommended minimum (U.S. Environmental Protection Agency, 1986a), but this is common for the area. The minimum pH of 4.4 occurred at site 15 in Brush Creek, an unmined basin, and is nearly the same as the minimum (4.6) reported for other streams draining undisturbed basins in the area (Puente and others, 1980).

The most common primary and secondary water types during low and high flow are given for selected sites in table 5. During low flow the primary water type at North River (site 1) was sodium sulfate; during high flow, magnesium sulfate.

During both low and high flow, sulfate was the primary anion for streams draining areas with significant surface mining--North River and Little, Cripple, and Turkey Creeks. In contrast, bicarbonate is the primary anion during low flow for Dry, Binion, Carroll, and Brush Creeks and represents natural water-quality conditions for the entire Lake Tuscaloosa basin.

As reported in the section on streamflow, about 56 to 59 percent of the mean annual flow to Lake Tuscaloosa is contributed by the drainage to North River. Consequently, changes in water quality at North River are very important in determining the water quality of the lake.

Water from North River (site 1) has become more mineralized since 1976 (Cole, 1985). Sulfate concentrations, commonly used as an indicator of mine drainage (Slack, 1983), have increased more than concentrations of any other constituent. Specific conductance values (1966-76) and sulfate concentrations (1972-76) were relatively constant prior to mining. However, both increased significantly during active mining in the basin (1977-86). (See figs. 7 and 8).

A plot of specific conductance versus stream discharge for North River (site 1) for the pre-mining versus active mining periods (fig. 9) shows the upward shift in the conductance-discharge relation reported by Cole (1985) for data through September 1983 has continued through September 1986. Dissolved-solids concentrations are directly proportional to specific conductance. A similar upward shift has been observed in the sulfate-discharge relation. The maximum sulfate concentration of water from North River through September 1986 was 180 mg/L (table 6), still well below the recommended secondary drinking water limit of 250 mg/L.

The upward shifts in the specific conductance-discharge and sulfate-discharge relations were even more pronounced for Cripple Creek, a small mined basin. No upward shift in these relations has occurred for Carroll Creek, an unmined basin in the study area. Therefore, the increased mineralization at North River and Cripple Creek is due to coal mining. (The specific conductance-discharge relations for Cripple Creek and Carroll Creek are compared in figure 10).

Table 5. Primary and secondary water type during low and high flow conditions at study sites
[Site numbers correspond to those in figure 2 and table 1]

Site number	Name	Water type: Low flow, Primary	Water type: Low flow, Secondary	Water type: High flow, Primary	Water type: High flow, Secondary
1	North River	Na_2SO_4 [a]	$MgCl_2$	$MgSO_4$	$Ca(HCO_3)_2$
2	Little Creek	$MgSO_4$	$Ca(HCO_3)_2$	$MgSO_4$	$Ca(HCO_3)_2$
3	Cripple Creek	$CaSO_4$	$Mg(HCO_3)_2$	$MgSO_4$	$Ca(HCO_3)_2$
5	Dry Creek	$Mg(HCO_3)_2$	$CaSO_4$	$MgSO_4$	$Ca(HCO_3)_2$
8	Turkey Creek	$MgSO_4$	$Ca(HCO_3)_2$	$MgSO_4$	$Ca(HCO_3)_2$
9	Lake--HEL [b]	$CaSO_4$	$Mg(HCO_3)_2$	$CaSO_4$	$Mg(HCO_3)_2$
10	Binion Creek	$Ca(HCO_3)_2$	$MgSO_4$	$CaSO_4$	$Mg(HCO_3)_2$
13	Tierce Creek	Na (mixed) [c]	$MgSO_4$	Na_2SO_4	$MgCl_2$
14	Carroll Creek	$NaHCO_3$	$MgCl_2$	$CaSO_4$	$Mg(HCO_3)_2$
15	Brush Creek	$NaHCO_3$	$MgCl_2$	Na_2SO_4	$Mg(HCO_3)_2$
16	Lake--at dam	$MgSO_4$	$Ca(HCO_3)_2$	$MgSO_4$	$Ca(HCO_3)_2$

[a] Na, sodium; SO_4, sulfate; Mg, magnesium; Cl, chloride; Ca, calcium; HCO_3, bicarbonate.

[b] HEL, Hilltop Estates Landing.

[c] No predominant anion.

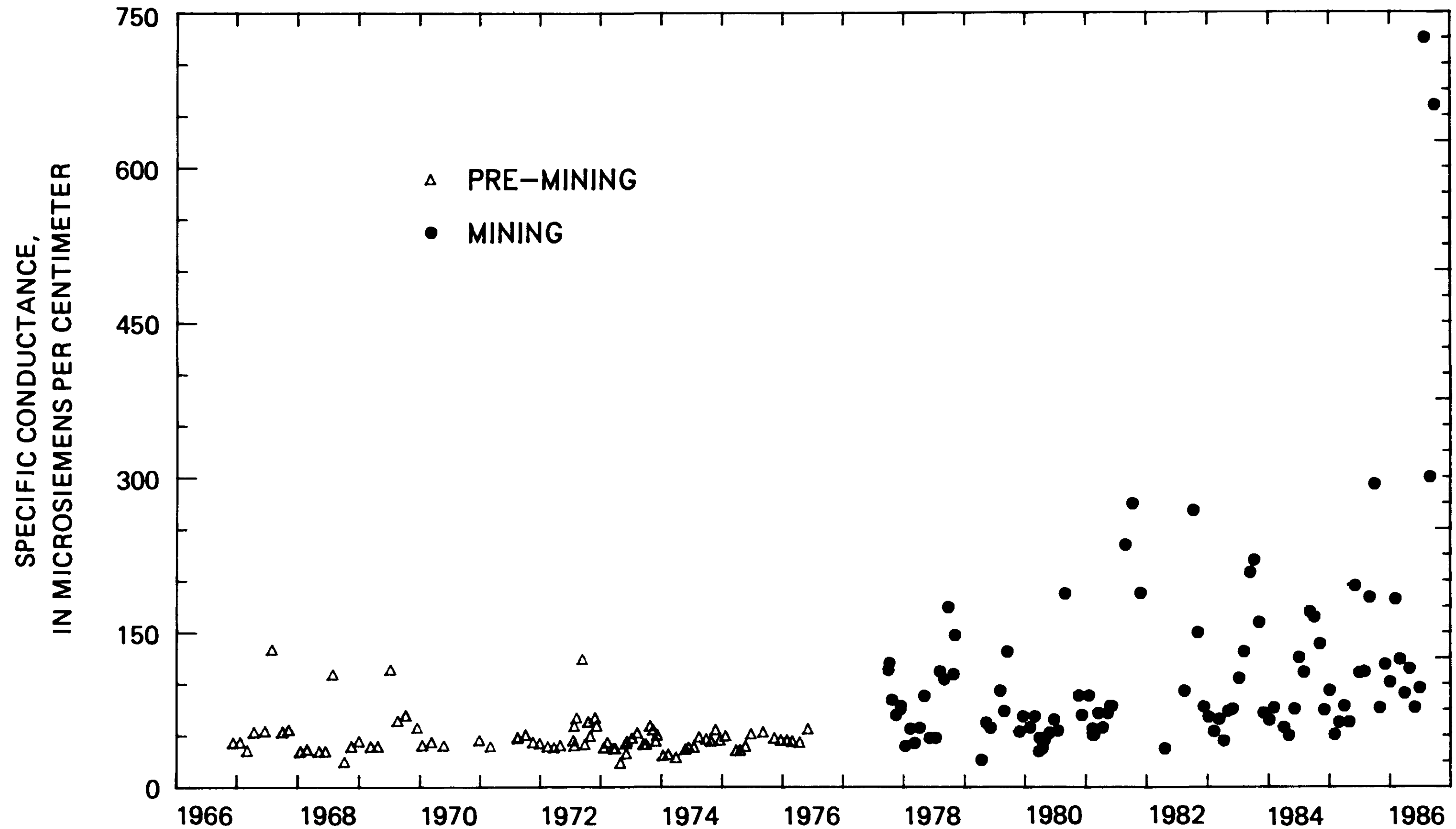

Figure 7.-- Specific conductance at North River (site1), 1966-86.

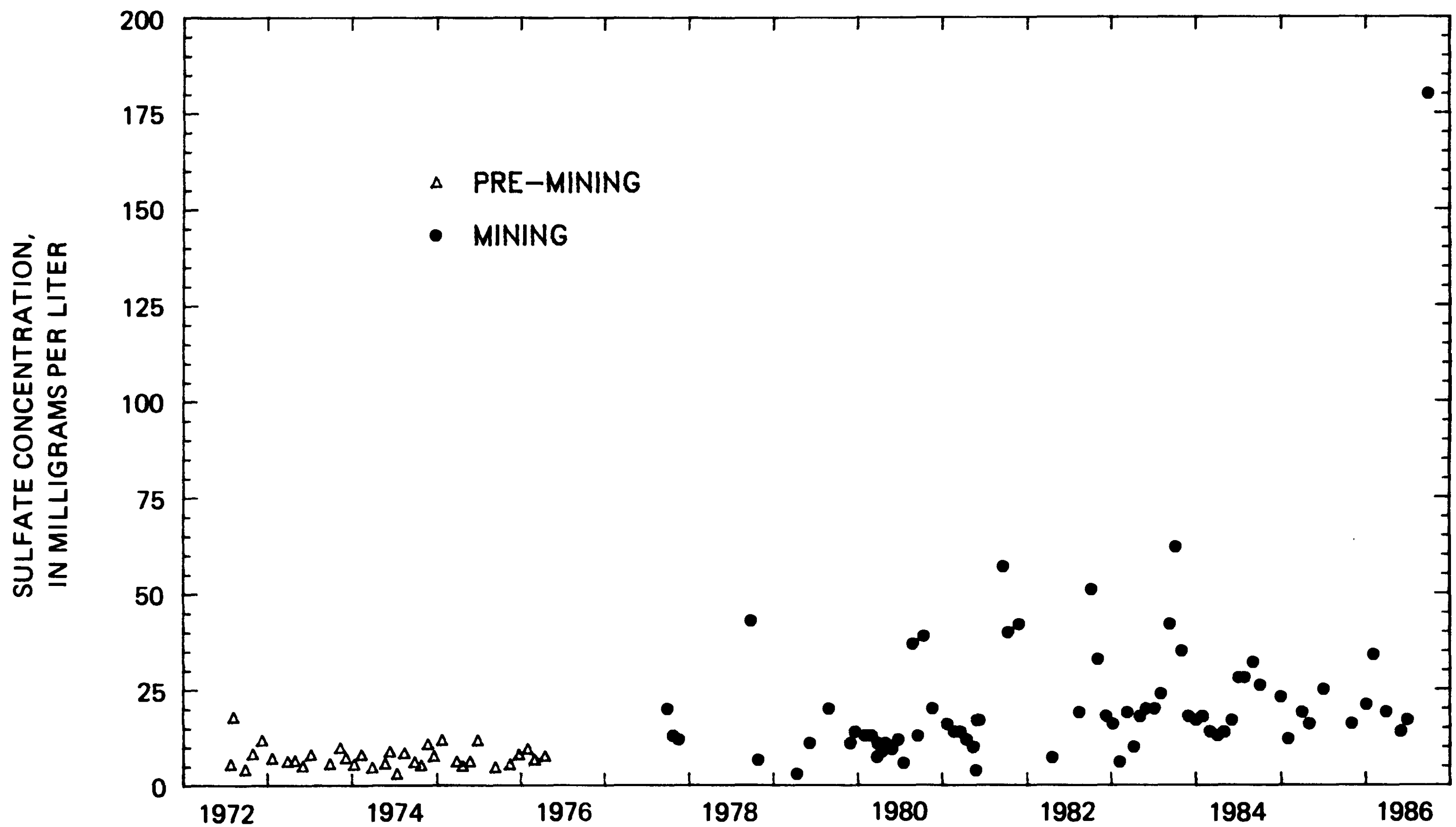

Figure 8.-- Sulfate concentration at North River (site1), 1972-1986.

Table 6. Median, minimum, and maximum values of selected constituents and properties in water at sites in the North River basin

[mg/L, milligrams per liter; uS/cm, microsiemens per centimeter at 25°C; DS, dissolved solids (sum); Fe, iron; Mn, manganese; total, total recoverable. Site numbers correspond to those in figure 2 and table 1.]

