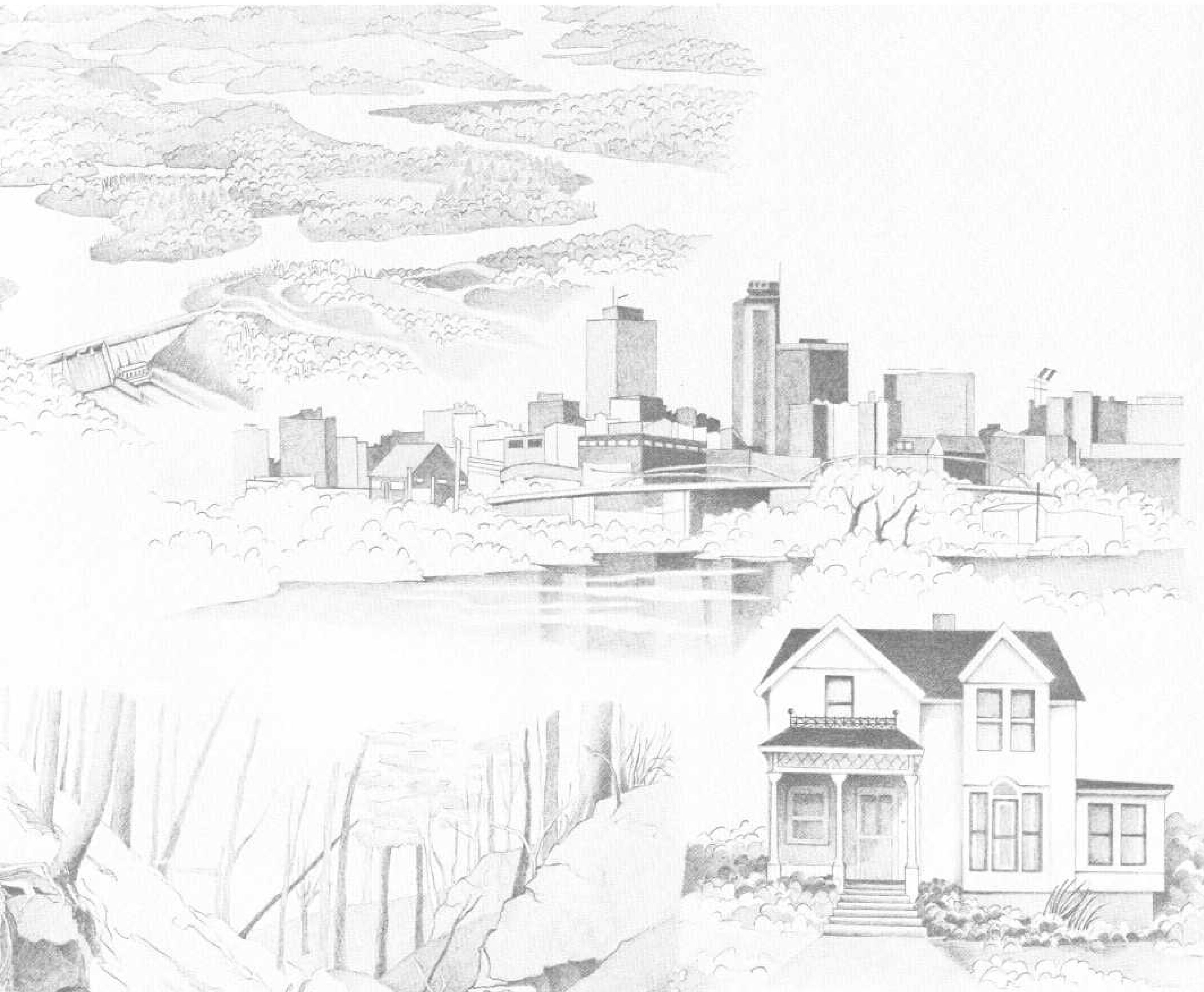
DROUGHT-RELATED IMPACTS ON MUNICIPAL AND MAJOR SELF-SUPPLIED INDUSTRIAL WATER WITHDRAWALS IN TENNESSEE--PART B



Prepared by
U. S. GEOLOGICAL SURVEY

in cooperation with
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT, Division of Water Management
TENNESSEE VALLEY AUTHORITY, Office of Natural Resources and Economic Development, Division of Air and Water Resources, Regional

Reservoir discharge (minimum daily average flow).--The minimum daily average discharge from Watauga Dam during the reference period ranged from a low of approximately 2.0 ft^3/s (1.3 Mgal/d) in 1971 to a high of about 45.0 ft^3/s (29.1 Mgal/d) in 1978. The average, 1-day minimum discharge during the reference period was about 12.1 ft^3/s (7.8 Mgal/d). With the exception of 1978, the minimum daily average discharge since 1974 has averaged about 20.3 ft^3/s (13.1 Mgal/d).

Average number of days of zero flow.--During the 22-year reference period, Watauga Dam has averaged almost 56 days of zero discharge per year ranging from a low of 42 days in 1973 and 1975 to a high of 92 days in 1964. Days of zero-discharge were most common during the months of February, March, April, and May. During the reference period, there were 73 instances of zero discharge for 3 or more consecutive days from Watauga Dam. In four of these instances during the years of 1960, 1961, 1963, and 1972; consecutive days of zero discharge from Watauga Dam ranged from a low of 7 days in several years to a high of 9 days in 1960.

Existing agreements regarding reservoir releases.--Whenever necessary to maintain a minimum average flow of about 112.0 ft^3/s (72.4 Mgal/d) at Elizabethton, releases are made from both Watauga and Wilbur Dams.

Wilbur Reservoir

Location and drainage area.--Wilbur Reservoir is formed by Wilbur Dam which is located on the Watauga River at river mile 34.0 in Carter County. Wilbur Dam controls 471 mi^2 of drainage area.

Reference period.--1962-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Wilbur Dam during the reference period ranged from a low of about 12.0 ft^3/s (7.8 Mgal/d) in 1972 to a high of about 46.0 ft^3/s (29.7 Mgal/d) in 1964. The average, 1-day minimum discharge during the reference period was about 29.2 ft^3/s (18.9 Mgal/d).

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--Whenever necessary to maintain a minimum average flow of about 112.0 ft^3/s (72.4 Mgal/d) at Elizabethton, releases are made from both Watauga and Wilbur Dams.

Ground Water

Ground water in the Holston River basin in Tennessee occurs in fractures in the underlying rock formations that have been subjected to severe folding and faulting. With the exception of the westernmost edge of Carter County which lies in the Valley and Ridge physiographic province, both Johnson and Carter Counties lie in the Blue Ridge province. The easternmost edge of Sullivan County also lies in that province. The Holston River basin in this area is underlain primarily by noncarbonate rocks such as shale, sandstone, siltstone, and highly siliceous crystalline rock. Fractures in these rocks are not significantly enlarged by solution that may be caused by percolating ground water. Consequently, well yields are generally low ranging mostly from 3 to 25 gal/min. However, larger yields (100 gal/min or more) are sometimes obtained particularly where carbonate rock formations are located. Yields sufficient for domestic purposes can usually be obtained with the possible exception of areas lying on the tops or slopes of prominent ridges and mountains. Reported well depths range from some 15 feet to usually not more than 200 feet. The shallower wells are those dug in the regolith, i.e., sand, clay, and rock fragments, while the majority are drilled wells. A number of wells have been reported as dry holes or as supplying an insignificant amount of water. However, in recent years wells capable of supplying 100 gal/min or more have been drilled at several locations in the Blue Ridge province. The sites for these wells were picked after a detailed geologic study was made of the area. These higher yield wells were found at or near fault zones covered by relatively thick regolith. In view of this finding, the true potential for the development of significant ground-water supplies in the Blue Ridge part of the basin needs further study at the present time. A number of municipalities in this area derive their water supplies from large springs. The ground-water quality is usually acceptable.

The remaining area of the Tennessee part of the Holston River basin lies in the Valley and Ridge province. This area is primarily underlain by carbonate rock formations such as limestone and dolomite together with calcareous shale and limy sandstone. Ground water occurs in fractures and bedding-plane openings in the limestone and dolomite formations which have been enlarged in varying degrees by the dissolving action of circulating ground water. Water also occurs in fractures in the shale and sandstone which may be enlarged somewhat by solution of the lime content, but to a much lesser degree than in the openings in the carbonate rocks. Ground water in quantities sufficient for domestic purposes can usually be obtained in areas underlain by the soluble carbonates and fractured sandstones. Although ground water moves through openings in shale beds, shale is an effective barrier to vertical ground-water movement and generally yields only limited ground water. Domestic supplies can usually be found in the sandstone at depths of 100 feet or less. Wells in dolomite and limestone are deeper on the average with the majority ranging from 50 to 200 feet in depth. These enlarged openings generally become smaller and less numerous with depth and it is generally not advisable to drill deeper than 300 to 350 feet on the basis of presently available information. Most of the wells reported in the Valley and Ridge province yield from 3 to 50 gal/min. However, yields from 100 to 250 gal/min are common. Water quality is usually acceptable.

It should be emphasized that the existing water-well data base is composed of wells drilled primarily for domestic needs which can be satisfied with relatively small supplies. Also, choices of favorable locations for drilling based on geologic studies are extremely limited. Springs flowing from openings in carbonate rocks are numerous. Pending further studies, the potential for the development of large ground-water supplies cannot be predicted with certainty.

Demography

Historical (1970) and recent (1980) population, total wage and salary employment including both full- and part-time workers, and per capita personal income data for the county boundary approximation of the Holston River basin are presented in table 32. Counties included in this approximation are Carter, Grainger, Hamblen, Hawkins, Johnson, Sullivan, and Washington. Major urban or metropolitan areas in the Tennessee part of this basin and their 1980 census population include Bristol (23,986), Elizabethton (12,431), Jefferson City (5,612), Johnson City (39,753), Kingsport (32,027), Morristown (19,683), and Rogersville (4,368). Also included in this basin is the Tennessee part of the Johnson City-Kingsport-Bristol, Tennessee-Virginia, Standard Metropolitan Statistical Area (SMSA) which consists of Carter, Hawkins, Sullivan, Unicoi, and Washington Counties.

Public and Self-Supplied Commercial and Industrial Water Users

Currently, there are a total of 54 public water-supply facilities and 11 large, self-supplied commercial and industrial water users whose use exceeds 0.1 Mgal/d in the Tennessee part of the Holston River basin. Detailed inventories containing pertinent information and data relative to each community or self-supplied user's source of water; average daily water use; source capacity; population served; treatment plant and storage capacities; and water-supply, quantity-related problems are found in tables 15 and 16 of appendix I, respectively. Total water use or withdrawal at the present time for public and large, self-supplied commercial and industrial purposes in the Holston River basin amounts to approximately 604.7 Mgal/d. The general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried in the Holston River basin are shown in figures 24 and 25, respectively.

Public water systems currently serve about 371,000 people or 91 percent of the basin's 1980 population. Average daily water use or withdrawal for public purposes equals about 51.8 Mgal/d of which approximately 34.9 Mgal/d or 67 percent is withdrawn from surface-water sources and 16.9 Mgal/d or 33 percent from ground-water sources. Major public water-supply facilities whose average daily use exceeds 1.0 Mgal/d include the following:

Facility name	Average water use (Mgal/d)
Elizabethton WD	4.800
Morristown WS	5.810
First UD - Hawkins County	1.075
Rogersville WS	1.135
Jefferson City WS	3.000
Northeast Knox UD	1.152
Bristol WS	5.000
Kingsport WS	12.000
Johnson City PWD	12.800

Together these systems account for about 91 percent of the total water use for public purposes.

Self-supplied commercial and industrial users use (withdraw) about 552.8 Mgal/d, of which some 540.1 Mgal/d or 98 percent is from surface-water sources and about 12.8 Mgal/d or 2 percent from ground-water sources. About 99 percent

Table 32.--County population, employment, and per capita personal income data, Holston River basin

[Per capita income based on 1970 income converted to 1980 dollars]

County	Population		Employment		Per capita personal income 1980 dollars	
	1970	1980	1970	1980	1970	1980
Carter	43,259	50,205	10,177	10,187	$5,017	$5,565
Grainger	13,948	16,751	1,543	2,469	4,240	5,136
Hamblen	38,696	49,300	19,884	23,039	5,915	6,427
Hawkins	33,757	43,751	5,179	9,702	5,047	5,610
Johnson	11,569	13,745	2,739	4,387	4,372	5,882
Sullivan	127,329	143,968	59,978	67,376	7,644	8,397
Washington	73,924	88,755	28,724	38,386	6,577	7,468
Total	342,482	406,475	128,224	155,546	-	-

Figure 24--Explanation

Site No.	Facility name	Site No.	Facility name
1	Elizabethton WD	16	Carderview UD
2	First UD - Carter County	17	Cold Springs WS
3	Hampton UD	18	Doe Valley WS
4	Hank Johnson Subdivision WS	19	Harbin Hill Community WS
5	Roan Mountain Water Co.	20	Mountain City WS
6	Luttrell-Blaine-Corryton UD	21	East Knox UD
7	Morristown WS	22	Northeast Knoxville UD
8	Camelot WS	23	Bloomingdale UD
9	First UD - Hawkins County	24	Bluff City WS
10	Lakemont UD	25	Bristol WS
11	Mooresburg UD	26	Bristol-Bluff City UD
12	Rogersville WS	27	Chinquapin Grove UD
13	Surgoinsville UD	28	Kingsport WS
14	Jefferson City WS	29	Johnson City PWD
15	Brownlow WS		

of the total water withdrawal for commercial and industrial purposes is withdrawn by the Holston Defense Corp. (67.6 Mgal/d) and Mead Papers (12.0 Mgal/d), and Tennessee Eastman Co. (454.3 Mgal/d) in Kingsport, and North American Rayon Corp. (11.1 Mgal/d) in Elizabethton. Consumptive water use by large, self-supplied commercial and industrial water users in the basin equals about 1.2 Mgal/d.

Summarized below is a list of the specific water-supply problems now being experienced by individual communities and self-supplied commercial and industrial water users in the Holston River basin. The number in parentheses following each identified problem indicates the number of communities and (or) self-supplied water users who are now or have experienced this problem in the past. Note, these problems are not listed in order of frequency of occurrence or overall severity.

- Low water pressure. (2)
- Inadequate storage and pumping capacity. (3)
- Occasional turbidity following periods of heavy rain. (2)
- Excessive water losses due to leaking mains and distribution lines. (2)
- Periodic water-supply, quantity-related shortages during dry months. (2)
- Occasional clogging of water-supply intakes by sand and other debris. (1)
- Considerable fluctuation in river level and temperature due to water holdup and discharge from Fort Patrick Henry Dam. (1)

Water Supply Adequacy Analysis

The Tennessee part of the Holston River basin encompasses some 2,253 mi^2 or about 1,442,000 acres of land and water area. This basin's surface and ground-water resources are replenished by an abundant rainfall whose long-term (1941-70) average ranges from 44.14 inches above Cherokee Dam to 47.28 inches

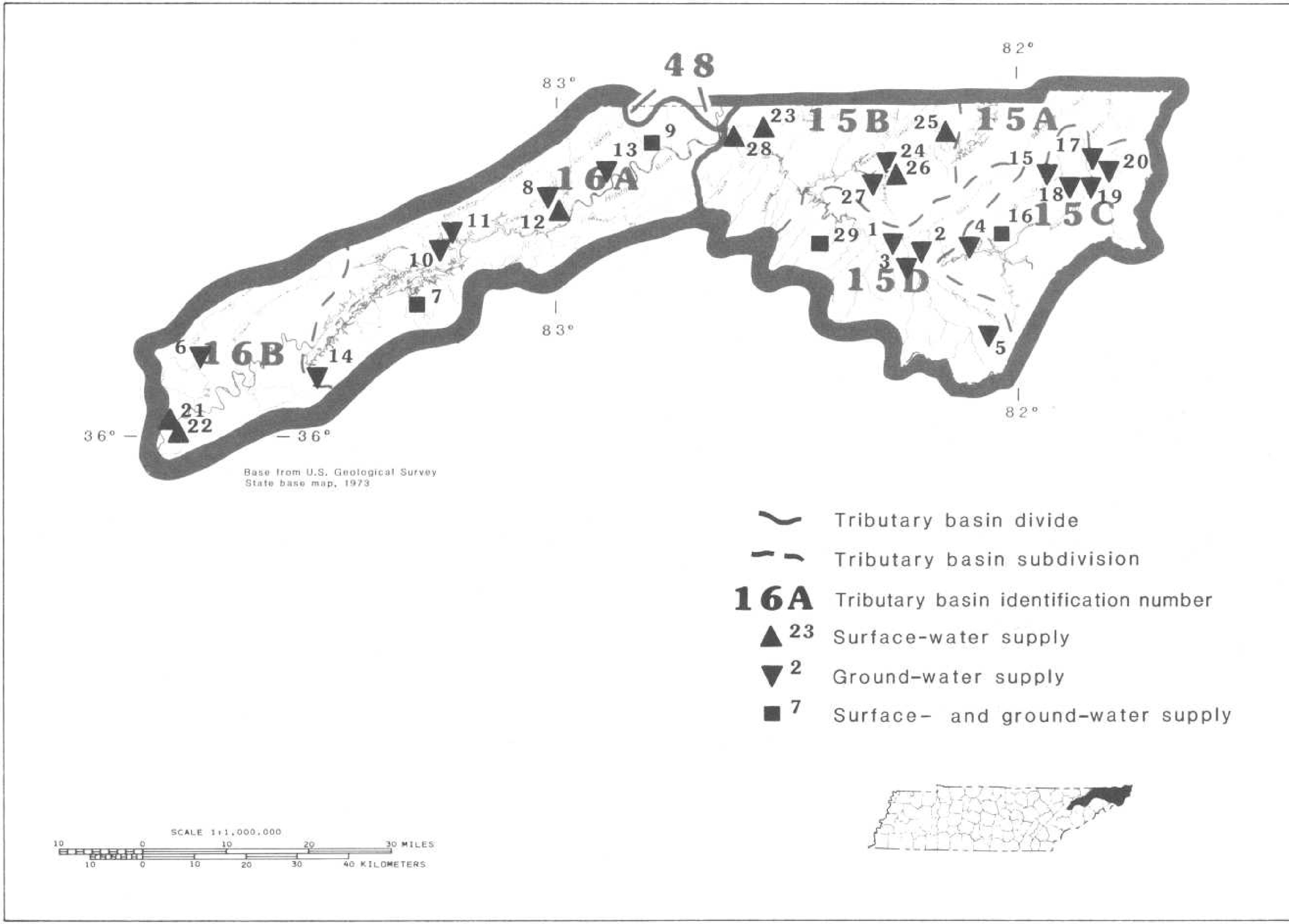


Figure 24.--Public water-supply facilities, Holston River basin.

Figure 25--Explanation

Site No.	Facility name
1	North American Rayon Corp. (Elizabethton)
2	ASG Industries, Inc. (Kingsport)
3	Holliston Mills, Inc. (New Canton)
4	Holston Defense Corp. (Kingsport)
5	ASARCO, Inc. (New Market)
6	ASARCO, Inc. (Mascot)
7	U.S. Steel Corp. (Jefferson City)
8	Knoxville By-Products (Knoxville)
9	Meads Paper (Kingsport)
10	Penn-Dixie Industries, Inc. (Kingsport)
11	Tennessee Eastman Co. (Kingsport)

above Knoxville. Average annual runoff ranges from 15 to 22 inches as one moves northeastward across the basin. Generally, the months of September, October, and November are the driest with July being the wettest month. It is not uncommon for small, unregulated streams to go dry during extended drought periods, particularly along the rim of the basin.

Total present water use or withdrawal for public and large, self-supplied commercial and industrial purposes in the Holston River basin amounts to approximately 604.7 Mgal/d. Of this amount, public water systems use is about 51.8 Mgal/d, of which about 34.9 Mgal/d or 67 percent is withdrawn from surface-water sources and 16.9 Mgal/d or 33 percent from ground-water sources. Self-supplied commercial and industrial users use about 552.8 Mgal/d, of which some 540.1 Mgal/d or 98 percent is from surface-water sources and about 12.8 Mgal/d or 2 percent from ground-water sources.

Generally, the basin's public water-supply systems, particularly those served by surface-water sources, are found to be adequate in quantity to meet the basin's present needs. However, several public water-supply systems that use springs or wells as their primary and frequently only water source are currently operating at or above their dependable, long-term source capacity. These systems such as Jefferson City, Doe Valley, and Mountain City could expect to experience water deficiencies either during extended drought periods or in the event of a significant increase in water use due to industrial expansion or an increase in population. Several communities or systems including Brownlow, Camelot, Carderview, Cold Springs, Lakemont, and Harbin Hill are presently utilizing ground-water sources of unknown capacity. While Harbin Hill is experiencing occasional water-supply shortages during dry months, it is unlikely that any of these communities would experience severe, long-term water-supply shortages because the systems are very small with average daily water use ranging from 0.002 to 0.017 Mgal/d.

Analysis of the basin's water supplies for self-supplied commercial and industrial water users indicates that while several users in Jefferson and Knox Counties are utilizing surface-water sources whose 3-day, 20-year recurrence interval low flow is less than their average daily use or ground-water sources

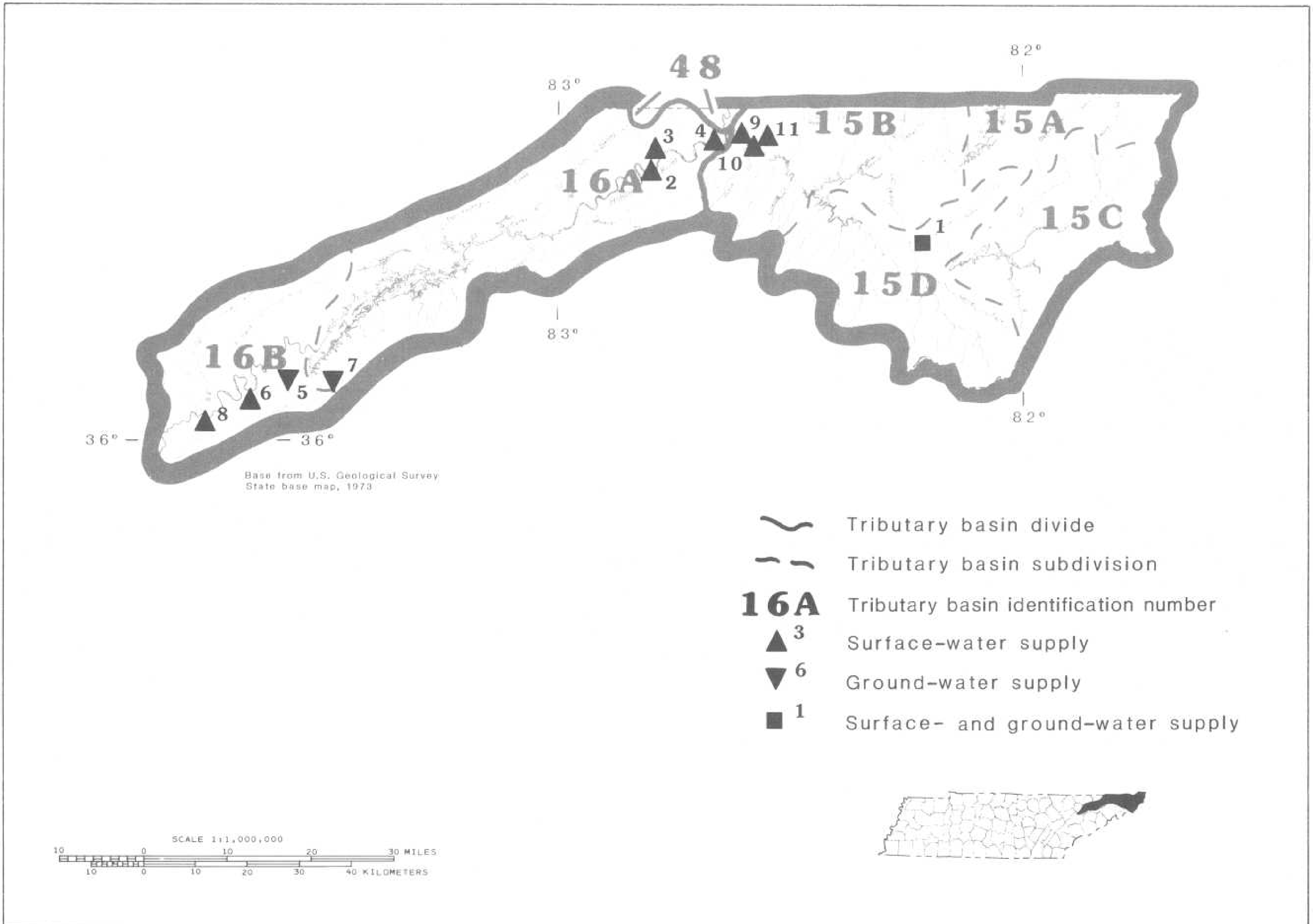


Figure 25.--Self-supplied commercial and industrial water users, Holston River basin.

of unknown capacity, none of these users have experienced any water-supply shortages in recent years. However, these industries could expect to face potentially serious water shortages during severe and extended drought conditions, particularly those utilizing surface-water sources, and should seek other more dependable sources.

It should also be noted that the principal source of water in Sullivan County is the South Fork Holston River and demand is approaching the limits of available supply, particularly in the Kingsport area (Brandes, W. F., 1981).

Water systems which are currently utilizing surface- and (or) ground-water resources which are inadequate, or of unknown capacity, should consider exploring the availability of alternative, cost-effective water-supply sources to augment or meet their future water needs if necessary. While the basin's water resources are subject to contamination from a variety of sources; existing and pending Federal, State, and local statutes relative to water-quality protection and maintenance or improvement should ensure that current water quality will be maintained with little, if any, future degradation of the basin's water resources. Potential sources of contamination include (1) leachate from municipal and industrial waste disposal facilities and septic tank systems; (2) agricultural pollution from fertilizers, pesticides and herbicides, and livestock wastes; and (3) runoff from surface mine lands and quarries.

Although there are periods of extended drought which cause seasonal water table declines and periodic local problems with adequate ground-water supplies, observation-well data indicate there are no long-term, regional water table declines. Periodic local problems associated with a decline in an area's water table are caused by excessive withdrawals. To alleviate this problem, optimum ground-water withdrawal rates should be determined during the initial test pumping of the source.

MEMPHIS AREA BASIN

Basin Description

The Memphis Area basin, including that part of the alluvial Mississippi River valley below the Loosahatchie River, covers 1,559 mi^2 of land and water area and consists of all or parts of the following tributary basins as delineated by the U.S. Geological Survey and the Tennessee Department of Water Management in 1982.

Tributary basin No. (fig. 26)	Basin description	Tennessee drainage area (square miles)
41D	Mississippi Alluvial Valley in Tennessee below the Loosahatchie River excluding the Wolf River and Nonconnah Creek.	98
43	Loosahatchie River	742
44A	Upper Wolf River to below Shaws Creek	349
44B	Lower Wolf River downstream from Shaws Creek.	220
44C	Nonconnah Creek	149
44D	Minor tributaries to Nonconnah Creek	1

The Memphis Area basin encompasses all or major parts of Fayette and Shelby Counties as well as minor parts of Hardeman, Haywood, Henry, and Tipton Counties. A map of West Tennessee which delineates the area drained by the Memphis Area basin is shown in figure 26.

Topography

The Memphis Area basin consists of that part of West Tennessee drained by the Loosahatchie and Wolf Rivers and Nonconnah Creek as well as that part of the alluvial Mississippi River Valley below the Loosahatchie River.

The Loosahatchie River rises in the steep hills of Hardeman County and flows in a westerly direction for about 65 miles across Fayette and Shelby Counties to its confluence with the Mississippi River at river mile 740.5, just north of the city of Memphis. Major tributaries include Big, Beaver, and Clear Cypress Creeks. The drainage area of this basin is approximately 742 mi^2. Elevations range from about 220 to 660 feet above sea level.

The Wolf River originates south of the Tennessee-Mississippi State line and flows in a northwesterly direction for about 80 miles across Fayette and Shelby Counties, through the northern part of the city of Memphis to its confluence with the Mississippi River at river mile 738.7. Major tributaries include Grays, Fletcher, Shaws, and North Fork Creeks. The drainage area of

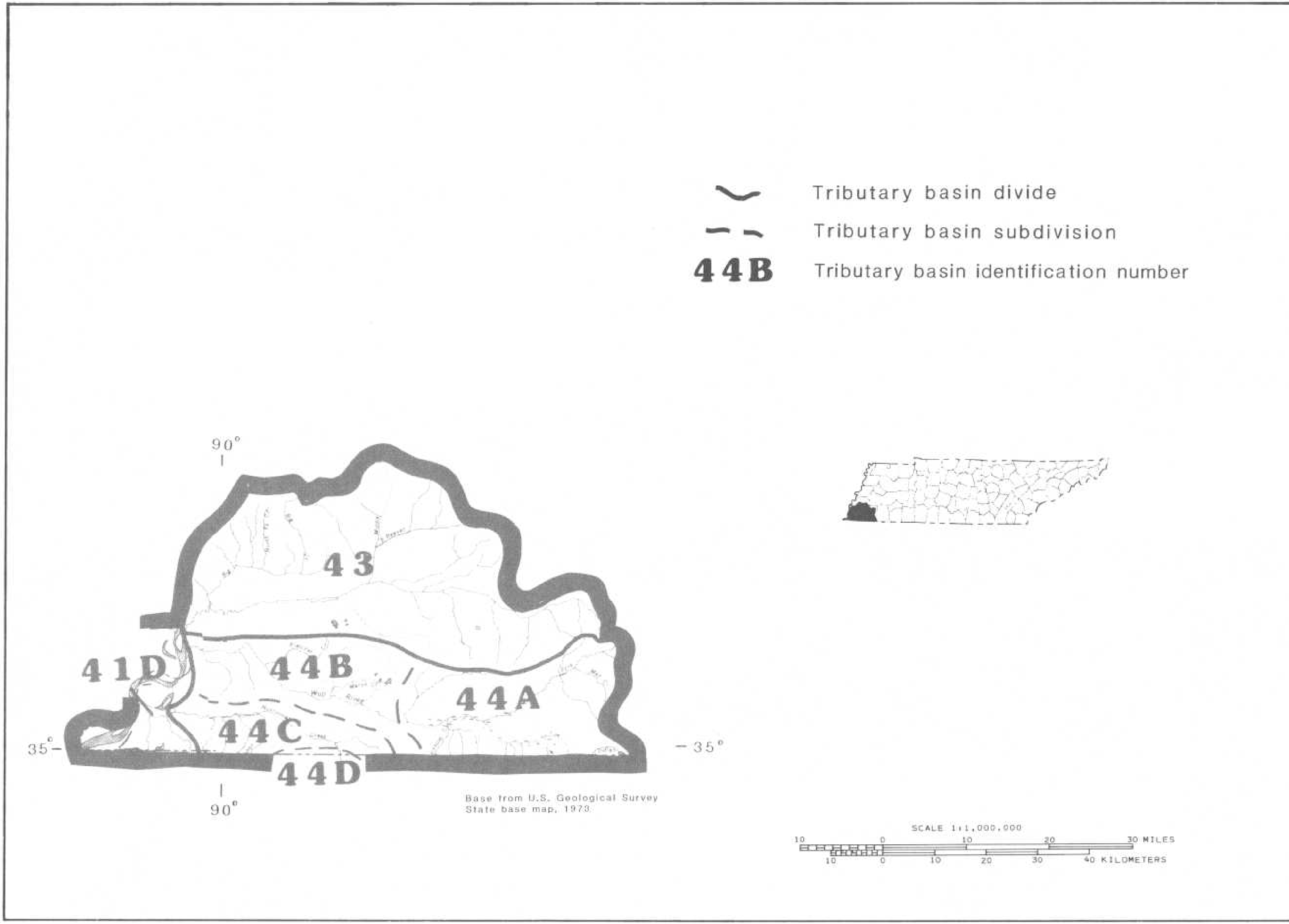


Figure 26.--Memphis Area basin.

this basin is approximately 825 mi^2. Of this, approximately 569 mi^2 are included in the West Tennessee area. Elevations range from about 215 to 660 feet above sea level.

Nonconnah Creek also originates just south of the Tennessee-Mississippi State line and flows in a northwesterly direction for 25 miles across Fayette and Shelby Counties, through the southern part of the city of Memphis to its terminus with McKellar Lake, an offshoot bendway run of the Mississippi River. Major tributaries include Johns, Ten Mile, Hurricane, and Days Creeks. The drainage area of this basin is approximately 183 mi^2. Of this, approximately 150 mi^2 are included in the West Tennessee area. Elevations range from about 200 to 400 feet above sea level.

Topography in the Loosahatchie River, Wolf River, and Nonconnah Creek basins is characterized as being gently rolling, interrupted by small ditches and drainage divides. Some gullied topography has developed and swampy conditions are common.

From the mouth of the Loosahatchie River, the Mississippi River flows in a southerly direction for about 25 miles along the western boundary of the Memphis area to the Tennessee-Mississippi State line. At Memphis, the Mississippi River has a drainage area of approximately 928,700 mi^2. Of this, approximately 98 mi^2 are included within the alluvial valley in the Memphis area. The Mississippi River is the outlet for all streams in the State located west of the Tennessee Valley.

Hydrology

Surface Water

Surface- and ground-water resources in the Memphis Area basin are replenished by an ample rainfall whose long-term (1941-70) average is approximately 47 inches. From 1970-79, the average precipitation was approximately 55 inches. The average 1979 rainfall was approximately 68 inches. Annual (1979) and long-term (1941-70) precipitation data for selected NWS rainfall stations in the Memphis Area basin are presented in table 33. The 1970-79 precipitation averages for these same rainfall stations with their high and low year of precipitation are presented in table 34.

The months of August, September, and October are usually the driest with the average rainfall ranging from 2.63 to 3.31 inches. During the remainder of the year, average rainfall ranges from 3.43 to 5.36 inches with April usually being the wettest month.

The surface-water supply for this basin is derived from precipitation and runoff within the area, streamflow including ground-water discharge entering the area from adjacent areas, and ground-water discharge to streams within the area. Average discharge data for selected hydrologic data stations are presented in table 35. Theoretically, there is a large quantity of surface water available for use in this basin. However, because of the small number of available storage sites and the increased evaporative losses of surface water that occur with this development, this quantity is not realistically obtainable.

Table 33.--Precipitation data for 1979 and for the period 1941-70 for selected rainfall stations, Memphis Area basin

Station location	Station owner	Elevation above sea level (feet)	Period of record (years)	1979 Precipitation (inches)	Long-term annual precipitation (inches)
Memphis	NWS	205	15	-	43.31
Memphis weather service office airport.	NWS	258	47	70.89	50.59
Bolton	NWS	300	38	69.94	48.43
Drummonds	NWS	450	28	59.70	43.54
Mason	NWS	319	39	64.30	45.79
Moscow	NWS	340	59	73.45	51.94

Table 34.--Precipitation data for the period 1970-79 for selected rainfall stations, Memphis Area basin

Watershed description	Precipitation (inches)				
	High	Year	Low	Year	10-year average
Memphis	65.40	1973	40.24	1971	52.39
Memphis weather service office airport	70.89	1979	41.20	1977	56.26
Bolton	69.94	1979	46.76	1977	57.82
Drummonds	70.90	1973	39.88	1971	52.61
Mason	70.30	1974	40.00	1976	53.42
Moscow	73.45	1979	44.15	1978	55.46

Table 35.--Average discharge data for selected hydrologic data stations, Memphis Area basin

Station name and location (county)	River mile	Drainage area (square miles)	Period of record (years)	Average discharge: Cubic feet per second	Average discharge: Inches per year	Average discharge: Cubic feet per second per square mile
Mississippi River at Memphis (Shelby).	734.7	928,700	45	528,071	7.72	0.57
Loosahatchie River near Arlington (Shelby).	30.4	262	11	403	20.95	1.54
Wolf River at Germantown (Shelby).	18.9	699	11	1,381	26.90	1.98

Ground Water

West Tennessee embraces two physiographic provinces. One is the West Tennessee Plain, including the subdivision known as the West Tennessee Uplands, and the other is the Mississippi River Valley.

The West Tennessee Plain extends from the western margin of the Western Valley of the Tennessee River, or the divide, known as the West Tennessee Uplands, separating eastward flowing drainage to the Tennessee River from streams flowing westward to the Mississippi River. This area contains three major drainage basins: the Obion-Forked Deer, the Hatchie, and the Memphis Area which includes the Loosahatchie River, Wolf River, and Nonconnah Creek.

West Tennessee lies in the region known as the Mississippi embayment. This is an area in which Paleozoic limestones were downwarped in the geologic past forming a trough with its axis or deepest part roughly parallel to the present course of the Mississippi River and extending from the Gulf Coast northward to the southern tip of Illinois. Its eastern margin lies in parts of Kentucky, Tennessee, Alabama, and Mississippi while its western margin lies in parts of Missouri, Arkansas, Louisiana, and Texas. During geologic time, the sea successively advanced and receded in the trough depositing sediments consisting of uncemented sand and clay with minor amounts of other materials. Thick nonmarine sediments were also deposited. Consequently, these sands and clays are at the surface east of the Mississippi River and dip at the rate of 15 to 30 ft/mi westward toward the river where they begin to rise again and reappear west of the river although covered by alluvial deposits. Inclination of the water-bearing sands and the presence of clay layers and lenses cause the water in the sands to be under artesian pressure away from the outcrop area. In West Tennessee, the oldest sediments appear on the surface near the Tennessee River and dip westward reaching a depth of over 3,000 feet below the Mississippi River.

Inasmuch as the sand aquifers are continuous through the West Tennessee Plain and extend into other states, it is not practical to discuss them on a river basin basis but rather on a regional basis. While almost any sand body in any formation may furnish adequate supplies of freshwater for domestic use at or near its outcrop area, there are four major aquifers that are capable of furnishing relatively large supplies for municipalities and industries. From oldest to youngest these aquifers are the Coffee Sand and McNairy Sand of Cretaceous age and the Wilcox Formation and the Claiborne Formation of Tertiary age. In the Memphis area, the Wilcox and Claiborne aquifers are respectively known as the "1,400-foot sand", or the Fort Pillow Sand, and the "500-foot sand", or the Memphis Sand." The outcrop areas and dominant recharge areas of these aquifers occur as bands trending from south-southwest to north-northeast across West Tennessee. The eastern margin of the outcrop area of the Coffee Sand lies near the Tennessee River and the outcrop areas of the younger aquifers occur successively to the west until the Claiborne, including the Memphis Sand, is hidden from view near Paris, Jackson, and Somerville by a blanket of relatively recent loess and terrace deposits which extend westward to the Mississippi River Valley.

The Coffee Sand of Upper Cretaceous age is present in northern Mississippi and crops out in a belt in Tennessee from southwestern Hardin County to the Kentucky State line in northeastern Henry County. This outcrop belt is approximately 6 miles wide near the Mississippi-Tennessee border and becomes narrower to the north-northeast where it merges with the younger McNairy Sand near the Kentucky line. Its thickness ranges from approximately 200 feet near the Mississippi line and thins northeastward to less than 50 feet in southern Henry County. It has been estimated to underlie an area of approximately 6,000 mi^2 overall. The Coffee Sand is the oldest and smallest of the four major aquifers, and wells producing from it generally have lower yields. The larger yield wells producing from this aquifer probably do not supply much more than 300 gal/min. The Coffee Sand dips beneath the surface westward from its outcrop area and is at a depth of some 3,000 feet or more at Memphis. Water in the aquifer becomes relatively highly mineralized near the Fayette-Shelby County line.

The McNairy Sand is present in northern Mississippi and extends across Tennessee into Kentucky. Its outcrop belt is approximately 12 miles wide in McNairy County and thins northward to less than 8 miles in Benton County. The outcrop area is narrowest near the Kentucky line. The McNairy Sand is approximately 200 feet thick in the northern end of the embayment and thickens to some 375 feet in the subsurface at Memphis. It has been estimated that this sand underlies approximately 11,000 mi^2 of Tennessee and Kentucky. The McNairy Sand is an excellent aquifer particularly at or near its outcrop area. Yields of wells drilled into it range from 250 to 500 gal/min. Like the Coffee Sand, the McNairy Sand dips westward from its outcrop area into the subsurface and lies at a depth of some 2,400 feet at Memphis. If freshwater is defined as water having a concentration of no more than 1,000 mg/L total dissolved solids, then the McNairy Sand is at the base of the zone of freshwater at Memphis as the water in it there contains the limit of total dissolved solids. Presently, it is not used as a source of water in the Memphis area.

The Wilcox Formation contains an aquifer known in the Memphis area as the "1,400-foot sand," or Fort Pillow Sand, which is present in Mississippi and extends across West Tennessee into Kentucky. Its outcrop is narrow in Tennessee due to thinning and overlap by the overlying Claiborne Formation. In some places the Wilcox is completely overlapped by the Claiborne. The outcrop area is about 13 miles wide in Hardeman County and is less than a mile wide in northern Henry County. The "1,400-foot sand," or Fort Pillow Sand, thickens from about 50 feet on the western edge of the Wilcox outcrop belt to over 300 feet thick in the subsurface in Lake, Dyer, and Lauderdale Counties near the Mississippi River. It has been estimated that the Fort Pillow Sand underlies about 7,000 mi^2 in Tennessee and Kentucky. A number of wells obtain water from it in or near its outcrop belt but few are known to exist elsewhere in Tennessee except for a large industrial user in Memphis. Well yields at Memphis are reported to range from 400 to 1,600 gal/min. The Wilcox Formation is considered to be a reserve source of water for the city of Memphis.

The Claiborne Formation is the largest aquifer in West Tennesse and contains the "500-foot sand," or the Memphis Sand in the Memphis area. It is exposed at the surface westward from its feather edge overlying the Wilcox until covered by loess and alluvial deposits when it becomes the subcrop bedrock. The Claiborne is overlain by the Jackson Formation in areas of the counties bordering the Mississippi River. The outcrop belt of the Claiborne is much wider than that of the Wilcox. The Memphis Sand thickens from a feather edge to an estimated thickness of about 900 feet at the Mississippi River in southwestern Shelby County and its areal extent is approximately 7,000 mi^2 in Tennessee and Kentucky. Its broad outcrop area and thickness make it an excellent aquifer. The city of Memphis secures its water supply from this sand which is capable of yielding as much as 2,500 gal/min to wells.

Water quality of all West Tennessee aquifers is generally good at or near their outcrop areas. However, their iron content is generally high and requires treatment. The total dissolved solids content is often less than 100 parts per million (ppm) in these areas. Water having a dissolved solids content of less than 500 ppm is usually available at depths of less than 1,000 feet, and water having a dissolved solids concentration of 1,000 mg/L or less is present in some places to depths of a little more than 2,000 feet. Iron content often decreases with depth. Water in any aquifer increases in dissolved solids content with depth. It also changes in chemical character from a calcium bicarbonate to a sodium bicarbonate type when relatively deeply buried.

The potential for ground-water development in most of the West Tennessee Plain is high. At present, no single aquifer has been developed to a point anywhere near its potential. Each major aquifer receives about 12.5 inches of recharge per year in the outcrop areas. This would represent an average recharge of about 0.6 (Mgal/d)/mi^2.

The Tennessee part of the Mississippi River Valley is a narrow strip of the Mississippi River flood plain extending from Memphis to the Kentucky line. At Memphis, it does not exist as the river extends to the base of the Chickasaw Bluffs which mark the western margin of the West Tennessee Plain with the exception of Presidents Island and the area south of Memphis. Northward it attains a maximum width of 10 miles. Much of the region is covered at times by the extreme high waters of the river. In the flood plain areas of Lauderdale, Dyer, and Lake Counties, the alluvium is capable of furnishing rather large quantities of water to wells. This water is generally high in iron and is not used for domestic supplies but is used for irrigation. South of Lauderdale County, the flood plain alluvium yields smaller quantities of water.

Demography

Historical (1970) and recent (1980) population, employment, and per capita personal income data for county boundary approximation of the basin are summarized in table 36. Counties included are Fayette and Shelby. Major urban or metropolitan areas in this area and their 1980 census population include Bartlett (17,170), Collierville (7,839), Germantown (21,482), Memphis (646,356), Millington (20,236), and Somerville (2,264).

Public and Self-Supplied Commercial and Industrial Water Users

Presently, there is a total of 19 public water-supply facilties and 27 large, self-supplied commercial and industrial water users whose use exceeds 0.1 Mgal/d in the Memphis Area basin. Detailed inventories containing pertinent information and data relative to each community or self-supplied users' source of water, average daily water use, source capacity, population served, treatment plant and storage capacities, and water-supply quantity related problems are found in tables 17 and 18 of appendix I, respectively. Total water use for

Table 36.--County population, employment, and per capita personal income data, Memphis Area basin

[Per capita income based on 1970 income converted to 1980 dollars]

County	Population		Employment		Per capita personal income 1980 dollars	
	1970	1980	1970	1980	1970	1980
Fayette	22,692	25,305	6,295	8,643	$2,738	$4,299
Shelby	722,111	777,113	265,876	322,287	5,862	6,697
Total	744,803	802,418	272,171	330,930	-	-

public and large, self-supplied commercial and industrial users in the basin equals about 186.6 Mgal/d. The general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried in the Memphis Area basin are shown in figures 27 and 28, respectively.

Public water systems currently serve about 666,000 or 83 percent of the basin's 1980 population. Total water use for public purposes averages about 125.1 Mgal/d, all of which is withdrawn from ground-water sources. Major public water-supply facilities whose average daily use exceeds 1.0 Mgal/d include the following:

Facility name	Average water use (Mgal/d)
Collierville WD	1.416
Germantown WD	2.901
Lakeland Development Corporation	1.200
Memphis Light, Gas and Water Division	115.000

Together, these systems account for about 96 percent of the total water use for public purposes.

Self-supplied commercial and industrial users currently withdraw about 61.4 Mgal/d of which 59.4 Mgal/d or 97 percent is withdrawn from ground-water sources and 2.0 Mgal/d or 3 percent is obtained from ponds. Major self-supplied commercial and industrial users whose average daily use exceeds 1.000 Mgal/d include the following:

Company name	Average water use (Mgal/d)
Agricultural Chemical Group - Memphis	1.980
Buckeye Cellulose Corp. - Memphis	10.000
Cargill, Inc. - Memphis	3.888
E. I. DuPont De Nemour & Co. - Memphis	16.800
Firestone Tire and Rubber Co. - Memphis	3.636
Humko Products, Inc. - Memphis	1.368
Kimberly Clark Corp. - Memphis	6.200
Memphis Stone and Gravel Co. - Arlington	1.100
Quaker Oats Co. - Memphis	2.938
Ralston Purina Co. Protein Division - Memphis	1.343
Joseph Schlitz Brewing Co. - Memphis	2.466
Tri-State Industries, Inc. - Memphis	1.000
United Foods, Inc. - Rossville	1.440
Velsicol Chemical Corp. - Memphis	2.300

The total consumptive use of the above industries is about 1.310 Mgal/d.

Summarized below is a list of the specific water-supply problems experienced in the basin during the period surveyed. The number in parentheses following each identified problem indicates the number of communities or self-supplied water users who are now or have experienced this problem in the past. Note, these are not listed in order of frequency of occurrence or overall severity.

- High level of iron content in water. (2)
- Inadequate distribution line sizes. (2)
- Inadequate storage capacity. (5)

Figure 27--Explanation

Site No.	Facility name
1	LaGrange WD
2	Oakland WD
3	Rossville WS
4	Somerville WD
5	Grand Junction WD
6	Arlington WD
7	Bartlett-Ellendale WD
8	Collierville WD
9	Lakeland Development Corp.
10	Memphis Light, Gas and Water Division
11	Germantown WD
12	Millington WD
13	Munford WD
14	Poplar Grove UD
15	Gallaway WD
16	Moscow WD
17	Mason WD

Water-Supply Adequacy Analysis

The Memphis Area basin covers 1,559 mi^2 (997,760 acres) of land and water area. This basin's surface- and ground-water resources are replenished by substantial rainfall whose long-term (1941-70) average is approximately 47 inches. The driest months of the year are usually August, September, and October with April usually being the wettest month.

Total present water use or withdrawal for public and large self-supplied commercial and industrial purposes in the Memphis Area basin amounts to approximately 186.6 Mgal/d. Of this amount, public-water systems use about 125.1 Mgal/d, all of which is withdrawn from ground-water sources. Self-supplied commercial and industrial users use about 61.4 Mgal/d, of which about 59.4 Mgal/d or 97 percent is withdrawn from ground-water sources and 2.0 Mgal/d or 3 percent is obtained from ponds.

Generally, the basin's public water-supply systems are adequate in quantity to meet the basin's present needs, and no single aquifer has been developed anywhere near its potential. Two systems (Collierville WD and Germantown WD) experience water shortages because of inadequate distribution line sizes and five systems (Atoka WD, Germantown WD, Mason WD, Munford WD, and Poplar Grove UD) have inadequate storage capacity.

No water-supply shortage problems were reported by any of the large, self-supplied water users.

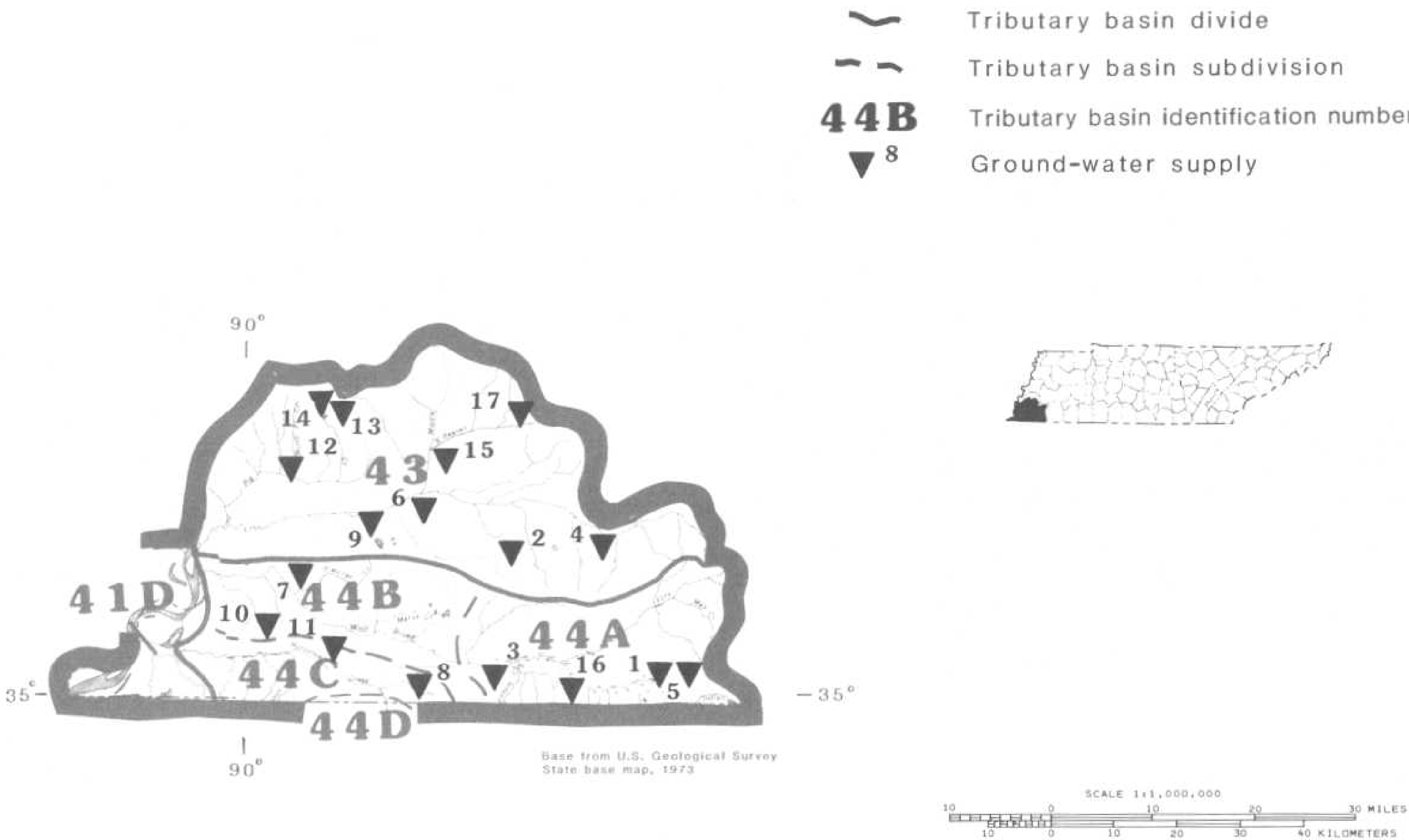


Figure 27.--Public water-supply facilities, Memphis Area basin.

Figure 28--Explanation

Site No.	Facility name
1	Alpha Chemical Corp. (Collierville)
2	Troxel Manufacturing Co., Inc. (Moscow)
3	United Foods, Inc. (Rossville)
4	Agricultural Chemical Group (Memphis)
5	Ashland-Warren, Inc. (Memphis)
6	Buckeye Cellulose Corp. (Memphis)
7	Cargill, Inc. (Memphis)
8	Celotex Corp. (Memphis)
9	Certainteed Corp. (Eads)
10	Velsicol Chemical Corp. (Memphis)
11	Chromium Mining Smelting Corp. (Memphis)
12	Delta Refining Co. (Memphis)
13	E. I. DuPont De Nemours & Co. (Memphis)
14	Firestone Tire and Rubber Co. (Memphis)
15	General Electric Memphis Lamp Plant (Memphis)
16	Humko Products, Inc. (Memphis)
17	Humko Products - Chemical Plant (Memphis)
18	Kellogg Co. (Memphis)
19	Kimberly Clark Corp. (Memphis)
20	Mid American Industries (Memphis)
21	Memphis Stone and Gravel Co. (Arlington)
22	Pulvair Corp. (Millington)
23	Quaker Oats Co. (Memphis)
24	Ralston Purina Co.-Protein Division (Memphis)
25	Joseph Schlitz Brewing Co. (Memphis)
26	Tri-State Industries, Inc. (Memphis)
27	Valley Products Co. (Memphis)

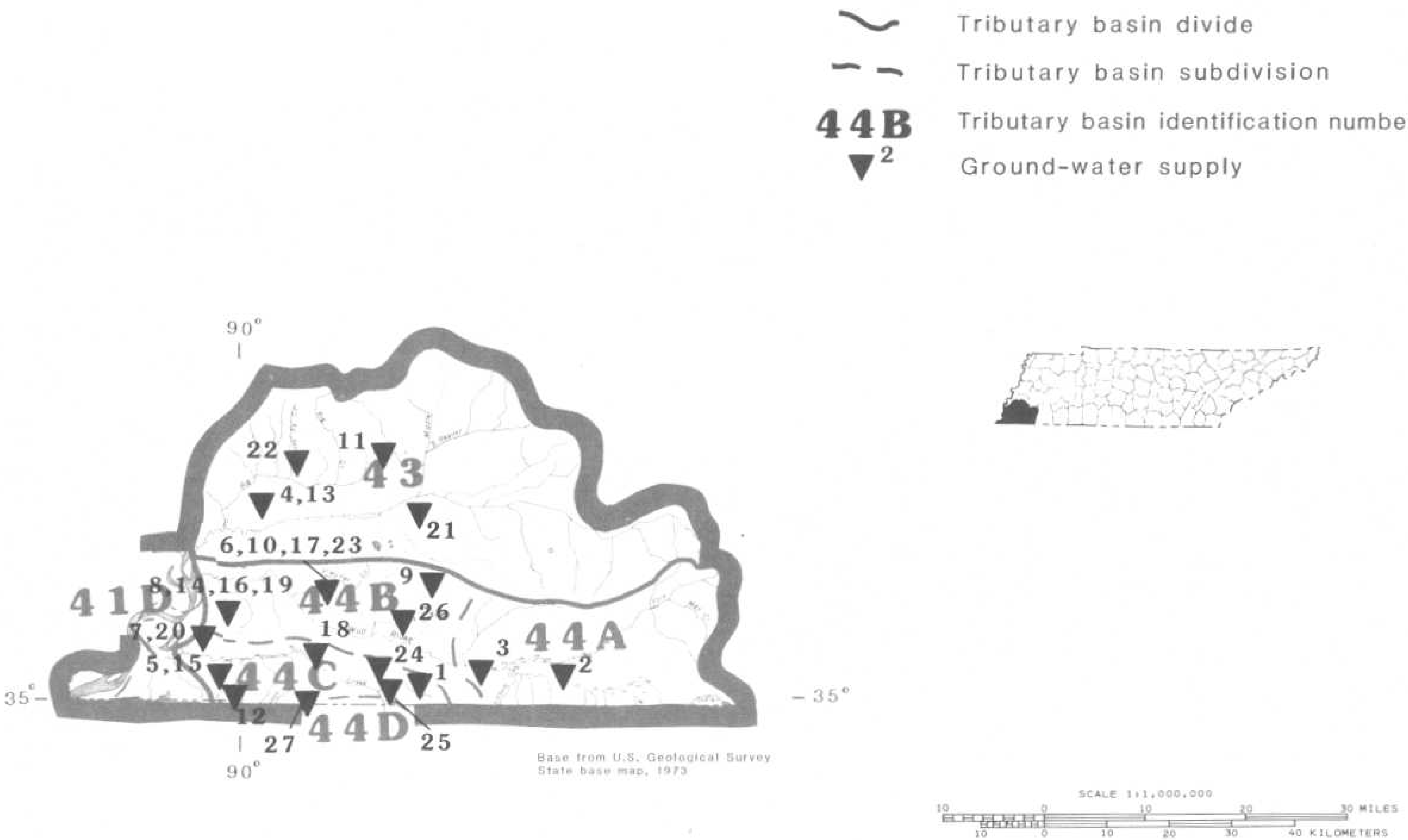


Figure 28.--Self-supplied commercial and industrial water users, Memphis Area basin.

OBION-FORKED DEER RIVER BASIN

Basin Description

The Tennessee part of the Obion-Forked Deer River basin, including that part of the alluvial Mississippi River Valley above the Obion River, covers 4,568 mi^2 of land and water area and consists of all or parts of the following tributary basins as delineated by the U.S. Geological Survey and the Tennessee Department of Water Management in 1982.

Tributary basin No. (fig. 29)	Basin description	Tennessee drainage area (square miles)
39A	Obion River above North Fork but excluding Middle Fork and Mud Creek.	732
39B	Middle Fork Obion River and Mud Creek	426
39C	North Fork Obion River	492
39D	Running Reelfoot Bayou	259
39E	Obion River from North Fork to mouth excluding Forked Deer River and Running Reelfoot Bayou.	418
39F	Minor tributaries south of Tennessee-Kentucky State line.	5
40A	South Fork Forked Deer River above Madison-Haywood County line.	680
40B	North and Middle Forks Forked Deer Rivers at confluence.	728
40C	South Fork Forked Deer River below Madison-Haywood County line.	381
40D	North Fork Forked Deer River below Middle Fork.	224
40E	Forked Deer River below confluence of North and South Forks.	67
41A	Mississippi Alluvial Valley in Tennessee above the Obion River.	156

The Obion-Forked Deer River basin encompasses all or major parts of Carroll, Chester, Crockett, Dyer, Gibson, Lake, Madison, Obion, and Weakley Counties as well as minor parts of Haywood, Henderson, Henry, Lauderdale, and McNairy Counties. A map of West Tennessee which delineates the area drained by the Obion-Forked Deer River basin is shown in figure 29.

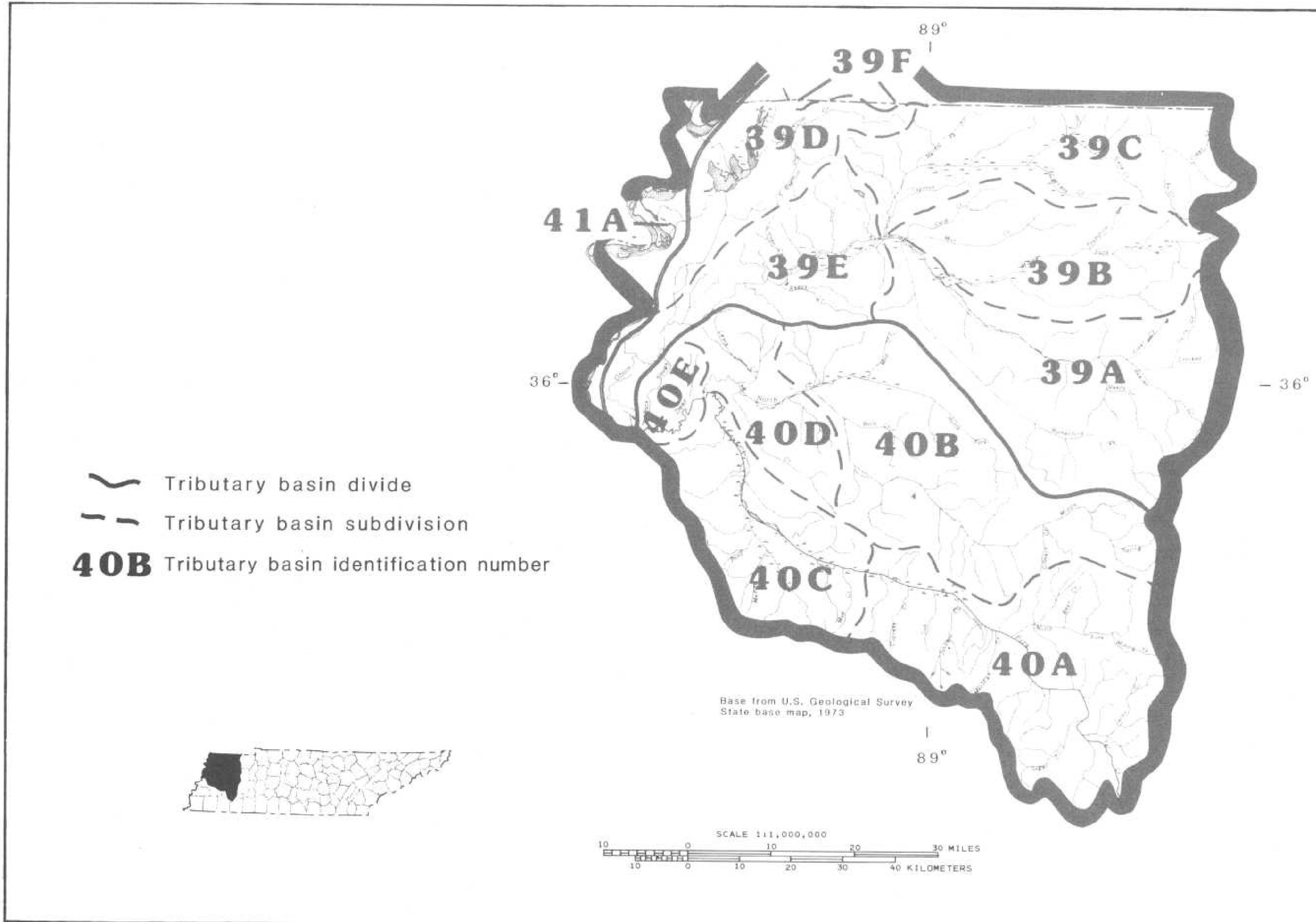


Figure 29.--Obion-Forked Deer River basin.

Topography

The Obion-Forked Deer River basin consists of that part of West Tennessee drained by the Obion and Forked Deer Rivers as well as that part of the alluvial Mississippi River Valley above the Obion River.

The Obion River, through its principal tributaries, the North, South, Middle, and Rutherford Forks, which spread fan-shaped in an area above the main stem, rises in the uplands of Henry, Weakley, and Carroll Counties and, from the junction of its North and South Forks, flows in a southwesterly direction for about 83 miles across Obion, Dyer, and Lauderdale Counties to its confluence with the Mississippi River at river mile 819.4. Other major tributaries include the Forked Deer River and Running Reelfoot Bayou. The drainage area of this basin (excluding the Forked Deer River watershed) is approximately 2,475 mi^2. Of this, approximately 2,332 mi^2 are in the West Tennessee area. Elevations range from about 250 to 630 feet above sea level.

The Forked Deer River, through its principal tributaries, the North, South, and Middle Forks, rises in the uplands of Gibson, Henderson, and McNairy Counties and, from the junction of its North and South Forks, flows in a southwesterly direction for 21 miles across Dyer and Lauderdale Counties to its confluence with the Obion River at river mile 4.2. The drainage area of this basin is approximately 2,072 mi^2. Elevations range from about 250 feet to 670 feet above sea level.

Topography in the Obion-Forked Deer basin is characterized as gently rolling, interrupted by small ditches and drainage divides. Some gullied topography has developed and swampy conditions are common.

From the Tennessee-Kentucky State line, the Mississippi River flows in a southerly direction for about 86 miles along the western boundary of the Obion-Forked Deer River basin to the mouth of the Obion River. At the mouth of the Obion River, the Mississippi River has a drainage area of approximately 924,000 mi^2. Of this, approximately 156 mi^2 are included within the alluvial valley in the Obion-Forked Deer River basin. The Mississippi River is the outlet for all streams in the State located west of the Tennessee Valley.

Hydrology

Surface Water

Surface- and ground-water resources of this basin are replenished by an abundant rainfall whose long-term (1941-70) average is approximately 48 inches. From 1970-79, the average precipitation was approximately 57 inches. The average 1979 rainfall was approximately 65 inches. Annual (1979) and long-term (1941-70) precipitation data for selected NWS rainfall stations in the Obion-Forked Deer River basin are presented in table 37. The 1970-79 precipitation averages for these same rainfall stations with their high and low year of precipitation are presented in table 38.

The months of August, September, and October are usually the driest with the average rainfall ranging from 2.78 to 3.10 inches. During the remainder of

Table 37.--Precipitation data for 1979 and for the period 1941-70 for selected rainfall stations, Obion-Forked Deer River basin

Station location	Station owner	Elevation above sea level (feet)	Period of record (years)	1979 Precipitation (inches)	Long-term annual precipitation (inches)
Dyersburg FAA airport	NWS	337	31	56.89	48.33
Dyersburg	NWS	385	37	59.30	45.53
Samburg wildlife refuge	NWS	290	54	62.00	46.39
Newbern	NWS	370	54	61.05	48.76
Union City	NWS	335	82	63.28	47.98
Jackson FAA airport	NWS	433	31	69.53	49.32
Jackson experimental station	NWS	400	90	73.59	47.75
Humboldt	NWS	332	36	65.00	47.55
Milan	NWS	430	98	67.02	51.10
Greenfield	NWS	400	35	64.30	47.50
Martin University of Tennessee	NWS	340	43	62.57	49.53
Dresden	NWS	450	54	66.92	50.04
Huntingdon Water Works	NWS	440	18	76.50	48.72

Table 38.--Precipitation data for the period 1970-79 for selected rainfall stations, Obion-Forked Deer River basin

Watershed description	Precipitation (inches) High	Year	Low	Year	10-year average
Dyersburg FAA airport	62.42	1973	41.77	1971	52.74
Dyersburg	59.30	1979	40.37	1971	52.72
Samburg wildlife refuge	66.56	1973	44.30	1976	53.10
Newbern	62.57	1973	44.26	1977	55.38
Union City	68.30	1973	40.30	1976	55.41
Jackson FAA airport	75.98	1974	42.82	1971	57.55
Jackson experimental station	73.59	1979	42.70	1976	57.54
Humboldt	65.40	1973	43.74	1971	55.22
Milan	67.44	1974	48.09	1976	59.87
Greenfield	64.30	1979	41.90	1976	54.08
Martin University of Tennessee	70.82	1975	45.73	1971	58.20
Dresden	71.87	1975	50.93	1976	59.16
Huntingdon Water Works	76.50	1979	51.72	1971	63.51

the year, average rainfall ranges from 3.96 to 5.33 inches with March usually being the wettest month.

The surface-water supply for this basin is derived from precipitation and runoff within the area, streamflow including ground-water discharge entering the area from adjacent areas, and ground-water discharge to streams within the area. Average discharge data for selected hydrologic data stations are presented in table 39. Theoretically, there is a large quantity of surface water available for use in this basin. However, because of the small number of available storage sites and the increased evaporative losses of surface water that occur with this development, this quantity is not realistically obtainable.

Ground Water

West Tennessee embraces two physiographic provinces. One is the West Tennessee Plain, including the subdivision known as the West Tennessee Uplands, and the other is the Mississippi River Valley.

The West Tennessee Plain extends from the western margin of the Western Valley of the Tennessee River, or the divide, known as the West Tennessee Uplands, separating eastward flowing drainage to the Tennessee River from streams flowing westward to the Mississippi River. This area contains three major drainage basins: the Obion-Forked Deer, the Hatchie, and the Memphis Area which includes the Loosahatchie River, Wolf River, and Nonconnah Creek.

West Tennessee lies in the region known as the Mississippi embayment. This is an area in which Paleozoic limestones were downwarped in the geologic past forming a trough with its axis or deepest part roughly parallel to the present course of the Mississippi River and extending from the Gulf Coast northward to the southern tip of Illinois. Its eastern margin lies in parts of Kentucky, Tennessee, Alabama, and Mississippi while its western margin lies in parts of Missouri, Arkansas, Louisiana, and Texas. During geologic time, the sea successively advanced and receded in the trough depositing sediments consisting of uncemented sand and clay with minor amounts of other materials. Thick nonmarine sediments were also deposited. Consequently, these sands and clays are at the surface east of the Mississippi River and dip at the rate of 15 to 30 ft/mi westward toward the river where they begin to rise again and reappear west of the river although covered by alluvial deposits. Inclination of the water-bearing sands and the presence of clay layers and lenses cause the water in the sands to be under artesian pressure away from the outcrop area. In West Tennessee, the oldest sediments appear on the surface near the Tennessee River and dip westward reaching a depth of over 3,000 feet below the Mississippi River.

Inasmuch as the sand aquifers are continuous through the West Tennessee Plain and extend into other states, it is not practical to discuss them on a river basin basis but rather on a regional basis. While almost any sand body in any formation may furnish adequate supplies of freshwater for domestic use at or near its outcrop area, there are four major aquifers that are capable of furnishing relatively large supplies for municipalities and industries. From oldest to youngest these aquifers are the Coffee Sand and McNairy Sand of Cretaceous age and the Wilcox Formation and the Claiborne Formation of Tertiary