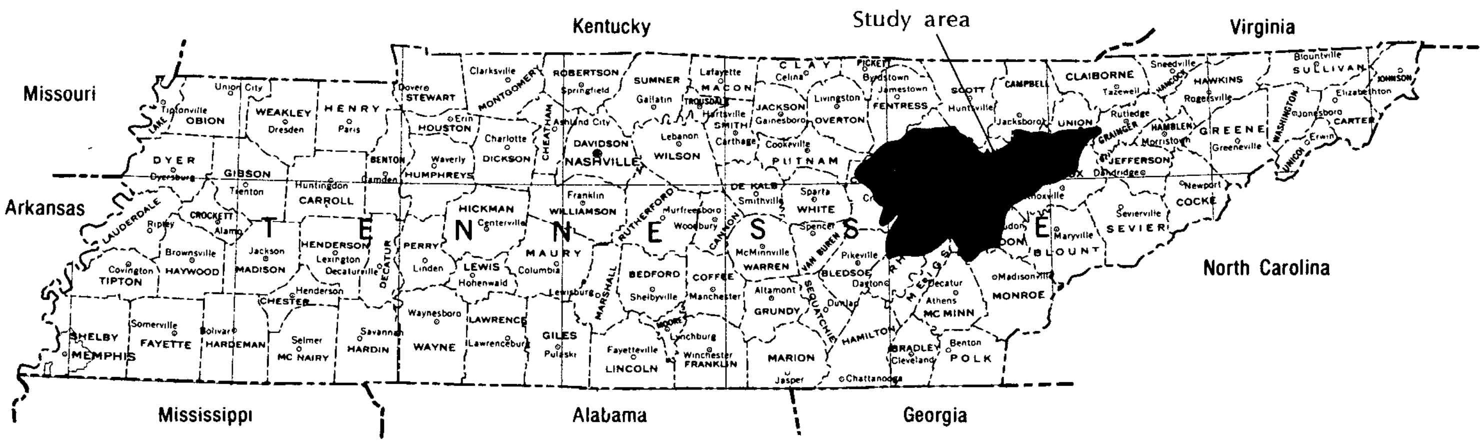
WATER-RESOURCES INVESTIGATIONS REPORT 85-417

WATER-QUALITY APPRAISAL OF NASQAN STATIONS BELOW IMPOUNDMENTS, EASTERN TENNESSEE



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WATER-QUALITY APPRAISAL OF NASQAN STATIONS BELOW IMPOUNDMENTS, EASTERN TENNESSEE

R.D. Evaldi and J.G. Lewis

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4171

Knoxville, Tennessee

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
A-413 Federal Bldg.
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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF (SI)

Multiply	By	To obtain
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 [$(m^3/s)/km^2$]
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
pound (lb)	0.4536	kilogram (kg)
ton, short	0.9072	metric ton

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

$$°C = \frac{°F - 32}{1.8}$$

APPRAISAL OF WATER-QUALITY DATA FROM NASQAN STATIONS BELOW IMPOUNDMENTS, EASTERN TENNESSEE

by Ronald D. Evaldi and James G. Lewis

ABSTRACT

The National Stream Quality Accounting Network (NASQAN) is a network of stations at which systematic and continuing water-quality data are collected. Major objectives of this U.S. Geological Survey program are (1) to depict areal variability of streamflow and water-quality conditions nationwide on a year-by-year basis and (2) to detect long-term changes in streamflow and stream quality.

Several NASQAN stations in East Tennessee are downstream from impoundments which have a significant effect on water quality. NASQAN data obtained from the Tennessee River below Watts Bar Dam and the Clinch River below Melton Hill Dam were compared to water-quality data from the basins upstream. The comparison indicates that NASQAN data obtained below impoundments may not be adequate to describe a composite picture of water quality in the accounting unit. Detention time of storage in the impoundments is believed to moderate the range of constituent values observed at the NASQAN stations. Data obtained upstream and downstream from Watts Bar Dam indicate that the water sampled at the NASQAN station comes from stratified layers of the impoundment and is not representative of an integrated sample of water from the impoundment. Values of total recoverable iron suggest that, because of adsorption to sediments in impoundments, some constituents are not accurately described by sampling below impoundments.

Relations between water-quality constituents and flow at stations on the Clinch River and Tennessee River are not well defined due to regulation. Direct load computations for many constituents were therefore not possible, which diminished the utility of data from these NASQAN stations to account for quantity versus quality of the water. Load computations were only possible for ionic constituents through use of a continuous specific-conductance record as an intermediary. Compensation for the effects of discharge prior to application of the Seasonal Kendall test for trends could not be done and identification of trends in water-quality constituents caused by some process (source) change was not possible. Some water-quality trends indicated by data from the Clinch and Tennessee Rivers might reflect the decreasing trend in discharge during the 1972-82 water years. Thus the stations below Watts Bar Dam and below Melton Hill Dam do not adequately meet the NASQAN objective to detect and assess long-term changes in stream quality.

INTRODUCTION

The National Stream Quality Accounting Network (NASQAN) is a network of stations at which systematic and continuing water-quality data are collected. The major objectives of this U.S. Geological Survey program are:

(1) To obtain information on the quality and quantity of water moving within and from the United States through a systematic and uniform process of data collection, summarization, analysis, and reporting such that the data may be used for:

(2) Description of the areal variability of water quality in the Nation's streams through analysis of data from this and other programs.

(3) Detection of changes or trends with time in the pattern of occurrence of water-quality characteristics.

(4) Providing a nationally consistent data base useful for water-quality assessments and hydrologic research.

The spacial distribution of NASQAN stations is based on a system of hydrologic subdivisions developed by the U.S. Water Resources Council and the Geological Survey. In this system, drainage basins in the United States are divided into 21 regions, 222 subregions, and 352 accounting units; the latter two divisions being progressively smaller parts of a region.

NASQAN stations generally are located at or near the most downstream point of accounting units. Some NASQAN sites are being operated downstream of impoundments. For example, all NASQAN stations in East Tennessee are located on highly regulated streams and several are located immediately below dams.

OBJECTIVE

The objective of this study was to describe the areal variability and long-term trends in water quality at NASQAN stations on the Tennessee River below Watts Bar Dam and the Clinch River below Melton Hill Dam in East Tennessee. The NASQAN station data was compared with the areal and temporal variability of water quality in the upstream NASQAN accounting unit. Comparison of NASQAN data obtained below an impoundment to water quality of the upstream basin will help to determine whether NASQAN stations located on regulated stream systems provide a composite picture of water quality within the accounting unit. Constituent concentrations which might be expected in a free-flowing stream may be changed due to storage in the impoundments, and samples obtained below the impoundments may not adequately describe the water quality of the drainage basin.

BASIN DESCRIPTION

The Tennessee River at Watts Bar Dam is the outlet for all surface flow leaving the study area. The drainage area at the streamflow-measuring and water-sampling station on the Tennessee River at Watts Bar Dam is 17,310 mi^2. However, this study was restricted, in general, the 2,201 mi^2 area above Watts Bar Dam t corresponds to the Area 19 hydrologic report area of the Eastern Coal province. This 2, mi^2 is downstream from other impoundments the NASQAN accounting unit. The follow descriptive information about the study area excerpted mainly from the Geological Sur publication "Hydrology of Area 19, Eastern C Province, Tennessee" (Gaydos and others, 1982).

Location

The study area, in eastern Tennes includes parts of 15 counties (fig. 1). This a lies in parts of two physiographic provinces, Cumberland Plateau (a section of the Appalach Plateau province) and the Ridge and Va province.

Topography

The Cumberland Plateau, in the northw part of the study area, has a general altitude 1,500 to 1,700 feet and an area of more t 1,100 mi^2. The terrain is mostly rolling h However, a line of mountains near the eastern e of the Cumberland Plateau is more than 1,000 f higher than the surrounding plateau, and sc streams have incised more than 600 feet be the plateau surface. Separating the Cumberl Plateau from the Ridge and Valley is a hig dissected southeast-facing escarpment which 700 to 900 feet relief in most areas.

The Ridge and Valley, in the southeast p of the study area, is characterized by long ric separated by valleys trending in a northe southwest direction (figs. 1 and 2). These vall are usually flat with a general altitude of 80 900 feet. Intervening ridges reach altitudes 1,000 to 1,300 feet.

Climate

The study area is in parts of two clima logical divisons, eastern Tennessee and Cumberland Plateau. Mean annual precipita is about 52 inches, with extremes ranging fr

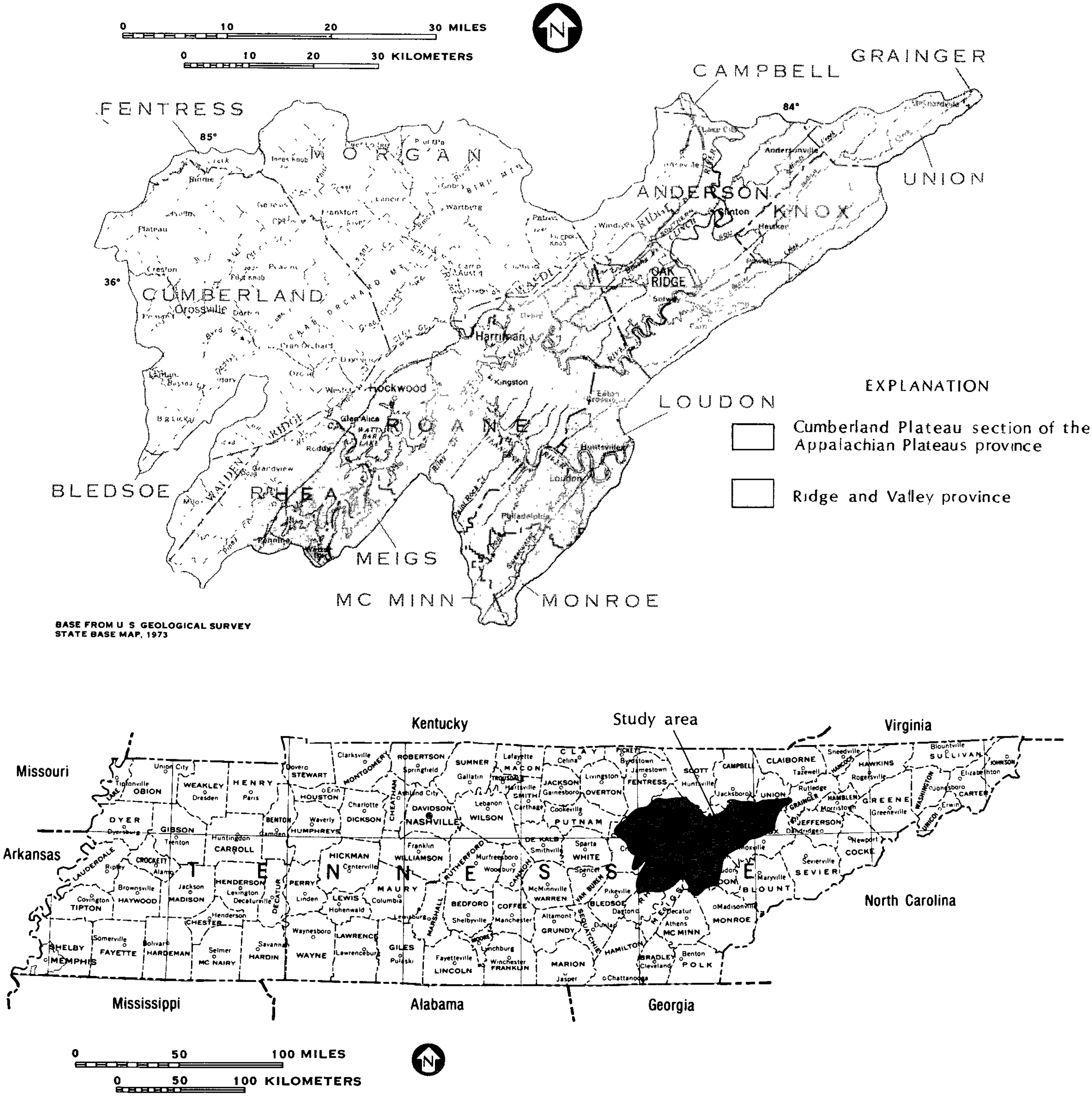
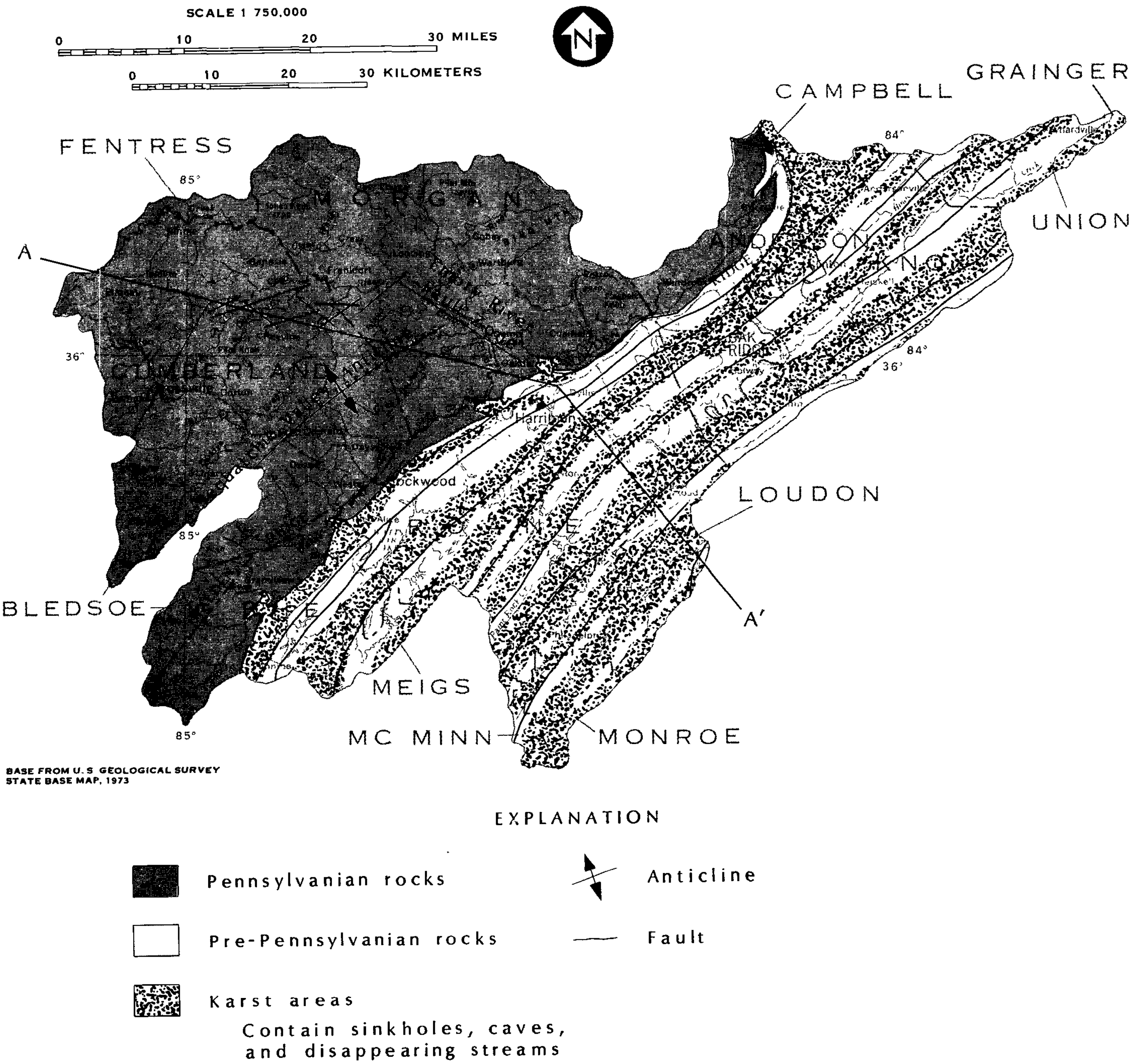


Figure 1.--Location of study area and relation to physiographic provinces (physiography from N. M. Fenneman, 1938)



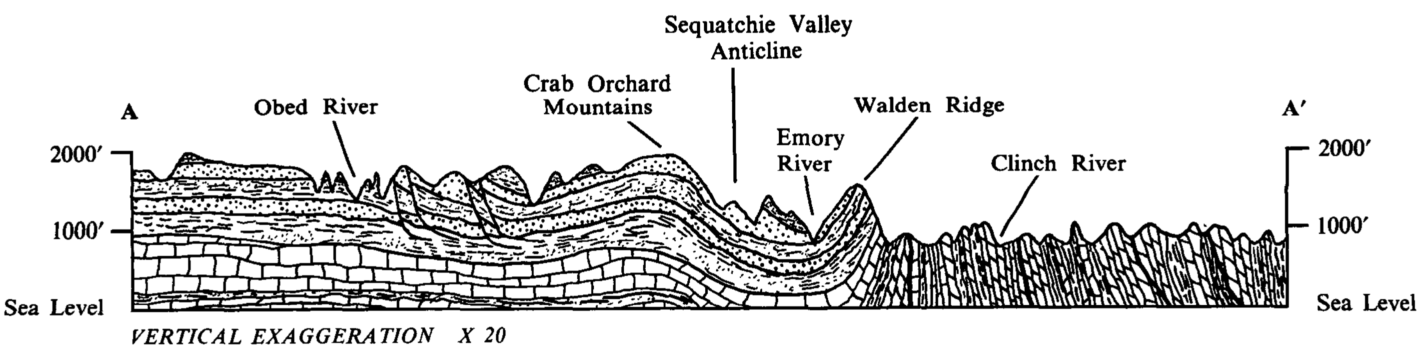


Figure 2.--Generalized geology and cross section of the NASQAN accounting unit above Watts Bar Dam (geology from W. D. Hardeman, 1966; karst areas from R. A. Miller and P. D. Sitterly, 1977).

about 35 inches in dry years to about 70 inches in wet years (U.S. Department of Commerce, 1961). Average annual temperature is about 58 °F with extremes seldom above 100 °F or below -5 °F.

Population

The 1980 population of the 15 counties, in which the study area is located, was 699,100, or about 15 percent of the total population of Tennessee. This represents an increase of 26 percent over the 1960 population (554,900). Several counties had a decrease in population between 1960 and 1970, but all showed a significant increase between 1970 and 1980. Distribution of the 1960, 1970, and 1980 population by counties is presented in table 1.

Geology

The Cumberland Plateau (fig. 2) is underlain by gently dipping Pennsylvanian sandstone and shale, some conglomerate, and coal, with a combined thickness of about 1,500 feet. These Pennsylvanian rocks overlie Mississippian carbonate rocks and are separated by the Pennington Formation of Mississippian age which is a transitional formation to the basal Pennsylvanian sandstone and shale. The Mississippian rocks are predominately limestone, calcareous shale, and siltstone with a maximum thickness of about 1,000 feet. These rocks crop out along the escarpment which separates the Cumberland Plateau from the Ridge and Valley. Chattanooga Shale of Devonian age and the Rockwood Formation of Silurian age underlie the Mississippian rocks and crop out along the base of the escarpment.

The Ridge and Valley is underlain by Ordovician and Cambrian rocks which are predominately carbonate, siltstone, shale, and some sandstone. Topographic relief consists of ridges underlain by resistant sandstone or cherty limestone, and valleys underlain by shale and soluble limestone. Formations within the Ridge and Valley have been deformed by folding and faulting (fig. 2).

Table 1.--Population of Tennessee and counties upstream of Watts Bar Reservoir in East Tennessee

[Source: U.S. Bureau of the Census]

	Year			Percent change	Percent change
	1960	1970	1980	1960-70	1970-80
Tennessee	3,567,089	3,926,018	4,591,120	10.0	16.9
Anderson	60,032	60,300	67,346	.4	11.6
Bledsoe	7,811	7,643	9,478	-2.1	24.0
Campbell	27,936	26,045	34,923	-6.7	34.1
Cumberland	19,135	20,733	28,676	8.3	38.3
Fentress	13,288	12,593	14,826	-5.2	17.7
Grainger	12,506	13,948	16,751	11.5	20.0
Knox	250,523	276,293	319,694	10.2	15.7
Loudon	23,757	24,266	28,553	2.1	17.6
McMinn	33,662	35,462	41,878	5.3	18.0
Meigs	5,160	5,219	7,431	1.1	42.3
Monroe	23,316	23,475	28,700	.6	22.2
Morgan	14,304	13,619	16,604	-4.7	21.9
Rhea	15,863	17,202	24,235	8.4	40.8
Roane	39,133	38,881	48,425	-.5	24.5
Union	8,498	9,072	11,707	6.7	29.0

Karst topography occurs mainly in the Valley and Ridge section of the study area (fig. 2), and in the Sequatachie anticline area of the Cumberland Plateau.

Soils

Soils of the Cumberland Plateau are predominately loamy and well-drained. Their thickness ranges from less than 1 foot to as much as 5 feet over most of the plateau. The potential for erosion is slight to moderate except on steep slopes where erosion can become severe if the vegetation cover is removed.

Soils of the Ridge and Valley are predominately clayey and loamy and are well drained to excessively drained. Their thickness ranges from 4 feet to more than 8 feet over most of the Ridge and Valley. These soils have a slight to moderate potential for erosion.

The soil associations of the study area are shown on figure 3. Also presented on figure 3 is a description of the groups of soils within each soil association.

Land Use

Changes in land use may alter infiltration and runoff rates as well as the quality of the water draining from the basin. Land use and land cover for the study area is shown in figure 4. The locations of coal-mining activities are based on permits issued by the Tennessee Division of Conservation since 1972. Locations of mine sites abandoned prior to 1972 or unlicensed mine sites are unknown.

Urban development reduces the amount of infiltration, increases runoff rates, and may adversely affect water-quality. Pollutants accumulate on urban surfaces, especially impervious areas which are subject to washoff by storm events. Automobile emissions, fertilizers applied to lawns, industrial effluents and many other pollutants are washed from the atmosphere or urban landscape into storm-drainage systems and eventually into streams.

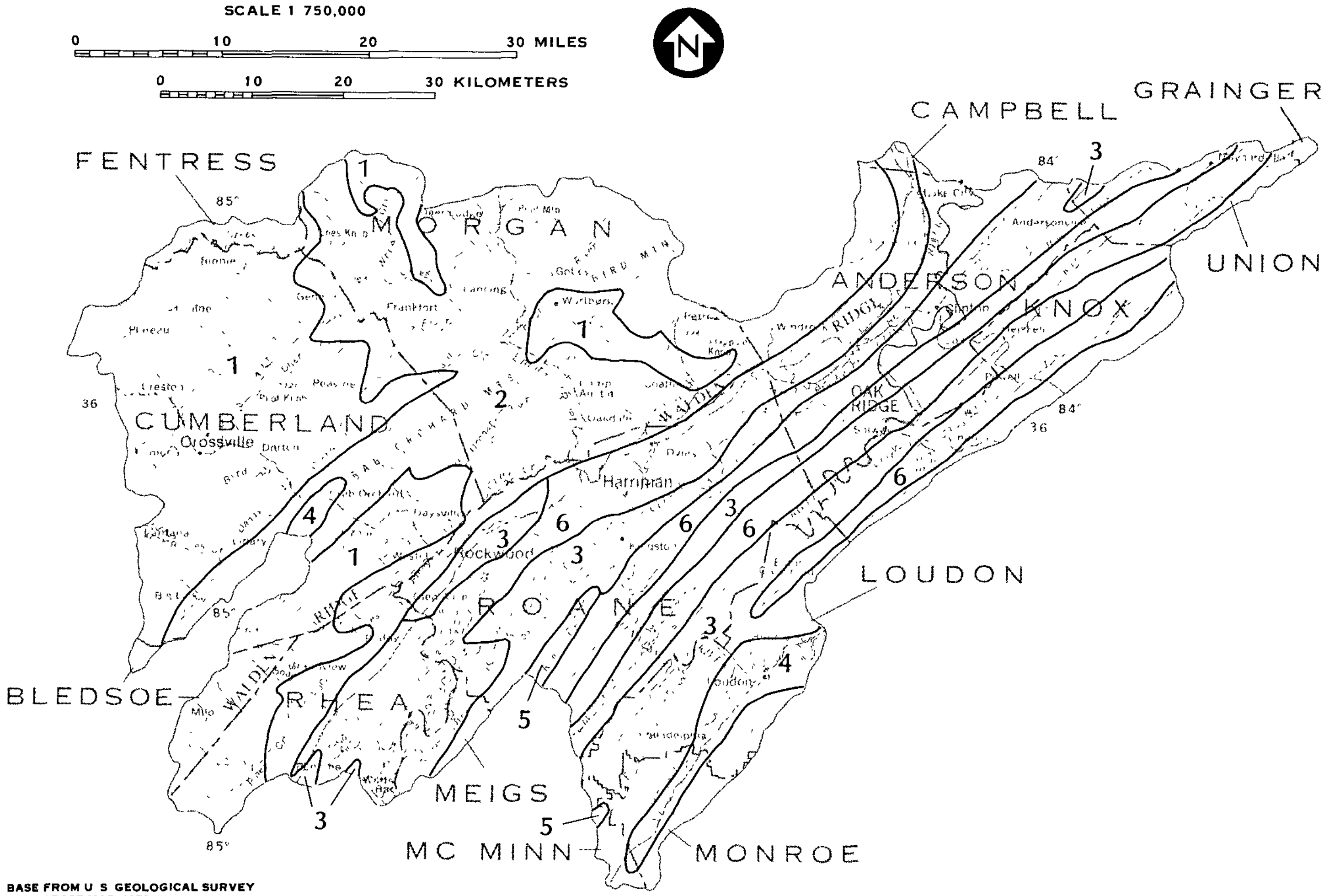
Forest cutting may cause long-term changes in streamflow and water quality. Following forest cutting, streamflow increases and then decline with the logarithm of time as the forest regrow (Swift and Swank, 1981). Much of the tre harvesting activity can lead to soil disturbanc This, coupled with steep terrain and storm runof makes erosion and the transport of sediment t surface streams highly probable. Logging acti ities around streams may result in debris beir left in streams that can lead to bank erosio leaching of toxic compounds, biodegradation c organic matter, and a general reduction in th dissolved oxygen level (U. S. Environmental Pr tection Agency, 1976a).

Agricultural activities can affect wat quality. In a study involving rural areas of Nor Carolina, Simmons and Heath (1979) state activities that most likely affect water quali include:

1. The use of fertilizers and pesticides on ro crops and pastures,
2. Pollution from farm animals, especially catt and poultry,
3. Pollution originating from septic tanks us for the disposal of domestic wastes, and
4. Exposure of the land to erosion during cult vation of fields and land clearing for building roads, or other developments.

The first three activities generally increa concentrations or densities of select water-quali constituents leaving a drainage basin. While th last activity is expected to increase concentr tions of suspended sediment and constituen sorbed on or in some way associated wi sediment.

Construction and surface-mining activitie though not as wide-spread as agricultural acti ities, can yield large quantities of sediment nearby waterways, causing severe adverse effec (EPA, 1976b). In addition to the sediment, co tamination of streams draining strip-mined co areas generally results from overland runoff ground-water seepage contacting iron-sulfur com pounds or minerals and introducing deleterio chemicals into solution (Bevans, 1980). Annu coal production for the years 1971-83 of the county study area is shown in figure 5. Productic exhibited an increasing trend from 1973 throu 1977 and a decreasing trend from 1978 into 1983.



BASE FROM U S GEOLOGICAL SURVEY
STATE BASE MAP, 1973

Map reference number	Soil association	Description
1	Hartsells-Lonewood-Ramsey-Gilpin	Moderately deep, well-drained, loamy soils from sandstone and shale
	Hartsells-Ramsey-Gilpin	Moderately deep to shallow, well-drained, loamy soils from sandstone and shale
2	Bouldin-Ramsey	Well-drained, stony and loamy soils with rock outcrops from colluvium sandstone and shale
	Ramsey-Hartsells-Grimsley-Gilpin	Well-drained stony and loamy soils from sandstone and shale
	Muskingum-Gilpin-Jefferson	Well-drained, loamy soils from shale and sandstone
3	Fullerton-Dewey	Deep, well-drained, cherty and clayey soils from dolomite and limestone
	Fullerton-Bodine	Deep, well-drained, cherty and clayey soils from dolomite and limestone
4	Decatur-Dewey-Waynesboro	Deep well-drained, clayey soils from alluvium and limestone
	Waynesboro-Etowah-Sequatchie-Allen	Deep well-drained, clayey and loamy soils from alluvium and colluvium
5	Talbott-Etowah	Shallow to deep well-drained, clayey and loamy soils with rock outcrops from shale and limestone
6	Wallen-Talbott-Montevallo	Shallow to moderately deep, excessively to well-drained stony and clayey soils from sandstone shale and limestone

Figure 3 --Generalized soils of the NASQAN accounting unit above Watts Bar Dam (soils from J A. Elder and M. E. Springer, 1978).

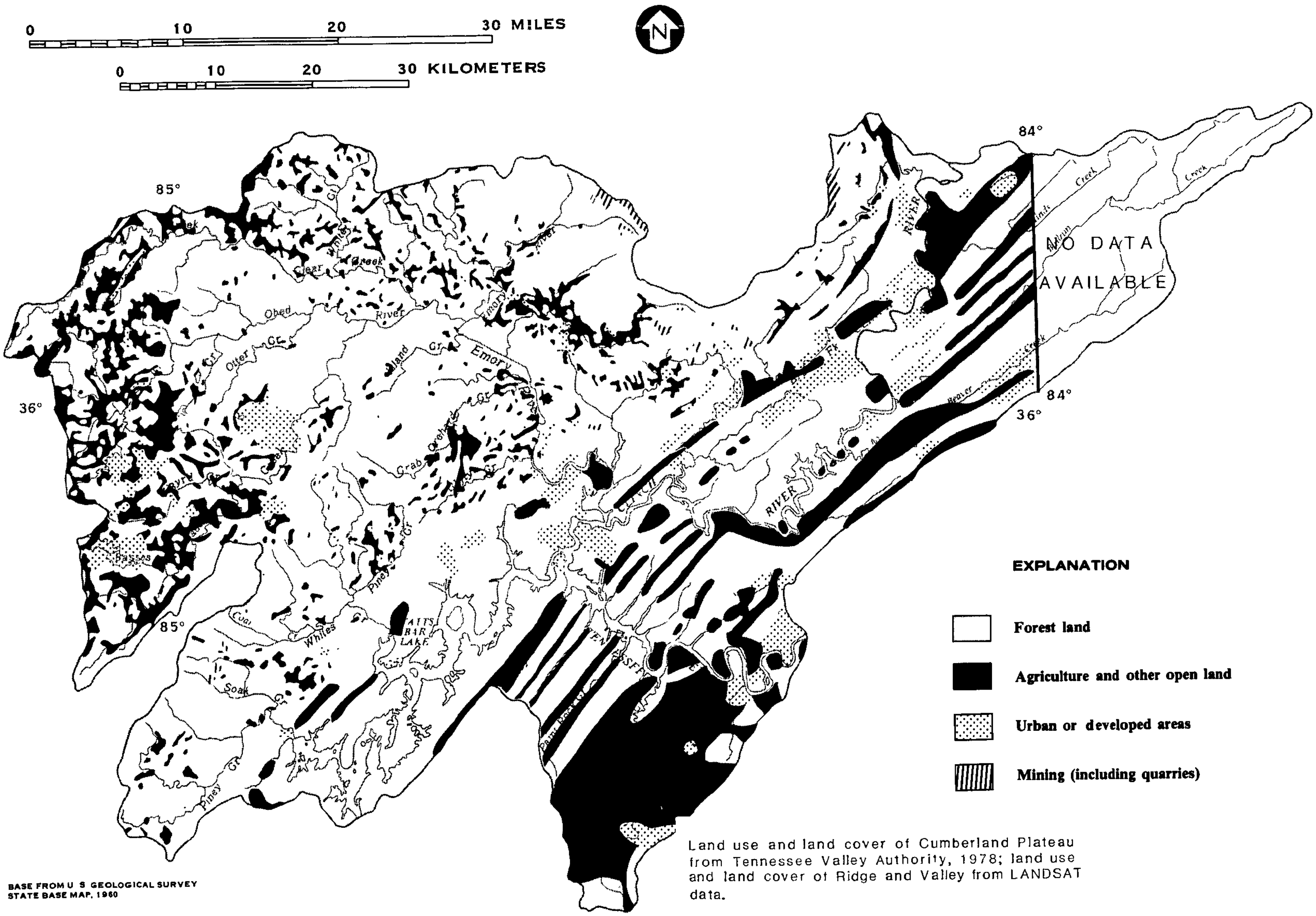


Figure 4.--Land use and land cover of the NASQAN accounting unit above Watts Bar Dam.

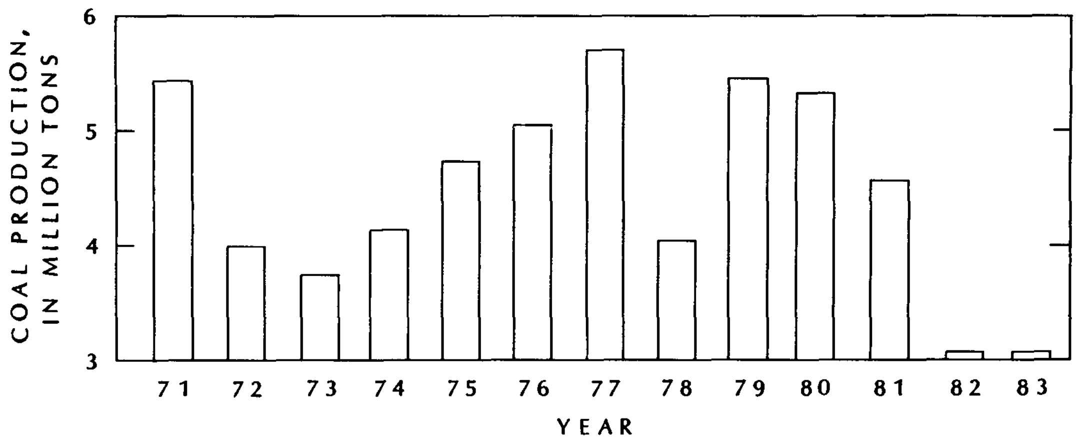


Figure 5.--July to June coal production in the 15-county study area from 1971 through 1983.

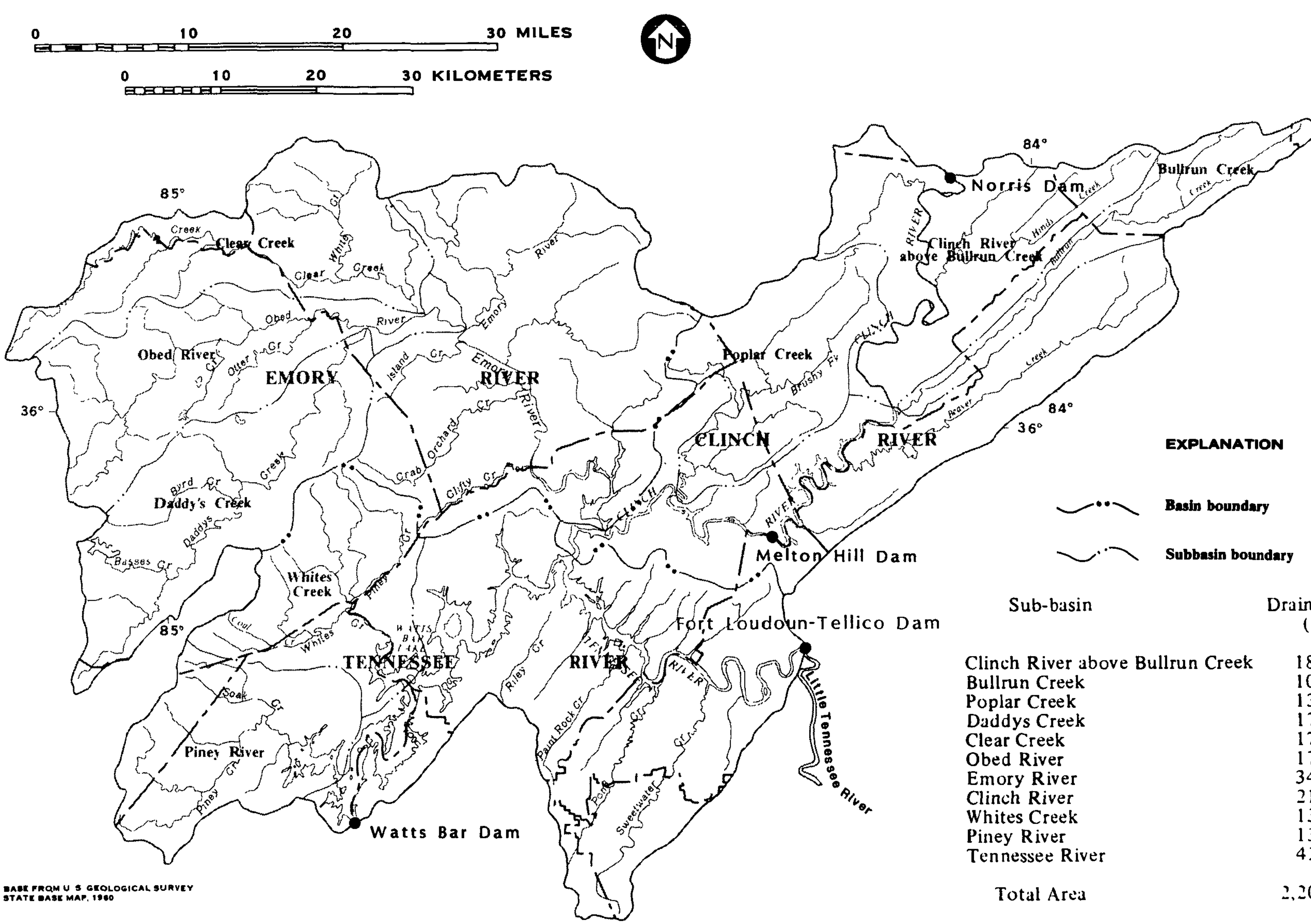
Surface Drainage

Principal sub-basins and drainage networks of the study area are shown on figure 6. Drainage basins for all streams in the study area except the Tennessee and Clinch Rivers are contained within the area. The Clinch River enters the study area at Norris Dam and drains an area of 2,912 mi^2 at that point. The Tennessee River enters the study area at Fort Loudoun Dam and drains an area of 12,197 mi^2 at that point.

Average discharge of sub-basin streams in the study area is approximately 2 $(ft^3/s)/mi^2$. However, during dry months the minimum monthly flows per square mile are much lower for streams on the Cumberland Plateau than for streams in the Ridge and Valley due to differences in underlying geology. Average discharge of long-term gaging stations on the main-channel systems of the study area are given in table 2. Flow duration information for the four dam sites in the study area are presented in table 3.

Table 2.--Average discharge of main-channel stations at and above Watts Bar Dam

Station	Period of record	Average discharge (ft^3/s)	Average discharge $((ft^3/s)/mi^2)$
Clinch River at Melton Hill Dam.	1936-64, 1967-68, 1978-82	4,650	1.4
Emory River at Oakdale.	1928-82	1,460	1.9
Tennessee River at Watts Bar Dam.	1935-39, 1975-82	28,700	1.7



Sub-basin	Drainage Area (mi^2)
Clinch River above Bullrun Creek	180
Bullrun Creek	104
Poplar Creek	136
Daddys Creek	175
Clear Creek	173
Obed River	172
Emory River	345
Clinch River	216
Whites Creek	138
Piney River	137
Tennessee River	425
Total Area	2,201

Figure 6.--Principal sub-basins and drainage networks of the NASQAN accounting unit above Watts Bar Dam (modified from M. W. Gaydos and others, 1982).

Table 3.--Flow duration of releases from Tennessee River and Clinch River Dams

Flow, in cubic feet per second, equaled or exceeded for percentage of time indicated										
99	90	80	70	60	50	40	30	20	10	1
Clinch River at Norris Dam 1936-74										
24	74	468	1,890	2,860	3,730	4,590	5,460	6,520	8,000	19,600
Clinch River at Melton Hill Dam 1962-1980										
-	-	1,540	2,740	3,700	4,600	5,490	6,470	7,620	9,460	22,400
Tennessee River 10.8 miles below Fort Loudoun Dam 1941-55										
4590	9,900	12,500	14,300	15,600	16,900	18,300	19,900	22,400	28,700	61,900
Tennessee River at Watts Bar Dam 1960-80										
5900	14,100	18,000	21,100	23,800	26,300	28,700	32,000	35,900	45,900	102,000

Hydrologic Modifications

Many farm ponds and small recreation lakes are scattered throughout the study area. In regions where strip-mining occurs, temporary settling ponds were constructed at many of the mine sites.

Upstream from Watts Bar Dam, the Tennessee River is regulated by several dams. These dams were placed into operation between 1936 and 1963. Release patterns for these dams vary daily and seasonally with different uses. The impoundments are used for flood control, power generation, and recreation. A typical pattern of flow releases from Melton Hill and Watts Bar Reservoirs is shown in figure 7.

Watts Bar Dam, at the outlet of the study basin (fig. 6), is a concrete dam with earth embankments. Storage began December 12, 1941. Total level pool capacity at an elevation of 745.00 feet, top of the gates, is 51.2 billion ft^3.

Fort Loudoun-Tellico Dam is just upstream from the study area (fig. 6). Closure of Fort Loudoun Dam was made August 2, 1943. Closure of the Tellico Dam was made November 29, 1979. Maximum combined level-pool capacity at an elevation of 815.00 feet, top of the gates, is 56.1 billion ft^3. The Tellico-Fort Loudoun canal, which connects Tellico and Fort Loudoun Lakes, was opened January 19, 1980. The spillway gates of Tellico Dam were closed February 7, 1980, diverting all flow from the Little Tennessee River. Since that date the two reservoirs have been operated as one. Prior to November 1979, all streamflow in the Little Tennessee River was discharged into the Watts Bar Lake below Fort Loudoun Dam.

Clinch River flow is regulated by Norris Dam just upstream of the study area and by Melton Hill Dam within the area (fig. 6). Closure of Norris Dam occurred on March 4, 1936, and the total capacity at an elevation of 1,034.11 feet, top of the gates, is 111 billion ft^3. Melton Hill Dam was closed May 1, 1963, and the total capacity at an elevation of 796 feet, top of the gates, is 5.5 billion ft^3.

The system of dams and reservoirs on the Clinch and Tennessee Rivers has resulted in backwater along much of the main-channel reaches of the study area. Backwater from Melton Hill Dam at normal maximum reservoir level extends about 44 miles upstream. Backwater from Watts Bar Dam at normal maximum reservoir level extends upstream along the Tennessee River to Fort Loudoun Dam, upstream along the Clinch River to Melton Hill Dam, and to about 13.5 miles above the mouth of the Emory River.

Locations of wastewater discharge sites in the study area as compiled by the Tennessee Department of Public Health (1978) are shown in figure 8. The degree of treatment that the wastewater receives prior to discharge at these sites has not been compiled.

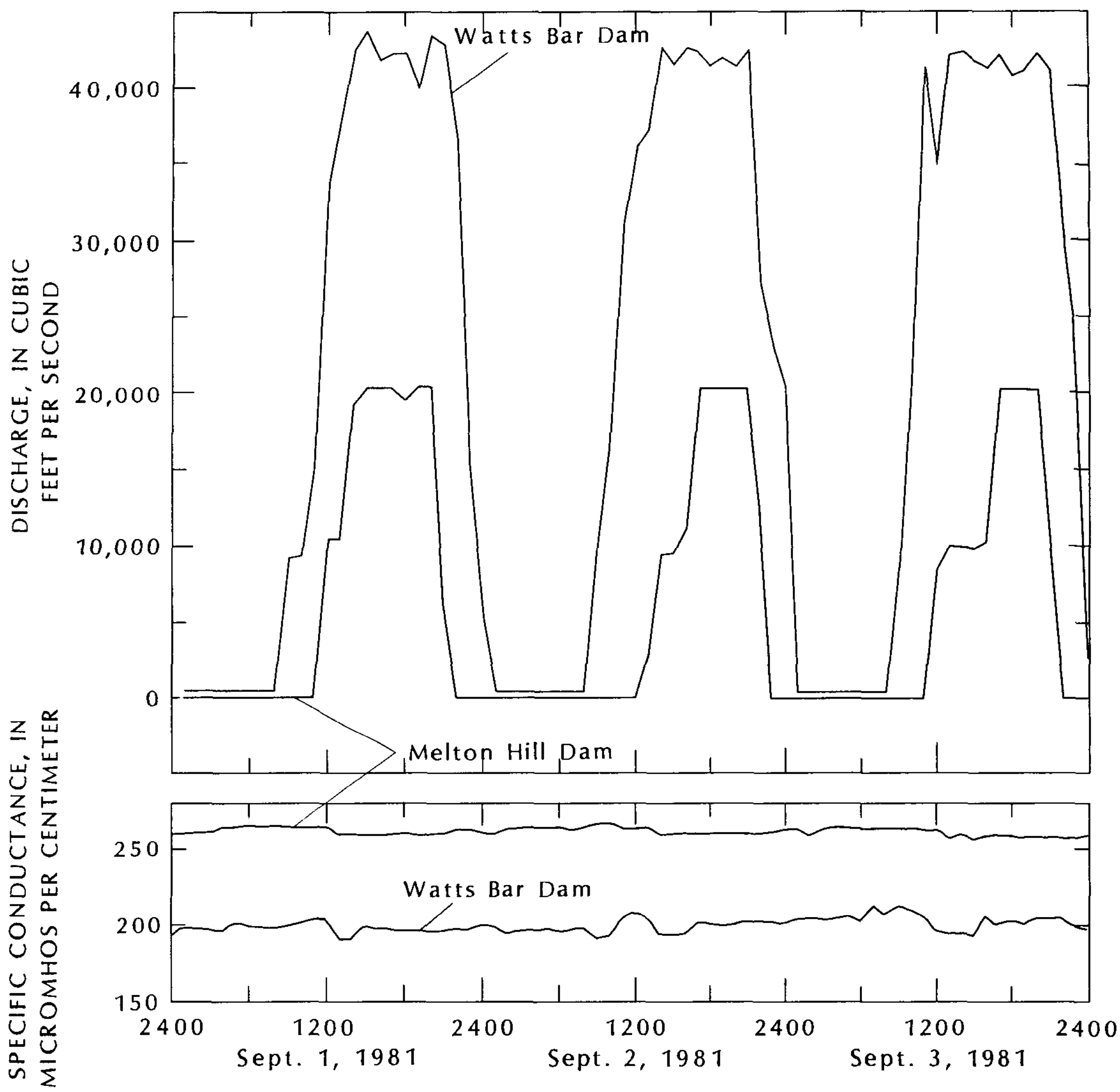


Figure 7.--Discharge and specific conductance of releases from Melton Hill Dam and Watts Bar Dam on September 1-3, 1981.

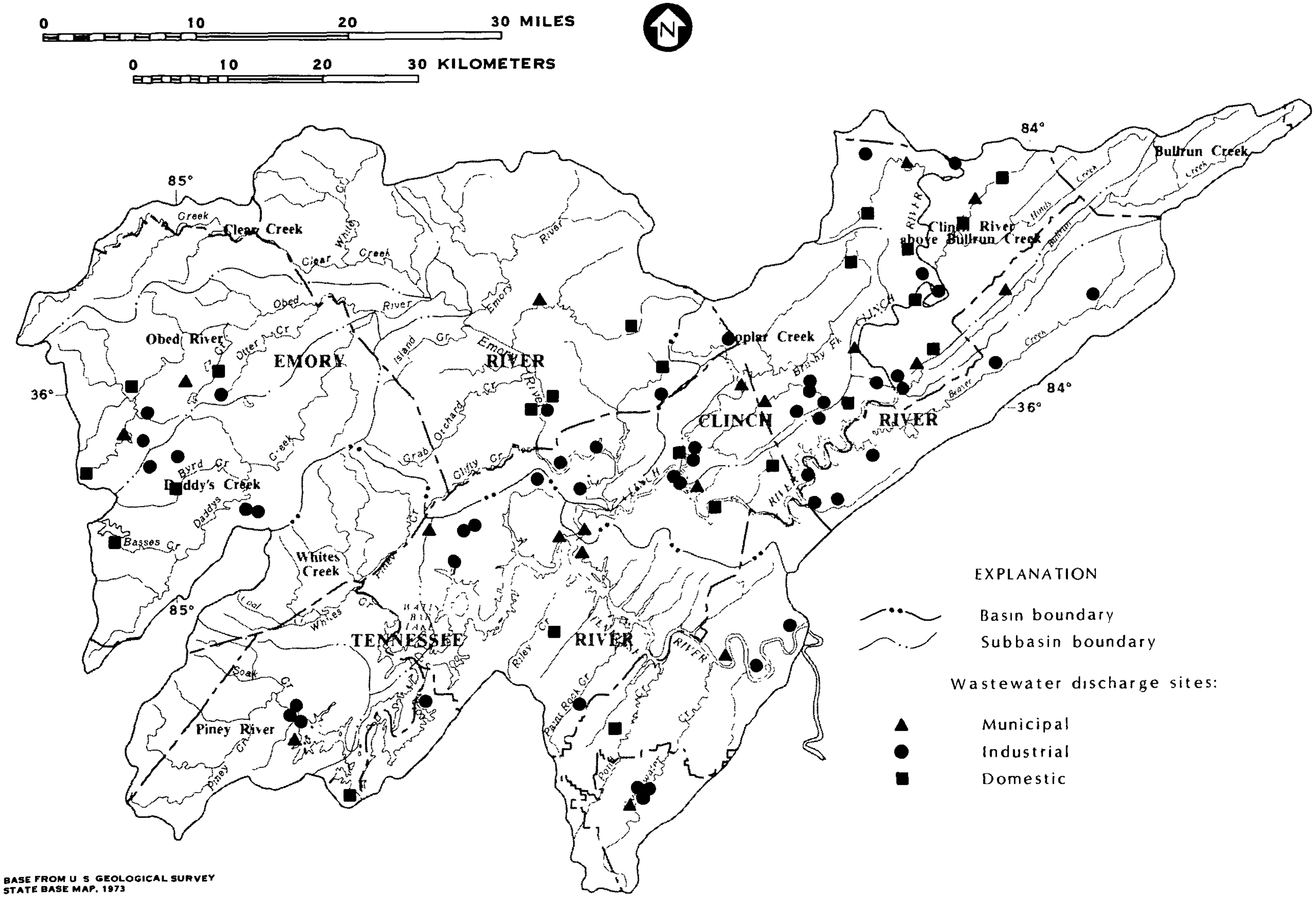


Figure 8.--Wastewater discharge sites in the NASQAN accounting unit above Watts Bar Dam (Tennessee Department of Public Health, 1978).

QUALITY OF WATER DATA

Data Sources

Most data collected by State and Federal agencies other than the U.S. Geological Survey and used in this report were obtained from STORET, the U.S. Environmental Protection Agency's computer file. The station locations and principal data-collection agency for each station are listed in table 4 and shown on figure 9.

NASQAN Data

NASQAN stations are operated in the study area on the Clinch River at mile 23.1 (below Melton Hill Dam), and on the Tennessee River at mile 529.9 (below Watts Bar Dam), and are referred to as "Melton Hill" and "Watts Bar" in this report. Continuous observations (hourly) of water temperature and specific conductance were obtained at Watts Bar from February 1976 to September 1981. Continuous observations (hourly) of water temperature and specific conductance were begun at Melton Hill in March 1981 and are currently being collected. Hourly discharge record for both stations is maintained by the Tennessee Valley Authority.

The NASQAN stations are sampled at relatively uniform time intervals, without consideration of streamflow. This temporal sampling scheme was designed to obtain water-quality data representative of what would be expected in a stream on an average day. In a natural stream system, this sampling pattern might be expected to reflect the full range of flow variability at the station. However, the NASQAN stations in the study area are not located on natural, uncontrolled stream systems.

Instantaneous flows at the time of sample collection at the NASQAN stations were compared to the daily mean flow duration tables for those stations (table 3). At Melton Hill, approximately 71 percent of the samples were collected during the upper 30 percent of the duration table, and approximately 16 percent were collected during the lower 30 percent of the duration table. At Watts Bar, approximately 71 percent of the samples were collected during the upper 30 percent of the duration table, and approximately 11 percent were collected during the lower : percent of the flow-duration table. These con parisons show the streamflow data obtained at tl time of sample collection below Melton Hill Da and Watts Bar Dam are not randomly distributed.

Duration statistics for daily specific-conduc tance values obtained at the two NASQA stations are presented in table 5. A comparis was made of instantaneous specific conductan obtained at the time of sample collection to tl parts of the daily specific-conductance durati table to which the values coincided. It w expected that by random sampling approximate 25 percent of the instantaneous observations specific conductance should fall in the range daily specific-conductance values equaled exceeded 25 percent of the time, and approx mately 25 percent of the instantaneous valu should fall below the daily specific-conductan value equaled or exceeded 75 percent of tl time. At Melton Hill, approximately 11 percent the instantaneous specific-conductance observ tions were obtained during the upper 25 perce of the duration table and approximately 71 perce were obtained during the lower 25 percent. Ho ever, the duration table of continuous specif conductance for Melton Hill is based on only years of record. At Watts Bar, which has 6 yea of data, approximately 22 percent of the insta taneous conductance observations were obtain during the upper 25 percent of the duration tabl and approximately 32 percent were obtained duri the lower 25 percent. The specific-conductan duration table comparisons for Watts Bar indicat that the relatively uniform time interval sampli scheme of the NASQAN program was effective obtaining randomly distributed samples.

Discharge relations to water quality cou not be well defined. This conclusion is support by comparisons of specific conductance to di charge using the following procedures:

(1) The relation between instantaneous dischar and specific conductance at the time of san ple collection was obtained.
(2) The relation between daily mean dischar and daily mean specific conductance for st tions with continuous water-quality monito was obtained.

Table 4.--Hydrologic data stations in the study area

[Agency codes: USGS, U.S. Geological Survey; TVA, Tennessee Valley Authority; TN, Tennessee Department of Health and Environment; EPA, U.S. Environmental Protection Agency]

Site No.	Station name	Agency	Latitude ° ' "	Longitude ° ' "	Drainage area (mi²)	River mile
C1	Clinch River below Norris Dam	USGS	36 12 56,	84 04 56	2,913	78.8
C2	Clinch River near Clinton	USGS	36 07 22,	84 06 52	2,980	66.3
C3	Clinch River at Clinton	USGS	36 05 45,	84 07 57		58.8
C4	Clinch River	TVA	36 02 43,	84 12 02		51.2
C5	Clinch River	TVA	36 02 25,	84 11 51		50.8
C6	Clinch River	TVA	36 01 47,	84 11 13		49.9
C7	Clinch River at Edgemoor	USGS	36 01 32,	84 10 03	3,089	48.6
	Clinch River	TVA	36 01 32,	84 10 03		48.7
C8	Clinch River	TVA	36 01 00,	84 10 00		48.0
C9	Clinch River	TVA	36 00 50,	84 09 45		47.7
C11	Clinch River	TVA	36 59 58,	84 09 22		46.6
C12	Clinch River	TVA	35 59 30,	84 10 26		45.0
C13	Clinch River at Melton Hill Dam	USGS	35 53 07,	84 18 03	3,343	23.1
	Melton Hill Dam Tailrace	TVA	35 53 07,	84 18 02		23.1
C14	Clinch River near Oak Ridge	TN	35 55 16,	84 25 53	3,526	10.0
C15	Clinch River	EPA	35 54 45,	84 26 15		9.2
C16	Clinch River	TVA	35 53 36,	84 28 12		5.7
C17	Clinch River	TVA	35 53 20,	84 29 25		4.0
C18	Clinch River	TVA	35 53 30,	84 31 25		2.6
	Clinch River	TVA	35 53 27,	84 31 25		2.5
C20	Clinch River	TVA	35 53 10,	84 31 41		2.1
C21	Clinch River	TVA	35 53 27,	84 31 25		1.0
C22	Clinch River at Watts Bar	EPA	35 52 00,	84 31 32		.5
E1	Emory River at Oakdale	USGS	35 58 59,	84 33 29	764	18.3
	Emory River	TVA	35 58 59,	84 33 29		18.3
E2	Emory River	TN	35 57 11,	84 34 35		14.9
E3	Emory River	EPA	35 56 25,	84 29 00		5.2
E4	Emory River	TVA	35 54 17,	84 30 12		1.9
T1	Tennessee R at Fort Loudoun Dam	USGS	35 47 30,	84 14 36	12,196[a]	602.3
	Fort Loudoun Dam Tailrace	TVA	35 47 30,	84 14 36		602.3
T2	Tennessee R above Union Carbide	TN	35 43 45,	84 18 45	12,210	593.3
T3	Loudon Water Intake	TN	35 43 57,	84 19 45		592.3
T4	Tennessee River (Watts Bar)	EPA	35 45 47,	84 20 03		590.1
T5	Tennessee River (Watts Bar)	EPA	35 51 10,	84 32 00	12,470	568.5
T6	Tennessee R (Hood Landing Light)	TVA	35 49 56,	84 33 41		564.6
T7	Tennessee River (Watts Bar)	TVA	35 50 32,	84 36 10		561.9
T8	Tennessee River (Watts Bar)	TVA	35 49 50,	84 36 33		560.8
T9	Tennessee River (Watts Bar)	TVA	35 48 47,	84 37 08		559.6
T10	Tennessee River (Watts Bar)	TVA	35 48 07,	84 37 19		558.6
T11	Tennessee River (Watts Bar)	TVA	35 47 21,	84 39 18		555.7
T12	Tennessee River (Watts Bar)	TVA	35 47 50,	84 39 00		555.2
T13	Tennessee River (Watts Bar)	TVA	35 48 50,	84 39 09		553.9
T14	Tennessee River (Watts Bar)	EPA	35 48 56,	84 40 30	16,950	553.0

Table 4.--Hydrologic data stations in the study area--Continued

Site No.	Station name	Agency	Latitude ° ' "	Longitude ° ' "	Drainage area (mi²)	River mile
T15	Tennessee River (Watts Bar)	TVA	35 45 38,	84 40 32		548.5
T16	Tennessee River (Watts Bar)	EPA	35 40 56,	84 44 52		538.0
T17	Tennessee River (Watts Bar)	TVA	35 39 00,	84 47 00		532.1
T18	Tennessee River (Watts Bar)	EPA	35 37 21,	84 47 00		530.0
T19	Tennessee R at Watts Bar Dam	USGS	35 37 13,	84 47 00	17,310	529.9
	Watts Bar Dam Tailrace	TVA	35 37 12,	84 46 59		529.9
BC1	Bullrun Cr nr Halls Crossroads	USGS	36 06 52,	83 59 16	68.5	16.3
	Bullrun Creek	TVA	36 06 52,	83 59 16		
CA1	Clear Creek near Andersonville	USGS	36 12 58,	84 03 00		
CA2	Clear Creek at Norris	USGS	36 12 48,	84 03 38		
CA3	Coal Creek at Lake City	USGS	36 13 14,	84 09 27	24.5	
CB1	Beaver Creek	TN	36 03 31,	83 58 23		
CC1	White Creek at Twin Bridges	USGS	36 10 40,	84 48 01	38.4	
CC2	Clear Creek near Lancing	USGS	36 07 18,	84 44 46	153	
DC1	Daddys Creek near Hebbertsburg	USGS	35 59 53,	84 49 24	139	
ER1	Rock Creek near Gobey	USGS	36 08 02,	84 37 31	31.2	
ER2	Emory River near Wartburg	USGS	36 06 46,	84 36 54	83.2	
ER3	Island Creek near Catoosa	USGS	36 03 10,	84 40 01	18.4	
ER4	Crooked Fork near Wartburg	USGS	36 05 05,	84 33 18	50.3	
ER5	Crooked Fork at Wartburg	USGS	36 04 56,	84 34 35		
	Crooked Fork Creek 4.22	TVA	36 04 55,	84 34 35		
ER6	Crab Orchard near Deermont	USGS	36 00 40,	84 36 44	33.7	
ER7	Emory River at Mahan Village	USGS	36 10 39,	84 28 28		
ER8	Emory River 34.52	TVA	36 06 47,	84 36 55		
ER9	Emory River at Gobey	USGS	36 08 58,	84 35 50	43.3	
ER10	Flat Fork near Petros	USGS	36 07 35,	84 30 11		
OR1	Obed River near Crossville	USGS	35 58 27,	85 02 55		
	Obed River NW of Crossvile	TVA	35 58 28,	85 02 55		
OR2	Obed River at Adams Bridge	USGS	36 03 42,	84 57 42		
OR3	Obed River near Lancing	USGS	36 04 53,	84 40 15	518	1.5
PC1	East Fork Poplar Creek	USGS	35 57 58,	84 21 30	19.5	3.3
PC2	Poplar Creek at Baily Road	USGS	36 01 57,	84 18 16	30.3	
PC3	Poplar Creek near Oak Ridge	USGS	35 59 55,	84 20 23	82.5	13.8
PR1	Piney River at Spring City	USGS	35 41 59,	84 51 17	95.9	
	Piney River 6.8	TN	35 42 28,	84 51 31		
PR2	Piney River above Spring City	USGS	35 43 02,	84 53 08	62.3	
	Piney River 9.0	TN	35 42 56,	84 52 51		
PR3	Piney River 12.6	TN	35 41 28,	84 54 40		
PR4	Piney River 20.9	TN	35 37 20,	84 57 52		
TR1	Pond Creek near Adolphus	USGS	35 42 20,	84 27 35	30.8	
TR2	Caney Creek 0.7	TVA	35 51 19,	84 35 54		
WC1	Whites Creek at Bakers Bridge	USGS	35 47 50,	84 48 43	33.8	
WC2	Piney Creek near Westel	USGS	35 51 14,	84 44 17	19.0	
WC3	Fall Creek near Ozone	USGS	35 50 16,	84 47 56	21.1	

[a]Prior to November, 1979, drainage area did not include that of the Little Tennessee River and was 9,550 mi².

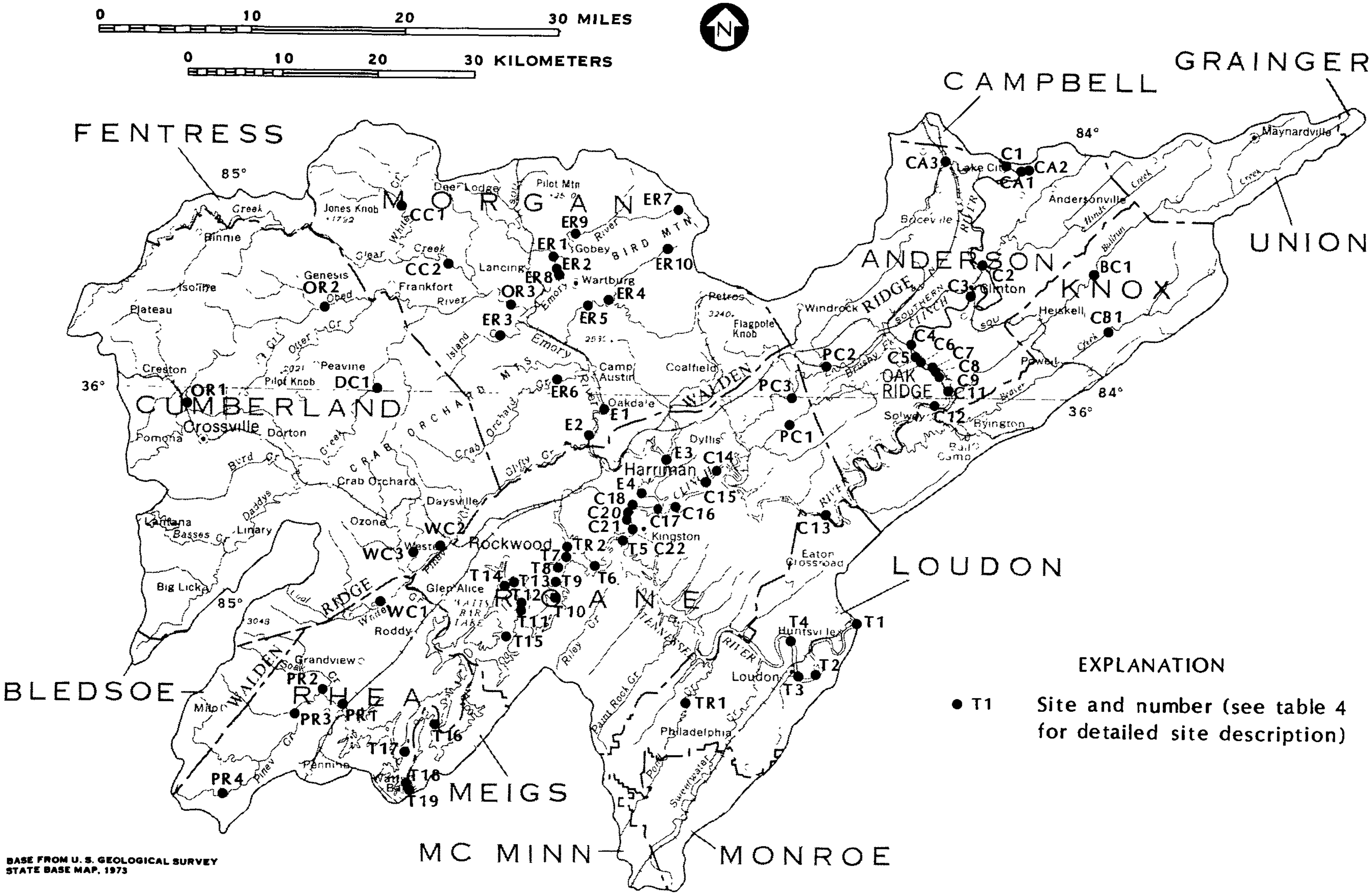


Figure 9.--Hydrologic data-collection sites in the NASQAN accounting unit above Watts Bar Dam.

Table 5.--Daily specific conductance, in microsiemens per centimeter at 25 °C, that was equaled or exceeded for the indicated percentage of time at the Melton Hill and Watts Bar NASQAN stations

Site No.	Station	No. of days of record	Percentage of time 1	5	10	25	50	75	90	95	99
C13	Melton Hill (1981-82)	547	281	272	269	262	254	240	231	219	199
T19	Watts Bar (1976-81)	1792	208	200	191	177	161	150	137	130	110

None of the regression results are considered significant. For example, the best model for comparison of mean daily discharge to mean daily specific conductance accounted for only 7 percent of the relation variation.

TREND ANALYSIS TECHNIQUES

The Seasonal Kendall test is a nonparametric test for trend applicable to data influenced by seasonal variations. By use of this test the effects of seasonal variations of the data is reduced by comparing only observations from the same time interval of the year.

The null hypothesis for the Seasonal Kendall test is that the random variable is independent and identically distributed. The resultant statistic (tau) has a value between -1 and +1. Negative values indicate decreasing trends, positive values indicate increasing trends. If no trend exists in the data, tau approaches zero. A significance probability (p-level) of the trend is computed that indicates the probability of erroneously rejecting the null hypothesis (that no trend exists). The Seasonal Kendall test is specifically designed to provide a single summary statistic for the entire record and will not indicate when there are trends in opposing directions.

The Seasonal Kendall Slope Estimator is an estimate of the magnitude of the trend defined by the Seasonal Kendall test. For this estimate the data value difference divided by the period of time separating the data values is computed. The median of these differences (expressed as slopes) is defined to be the change per year due to t trend. By using the median of these individu slope values, the trend estimate is resistant to t effect of extreme values in the data. The estima is also unaffected by seasonal variations in t data because the slopes are always comput between values that are multiples of 12 mont apart (Hirsch and others, 1982).

In many streams, some water-quality parar eters are related to stream discharge. F example, much of the constituent loadings may from point sources and any decrease in flow wou tend to be accompanied by increases in conce tration. Another example is that of rainfall ov an urban area that results in washoff of acc mulated pollutants into receiving waters th increasing concentrations of some water-quali constituents. Conversley, increased stream di charge may result in lower concentratio because of dilution.

Compensation for the effects of discharge necessary in order to identify trends in wate quality constituents caused by some proce (source) change. To minimize the effects of di charge, a time series of flow-adjusted conce trations is developed and this time series is th tested for trend. For this report, regression equ tions were developed for each water-quali parameter for each data collection site. conditional expected concentration was estimat for parameters having a well-defined relation discharge. The Seasonal Kendall trend te procedures were applied to the actual conce trations minus the estimated conditional expect concentration (residual analysis).

Some common models used for flow adjustment include the following (Crawford and others, 1983):

(1)	$C = a+bQ$	linear
(2)	$C = a+b\ln(Q)$	log-linear
(3)	$C = a+b(1/1+BQ)$	hyperbolic
(4)	$C = a+b(1/Q)$	inverse
(5)	$C = a+b_1Q+b_2Q^2$	quadratic
(6)	$\ln C = a+b\ln Q$	log-log
(7)	$\ln C = a+b\ln Q+b_2(\ln Q)^2$	log-quadratic log

where

C is the expected concentration,

Q is the discharge at the time of sampling, and

B is a constant typically in the range $10^{-3} q^{-1} \leq B \leq 10^2 q^{-1}$

where q is the mean discharge.

The model selected for flow adjustment is generally the one that explains the greatest relation variance. If the probability of rejecting the null hypothesis that b = 0 for the relation is high (greater than 0.10 for this study), then no flow adjustment is recommended. Note that for C models the residuals have the dimensions of C, but for ln C models the residuals are dimensionless.

Results of Seasonal Kendall tests on discharge and specific-conductance data for continuous-record stations in the study area are shown in table 6. Discharge at all continuous-record stations in the study area shows a significant decreasing trend during the 1972-82 water years. It is important to note that because of regulation, discharge versus water-quality relations for the Clinch River and Tennessee River stations in the study area are not well defined and no flow adjustment was possible. Therefore, the water-quality trends indicated in this report for the Clinch River and Tennessee River stations may only be reflective of the discharge trend rather than changes in the processes that affect the introduction and fate of a given constituent in the river.

WATER-QUALITY SUMMARIES AND TREND TEST RESULTS

Water-quality data obtained in the study area sub-basins are summarized in tables 7 and 8.

Table 6.--Results of trend tests of discharge and specific conductance obtained at daily record stations at or above Watts Bar Dam during the 1972-82 water years

[Nvals, the number of seasonal values constructed. Seasons were based on weekly median values. Units are the reporting units, cubic feet per second or microsiemens per centimeter per year]

Site No.	Station	Nvals	Tau	P level	Slope (units/yr)	Water years
	Discharge (cubic feet per second)					
T19	Tennessee R. at Watts Bar Dam	416	-0.197	0	-860	75-82
C13	Clinch R. at Melton Hill Dam	208	-.349	0	-730	79-82
E1	Emory River at Oakdale	572	-.123	0	-15	72-82
BC1	Bullrun Cr. nr Halls Crossroads	572	-.174	0	-1.0	72-82
PC3	Poplar Cr. near Oak Ridge	572	-.193	0	-2.1	72-82
PC1	E. Fork Poplar Creek	572	-.195	0	-.67	72-82
OR3	Obed River near Lancing	499	-.149	0	-11	73-82
	Specific Conductance (microsiemens per centimeter at 25 °C)					
T19	Tennessee R. at Watts Bar Dam	263	.163	0.004	2.4	76-82
C13	Clinch R. at Melton Hill Dan	80	-.679	.001	-16	81-82

Table 7.--Median value of selected water-quality
in the sub-basins of the study

Site No.	Specific conductance: No. of samples	Specific conductance: Median µS/cm	pH: No. of samples	pH: Median	Total nitrite plus nitrate nitrogen: No. of samples	Total nitrite plus nitrate nitrogen: Median (mg/L)	Suspended sediment: No. of samples	Suspended sediment: Median (mg/L)
BC1	68	309	15	7.7	15	0.30		
CA1	7	220	7	7.5				
CA2	8	225	8	7.6				
CA3	8	348	9	7.8	1	.16	8	20
CB1	61	289			90	.23		
CC1	4	27	4	6.6	1	.06	3	1
CC2	11	48	11	7.0	1	.04	10	4
DC1	8	49	8	7.2	1	.44	7	38
ER1	6	54	6	7.0	1	.16	5	55
ER2	12	54	13	6.8	12	.08		
ER3	6	30	6	6.6	1	.08	4	5
ER4	6	218	6	7.0			4	8
ER5	16	165	17	7.1	15	.25		
ER6	6	98	6	5.4	1	.08	5	7
ER7	2	200	2	7.3				
ER8	16	60	17	6.9	16	.08		
ER9	9	105	9	6.9	1	.04	8	7
ER10	1	34	1	8.0				
OR1	17	100	18	6.9	15	.61		
OR2	11	46	11	5.8	11	.25		
OR3	30	60						
PC1	43	340						
PC2	6	198	6	7.5	1	.11	5	20
PC3	59	240	23	7.5	2	.53	23	31
PR1	6	54	7	7.0	2	.12	5	3
PR2	6	44	7	6.6	2	.06	5	14
PR3			1	6.3	1	.01		
PR4			1	5.5	1	.11		
TR1	8	272						
TR2	6	191	6	7.8	6	.30		
WC1	9	29	9	6.9	1	.03	8	3
WC2	6	50	6	6.9	1	.12	5	8
WC3	6	74	6	7.3	1	.06	5	14

parameters and number of samples obtained at stations
area during the 1972-82 water years

Total iron		Dissolved sulfate		Dissolved solids	
No. of samples	Median (µg/L)	No. of samples	Median (mg/L)	No. of samples	Median (mg/L)
15	440	15	10	12	180
7	40	7	2.9	7	127
8	35	8	3.0	8	124
9	510	9	84	4	258
91	1300	91	12		
4	390	4	4.0	1	43
9	200	9	7.3	5	33
8	755	8	5.8	1	79
6	880	6	7.4	1	88
12	525	12	15	12	40
6	240	6	7.7	1	26
6	560	6	72	1	259
16	410	16	49	16	110
6	480	6	34	1	337
		2	72	2	101
16	560	16	16	16	45
8	470	9	30	4	68
		1	7.6	1	46
15	360	17	10	12	55
11	350	10	7.0	11	30
6	565	6	48	1	226
21	570	22	39	23	146
7	150	6	7.8	1	56
7	250	6	7.2	1	39
1	180				
1	400				
3	465				
9	200	9	5.2	4	20
6	215	6	5.7	1	64
6	390	6	8.2	1	85

Table 8.--Summaries of selected constituent values obtained in sub-basins above Watts Bar Dam during the 1972-82 water years

Sub-basin	Number of samples	Minimum	Maximum	Median	Mean	Standard deviation
	Dissolved solids, residue at 180 °C (mg/L)					
Clinch River above Bullrun Cr.	19	85	270	131	146	58
Bullrun Creek	12	160	210	180	182	18
Poplar Creek	24	69	226	157	154	48
Daddys Creek	1		79			
Clear Creek	6	25	46	34	36	7.7
Obed River	23	20	180	40	59	42
Emory River	67	20	337	80	90	67
Whites Creek	6	18	85	26	40	28
Piney River	2	39	56			
	Specific conductance (microsiemens per centimeter at 25 °C					
Clinch River above Bullrun Cr.	23	115	580	230	250	110
Bullrun Creek	80	17	400	310	291	71
Poplar Creek	108	80	480	268	267	86
Daddys Creek	8	36	130	49	70	39
Clear Creek	15	22	67	48	45	15
Obed River[a]	68	36	350	69	98	81
Emory River	92	20	695	108	130	110
Clinch River below Bullrun Cr.	61	4	379	289	282	49
Whites Creek	21	26	195	41	61	46
Piney River	12	26	120	46	55	32
Tennessee River below Fort Loudoun	14	25	310	222	220	72
	pH (standard units)					
Clinch River above Bullrun Cr.	24	6.8	8.7	7.6		
Bullrun Creek	27	7.0	8.1	7.7		
Poplar Creek	29	5.8	8.1	7.5		
Daddys Creek	8	6.6	7.8	7.2		
Clear Creek	15	6.1	7.5	6.9		
Obed River	40	5.1	7.9	6.8		
Emory River	96	4.0	8.3	6.9		
Whites Creek	21	6.3	7.9	6.9		
Piney River	16	5.3	8.1	6.6		
Tennessee River below Fort Loudoun	6	7.4	8.3	7.8		

Table 8.--Summaries of selected constituent values obtained in sub-basins above Watts Bar Dam during the 1972-82 water years--Continued

Sub-basin	Number of samples	Minimum	Maximum	Median	Mean	Standard deviation
	Sulfate, dissolved (mg/L as SO_4)					
Clinch River above Bullrun Cr.	24	2.0	130	3.5	31	41
Bullrun Creek	27	1.0	16	10	9.3	4.6
Poplar Creek	28	21	88	40	42	17
Daddys Creek	8	5.0	8.7	5.8	6.2	1.2
Clear Creek	13	2.9	9.8	5.7	6.1	2.2
Obed River	37	5.0	32	8.0	9.8	5.0
Emory River	92	4.8	210	24	49	56
Clinch River below Bullrun Cr.	91	3.0	43	12	13	6.9
Whites Creek	21	4.1	13	5.6	6.5	2.4
Piney River	12	4.8	13	7.4	8.3	3.2
	Iron, total recoverable (μg/L as Fe)					
Clinch River above Bullrun Cr.	24	10	44,000	45	2150	8900
Bullrun Creek	27	130	1,600	440	652	450
Poplar Creek	27	220	12,000	570	1900	3200
Daddys Creek	8	180	3,400	755	1100	1100
Clear Creek	13	50	950	260	308	240
Obed River	36	150	2,000	368	478	410
Emory River	88	80	10,000	495	999	1900
Clinch River below Bullrun Cr.	91	150	3,900	1300	1360	750
Whites Creek	21	60	3,400	200	454	720
Piney River	16	100	7,400	215	910	2000
Tennessee River below Fort Loudoun	3	305	670	465	480	180
	Nitrogen, total NO_2 + NO_3 (mg/L as N)					
Clinch River above Bullrun Cr.	1		0.16			
Bullrun Creek	27	0.01	.61	0.30	0.29	0.15
Poplar Creek	3	.11	.58	.48	.39	.25
Daddys Creek	1		.44			
Clear Creek	2	.04	.06			
Obed River	36	.05	5.6	.42	.95	1.3
Emory River	60	.01	5.2	.14	.36	.94
Clinch River below Bullrun Cr.	90	.01	.87	.23	.24	.15
Whites Creek	3	.03	.12	.06	.07	.05
Piney River	6	.01	.23	.06	.08	.09
Tennessee River below Fort Loudoun	6	.08	.73	.30	.33	.25

Table 8.--Summaries of selected constituent values obtained in sub-basins above Watts Bar Dam during the 1972-82 water years--Continued

Sub-basin	Number of samples	Minimum	Maximum	Median	Mean	Standard deviation
		Phosphorus, total (mg/L as P)				
Clinch River above Bullrun Cr.	1		0.05			
Bullrun Creek	27	0.01	0.11	0.03	0.03	0.02
Poplar Creek	3	.02	.33	.08	.14	.16
Daddys Creek	1		.01			
Clear Creek	2	.01	.02			
Obed River	36	.01	4.0	.13	.91	1.3
Emory River	60	.01	.10	.02	.02	.02
Clinch River below Bullrun Cr.	90	.01	.93	.07	.10	.11
Whites Creek	3	.01	.01	.01		
Piney River	6	.01	.04	.02	.02	.01
Tennessee River below Fort Loudoun	6	.02	.04	.02	.02	.01
		Fecal coliform, 0.45 µm-MF (colonies/100 mL)				
Bullrun Creek	5	20	630	250		
Obed River	29	10	1200	200		
Emory River	31	10	670	60		
Tennessee River below Fort Loudoun	3	10	30	10		
		Organic carbon, total (mg/L as C)				
Emory River	8	1.0	7.2	2.7	3.3	2.6
Clinch River below Bullrun Cr.	83	1.0	19	5.0	5.7	4.5
Tennessee River below Fort Loudoun	3	1.8	2.2	2.2	2.1	.25
		Suspended sediment (mg/L)				
Clinch River above Bullrun Cr.	8	2.0	2170	20	294	760
Poplar Creek	28	2.0	685	28	66	130
Daddys Creek	7	3.0	379	38	113	150
Clear Creek	13	1.0	17	3.0	5	5.6
Obed River	23	13	60	26	27	14
Emory River	26	1.0	569	9.5	54	120
Whites Creek	18	1.0	187	6.5	22	44
Piney River	10	1.0	709	8.5	112	230

[a]Includes summary of data obtained at Obed River mile 1.5 (Map No. OR3, table 4) which is located below confluence with the Daddys Creek and Clear Creek sub-basins.

Long-term data were generally unavailable at specific stations in the sub-basins to define trends; therefore, trend test results are not presented. Water-quality data obtained at main-channel stations at or above the Watts Bar NASQAN station are summarized in table 9 for selected constituents. Trace constituents obtained at main-channel stations at or above Watts Bar are summarized in table 10. Water-quality data obtained at main-channel stations at or above Watts Bar Dam were tested for trend using the Seasonal Kendall test and the results are presented in table 11. Trend tests were applied to data unadjusted for the effects of flow for all stations, and also to flow adjusted concentrations for the Emory River station at mile 18.3 (site E1).

Water Type

Water can be classified on the basis of the predominant inorganic constituents, and the relation between concentrations of constituents helps describe similarities and differences in water quality. Major constituent percent composition of water from main-channel stations and sub-basins of the study area are given in table 12. Water from both the Clinch and Tennessee Rivers is classified as a calcium bicarbonate type, but water from the Emory River is a calcium sulfate bicarbonate type which is believed to be a result of coal-mining activities on the Cumberland Pleateau.

The Seasonal Kendall test was applied to the percent composition data for Watts Bar and the results are shown in table 13. The percentage of individual constituents of the total cations or anions (in milliequivalents) was calculated. Slopes generated by the Seasonal Kendall tests are estimates of the change in percent composition (unitless) per year. Results of the trend tests based on percentage composition cannot estimate increases or decreases in specific constituent concentrations, but rather indicate the proportional change of water type over time. The following changes in the water from Watts Bar can be estimated using the percentage of composition from table 12, and the slope estimates from table 13:

Ratio	Change per year expressed as percent of mean ratio
Ca / Cations	- 0.6
Mg / Cations	+ .8
(Na + K) / Cations	+ 1.7
SO_4 / Anions	+ 4.8
Cl / Anions	+ 6.3
(HCO_3 + CO_3) / Anions	- 2.6

Common Constituents

Dissolved solids

Values of median dissolved solids for stations in the Ridge and Valley physiographic province are generally higher than those for stations on the Cumberland Plateau (table 7). Two major sources of dissolved solids are indicated in the study area; dissolved calcium, magnesium, and bicarbonate from dissolution of the carbonate rocks of the Ridge and Valley, and dissolved sulfate resultant from mining activities of the Cumberland Plateau.

In general, concentrations of dissolved solids in streams of the study area show an increasing trend, at least in the Clinch and Emory River basins (table 11). No significant trend is evident in dissolved-solids concentrations in the Tennessee River as flow enters the study area at Fort Loudoun Dam, but an increasing trend is indicated at Watts Bar Dam. An increasing trend of dissolved solids is indicated on the Clinch River at mile 78.8 as it enters the study area at Norris Dam, and at mile 23.1 below Melton Hill Dam. However, data on the Clinch River at miles 66.3 and 48.6, although indicating the possibility of an increasing trend, are not considered to define a significant trend. Data on the Emory River at mile 18.3 indicate an increasing trend in dissolved solids.

Specific conductance

Specific conductance is a measure of the ability of water to conduct an electrical current and is related to the quantity and types of ionized substances in water. Specific conductance can be

Table 9.--Summary of water-quality parameters obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years

[Estimated median, value estimated from specific-conductance regressions using the median value of continuous conductance record for the Tennessee River at mile 529.9 (site T19)]

Site No.	Station	Number of samples	Minimum	Maximum	Median	Mean	Standard deviation	Estimate median
		Dissolved solids, residue at 180 °C (mg/L)						
T1	Tennessee River at mile 602.3	142	90	230	120	119	16	117
T19	Tennessee River at mile 529.9	104	60	180	95	97	17	96
C1	Clinch River at mile 78.8	50	100	250	132	138	20	
C2	Clinch River at mile 66.3	33	60	160	130	130	20	
C7	Clinch River at mile 48.6	79	60	170	130	130	17	
C13	Clinch River at mile 23.1	76	10	190	140	135	22	135
E1	Emory River at mile 18.3	68	20	192	40	50	28	50
		Specific conductance (microsiemens per centimeter at 25 °C)						
T1	Tennessee River at mile 602.3	63	140	270	200	195	28	196
T3	Tennessee River at mile 592.3	54	101	230	160	159	26	164
T8	Tennessee River at mile 560.8	14	125	250	167	169	32	
T11	Tennessee River at mile 555.7	14	113	260	167	169	36	
T13	Tennessee River at mile 553.9	14	126	260	171	173	34	
T15	Tennessee River at mile 548.5	14	125	260	170	173	35	
T17	Tennessee River at mile 532.1	12	154	251	178	179	26	
T19	Tennessee River at mile 529.9	127	97	320	160	162	28	161
C1	Clinch River at mile 78.8	54	160	440	230	229	36	
C2	Clinch River at mile 66.3	38	200	270	220	222	16	
C3	Clinch River at mile 58.8	11	210	250	230	227	13	
C7	Clinch River at mile 48.6	84	94	310	220	221	30	
C13	Clinch River at mile 23.1	86	156	290	235	232	25	233
C14	Clinch River at mile 10.0	54	173	370	247	246	33	248
E1	Emory River at mile 18.3	105	37	305	60	79	43	77
E2	Emory River at mile 14.9	58	18	360	60	78	50	82
		pH (standard units)						
T1	Tennessee River at mile 602.3	63	6.2	8.0	7.4			
T17	Tennessee River at mile 532.1	12	7.3	8.2	7.6			
T19	Tennessee River at mile 529.9	123	6.0	8.9	7.5			7.4
C1	Clinch River at mile 78.8	54	6.5	8.1	7.6			
C2	Clinch River at mile 66.3	38	6.4	8.6	7.7			
C7	Clinch River at mile 48.6	72	6.4	8.6	7.6			
C13	Clinch River at mile 23.1	88	6.8	8.6	7.7			
E1	Emory River at mile 18.3	76	4.9	8.5	6.8			6.7

Table 9.--Summary of water-quality parameters obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years--Continued

Site No.	Station	Number of samples	Minimum	Maximum	Median	Mean	Standard deviation	Estimated median
		Dissolved sulfate (mg/L as SO_4)						
T1	Tennessee River at mile 602.3	150	2.0	37	18	17	4.1	16
T3	Tennessee River at mile 592.3	110	3.0	61	11	12	8.2	9.5
T19	Tennessee River at mile 529.9	110	3.0	20	13	13	2.6	13
C1	Clinch River at mile 78.8	51	7.0	25	18	18	3.3	
C2	Clinch River at mile 66.3	33	14	32	16	18	4.3	
C7	Clinch River at mile 48.6	67	11	40	17	17	4.8	
C13	Clinch River at mile 23.1	81	4.0	24	17	17	3.9	17
C14	Clinch River at mile 10.0	56	4.0	68	17	20	11	
E1	Emory River at mile 18.3	71	3.0	86	13	17	12	17
E2	Emory River at mile 14.9	88	7.0	35	12	14	6.5	13
		Iron, total recoverable (μg/L)						
T1	Tennessee River at mile 602.3	141	50	1900	390	446	245	
T3	Tennessee River at mile 592.3	111	70	3800	600	758	658	
T19	Tennessee River at mile 529.9	76	70	2500	322	415	338	
C1	Clinch River at mile 78.8	48	10	840	80	136	158	
C2	Clinch River at mile 66.3	37	10	1600	90	285	413	
C7	Clinch River at mile 48.6	79	20	8600	290	457	974	
C13	Clinch River at mile 23.1	67	80	1000	290	356	221	
C14	Clinch River at mile 10.0	56	25	2600	400	550	553	
E1	Emory River at mile 18.3	66	50	3700	245	398	519	
E2	Emory River at mile 14.9	89	70	2800	390	633	587	
		Nitrogen, total $NO_2 + NO_3$ (mg/L as N)						
T1	Tennessee River at mile 602.3	148	0.28	6.2	0.49	0.60	0.58	
T3	Tennessee River at mile 592.3	102	.03	1.1	.44	.44	.16	
T17	Tennessee River at mile 532.1	10	.06	.55	.25	.29	.15	
T19	Tennessee River at mile 529.9	107	.11	.68	.35	.36	.12	
C1	Clinch River at mile 78.8	38	.19	1.1	.51	.54	.24	
C2	Clinch River at mile 66.3	21	.19	.72	.46	.47	.17	
C7	Clinch River at mile 48.6	67	.12	1.1	.50	.48	.18	
C13	Clinch River at mile 23.1	80	.09	4.0	.52	.56	.47	
C14	Clinch River at mile 10.0	99	.01	1.5	.42	.44	.27	
E1	Emory River at mile 18.3	54	.01	.39	.14	.15	.10	0.14
E2	Emory River at mile 14.9	89	.01	.89	.15	.20	.16	.14

Table 9.--Summary of water-quality parameters obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years--Continued

Site No.	Station	Number of samples	Minimum	Maximum	Median	Mean	Standard deviation	Estimated median
			Phosphorus, total (mg/L as P)					
T1	Tennessee River at mile 602.3	151	0.01	0.11	0.04	0.05	0.01	
T3	Tennessee River at mile 592.3	109	.01	.30	.07	.08	.06	
T17	Tennessee River at mile 532.1	9	.02	.04	.02	.03	.01	
T19	Tennessee River at mile 529.9	114	.01	.27	.03	.03	.02	
C1	Clinch River at mile 78.8	38	.01	.04	.01	.01	.01	
C2	Clinch River at mile 66.3	19	.01	.05	.02	.02	.01	
C7	Clinch River at mile 48.6	64	.01	.41	.02	.03	.05	
C13	Clinch River at mile 23.1	86	.01	1.0	.02	.03	.11	0.03
C14	Clinch River at mile 10.0	109		.99	.05	.09	.12	
E1	Emory River at mile 18.3	54	.01	.07	.01	.02	.01	
E2	Emory River at mile 14.9	89	.01	1.0	.05	.09	.12	
			Fecal coliform, 0.45 μm-MF (colonies/100 mL)					
T1	Tennessee River at mile 602.3	15	10	340	10			
T3	Tennessee River at mile 592.3	27	6.0	13,000	55			
T19	Tennessee River at mile 529.9	32	1.0	100	10			
C1	Clinch River at mile 78.8	5	10	10	10			
C7	Clinch River at mile 48.6	6	10	160	10			
C13	Clinch River at mile 23.1	5	10	10	10			
E1	Emory River at mile 18.3	26	10	210	10			
			Organic Carbon, total (mg/L as C)					
T1	Tennessee River at mile 602.3	30	1.5	4.2	3.0	2.9	0.71	
T2	Tennessee River at mile 593.3	100	0	24	4.0	4.8	4.0	
T17	Tennessee River at mile 532.1	10	1.8	4.1	2.2	2.4	.72	
T19	Tennessee River at mile 529.9	46	1.0	12	2.4	3.2	2.1	
C1	Clinch River at mile 78.8	20	.4	3.6	1.9	1.9	0.95	
C2	Clinch River at mile 66.3	3	1.0	2.1	1.6			
C7	Clinch River at mile 48.6	31	.4	13	1.7	2.0	2.1	
C13	Clinch River at mile 23.1	37	.3	7.6	2.1	2.4	1.4	
C14	Clinch River at mile 10.0	35	0	35	6.0	7.4	6.7	
E1	Emory River at mile 18.3	30	.4	4.2	1.6	1.8	.77	
E2	Emory River at mile 14.9	84	1.0	14	2.8	3.6	3.2	
			Suspended sediment (mg/L)					
T19	Tennessee River at mile 529.9	78	1.0	43	8.0	9.4	6.8	
C13	Clinch River at mile 23.1	30	2.0	19	8.0	8.4	4.4	
E1	Emory River at mile 18.3	23	1.0	194	6.0	18	40	

Table 10.--Summary of trace-constituent data obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years

Site No.	Station	Number of samples	Minimum	Median	Maximum	Date of maximum
	Arsenic, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	31	< 1	< 1	3	
C13	Clinch River at mile 23.1	14	< 1	1	2	
	Arsenic, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	17	< 2	< 5	< 10	
T3	Tennessee River at mile 592.3	58	< 1	< 1	< 20	
T19	Tennessee River at mile 529.9	47	< 1	< 2	< 10	
C1	Clinch River at mile 78.8	6	< 2	< 5	< 5	
C2	Clinch River at mile 66.3	3	< 2	< 2	< 2	
C7	Clinch River at mile 48.6	36	< 2	< 4	9	4- 5-77
C13	Clinch River at mile 23.1	29	< 1	< 5	6	6-18-75
C14	Clinch River at mile 10.0	64	< 1	< 1	25	10- 4-76
E1	Emory River at mile 18.3	17	1	< 5	7	8-12-75
E2	Emory River at mile 14.9	62	< 1	< 1	4	9- 1-74
	Cadmium, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	31	ND	ND	3	
C13	Clinch River at mile 23.1	14	ND	< 2	5	
	Cadmium, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	123	< 2	< 2	15	11-11-74
T3	Tennessee River at mile 592.3	85	< 2	< 2	240	8- 9-72
T19	Tennessee River at mile 529.9	49	ND	< 2	10	8- 5-75
C1	Clinch River at mile 78.8	23	< 2	< 2	< 2	
C2	Clinch River at mile 66.3	3	< 2	< 2	< 2	
C7	Clinch River at mile 48.6	35	< 2	< 2	< 2	
C13	Clinch River at mile 23.1	38	ND	< 2	4	3-12-74
C14	Clinch River at mile 10.0	65	< 2	< 2	20	5-18-77
E1	Emory River at mile 18.3	34	ND	< 2	< 2	
E2	Emory River at mile 14.9	89	ND	< 2	3	11- 1-77
	Chromium, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	31	ND	6	40	12- 3-79
C13	Clinch River at mile 23.1	14	< 20	< 20	20	
	Chromium, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	16	< 5	< 5	< 5	
T3	Tennessee River at mile 592.3	84	< 2	< 2	5	
T19	Tennessee River at mile 529.9	47	< 2	8	40	12- 3-79
C1	Clinch River at mile 78.8	6	< 5	< 5	14	7-19-76
C2	Clinch River at mile 66.3	3	< 5	< 5	< 5	
C7	Clinch River at mile 48.6	35	< 5	< 5	51	3- 7-78
C13	Clinch River at mile 23.1	29	< 5	< 5	30	7-10-79
C14	Clinch River at mile 10.0	64	< 2	< 2	< 40	
E1	Emory River at mile 18.3	17	< 5	< 5	36	8- 9-76
E2	Emory River at mile 14.9	84	< 2	< 2	21	9- 1-80

Table 10.--Summary of trace-constituent data obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years --Continued

Site No.	Station	Number of samples	Minimum	Median	Maximum	Date of maximum
	Cobalt, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	31	ND	ND	3	
C13	Clinch River at mile 23.1	14	ND	< 2	2	
	Cobalt, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	2	< 5		< 5	
T19	Tennessee River at mile 529.9	27	ND	< 2	< 5	
C13	Clinch River at mile 23.1	15	ND	< 2	< 5	
E1	Emory River at mile 18.3	2	< 5		< 5	
	Copper, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	30	ND	2	5	1-29-75
C13	Clinch River at mile 23.1	14	ND	< 2	8	9- 4-80
	Copper, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	125	< 20	< 20	840	9-27-74
T3	Tennessee River at mile 592.3	85	2	117	1350	4- 1-80
T19	Tennessee River at mile 529.9	49	ND	< 20	470	5-23-78
C1	Clinch River at mile 78.8	23	< 20	< 20	140	11-20-78
C2	Clinch River at mile 66.3	3	20	600	5400	4-28-77
C7	Clinch River at mile 48.6	37	< 20	45	220	1-15-74
C13	Clinch River at mile 23.1	39	< 2	12	80	5-15-78
C14	Clinch River at mile 10.0	65	< 20	< 20	20	8- 9-72
E1	Emory River at mile 18.3	34	5	< 20	40	11- 8-76
E2	Emory River at mile 14.9	89	13	239	1850	9- 1-74
	Lead, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	30	ND	2	8	6-13-77
C13	Clinch River at mile 23.1	14	ND	< 2	4	6-22-81
	Lead, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	123	< 2	< 10	60	4-18-73
T3	Tennessee River at mile 592.3	86	< 5	10	90	8- 9-72
T19	Tennessee River at mile 529.9	48	ND	< 10	72	2- 4-75
C1	Clinch River at mile 78.8	23	< 10	< 10	25	3-15-77
C2	Clinch River at mile 66.3	3	< 10	21	27	
C7	Clinch River at mile 48.6	35	< 10	< 10	19	11- 2-76
C13	Clinch River at mile 23.1	39	ND	< 10	33	3-11-75
C14	Clinch River at mile 10.0	66	< 2	< 10	100	8- 9-72
E1	Emory River at mile 18.3	34	2	< 10	22	5- 6-75
E2	Emory River at mile 14.9	89	< 5	< 10	10	
	Manganese, dissolved (µg/L)					
T1	Tennessee River at mile 602.3	13	< 10	20	50	4-18-73
T19	Tennessee River at mile 529.9	48	< 10	< 10	75	8- 4-76
C1	Clinch River at mile 78.8	8	< 10	35	410	
C13	Clinch River at mile 23.1	18	ND	2	40	11-19-80
E1	Emory River at mile 18.3	71	< 10	50	140	11- 6-74

Table 10.--Summary of trace-constituent data obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years --Continued

Site No.	Station	Number of samples	Minimum	Median	Maximum	Date of maximum
	Manganese, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	141	20	50	330	11-16-76
T3	Tennessee River at mile 592.3	111	< 1	67	390	5- 1-81
T19	Tennessee River at mile 529.9	75	< 10	50	280	11- 7-78
C1	Clinch River at mile 78.8	31	< 10	20	500	10-18-76
C2	Clinch River at mile 66.3	20	< 10	40	370	9-11-74
C7	Clinch River at mile 48.6	60	< 10	60	450	4- 5-77
C13	Clinch River at mile 23.1	67	< 10	40	130	8-16-76
C14	Clinch River at mile 10.0	56	< 5	60	280	1-10-77
E1	Emory River at mile 18.3	65	20	60	920	8- 3-77
E2	Emory River at mile 14.9	89	33	79	1350	8- 1-74
	Mercury, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	31	< .1	< .5	.5	
C13	Clinch River at mile 23.1	14	< .1	< .1	.5	
	Mercury, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	120	< .2	< .2	7.6	3-12-74
T3	Tennessee River at mile 592.3	7	< .2	< .2	< .5	
T19	Tennessee River at mile 529.9	49	< .1	< .2	.9	5-15-74
C1	Clinch River at mile 78.8	23	< .2	< .2	2.2	1-21-80
C2	Clinch River at mile 66.3	3	< .2	< .5	< .5	
C7	Clinch River at mile 48.6	34	< .2	< .2	< .5	
C13	Clinch River at mile 23.1	38	< .1	< .2	9.1	4-23-74
C14	Clinch River at mile 10.0	64	< .2	< .2	<1.0	
E1	Emory River at mile 18.3	33	.1	< .2	1.4	5-13-74
	Zinc, dissolved (µg/L)					
T19	Tennessee River at mile 529.9	31	ND	< 4	40	5- 5-76
C13	Clinch River at mile 23.1	14	ND	< 4	30	3- 5-80
	Zinc, total recoverable (µg/L)					
T1	Tennessee River at mile 602.3	126	< 20	< 20	150	1-27-75
T3	Tennessee River at mile 592.3	85	4	17	130	8- 9-72
T19	Tennessee River at mile 529.9	49	< 20	20	160	5-23-78
C1	Clinch River at mile 78.8	23	< 20	40	150	6-12-77
C2	Clinch River at mile 66.3	3	50	80	200	12- 7-76
C7	Clinch River at mile 48.6	35	< 20	70	150	7-11-78
C13	Clinch River at mile 23.1	39	9	20	90	6-18-74
C14	Clinch River at mile 10.0	11	< 2	< 20	63	5-30-79
E1	Emory River at mile 18.3	34	< 20	20	90	5- 4-77
E2	Emory River at mile 14.9	89	< 2	14	112	6- 1-79

Table 11.--Trends in water-quality parameters obtained at main-channel stations at or above Watts Bar Dam

[Flow adjustment equation used: HYP, hyperbolic; INV, inverse; QAD, quadratic; LOG, logarithmic; NST indicates no significant trend at the 90 percent confidence interval; a, Units means the individual constituent reporting units; for example milligrams per liter. However, if a logarithmic flow adjustment equation is used the slope is unitless]

Site No.	Station	Nvals	Tau	P level	Slope (units/yr)[a]	Notes	Water years
	Dissolved solids, residue at 180 °C (mg/L)						
T1	Tennessee River at mile 602.3	49	-0.122	0.426		NST	74-80
T19	Tennessee River at mile 529.9	86	.216	.019	1.42		74-82
C1	Clinch River at mile 78.8	50	.411	.003	1.16		72-80
C2	Clinch River at mile 66.3	33	.094	.751		NST	72-77
C7	Clinch River at mile 48.6	68	.121	.272		NST	72-78
C13	Clinch River at mile 23.1	66	.382	.001	2.68		74-82
E1	Emory River at mile 18.3	63	.383	.001	2.83		74-81
		62	.328	.005	2.82	INV	74-81
	Specific conductance (microsiemens per centimeter at 25 °C)						
T1	Tennessee River at mile 602.3	58	- .222	.077	-2.00		72-80
T3	Tennessee River at mile 592.3	52	.152	.280		NST	75-81
T19	Tennessee River at mile 529.9	92	.270	.002	1.67		73-82
C1	Clinch River at mile 78.8	54	.233	.072	.33		72-80
C2	Clinch River at mile 66.3	38	.395	.026	5.00		72-77
C7	Clinch River at mile 48.6	72	.187	.070	2.50		72-79
C13	Clinch River at mile 23.1	76	.227	.023	2.33		73-82
C14	Clinch River at mile 10.0	53	- .129	.363		NST	77-82
E1	Emory River at mile 18.3	81	.407	.000	3.46		73-82
		79	.444	.000	3.27	HYP	73-82
E2	Emory River at mile 14.9	56	.171	.189		NST	74-81
	pH (standard units)						
T1	Tennessee River at mile 602.3	58	.060	.668		NST	72-80
T19	Tennessee River at mile 529.9	90	- .046	.625		NST	73-82
C1	Clinch River at mile 78.8	54	.046	.772		NST	72-80
C2	Clinch River at mile 66.3	38	- .047	.887		NST	72-77
C7	Clinch River at mile 48.6	60	.117	.348		NST	72-79
C13	Clinch River at mile 23.1	77	.091	.375		NST	73-82
E1	Emory River at mile 18.3	69	.0512	0			74-81
	Dissolved sulfate (mg/L as SO_4)						
T1	Tennessee River at mile 602.3	57	- .036	.827		NST	72-80
T3	Tennessee River at mile 592.3	104	- .156	.050	-0.33		72-82
T19	Tennessee River at mile 529.9	90	.234	.008	.20		73-82
C1	Clinch River at mile 78.8	51	.457	.001	.50		72-80
C2	Clinch River at mile 66.3	33	.0	1.000		NST	72-77
C7	Clinch River at mile 48.6	61	.271	.020	.50		72-78
C13	Clinch River at mile 23.1	71	.508	.000	.86		73-82
C14	Clinch River at mile 10.0	56	- .179	.168		NST	72-77
E1	Emory River at mile 18.3	65	.467	.000	.88		73-81
		63	.307	.008	.65	LOG	73-81
E2	Emory River at mile 14.9	84	.052	.583		NST	74-82

Table 11.--Trends in water-quality parameters obtained at main-channel stations at or above Watts Bar Dam--Continued

Site No.	Station	Nvals	Tau	P level	Slope (units/yr)	Notes	Water years
			Iron, total recoverable (µg/L)				
T1	Tennessee River at mile 602.3	48	-0.346	0.019	-56.7		72-79
T3	Tennessee River at mile 592.3	104	-.258	.001	-35.0		72-82
T19	Tennessee River at mile 529.9	70	-.500	.000	-34.6		73-82
C1	Clinch River at mile 78.8	48	.545	.000	20.0		72-79
C2	Clinch River at mile 66.3	37	.714	.000	40.0		72-77
C7	Clinch River at mile 48.6	73	.267	.010	32.5		72-79
C13	Clinch River at mile 23.1	64	-.269	.018	-22.0		73-82
C14	Clinch River at mile 10.0	56	-.151	.255		NST	72-77
E1	Emory River at mile 18.3	65	-.093	.436		NST	73-81
		63	-.163	.171		NST QAD	73-81
E2	Emory River at mile 14.9	84	.366		-80.0		74-82
			Nitrogen, total NO_2 + NO_3 (mg/L as N)				
T1	Tennessee River at mile 602.3	55	-.095	.496		NST	73-80
T3	Tennessee River at mile 592.3	96	.009	.945		NST	73-82
T19	Tennessee River at mile 529.9	85	-.253	.006	-.01		73-82
C1	Clinch River at mile 78.8	38	.319	.082	.04		75-80
C7	Clinch River at mile 48.6	55	.297	.023	.03		74-79
C13	Clinch River at mile 23.1	70	-.136	.209		NST	73-81
C14	Clinch River at mile 10.0	98	-.126	.134		NST	73-82
E1	Emory River at mile 18.3	53	.216	.108		NST	73-80
E2	Emory River at mile 14.9	84	.547	0	.03		74-82
			Phosphorus, total (mg/L as P)				
T1	Tennessee River at mile 602.3	58	-.333	.007	.002		72-80
T3	Tennessee River at mile 592.3	103	-.254	.001	-.005		72-82
T19	Tennessee River at mile 529.9	91	.010	.940		NST	73-82
C1	Clinch River at mile 78.8	38	.213	.215		NST	75-80
C7	Clinch River at mile 48.6	53	.0	1.000		NST	74-79
C13	Clinch River at mile 23.1	76	.0	1.000		NST	73-82
C14	Clinch River at mile 10.0	108	.103	.187		NST	72-82
E1	Emory River at mile 18.3	53	.175	.176		NST	73-80
E2	Emory River at mile 14.9	85	.150	.006	-.007		74-82
			Fecal coliform, 0.45 µm-MF (colonies/100 mL)				
T3	Tennessee River at mile 592.3	27	-.368	.197		NST	72-82
T19	Tennessee River at mile 529.9	26	-.080	.860		NST	72-82
E1	Emory River at mile 18.3	26	.174	.551		NST	73-82
		24	.053	1.000		NST QAD	73-82

Table 11.--Trends in water-quality parameters obtained at main-channel stations at or above Watts Bar Dam--Continued

Site No.	Station	Nvals	Tau	P level	Slope (units/yr)	Notes	Water years
	Organic carbon, total (mg/L as C)						
T1	Tennessee River at mile 602.3	30	0.351	0.110		NST	74-80
T3	Tennessee River at mile 592.3	95	-.219	.010	-0.33		72-82
T19	Tennessee River at mile 529.9	41	.198	.201		NST	73-82
C1	Clinch River at mile 78.8	20	.333	.359		NST	75-80
C7	Clinch River at mile 48.6	28	0	1.000		NST	74-78
C13	Clinch River at mile 23.1	34	.104	.640		NST	73-82
C14	Clinch River at mile 10.0	35	.073	.789		NST	72-77
E1	Emory River at mile 18.3	30	.095	.706		NST	73-80
E2	Emory River at mile 14.9	80	-.121	.198		NST	74-82
	Suspended sediment (mg/L)						
T19	Tennessee River at mile 529.9	74	-.175	.087	- .33		72-82
C13	Clinch River at mile 23.1	24	-.550	.043	-1.88		72-82
E1	Emory River at mile 18.3	22	-.833	.014	-8.00		73-82
		22	-.167	.784		NST QAD	73-82

Table 12.--Mean values of milliequivalent ratios expressed as percent of cations ($Ca + Mg + Na + K$) or anions ($SO_4 + Cl + HCO_3 + CO_3$)

Site No.	Station	Ca	Mg	Na + K	SO_4	Cl	HCO_3 + CO_3
T1	Tennessee River at mile 602.3				21	17	62
T19	Tennessee River at mile 529.9	60	23	17	18	11	71
C1	Clinch River at mile 78.8	65	29	6	15	4	82
C2	Clinch River at mile 66.3	64	29	6	16	4	80
C7	Clinch River at mile 48.6	64	29	6	16	4	80
C13	Clinch River at mile 23.1	64	28	8	15	5	80
E1	Emory River at mile 18.3	53	28	19	46	21	33
	Sub-basin						
	Clinch River above Bullrun Cr	59	36	5	3	3	94
	Poplar Creek	59	32	10			
	Daddys Creek	66	11	23			
	Clear Creek	48	19	33			
	Emory River	51	32	17	73	5	22
	Whites Creek	62	17	21			
	Piney River	55	28	17			

Table 13.--Trend test of percent composition data for the Watts Bar NASQAN station (site T19)

Composition	Nvals	Tau	P level	Slope
Ca	73	-0.361	0.000	-0.00363
Mg	73	.144	.171*	.00186
Na + K	73	.206	.048	.00295
SO_4	26	.368	.204*	.00841
HCO_3+CO_3	26	-.368	.204*	-.01846
Cl	26	.263	.397*	.00720

*Not significant at the 90 percent confidence interval.

used as a general indicator of dissolved solids. Median specific-conductance values for stations in the Ridge and Valley physiographic province are generally higher than those for stations on the Cumberland Plateau (table 7). This is in agreement with the dissolved-solids data obtained in the study area.

In general, conductance of water from streams in the study area shows an increasing trend, at least in the Clinch and Emory River basins (table 11). The dissolved-solids trends of the main-channel stations generally agree with the pattern of specific-conductance trends.

Conductance of water from the Tennessee River shows a slight decreasing trend at Fort Loudoun Dam as water enters the study area. Instantaneous observations of specific conductance indicate a slight increasing trend at the outlet of the study area at Watts Bar Dam, which is in agreement with the trend test of continuous specific conductance record. Trend tests of instantaneous specific-conductance observations on the Clinch River between Norris and Melton Hill Dams indicate increased conductance during the 1972-82 water years. This does not agree with the trend test of continuous specific-conductance record of Melton Hill Dam (table 6), perhaps because the daily record reflects only the period 1981-82. The Clinch River at mile 10 does not show a significant trend in conductance. But, since this station is affected by backwater from Watts Bar Reservoir, the data are inconclusive. Trend tests of the Emory River at mile 18.3 indicate an increasing trend in specific conductance, whereas no significant trend is indicated at mile 14.9. No major inflow occurs between these sites, but less data were available for analysis at mile 14.9 than at mile 18.3 which may be the cause for this inconsistency.

Sufficient data for trend analysis were available at only five sub-basin stations. No significant trends were indicated by two stations in the Poplar Creek sub-basin, nor were trends indicated by stations in the Bullrun Creek or Clinch River below Bullrun Creek sub-basins. An increasing conductance trend was indicated at mile 1.5 on the Obed River which includes drainage from the Clear Creek, Daddys Creek, and Obed River sub-basins.

Because of its relation to ionized substances, specific conductance can be used to estimate dissolved-solids concentrations and concentrations of some individual dissolved chemical constituents in water. If a satisfactory set of relations between conductance and other constituents can be developed, individual constituent concentrations can be estimated simply by measuring conductance. Sampling could be directed toward determination of constituents which do not correlate with conductance.

Regression statistics describing the relation between specific conductance and several water-quality constituents were determined for stations on the Clinch, Emory, and Tennessee Rivers. Statistical parameters for these relations are given in table 14. Sufficient data were generally unavailable at stations of the sub-basins for regression analysis. The concentration of a particular constituent can be estimated by the equation:

$$C = R\,(SC) + B$$

where

C is concentration, in milligrams per liter;
R is the regression coefficient;
SC is specific conductance in microsiemens per centimeter at 25 °C; and
B is the regression constant.

Note: The regression equations should be used with caution in estimating concentrations of constituents at some stations due to relatively small sample sizes. To guide the data user, table 14 contains the values of percent explained variance of the relations between conductance and the other constituents, as well as the standard error of estimate for each regression.

A specific-conductance profile of the main-channel system of the study area based on observations obtained during the same day at several main-channel stations is shown in figure 10. Also displayed in figure 10 is a profile based on the median values of specific conductance obtained at main-channel stations which had at least 12 observations (see table 9). The median value profiles generally agree with the shapes of the "same-day" profiles and are considered a good representation of specific-conductance variability along the main channels of the study area.

Table 14.--Regression statistics describing the relations between specific conductance and several water-quality parameters obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years

[All relations shown are above the 90 percent confidence interval]

Constituent	Number of comparisons	Slope R	Intercept B	Standard error of estimate	Percent explained variance
Tennessee River at mile 602.3 (site T1)					
Specific-conductance range = 140 to 270 microsiemens					
Chloride, dissolved (mg/L as Cl)	61	1.249×10^{-1}	-13.2	4.37	39
Hardness (mg/L as $CaCO_3$)	35	2.524×10^{-1}	21.4	14.6	14
Sulfate, dissolved (mg/L as SO_4)	62	9.679×10^{-2}	-3.23	4.87	23
Silica, dissolved (mg/L as SiO_2)	23	-2.172×10^{-2}	9.49	.94	19
Solids, residue @ 180°C, dissolved	54	3.326×10^{-1}	52.3	21.9	12
Tennessee River at mile 592.3 (site T3)					
Specific-conductance range = 101 to 230 microsiemens					
Hardness (mg/L as $CaCO_3$)	53	3.080×10^{-1}	16.7	7.77	50
Sulfate, dissolved (mg/L as SO_4)	54	4.402×10^{-2}	2.32	2.25	20
Tennessee River at mile 529.9 (site T19)					
Specific-conductance range = 97 to 230 microsiemens					
pH (standard units)	122	5.490×10^{-3}	6.50	.43	12
Bicarbonate (mg/L as HCO_3)	34	1.308×10^{-1}	46.8	5.22	39
Carbonate (mg/L as CO^3)	29	2.918×10^{-2}	-4.63	.54	78
Hardness (mg/L as $CaCO^3$)	100	3.212×10^{-1}	15.1	6.10	53
Calcium, dissolved (mg/L as Ca)	77	7.376×10^{-2}	7.66	1.76	41
Magnesium, dissolved (mg/L as Mg)	78	2.045×10^{-2}	1.27	.41	48
Sodium, dissolved (mg/L as Na)	78	6.399×10^{-2}	-4.74	1.11	56
Potassium, dissolved (mg/L as K)	78	4.047×10^{-3}	.748	.17	18
Chloride, dissolved (mg/L as Cl)	109	1.023×10^{-1}	-9.93	2.04	62
Sulfate, dissolved (mg/L as SO_4)	108	4.330×10^{-2}	6.14	2.38	18
Solids, residue @ 180°C dissolved	103	5.524×10^{-1}	7.38	9.35	70
Solids, sum of constituents, dissolved (mg/L)	63	4.407×10^{-1}	18.2	4.27	82
Clinch River at mile 78.8 (site C1)					
Specific-conductance range = 160 to 440 microsiemens					
Bicarbonate (mg/L as HCO_3)	29	3.911×10^{-1}	30.4	9.16	46
Magnesium, dissolved (mg/L as Mg)	17	2.337×10^{-2}	3.38	.65	30
Sulfate, dissolved (mg/L as SO_4)	49	2.613×10^{-2}	11.6	3.28	8
Solids, residue @ 180°C, dissolved	48	4.173×10^{-1}	42.1	11.3	66
Clinch River at 66.3 (site C2)					
Specific-conductance range = 200 to 270 microsiemens					
Bicarbonate (mg/L as HCO_3)	27	2.662×10^{-1}	54.0	8.58	22
Nitrogen,total NO_2+NO_3 (mg/L as N)	21	-4.926×10^{-3}	1.59	.15	26
Hardness (mg/L as $CaCO_3$)	30	2.778×10^{-2}	48.6	11.5	9
Magnesium, dissolved (mg/L as Mg)	17	5.334×10^{-2}	-3.02	1.01	29
Sodium, dissolved (mg/L as Na)	17	-1.550×10^{-2}	6.06	.30	27
Solids, residue @ 180°C, dissolved	33	4.505×10^{-1}	30.3	19.2	9

Table 14.--Regression statistics describing the relations between specific conductance and several water-quality parameters obtained at main-channel stations at or above Watts Bar Dam during the 1972-82 water years--Continued

Constituent	Number of comparisons	Slope R	Intercept B	Standard error of estimate	Percent explained variance
Clinch River at mile 48.6 (site C7)					
Specific-conductance range = 94 to 130 microsiemens					
Bicarbonate (mg/L as HCO_3)	24	4.949×10^{-1}	7.47	8.06	78
Phosphorus, total (mg/L as P)	63	-7.017×10^{-4}	.184	.03	21
Hardness (mg/L as $CaCO_3$)	55	2.729×10^{-1}	47.6	15.7	16
Magnesium, dissolved (mg/L as Mg)	17	5.044×10^{-2}	-2.34	.86	43
Chloride, dissolved (mg/L as Cl)	67	5.746×10^{-3}	2.00	.86	4
Solids, residue @ 180°C, dissolved	79	3.481×10^{-1}	53.1	14.6	30
Solids, sum of constituents, dissolved (mg/L)	17	2.447×10^{-1}	72.9	6.98	21
Clinch River at mile 23.1 (site C13)					
Specific-conductance range = 156 to 290 microsiemens					
Bicarbonate (mg/L as HCO_3)	10	7.890×10^{-1}	-61.9	8.56	80
Phosphorus, total (mg/L as P)	85	9.299×10^{-4}	-.184	.10	4
Hardness (mg/L as $CaCO_3$)	55	2.935×10^{-1}	42.1	11.0	31
Calcium, dissolved (mg/L as Ca)	30	7.820×10^{-2}	13.1	1.54	70
Magnesium, dissolved (mg/L as Mg)	30	3.636×10^{-2}	.014	.61	76
Potassium, dissolved (mg/L as K)	30	2.352×10^{-3}	.843	.20	11
Sulfate, dissolved (mg/L as SO_4)	80	8.567×10^{-2}	-3.23	3.35	27
Silica, dissolved (mg/L as SiO_2)	54	-2.007×10^{-2}	8.70	1.16	16
Solids, Residue @ 180°C, dissolved	76	5.483×10^{-1}	7.27	17.7	33
Solids, sum of constituents, dissolved (mg/L)	30	3.906×10^{-1}	37.7	5.72	81
Emory River at mile 18.3 (site E1)					
Specific-conductance range = 156 to 290 microsiemens					
Streamflow, instataneous (ft^3/s)	103	-2.102×10	3100	1921	18
pH (standard units)	75	6.962×10^{-3}	6.18	.58	24
Bicarbonate (mg/L as HCO_3)	10	1.884×10^{-1}	1.28	2.82	81
Nitrogen, total NO_2 + NO_3 (mg/L as N)	54	-1.095×10^{-3}	.229	.07	14
Hardness (mg/L as $CaCO_3$)	39	3.313×10^{-1}	2.18	5.14	84
Chloride, dissolved (mg/L as Cl)	50	1.226×10^{-2}	2.50	1.29	10
Sulfate, dissolved (mg/L as SO_4)	71	2.429×10^{-1}	-1.91	5.12	83
Silica, dissolved (mg/L as SiO_2)	24	-1.548×10^{-2}	4.19	.89	28
Solids, residue @ 180°C, dissolved	68	5.469×10^{-1}	7.48	11.1	84
Emory River at mile 14.9 (site E2)					
Specific-conductance range = 18 to 360 microsiemens					
Nitrogen, total NO_2 + NO_3 (mg/L as N)	57	-4.537×10^{-4}	.175	.08	7
Hardness (mg/L as $CaCO_3$)	57	5.509×10^{-1}	-11.3	12.0	84
Sulfate, dissolved (mg/L as SO_4	58	6.599×10^{-2}	8.05	3.90	42

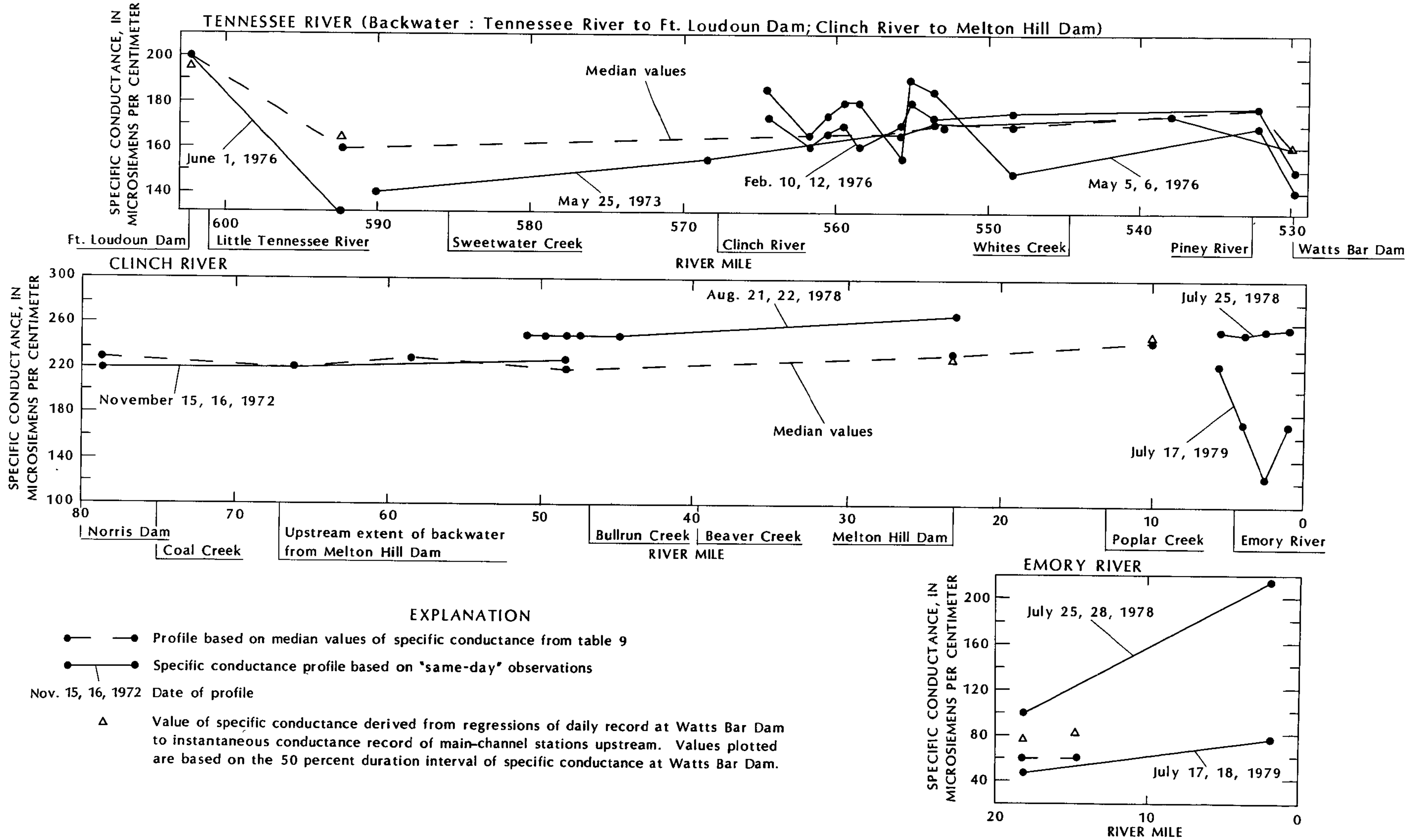


Figure 10.--Specific-conductance profiles of the main-channel system in the NASQAN accounting unit above Watts Bar Dam.

The daily mean values of specific conductance at the Watts Bar NASQAN station were regressed against the instantaneous observations of specific conductance made the same day at other main-channel stations (table 15). Sufficient concurrent data were not available for regressions based on the daily conductance record of the Melton Hill NASQAN station. The regression relations presented in table 15 were used to estimate the specific conductance at other main-channel stations that correspond to the 50 percent duration interval (median) value of the Watts Bar daily conductance record. These estimated median values compare favorably with the medians of observed conductance values and are plotted on figure 10. It is considered that through specific-conductance relations the NASQAN station is able to represent the water-quality of the main-channel system of the accounting unit. The specific-conductance profile of estimated median values were used with the regression statistics presented in table 14 to generate the estimated median values of selected constituents presented in table 9.

Hydrogen-ion activity (pH)

The most acidic waters of the study area (minimum pH values, table 8) come from subbasins in which known mining activities have occurred.

No significant pH trends were indicated from data of the Clinch River and Tennessee River stations, however an increasing pH trend was indicated on the Emory River at mile 18.3 (table 11). This trend for the Emory River, which drains an area of extensive coal mining, may be in part due to reduced acid-mine runoff since implementation of the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87). The Act specifies that the pH of mine effluents must be between 6.0 and 9.0 units. It is not surprising that this increasing pH trend is not reflected at the NASQAN station at Watts Bar because the Emory River basin is only 5 percent of the drainage area.

Table 15.--Regression statistics describing the relations between daily specific conductance obtained at the Watts Bar NASQAN station and instantaneous specific-conductance observations obtained at main channel stations above Watts Bar Dam

Site No.	Station	Number of comparisons	Slope R	Intercept ·B	Standard error of estimate	Percent explained variance
T1	Tennessee River at mile 602.3.	27	0.7832	69.7	20.0	37
T2	Tennessee River at mile 593.3.	46	.5357	78.0	22.0	18
C13	Clinch River at mile 23.1.	44	.4989	153	25.1	14
C14	Clinch River at mile 10.0.	39	.6997	136	31.0	19
E1	Emory River at mile 18.3.	72	.6201	-22.7	35.5	11
E2	Emory River at mile 14.9.	46	1.214	-114	48.8	19

Sulfate

Median values of dissolved sulfate obtained at stations in the sub-basins of the study area during the 1972-82 water years are presented in table 7. As might be expected, the highest dissolved sulfate values were obtained on streams that drain coal-mining areas of the Cumberland Plateau (CA3 84 mg/L and ER4 72 mg/L).

In general, dissolved sulfate concentrations showed an increasing trend in the Clinch and Emory River basins during the 1972-82 water years (table 11). These rivers drain areas in which coal-mining is prevalent. No increasing trend in dissolved sulfate was indicated on the Tennessee River above its confluence with the Clinch River, but below the confluence, a slightly increasing trend was indicated.

No significant trend in dissolved sulfate was indicated on the Tennessee River at mile 602.3, but a decreasing trend was indicated at mile 592.3. The major inflow between Tennessee River miles 602.3 and 592.3 is from the Little Tennessee River. An increasing trend in sulfate was indicated on the Clinch River at miles 78.8, 48.6, and 23.1 (Melton Hill), but no significant trend was indicated at mile 66.3. Fewer determinations of dissolved sulfate were obtained at Clinch River mile 66.3 than at the other locations which may be the reason for this inconsistency. No significant trend was indicated on the Clinch River at mile 10.0 which is affected by backwater from Watts Bar Reservoir. An increasing trend in dissolved sulfate was indicated on the Emory River at mile 18.3 but not at mile 14.9. This inconsistency cannot be fully explained, but it should be noted that a trend test of flow-adjusted concentrations performed on Emory River at mile 18.3 data indicates a lesser increasing trend than the unadjusted trend test. A slightly increasing trend in dissolved sulfate was indicated at the outlet of the study area at Watts Bar Dam.

Trace Constituents

Concentrations of a variety of constituents occur naturally in surface waters in trace amounts only. Certain trace constituents such as arsenic, cadmium, lead, and mercury can be highly toxic to both humans and wildlife. Other constituents, such as copper and zinc, are believed to be essential to life. Some trace constituents, such as iron and manganese, may cause undesirable water taste, or may cause industrial problems such as scaling in pipes and boilers.

Several different analytical procedures with different levels of detection were used to determine trace constituent data during the 1972-82 water years. Differing detection levels and accuracies can be attributed to both laboratory procedure inconsistencies of the various data collection agencies and improvements of analytical techniques during the period. To reduce the possibility of detecting false trends, the following procedure was used:

(1) The least sensitive detection limit of all the analytical procedures used for each constituent at each station was determined.

(2) All values reported as less than the least sensitive detection limit were set to one-half the value of the detection limit.

The Seasonal Kendall test was applied only to data from the main-channel stations due to a lack of trace constituent data in most of the sub-basins. The test, which was performed on a quarterly seasonal basis, showed no significant trends except for the following:

- Total recoverable copper on the Clinch River at mile 48.6, indicated a decreasing trend estimate of 10 μg/L per year.
- Total recoverable manganese on the Clinch River at mile 48.6, indicated a decreasing trend of about 12 μg/L per year.
- Total recoverable manganese on the Clinch River at mile 23.1, indicated a decreasing trend estimate of 2 μg/L per year.

Mercury

Very few natural waters contain readily detectable concentrations of mercury (Hem, 1970). Concentrations of mercury in unpolluted rivers in areas where no natural mercury deposits are known is generally less than 0.1 µg/L (Wershaw, 1970). The national drinking-water regulations recommend a limit of 2 µg/L dissolved mercury for domestic water supply.

An estimated 2.4 million pounds of mercury were lost or otherwise unaccounted for from the Oak Ridge National Laboratory between 1950 and 1977, with an estimated 475,000 pounds discharged to streams in the Poplar Creek basin (TVA, 1983). This mercury entered the stream system at the headwaters of East Fork Poplar Creek, which flows into Poplar Creek at mile 5.5, and then into the Clinch River at mile 12.

The maximum value of total recoverable mercury determined 1972-82 in water obtained at the Watts Bar NASQAN station (below the mercury spill) or at the Melton Hill NASQAN station (above the mercury spill) did not exceed 0.5 µg/L.

Iron

The maximum values of total recoverable iron in sub-basins of the study area (table 8) are highest in basins where coal mining is known to have occurred. However, comparison of median total recoverable iron values obtained at stations in the sub-basins (table 7) to land-use information (fig. 4) shows high iron values in some streams draining areas in which no mining activities have been documented. Notably, a median value of 1,300 µg/L was obtained on Beaver Creek which drains a predominately urban area.

Total recoverable iron data indicate decreasing trends at stations on the Tennessee River at miles 602.3, 593.3, and 529.9 (Watts Bar) (table 11). Total recoverable iron also shows a decreasing trend or no significant trend near the mouths of the Clinch and Emory Rivers. However, increasing trends in iron concentrations are indicated on the Clinch River from mile 78.8 to 48.6. Between Clinch River miles 48.6 and 23.1 (Melton Hill) the indicated trend reverses. It is probable that iron adsorption to sediment that settles-out in the reservoir above Melton Hill Dam may be the reason that the total recoverable iron increasing trend is not observed below the reservoir.

Nutrients

Nitrogen

Median values of total nitrite plus nitra nitrogen (NO_2 + NO_3 mg/L as N) obtained stations in the sub-basins of the study area duri the 1972-82 water years are presented in table Although not conclusive, comparisons of medi total nitrite plus nitrate-nitrogen values obtain at sub-basin stations to wastewater discharge sit (fig. 8) suggest that stations downstream of know wastewater discharge sites have higher nitrog values than stations above known wastewat discharges.

Trend test results for main-channel stati nitrogen data are given in table 11. An increasi trend in total nitrite plus nitrate nitrogen is inc cated on the Clinch River at mile 78.8 and mi 48.6, however no significant trend is indicat below Melton Hill Dam at Clinch River mile 23. No significant trends are indicated on the Tenne see River at mile 602.3 and mile 593.3, but a slig decreasing trend in nitrogen is indicated bel Watts Bar Dam at Tennessee River mile 529. Station data for the Emory River, which flo into Watts Bar Reservoir, indicates no significa trend at mile 18.3 but an increasing trend in tot nitrite plus nitrate nitrogen at mile 14.9.

Phosphorus

In general, a desirable guideline for allowab limits of total phosphorus is 0.1 mg/L for rive and 0.05 mg/L where streams enter lakes or rese voirs (National Technical Advisory Committe 1968). The median values of total phosphorus f main-channel stations in the study area are gene ally within the recommended limit for strear entering reservoirs (table 9). However, the ma mum total phosphorus values obtained at many these main-channel stations exceeded the recor mended limit.

No significant total phosphorus trends we indicated on the Clinch River from mile 78.8 mile 10.0. A slightly increasing trend in tot phosphorus was indicated on the Tennessee Riv at mile 602.3, and a slightly decreasing trend w indicated at mile 592.3. Most of the sampl collected at Tennessee River mile 602.3 did not include the flow of the Little Tennessee River, which may account for the difference in trends at these two locations. No significant trend in total phosphorus was indicated on the Emory River at mile 18.3, however a decreasing trend was indicated on the Emory River at mile 14.9 where a greater number of samples were obtained. No significant trend in total phosphorus was indicated at Watts Bar Dam, the discharge end of the study area.

Organics and Biological

Fecal coliform bacteria

The maximum values of fecal coliform bacteria obtained in the Bullrun Creek, Obed River, and Emory River sub-basins ranged from 630 to 1,200 colonies per 100 mL (table 8). However, insufficient data were available on an area-wide basis to determine the possible sources. The maximum value of fecal coliform bacteria obtained on the Tennessee River at mile 593.3 was 13,000 colonies per 100 mL (table 9). According to the Knoxville News-Sentinel (May 20, 1983), raw sewage has occasionally bypassed treatment plants and entered Fort Loudoun Lake above the study area. Samples taken from one tributary to Fort Loudoun Lake showed a fecal coliform bacteria count of 81,000 colonies per 100 mL. The report also states that during wet weather 5 to 10 million gallons of raw sewage bypasses the treatment plant daily. No other main-channel station of the study area had unusually high fecal coliform values, however, data were very limited.

Organic Carbon

No significant trends in total organic carbon were indicated at main-channel stations except on the Tennessee River at mile 592.3 (table 11).

Sediment

According to a sediment study by Trimble and Carey (1984), the Tennessee River and Clinch River Reservoirs in the study area act as sediment traps. Sediment yield, accumulation, and outflow of reservoirs in the study areas as computed by Trimble and Carey are given in table 16.

Table 16.-- Sediment yield, accumulation, and outflow of Norris, Melton Hill, Fort Loudoun, and Watts Bar Reservoirs

[a, Average yield of contributing drainage area between reservoirs. Watts Bar calculations include the drainage area of the Little Tennessee River and the Fort Loudoun calculations do not; from Trimble and Carey, 1984]

Reservoir	Bulk density (lb/ft^3)	Local sediment yield[a] [(ton/mi^2)/yr]	Sediment outflow (tons/yr)	Sediment accumulation (tons/yr)	Trap efficiency (Brune percent)	Local trap efficiency (Churchill percent)	Outflow trap efficiency (Churchill percent)	Outflow routed to:
Norris	55	310	0	884,000	100	100	95	Melton Hill
Melton Hill	55	150	9,700	56,000	75	85	60	Watts Bar
Fort Loudoun	50	490	160,000	620,000	75	80	50	Watts Bar
Watts Bar	55	630	343,000	1,650,000	80	85	60	

Suspended sediment

The maximum known values of suspended sediment in sub-basins of the study area range from 17 mg/L in the Clear Creek basin where little or no coal mining has occurred, to 2,170 mg/L in the Clinch River basin above Bullrun Creek where mining is prevalent (table 8). Maximum known values of suspended sediment below Watts Bar Dam and Melton Hill Dam are only 43 mg/L and 19 mg/L, respectively.

Suspended-sediment data unadjusted for the effects of flow indicate decreasing trends at Watts Bar, Melton Hill, and the Emory River at mile 18.3 (table 11). However, the trend test of flow adjusted concentrations of the Emory River at mile 18.3 showed no significant trend. This probably indicates that the decreasing sediment trends of unadjusted concentrations reflect the decreasing flow trend of the study area during the 1972-82 water years.

Bed material

Small particle-size bed material is virtually nonexistent in the channel reaches below Watts Bar Dam and Melton Hill Dam where water-quality sampling for NASQAN is conducted. This is probably due to high flow energies during dam operations. Available data for constituents in bed material are summarized in table 17 and show that concentrations of mercury, chromium, copper, lead, and nickel in East Fork Poplar Creek, Poplar Creek, and the Clinch River are generally above background concentrations (TVA, 1983).

Table 17.-- Mean concentrations of trace constituents in bed material samples obtained from streams above Watts Bar Dam during the period 1970-83

[Values in microgram per gram dry weight]

Location	Mercury	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Aluminum	Beryllium	Manganese
East Fork Poplar Creek										
mile 15 - 10,	45.6	<400	150	135		<100	<800	76,250	<10	
mile 10 - 5,	24.0		76.0							
mile 5 - 0.	21.9	<83.2	75.1	64.4	41.5	76.9	190	45,714	<10	584
Poplar Creek										
mile 6 - 3,	13.1	<4.55	92.5	81.4	40.7	178	113	40,372		588
mile 3 - 0.	10.0	<4.46	111	73.6	52.5	139	127	48,866	<.60	593
Clinch River at mile 10.0.	6.39	<4.0	69.5	29.2	23.1	32.4	57.8	34,917		624
Tennessee River mile 565 - 530.	1.24	1.13	25.7	7.8	52.7	25.2	85.0	3,000	<.60	670
Bear Creek mile 8 - 0.	2.03	<400	<100	50		<100	<1350	45,000	<10	
White Oak Creek mile 4 - 0.	2.05	.65	6.5	8.9	20.0	6.5	48.0		<.60	1255
Clinch River and tributaries above mile 23.1.	< .16	1.43	19.3	18.2	31.6	30.5	69.6	7,452	<1.0	1093

Compilation by the Tennessee Valley Authority.

WATER TEMPERATURE

Measurements of continuous water temperatures were obtained at the two NASQAN stations in the study area. Daily average water temperatures were analyzed using a statistical technique of Steele (1974) to fit the data to a harmonic (sinusoidal) equation. The harmonic expression used to represent daily temperature has the form:

$$T'(D) = M + A \sin [0.0172 \times (D) + C]$$

where

T'(D) is estimated temperature on the Dth day, in °C;

D is a day of the year (October 1, the beginning of the water year, is represented by integer 1);

M is the harmonic mean temperature, in °C;

A is the harmonic amplitude of the stream temperature curve, in °C; and

C is the phase angle, in radians.

The harmonic coefficients (M, A, and C), the standard error of estimate of a daily temperature value in °C, and the percentage of the variation in daily temperature values that is accounted for by the harmonic function are shown in table 18. Standard errors of estimate of stream temperature at the two NASQAN stations were less than 2 °C, and the explained variations were 85 percent or greater. Comparisons of estimated water temperatures from the harmonic analyses to average observed water temperatures at Watts Bar and Melton Hill are shown in figure 11.

LOAD COMPUTATIONS

As stated previously, the relation between water-quality constituents and discharge are not well defined on the Clinch and Tennessee Rivers due to regulation. However, relations of specific conductance to other water-quality parameters were evaluated, and continuous specific-conductance and discharge records were available at the NASQAN stations. This information was used to estimate constituent loads of the two NASQAN stations presented in table 19 by the following procedure:

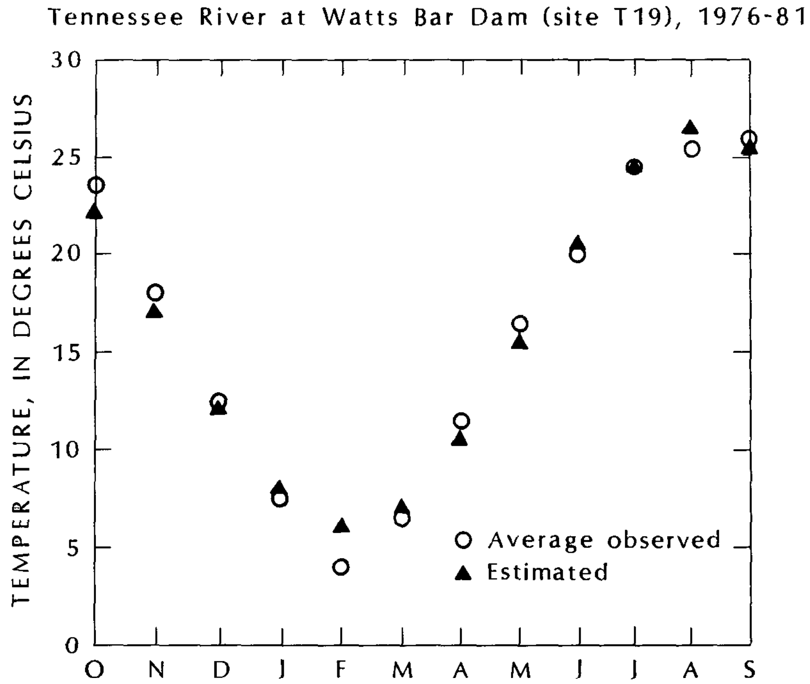
- Constituent to specific-conductance linear regressions were computed (table 14).
- Duration tables of daily specific conductance were compiled from the NASQAN station records (table 5).
- Duration tables of other constituents were computed from the specific-conductance duration tables by use of constituent to specific-conductance regressions. A weighted mean concentration was estimated from the constituent duration tables.
- These average yearly constituent concentrations were then multiplied by the average discharge of the station (table 2) to give an estimate of yearly constituent loads.

Constituent load estimates for other main-channel stations were not possible using this method because continuous specific-conductance records were not available. Also, sufficient data were not available for estimates of sub-basin constituent loads.

Table 18.--Harmonic analyses of stream temperature records of Melton Hill Dam and Watts Bar Dam

[Form of equation: $T'D = M + A \times \sin (0.0172 \times D + C)$]

Site No.	Station	Sample size	Harmonic mean M (°C)	Amplitude A (°C)	Phase angle-C (radians)	Variation explained (percent)	Standard error (°C)
C13	Melton Hill	547	14.50	6.44	2.60	85	1.84
T19	Watts Bar	1808	16.29	10.29	2.52	95	1.59



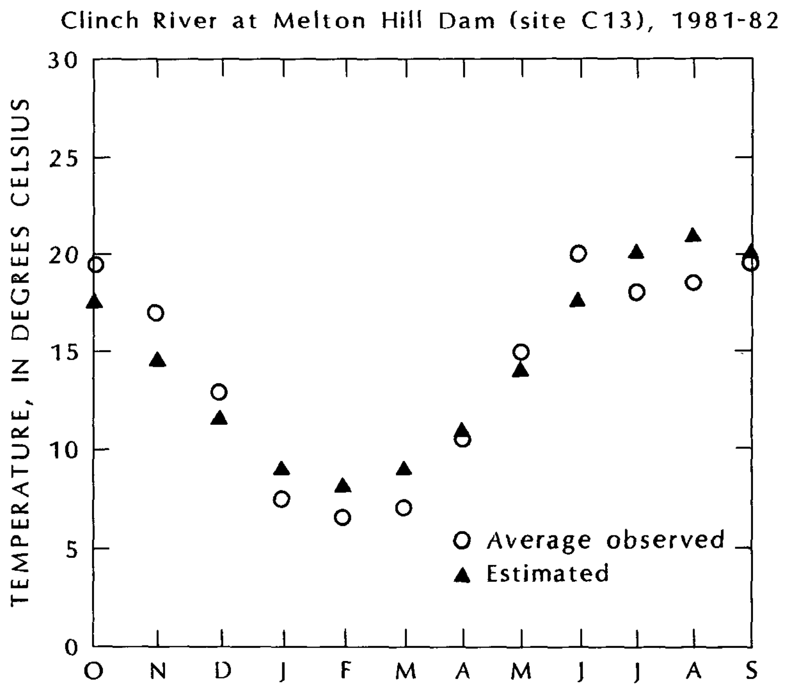


Figure 11.--Comparison of estimated water temperatures from harmonic analyses to the average observed water temperatures at the Watts Bar and Melton Hill NASQAN stations. [Form of equation: $T'D = M + A \sin(0.0172 \times D + C)$]

Table 19.--Load estimates of selected constituents sampled at the Watts Bar and Melton Hill NASQAN stations

Constituent	Weighted mean concentration estimate (mg/L)	Load estimate (tons/yr)
Tennessee River at Watts Bar Dam (site T19)		
Solids, residue at 180 °C, dissolved	99	2,800,000
Solids, sum of constituents, dissolved	90	2,550,000
Calcium, dissolved	20	566,000
Magnesium, dissolved	4.6	130,000
Sodium, dissolved	5.7	161,000
Sulfate, dissolved	13	368,000
Chloride, dissolved	6.7	190,000
Bicarbonate	68	1,930,000
Clinch River at Melton Hill Dam (site C13)		
Solids, residue at 180 °C, dissolved	145	664,000
Solids, sum of constituents, dissolved	135	618,000
Calcium, dissolved	33	151,000
Magnesium, dissolved	9.1	42,000
Sulfate, dissolved	18	82,000
Bicarbonate	135	618,000
Silica, dissolved	3.7	17,000

RESERVOIR STRATIFICATION

Significant water-quality differences can occur between the surface, mid-depth, and bottom of a lake or reservoir. Water released from an impoundment from one vertical position therefore may not be fully representative of the upstream impoundment. The river profile of specific conductance presented in figure 10 indicates that specific conductance is higher upstream of Watts Bar Dam than downstream. Additional same-day data show higher specific-conductance values upstream of Watts Bar Dam than downstream of the dam (table 20). Values of pH obtained above Watts Bar Dam are also generally higher than those obtained below the dam, however neither total phosphorus nor total nitrite plus nitrate nitrogen data showed discernible differences above or below Watts Bar Dam.

Flow through the power-generation turbines accounted for more than 95 percent of the dam releases for the dates of sample collection listed in table 20. The normal minimum operating level of Watts Bar Reservoir is at an elevation of 735 feet. There are five turbine intakes with three bays each. Each bay opening is 21.08 feet wide by 47.46 feet high, with the top of the intake located at an elevation of 712.5 feet. The center line of the turbine distributor is at an elevation of 676 feet. Design of the turbine intakes may result in releases from stratified layers of the impoundment; therefore, further study is needed to determine whether the NASQAN data obtained below Watts Bar Dam is representative of the water quality of Watts Bar Reservoir. No data were available both above and below Melton Hill Dam for comparison.

Table 20.--Water-quality parameters obtained the same day above and below Watts Bar Dam (sites T17 and T19)

Date	Specific conductance		pH		Total phosphorus (mg/L as P)		Total $NO_2 + NO_3$ nitrogen (mg/L as N)	
	above	below	above	below	above	below	above	below
5-19-75	154	150	7.5	7.4				
2-12-76	178	150	7.5	7.5	0.040	0.040	0.55	0.53
5- 5-76	169	141	7.8	7.5	.020	.020	.21	.21
8- 4-76	159	150	7.6	7.2	.023	.030	.21	.29
11- 4-76	178	177	7.4	7.4	.023	.024	.29	.31
2- 9-77	193	180	7.9	7.8	.017	.020	.47	.42
5- 3-77	154	140	7.5	6.5	.023	.020	.36	.37
8- 2-77	183	162	7.7	7.5	.020	.027	.15	.25
11- 8-77	180	180	7.3	7.4	.043	.025	.38	.35

ANALYSIS OF TREND PROCEDURES

The major problem with the use of trend procedures for this study was the lack of a means to perform flow adjustments. Identification of trends caused by process (source) change was therefore not possible on the Clinch and Tennessee Rivers. The fact that flow itself indicated a decreasing trend throughout the study area compounded this problem. Thus indicated trends in concentrations of chemical constituents may be reflections of the trends in discharge rather than of source changes.

The Seasonal Kendall test provides a single summary statistic for the available record. Comparison of constituent trends from two or more stations along a channel should be restricted to periods of concurrent record because trends in opposing directions outside of the concurrent record period could result in inconsistent trend indications. For example, an increasing trend in specific conductance is indicated at Emory River mile 18.3 but no significant trend is indicated at mile 14.9. No major inflows occur between these sites and both locations are above backwater from Watts Bar Reservoir. The reason for this inconsistency was judged to be differences in completeness of the record and some nonconcurrent record periods. Trends of data from Emory River miles 18.3 and 14.9 are not in agreement for several of the other constituent tests [total phosphorus, total nitrite plus nitrate nitrogen, total recoverable iron, and dissolved sulfate].

SUMMARY AND CONCLUSIONS

The Clinch, Emory, and Tennessee Rivers compose the main-channel systems of the study area. The Clinch and Tennessee Rivers are highly regulated by flood-control and power-generation control structures. Two NASQAN stations are located in the study area; one is below Watts Bar Dam on the Tennessee River, and the other is below Melton Hill Dam on the Clinch River. Comparison of data from these NASQAN stations to water-quality data from the drainage basins upstream of the dams was made to determine if NASQAN data obtained below impoundments can be used to meet the objectives of the NASQAN program.

The following findings of this study have shown that NASQAN data obtained below impoundments may be inadequate to describe a composite picture of water quality in the accounting unit:

- Extreme concentrations of constituents that might be expected in a free-flowing stream appear to be moderated due to storage in the reservoirs. Comparison of the ranges of constituent values obtained in study area sub-basins to the ranges of values observed at the two NASQAN stations shows sub-basin data to be much more variable.
- Significant water-quality differences can occur between the surface, mid-depth, and bottom of a lake or reservoir. Comparisons of data obtained above and below Watts Bar Dam suggest that the water sampled at the NASQAN station comes from stratified layers of the impoundment.
- Total recoverable iron data suggests that because of adsorption to sediments in the impoundments, some constituents are not accurately described by data obtained below dams.

Relations between specific conductance and common ionic constituents were defined for several main-channel stations. Relations were also defined between the continuous specific-conductance record of the NASQAN station below Watts Bar Dam and the instantaneous observations of specific conductance obtained at upstream main-channel stations of the study area. Using these specific-conductance relations, the variability of several common constituents along the main-channel system could be described. Estimates of common constituent loads at the two NASQAN stations were developed from specific-conductance relations and from duration tables of specific conductance.

Relations between water-quality constituents and flow at stations on the Clinch and Tennessee Rivers are not well defined because of regulation. Compensation for the effects of discharge prior to application of the Seasonal Kendall test for trends was therefore impossible and identification of trends in water-quality constituents caused by some process (source) change was impossible. Some water-quality trends indicated at stations on the Clinch and Tennessee Rivers might be reflections of the decreasing trend in discharge during the 1972-82 water years. Thus the stations below Watts Bar Dam and below Melton Hill Dam inadequately meet the NASQAN objective to detect and assess long-term changes in stream quality.

REFERENCES CITED

Bevans, H.E., 1980, A procedure for predicting concentrations of dissolved solids and sulfate ion in streams draining areas strip mined for coal: U.S. Geological Survey Water-Resources Investigations Report 80-764, 17 p.

Crawford, C.G., Slack, J.R., and Hirsch, R.M., 1983, Nonparametric tests for trends in water-quality data using the Stastical Analysis System: U.S. Geological Survey Open-File Report 83-550, 102 p.

Elder, J.A., and Springer, M.E., 1978, General soil map, Tennessee: U. S. Soil Conservation Service, scale 1:750,000.

Fenneman, N.M., 1938, Physiography of eastern United States: New York and London, McGraw-Hill, 714 p.

Gaydos, M.W., and others, 1982, Hydrology of area 19, eastern coal province, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 81-901, 75 p.

Hardeman, W.D., 1966, Geologic map of Tennessee, east-central sheet: Tennessee Division of Geology, scale 1:250,000.

Hem, J.D., 1970, Study and interpretation of the chemical characteristics of natural water (2d ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Hirsch, R.M., Slack, J.R., and Smith, R.A., 1982 Techniques of trend analysis for monthly water quality data: Water Resources Research, v. 18, no. 18, p. 107-121.

Miller, R.A., 1974, The geologic history of Tennessee: Tennessee Division of Geology Bulletin 74, 63 p.

National Technical Advisory Committee, 1968, Water-quality criteria, a report of the National Technical Advisory Committee to the Secretary of the Interior: Washington, D. C., U.S. Government Printing Office.

Simmons, C.E., and Heath, R.C., 1979, Water-quality characteristics of streams in forested and rural areas of North Carolina: U.S. Geological Survey Water-Resources Investigations Report 79-108, 49 p.

Steele, T.D., 1974, Harmonic analysis of stream temperatures: U.S. Geological Survey Computer Center Contribution, Program no. B260, PB-239 016/AS, 48 p.

Swift, L.W., and Swank, W.T., Jr., 1981, Long-term responses of streamflow following clear-cutting and regrowth: Hydrological Sciences Bulletin, v. 26, p. 245-256.

Tennessee Department of Public Health, 1978, Water quality management plan for the Clinch River basin: Nashville, Tennessee, Division of Water Quality Control, 89 p.

Tennessee Valley Authority, 1983, Summary of existing water, sediment, fish, and soil data in the vicinity of the Oak Ridge Reservation: Knoxville, Tennessee, Tennessee Valley Authority.

Trimble, S.W., and Carey, W.P., 1984, Sediment characteristics of Tennessee streams and reservoirs: U.S. Geological Survey Open-File Report 84-749, 32 p.

U.S. Department of Commerce, 1961, Rainfall frequency atlas of the United States: U.S. Weather Bureau Technical Paper no. 40, 115 p.

U.S. Environmental Protection Agency, 1976a, Forest Harvesting and water quality: Environmental Protection Agency Report 625/5-76-013, 18 p.

------ 1976b, Erosion and sediment control surface mining in the eastern U.S.: Environmental Protection Agency Report 625/3-76-006, Part 1, 102 p.

U.S. 95th Congress, 1977, Public law 95-87, 91 Statute 445, 88 p.

Wershaw, R.L., 1970, Mercury in the environment: U.S. Geological Survey Professional Paper 713, p. 29-31.

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