Median values of selected constituents

Site	Name	Chloride (mg/L, dissolved)	Sulfate (mg/L, dissolved)	DS (mg/L, dissolved)	Conductance (uS/cm)	pH	Fe, dissolved (Micrograms per liter)	Fe, total (Micrograms per liter)	Mn, dissolved (Micrograms per liter)	Mn, total (Micrograms per liter)
1	North R	2.8	13	39	60	6.5	190	900	84	110
2	Little C	1.8	195	310	565	6.6	195	600	2,450	2,300
3	Cripple	2.9	40	95	161	6.7	77	560	520	610
4	North R	3.6	39	79	134	6.6	277	845	360	240
5	Dry C	1.3	4.4	25	31	6.2	80	820	70	85
6	Dry C	1.5	3.0	23	36	6.1	360	1,000	24	20
7	Turkey C	1.4	11	29	38	6.0	98	345	84	90
8	Turkey C	1.6	12	33	60	6.4	92	420	170	190
9	Lake	2.4	18	46	77	6.3	140	890	150	170
10	Binion C	2.1	6.8	28	40	6.2	225	1,700	190	250
11	Lake	2.8	22	52	70	6.4	200	390	110	120
12	Lake	2.1	15	45	79	7.0	160	230	250	290
13	Tierce C	1.7	1.8	15	16	5.9	85	410	29	30
14	Carroll	2.4	2.6	20	25	6.0	230	1,400	110	130
15	Brush C	1.5	1.5	13	13	5.8	91	250	24	30
16	Lake	2.1	12	32	52	6.2	110	420	120	160

Minimum values of selected constituents

Site	Name	Chloride (mg/L, dissolved)	Sulfate (mg/L, dissolved)	DS (mg/L, dissolved)	Conductance (uS/cm)	pH	Fe, dissolved (Micrograms per liter)	Fe, total (Micrograms per liter)	Mn, dissolved (Micrograms per liter)	Mn, total (Micrograms per liter)
1	North R	0.0	3.0	18	24	4.8	<10	50	9	10
2	Little C	1.4	58	100	158	5.8	86	240	10	390
3	Cripple	.0	4.7	19	24	4.5	6	160	30	50
4	North R	2.9	35	78	134	6.6	44	690	360	120
5	Dry C	.0	.0	21	22	4.8	3	270	17	20
6	Dry C	1.2	3.0	20	22	5.2	210	430	15	10
7	Turkey C	1.2	3.8	19	13	4.9	3	140	20	20
8	Turkey C	.0	3.6	19	35	5.3	43	230	34	30
9	Lake	.0	9.0	21	33	5.7	10	50	10	10
10	Binion C	.0	3.0	22	22	5.2	10	50	10	10
11	Lake	2.8	22	52	44	6.0	200	390	110	120
12	Lake	.0	.0	20	27	6.2	160	50	250	290
13	Tierce C	.0	.1	12	6	4.5	29	130	9	20
14	Carroll	.0	.1	16	17	4.6	10	50	10	10
15	Brush C	.0	.0	12	11	4.4	30	180	10	10
16	Lake	1.0	5.2	27	29	5.2	10	50	10	10

Maximum values of selected constituents

Site	Name	Chloride (mg/L, dissolved)	Sulfate (mg/L, dissolved)	DS (mg/L, dissolved)	Conductance (uS/cm)	pH	Fe, dissolved (Micrograms per liter)	Fe, total (Micrograms per liter)	Mn, dissolved (Micrograms per liter)	Mn, total (Micrograms per liter)
1	North R	66	180	150	725	7.4	710	12,000	820	1,000
2	Little C	2.6	550	460	1,420	7.4	280	1,300	4,100	6,600
3	Cripple	66	960	1,400	1,840	8.2	810	17,000	3,300	3,300
4	North R	4.4	42	80	134	6.7	510	1,000	360	360
5	Dry C	1.9	10	37	54	7.1	720	5,600	470	520
6	Dry C	2.0	4.4	28	40	7.3	510	1,500	32	100
7	Turkey C	1.7	21	32	81	6.9	240	980	300	340
8	Turkey C	2.6	31	70	250	7.0	230	6,900	900	940
9	Lake	5.5	26	64	115	6.9	2,100	5,100	1,200	1,300
10	Binion C	3.3	15	42	69	6.8	570	9,600	380	650
11	Lake	2.8	22	52	87	6.9	200	390	110	120
12	Lake	4.4	15	47	79	7.8	160	340	250	290
13	Tierce C	2.2	5.0	17	27	6.8	210	690	86	90
14	Carroll	4.0	7.7	27	33	6.8	780	4,100	260	500
15	Brush C	1.9	5.0	16	19	6.4	190	650	43	70
16	Lake	3.7	18	43	75	7.1	250	1,200	610	1,100

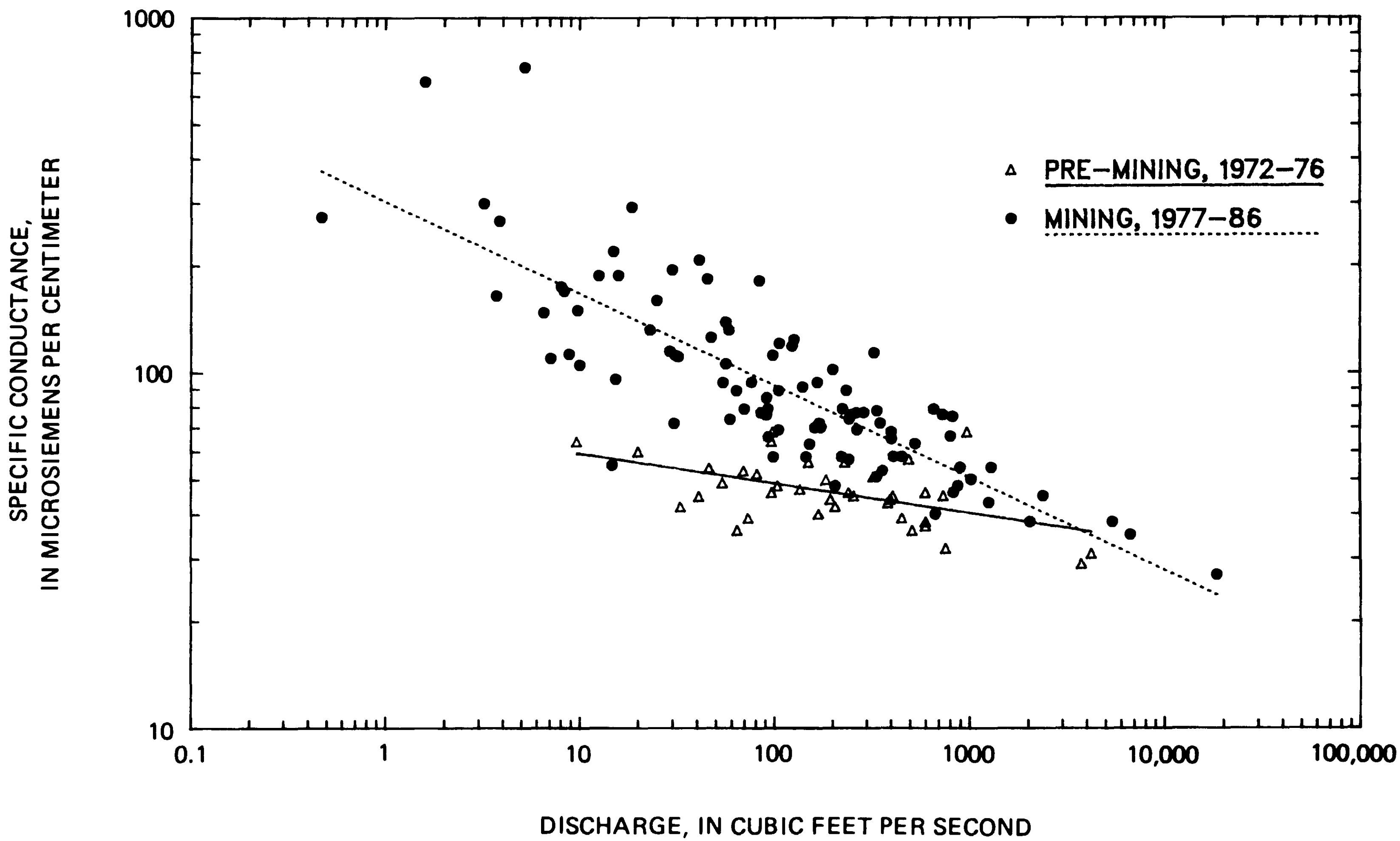

Figure 9.-- Relation between specific conductance and instantaneous stream discharge at North River (site 1), 1972-76 and 1977-86.

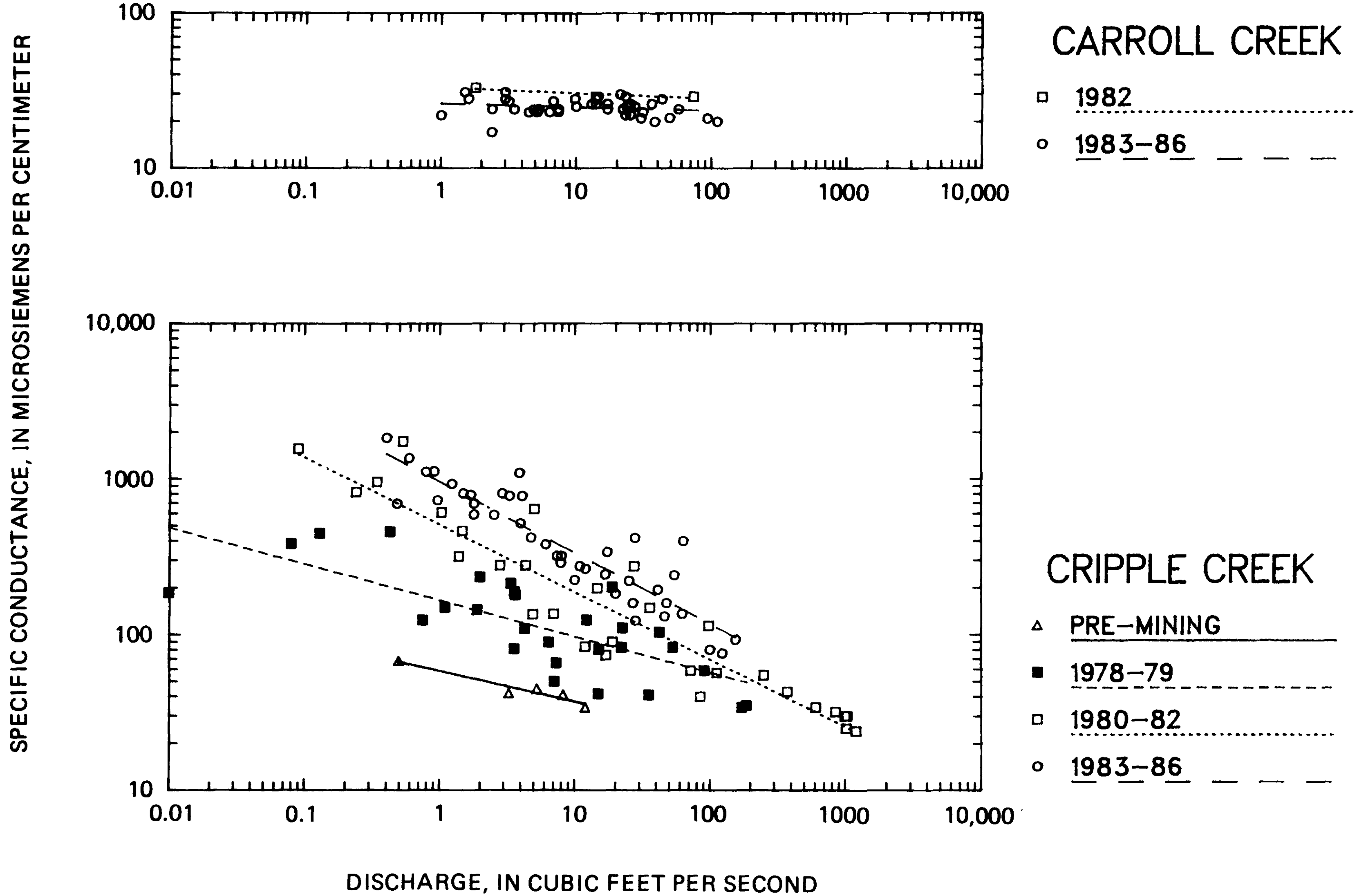

Figure 10.-- Relation between specific conductance and instantaneous stream discharge at Cripple Creek and Carroll Creek.

Although dissolved and total recoverable iron and manganese concentrations have increased in North River since mining began in the basin, insufficient data exist to determine if concentrations of these constituents are continuing to increase. Median total recoverable iron and manganese concentrations exceeded secondary drinking water standards at most sites (table 6).

Increases in conductance values and in sulfate, and dissolved and total recoverable iron and manganese concentrations during mining were even greater for Cripple Creek than for North River. Cripple Creek is a much smaller basin and has had a much larger percentage of its drainage area disturbed by surface mining than North River. Consequently, concentrations of dissolved solids and sulfate are greater (less diluted) in Cripple Creek than in North River. The maximum dissolved solids (sum) and sulfate concentrations (table 6) in water from Cripple Creek (1,400 and 960 mg/L, respectively) exceeded the recommended drinking water limits of 500 and 250 mg/L. However, the median dissolved solids and sulfate concentrations (95 and 40 mg/L, respectively) were well below the recommended limits. (See table 6).

Total and dissolved iron and manganese concentrations in water from Cripple Creek (table 6) frequently exceeded the recommended secondary drinking water limits (300 and 50 ug/L, respectively). The median concentrations were: total recoverable iron, 560 ug/L; total recoverable manganese, 610 ug/L; dissolved iron, 77 ug/L; and dissolved manganese, 560 ug/L. Although the maximum total recoverable iron (17,000 ug/L) and total recoverable manganese (6,600 ug/L) concentrations occurred in water from Cripple and Little Creeks which drain mined areas, large concentrations (5,600 ug/L iron and 520 ug/L manganese) also occurred in Dry Creek which drains an unmined basin.

Prior to mining, the specific conductance values and sulfate concentrations of Turkey Creek (site 7) varied little, but they increased significantly after mining began in the Turkey Creek basin in 1981 (figs. 11 and 12). The trend of increasing conductance and sulfate concentrations continued through September 1986, similar to the increases for North River and Cripple Creek.

During low-flow conditions water in Turkey Creek is much less mineralized than water in North River and Cripple Creek (Cole, 1985). Cole concluded that the lower mineralization of water in Turkey Creek results from dilution by larger, relatively unmineralized base flow contributed by the Coker Formation which underlies parts of the Turkey Creek basin.

Except for samples collected during the drought of the summer of 1986, the maximum concentrations of dissolved solids (49 mg/L), sulfate (29 mg/L), dissolved iron (230 ug/L) and manganese (900 ug/L), and total recoverable iron (6,900 ug/L) and manganese (940 ug/L) in water from Turkey Creek site 8 occurred between June and December 1982 and likely were associated with an initial flushing of minerals from the overburden exposed by mining.

As noted above, the maximum concentrations of dissolved solids and sulfate in Turkey Creek were well below the 500 mg/L and 250 mg/L recommended drinking water limits. However, the median total recoverable iron (420 ug/L) and dissolved and total recoverable manganese (170 and 190 ug/L) concentrations in water from the most downstream site on Turkey Creek (site 8) exceeded drinking water limits (table 6).

