Water-Resources Investigations in Tennessee: Programs and Activities of the U.S. Geological Survey, 1992-94

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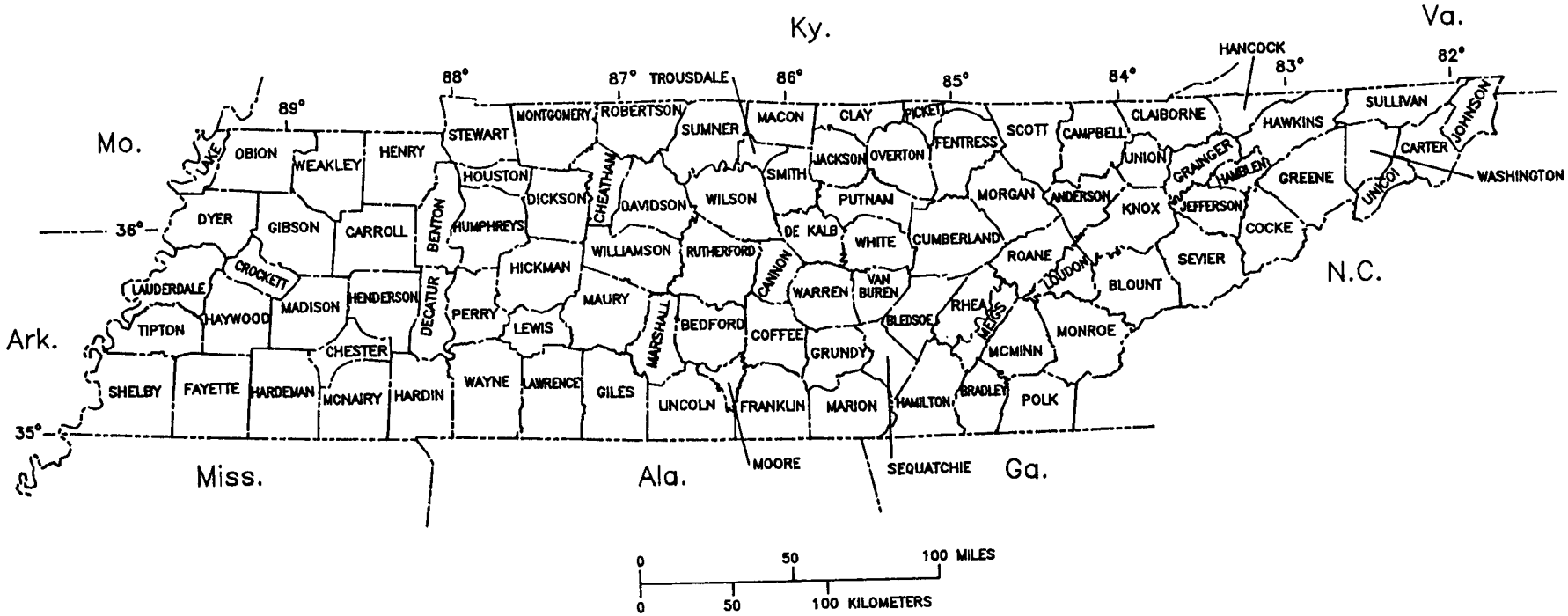

Location of Tennessee Counties

Water-Resources Investigations in Tennessee: Programs and Activities of the U.S. Geological Survey, 1992-94

by BARBARA H. BALTHROP and HAROLD C. MATTRAW, JR.

U.S. Geological Survey

Open-File Report 94-498

Nashville, Tennesee

1995

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

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A Message from the District Chief

This report is the most recent in a series published about every 2 years that describes the programs and activities of the Tennessee District of the U.S. Geological Survey (USGS), Water Resources Division. The report summarizes the main objectives and status of the projects developed from 1992-94 as part of the cooperative and Federal programs of the USGS in Tennessee.

Tennessee is blessed with an abundance of surface and ground water, but the quality and distribution of the water resources throughout the State is not uniform. Also, the demand for and use of water continues to increase, affecting its availability and reducing its quality. Past and current generations considered water an inexhaustible resource with little concern for its protection and conservation. At many areas across Tennessee, sources of pollution to surface and ground waters are present, and will require sizable resources to remedy. This reflects in a decrease in the quality of the water and higher costs to supply increasing water needs that meet quality criteria for a variety of uses.

Some of the many water-resources related problems faced by future generations in Tennessee include:

- Nonpoint-source pollution of surface waters from several sources including agriculture and urban storm runoff.
- Acid rain.
- Increasing water-supply demands, resulting in localized water shortages and the need to develop new sources of supply.
- Point-source pollution of ground water from industrial and domestic hazardous-waste sites and abandoned mines.
- Point-source pollution of surface water by waste discharges from sewage treatment plants and industrial facilities.

These problems are widespread across the State and include private, State, and Federal lands and facilities. Agricultural activities in West and Middle Tennessee contribute large amounts of sediment and chemicals to runoff. Active and inactive domestic and industrial landfills leach contaminants to aquifers and streams in the karst areas of Middle Tennessee. Sediment and coal spoils decrease the quality of the water in streams throughout East Tennessee, affecting the habitat of critical species such as mussels. Significant efforts and resources will be required to properly define the extent of these problems, and to develop remediation strategies.

The mission of the Tennessee District of the USGS is to assist local, State, and Federal agencies in collecting needed water-resources data to understand the problems that affect this important resource, and to provide scientific analyses in search of solutions. The projects described in this report are designed with that purpose. The USGS staff is dedicated to work in partnership with local, State, and Federal agencies to meet these goals. I am proud of the dedication, capabilities, and accomplishments of the employees of the Tennessee District as reflected in the summaries provided in this report.

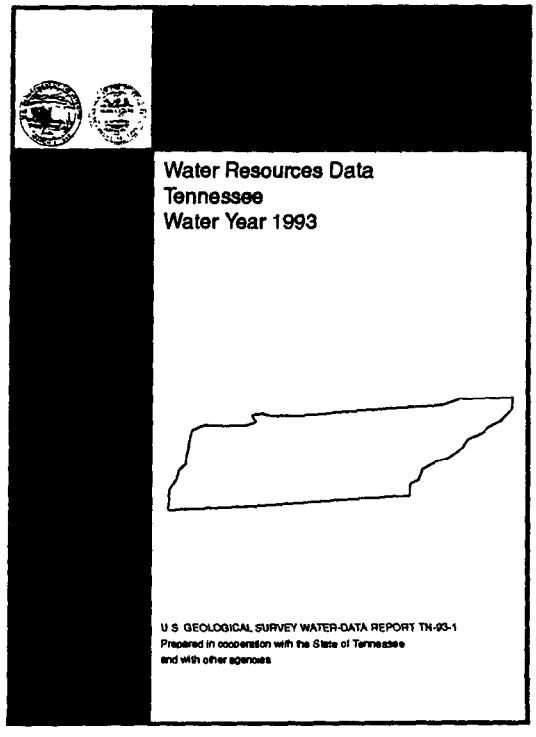
Harold C. Mattraw, Jr.
District Chief
Tennessee District

Water-Resources Investigations in Tennessee: Programs and Activities of the U.S. Geological Survey, 1992-94

By Barbara H. Balthrop *and* Harold C. Mattraw, Jr.

HYDROLOGIC DATA COLLECTION

Hydrologic data, or basic data as this type of information is commonly known, is the mainstay of the investigations conducted by the Water Resources Division of the U.S. Geological Survey (USGS). The basic-data collection programs carried out by the Tennessee District provide streamflow, quality-of-water, and ground-water level information essential to the assessment and management of the State's water resources. Long-term streamflow, quality-of-water, and ground-water level networks are operated as part of the function of the Hydrologic Data Section. Field operations are about equally divided among field offices in Memphis, Nashville, and Knoxville. A staff of about 45 hydrologists and hydrologic technicians provide operational support for both long-term networks as well as shorter term networks established for areal investigations. The data collected from the networks are published in the series of annual data reports titled "Water Resources Data for Tennessee." The data also are readily available as computer printouts and in disc format from the USGS District office in Nashville.



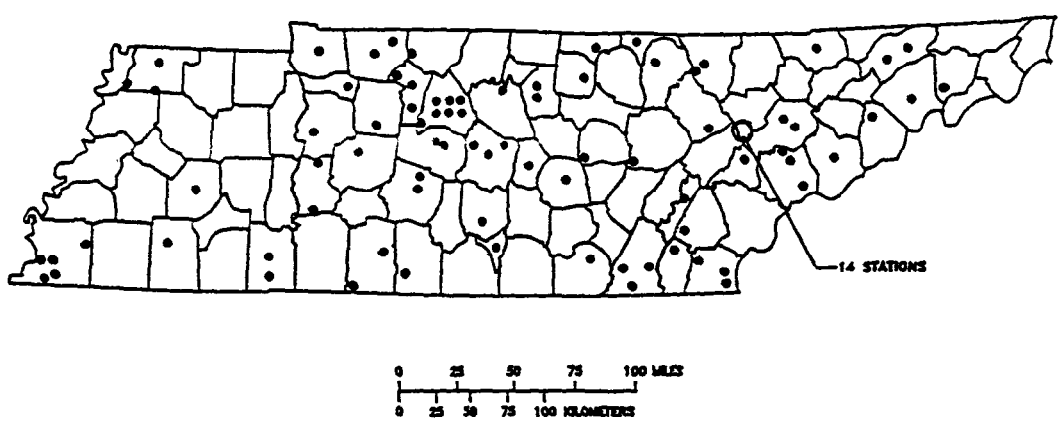
Surface-Water Monitoring Network

The USGS, Tennessee District, operates a network of continuous streamflow-gaging stations throughout Tennessee. In 1994, the number of stations in the network increased slightly to a total of 121. Additionally, rainfall data are collected at about 60 sites. Continuous streamflow data are recorded and disseminated for many purposes, including:

- Assessment of water availability
- Operation of impoundments and pumping facilities
- Flood or drought monitoring and forecasting
- Waste disposal and control
- Legal requirements and enforcement
- Research and hydrologic trends or other special studies

This program is conducted by the USGS in cooperation with the following agencies or municipal governments:

Tennessee Valley Authority
U.S. Army Corps of Engineers, Nashville District
Tennessee Department of Environment and Conservation
Tennessee Wildlife Resources Agency
U.S. Department of Energy
Memphis Light, Gas and Water
Shelby County, and
the cities of Alcoa, Bartlett, Lawrenceburg, Memphis, Metropolitan Government of Nashville and Davidson County, Rogersville, Dickson, Franklin, Murfreesboro, Harriman, Spring Hill, Sevierville, Union City, Camden, Columbia, Crossville, Red Boiling Springs, Tullahoma, Wartrace, and Shelby County.



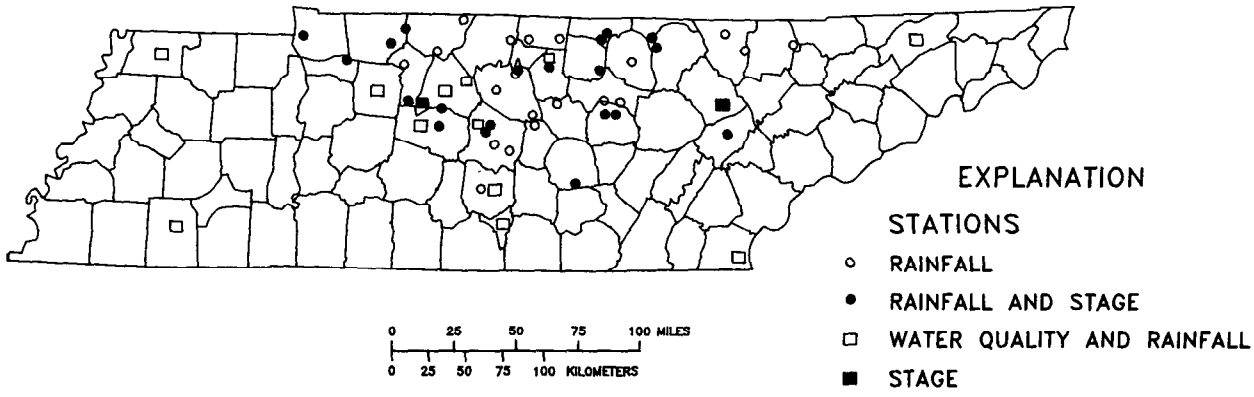
Location of streamflow stations in Tennessee.

Real-Time Data-Collection Network

The surface-water monitoring network includes about 60 real-time gaging stations that monitor streamflow, rainfall, and, at some locations, water quality and air temperature. Most of these stations are operated in cooperation with the U.S. Army Corps of Engineers (COE), and a few stations are operated in cooperation with the Tennessee Valley Authority (TVA) or with local governments.

At each of these stations, data are recorded in digital format, and at 2- or 4-hour intervals, are radioed to the Geostationary Orbiting Earth Satellite (GOES). The data are returned to ground stations in South Carolina, Mississippi, or Tennessee, as appropriate, and are transmitted to offices of the USGS, COE, or TVA where the data can be displayed on computer screens or printed in graphic and tabular format. The real-time data-collection network permits the continuous monitoring of conditions at stations many miles away.

The COE and TVA use the data for the management and operation of the reservoir systems on the Cumberland and Tennessee Rivers. The rapid transmission of data describing events taking place in the field enables quick response during extreme hydrologic conditions, such as floods and droughts. Several towns and cities in Tennessee also use real-time data to determine when streamflow is adequate to dispose of waste into the streams. The USGS uses the data to compute discharge and water-quality characteristics. Data transmitted to USGS offices are archived in computer files and included in the annual data reports.



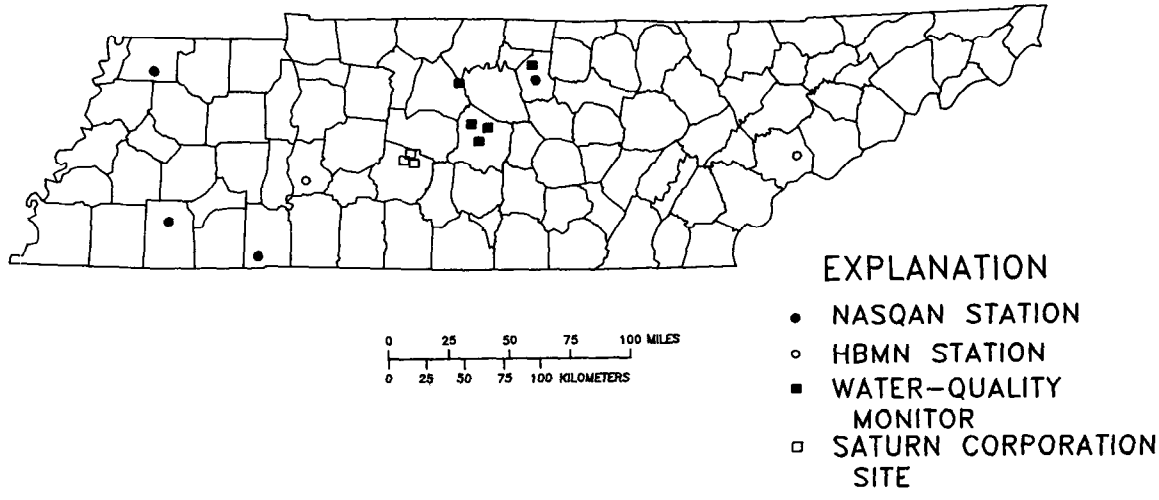
Location of network stations.

Water-Quality Network

The USGS monitors water quality at numerous surface-water stations in Tennessee. In 1994, four stations were included in the National Stream Quality Accounting Network (NASQAN). NASQAN data-collection sites are located at or near the downstream end of hydrologic accounting units. A comprehensive list of physical and chemical characteristics are measured quarterly or bimonthly to fulfill the information needs of water-resources planners and managers. Two sites within the State were part of the national Hydrologic Bench-Mark Network (HBMN) during 1994. At HBMN stations, the USGS assesses natural streamflow and water quality of river basins that are known to be minimally affected by human activity.

Water-quality monitors are operated by the USGS, in cooperation with the U.S. Army Corps of Engineers, at four stations along the Cumberland River and its tributaries in Middle Tennessee. A fifth monitor is operated in cooperation with the City of Murfreesboro at a point above the wastewater treatment plant. These instruments record hourly values for water temperature and specific conductance, and in some cases, pH and dissolved-oxygen concentration.

Water quality is assessed quarterly at three stations in Maury County near the Saturn Corporation industrial facility. At these sites concentrations of suspended sediments, bacteria, organic compounds, and priority-pollutant metals are determined.



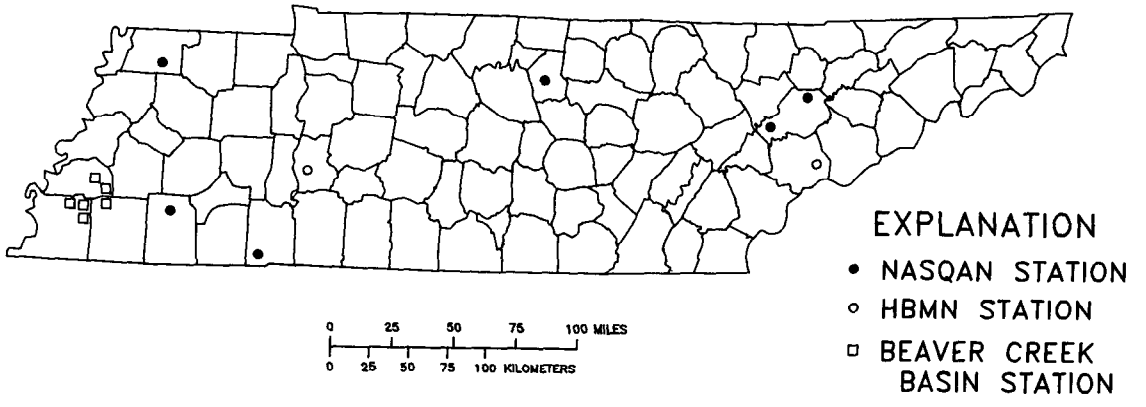
Water-quality data-collection sites in Tennessee.

Suspended-Sediment Data Collection

Sediment is considered perhaps the most important nonpoint-source pollutant in stream water. Nutrients, pesticides, metals, and other undesirable constituents are transported attached to sediment. In order to quantify nonpoint loads of pollutants, measurements of suspended- and bed-sediment loads must be made.

The USGS currently (1994) measures suspended sediment bi-monthly at four National Stream Quality Accounting Network (NASQAN) stations in Middle and West Tennessee. It also measures suspended sediment and other constituents in samples collected at two Hydrologic Bench-Mark Network (HBMN) stations, one on the Buffalo River near Flat Woods and the other on the Little River above Townsend at about monthly intervals.

In addition to these network stations, suspended sediment is also measured in some of the project-oriented studies, such as the studies of the Beaver Creek drainage basin and the Clinch-Powell Rivers.

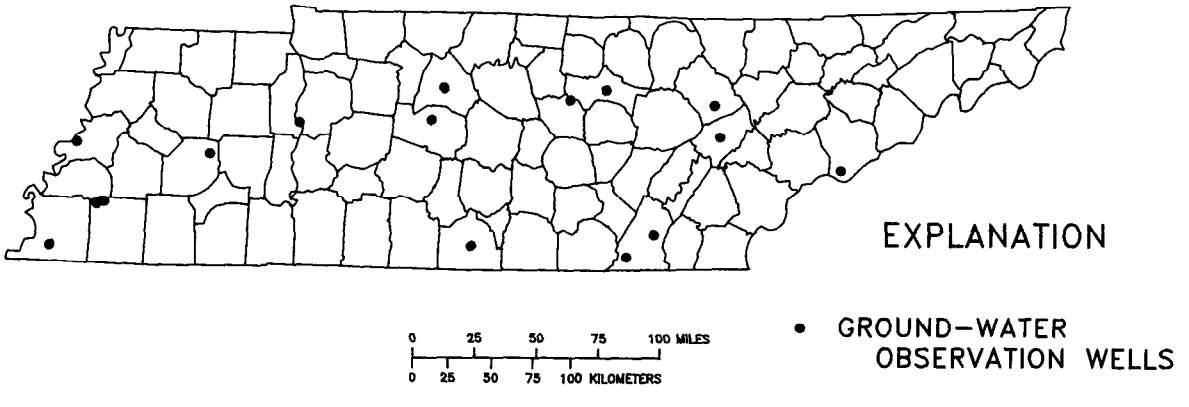


Location of suspended-sediment stations in Tennessee.

Ground-Water Level Network

The USGS measures water levels in about 30 to 35 wells throughout Tennessee to determine long-term trends and shorter term changes in depth to ground water. These wells constitute the Statewide ground-water level network. The network includes about 20 wells owned by the Memphis Gas, Light and Water Division of the city of Memphis, the single largest user of ground water in the State.

The water-level data are collected in cooperation with several Federal, State, and local agencies.



Location of observation wells in Tennessee.

Participation in the National Atmospheric Deposition Program

The USGS, Tennessee District, is sponsoring a station for the collection of data on chemical and physical properties of wet and dry deposition. The monitoring station was established in 1984 at the Hatchie National Wildlife Refuge near Brownsville, Tennessee, as part of the National Atmospheric Deposition Program. This program is assessing an environmental problem that is receiving international attention--acid rain. Each data-collection station in the program is carefully located in an area that typifies a region. The refuge site in Haywood County was selected because it is representative of the West Tennessee region and offers some protection from local unrepresentative sources of contamination that might invalidate the findings.

Samples of both wet and dry deposition are collected weekly by an observer from Brownsville, Tennessee, who also services the rain gage. After making some initial water chemistry measurements on the samples, the observer ships them to a central laboratory in Champaign, Illinois, for further chemical analyses. The USGS acts as a cooperator to the laboratory, operated by the Illinois State Water Survey.

National Baseline Network

Federal agencies coordinate their efforts for acquiring and managing water data through the Interagency Advisory Committee on Water Data (IACWD). This committee is composed of 30 major organizations representing seven departments and seven independent agencies of the Federal Government. The IACWD seeks to assure the continued availability of sufficient information about the amount and distribution of freshwater resources in the United States.

In light of a declining number of stream-gaging stations nationwide, the following steps have been proposed by the IACWD to help assure that an adequate amount of surface-water quantity information continues to be available for making decisions about the management of the Nation's water resources.

- Identify a National Baseline Network (NBN) of critical streamgaging stations needed to meet national objectives and priorities.

- Conduct a critical evaluation of alternative approaches to operating streamgaging stations that are part of the NBN.

- Develop a plan to provide staffing, funding, and other resources needed to support the proposed NBN.

The USGS Tennessee District is assisting the IACWD by coordinating the collection of surface-water gaging station information from 51 districts comprising the Water Resources Division of the USGS. The information supplied by the districts is being compiled in a digital data base that will be circulated among all the members of the IACWD for the inclusion of agency-specific information. The IACWD will use the information in this data base to identify a National Baseline Network of multi-purpose gaging stations and stations critical to missions of one or more agencies.

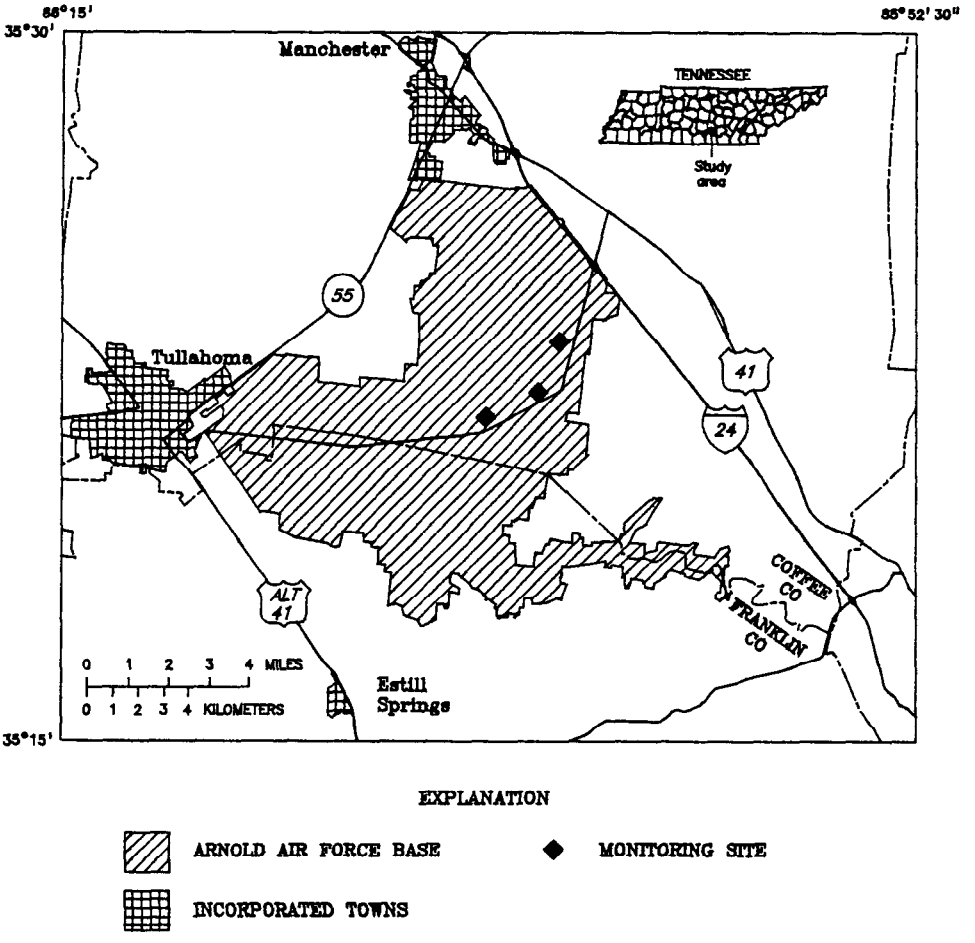
Monitoring at Arnold Engineering and Development Center for the National Pollutant Discharge Elimination System

The USGS is helping conduct a streamflow monitoring program at Arnold Air Force Base. The base is located in Coffee and Franklin Counties, near Tullahoma, in south-central Tennessee. An area of about 3,000 acres on the base known as Arnold Engineering and Development Center (AEDC) is devoted to testing and support facilities.

To comply with the U.S. Environmental Protection Agency National Pollutant Discharge Elimination System, AEDC is monitoring streamflow and certain water-quality characteristics at the major outflows from the AEDC area. Three stations provide measurements of:

- Streamflow,
- Water temperature, and
- pH.

These data are transmitted by satellite to a USGS computer in Nashville from which AEDC personnel can obtain nearly real-time data by telephone linkage.



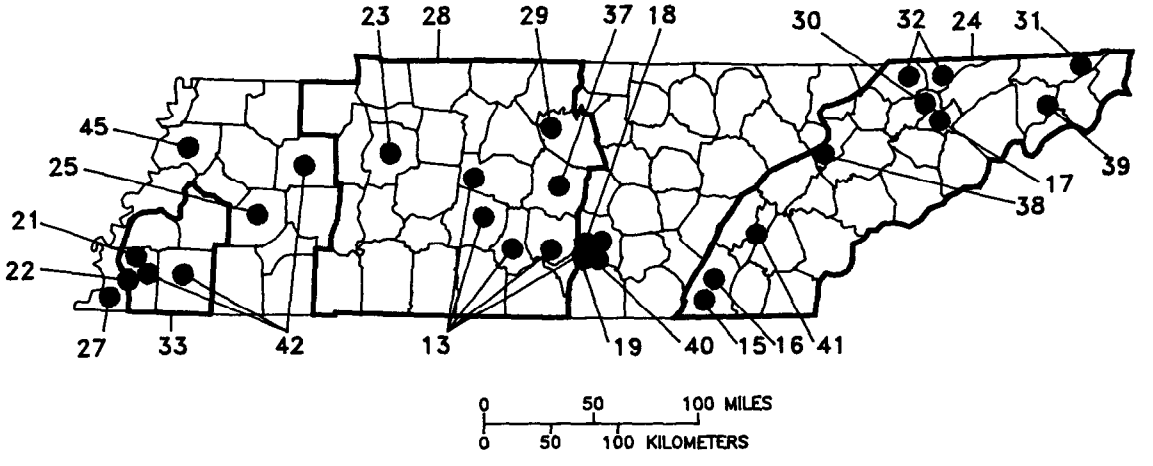
Location of monitoring sites on the Elk River.

HYDROLOGIC INVESTIGATIONS

The Water Resources Division of the USGS provides hydrologic information and understanding of the Nation's water resources. The Tennessee District is responsible for surface-water, ground-water, and quality-of-water investigations throughout the State. These investigations are conducted in cooperation with Federal, State, and local agencies to provide hydrologic data and information.

For the 3-year period 1992 through 1994, the Tennessee District was involved in hydrologic or hydrogeologic investigations. Investigations were made in most parts of the state and ranged in scope from study of small sites to study of multi-State areas. Some of the studies, such as the flood-frequency investigation and the definition of low-flow characteristics of streams, have relied heavily on the long-term record of data produced by the USGS over a period of many years. Other studies have had to generate new information in order to address the problems that the USGS has been asked to solve. The studies span a broad range in the field of hydrology. In addition to the applications of basic data, they include determining water use, ground-water availability, extent of contamination, the effect of agriculture and urban areas on water quality, potential for channel scour at bridge sites, human impact on wetland areas, and other topics.

Brief descriptions of investigations conducted in Tennessee during this 3-year period are presented in the following section of the report.



Generalized location of the principal areal investigations. Numbers refer to page in this report describing investigation.

Low-Flow and Flow-Duration Characteristics for Streams in Tennessee

Low-flow and flow-duration data are critical for the effective management and use of the surface-water resources in Tennessee. Several key regulatory programs within the Tennessee Department of Environment and Conservation depend on these data for day-to-day operations. For example, the 3-day 20-year recurrence low-flow interval (the "3Q20") is the statistic used for regulating discharge from wastewater treatment plants to streams and also for prohibiting pumpage by water users from streams in order that minimal flows may be maintained. City and county governments, utility districts, consulting engineers, and many others also use these data.

The USGS, in cooperation with the Tennessee Department of Environment and Conservation and the Tennessee Valley Authority, has continued a study to update the low-flow and flow-duration data for streams in Tennessee. Data were collected for three types of gaged sites: (1) long-term continuous-record sites, (2) short-term continuous-record sites, and (3) partial-record sites.

Low-flow characteristics for long-term continuous-record sites were based on the log-Pearson Type III frequency distribution, and were computed for 1, 3, 7, 14, 30, 60, and 90 consecutive days for recurrence intervals of 2, 5, 10, and 20 years. Flow-duration characteristics for long-term continuous-record stations were calculated by statistical analysis of the period-of-record daily mean flows.

For short-term continuous-record sites and partial-record sites, low-flow characteristics were estimated by correlating base-flow discharges at these sites to daily-mean discharge values at long-term continuous-record sites with similar basin characteristics. Low-flow values for the short-term continuous-record stations and partial-record stations were estimated for 1, 3, and 7 consecutive days for a recurrence interval of 10 years, and for 3 consecutive days for a recurrence interval of 20 years.

George S. Outlaw of the District office is in charge of the study.

Flood Investigations

The USGS conducts flood investigations in Tennessee in cooperation with the Tennessee Department of Transportation and the Metropolitan Government of Nashville and Davidson County. A knowledge of flood-frequency characteristics of streams is essential to the design of adequate and economical bridges, culverts, embankments, dams, levees, and other stream-related structures. Information on flood magnitude and frequency also is used by city and county planners for managing development of flood plains and by insurers for establishing flood-insurance rates.

The objective of the Flood Investigations program is to better appraise and define the flood characteristics of Tennessee streams by:

- Investigating and documenting outstanding floods.
- Operating a network of about 90 crest-stage partial-record gages to provide flood data on small streams and other streams in parts of the State where data are sparse.
- Providing analytical techniques and reports as needed to further understand the flood hydrology of Tennessee.

A recently published report focused on flood frequency of streams in rural basins of the State. Several analytical reports, in addition to reports documenting outstanding floods, have been prepared within the past several years to provide information for use in the proper design of hydraulic structures within the highway system in Tennessee. Information in these reports includes:

- Methods to compute depth of floods of various recurrence intervals at ungaged sites.
- Methods to estimate an average flood hydrograph and runoff volume, in inches, for ungaged sites within the State.
- Regional flood-frequency analyses to provide peak discharges for ungaged sites for various recurrence intervals.

The areal extent of the project is statewide. The project chief is Jess D. Weaver of the District office.

PUBLICATION

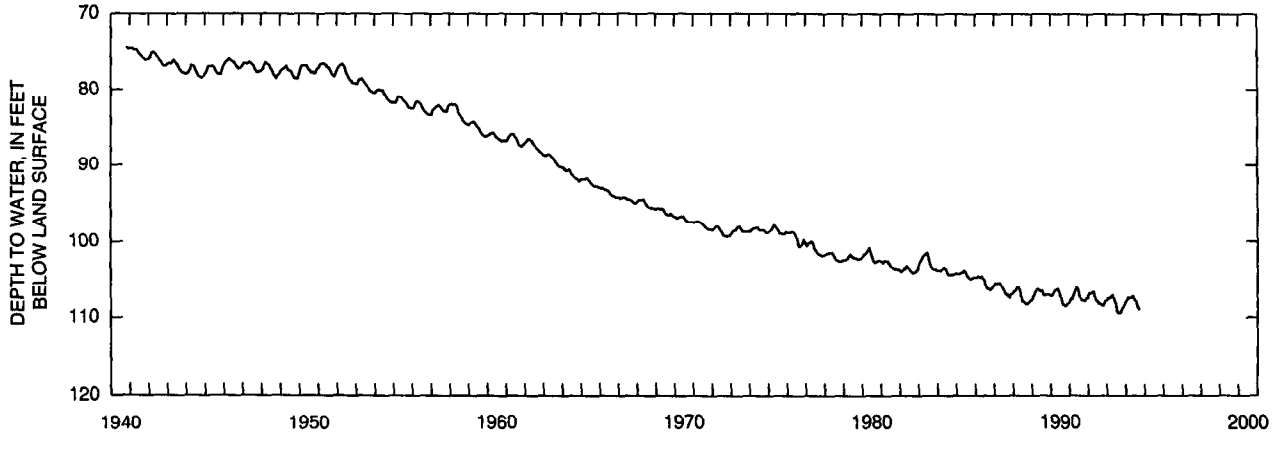
Weaver, J.D., and Gamble, C.R., 1993, Flood frequency of streams in rural basins of Tennessee: U.S. Geological Survey Water-Resources Investigations Report 92-4165, 38 p.

Monitoring of Depth to Water in Aquifers in the Memphis Area, Tennessee

Large amounts of water are pumped daily from wells in the metropolitan Memphis area to meet the demand for domestic, commercial, and industrial water supply. The USGS, in cooperation with the Memphis Light, Gas and Water Division (MLGW) of the City of Memphis and the City of Germantown, monitors water levels in the three principal aquifers underlying this area. Water-level data are collected at an observation network consisting of 43 wells. Twelve of the wells are screened in the shallow water-table aquifer, 23 in the Memphis aquifer, and 8 in the Fort Pillow aquifer. In addition, an extensometer is maintained in the MLGW Mallory well field to measure the compaction of sediments resulting from water-level declines and the reduction of fluid pressure within the sediments.

The largest amounts of water are withdrawn from the Memphis aquifer. During fall of each year, water levels in about 40 wells in this aquifer in the Shelby County area are measured within a period of a few days to supplement data from the observation-well network and to record the extent of seasonal water-level decline. These data are tabulated for comparison with measurements from previous years to determine areas where significant changes in water levels have occurred. The data are also used in the preparation of potentiometric-surface maps, which show the areal configuration of the pressure surface in this aquifer. These maps are useful for showing the location of historical changes in the pressure surface and for identifying areas having potential for the transfer of less-desirable-quality water from the water-table aquifer to the underlying Memphis aquifer.

Annually, during times of high pumping stress, 12 wells in the Memphis aquifer are sampled for water quality. The purpose of sampling is to document present conditions and long-term changes in the quality of water in the major well fields and in the large cone of depression in the aquifer. The wells sampled include eight production wells (one in each of MLGW's major well fields), two industrial wells in outlying areas, and two wells in the City of Germantown.



Water levels in observation well Sh:Q-1.

Statewide Water-Use Program

The Tennessee Water-Use Program is conducted in cooperation with the Tennessee Department of Environment and Conservation, Division of Water Supply. The need for detailed water-use information for Tennessee has become increasingly important. Competing demands for local sources of surface and ground water continue to increase. Detailed accounting of the rate at which water resources are being used and the locations where the demands are greatest is needed in order to develop management strategies necessary to ensure both sufficient water supply and adequate water quality. An inventory of ground-water use was conducted for Tennessee as of 1990. Data related to ground-water public-supply use were analyzed during 1993 and a report presenting the results has been prepared. Some statistics included in the report are:

- Total ground-water use by public water-supply systems increased 33 percent from 1980 to 1990 to 269 million gallons per day (Mgal/d).

- Thirty-four of the 267 systems inventoried withdrew 1 Mgal/d or more of ground water. These withdrawals accounted for 83 percent of the total ground-water withdrawals for public supply.

- Seventy-nine percent of the ground water used for public supply was withdrawn from the Tertiary sand and Cretaceous sand aquifers in western Tennessee.

- The largest ground-water withdrawals for public supply occurred in Shelby County. Withdrawals in this county alone were 154 Mgal/d, or 58 percent of the total Tennessee ground-water use.

Susan S. Hutson in the Memphis Subdistrict office is coordinator of the Tennessee Water-Use Information Program.

PUBLICATIONS

Hutson, S.S., 1991, Ground-water use by public-supply systems in Tennessee in 1988: U.S. Geological Survey Open-File Report 91-176, 1 sheet.

Estimates of Future Demand for Selected Water-Service Areas in the Upper Duck River Basin, Middle Tennessee

Water demand in the upper Duck River basin downstream of Normandy Dam increased significantly from 1980 to 1993. Water for domestic, industrial, and commercial uses from public-supply facilities increased 21 percent from 14.5 million gallons per day (Mgal/d) in 1980 to 17.5 Mgal/d in 1993. Projected residential, industrial, and commercial developments in the basin indicate that water use will continue to increase. Considerable uncertainty exists among officials from agencies in the basin as to whether or not existing water supplies are adequate to meet additional demands. Long-term projections are needed to determine if the Duck River, the principal source of water in the basin, can supply future demands.

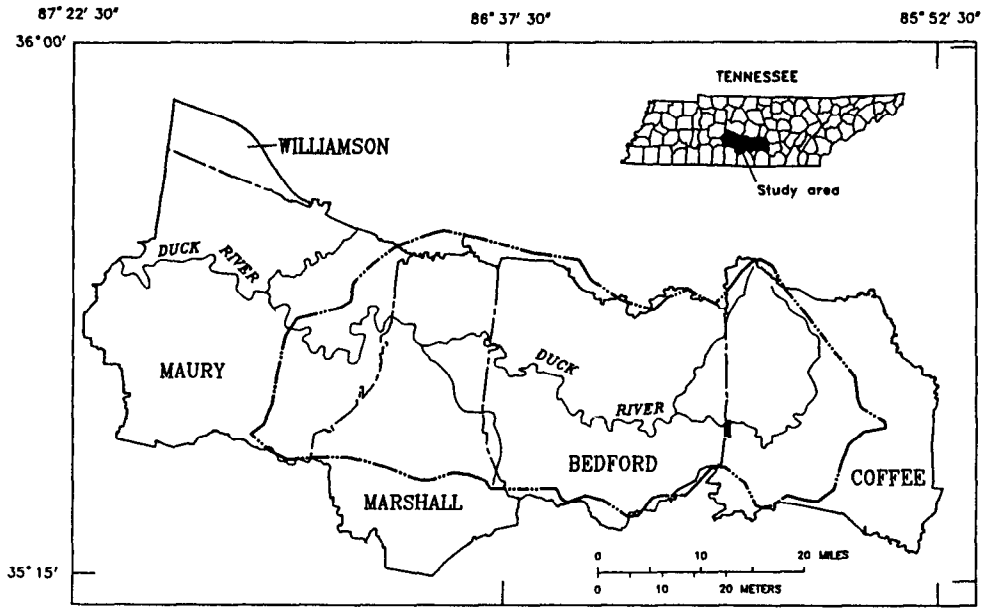
The USGS, in cooperation with the Duck River Agency, conducted an investigation in 1994 to document trends in water use and future water demand in the upper Duck River basin in Middle Tennessee. The study provided estimates of future water demands through the year 2050.

The following tasks were designed to accomplish the project objectives:

- Municipal water use was analyzed using data collected for years 1980, 1985, 1989, 1990, and 1993.
- The IWR-MAIN water-use models were calibrated for the study area using demographic and economic data for 1993. The calibrated models were used to estimate municipal water demands for years 2000 and 2015.
- Regression analysis was used to estimate the relation between population data and time. Population projections based on the log-linear type model were selected for the water-demand analysis for years 2025, 2035, and 2050.

Preliminary results indicate that for a steady growth scenario, water demand in the basin could increase 129 percent to 37 Mgal/d in year 2050; for a higher growth scenario for selected industrial and commercial sectors, water demand could increase 165 percent to 43.2 Mgal/d.

The study was conducted by Susan S. Hutson of the Memphis Subdistrict office and Gregory E. Schwarz of the USGS Headquarters office in Reston, Virginia.



Location of the upper Duck River study area.

Appalachian Valley-Piedmont Regional Aquifer-System Analysis

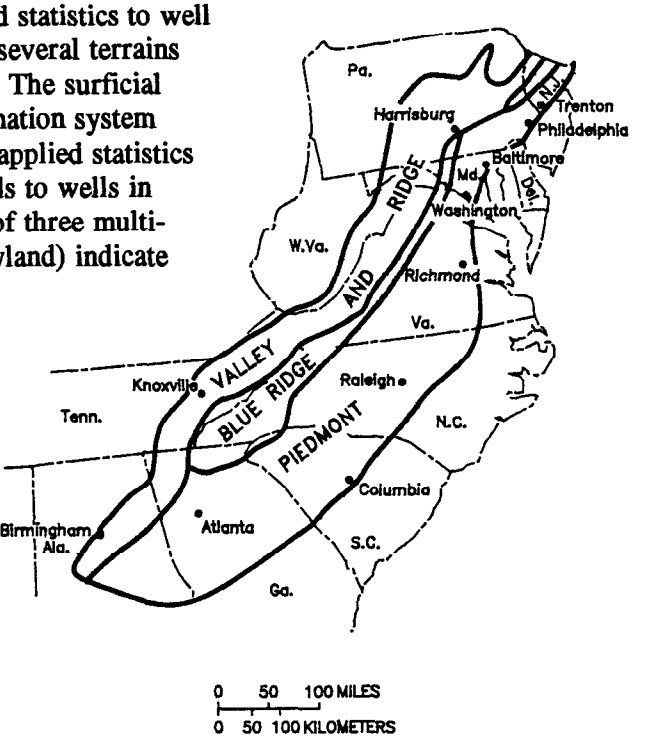
The Regional Aquifer System-Analysis Program was established (1) to define the regional geology and hydrology of the major aquifer systems throughout the United States, and (2) to establish a framework of information that can be used for regional assessments of ground water and for support of detailed local studies. The Appalachian Valley-Piedmont Regional Aquifer System is one of 28 such systems identified for study under the program. It includes the water-bearing rocks in the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces, and covers parts of eight states from New Jersey to Alabama.

The team studying the Valley and Ridge province applied statistics to well records in order to identify and categorize rock types into several terrains on the basis of similarity of hydrogeologic characteristics. The surficial extent of each terrain was mapped using geographic information system coverages derived from geologic maps. The team further applied statistics to well records to estimate median ranges in potential yields to wells in each terrain. For example, results of analysis in the first of three multi-State reporting areas (New Jersey, Pennsylvania, and Maryland) indicate that that part of the Valley and Ridge province can be divided into five hydrogeologically distinct terrains.

The middle 50-percent range in estimated potential yield to selected, non-domestic wells by terrain in this tristate region is, alluvium of glacial origin, 170 to 600 gallons per minute (gal/min); dolomite, 280 to 1,700 gal/min; limestone, 80 to 520 gal/min; clay-rich carbonate rock, 60 to 550 gal/min; and siliciclastic rock, 60 to 240 gal/min.

This analysis allows water users to seek water in the more favorable terrains and provides information on the probable range in yields to wells before drilling is attempted.

The Valley and Ridge team of the study is located at the Tennessee District office at Nashville. E.F. "Pat" Hollyday is the team leader.



Location of the Appalachian Valleys-Piedmont Regional Aquifer-System Analysis study area.

PUBLICATIONS

Hollyday, E.F., Knopman, D.S., Smith, M.A., and Hileman, G.E., 1992, Statistical analysis of well records for use in classifying and mapping hydrogeologic terrains in the Valley and Ridge Province, *in* Aquifers of the southern and eastern states: Bethesda, Maryland, American Water Resources Association Monograph Series 17, p. 75-92.

Knopman, D.S., and Hollyday, E.F., 1993, Variation in specific capacity in fractured rocks, Pennsylvania: Ground Water, v. 31, no. 1, p. 135-145.

Swain, L.A., Hollyday, E.F., Daniel, C.C. III, Mesko, T.O., 1992, An overview of the Appalachian Valleys - Piedmont Regional Aquifer System Analysis, *in* Aquifers of the southern and eastern states: Bethesda, Maryland, American Water Resources Association Monograph Series 17, p. 43-57.

Hydrogeology of Cave Springs Basin, near Chattanooga, Tennessee, as Part of the Appalachian Valley-Piedmont Regional Aquifer-System Analysis Study

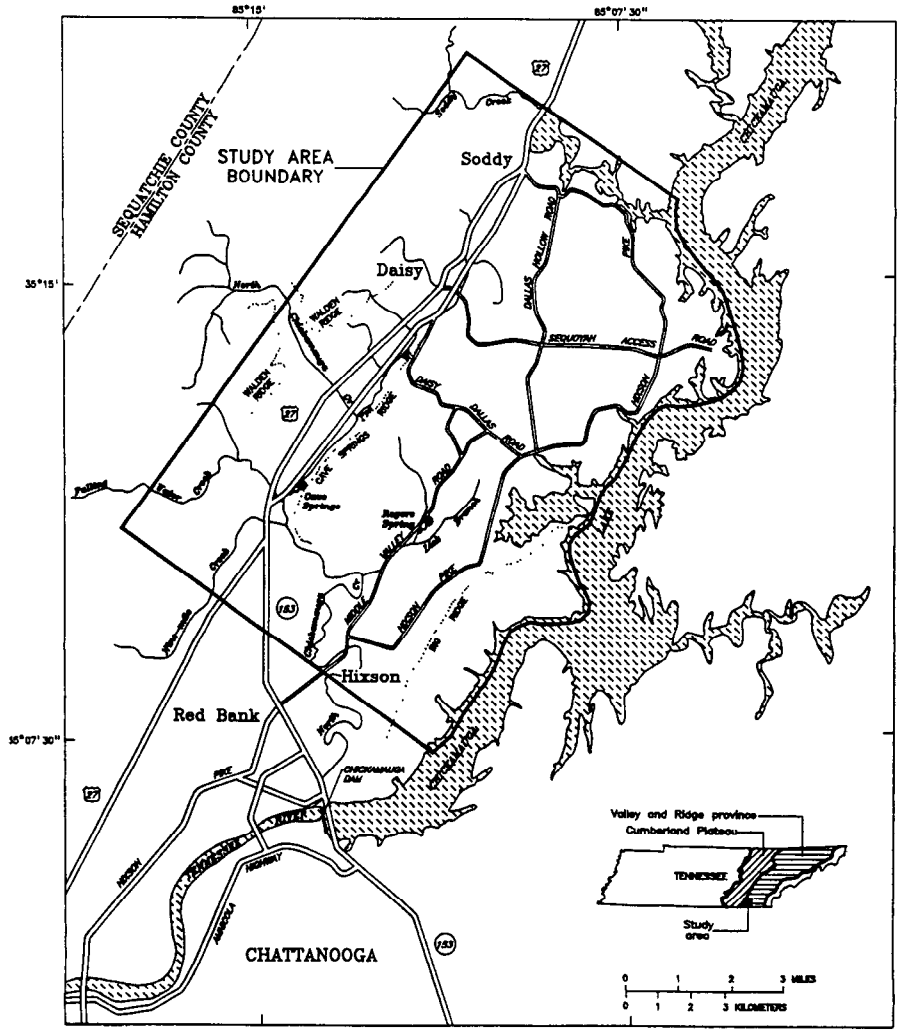
The Appalachian Valley-Piedmont Regional Aquifer-System Analysis study area is characterized by many local, discontinuous flow systems. Local systems which are representative of the region have been selected for detailed study.

The Cave Springs ground-water basin in Hamilton County near Chattanooga was chosen as a representative Valley and Ridge Province karstic spring ground-water basin. This type-area study was conducted in cooperation with the Hixson Utility District, which obtains its water from wells at Cave Springs, the second largest spring in Tennessee.

The objectives of the Cave Springs type-area study were to:

- Characterize the hydrogeologic framework of the ground-water basin;
- Determine sources of recharge to the ground-water basin and recharge areas; and
- Quantify the Cave Springs ground-water basin with regard to recharge, discharge, and water in storage.

The results of this study have transfer value to other areas in the carbonate aquifer dominated Valley and Ridge Province. The project was completed in 1993 and directed by Dianne J. Pavlicek with the assistance of Arthur D. Bradfield.



Location of study area near Hixson, Tennessee.

Ground-Water Resources of Hamilton County, Tennessee

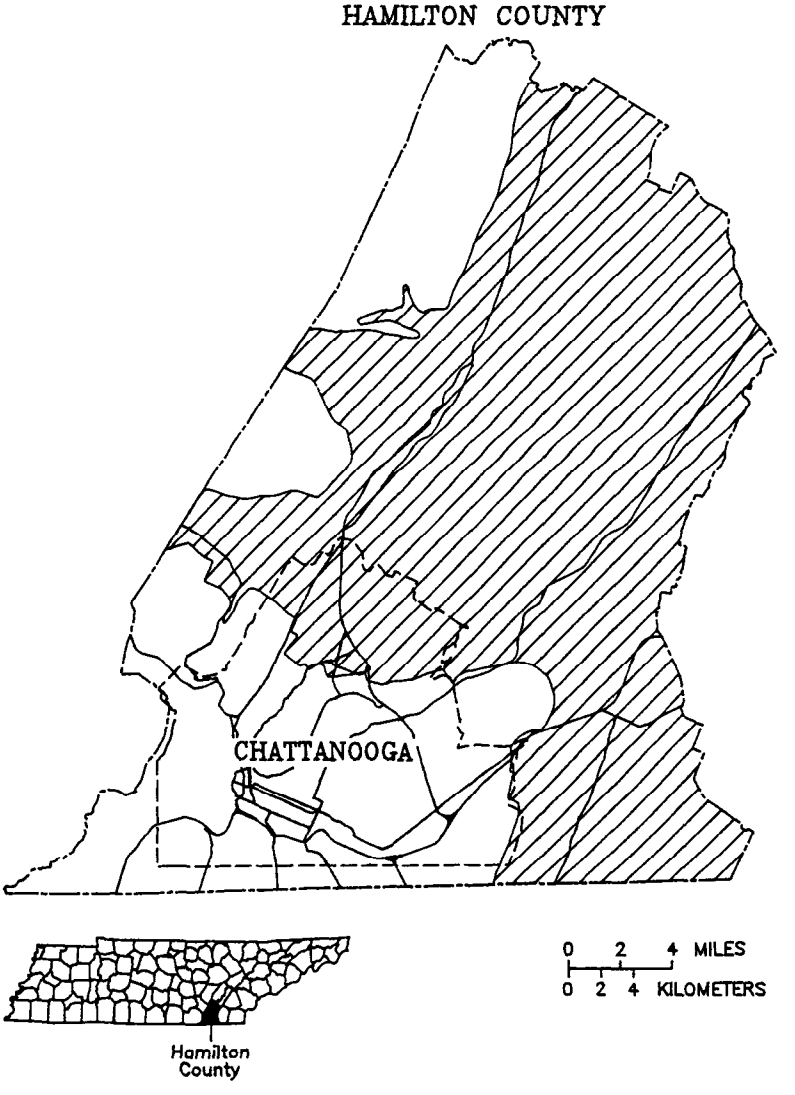
The USGS, in cooperation with the City of Chattanooga, Hamilton County, and the Hamilton County Association of Utility Districts, is conducting an investigation of the ground-water resources of Hamilton County. More than one-third of the population of Hamilton County depends on ground water for its drinking-water supply. In order to protect and maintain the high quality of ground water in the county, the Chattanooga/Hamilton County Regional Planning Commission is drafting wellhead-protection and zoning regulations for the area. The Commission needs information on recharge areas, flow directions, water quality, possible contaminant sources, and ground-water use to help formulate realistic and adequate regulations.

Towards addressing these needs, the primary objectives of the USGS study were to:

- Provide information on geology, ground-water occurrence, and water quality in Hamilton County and
- Identify recharge areas for the wells and springs used by the major utility districts in Hamilton County.

Information on area geology, sinkhole locations, well and spring locations, and water quality was collected from various sources and compiled into a geographic-information-system data base. Water-level measurements were made at 275 domestic wells to determine the approximate recharge areas for the utility districts' public supply wells and the general directions of ground-water flow. Data recorders were installed at three wells in the county to permit the continuous monitoring of water levels at those points. Data on utility district pumpage from wells, collected under the USGS's Statewide Water Use Program, provided information on ground-water use.

The study was performed under the direction of Stephanie E. Johnson of the District office.



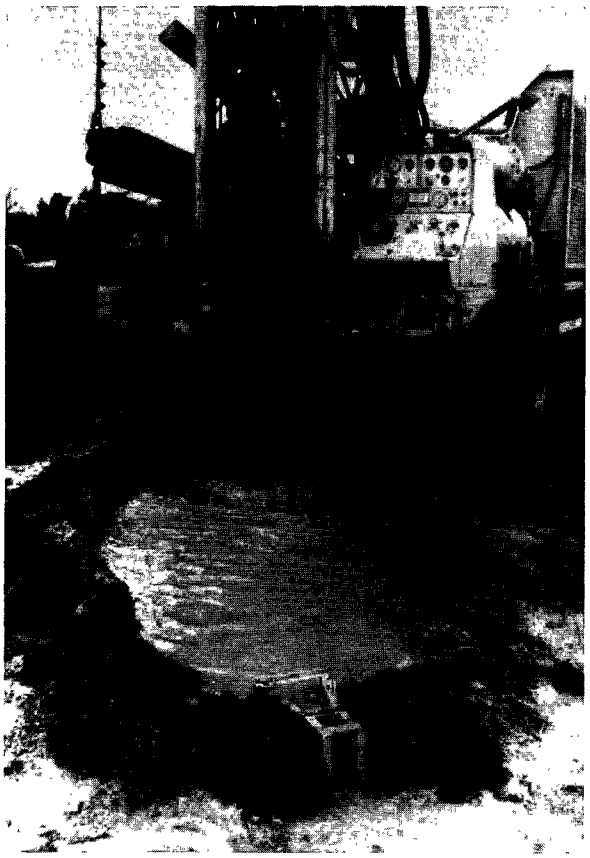
Pattern indicates area serviced by utility districts using ground water.

Ground-Water Resources of Mill Hole Spring and the Adjacent Carbonate Aquifer in the Valley and Ridge Province, East Tennessee

In cooperation with the Alpha-Talbott Utility District, the USGS conducted a study of Mill Hole Spring and the adjacent carbonate aquifer to determine their potential for additional resource development. Mill Hole Spring, in Hamblen County, is located near the upper end of a broad karst valley that has no perennial surface drainage. The spring seems to be part of a shallow, ground-water conduit system that mimics a "storm sewer" and responds quickly to rainfall. During low-flow conditions, water from the spring is fairly clear. Following precipitation, both the discharge and turbidity of water from the spring increase rapidly indicating direct connection between the spring and surface drains.

Ground-water flow in the carbonate aquifer of the karst valley is primarily through fractures and solution openings. Yields of wells completed in this aquifer vary depending on the number and size of solution openings penetrated below the water table. Fourteen wells were drilled and tested as part of this study; 4 wells are located up valley near Mill Hole Spring and 10 wells are located several miles down valley. Yields of these wells, measured during drilling, ranged from less than 1 to 220 gallons per minute (gal/min). Six of the 10 down-valley wells intersected openings in the carbonate rocks yielding 15 gal/min or more at depths from 120 to 180 feet below land surface. All 14 wells penetrated dry or mud-filled openings within 40 feet of land surface. The most productive well was pumped at 300 gal/min for more than 24 hours. This pumping resulted in a maximum drawdown of 6 feet in the pumped well and a cone of depression in the aquifer that was elongated parallel to the strike of the rock units. Test pumping indicates that deep conduits in the carbonate aquifer of this area are capable of transmitting large quantities of water to wells.

The project chief is Gregg E. Hileman of the District office.



Pumping test at Mill Hole Spring, East Tennessee.

Hydrogeology of the Cascade Springs Area, Tennessee

Cascade Springs discharge from the Highland Rim escarpment in western Coffee County, Tennessee. Left Cascade Spring provides the sole source of water for the Wartrace Water System, supplying over 0.5 million gallons of water per day to the town of Wartrace and to a local whiskey distillery. Little was known about the area of recharge to the spring, the aquifer characteristics, or the water quality. A recent water-quality analysis of left Cascade Spring raised concerns about possible nonpoint-source pollution after low concentrations of two volatile organic compounds were detected.

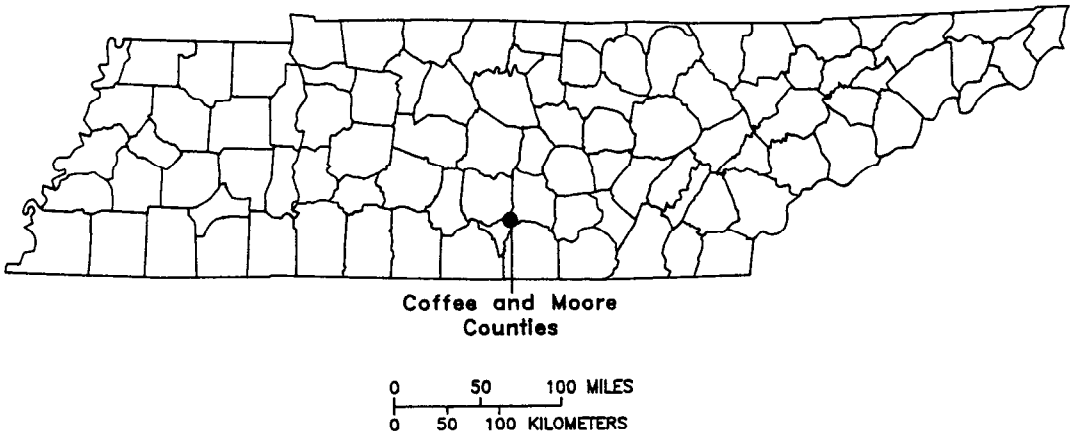
To address these concerns, the USGS, in cooperation with the town of Wartrace, conducted a hydrogeologic investigation of the Cascade Springs area from September 1991 to May 1992. The objectives of the investigation were to:

- Identify the area of recharge to Cascade Springs,
- Describe the hydrogeology of the recharge area, and
- Describe the water quality of Cascade Springs using available data.

Hydrogeologic data collected in support of this study included water-level measurements made at 41 domestic wells. Natural gamma and caliper geophysical logs also were made at three domestic wells.

The water-level data collected indicate that the primary recharge area for Cascade Springs is located southeast of the springs. The boundary of the recharge area cannot be fully delineated, however, because few wells are located south of Cascade Springs.

The project chief was Stephanie E. Johnson of the District office.



Location of Cascade Springs.

Study of the Hydrogeology near the J4 Test Cell at the Arnold Air Force Base, Tennessee

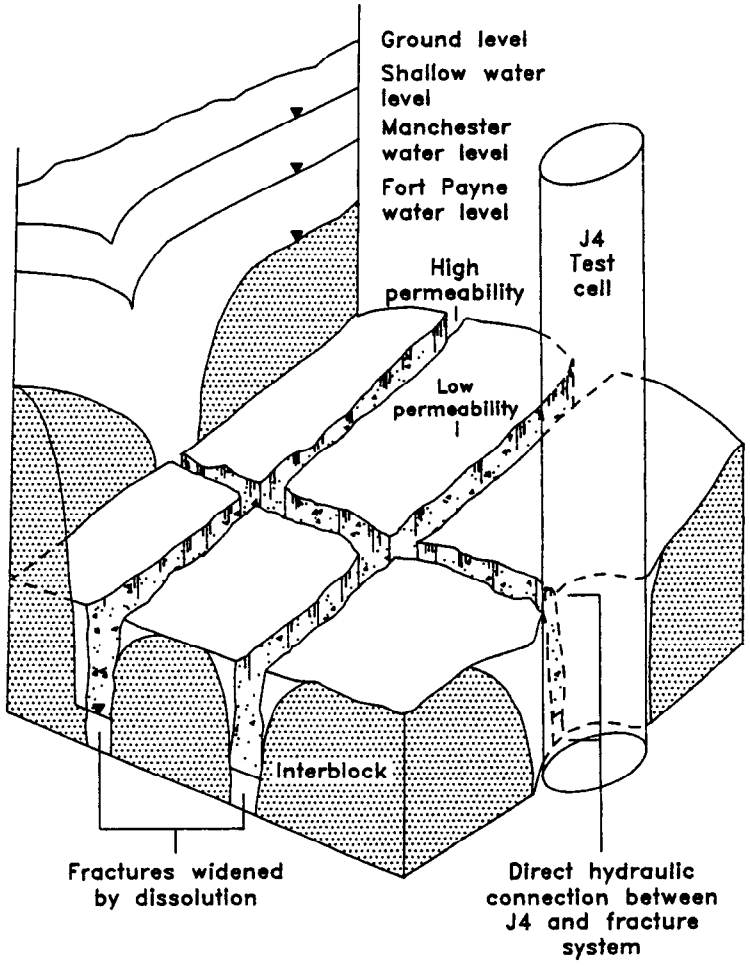
As part of a study of the hydrogeology of Arnold Air Force Base, near Manchester, Tennessee, the USGS is investigating the hydrologic effects of dewatering aquifers at the J4 rocket test cell. The J4 test cell, constructed in the early 1960's to support testing of rocket motors, is about 100 feet in diameter and about 250 feet deep. It penetrates three water-bearing units of carbonate origin (the shallow aquifer, the Manchester aquifer, and the Fort Payne aquifer), the Chattanooga Shale, and ends in a lower carbonate unit. The deep hole causes water to drain from the upper carbonate units to a sump at the bottom of the hole from which the water is pumped to land surface. The continual draining of the units above the Chattanooga Shale has caused water levels in them to decline, although the exact shape and extent of the cone of depression cannot be adequately defined with existing wells. In addition, organic contaminants have been detected in the pumpage from the test cell. Water containing these contaminants has been induced to move from nearby sites towards the test cell. The study is being conducted in cooperation with the U.S. Air Force at Arnold Air Force Base.

The objectives of the investigation are to:

- Describe the hydrogeology around the J4 test cell,
- Define in each unit the extent of the cone of depression from dewatering the aquifers at the test cell, and
- Determine if contaminants are being transported from the shallow aquifers above the Chattanooga Shale to the deeper aquifer below.

In 1994, 27 new wells were installed and data were collected. The data include analyses of ground-water samples for major constituents, trace metals, and volatile organic compounds; borehole geophysical logs; surface geophysical data; and continuous ground-water level measurements at about 10 wells.

Connor J. