EFFECTS OF COAL MINING ON THE WATER QUALITY
AND SEDIMENTATION OF LAKE TUSCALOOSA
AND SELECTED TRIBUTARIES, NORTH RIVER BASIN, ALABAMA

By Elizabeth F. Cole

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

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
tons per square mile per year ($tons/mi^2$)/yr	0.3503	metric tons per square kilometer per year (metric t/km^2)/yr

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

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ABSTRACT

Lake Tuscaloosa, a reservoir on North River, is the primary source of water supply for the city of Tuscaloosa, Alabama, and surrounding areas. Coal mining in basins draining into the lake has caused concern about changes in the water quality and the rate of sedimentation in Lake Tuscaloosa.

Fourteen sites in the North River basin were sampled to determine if surface coal mining has impacted the quality of water in the lake and selected tributaries. An increase in mineralization of the reservoir water, primarily sulfate concentrations, has occurred since the beginning of major surface coal mining in the basin. Water draining mined basins showed increases in specific conductance, sulfate concentrations, and dissolved and total recoverable iron and manganese concentrations after mining started. These increases have contributed to the increased mineralization of the reservoir water. Although water in the reservoir has become more mineralized with only an estimated 5 percent of the basin mined, total dissolved solids concentrations are still very low, ranging from 28 to 35 milligrams per liter at the dam.

Water draining mined areas, such as Cripple Creek basin, is often very mineralized, particularly during low-flow conditions. Water draining Cripple Creek basin (low flow specific conductance equals 610 micromhos) contributes an estimated 310 tons per square mile per year of dissolved solids to the reservoir compared with water draining an unmined basin such as Binion Creek (low flow specific conductance equals 40 micromhos) which contributes an estimated 50 tons per square mile per year of dissolved solids to the reservoir.

Between October 1982 and September 1983, the quality of water at all sites, with some exceptions, was within limits of the National secondary drinking water standards (U.S. Environmental Protection Agency, 1982). Some samples downstream of mined areas contained sulfate concentrations exceeding the 250 milligrams per liter level with a maximum concentration of 700 milligrams per liter observed in one sample. The pH of water from streams draining mined and unmined basins generally was less than 6.5 with a minimum pH of 4.6 for two sites in unmined basins. Concentrations of total recoverable iron and manganese exceeded secondary drinking water standard levels in more than half the samples at most sampling sites. The maximum total recoverable iron concentration was 5,600 micrograms per liter, and the maximum total recoverable manganese concentration was 2,600 micrograms per liter.

A fathometer survey showed that from 2 to 20 feet of sedimentation has occurred at 14 of the 17 measured cross sections in Lake Tuscaloosa since impoundment. However, the maximum deposition measured was approximately 20 feet at a Lake Tuscaloosa cross section in Brush Creek basin, an unmined basin with steep overland and channel slopes. Therefore, natural factors affecting sediment deposition in the reservoir, such as steep overland and channel slopes, in some instances may cause more sedimentation in the lake than disruption due to coal mining. Because of a lack of data on sediment deposition between cross sections and in other parts of the lake, the amount of reservoir storage lost due to sedimentation is unknown.

INTRODUCTION

Lake Tuscaloosa, a reservoir in Tuscaloosa County in west-central Alabama (fig. 1), was created in 1969 by impoundment of North River. The principal function of the reservoir is to provide the primary water supply for the city of Tuscaloosa and surrounding areas. Secondary functions include recreation and shoreline residential development. Coal mining in basins draining into Lake Tuscaloosa has caused concern about the effects of mining on the quality of water and the rate of sedimentation in the lake and its tributaries. Other changes in land use, such as agriculture and timber clear-cutting in basins draining into the lake may also affect the reservoir water quality and rate of sedimentation.

Purpose and Scope

The purpose of this report is to document the effects of coal mining on the water quality and sedimentation of Lake Tuscaloosa and selected tributaries in the North River basin. The report also provides hydrologic information on present conditions in North River basin that can be used to identify effects of future land use changes on the reservoir and inflow tributaries. The study involved collection of streamflow and water-quality data at 14 sites in the North River basin and measurement of cross sections to document erosion and sediment accumulation at 17 locations in Lake Tuscaloosa during the 1983 water year (October 1982-September 1983). Data were compared with data from previous investigations to show changes in water quality and to evaluate the significance of sedimentation in the reservoir.

Previous Investigations

Most previous investigations have been reconnaissance in nature and provide limited information to define the hydrologic conditions of the reservoir since impoundment. Keener and others (1975) presented geologic and hydrologic data for Lake Tuscaloosa, its tributaries, and drainage basin. They described the geology in the general area, soil associations and thickness, and provided basic data on ground- and surface-water quality. They also presented baseline sedimentation data collected from a fathometer survey of 39 cross sections in the lake. Almon and Associates (1976) addressed requirements of the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, as they

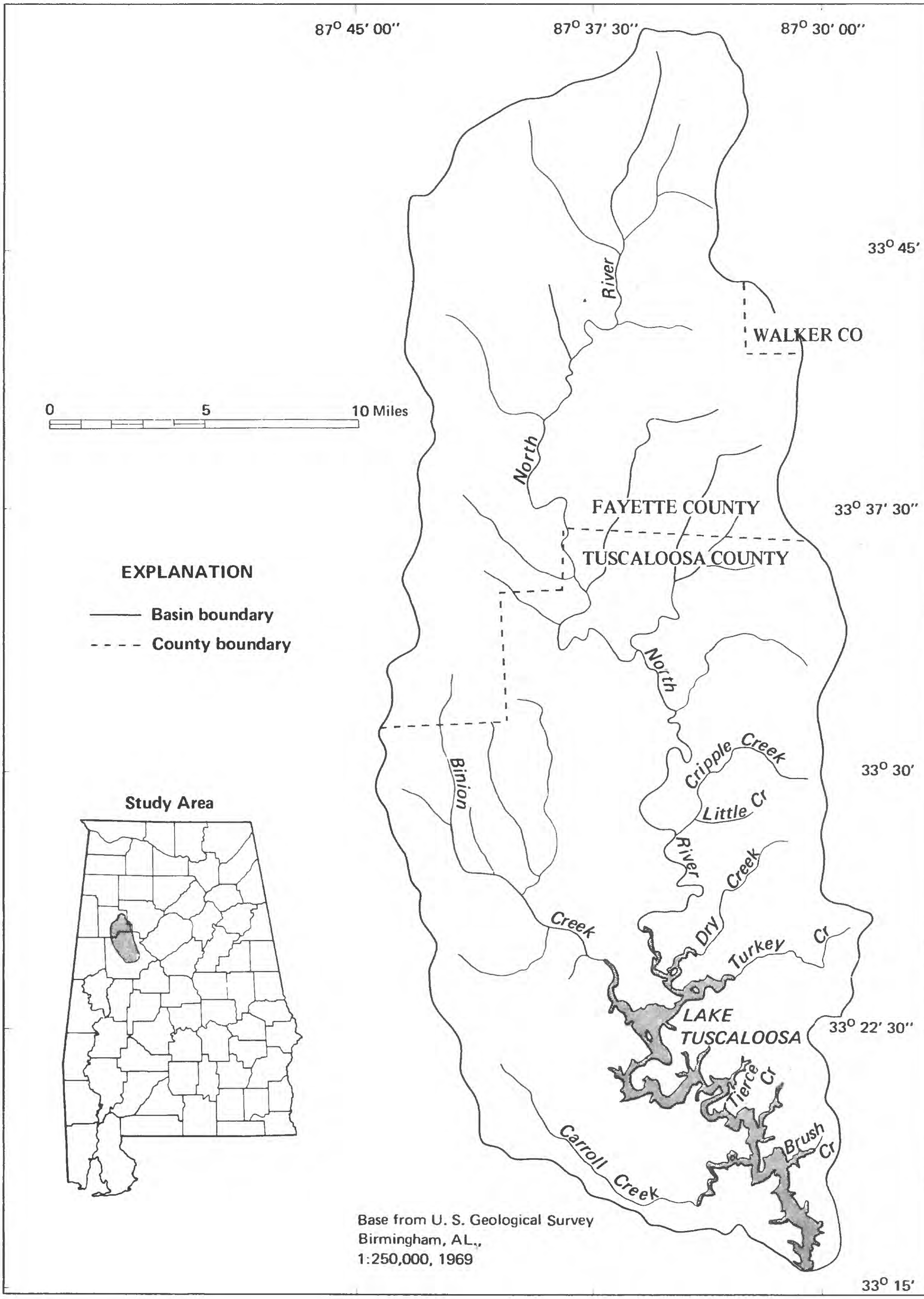


Figure 1.--Study area.

relate to the Lake Tuscaloosa area. Included were descriptions of the reservoir and drainage area, housing development information, and water-quality data. Hubbard (1976a) presented results of an investigation on the rate of sedimentation in Lake Tuscaloosa. He also addressed the magnitude of potential sedimentation that could result from an increase in logging activities, coal mining, construction, or agriculture in the basin. Hubbard (1976b) presented results of a water-quality reconnaissance study of the lake for the period March-June 1975 that included: standard chemical analyses of surface waters with analyses for nutrients and trace elements, bacteriological determinations, chemical analyses of bottom deposits, and temperature and dissolved oxygen vertical profiles. The West Alabama Planning and Development Council (1979) prepared an area-wide waste treatment management plan for Tuscaloosa County containing empirical and historical water-quality analyses of the major streams.

Several studies of the effects of coal mining on hydrology that are pertinent to this investigation have been made in the Warrior Coal Field. Puente and Newton (1979) reported the impact of surface coal mining on the hydrology of Crooked and Turkey Creek basins in Jefferson County. Puente and others (1980) provided baseline hydrologic information for selected basins. Harkins and others (1980) described the hydrology of part of the Warrior Coal Field that included the North River basin. The Bureau of Land Management (1980, 1983) assessed impacts of coal mining on Federal coal-lease tracts in North River and adjacent basins. Puente and Newton (1982) developed methods to estimate effects of surface mining on the hydrology of basins in the Warrior Coal Field. Puente and others (1982) described hydrologic conditions in four coal-lease tracts in the Warrior Coal Field.

Data-Collection Methods

Streamflow and (or) selected water-quality data were collected at 14 sites in the North River basin (fig. 2, table 1) to determine the impact of mining on surface water in the study area. Field measurements of streamflow, specific conductance, pH, alkalinity, water temperature, and dissolved oxygen were made at the time of sampling. Analyses of all samples were performed by the U.S. Geological Survey National Water Quality Laboratory-Atlanta, Doraville, Georgia and included major chemical constituents, selected nutrients, and some trace elements. Data collected during the study will be published in the annual data report for Alabama, and are not presented in this report. However, selected analyses and historic water-quality data are used to illustrate variations in chemical quality.

Water-quality samples collected at the lake stations (sites 9 and 14) were collected to represent the entire water column and cross section at the sampling location. Water was collected from the surface to the lake bottom from multiple verticals along a cross section and composited for analysis. Field determinations of temperature and dissolved oxygen were made approximately 2 ft below the water surface.

Cross sections were established at 17 locations in Lake Tuscaloosa in October and November 1982 to measure changes in sedimentation. The cross sec-

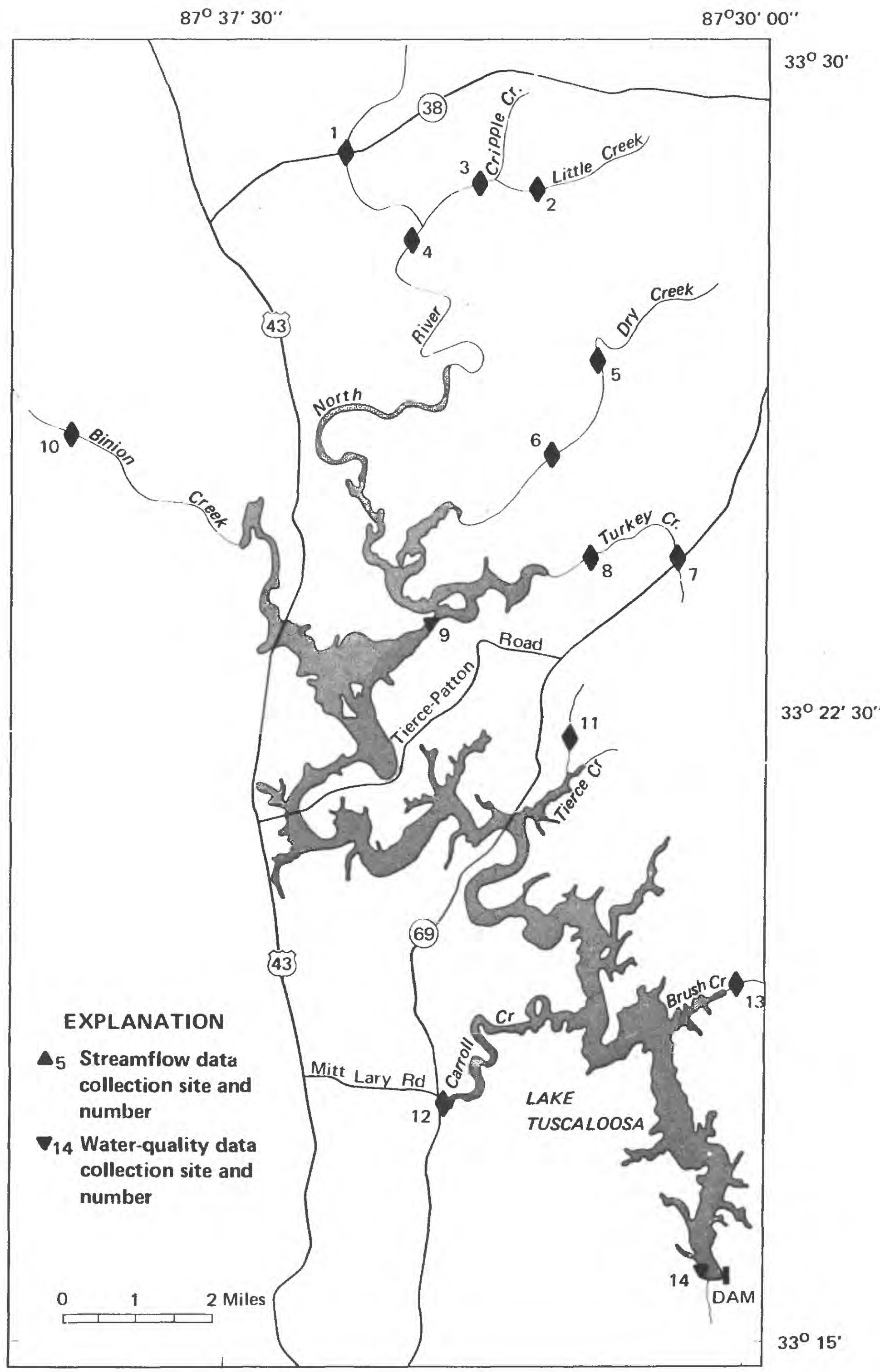


Figure 2.--Location of surface-water data collection sites. (See table 1.)

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	219	1938-54, 1968-83	1966-68, 1971-83	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	1977-83	1977-83	1979-83
4	02464040	North River 1500 ft below confluence of Cripple Creek	241	1982-83	1982-83	--
5	02464100	Dry Creek near Samantha	7.56	1981-83	1981-83	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	1982-83	1982-83	1982-83
9	02464155	Lake Tuscaloosa at Hilltop Estates Landing near Northport	282	--	1975,1983	1975
10	02464360	Binion Creek below Gin Creek near Samantha	57.0	1982-83	1982-83	1982-83
11	02464505	Tierce Creek near Northport	2.17	1983	1983	1983
12	02464660	Carroll Creek at State Highway 69 near Northport	20.9	1983	1983	1983
13	02464680	Brush Creek near Northport	0.92	1983	1983	1983
14	02464800	Lake Tuscaloosa Reservoir near Tuscaloosa	417	--	1975,1983	1975

tions were located near points of inflow because most settling and deposition of sediment occur where decreases in streamflow velocity occur. Bottom profiles were recorded at each cross section using a fathometer which produces a pen trace of the lake bottom through reflection of a sonic signal. The accuracy of the fathometer is reported to be ±1.0 ft. Elevation of the lake surface was 223.1 ft above sea level during the survey.

Pre-impoundment cross sections were taken from topographic maps (5-foot contour interval) of the area furnished by the city of Tuscaloosa. Keener and others (1975) recorded 39 cross sections in Lake Tuscaloosa in 1975. Data for these cross sections were not available for additional comparison because their locations could not be verified.

DESCRIPTION OF THE STUDY AREA

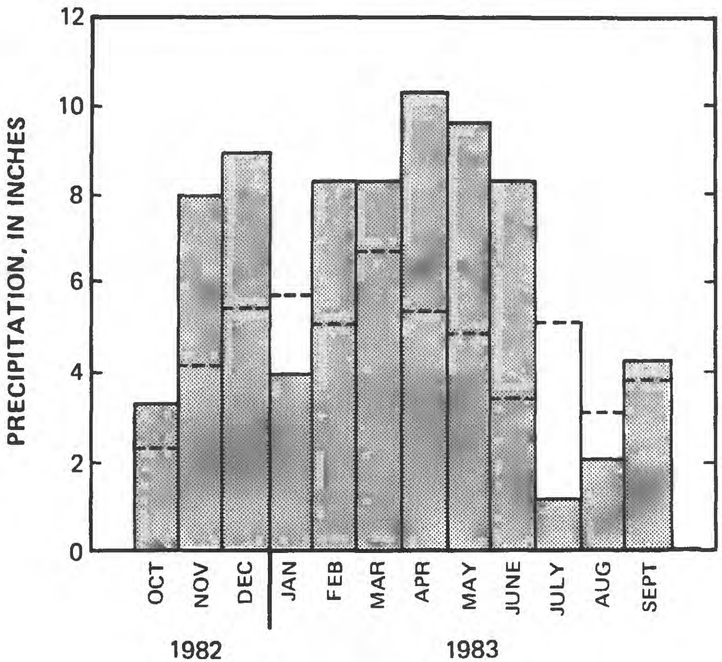
Lake Tuscaloosa

Lake Tuscaloosa is located in north-central Tuscaloosa County, Alabama (fig. 1). The reservoir was created by the impounding of North River approximately 1.2 mi upstream from its confluence with the Black Warrior River. The drainage area from which Lake Tuscaloosa receives surface runoff is 417 mi^2. Seven major streams discharge to Lake Tuscaloosa (North River basin): North River and Dry, Turkey, Binion, Tierce, Carroll, and Brush Creeks (fig. 1). Cripple Creek discharges to North River about 5 river miles before North River discharges to Lake Tuscaloosa. The normal pool elevation is 223.2 ft above sea level. The lake, approximately 25 mi long as measured along the old river channel, has a surface area at normal pool of 5,885 acres. The reservoir capacity is 123,100 acre feet, and the present safe yield has been calculated to be approximately 200 million gallons per day (Keener and others, 1975).

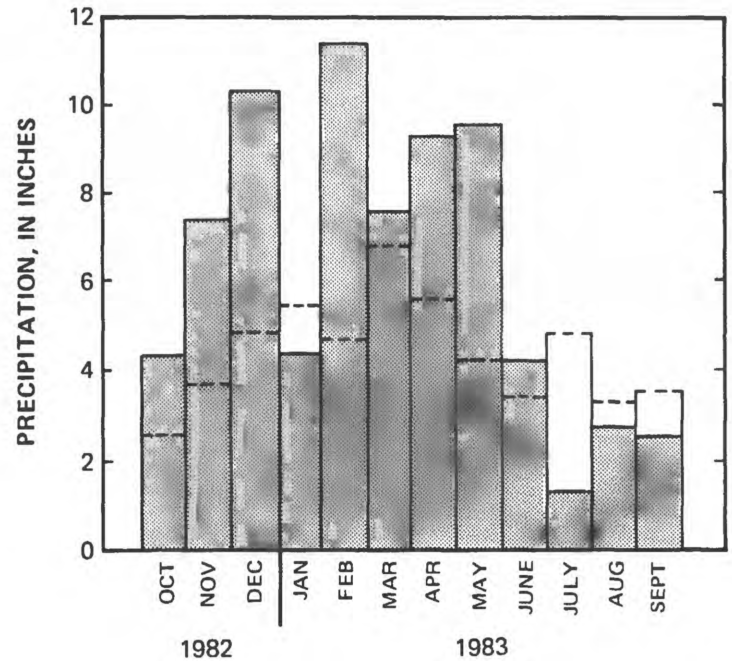
Climate

The area of study has a subtropical climate characterized by warm, humid weather. According to long-term climatological records compiled by Frentz and Lynott (1978), the mean annual temperature is 62.5°F. Generally, July is the hottest month with a mean temperature of 80.0°F, and January the coldest with a mean temperature of 44.0°F. The length of the growing season varies from 210 days in the northern part of the area to 230 days in the southern part.

Precipitation is usually in the form of rain, with snowfall very light and infrequent. March is usually the wettest month and October the driest. Monthly precipitation for the study year at nearby National Oceanic and Atmospheric Administration (NOAA) precipitation stations at Bankhead Lock and Dam, Winfield, and Tuscaloosa Oliver Dam is shown in figure 3. Mean monthly precipitation, based on records for the period 1951-80, is also shown. Average annual precipitation for the three stations during this period was about 55 in. Rainfall for the study year exceeded the long-term average annual precipitation by 21 in. at the Winfield station.



WINFIELD 2 SW



TUSCALOOSA OLIVER DAM

EXPLANATION

- - - Mean monthly precipitation (Based on NOAA records for 1951-80.)

Monthly precipitation

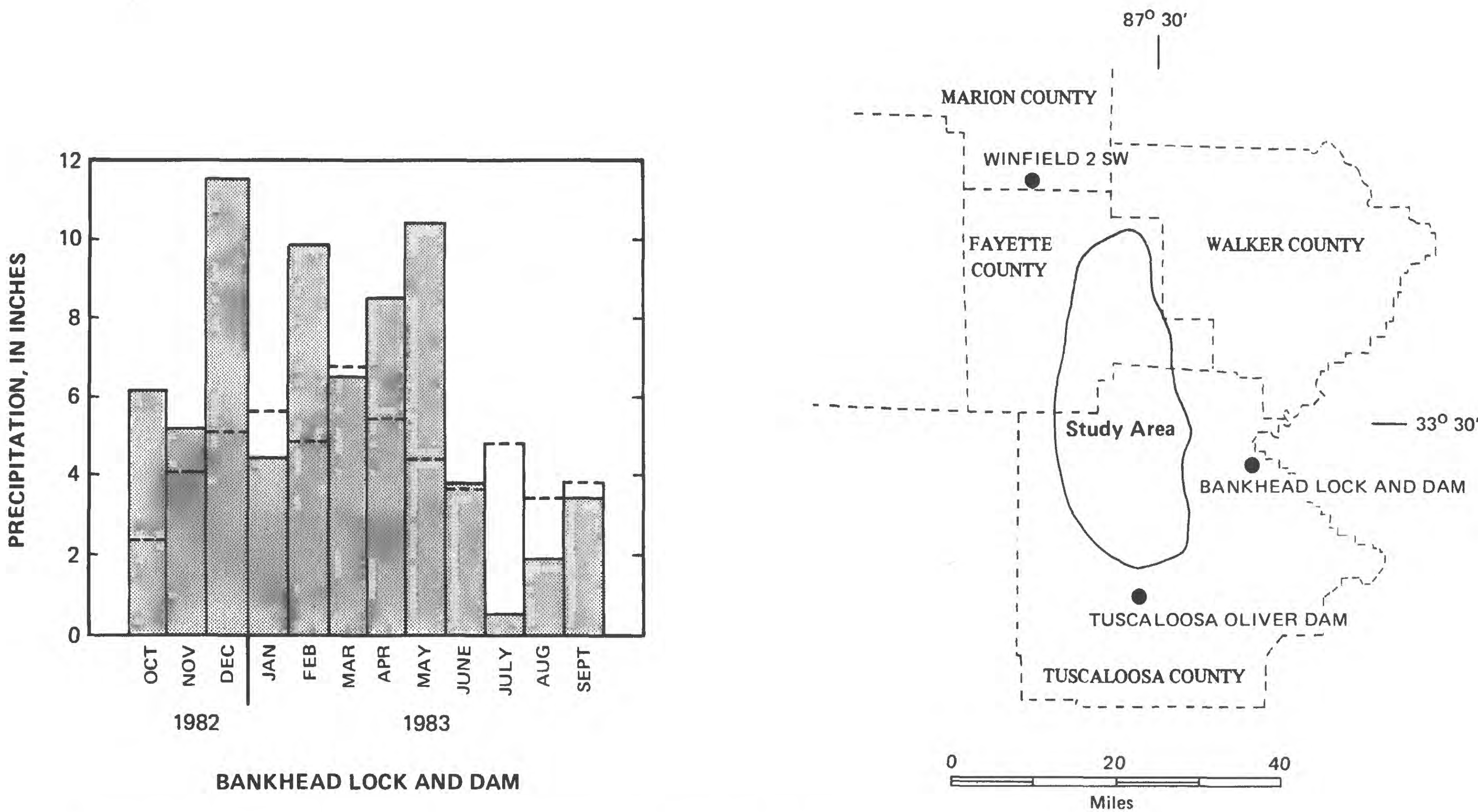


Figure 3.--Monthly and mean monthly precipitation at Winfield 2 SW, Bankhead Lock and Dam, and Tuscaloosa Oliver Dam.

Long-term evaporation data are not available for the general area, but Farnsworth and others (1982) reported a free water surface evaporation of approximately 40 in. per year in the North River basin. The free water surface evaporation for this area was computed by multiplying observed pan evaporation by a coefficient of 0.76. Due to changes in heat storage in reservoir water, however, actual evaporation from a lake may differ significantly from the free water surface evaporation.

Land Use

The study area is sparsely populated with only a few small communities located in the central part of the basin. Development of housing on and near the periphery of the lake has been continuous since the creation of Lake Tuscaloosa. Most of the land in the North River basin is forested (fig. 4). Some areas are cleared and devoted to agricultural uses such as production of cotton, corn, soybeans, and other crops. A few areas in the basin have been disturbed by surface coal mining. Only an estimated 5 percent of the basin has been disturbed by mining. The locations of surface mines shown in figure 4 were taken from aerial photographs and unpublished information from previous investigations in the North River basin. The scope of the project did not allow for a physical verification of the extent of mining in the basin.

Soils

Soils in the study area generally: (1) are acidic, with pH ranging from 3.6 to 6.5 units, (2) have low organic matter content, (3) have moderate permeability rates, and (4) have high erosion potential (U.S. Department of Agriculture, 1965, 1981). Factors affecting soil erosion potential include infiltration and permeability rates, soil texture and stability, soil depth, slope gradient, and vegetative cover. Disturbance of the land surface may drastically alter soil characteristics causing an increase in erosion and sediment yield. Detailed information on soils in the study area is compiled in surveys by the Soil Conservation Service (U.S. Department of Agriculture, 1965, 1981).

Physiography

North River basin is located in the Appalachian Plateaus and Coastal Plain provinces. The northeastern part is in the Cumberland Plateau section of the Appalachian Plateaus province, and the southwestern part is in the Fall Line Hills belt of the East Gulf Coastal Plain (Fenneman, 1938). The Cumberland Plateau section is underlain by resistant sedimentary rocks such as shale and sandstone. The area is characterized by a rugged topography with maximum relief about 300 ft, and by streams that are sharply incised with deep, narrow, steep-sided valleys. The Fall Line Hills is underlain largely by unconsolidated deposits of clay, sand, and gravel. Its terrane is not as rugged as that to the northeast. Streams are less incised and have wider flood plains with more gently sloping sides.

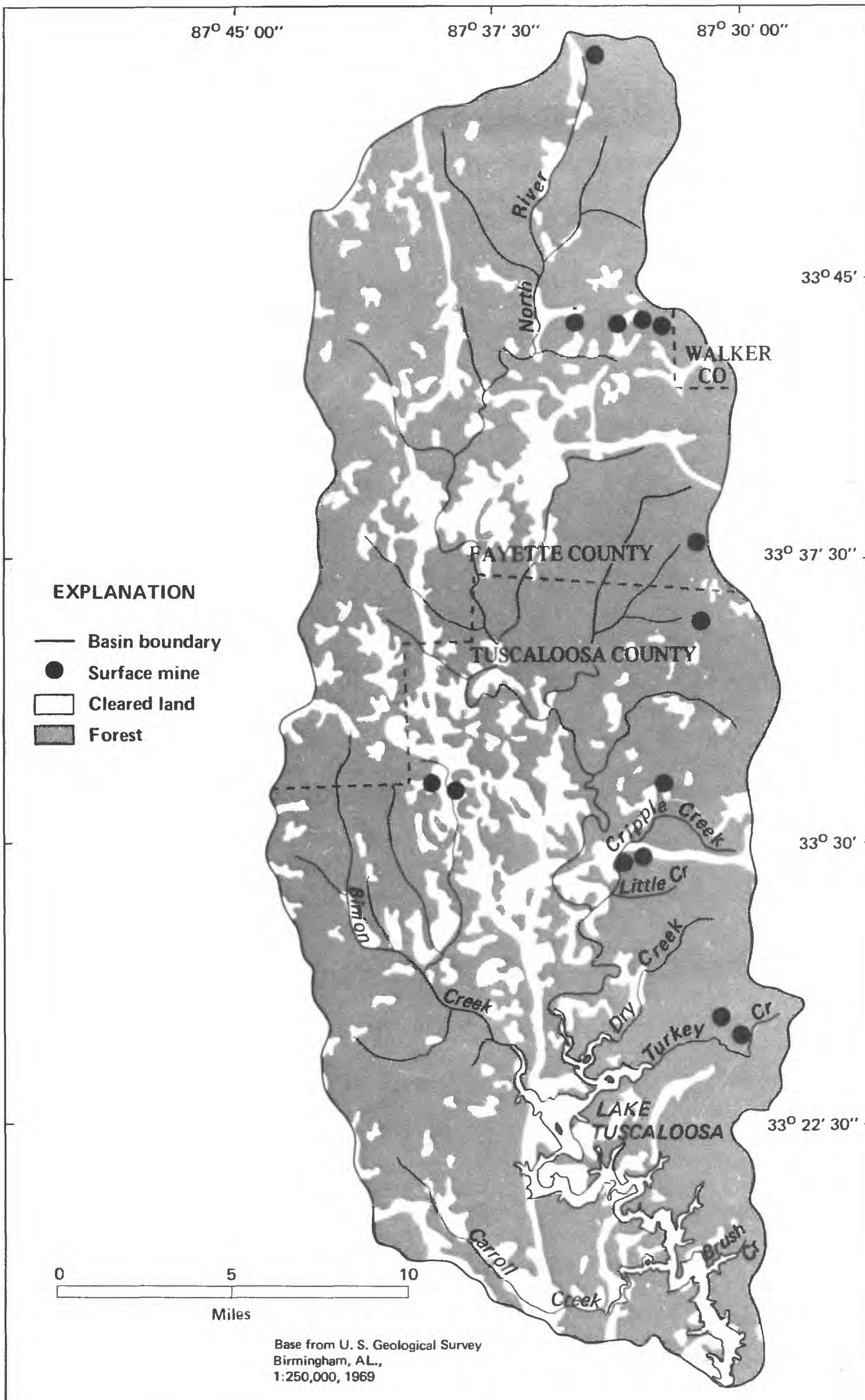


Figure 4.--Land use in study area.

Geohydrology

The North River drainage basin is in the outcrop of the Pottsville Formation of Pennsylvanian age and the overlying Coker Formation of Late Cretaceous age. The Pottsville Formation underlies all of the study area, but is exposed mainly in the northeastern part. The Coker Formation (basal unit of the Tuscaloosa Group) crops out in the southern and western parts of the basin. Regionally, strata in the Pottsville strike northwestward and dip southwestward 30 to 200 ft/mi (Culbertson, 1964). Strata in the Coker strike northwestward and dip southwestward 30 to 50 ft/mi (Puente and others, 1982).

The Pottsville Formation is approximately 2,500 to 4,500 ft thick (Mertzger,1965). The formation consists mainly of sandstone, shale, and siltstone with shale being the dominant rock type. Beds of coal and underclay are also present in different parts of the formation. Ground water in the consolidated rocks of the Pottsville Formation usually occurs in openings along joints, fractures, and bedding planes. The quantity of water available to wells and to streams as base flow, because of the impermeable nature of the rocks, is generally limited and is dependent on the number, size, and extent of water-bearing openings. The size and number of water-bearing openings generally decrease with depth. The geohydrologic units in the southern part of North River basin are shown in figure 5.

The Coker Formation is as much as 400 ft thick in the North River basin. The lower 100 ft consists chiefly of sand and gravel with some beds of cemented sandstone and conglomerate usually occurring near the base. The upper 300 ft consists chiefly of clay. The permeable sand and gravel beds in the lower 100 ft of the Coker Formation (fig. 5) provide significant quantities of base flow to streams and are the principal source of water obtained by wells in much of the area. Because of the dip of its beds, the movement of most water in the formation is toward the southwest.

Streamflow Characteristics

Streamflow characteristics are dependent upon climate, topography, geology, and land use. Basins may have similar streamflow characteristics where these conditions are similar.

Streamflow is generally highest during December through April because of the large amount of precipitation during this period. Similarly, it is generally lowest during May through November due to a decrease in precipitation and increase in evapotranspiration that occurs during the growing season. This is illustrated by hydrographs of daily discharge for site 1 on North River and site 7 on Turkey Creek (fig. 6). (Site numbers correspond to those in figure 2 and table 1.) Discharges are given per unit area to eliminate the effect of the large difference in drainage areas between the two basins.

North River (above site 1) and Turkey Creek drain basins with similar climate, topography, and land use; however, the geologic environments of the two basins are somewhat different. North River basin (above site 1) is underlain primarily by the relatively impermeable Pottsville Formation. Conse-

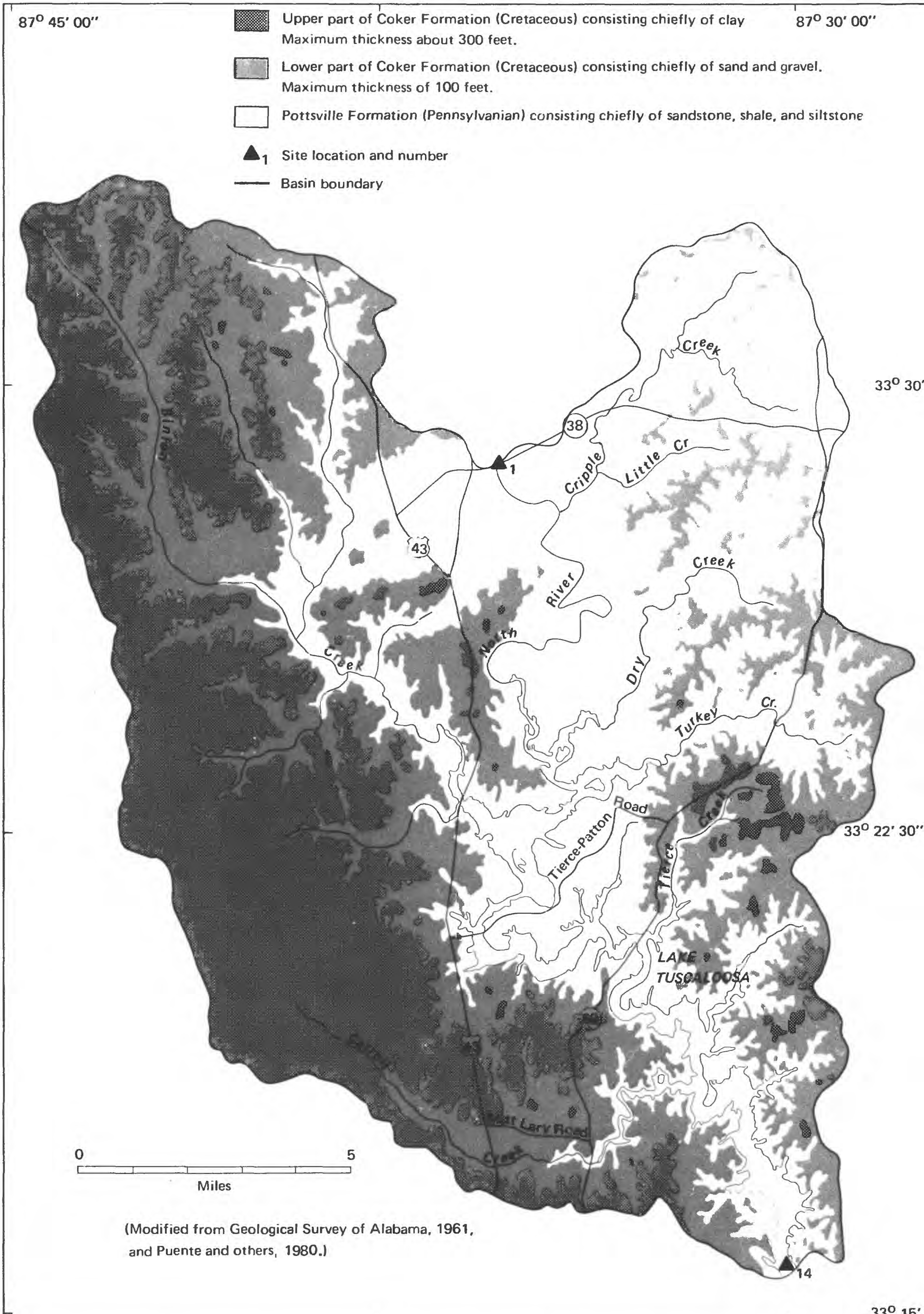


Figure 5.--Geohydrologic units in North River basin between North River (site 1) and Lake Tuscaloosa (site 14). (Site numbers correspond to those in figure 2 and table 1.)

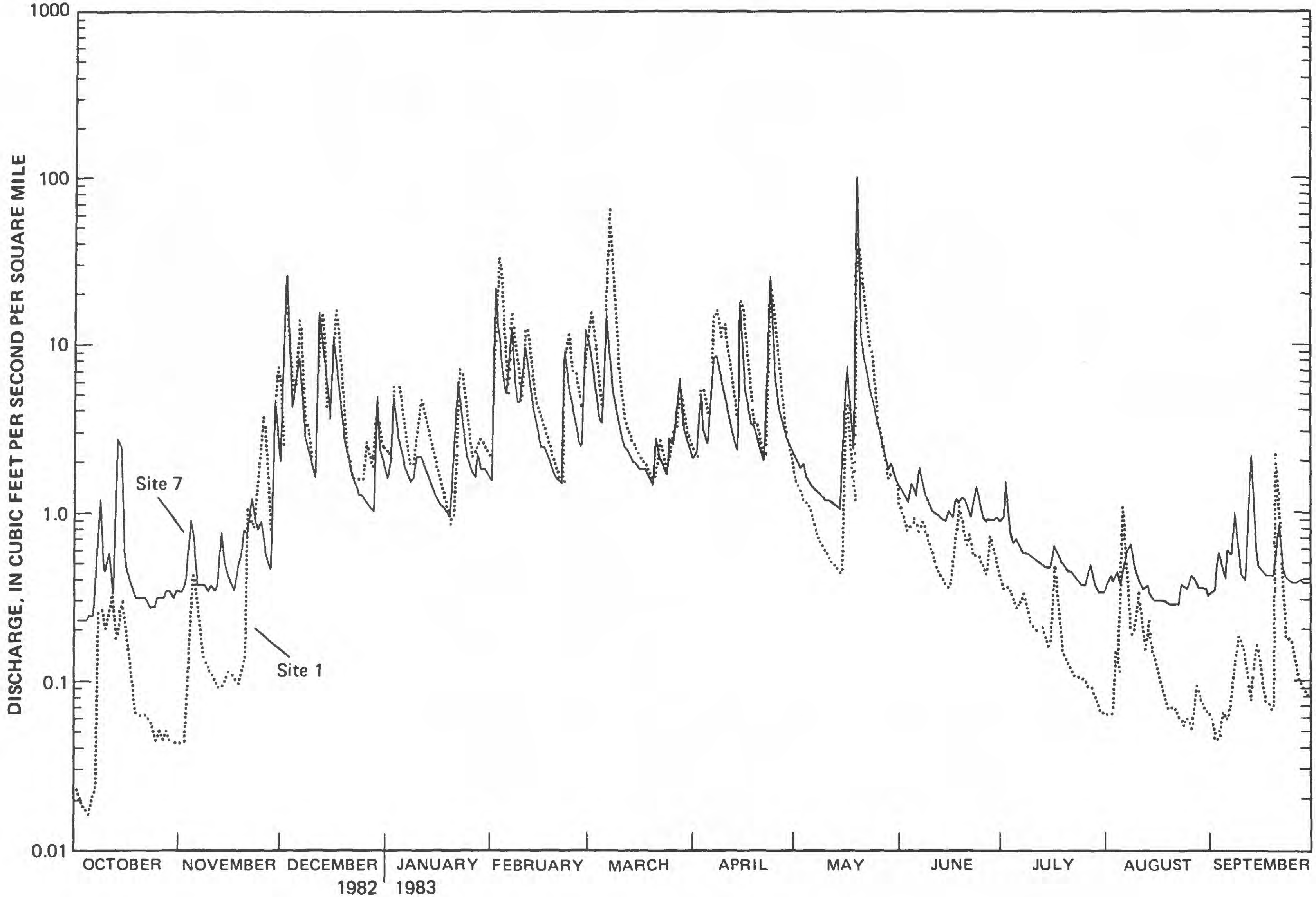


Figure 6.--Daily discharge at North River (site 1) and Turkey Creek (site 7), 1983 water year. (Site numbers correspond to those in figure 2 and table 1.)

quently, poorly sustained base flows occur at site 1 on North River during July through November due to the underlying impermeable formation that inhibits ground water storage. Poorly sustained base flows are also characteristic of Little Creek (site 2) and Cripple Creek (site 3) which drain basins similar to North River basin (above site 1). Turkey Creek basin is underlain by the Pottsville Formation and sand and gravel deposits in the Coker Formation. The hydrograph for site 7 on Turkey Creek (fig. 6) shows the contribution of base flow (flow during periods of little or no precipitation) from storage in this permeable formation. Dry Creek, Tierce Creek, and Brush Creek basins have similar streamflow characteristics. Well sustained base flow of Turkey Creek during dry periods contrasts with poorly sustained base flow at site 1 on North River during the same periods.

Streams draining areas west of Lake Tuscaloosa are underlain by significant deposits of the Coker Formation (fig. 5) and have well-sustained base flows during dry-weather conditions. The low-flow characteristics of streams were examined to estimate the amount of water contributed to the reservoir by base flow. Indices generally used to define low-flow characteristics of streams are the lowest mean discharges for seven consecutive days having recurrence intervals of 2 and 10 years. For simplicity, these indices are referred to as the 7-day Q_2 ($7Q_2$) and 7-day Q_{10} ($7Q_{10}$) discharges, respectively. These discharges are taken from a frequency curve of annual values showing mean discharges. Low-flow characteristics for North River (site 1) were computed by using available streamflow records for the periods 1940-54 and 1969-82 and are presented in table 2.

Because continuous streamflow records were not available for the other streams in North River basin, $7Q_2$ and $7Q_{10}$ values were estimated using the procedure and equations developed by Bingham (1979). The estimated values of $7Q_2$ and $7Q_{10}$ for seven sites are presented in table 2. These seven sites together with the North River site represent the major drainage to Lake Tuscaloosa (North River basin). Water from the North River drainage area--underlain mainly by relatively impermeable rocks (Pottsville Formation--contrasts greatly with that from Carroll and Binion Creek basins--underlain largely by permeable sand and gravel deposits (Coker Formation). Based on the $7Q_2$ data in table 2, about 80 percent of the base flow supplied to the reservoir during low flow is from Carroll and Binion Creeks which drain only 19 percent of the study area. North River, draining more than one-half of the basin, contributes less than 18 percent of the estimated base flow to the reservoir.

Variations of streamflow into Lake Tuscaloosa and the amounts of water diverted and released from the lake cause fluctuations in reservoir storage. Daily water-surface elevations at site 14 in Lake Tuscaloosa, for November 1982 to September 1983, are shown in figure 17.

Table 2.--Summary of low-flow characteristics of selected streams in North River basin
(Site numbers correspond to those in figure 2 and table 1)

Name	Percent of total drainage area	$7Q_2$ (ft^3/s)	$7Q_2/mi^2$ [(ft^3/s)/mi^2]	$7Q_{10}$ (ft^3/s)	$7Q_{10}/mi^2$ [(ft^3/s)/mi^2]
North River (site 1)	52	6.4	0.03	1.2	0.005
*Cripple Creek (site 3)	3.9	0.09	0.01	0.01	0.001
*Dry Creek (site 6)	2.3	0.14	0.02	0.03	0.003
*Turkey Creek (site 8)	2.5	0.16	0.02	0.03	0.003
*Binion Creek (site 10)	14	21	0.37	11.7	0.20
*Tierce Creek (site 11)	0.5	0.04	0.02	0.01	0.003
*Carroll Creek (site 12)	5.0	8.2	0.39	4.1	0.20
*Brush Creek (site 13)	0.2	0.02	0.02	0.002	0.002
Total	80.4	36.05	0.88	17.082	0.417

* $7Q_2$ and $7Q_{10}$ estimated using methods developed by Bingham (1979).

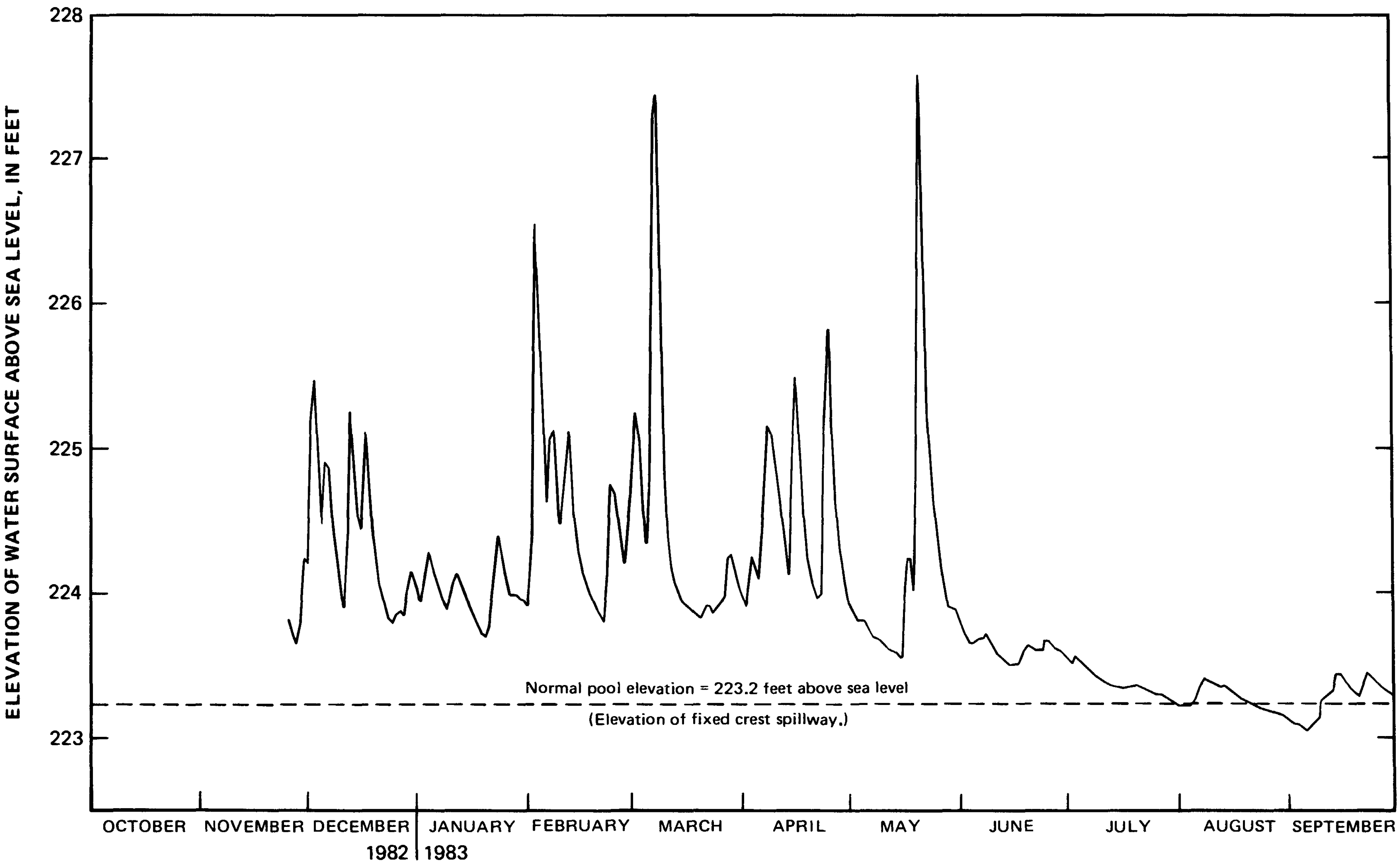


Figure 7-- Daily water-surface elevation at Lake Tuscaloosa (site 14), November 1982–September 1983. (Site number corresponds to those in figure 2 and table 1.)

EFFECTS OF COAL MINING ON THE WATER QUALITY OF LAKE TUSCALOOSA AND SELECTED TRIBUTARIES

General Effects of Mining

Changes in surface-water quality accompany changes in the environment. Seasonal or daily changes such as fluctuations in temperature or the occurrence of precipitation and variation of stream discharge, for example, can cause changes in water quality. During periods of little or no precipitation, streamflow mainly consists of base flow contributed from ground-water reservoirs. Base flow is generally more mineralized than overland flow because it has been in contact with soils and rocks for extended periods of time. Conversely, streamflow during high-flow conditions is usually much less mineralized because overland flow and subsurface flow, with a shorter period of contact with soluble minerals, dilute base flow.

Water quality is affected by coal mining and, generally to a lesser degree, by other changes in land use. A common problem resulting from surface mining is acid-mine drainage. Pyritic minerals (those containing iron sulfides) exposed in spoil are subject to accelerated weathering that produces sulfuric acid and soluble mineral salts. This production results in mine drainage that generally has a lower pH and a higher sulfate concentration than water draining less disturbed basins. Increases in concentrations of other elements such as aluminum, calcium, magnesium, iron, and manganese also commonly occur. Concentrations of these dissolved constituents are highly variable, depending on the character of the spoil material, the extent of weathering, and the quantity of water leaving the mined area. Mineralization of mine drainage is greatest in the vicinity of the mine. Mineralization decreases with distance from the mined area due to aeration that results in precipitation of some constituents, such as iron and manganese, and because of dilution by streams from unmined areas in downstream reaches.

The chemical characteristics or type of water can be illustrated by cation-anion diagrams. The diagrams are constructed by plotting concentrations expressed in milliequivalents per liter (meq/L) of the major or common cations and anions (in this report, for single analyses). Concentrations of all ions, when expressed in milliequivalents per liter, are chemically equivalent. The sum of the cations (positively charged ions) equals the sum of the anions (negatively charged ions). The points on the cation-anion diagram are connected to form a unique pattern representing the sample or composite analysis. The size and shape of the pattern indicate the degree of mineralization and the dominant ions in solution.

Two other common indicators of degree of mineralization are: (1) dissolved solids concentration--the sum of the anions and cations dissolved in the solution--expressed in milligrams per liter (mg/L), and (2) specific conductance--the ability of the water to conduct an electrical current--expressed in micromhos per centimeter at 25° Celsius.

Changes in the Water Quality in the Tributaries

From October 1982 to September 1983, samples were collected at various flow conditions to examine the quality of water in streams draining into Lake Tuscaloosa, and to determine if surface coal mining has impacted the quality of water in the lake. Selected physical and chemical characteristics of water at eight stream sites and two lake sites are summarized in table 3.

The chemical characteristics of water in streams draining mined and unmined basins in the study area are illustrated by cation-anion diagrams of water collected at sites in November 1982 during low-flow conditions (fig. 8). Water quality of tributaries is generally good, except downstream from mined areas--North River, Cripple Creek, and Turkey Creek sites. Binion Creek basin has also been disturbed by mining, but its water quality has not been affected significantly.

As indicated by the cation-anion diagram (fig. 9), water from site 1 on North River was much more mineralized in 1983 than in 1975. Sulfate concentrations, commonly used as an indicator of mine drainage, have increased more than concentrations of any other constituent. Specific conductance and sulfate concentrations were relatively constant during the period 1971-76 (no significant mining), but increased significantly during the period 1977-83 (figs. 10 and 11), corresponding to the period of active mining in the basin.

Analyses from site 1 on North River show a trend of increasing mineralization with decreasing streamflow (figs. 9 and 12). For example, the sum of the cations (or anions) increased from about 0.34 to 0.38 to 0.52 meq/L in 1975 and from 0.58 to 0.70 to 0.82 meq/L in 1983 as discharge decreased from high to median to low flow (fig. 9). The relation between discharge and specific conductance for the pre-mining versus the active mining periods (fig. 12) shows the increase in specific conductance occurred over a wide range of discharges and represented a significant upward shift in the specific conductance versus discharge plot. Consequently, the increased mineralization at site 1 is due to coal mining and not anomalous flow conditions. Site 1 (North River) has a low flow (November 1982) specific conductance of 150 micromhos (fig. 8).

Except for pH and dissolved and total recoverable iron and manganese concentrations, water from site 1 on North River (and all the other sites in this study) generally is within recommended drinking water limits as a source for public supply (table 3). Between October 1982 and September 1983, the pH of water from streams draining mined and unmined basins generally was less than the minimum level of 6.5 pH units recommended in the standards; however, this is not unusual. The minimum pH of 4.6 observed at Carroll and Brush Creeks (table 3) is the same as the minimum reported by Puente and others (1980) for streams draining undisturbed basins in the Warrior coal field.

Dissolved and total recoverable iron and manganese concentrations have increased for site 1 on North River since the basin was disturbed by mining. However, total recoverable iron and manganese concentrations exceeded secondary drinking water standard levels in more than half of the samples at most sampling sites. The maximum total recoverable iron concentration (5,600 ug/L) was from a sample collected from an unmined basin (Dry Creek, site 5).

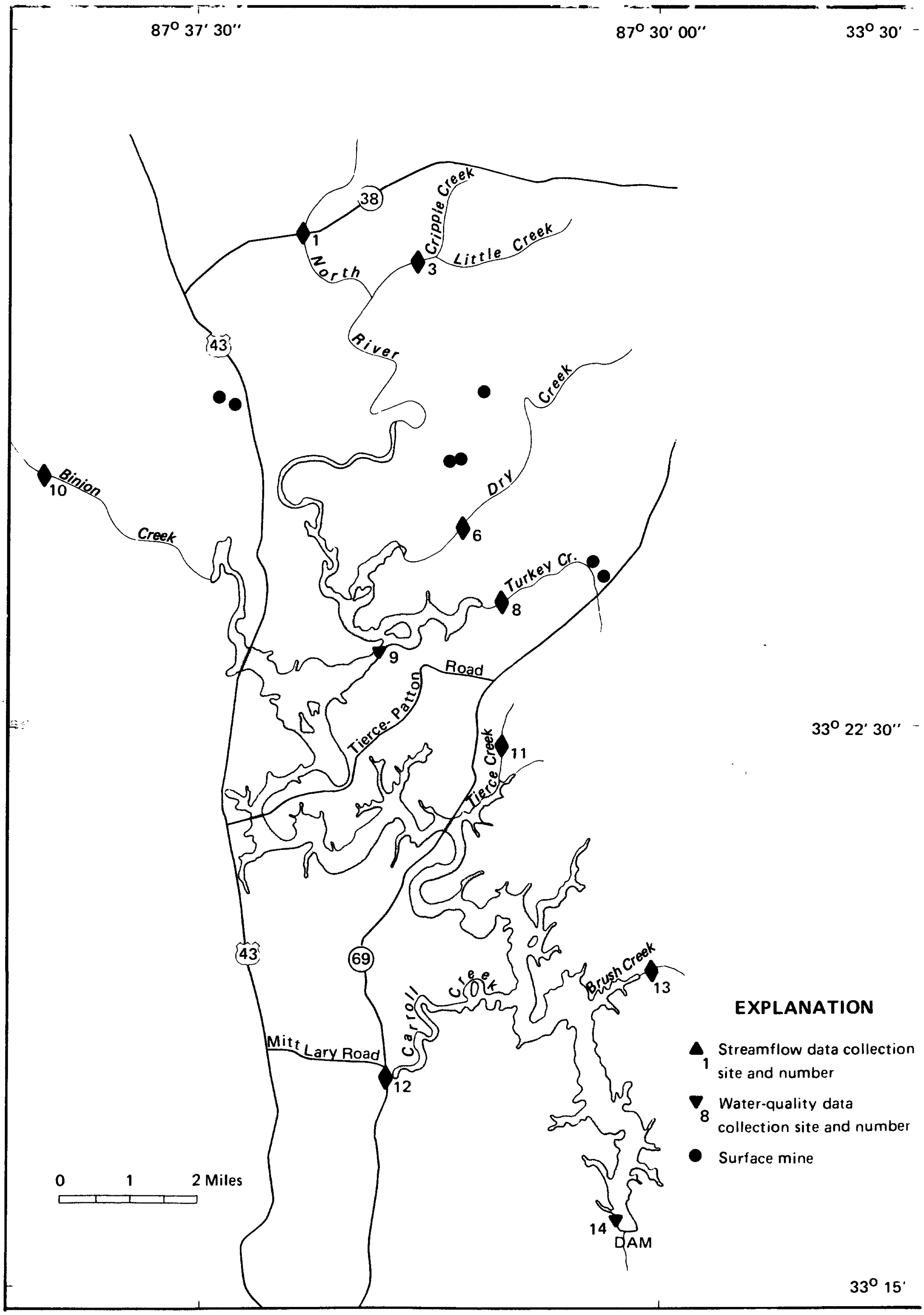
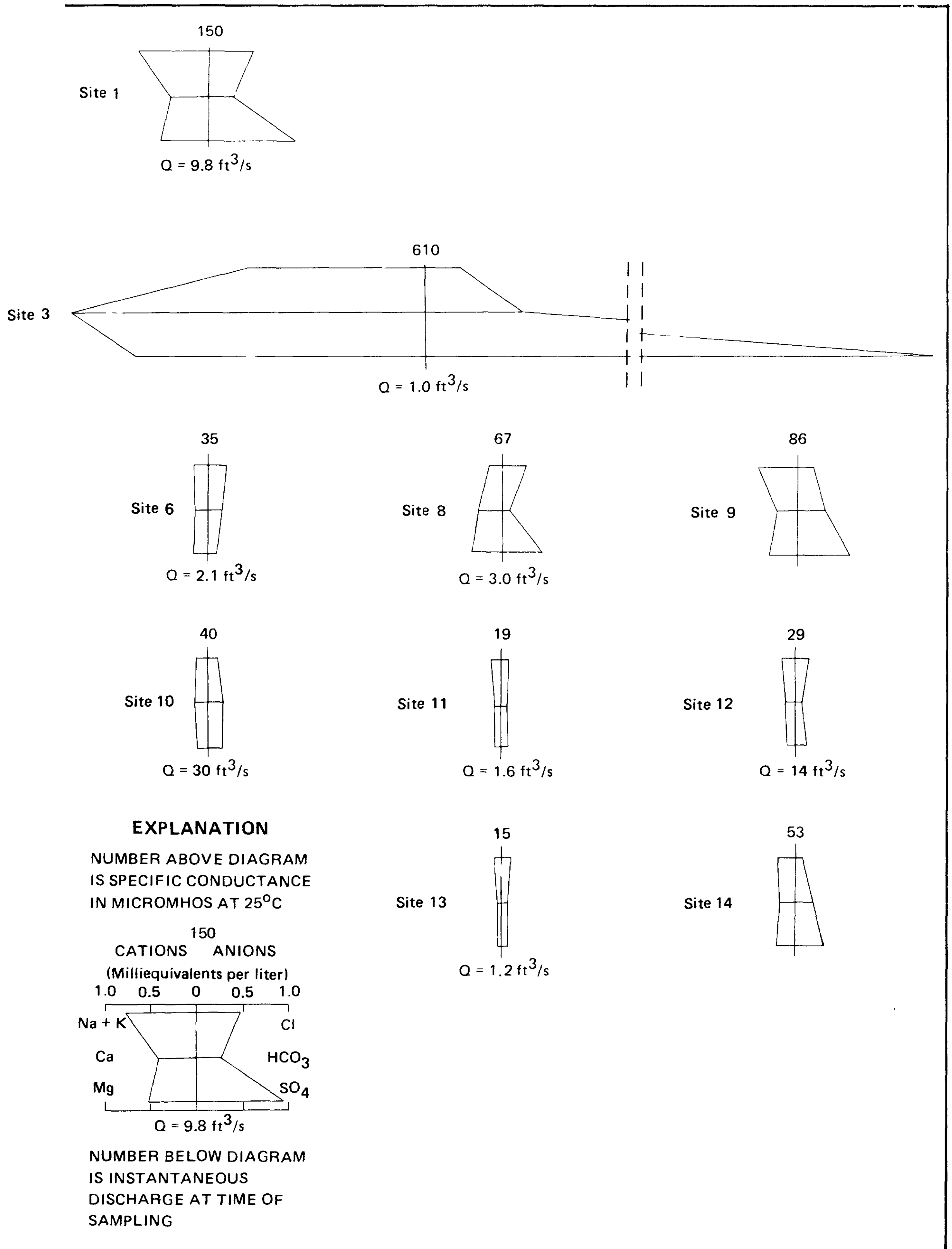
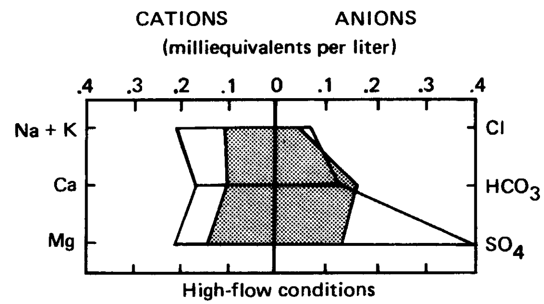
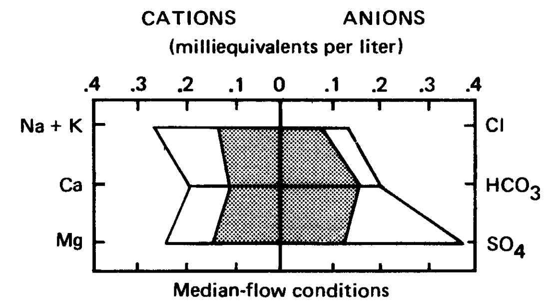


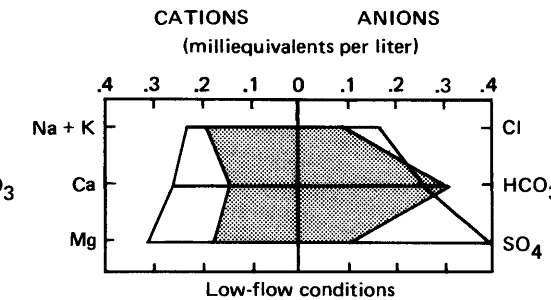
Figure 8.--Chemical character of water during low-flow conditions (November 1982) at sites in North River basin. (Site numbers correspond to those in figure 2 and table 1.)


150
Site 1
Q = 9.8 ft3/s
610
Site 3
Q = 1.0 ft3/s
35
Site 6
Q = 2.1 ft3/s
67
Site 8
Q = 3.0 ft3/s
86
Site 9
40
Site 10
Q = 30 ft3/s
19
Site 11
Q = 1.6 ft3/s
29
Site 12
Q = 14 ft3/s
EXPLANATION
NUMBER ABOVE DIAGRAM IS SPECIFIC CONDUCTANCE IN MICROMHOS AT 25°C
150
CATIONS ANIONS
(Milliequivalents per liter)
1.0 0.5 0 0.5 1.0
Na + K
Cl
Ca
HCO3
Mg
SO4
Q = 9.8 ft3/s
NUMBER BELOW DIAGRAM IS INSTANTANEOUS DISCHARGE AT TIME OF SAMPLING
15
Site 13
Q = 1.2 ft3/s
53
Site 14

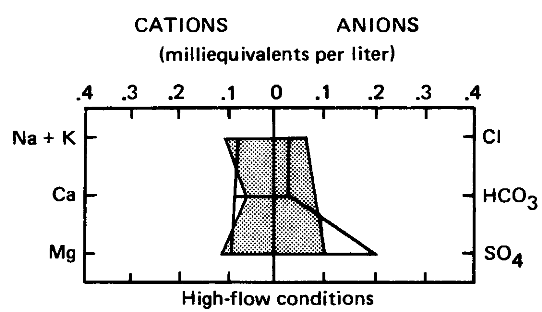
SITE 1 — NORTH RIVER NEAR SAMANTHA

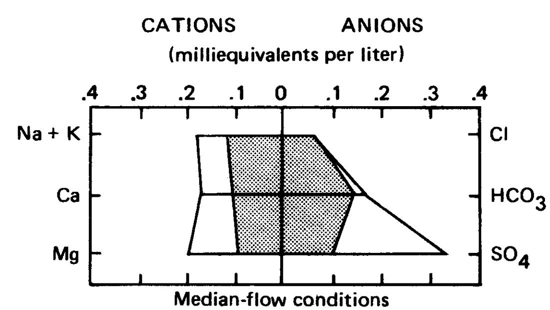


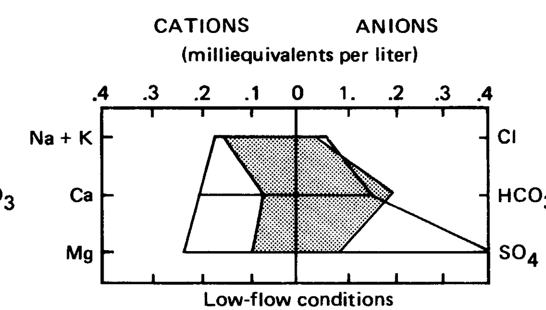




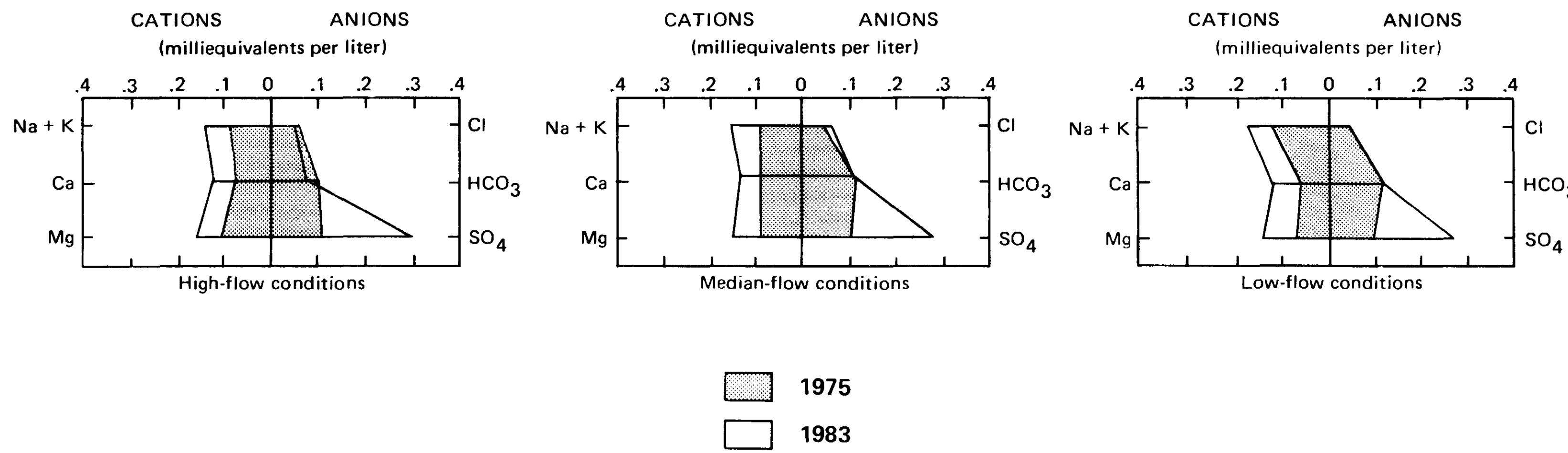
SITE 9 - LAKE TUSCALOOSA AT HILLTOP ESTATES LANDING NEAR NORTHPORT







SITE 14 – LAKE TUSCALOOSA RESERVOIR NEAR TUSCALOOSA



CATION SUM (meq/L)

		High Flow	Median Flow	Low Flow
Site 1	1975	.34	.38	.52
	1983	.58	.70	.82
Site 9	1975	.26	.30	.32
	1983	.25	.54	.61
Site 14	1975	.26	.27	.25
	1983	.43	.43	.43

Figure 9.--Comparisons of water quality in 1975 and 1983 during high-, median-, and low-flow conditions at North River (site 1) and Lake Tuscaloosa (sites 9 and 14) using cation-anion diagrams. (Site numbers correspond to those in figure 2 and table 1.)

Table 3.--Summary of selected physical and chemical characteristics of water at sites in North River basin, October 1982 - September 1983

(Chemical analyses in milligrams per liter except as indicated. Site numbers correspond to those in figure 2 and table 1.)

Property or Constituent	North River (site 1) Median	Range	Number of Observations	Cripple Creek (site 3) Median	Range	Number of Observations	U.S. EPA (1982) Secondary drinking water regulations
Discharge at time of sampling (ft^3/s)	245	3.8-2390	12	25	0.59-124	13	---
Specific conductance (micromhos at 25°C)	77	45-268	12	240	76-1360	13	---
pH (units)	6.4	5.4-6.9	12	6.8	5.6-7.4	13	6.5-8.5 pH units
Temperature (°C)	17.0	6.5-25.0	12	16.0	8.0-25.0	13	---
Dissolved oxygen	9.0	6.2-12.3	12	9.9	6.9-12.0	13	---
Hardness (as $CaCO_3$)	22	12-34	12	81	27-740	9	---
Noncarbonate hardness (as $CaCO_3$)	12	6-24	12	72	22-670	9	---
Calcium (Ca), dissolved	4.0	2.0-6.3	12	14	5.0-160	9	---
Magnesium (Mg), dissolved	2.8	1.8-4.6	12	11	3.4-82	9	---
Sodium (Na), dissolved	5.0	2.0-36	12	3.8	1.8-37	9	---
Potassium (K), dissolved	0.9	0.8-2.4	12	--	---	--	---
Alkalinity (as $CaCO_3$)	9	5-16	12	10	4-69	11	---
Sulfate (SO_4), dissolved	20	6.0-51	12	82	26-700	9	250 mg/L maximum
Dissolved solids (sum of constituents)	50	27-140	12	--	---	--	500 mg/L maximum
Iron (Fe), total recoverable (ug/L)	810	520-1300	11	460	160-1900	9	300 ug/L maximum
Iron (Fe), dissolved (ug/L)	210	70-610	12	91	8-250	9	---
Manganese (Mn), total recoverable (ug/L)	120	70-230	10	800	190-2600	8	50 ug/L maximum
Manganese (Mn), dissolved (ug/L)	96	48-170	12	570	180-2400	9	---

Table 3.--Summary of selected physical and chemical characteristics of water at sites in North River basin, October 1982 - September 1983 (continued)
(Chemical analyses in milligrams per liter except as indicated. Site numbers correspond to those in figure 2 and table 1.)

Property or Constituent	Dry Creek (site 5)			Turkey Creek (site 8)			U.S. EPA (1982) Secondary drinking water regulations
	Median	Range	Number of Observations	Median	Range	Number of Observations	
Discharge at time of sampling (ft^3/s)....	7.9	0.09-60	13	13	2.6-25	13	---
Specific conductance (micromhos at 25°C).	26	22-41	13	47	36-110	13	---
pH (units)............................	6.0	5.2-6.8	13	6.2	5.4-6.6	13	6.5-8.5 pH units
Temperature (°C)......................	12.5	4.5-23.5	13	14.0	5.0-24.5	13	---
Dissolved oxygen......................	10.2	4.5-13.3	13	10.0	8.1-12.8	12	---
Hardness (as $CaCO_3$)....................	7	4-23	9	17	12-38	9	---
Noncarbonate hardness (as $CaCO_3$).........	2	0-15	9	9	8-35	9	---
Calcium (Ca), dissolved.................	1.4	0.6-2.3	8	2.8	1.8-5.8	9	---
Magnesium (Mg), dissolved...............	1.0	0.6-1.6	8	2.3	1.5-5.6	9	---
Sodium (Na), dissolved..................	1.3	0.8-1.7	9	1.5	1.1-1.9	9	---
Potassium (K), dissolved................	--	---	--	--	---	--	---
Alkalinity (as $CaCO_3$)...................	7	2-13	12	4	3-8	12	---
Sulfate (SO_4), dissolved................	4.6	3.0-10	9	13	12-29	9	250 mg/L maximum
Dissolved solids (sum of constituents)...	--	---	--	--	---	--	500 mg/L maximum
Iron (Fe), total recoverable (ug/L)......	440	270-5600	9	310	270-660	9	300 ug/L maximum
Iron (Fe), dissolved (ug/L).............	110	42-720	8	110	43-170	9	---
Manganese (Mn), total recoverable (ug/L).	40	30-260	7	250	70-940	9	50 ug/L maximum
Mpnganese (Mn), dissolved (ug/L)........	31	17-140	9	220	67-900	9	---

Table 3.--Summary of selected physical and chemical characteristics of water at sites in North River basin, October 1982 - September 1983 (continued)

(Chemical analyses in milligrams per liter except as indicated. Site numbers correspond to those in figure 2 and table 1.)

Property or Constituent	Lake Tuscaloosa (site 9) Median	Range	Number of Observations	Binion Creek (site 10) Median	Range	Number of Observations	U.S. EPA (1982) Secondary drinking water regulations
Discharge at time of sampling (ft^3/s)	--	---	--	82	16-370	12	---
Specific conductance (micromhos at 25°C)	67	33-102	12	36	32-69	12	---
pH (units)	6.2	5.7-6.8	12	5.9	5.2-6.4	12	6.5-8.5 pH units
1/ Temperature (°C)	19.5	8.0-30.5	12	18.5	6.5-23.0	12	---
1/ Dissolved oxygen	8.4	7.4-10.9	11	8.0	7.3-11.8	12	---
Hardness (as $CaCO_3$)	19	9-28	12	12	10-20	12	---
Noncarbonate hardness (as $CaCO_3$)	10	7-14	12	4	3-15	12	---
Calcium (Ca), dissolved	3.4	1.7-5.3	12	2.4	2.1-3.9	12	---
Magnesium (Mg), dissolved	2.6	1.1-3.5	12	1.3	1.2-2.4	12	---
Sodium (Na), dissolved	2.9	1.0-5.8	12	1.4	1.0-2.2	12	---
Potassium (K), dissolved	0.9	0.7-1.2	12	0.9	0.7-1.1	12	---
Alkalinity (as $CaCO_3$)	8	2-16	12	6	3-8	12	---
Sulfate (SO_4), dissolved	16	9.0-22	12	6.4	3.0-13	12	250 mg/L maximum
Dissolved solids (sum of constituents)	42	21-59	12	28	23-36	12	500 mg/L maximum
Iron (Fe), total recoverable (ug/L)	960	340-5100	11	1800	950-2400	12	300 ug/L maximum
Iron (Fe), dissolved (ug/L)	160	72-2100	12	280	110-470	12	---
Manganese (Mn), total recoverable (ug/L)	240	120-1100	10	250	160-400	11	50 ug/L maximum
Manganese (Mn), dissolved (ug/L)	160	100-1100	12	180	110-320	12	---

1/ Measurement made approximately 2 feet below water surface at site 9.

Table 3.--Summary of selected physical and chemical characteristics of water at sites in North River basin, October 1982 - September 1983 (continued)

(Chemical analyses in milligrams per liter except as indicated. Site numbers correspond to those in figure 2 and table 1.)

Property or Constituent	Tierce Creek (site 11)			Carroll Creek (site 12)			U.S. EPA (1982) Secondary drinking water regulations
	Median	Range	Number of Observations	Median	Range	Number of Observations	
Discharge at time of sampling (ft^3/s)....	4.4	0.98-11	12	22	1.8-111	12	---
Specific conductance (micromhos at 25°C).	16	13-22	12	24	20-33	12	---
pH (units)............................	5.5	4.9-6.0	12	5.9	4.6-6.2	12	6.5-8.5 pH units
Temperature (°C)......................	15.0	9.0-21.0	12	17.5	5.0-23.5	12	---
Dissolved oxygen......................	9.8	8.6-11.4	12	8.7	7.6-11.8	12	---
Hardness (as $CaCO_3$)....................	4	3-5	12	6	5-8	12	---
Noncarbonate hardness (as $CaCO_3$)........	2	0-3	12	2	0-5	12	---
Calcium (Ca), dissolved................	0.7	0.5-0.9	12	1.3	0.8-1.6	12	---
Magnesium (Mg), dissolved..............	0.5	0.4-0.7	12	0.7	0.5-0.9	12	---
Sodium (Na), dissolved.................	1.0	0.9-2.0	12	1.6	1.0-2.4	12	---
Potassium (K), dissolved...............	0.4	0.3-0.7	11	0.8	0.2-1.3	12	---
Alkalinity (as $CaCO_3$)..................	2	2-3	12	4	1-7	12	---
Sulfate (SO_4), dissolved...............	2.2	1.1-3.6	11	3.6	1.0-7.7	11	250 mg/L maximum
Dissolved solids (sum of constituents)...	15	14-17	11	20	16-27	11	500 mg/L maximum
Iron (Fe), total recoverable (ug/L)......	430	230-690	12	1400	640-2500	12	300 ug/L maximum
Iron (Fe), dissolved (ug/L).............	94	46-210	12	260	140-560	12	---
Manganese (Mn), total recoverable (ug/L).	30	20-90	11	120	50-330	12	50 ug/L maximum
Manganese (Mn), dissolved (ug/L).........	26	11-86	12	100	23-260	12	---

Table 3.--Summary of selected physical and chemical characteristics of water at sites in North River basin, October 1982 - September 1983 (continued)

(Chemical analyses in milligrams per liter except as indicated. Site numbers correspond to those in figure 2 and table 1.)

PACIRATG CA 4C:OTETLR:T r	Brush Creek (site 13) XRMES:	6S:WR	Number of $BORA,STEC:O	Lake Tuscaloosa (site 14) XRMES:	6S:WR	Number of $BORA,STEC:O	U.S. EPA (1982) Secondary drinking PSTRA ARWLZSTEC:O
Discharge at time of sampling (ft^3/s)....	2.6	0.88-3.7	12	--	---	--	---
Specific conductance (micromhos at 25°C).	14	11-17	12	50	39-59	12	---
pH (units)............................	5.8	4.6-6.2	12	6.1	5.4-6.5	12	6.5-8.5 pH units
1/Temperature (°C)......................	14.5	7.5-21.0	12	19.0	8.5-31.0	12	---
1/Dissolved oxygen......................	9.8	8.6-12.3	12	8.4	7.3-10.3	12	---
Hardness (as $CaCO_3$).....................	3	3-4	12	14	12-16	12	---
Noncarbonate hardness (as $CaCO_3$).........	1	0-3	12	8	4-11	12	---
Calcium (Ca), dissolved.................	0.6	0.4-0.6	12	2.5	2.2-2.9	12	---
Magnesium (Mg), dissolved...............	0.4	0.3-0.5	12	1.8	1.5-2.3	12	---
Sodium (Na), dissolved..................	1.1	0.9-2.1	12	2.2	1.7-2.9	12	---
Potassium (K), dissolved................	0.4	0.1-0.5	11	0.8	0.5-1.2	12	---
Alkalinity (as $CaCO_3$)...................	2	1-3	12	5	3-8	12	---
Sulfate (SO_4), dissolved................	2.1	1.7-3.7	9	12	10-14	12	250 mg/L maximum
Dissolved solids (sum of constituents)...	14	13-16	8	32	28-35	12	500 mg/L maximum
Iron (Fe), total recoverable (ug/L)......	270	180-640	12	440	100-740	12	300 ug/L maximum
Iron (Fe), dissolved (ug/L)..............	100	65-190	12	140	24-250	12	---
Manganese (Mn), total recoverable (ug/L).	30	20-70	11	160	100-590	12	50 ug/L maximum
Manganese (Mn), dissolved (ug/L).........	28	11-43	12	130	65-490	12	---

1/ Measurement made approximately 2 feet below water surface at site 14.

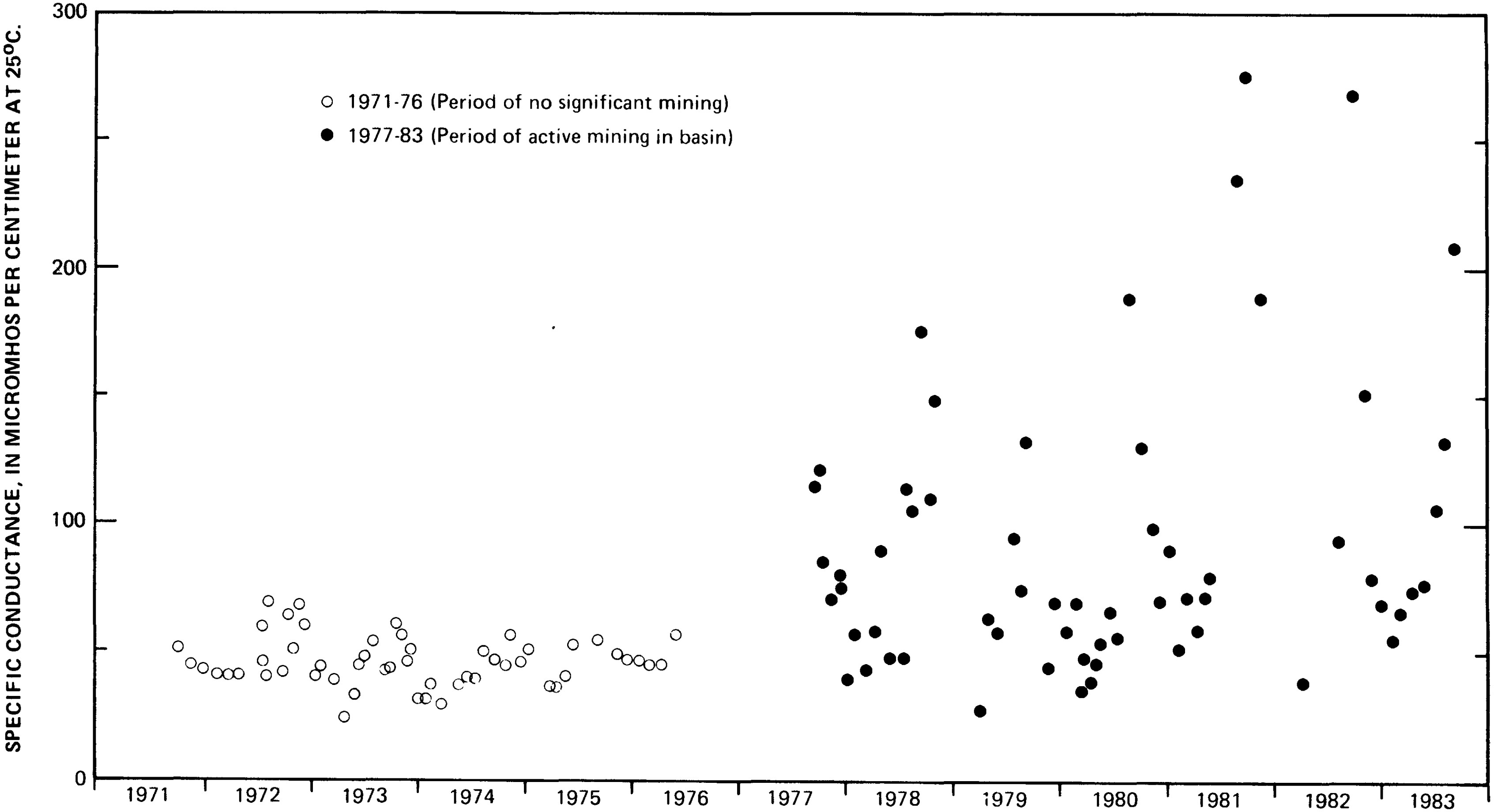


Figure 10.--Specific conductance at North River (site 1) for the period 1971-83. (Site number corresponds to those in figure 2 and table 1.)

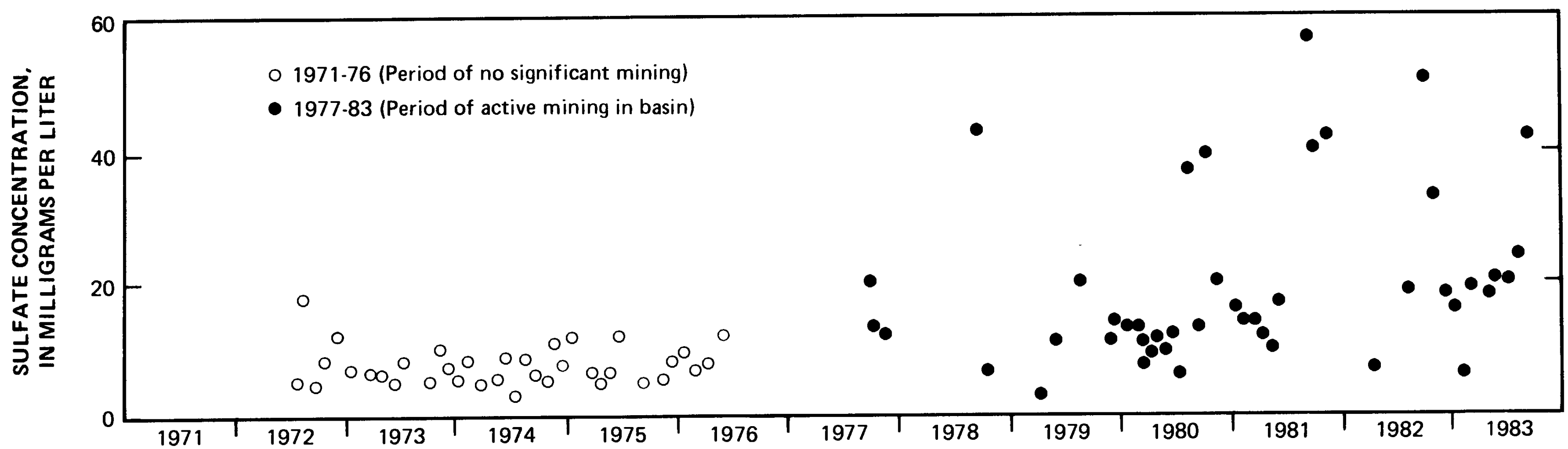


Figure 11.--Sulfate concentration at North River (site 1) for the period 1971-83. (Site number corresponds to those in figure 2 and table 1.)

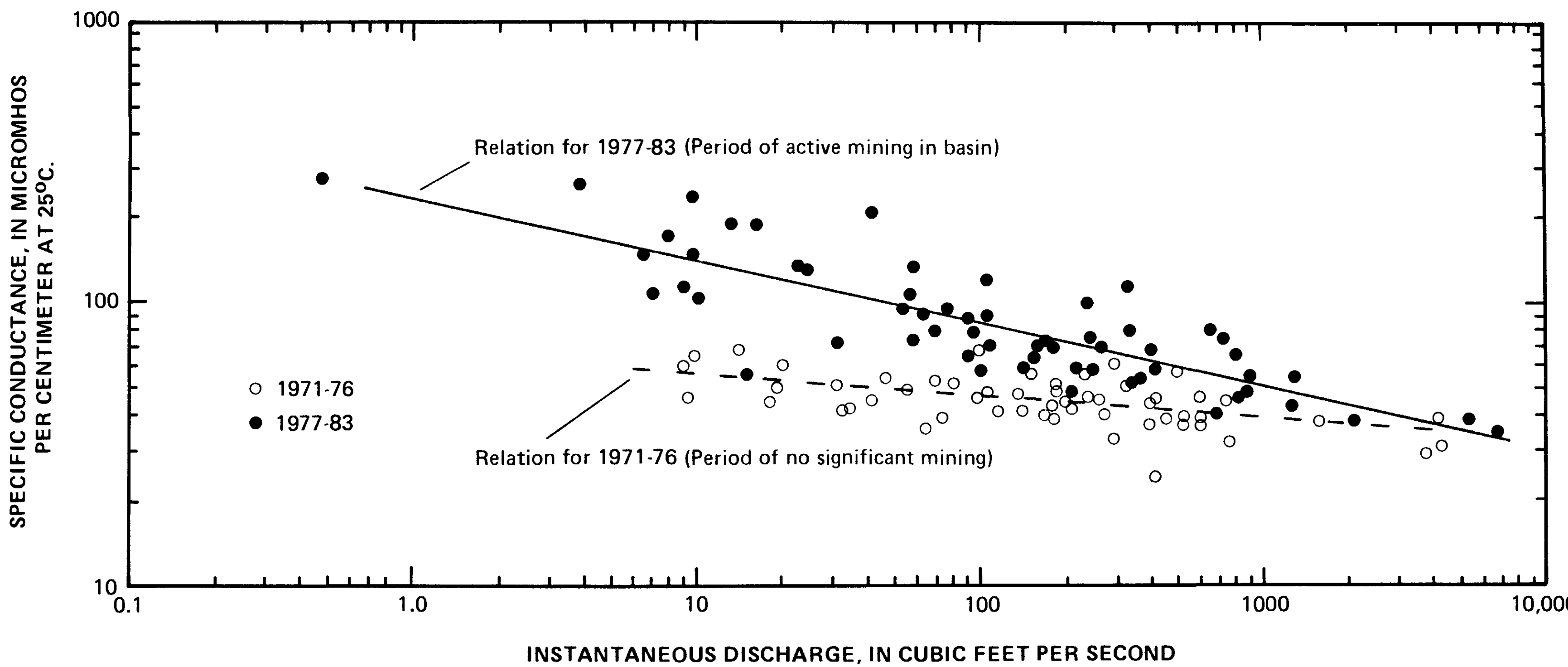


Figure 12.--Relation between specific conductance and instantaneous stream discharge at North River (site 1) for the periods 1971-76 and 1977-83. (Site number corresponds to those in figure 2 and table 1.)

Historic data for Cripple Creek (site 3) indicate increases in specific conductance, sulfate concentrations, and dissolved and total recoverable iron and manganese concentrations during mining (1977-83) similar to the increases described previously for North River. Some samples collected from Cripple Creek (table 3) contained sulfate concentrations exceeding the 250 mg/L contaminant level, with a maximum concentration of 700 mg/L in one sample. The maximum total recoverable manganese concentration for any of the samples in 1983 was for water from Cripple Creek (site 3) which contained a concentration of 2,600 ug/L. Cripple Creek has a low flow specific conductance of 610 micromhos (fig. 8) and a maximum specific conductance of 1,360 micromhos (table 3).

Turkey Creek (site 7) is a small basin (6.16 mi^2) studied prior to and during coal mining activities. Site 8 on Turkey Creek was added as a data-collection site during this study in order to monitor water quality immediately before input to Lake Tuscaloosa. Prior to mining, specific conductance and sulfate concentrations of water from Turkey Creek (site 7) were relatively stable (figs. 13 and 14). After the beginning of mining in 1981, both specific conductance and sulfate concentrations increased.

During low-flow conditions (November 1982, fig. 8) water in Turkey Creek is much less mineralized than water in North River and Cripple Creek. Parts of Turkey Creek basin are underlain by permeable sand and gravel deposits in the Coker Formation. Water in the Coker Formation is low in mineralization. Consequently, the lower mineralization of water in Turkey Creek (67 micromhos, site 8, fig. 8) results form dilution by larger base flows (with little mineralization) contributed by the Coker Formation.

Increases in dissolved and total recoverable manganese concentrations in water from Turkey Creek occurred after mining began (fig. 15). Changes in dissolved and total recoverable iron concentrations also occurred (fig. 16), but were not as pronounced as those for manganese. Iron concentrations varied considerably before and during mining. Unusually high concentrations of iron and manganese, mostly in the suspended phase, were present in a high-flow sample collected in February 1981 shortly after mining started (figs. 15 and 16). These high concentrations probably were caused by an initial flushing of minerals from the overburden exposed by mining.

Changes in the Water Quality in the Lake

Dissolved solids loads for the 1983 water year were computed for several streams to evaluate loads from mining areas. Insufficient data exist to identify the total amount of dissolved mineral matter which potentially may reach the reservoir from various sources. Aeration and dilution of waters downstream from the sampling locations may reduce the dissolved solids loads that are actually contributed to the reservoir. Water at site 1 on North River (fig. 8), located downstream from mining areas, represents drainage from more than half of North River basin and contributes a dissolved solids load of 100 (tons/mi^2)/yr. Water at site 3 on Cripple Creek, also located downstream from mined areas, is very mineralized during low-flow conditions (fig. 8) and contributes a much larger dissolved solids load of 310 (tons/mi^2)/yr. Water

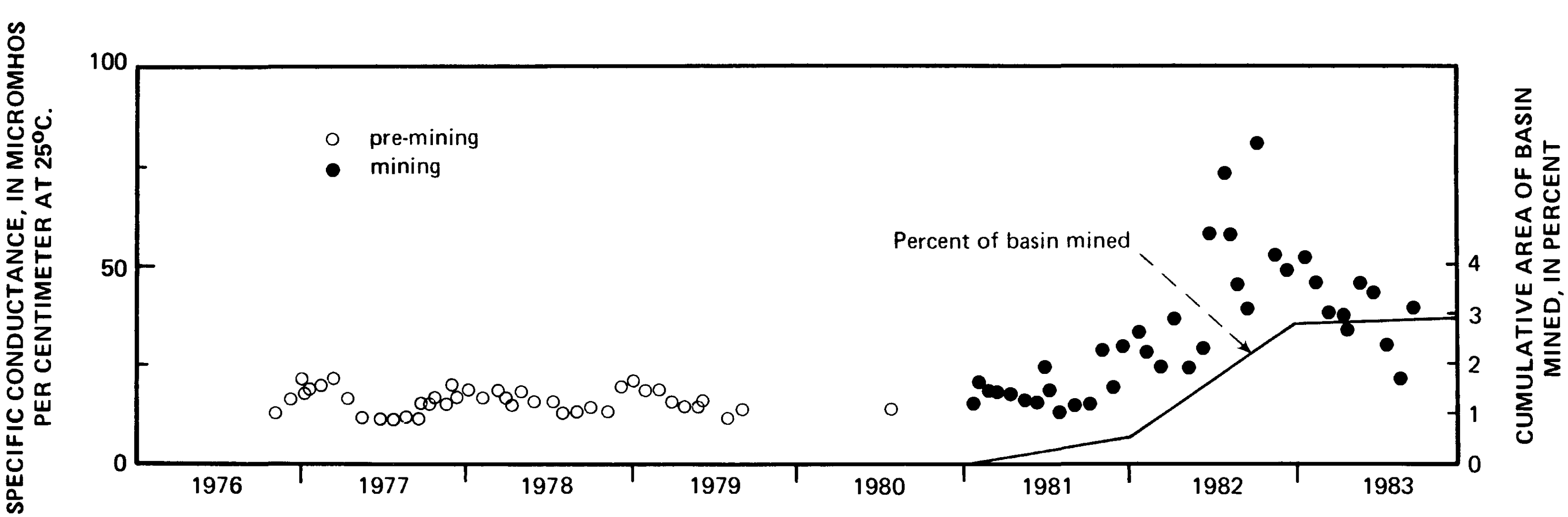


Figure 13.--Specific conductance and cumulative area of basin mined at Turkey Creek (site 7) for the period 1976-83. (Site number corresponds to those in figure 2 and table 1.)

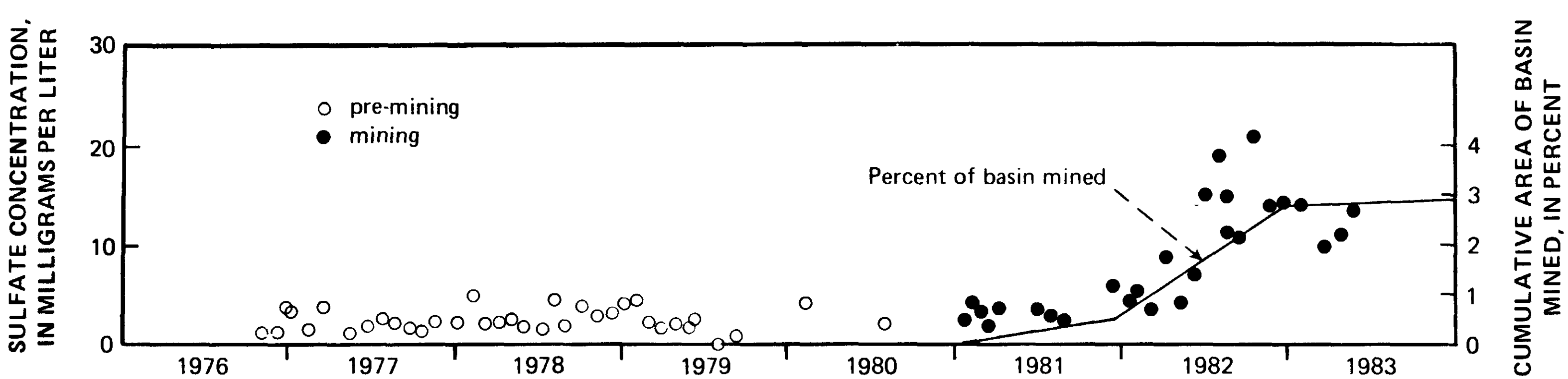


Figure 14.--Sulfate concentration and cumulative area of basin mined at Turkey Creek (site 7) for the period 1976-83. (Site number corresponds to those in figure 2 and table 1.)

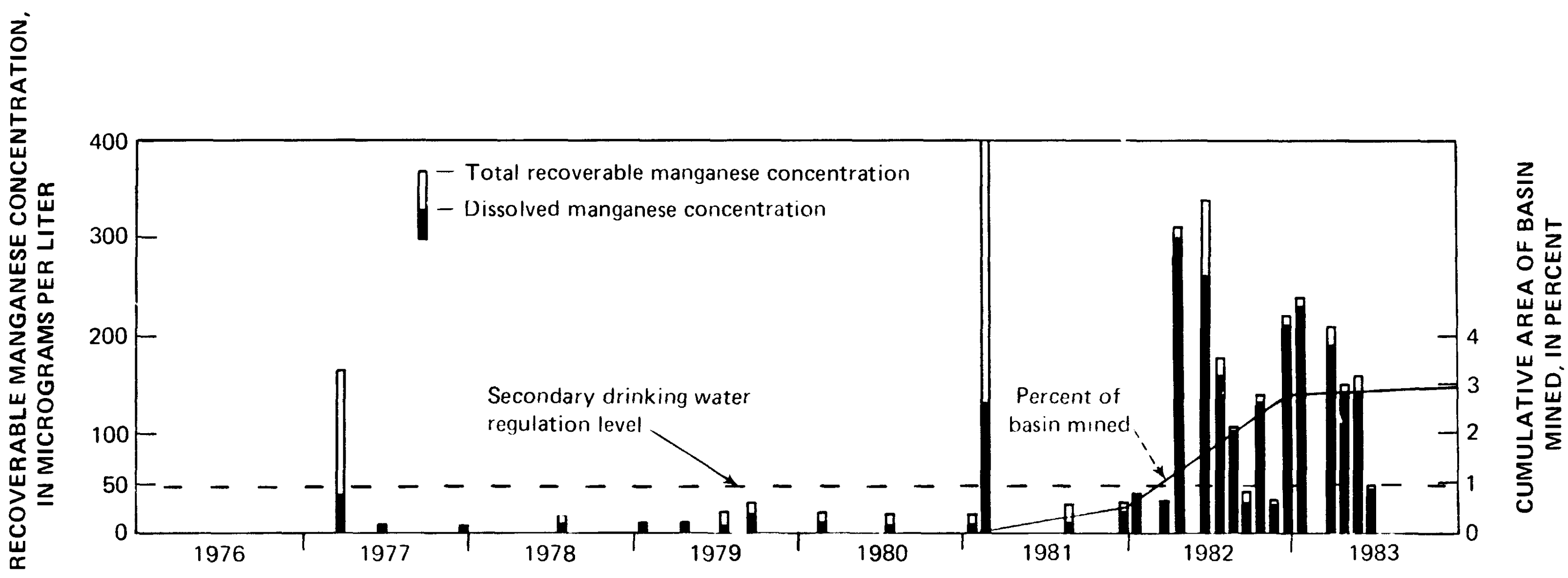


Figure 15.--Total recoverable and dissolved manganese concentrations and cumulative area of basin mined at Turkey Creek (site 7) for the period 1976-83. (Site number corresponds to those in figure 2 and table 1.)

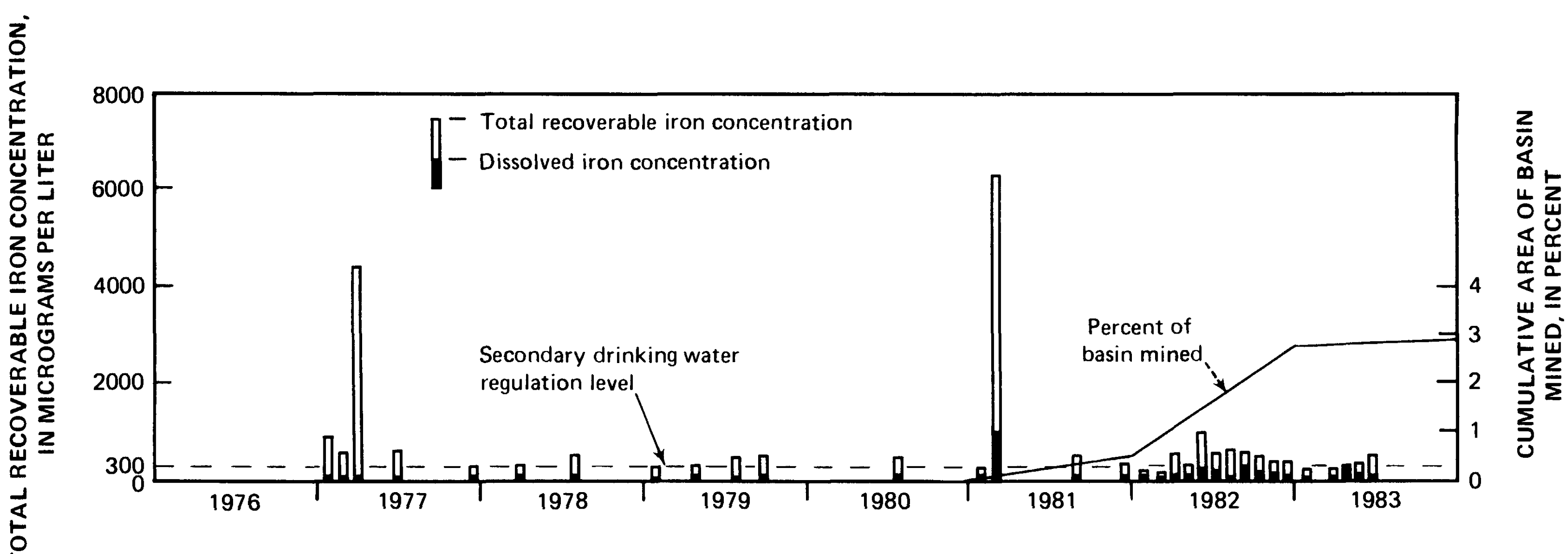


Figure 16.--Total recoverable and dissolved iron concentrations and cumulative area of basin mined at Turkey Creek (site 7) for the period 1976-83. (Site number corresponds to those in figure 2 and table 1.)

at site 8, located downstream from mined areas in Turkey Creek basin, is considerably less mineralized than that at site 3 on Cripple Creek and has a dissolved solids load of 80 (tons/mi^2)/yr. Water at site 10 on Binion Creek is low in mineralization (low flow specific conductance equals 40 micromhos) and has a dissolved solids load of 50 (tons/mi^2)/yr. Water at sites 9 and 14 in the reservoir is less mineralized than the inflow from North River (fig. 8), mainly because of dilution by less mineralized water from streams such as Binion and Turkey Creeks.

Instantaneous discharge measurements show that the majority of water supplied to the reservoir during the low-flow sampling (fig. 8) was from Binion and Carroll Creek basins (sites 10 and 12). Low specific conductance values for samples at both sites (40 micromhos at Binion Creek and 29 micromhos at Carroll Creek) indicate low concentrations of dissolved constituents. During low-flow conditions water from these streams play a major role in the dilution of more highly mineralized water entering the lake from other sources, such as Cripple Creek with a specific conductance of 610 micromhos.

Analyses of samples collected from North River (site 1) and Lake Tuscaloosa (sites 9 and 14) during this study were compared with analyses of samples collected at the same sites in 1975 (Hubbard, 1976b) to provide an overview of any changes in water quality between 1975 and 1983. Cation-anion diagrams for the sites were used to compare the quality of water in 1975 and 1983 during high-, median-, and low-flow conditions (fig. 9).

Water at the three sites, with the exception of that for high-flow samples at site 9, was more mineralized in 1983 than in 1975. The increase in specific conductance (dissolved solids), sulfate concentrations, and dissolved and total recoverable iron and manganese concentrations observed for water from North River, Cripple Creek, and Turkey Creek--since the beginning of major coal mining in the Lake Tuscaloosa (North River) basin--have contributed to the increase in mineralization (primarily sulfate concentrations) of water in Lake Tuscaloosa. Analyses of water from site 9 on Lake Tuscaloosa show the the same trend of increasing mineralization with decreasing streamflow as observed at site 1. (See "Changes in Water Quality in the Tributaries.") However, analyses of water from site 14 (at the dam) show little variation between flow conditions, indicating water in the reservoir has been diluted by stream inflow between sampling sites 9 and 14.

The quality of the water collected at the lake sites between October 1982 and September 1983 was, with the same exceptions reported previously for the tributaries, within recommended drinking water limits and is suitable as a source of public supply. (See table 3 and "Changes in Water Quality in the Tributaries.") Natural aeration of waters containing high dissolved iron and manganese concentrations commonly causes these constituents to precipitate out of solution. High concentrations may persist in the lake at times, however, due to low dissolved oxygen concentrations present in the deeper parts of the lake (Hubbard, 1976b). Suspended iron and manganese concentrations will decrease with a reduction in suspended sediment and particulate matter.

Although the reservoir water has become more mineralized, dissolved solids concentrations are still very low, ranging from 28 to 35 mg/L at the dam during the study. It is important to note that changes in water quality have been detected in the lake with only an estimated 5 percent of the basin mined. Continued surveillance of mining activities in the basin and monitoring of the reservoir water quality is important to maintain the water quality of Lake Tuscaloosa for public supply.

EFFECTS OF COAL MINING ON SEDIMENTATION OF LAKE TUSCALOOSA AND SELECTED TRIBUTARIES

Sediment deposition in Lake Tuscaloosa and its tributaries is continuous. Factors affecting the rate of sedimentation include physiography, soils, precipitation, and land use within the drainage basin. Some areas are underlain by relatively impervious rocks, have steep slopes, and soils with high erosion potential. These properties cause rapid runoff and increase sediment yield. Dense forest cover in much of the area, however, reduces erosion rates. Natural erosion and sediment yields are drastically altered by logging, agriculture, construction, and surface coal mining.

Surface coal mining involves removal of the vegetative cover, construction of haul roads, and creation of large volumes of spoil materials subject to weathering and erosion. These activities can drastically increase sediment yields that can result in reduced reservoir storage capacity. Previous studies have reported increases in annual suspended-sediment yields due to surface coal mining in North River basin and in adjacent areas. Annual sediment yields from selected basins in the Warrior Coal Field generally ranged from 54 to 1,800 (tons/mi^2)/yr in relatively undisturbed basins to 250 to 4,000 (tons/mi^2)/yr in basins disturbed by mining (Puente and Newton, 1982). Annual sediment yields for streams draining heavily mined, unreclaimed areas can be as high as 300,000 (tons/mi^2)/yr (Hubbard, 1976a).

Increased suspended-sediment yield to a reservoir may have detrimental and beneficial effects on the water treatment process. The suspended material that must be removed for municipal supply increases the cost of treatment. Some sedimentation may be advantageous, however, in that harmful constituents such as trace metals and pesticides, or nutrients that might accelerate eutrophication, adhere to suspended clay particles that settle to the bottom of the reservoir. Through this process, these constituents are removed from the water column and have little immediate effect on the water quality or its treatment.

Sedimentation occurring since impoundment of North River was determined by comparing the lake cross sections measured by fathometer in October and November 1982 with pre-impoundment cross sections. (See "Data-collection methods.") The cross sections established for this study (fig. 17) were measured again in July 1983 to determine if changes had resulted from high flow conditions during the study year. Comparison of these cross sections with those measured in October and November 1982, considering the accuracy of the measuring equipment, showed very little change.

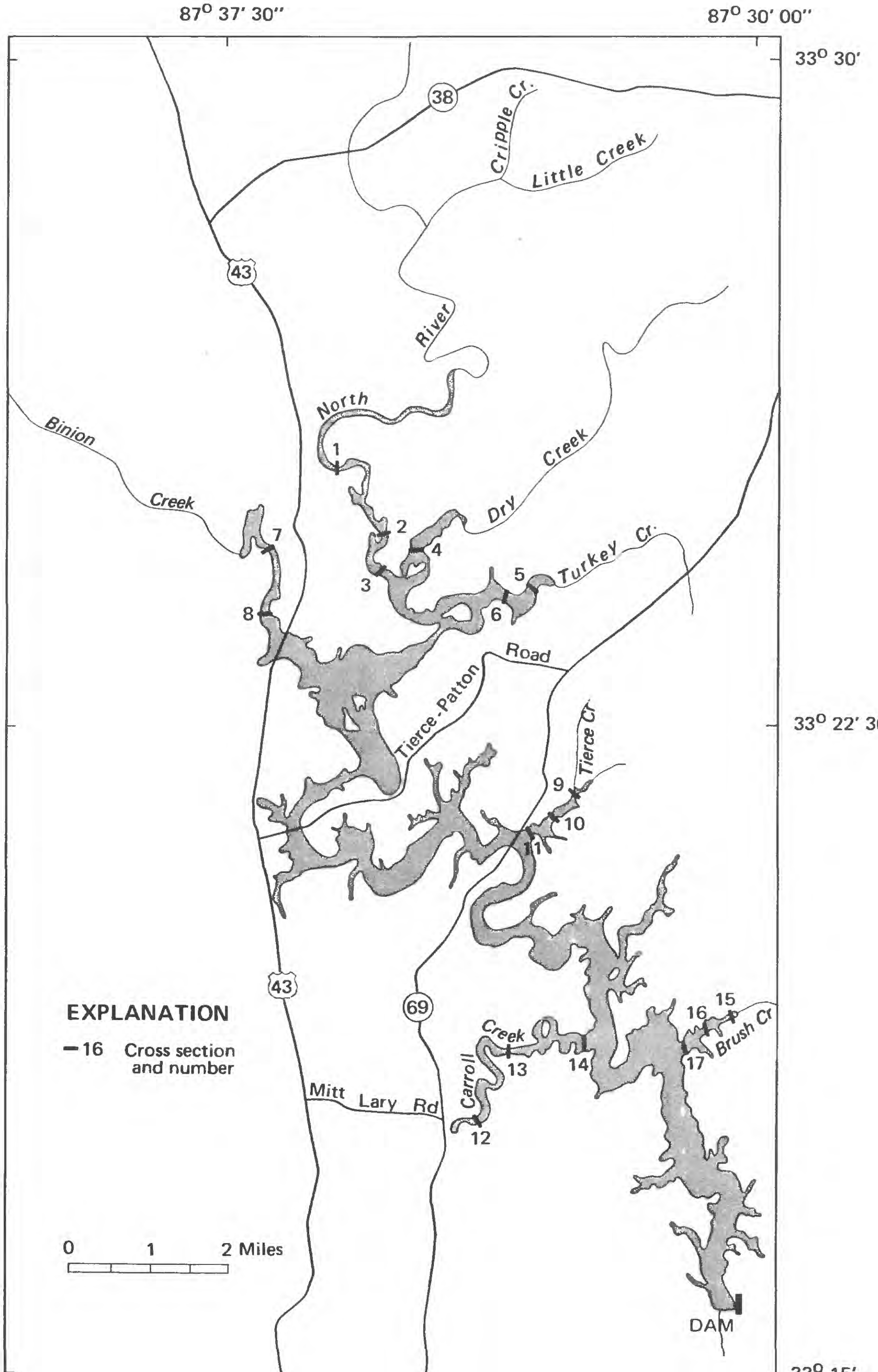


Figure 17.-- Location of lake cross sections.

Plots showing recent (1982) and the pre-impoundment (1960) lake cross sections are illustrated in figures 18-34. The stream basins associated with each lake cross section are identified in the figure titles. The plots generally show some variation in width and bank configuration between the two bottom profiles at each cross section. Some variations are due to the different methods used to determine elevations and distances. The pre-impoundment cross section determinations are not necessarily replicated by the impoundment cross section determinations. Consequently, maximum sediment deposition (table 4) has been established for the 17 cross sections by assuming banks and troughs indicated on the impoundment and pre-impoundment cross sections are equivalent and that maximum deposition was in troughs. Sedimentation has occurred at 14 of the 17 cross sections. Maximum thicknesses of sediment deposits usually occur in stream channels inundated by a reservoir. Therefore, most of the deposition found at the cross sections in Lake Tuscaloosa occurred after impoundment.

Geology, topography, and land use in basins were evaluated to identify possible causes of variation in sediment accumulation at the measured cross sections. For instance, Brush and Tierce Creeks drain very similar basins. Both are small, unmined basins underlain primarily by the Pottsville Formation; however, there is a difference in their topography. The average overland slope for Brush Creek basin is 800 ft/mi and the mean channel slope is 110 ft/mi. Tierce Creek basin has an average overland slope of 610 ft/mi and a mean channel slope of 84 ft/mi. Lake cross section 15 in Brush Creek basin received the greatest amount of sediment deposition between 1960 and 1982 (table 4), approximately 20 ft, whereas, lake cross sections 9 and 10 in Tierce Creek basin (figs. 26 and 27) appear to have been scoured and lost approximately 2 ft of sediment deposition. The steeper overland and channel slopes in Brush Creek basin increase the velocity of runoff, causing more erosion and sediment delivery to the reservoir. The scour at cross sections 9 and 10 in Tierce Creek basin may indicate inaccuracy in the measuring equipment and comparison methods, or it may accurately represent scour which occurred between March 1960 and 1969 when the lake was created.

Carroll Creek and Binion Creek basins on the west side of Lake Tuscaloosa are underlain by significant deposits of the Coker Formation. Land use in both basins is similar, including some areas cleared for agriculture. These basins, compared with Tierce Creek and Brush Creek basins, have larger drainage areas, wider flood plains, and considerably less overland and channel slope. The average overland slope for Carroll Creek basin is 330 ft/mi, and the mean channel slope is 16 ft/mi. Topography of Binion Creek basin is very similar to Carroll Creek basin. Maximum sediment deposition at lake cross sections in Binion and Carroll Creek basins varied only from 0 to 4 ft (table 4). Available information indicates that these basins provide less sediment to the lake than other sources of inflow.

Dry Creek and Turkey Creek basins are very similar in size, topography, and geology. However, Dry Creek basin is basically undisturbed, whereas Turkey Creek basin has been disturbed by surface coal mining. The average overland slope for both basins is 690 ft/mi and the mean channel slope is 53 ft/mi. Outcrops of the Coker Formation are found in both basins; however, those in Turkey Creek basin are more extensive. Between 1960 and 1982, lake

Table 4.--Basin, formation drained, whether disturbed or undisturbed by surface mining for coal, and estimated maximum sediment deposition (between 1960 and 1982) at 17 lake cross sections

Lake cross section[a]	Basin	Principal formation drained	Disturbed (D) or undisturbed (U) by coal mining	Maximum[b] sediment deposition (ft)
1	North River	Pottsville	D	8
2	North River	Pottsville	D	11
3	North River	Pottsville	D	8
4	Dry Creek	Pottsville	U	2
5	Turkey Creek	Pottsville and Coker	D	15
6	Turkey Creek	Pottsville and Coker	D	7
7	Binion Creek	Coker	D	2
8	Binion Creek	Coker	D	2
9	Tierce Creek	Pottsville	U	-2 (scour)
10	Tierce Creek	Pottsville	U	-2 (scour)
11	Tierce Creek	Pottsville	U	4
12	Carroll Creek	Coker	U	4
13	Carroll Creek	Coker	U	0
14	Carroll Creek	Coker	U	3
15	Brush Creek	Pottsville	U	20
16	Brush Creek	Pottsville	U	13
17	Brush Creek	Pottsville	U	3

[a] Location of cross sections shown on figure 17.

[b] Estimated from figures 18-34 after assuming banks and troughs indicated on the impoundment (1982) and pre-impoundment (1960) cross sections are equivalent and that maximum deposition was in troughs.

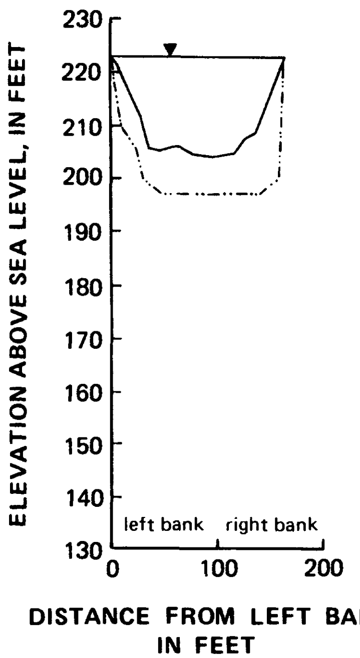


Figure 18.-- Lake cross section 1 in North River basin, March 1960 and November 1982.

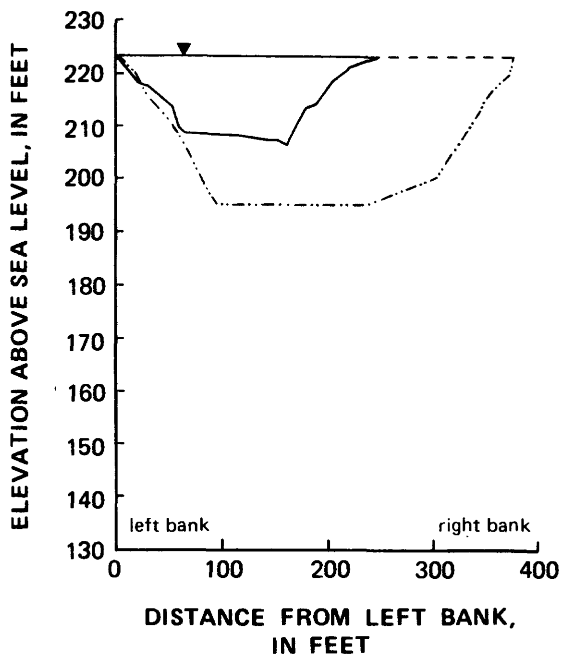


Figure 19.-- Lake cross section 2 in North River basin, March 1960 and November 1982.

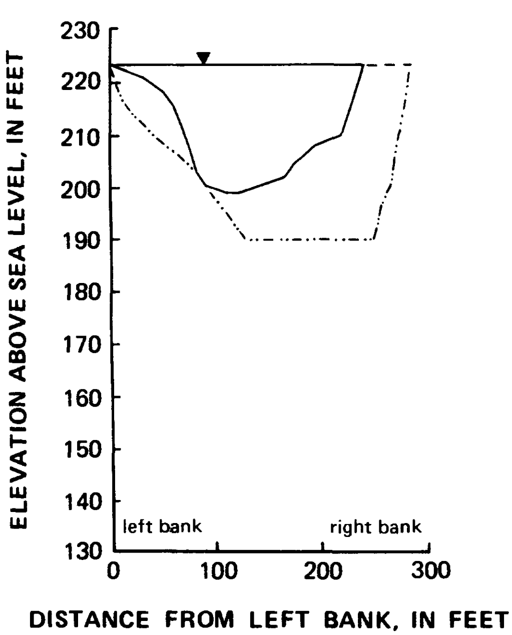
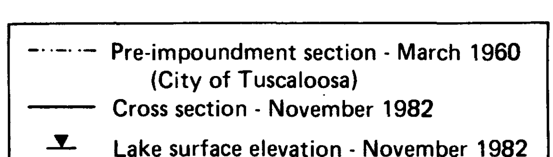


Figure 20.-- Lake cross section 3 in North River basin, March 1960 and November 1982.



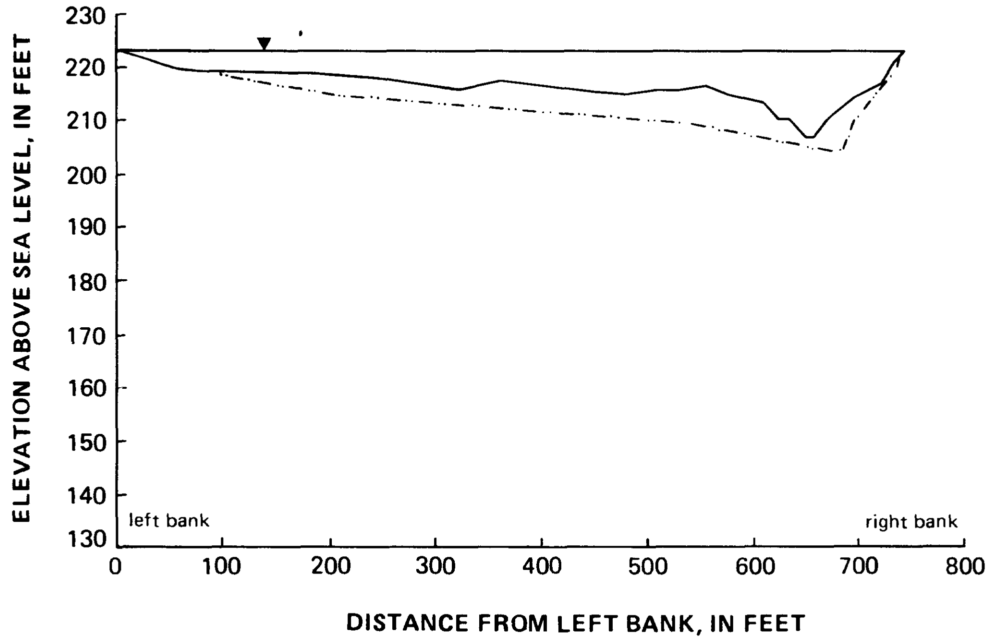


Figure 21.-- Lake cross section 4 in Dry Creek basin, March 1960 and November 1982.

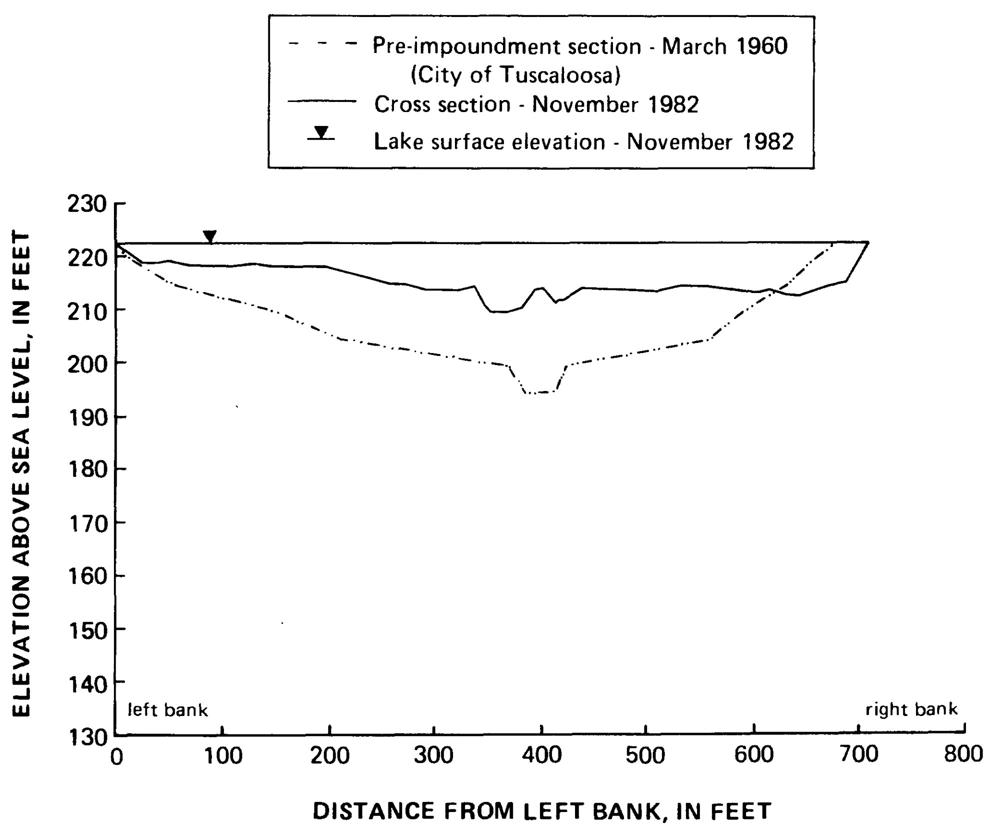


Figure 22.-- Lake cross section 5 in Turkey Creek basin, March 1960 and November 1982.

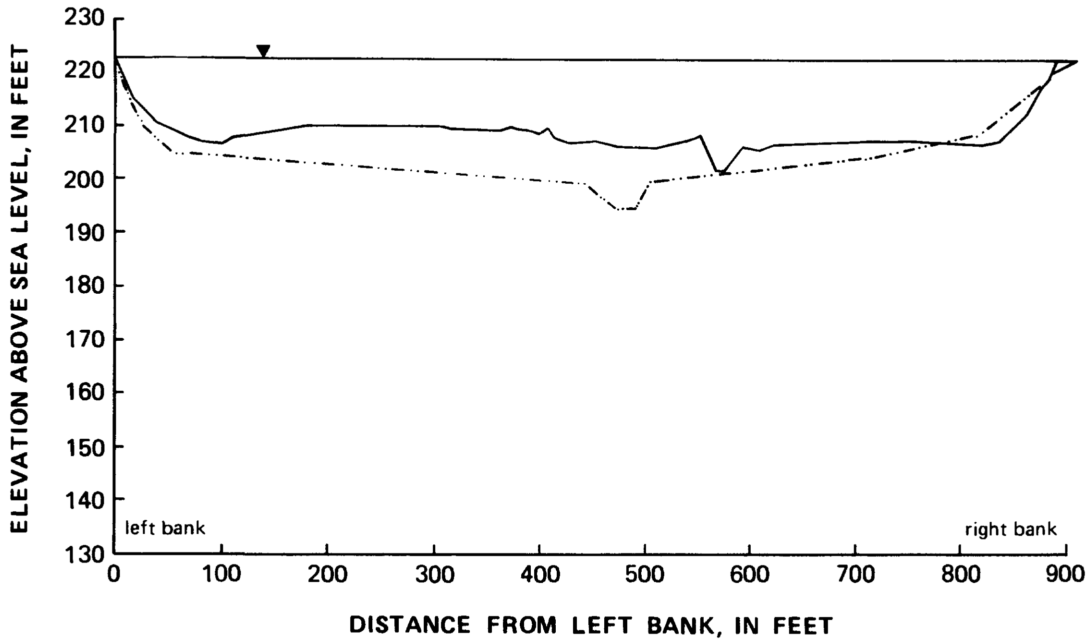


Figure 23.-- Lake cross section 6 in Turkey Creek basin, March 1960 and November 1982.

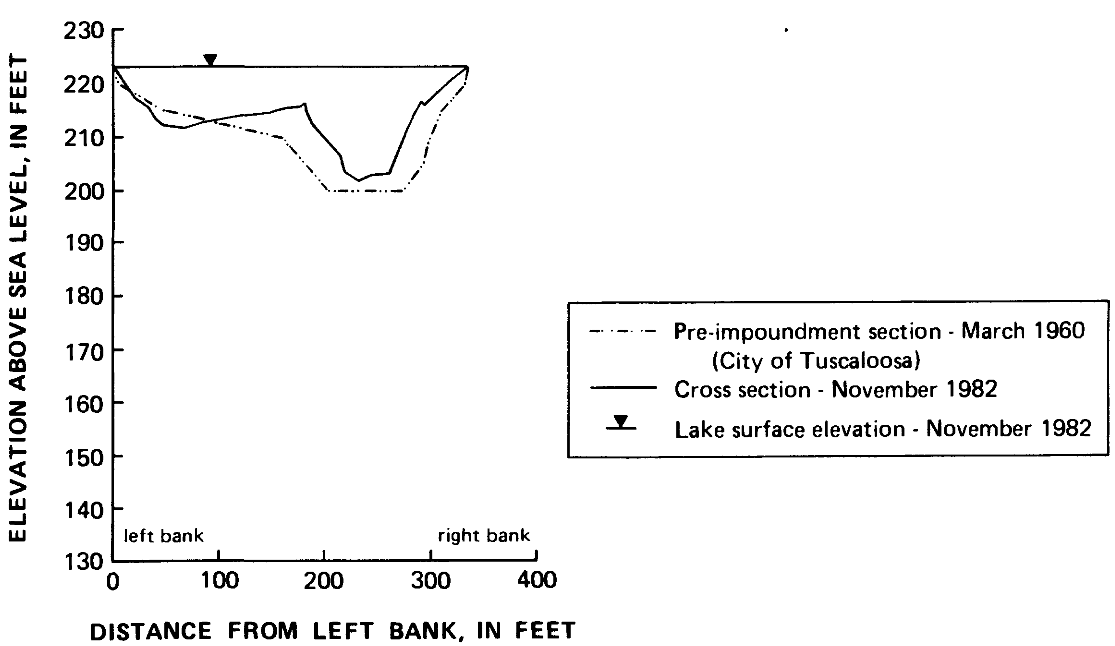


Figure 24.-- Lake cross section 7 in Binion Creek basin, March 1960 and November 1982.

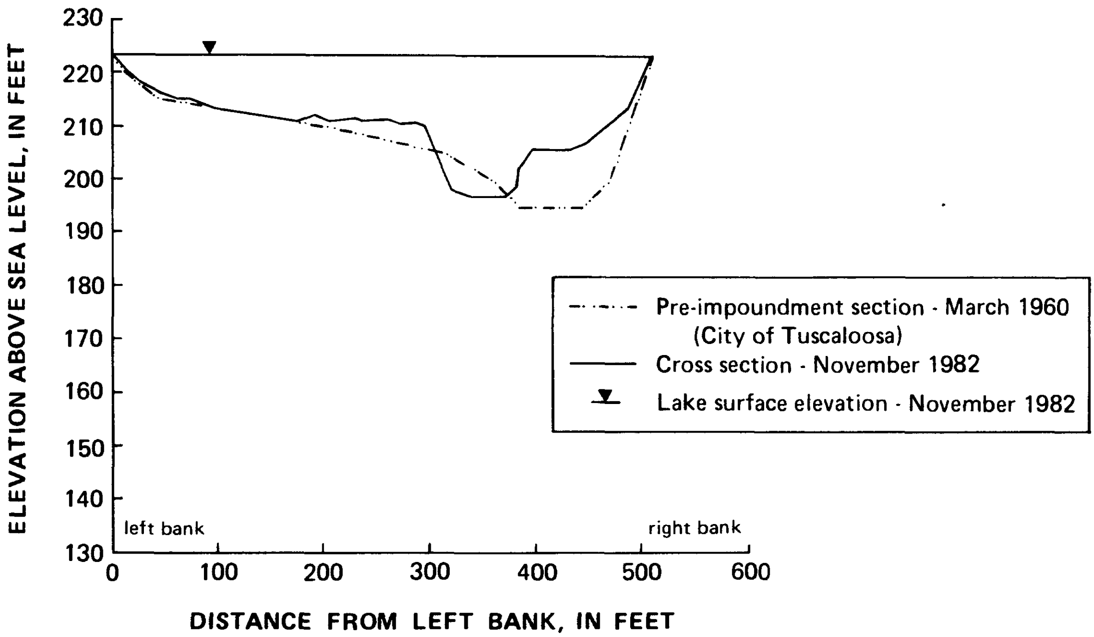


Figure 25.-- Lake cross section 8 in Binion Creek basin, March 1960 and November 1982.

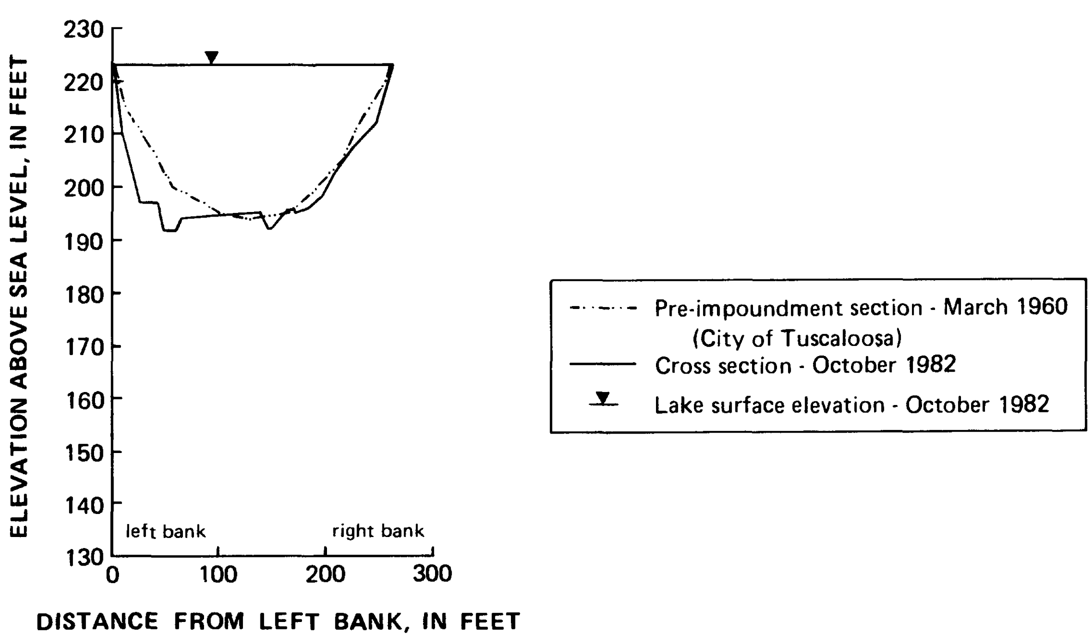


Figure 26.-- Lake cross section 9 in Tierce Creek basin, March 1960 and October 1982.

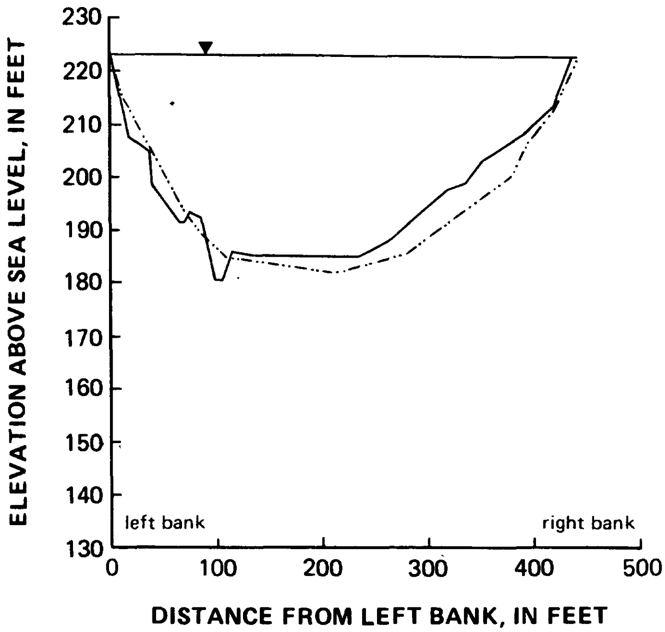


Figure 27.-- Lake cross section 10 in Tierce Creek basin, March 1960 and October 1982.

-·-·- Pre-impoundment section - March 1960 (City of Tuscaloosa)

——— Cross section - October 1982

▼ Lake surface elevation - October 1982

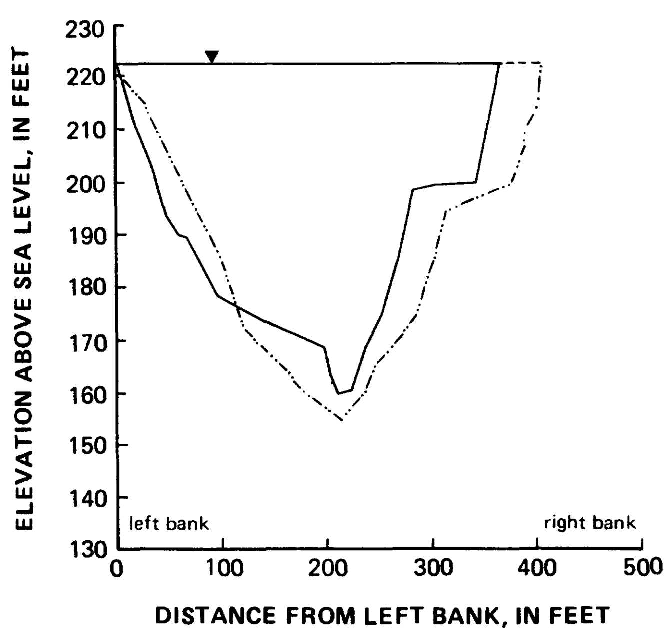


Figure 28.-- Lake cross section 11 in Tierce Creek basin, March 1960 and October 1982.

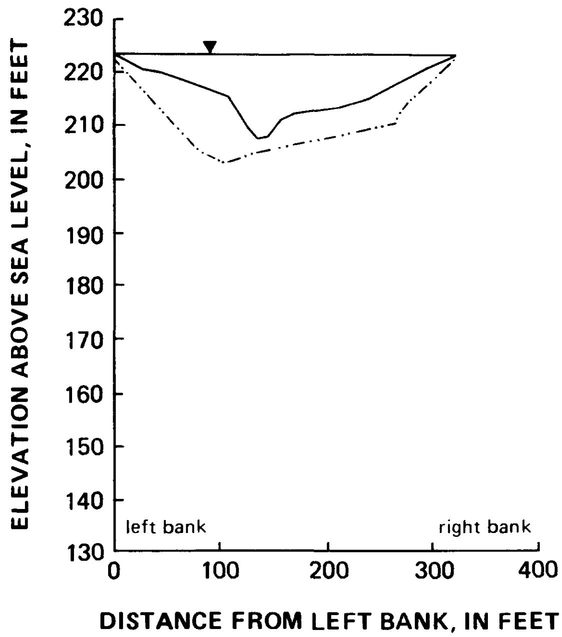


Figure 29.-- Lake cross section 12 in Carroll Creek basin, March 1960 and October 1982.

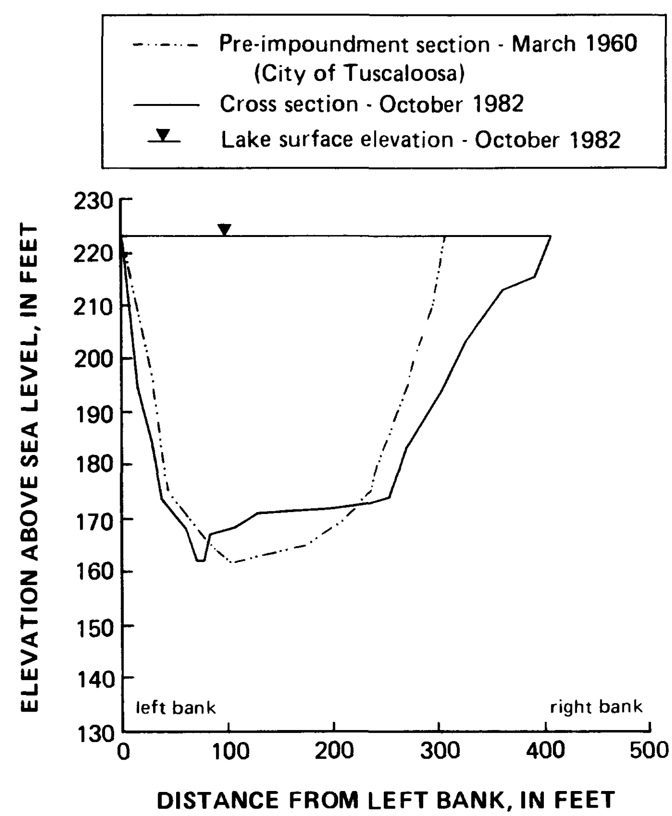


Figure 30.-- Lake cross section 13 in Carroll Creek basin, March 1960 and October 1982.

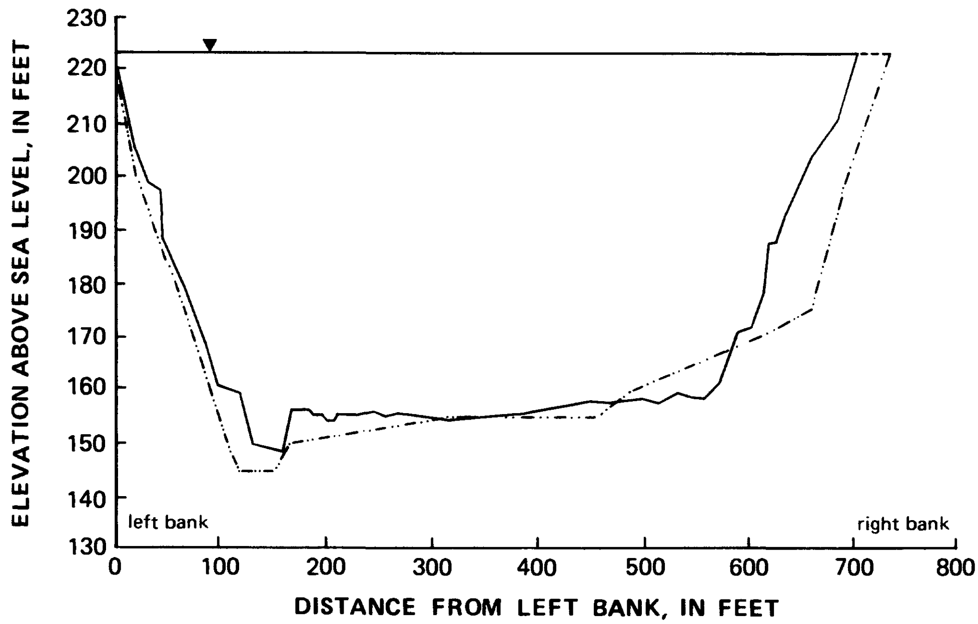


Figure 31.-- Lake cross section 14 in Carroll Creek basin, March 1960 and October 1982.

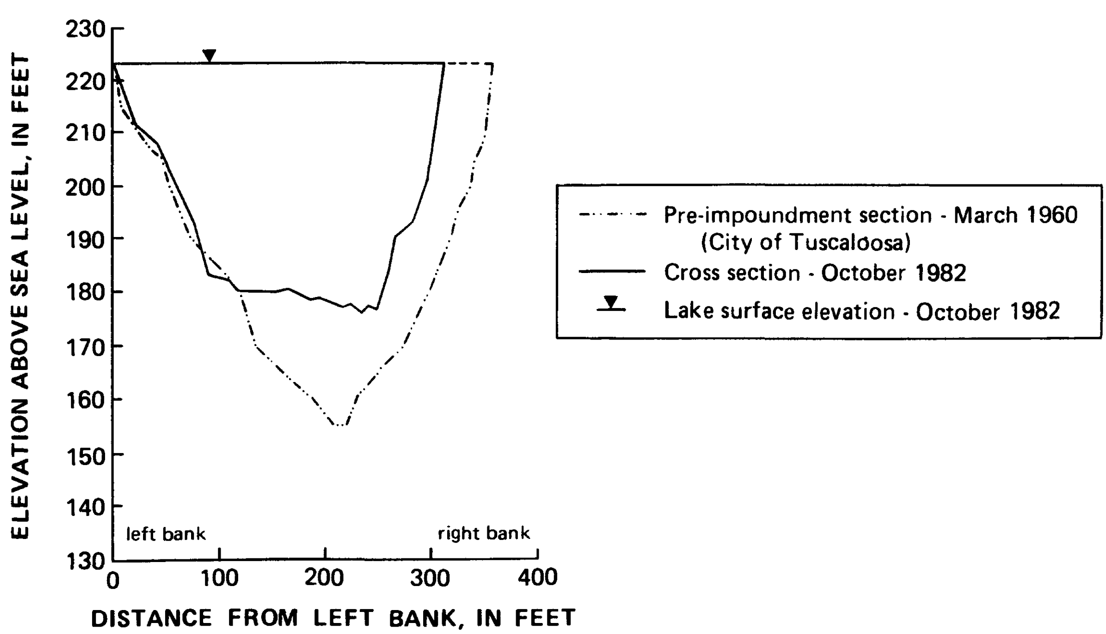


Figure 32.-- Lake cross section 15 in Brush Creek basin, March 1960 and October 1982.

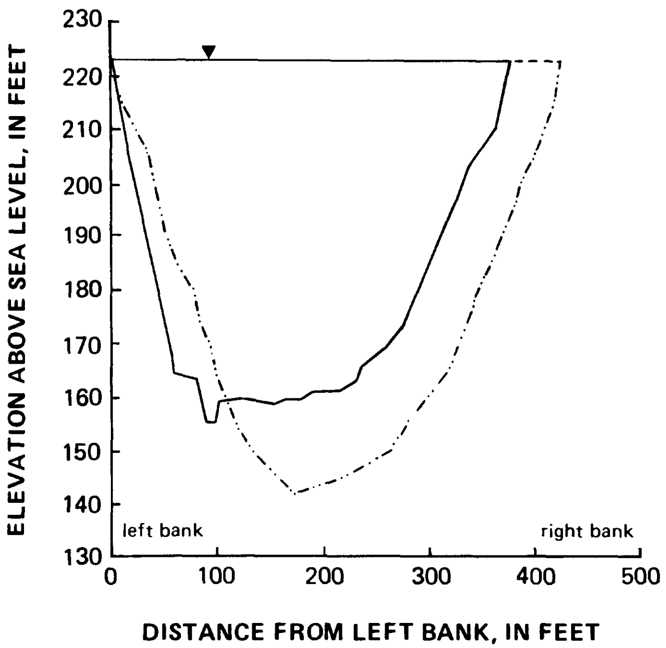


Figure 33.-- Lake cross section 16 in Brush Creek basin, March 1960 and October 1982.

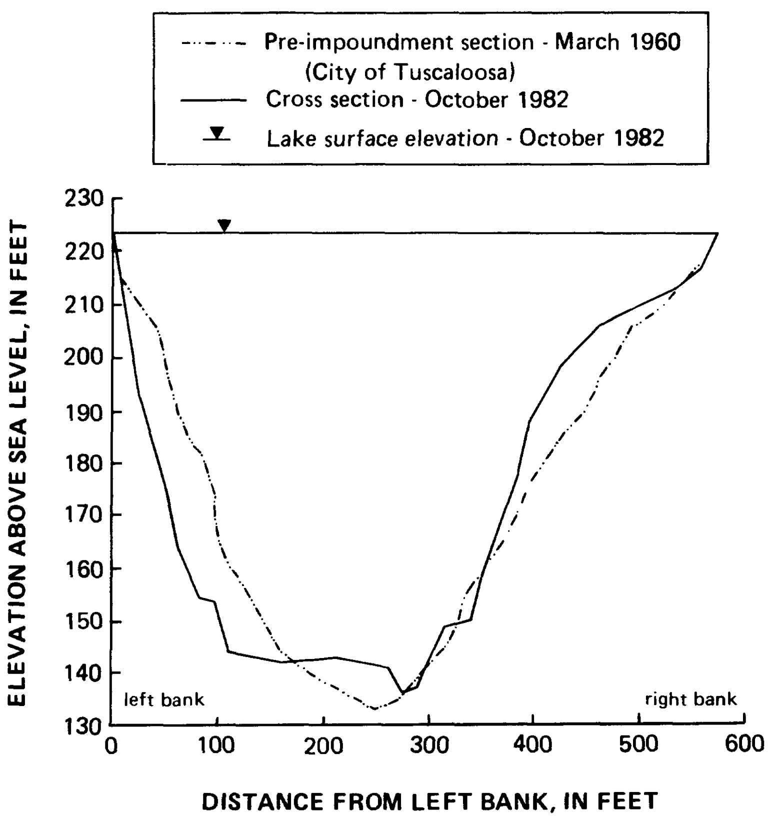


Figure 34.-- Lake cross section 17 in Brush Creek basin, March 1960 and October 1982.

cross section 4 in Dry Creek basin received a maximum of approximately 2 ft of sediment deposition, while cross section 5 in Turkey Creek basin received about 15 ft (table 4). The larger amount of deposition observed at lake cross sections in Turkey Creek basin may be due to the more extensive deposits of the Coker Formation or, more probably, disruption by surface mining. The three lake cross sections established in North River basin received a maximum sediment deposition ranging, approximately, from 8 to 11 ft between 1960 and 1982 (table 4). The results indicate that natural factors affecting sediment deposition in the reservoir, such as steep overland and channel slopes in the contributing basin, in some instances may cause more sedimentation in the lake than disruption due to coal mining of a different basin having less severe slopes. Again it is important to note that less than 5 percent of the Lake Tuscaloosa (North River) basin has been mined. Due to the variability of sediment deposition at and between cross sections and the lack of sedimentation data for other parts of the lake, the amount of reservoir storage lost due to sedimentation is unknown. Continued monitoring of benchmark cross sections established in the fathometer survey and surveillance of land use changes in North River basin may identify the effect of future land use changes on sediment deposition in the reservoir.

SUMMARY

The primary function of Lake Tuscaloosa, a reservoir on North River, is to provide the primary water supply for the city of Tuscaloosa and surrounding areas. Changes in land use, such as surface coal mining in North River basin, have caused concern about impacts on the quality of water and the rate of sedimentation in the impoundment.

The Pottsville Formation, consisting mainly of sandstone, shale, and siltstone, underlies the entire study area, but is exposed mainly in the northeastern part of the basin. The Coker Formation, consisting mainly of sand, gravel, and clay, overlies the Pottsville Formation and crops out in southern and western parts of the basin.

Carroll and Binion Creeks, which drain basins west of Lake Tuscaloosa that are underlain by unconsolidated deposits of the Coker Formation, exhibit well-sustained flows during dry-weather conditions. Approximately 80 percent of the estimated inflow to the reservoir during low-flow conditions is from Carroll and Binion Creeks which drain only 19 percent of the North River basin.

Water in the reservoir is suitable for public supply. However, an increase in mineralization, primarily sulfate concentrations, has occurred since the beginning of major surface coal mining in the basin. Water draining mined basins (North River, Turkey Creek, and Cripple Creek) showed increases in specific conductance, sulfate concentrations, and dissolved and total recoverable iron and manganese concentrations after mining started. These increases in mineralization have contributed to the increased mineralization of the reservoir water. Although water in the reservoir has become more mineralized with only an estimated 5 percent of the basin mined, total dissolved solids concentrations are still very low, ranging from 28 to 35 mg/L at the dam.

The quality of water in streams in the study area, with the exception of that downstream from mined areas, is generally good. Water draining mined areas, such as Cripple Creek basin, often is very mineralized, particularly during low-flow conditions. This highly mineralized water draining Cripple Creek basin contributes an estimated 310 (tons/mi^2)/yr of dissolved solids to the reservoir. North River, draining more than half the study area, contributes an estimated dissolved solids load of 100 (tons/mi^2)/yr. Water in the reservoir is less mineralized than the inflow from North River, however, mainly because of dilution by less mineralized water from streams such as Binion Creek which contributes an estimated 50 (tons/mi^2)/yr of dissolved solids to the reservoir.

The quality of water at most sites during the study year, with some exceptions, was within limits of the National secondary drinking water standards. Some samples from Cripple Creek, downstream of mined areas, contained sulfate concentrations exceeding the 250 mg/L drinking water limit, with a maximum concentration of 700 mg/L in one sample. The pH of water from streams draining mined and unmined basins was generally less than 6.5 units. Concentrations of total recoverable iron and manganese exceeded recommended secondary drinking water standard levels of 300 ug/L and 50 ug/L, respectively, in more than half the samples at most sites. The maximum total recoverable iron concentration was 5,600 ug/L and the maximum total recoverable manganese concentration was 2,600 ug/L.

A fathometer survey showed that sedimentation has occurred at most measured points since impoundment. Lake cross sections in Turkey Creek basin indicate that mining has probably increased the sediment yield from this basin. However, the maximum sediment deposition, approximately 20 ft, was measured at a lake cross section in Brush Creek basin. Brush Creek drains a small, unmined basin, but the steep overland and channel slopes increase the velocity of runoff and sediment delivery to the reservoir. Therefore, natural factors affecting sediment deposition in the reservoir, such as steep overland and channel slopes, may cause more sedimentation in the lake than disruption due to coal mining of a different basin having less severe slopes. The amount of sediment deposited in the lake, with the exception of that along the lake cross sections, is unknown. Because of this, the amount of reservoir storage lost due to sedimentation is also unknown.

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