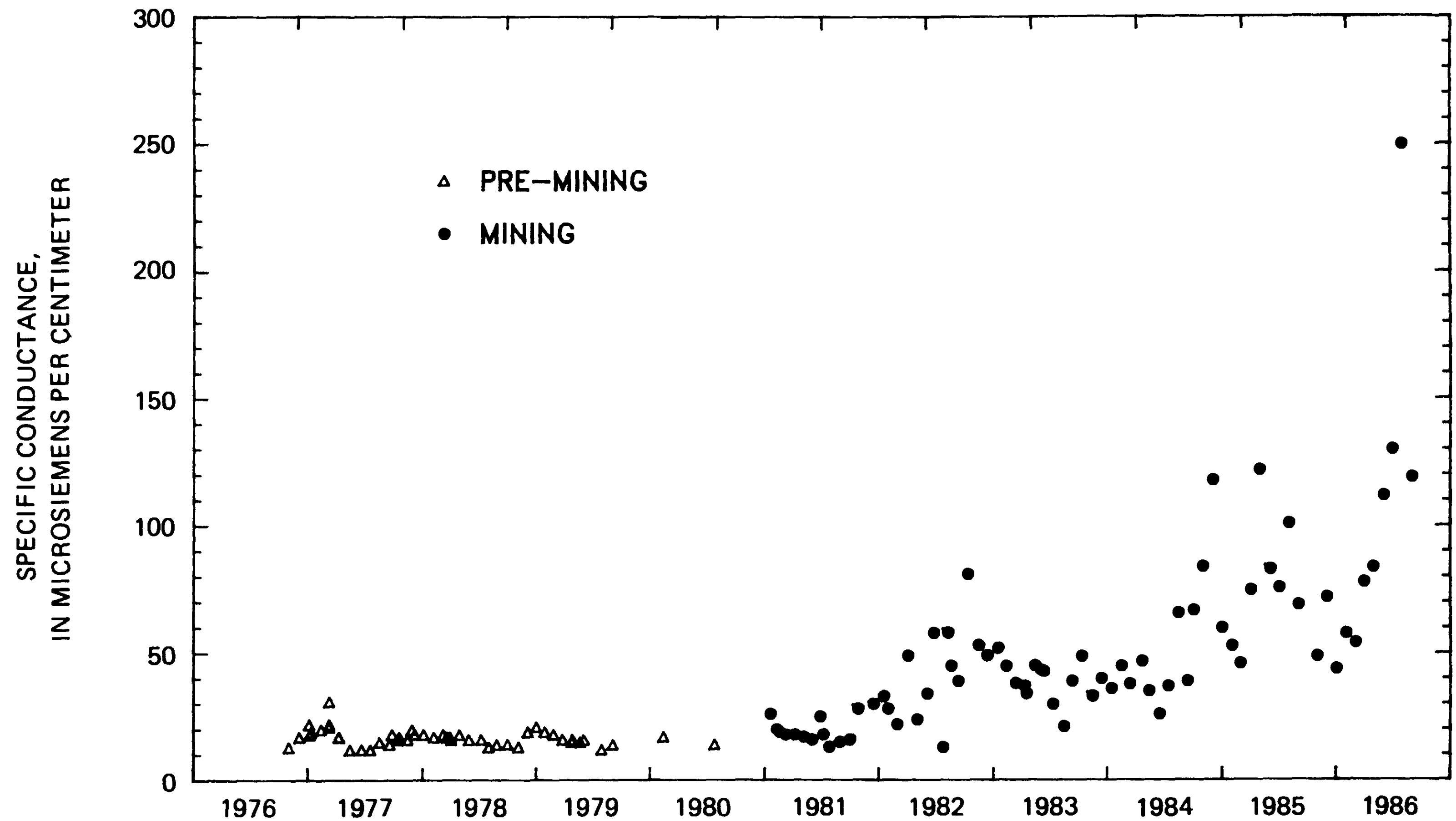

Figure 11.-- Specific conductance at Turkey Creek (site 7), 1976-86.

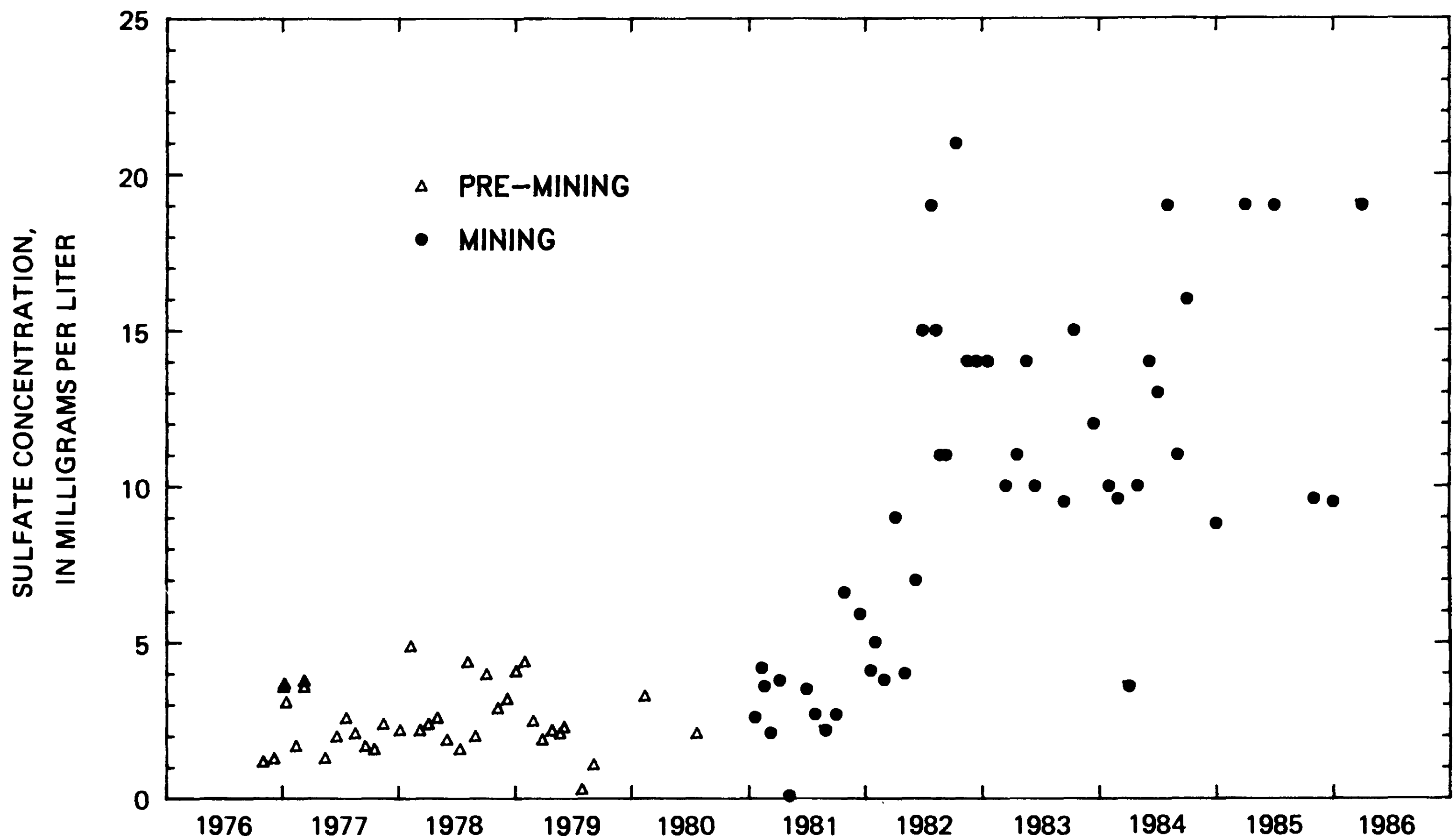

Figure 12.-- Sulfate concentration at Turkey Creek (site 7), 1976-86.

The water quality of Binion Creek has remained relatively constant as compared with the water quality of North River and Cripple and Turkey Creeks. The maximum dissolved solids (42 mg/L) and median dissolved iron (225 ug/L) concentrations were well within recommended drinking water limits. However, the maximum dissolved and total recoverable iron (570 and 9,600 ug/L) and the median dissolved and total recoverable manganese (190 and 250 ug/L) concentrations exceeded the drinking water limits (50 ug/L) (table 6).

The water quality of Brush, Carroll, Dry, and Tierce Creeks has remained good and relatively unchanged. The maximum dissolved solids (sum) for water samples from any of these four streams was 37 mg/L. The median dissolved solids (sum) for water samples from these streams ranged from 13 to 25 mg/L (table 6). However, dissolved and total recoverable iron and manganese concentrations in samples from these sites frequently exceeded drinking water limits (table 6). The high iron and manganese concentrations appear to be from natural sources.

WATER QUALITY OF LAKE TUSCALOOSA

The water quality of Lake Tuscaloosa is generally within drinking water limits and the water acceptable for most uses. However, the lake is becoming more mineralized. Plots of water-quality data for samples from Lake Tuscaloosa at the dam (site 16) show a trend of increasing specific conductance and dissolved solids (sum) and sulfate concentrations with time (figs. 13-15).

The trend of increasing mineralization of Lake Tuscaloosa (since 1979) was similar to, and largely caused by, the trend of increasing mineralization of the water at North River at Samantha (site 1), which is located downstream from mining areas and represents drainage from 223 mi^2--more than half the drainage area above the dam (423 mi^2). The maximum and median concentrations of sulfate increased every year at the dam from 1979 to 1985 (7.2 to 18 mg/L and 6.2 to 14 mg/L, respectively) but not for North River (table 7). The maximum and median concentrations of sulfate increased between 1979 and 1985 at North River (20 to 25 mg/L and 11 to 17.5 mg/L, respectively) but fluctuated up and down in the intervening years.

With only an estimated 5 percent of the basin mined, the dissolved solids concentrations for water at the dam have ranged (1979-86) from 27 to 43 mg/L; the sulfate, 5.2 to 18 mg/L; and the dissolved iron, 10 to 250 ug/L--all well within the recommended drinking-water limits. However, concentrations of dissolved manganese and total recoverable iron and manganese at the dam frequently exceeded the recommended drinking-water limits (table 6).

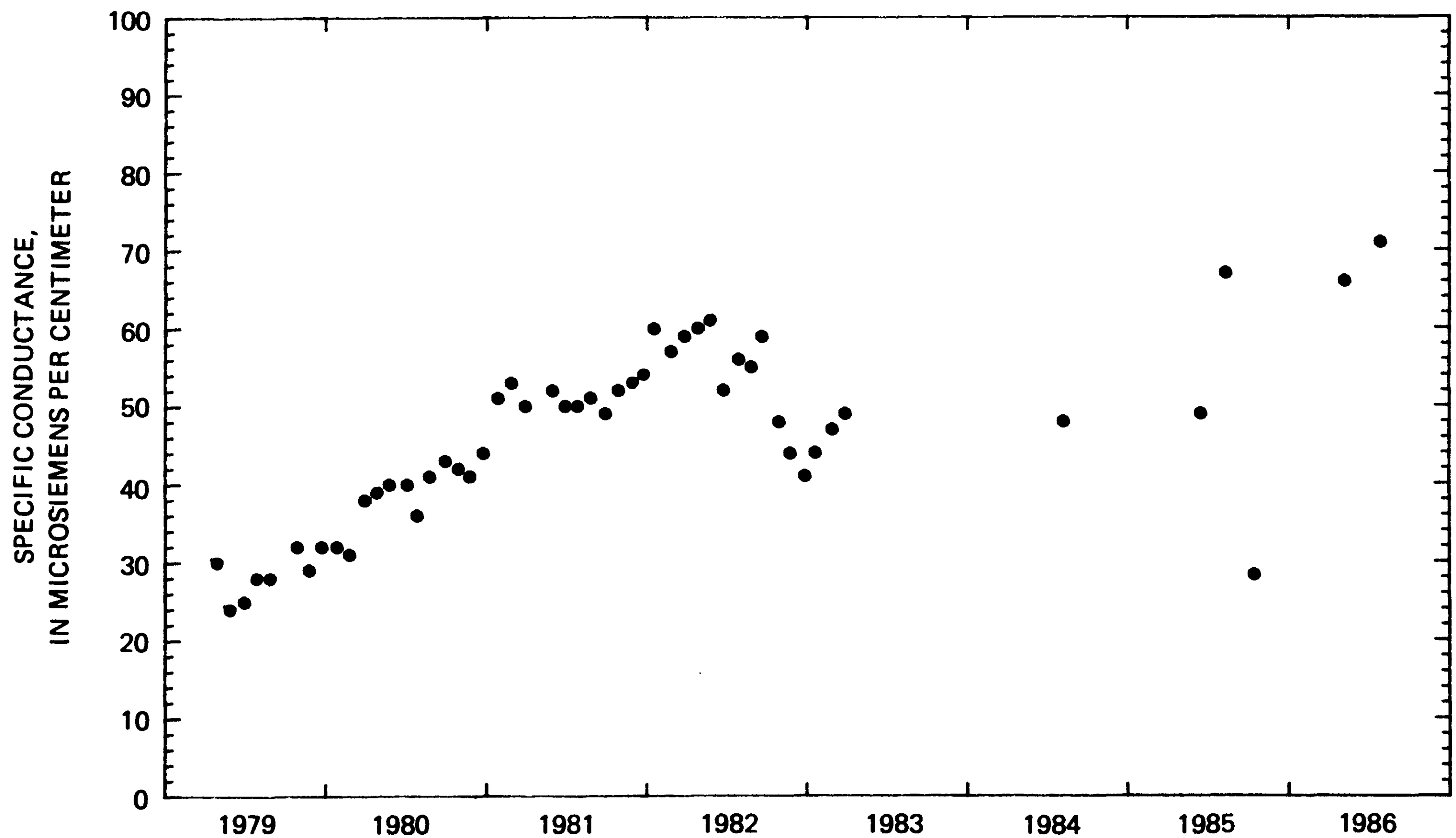

Figure 13.-- Specific conductance of Lake Tuscaloosa at the dam (site 16), 1979-86.

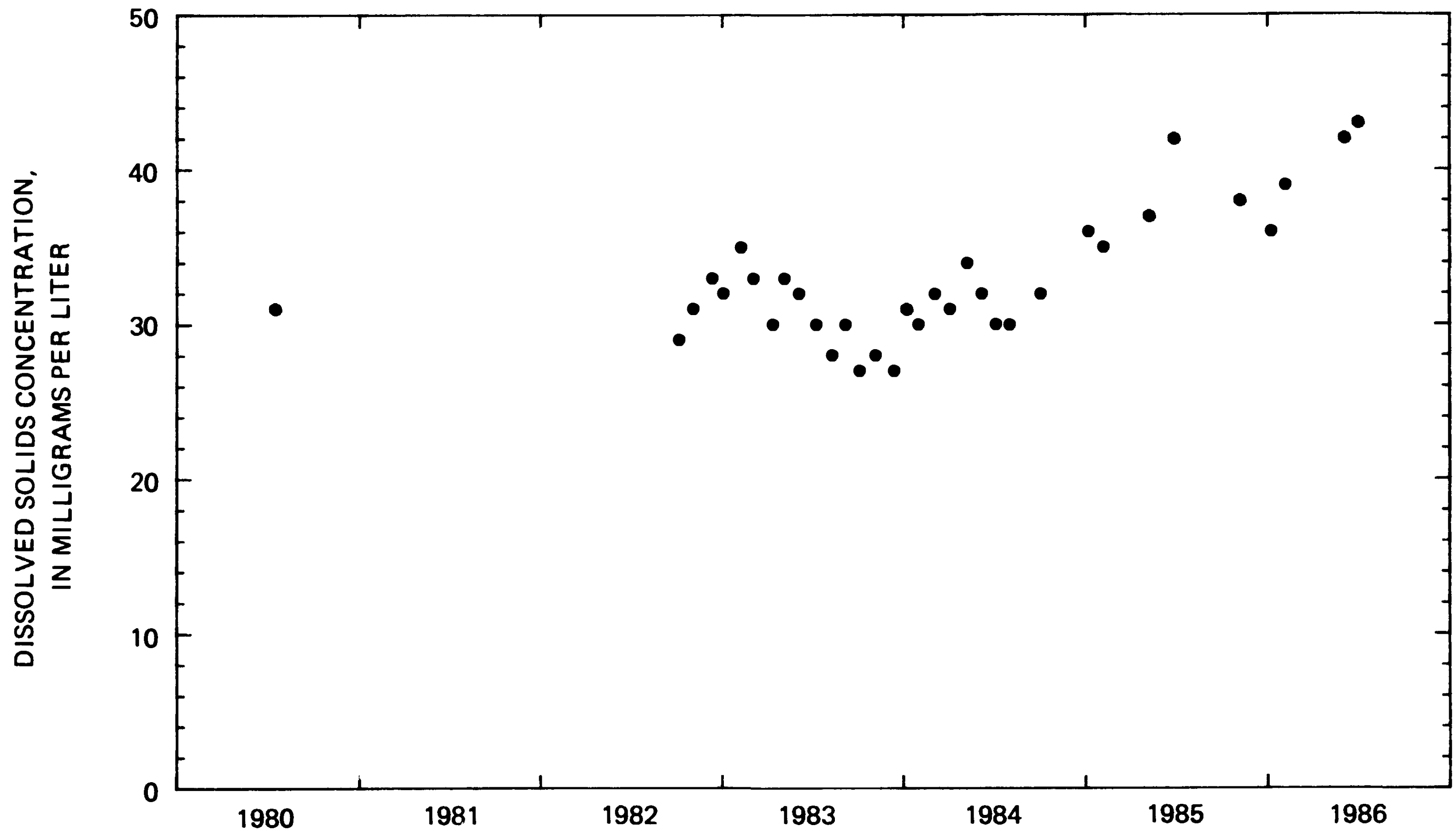

Figure 14.-- Dissolved solids concentration of Lake Tuscaloosa at the dam (site 16), 1980-86.

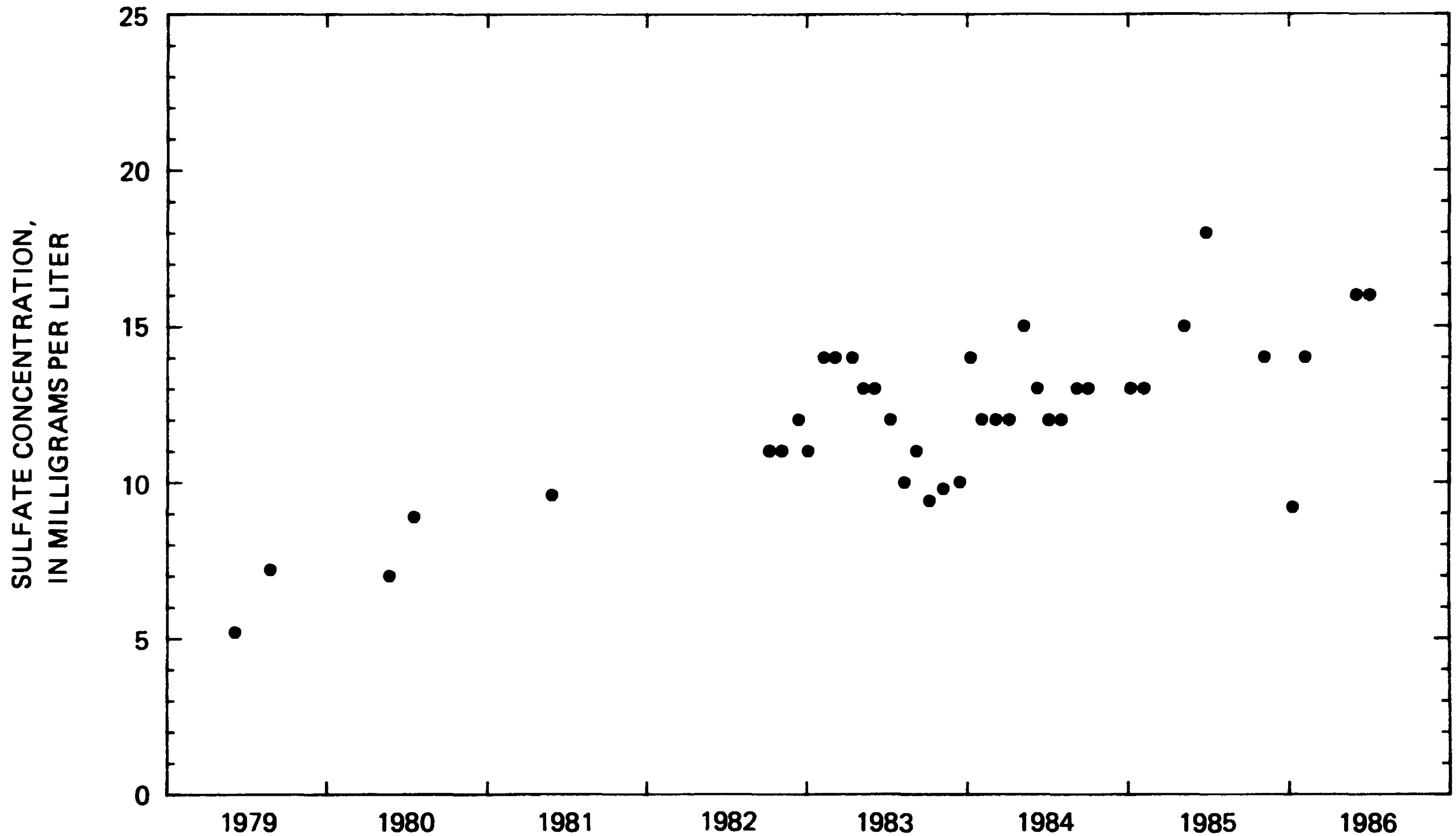

Figure 15.-- Sulfate concentration of Lake Tuscaloosa at the dam (site 16), 1979-86.

Table 7.--Maximum and median annual sulfate concentrations in water at North River (site 1) and Lake Tuscaloosa (site 16), water years 1979-86.

	Sulfate concentrations, in milligrams per liter			
	North River		Lake Tuscaloosa	
Water year	Maximum	Median	Maximum	Median
1979	20	11	7.2	6.2
1980	39	12	8.9	8.0
1981	57	16	9.6	9.6
1982	51	19	12	11
1983	62	19.5	14	11.5
1984	32	17.5	15	12.5
1985	25	17.5	18	14
1986	180	19	16	14

Dissolved oxygen, temperature, specific conductance, and pH depth profiles were obtained at five sites on Lake Tuscaloosa (sites A to E, table 1 and fig. 2) in March and November 1985, and January and March 1986. Dissolved oxygen and temperature profiles were obtained twice (site E) in December 1985 to determine if significant changes in these constituents and properties (which largely control the solubility, chemical reactions, and stability of constituents in the water) were occurring before and after lake turnover. (See figs. 16-27.)

Lake turnover refers to the rapid circulation of much or most of the water in a lake. Turnover is caused by the movement of cooler, more dense water to the bottom and the simultaneous movement of warmer, less dense water to the upper portion of a lake. Turnover of the lake usually takes place in late fall or early winter. In 1985-86, the turnover began in late December and was completed in early January.

In March 1985, following the fall/winter turnover, water quality at all five profile sites was acceptable for most uses. Specific conductance values were in the 50's and 60's (uS/cm); the pH ranged from 5.7 to 6.8; the dissolved oxygen concentration ranged from about 8.0 to 9.8; and the temperature ranged from about 6 to 14 °C. (See figs. 16-20.)

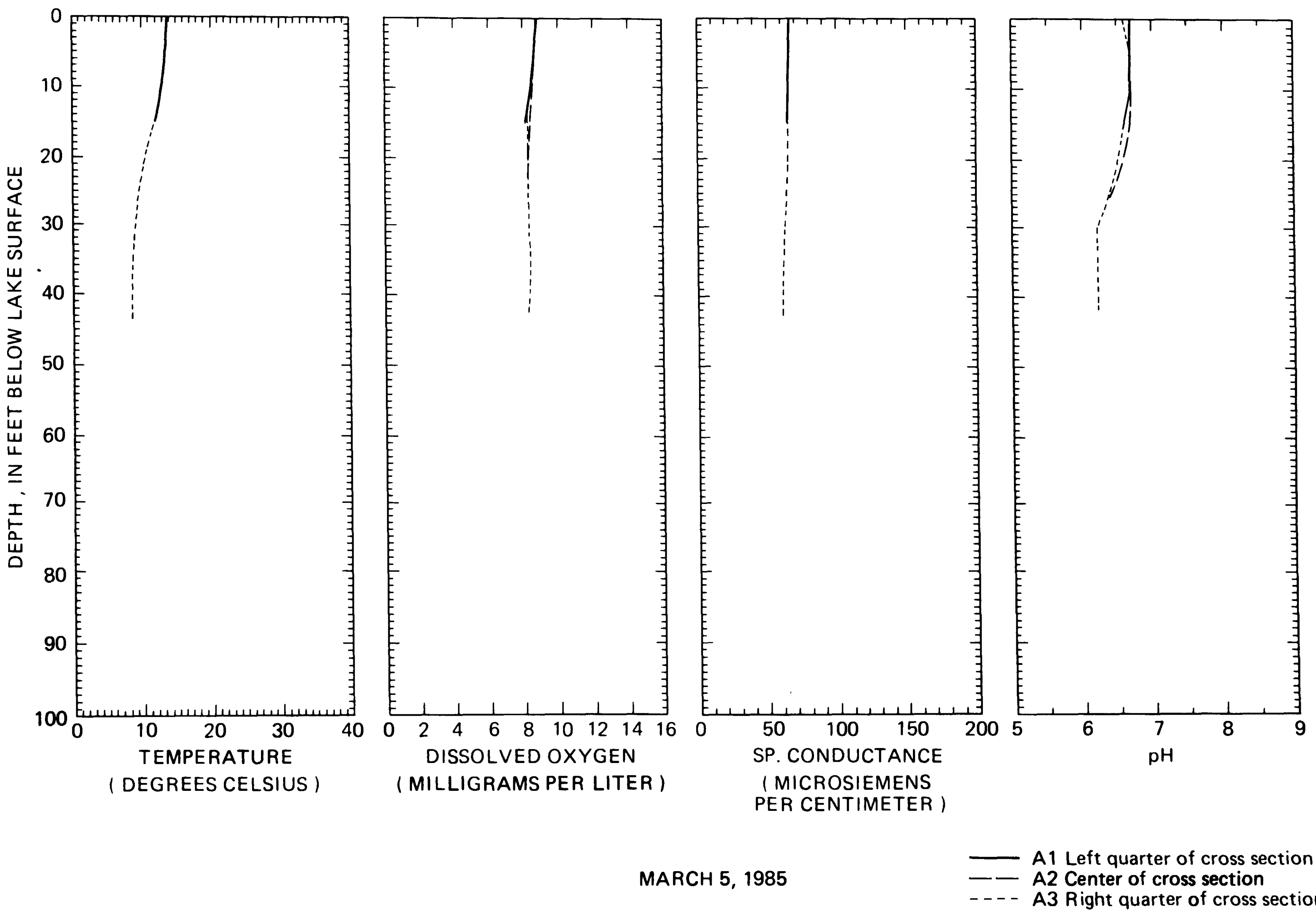

Figure 16.-- Water-quality profiles, Lake Tuscaloosa, March 1985: site A.

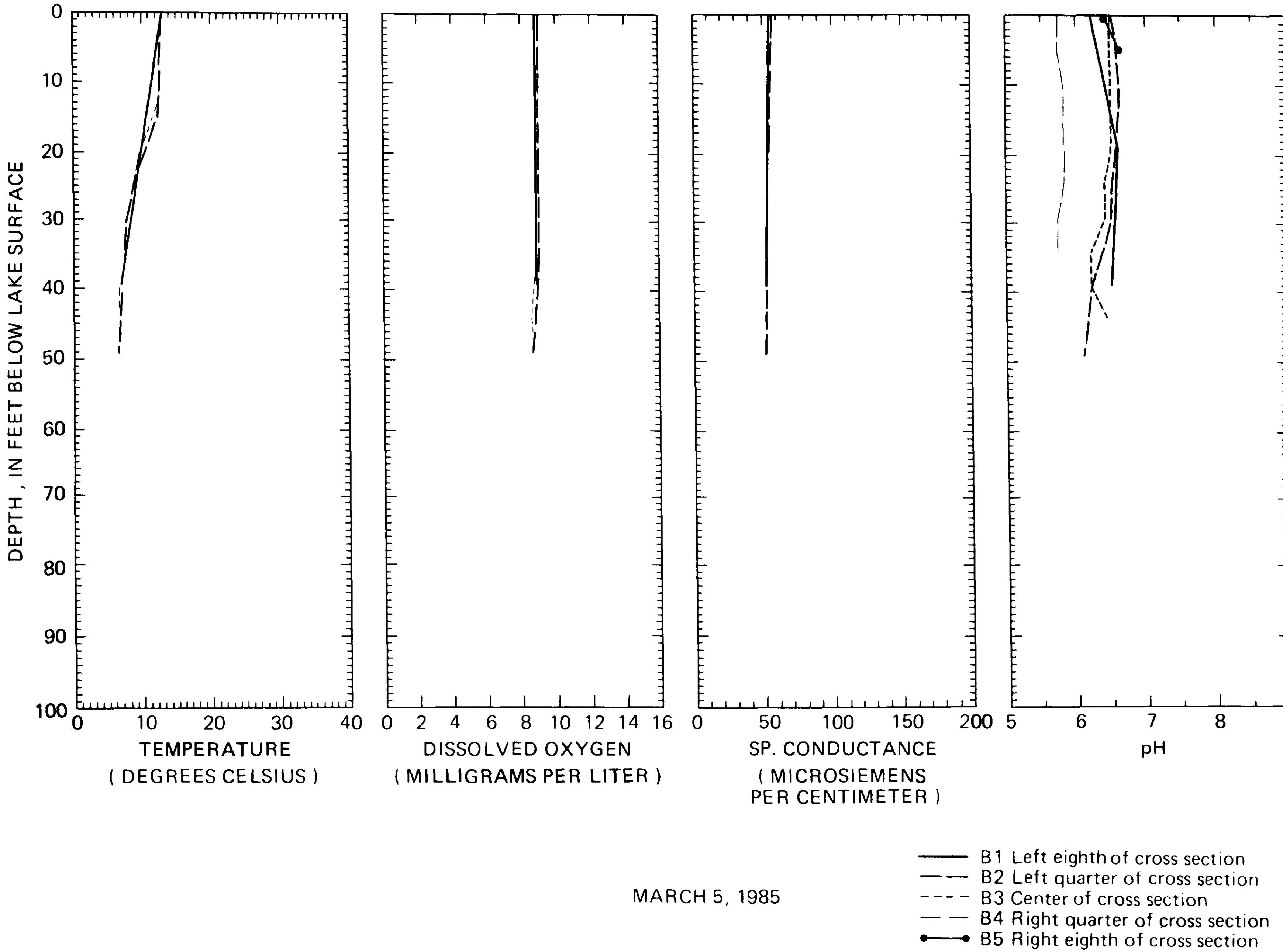

Figure 17.-- Water-quality profiles, Lake Tuscaloosa, March 1985: site B.

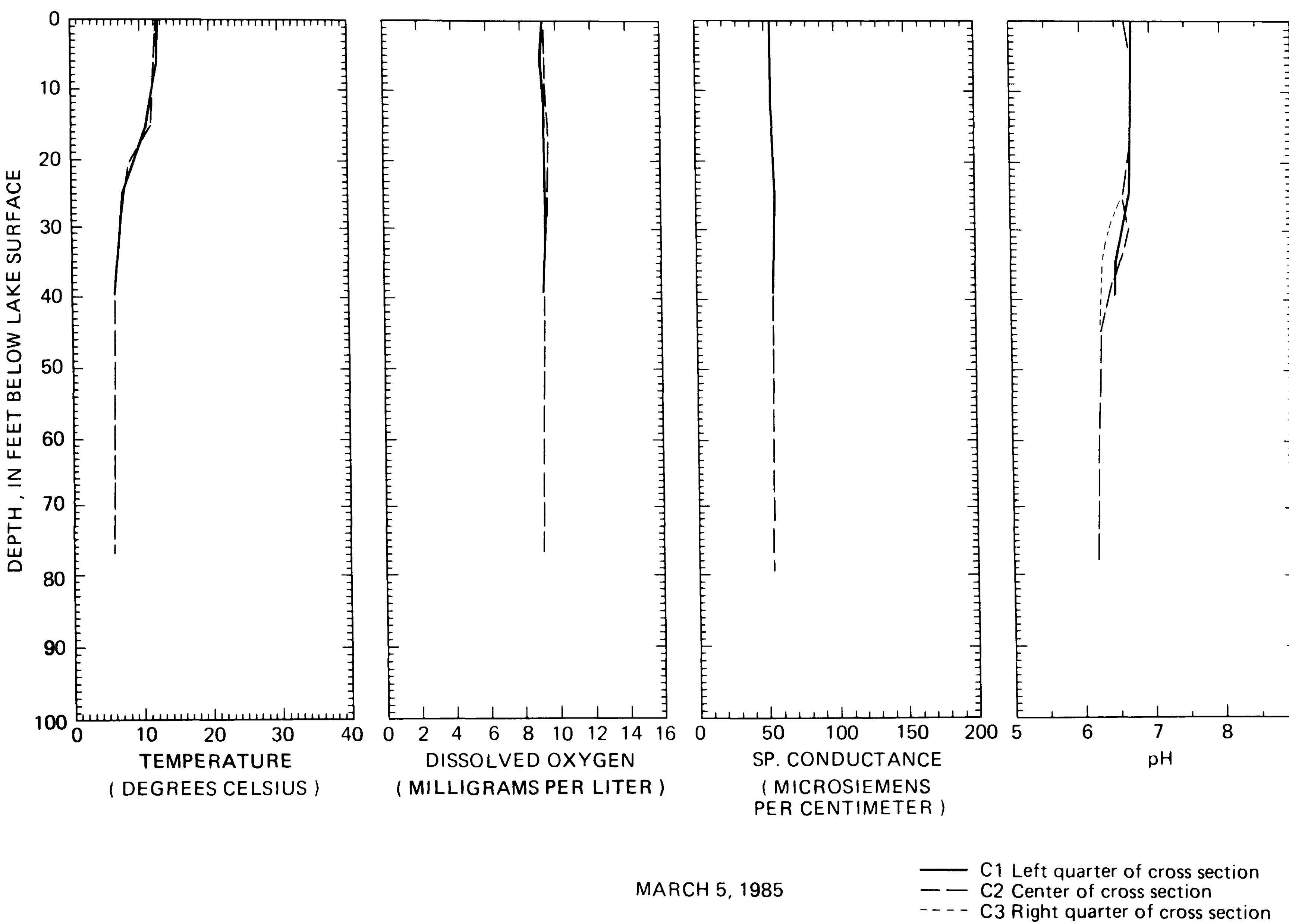

Figure 18.-- Water-quality profiles, Lake Tuscaloosa, March 1985: site C.

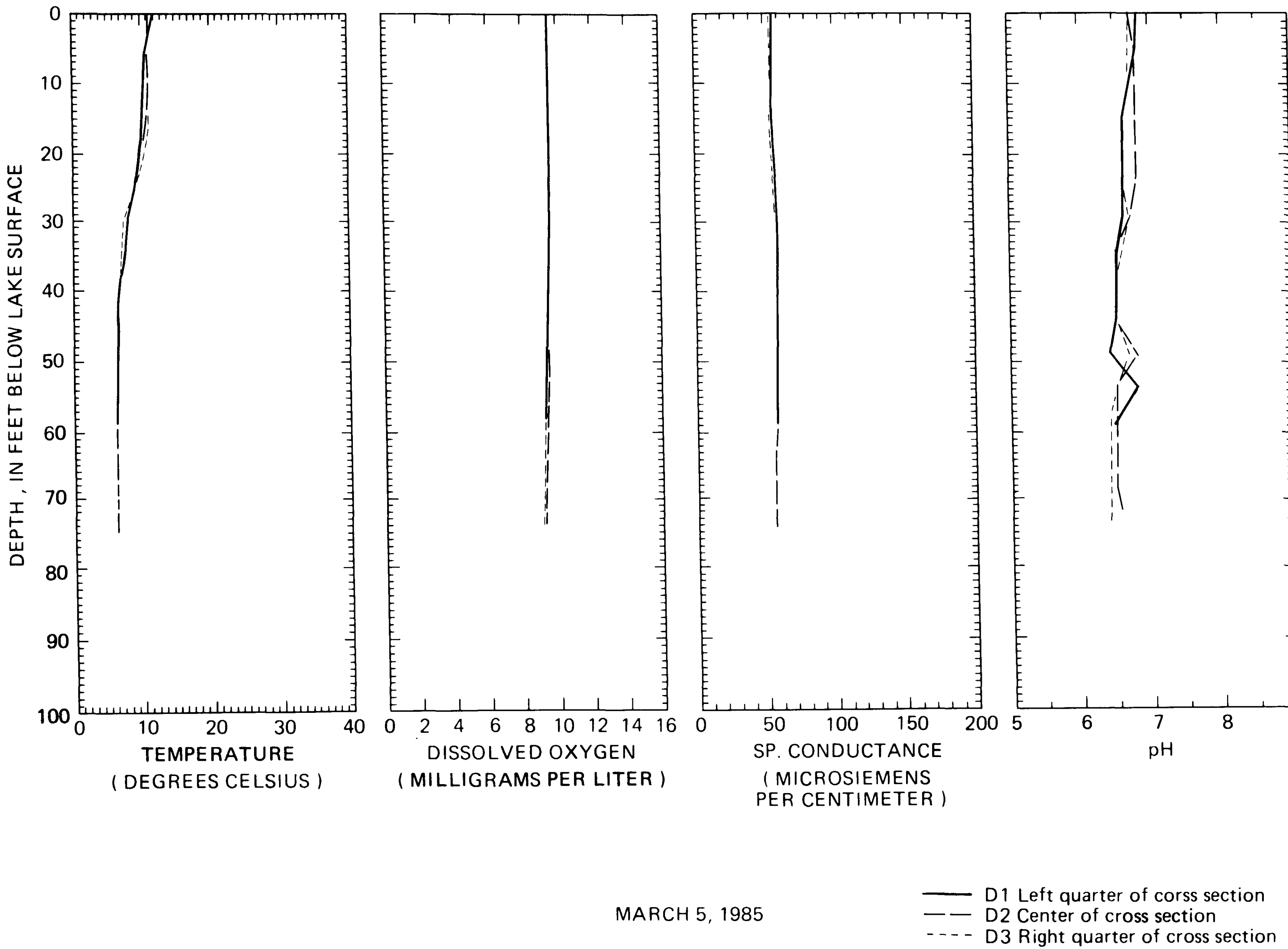

Figure 19.-- Water-quality profiles, Lake Tuscaloosa, March 1985: site D.

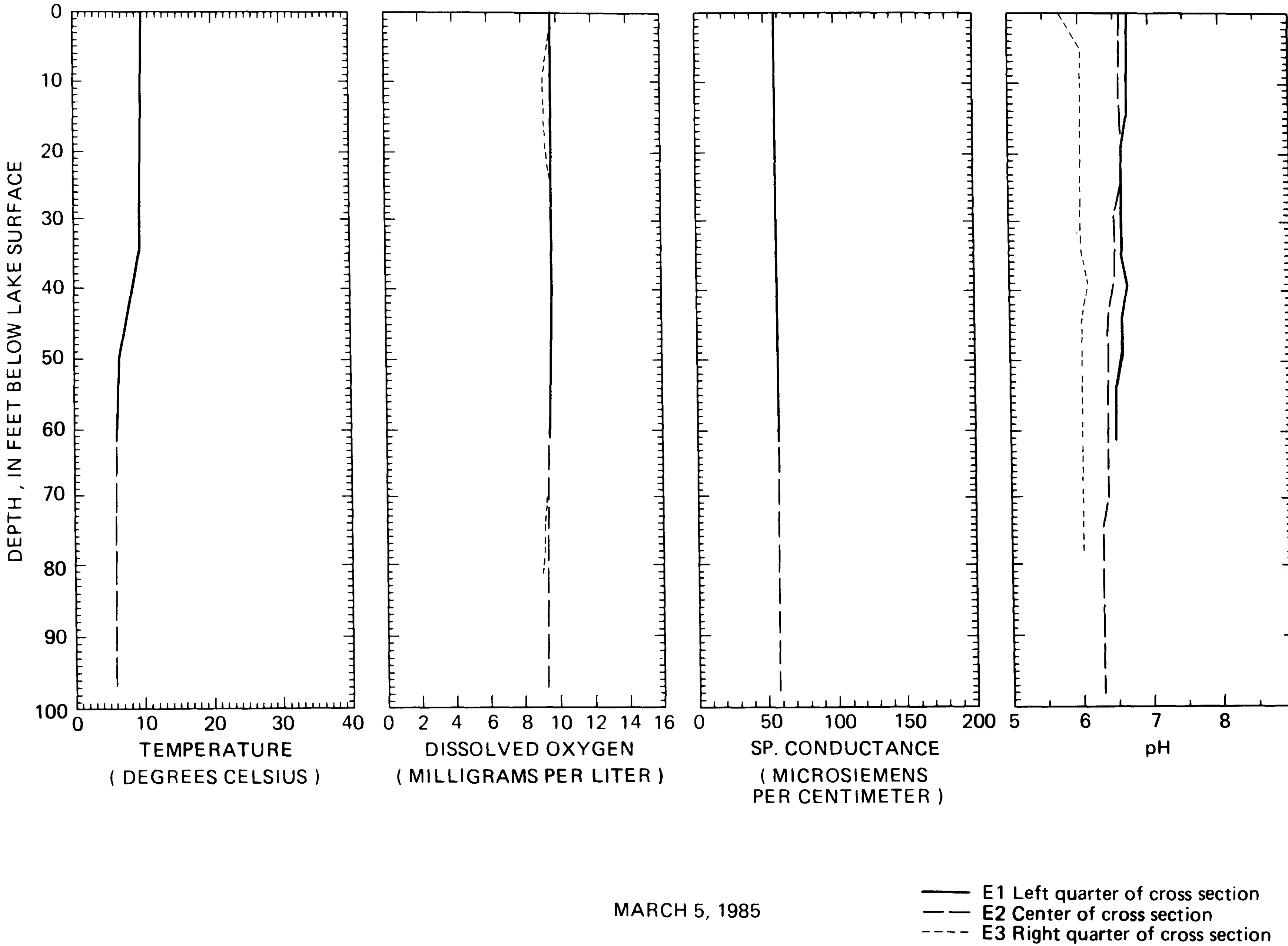

Figure 20.-- Water-quality profiles, Lake Tuscaloosa, March 1985: site E.

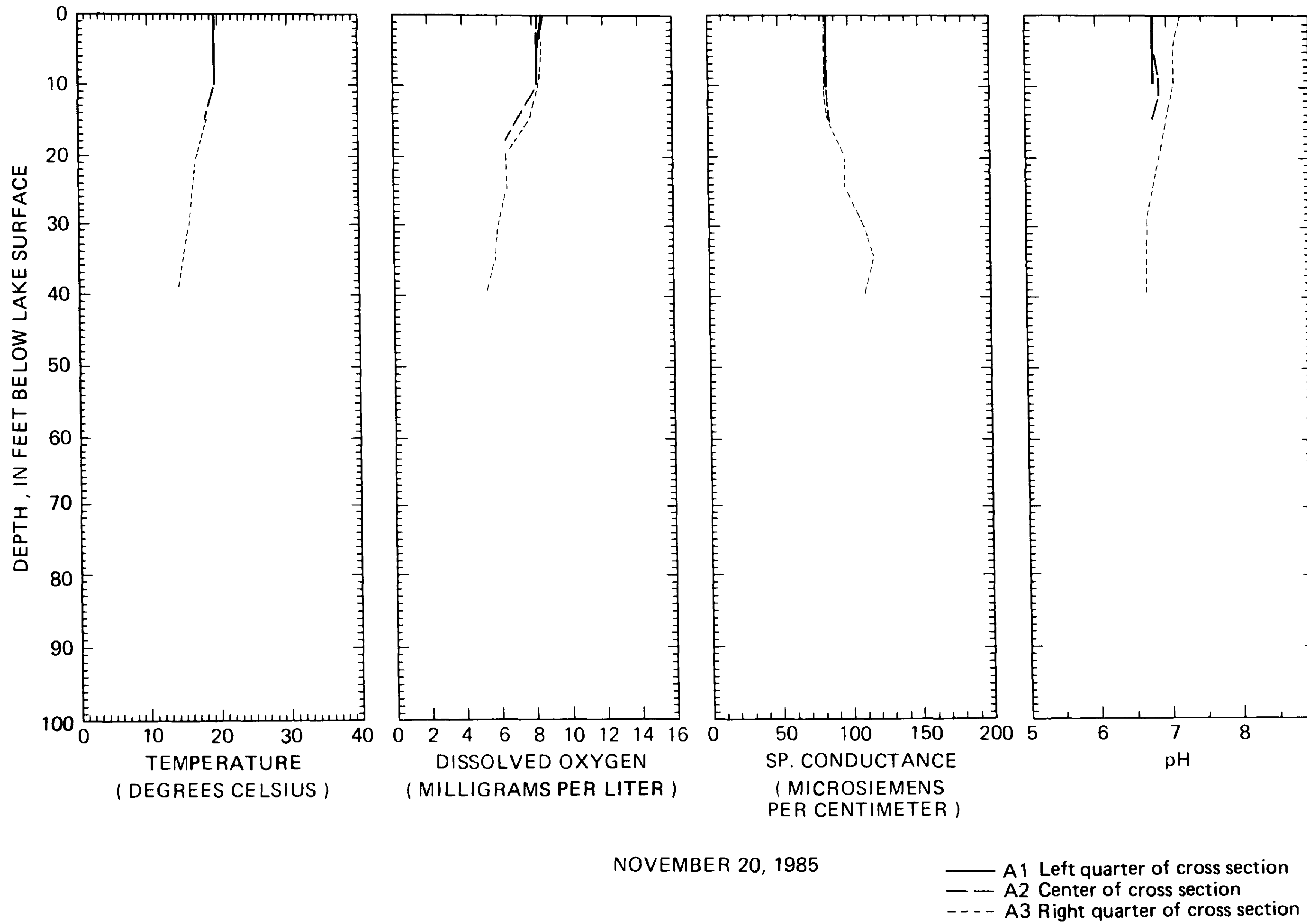

Figure 21.-- Water-quality profiles, Lake Tuscaloosa, November 1985: site A.

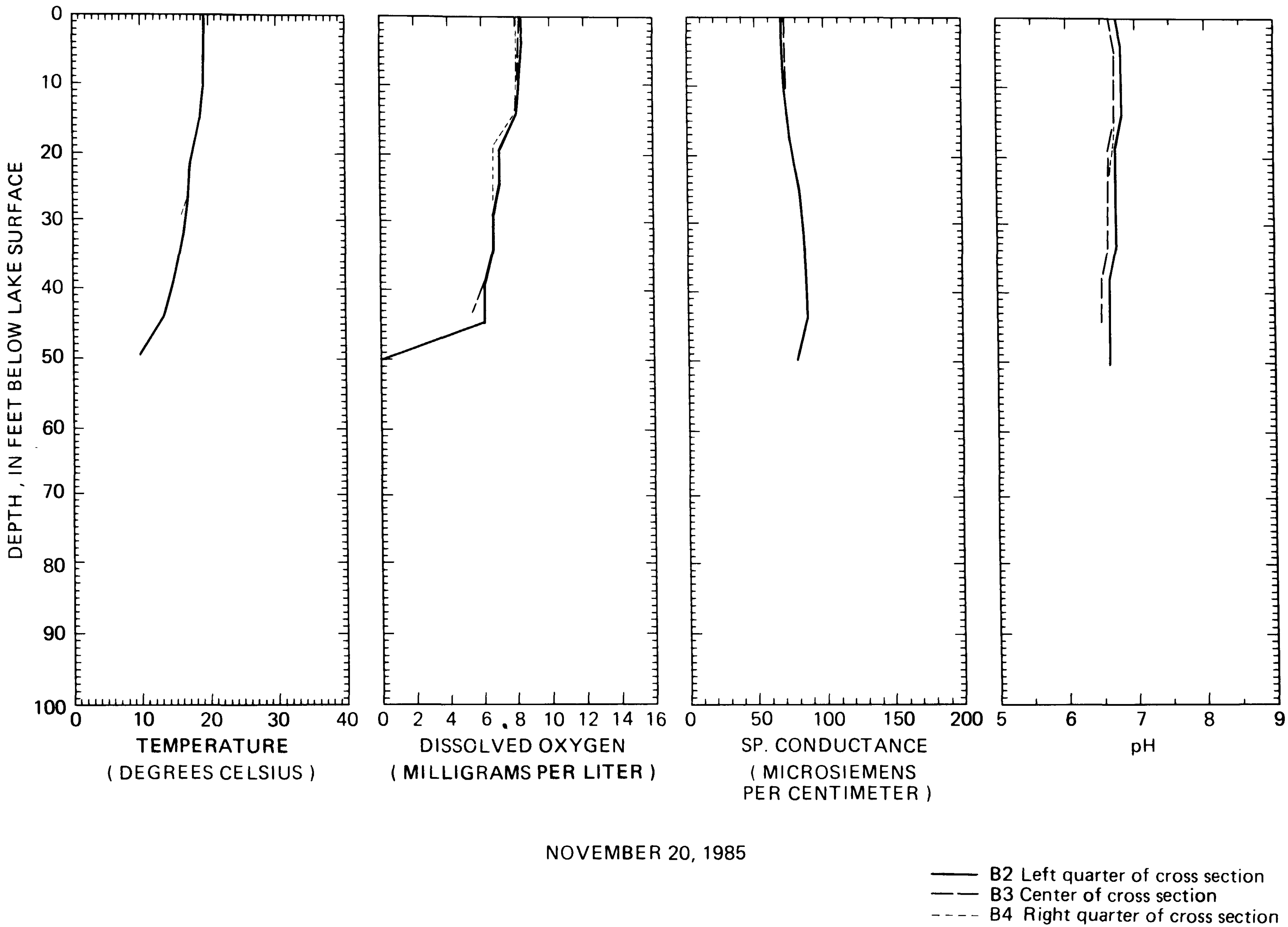

Figure 22.-- Water-quality profiles, Lake Tuscaloosa, November 1985: site B.

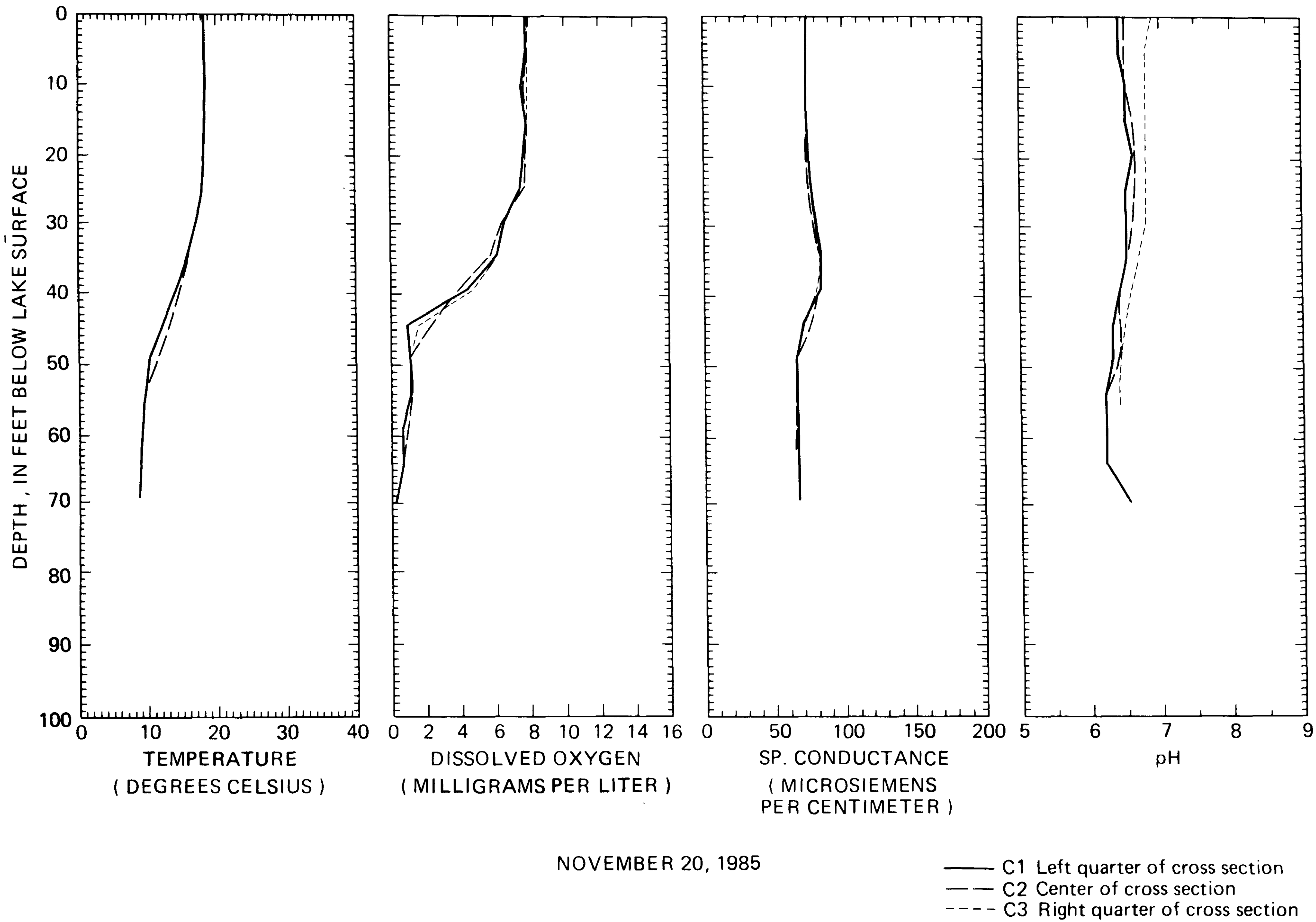

Figure 23.-- Water-quality profiles, Lake Tuscaloosa, November 1985: site C.

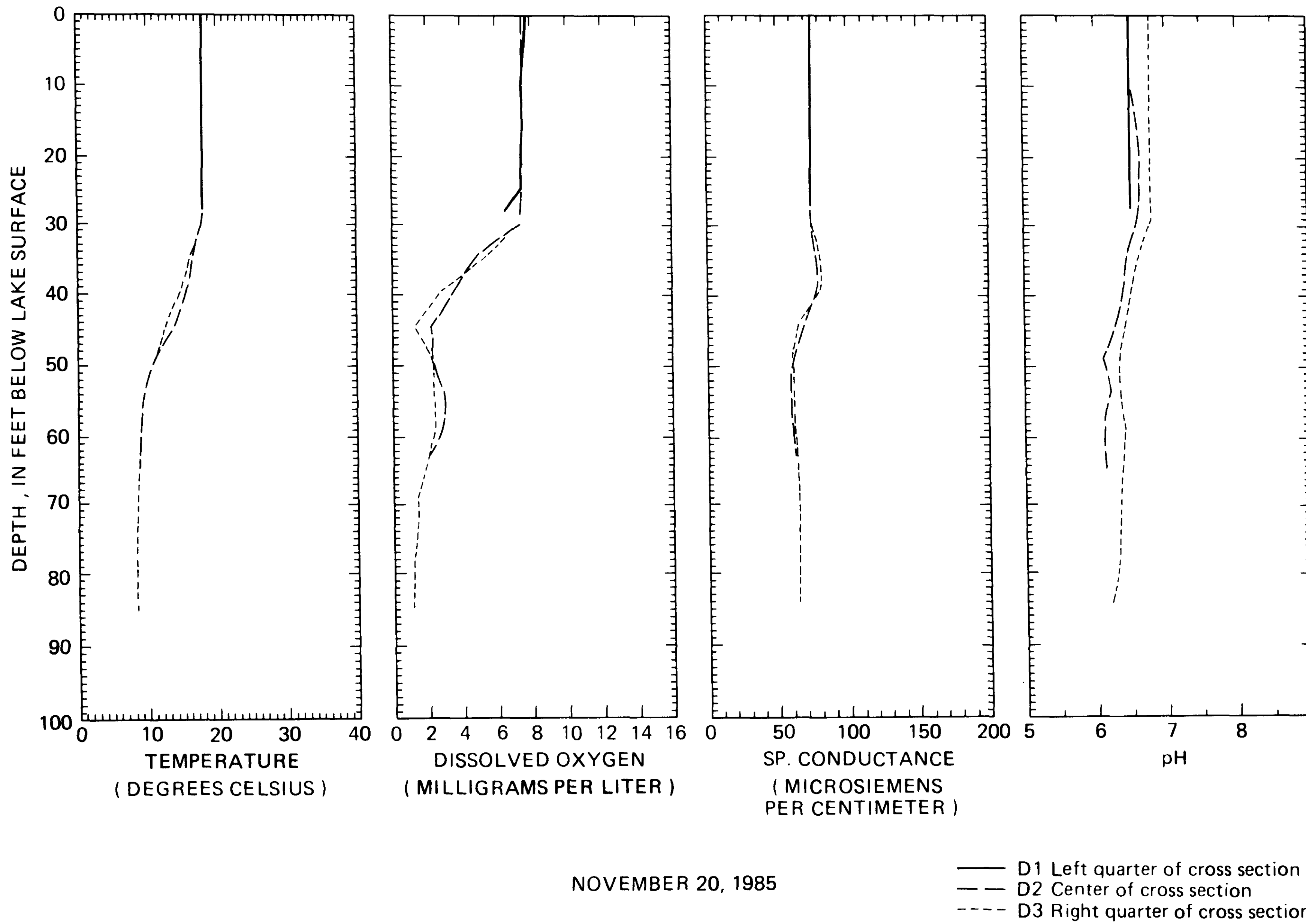

Figure 24.-- Water-quality profiles, Lake Tuscaloosa, November 1985: site D.

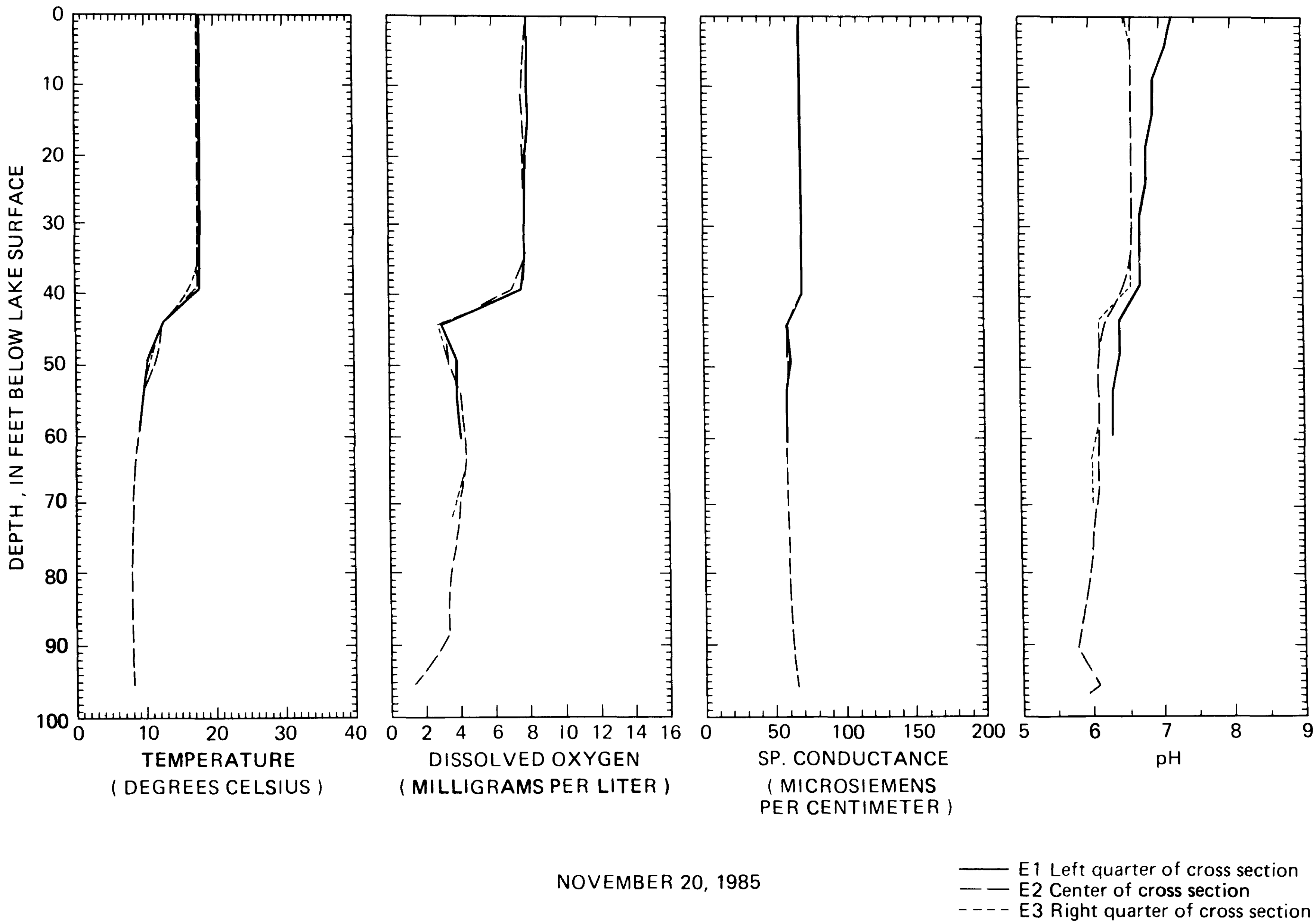

Figure 25.-- Water-quality profiles, Lake Tuscaloosa, November 1985: site E.

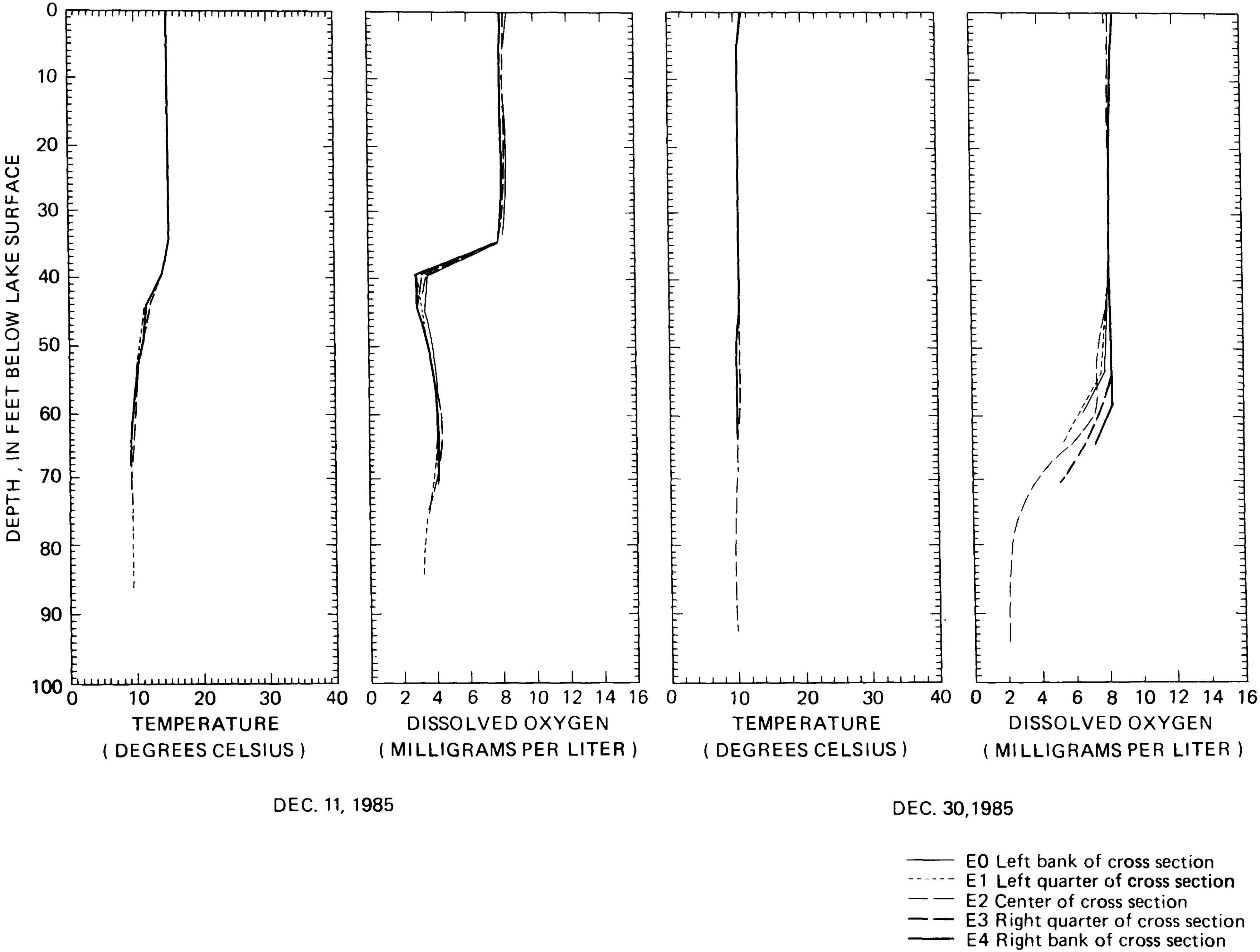

Figure 26.-- Water-quality profiles, Lake Tuscaloosa, site E: December 11 and 30, 1985.

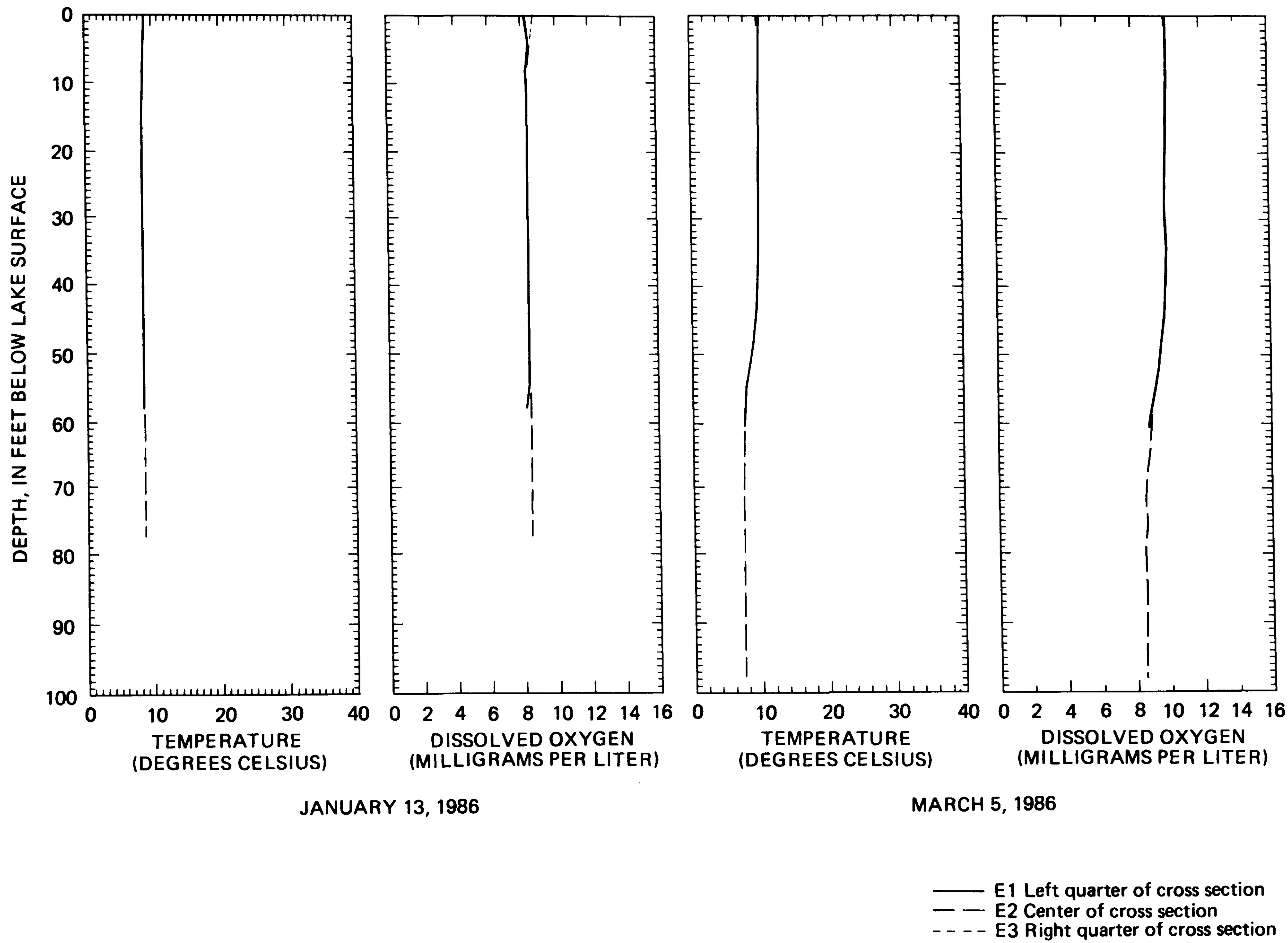

Figure 27.-- Water-quality profiles, Lake Tuscaloosa, site E: January and March 1986.

The water at each of the sites was stratified with respect to temperature. Temperatures were highest at the surface and lowest at the bottom of each profile. The maximum change in temperature from top to bottom at any of the sites was about 6 °C at the center section at site C (depth 78 ft). Dissolved oxygen concentrations were highest at the surface and lowest at the bottom at each of the sites. However, at some of the profiles dissolved oxygen increased with depth from the surface for the upper part of the lake and then decreased slightly. The maximum decrease in dissolved oxygen concentration with depth was less than 1 mg/L at site E. Percent saturation was generally in the 70's and 80's. The conductance profiles showed no significant changes with depth. The pH values generally decreased slightly with depth. (See figs. 16-27.)

Some significant differences in pH profiles were observed in March 1985 at sites B and E. At site B, the pH at the right-quarter profile (B4) was about 1.0 to 1.7 units lower than the pH at the other profiles. Site B is near Lake Tuscaloosa at Highway 69--roughly two-thirds the distance downstream from Binion Creek to Carroll Creek. The pH anomaly may represent natural drainage from Binion Creek to the lake. However, because of the size of the lake, many additional profiles at more sites would be necessary for this to be determined. Similarly, the pH of the right-quarter profile (E3) at site E (Lake Tuscaloosa at the dam) was about 0.5 to 2.0 units lower than the pH at the middle and left-quarter profiles. However, no significant differences were observed in pH profiles at sites A, C, and D.

It is interesting to note that by November 1985, the pH profiles had changed considerably. At site A the right quarter pH profile was about 0.4 to 0.7 unit higher than the pH at the center and left quarter. At site B the left quarter pH was 0.2 to 0.3 unit larger than the pH at the center and right quarter. At site C the right-quarter pH profile was about 0.2 to 1.0 unit larger than the pH at the center and left quarter. At site D the right-quarter pH profile was about 0.2 to 0.6 unit larger than at the center and left quarter. At site E the left-quarter profile was about 0.2 to 1.5 units larger than at the center and right quarter. Some of the pH differences may be associated with differences in basin drained, inflow, turnover, and other mixing factors. (See figs. 21-25.)

In November 1985, following the summer warmup and increase in biological activity, the water quality at all five sites was still good, generally. The specific conductance ranged from 58 to 118 uS/cm; the pH ranged from 5.9 to 7.3; at a depth of about 35 ft or less, the dissolved oxygen ranged from about 5 to 8 mg/L; the temperature ranged from about 8 to 20 °C. (See figs. 21-25.)

At site B (left quarter) at a depth of 50 ft the dissolved oxygen dropped to 0.4 mg/L. All the other dissolved oxygen concentrations for site B varied from 5.5 to 8.5 mg/L. At site C the dissolved oxygen concentration dropped to less than 5 mg/L at all depths greater than 35 ft. A dissolved oxygen concentration of 1 mg/L or less was observed at the bottom 5 or 10 ft for all three profiles (midstream, left quarter, and right quarter). At site D at depths greater than about 35 ft, all the dissolved oxygen values were less than 5 mg/L. The dissolved oxygen concentration at the bottom was 1.6 and 1.0 mg/L for the two deeper profiles (midstream and right quarter). The left quarter was only 28 ft deep. At site E, at depths greater than about 40 ft the dissolved oxygen concentration was less than 5 mg/L. The dissolved oxygen concentration at the bottom was 1.3, 4.0, and 3.8 mg/L for the center, left and right quarters, respectively. Most of the sites had only small changes (a few tenths of a pH unit) in pH with depth. For those sites which did show a change, the trend was decreasing pH with increasing depth. The maximum change in pH with depth was 0.9 pH unit at site E (left quarter).

At the end of December 1985 (mid turnover), at site E the maximum range in temperature from surface to bottom was 11.0 to 9.5 °C (or a difference of -1.5 °C). The dissolved oxygen concentration was greater than 7 mg/L for all depths of 55 ft or less. The only dissolved oxygen concentrations less than 5 mg/L were at depths of about 70 ft or more at the center section. The bottom dissolved oxygen concentration at the center section was 1.8 mg/L. (See fig. 26.)

By January 13, 1986, the temperature and dissolved oxygen profiles were practically constant from top to bottom at all five sites (A-E), indicating turnover was complete (fig. 27). As reported for the earlier profiles, though, significant variation existed in pH profiles.

SUMMARY

Lake Tuscaloosa, created in 1969 by impoundment of North River, provides the primary water supply for Tuscaloosa and surrounding areas. Changes in land use, such as surface coal mining, timber clear-cutting, agriculture, and residential development, have caused concern about possible changes in the water quality of Lake Tuscaloosa and its tributaries. However, coal mining in the Lake Tuscaloosa basin is the only land-use change that has significantly affected the water quality of the lake.

During base-flow conditions, about 60 percent of the total flow into Lake Tuscaloosa is contributed by Binion and Carroll Creeks, which drain only 22 percent of the Lake Tuscaloosa basin. Binion and Carroll Creek basins are underlain primarily by sand and gravel deposits of the Cretaceous Coker Formation. Poorly sustained flows are characteristic of the North River and Little, Cripple, Dry, Tierce, and Brush Creeks, which are underlain primarily by the relatively impermeable Pottsville Formation.

Mean inflow to the lake was 1,150 ft^3/s during 1983, a wet year, and 450 ft^3/s during 1985, a relatively dry year. More than 80 percent of the total inflow during both years was contributed by North River and Binion, Cripple, and Carroll Creeks. About 59 percent was contributed by North River.

Except for pH, sulfate, and dissolved and total recoverable iron and manganese, the water quality of the tributaries is generally within drinking water limits and acceptable for most uses. However, the water quality of some streams that receive drainage from mined areas--North River, Little, Cripple, and Turkey Creeks--is deteriorating.

The median pH for most streams that drain mined and unmined areas was less than the 6.5 recommended minimum, but this is common for the area. The minimum pH of 4.4 occurred in an unmined basin (Brush Creek) and is nearly the same as the minimum reported for other streams that drain undisturbed basins in the area.

During both low- and high-flow conditions, sulfate was the primary anion for streams draining areas with significant surface mining--North River and Little, Cripple, and Turkey Creeks. Increases in specific conductance, sulfate, and dissolved and total recoverable iron and manganese concentrations occurred during mining (1977-86) at each of these sites but were greatest for Cripple Creek. Bicarbonate is the primary anion during low flow for Dry, Binion, Carroll, and Brush Creeks and represents natural water quality for the Lake Tuscaloosa basin.

The water quality of Lake Tuscaloosa is generally within drinking water limits and acceptable for most uses. The trend of increasing mineralization of Lake Tuscaloosa was similar to, and largely caused by, the trend of increasing mineralization of the water in the North River. The maximum and median concentrations of sulfate increased every year at the dam from 1979 to 1985 (7.2 to 18 mg/L and 6.2 to 14 mg/L, respectively).

With only an estimated 5 percent of the basin mined, the dissolved solids concentrations for water at the dam has increased between 1979 and 1986 from 27 to 43 mg/L; the sulfate, 5.2 to 18 mg/L; and the dissolved iron, 10 to 250 ug/L--all well within the recommended drinking-water limits. However, concentrations of dissolved manganese and total recoverable iron and manganese at the dam commonly exceeded the recommended drinking-water limits.

In March 1985, water quality at five depth profile sites on the lake was acceptable for most uses. In November 1985, after the summer warmup and increase in biological activity, the water quality at all five sites was still acceptable, generally. The specific conductance ranged from 58 to 118 uS/cm; the pH ranged from 5.9 to 7.3; at a depth of about 35 ft or less, the dissolved oxygen ranged from about 5 to 8 mg/L; the temperature ranged from about 8 to 20 °C. However, a dissolved oxygen concentration of 1 mg/L or less was observed at the bottom 5 or 10 ft for several depth profiles. At several sites, at depths greater than about 35 to 40 ft the dissolved oxygen concentration was less than 5 mg/L.

At the end of December 1985, the only dissolved oxygen concentrations less than 5 mg/L at the dam (site E) were at depths of about 70 ft or more at the center section.

By January 13, 1986, the temperature and dissolved oxygen depth profiles were practically constant from top to bottom at all five sites. This indicated that the lake turnover was complete. However, significant variation existed in pH profiles.

SELECTED REFERENCES

Almon and Associates, 1976, Water-quality management in the Lake Tuscaloosa watershed: Report to the City of Tuscaloosa, Alabama, in response to public law 92-500, 110 p.

Bingham, R. H., 1979, Low-flow characteristics of Alabama streams: Alabama Geological Survey Bulletin 117, 39 p.

Cole, E. F. 1985, Effects of coal mining on the water quality and sedimentation of Lake Tuscaloosa and selected tributaries, North River basin, Alabama: U.S. Geological Survey Water-Resources Investigations Report 84-4310, 53 p.

Culbertson, W. C., 1964, Geology and coal resources of the coal-bearing rocks of Alabama: U.S. Geological Survey Bulletin 1182-B, 79 p.

Drennen, C. W., 1961, Geologic map of Tuscaloosa County, Alabama: Alabama Geological Survey Special Map 16.

Farnsworth, R. K., Thompson, E. S., and Peck, E. L., 1982, Evaporation atlas for the contiguous 48 United States: National Oceanic and Atmospheric Administration, NOAA Technical Report NWS 33, 26 p.

Fenneman, N. M., 1938, Physiography of eastern United States: New York, McGraw-Hill, 724 p.

Frentz, H. J., and Lynott, W. P., 1978, Baseline study of the climate and air quality of Fayette, Walker, Jefferson, and Tuscaloosa Counties, Alabama: Science Applications, Inc., Report to the Bureau of Land Management (contract no. 1-022-03-080-62), 274 p.

Harkins, J. R. and others, 1980, Hydrologic assessment, Eastern Coal Province Area 23, Alabama: U.S. Geological Survey Water-Resources Investigations Report 80-683, 76 p.

Hubbard, E. F., 1976a, Sedimentation in Lake Tuscaloosa, Alabama: U.S. Geological Survey Open-File Report 76-158, 35 p.

_____ 1976b, Water-quality reconnaissance of Lake Tuscaloosa, Alabama, March-June 1975: U.S. Geological Survey Open-File Report 76-160, 34 p.

Keener, M. J., Moore, J. D., and Hubbard, E. F., 1975, Geologic and hydrologic investigation of the Lake Tuscaloosa drainage basin: Geological Survey of Alabama, Draft report to the City of Tuscaloosa (contract no. GSA-74-15), 196 p.

Metzger, W. J., 1965, Pennsylvania stratigraphy of the Warrior basin, Alabama: Alabama Geological Survey Circular 30, 80 p.

Puente, Celso, and Newton, J. G., 1979, Effects of surface coal mining on the hydrology of Crooked and Turkey Creek basins, Jefferson County, Alabama: U.S. Geological Survey Water-Resources Investigations Report 79-91, 39 p.

_____ 1982, Hydrology of potential mining areas in the Warrior Coal Field, Alabama: U.S. Geological Survey Open-File Report 82-105, 83 p.

Puente, Celso, Newton, J. G., and Bingham, R. H., 1982, Assessment of hydrologic conditions in potential coal-lease tracts in the Warrior Coal Field, Alabama: U.S. Geological Survey Water-Resources Investigations Report 81-540, 43 p.

Puente, Celso, Newton, J. G., and Hill, T. J., 1980, Hydrology of selected basins in the Warrior coal field, Alabama--A progress report: U.S. Geological Survey Water-Resources Investigations Report 80-22, 62 p.

Riggs, H. C., 1969, Mean streamflow from discharge measurements: International Association of Science Hydrology Bulletin, vol. XIV, no. 4, December 1969.

Slack, L. J., 1983, Hydrology of an abandoned coal-mining area near McCurtain, Haskell County, Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 83-4202, 117 p.

U.S. Bureau of Land Management, 1980, Southern Appalachian regional coal environmental impact statement: U.S. Bureau of Land Management, 447 p.

_____ 1983, Southern Appalachian regional coal environmental impact statement II: U.S. Bureau of Land Management, 188 p.

U.S. Department of Agriculture, 1965, Soil survey, Fayette County, Alabama: Soil Conservation Service, Series 1962, No. 4.

_____ 1981, Soil survey of Tuscaloosa County, Alabama: Soil Conservation Service and Forest Service, 118 p., maps.

U.S. Department of Commerce, 1950-85, Climatological data for Alabama, National Oceanic and Atmospheric Administration climatological data reports (published monthly).

U.S. Environmental Protection Agency, 1986a, Secondary maximum contaminant levels (section 143.3 of part 143, national secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 587-590.

_____ 1986b, Maximum contaminant levels (subpart B of part 141, national interim primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 524-528.

West Alabama Planning and Development Council, 1979, Area wide waste treatment management plan for Tuscaloosa County, Alabama.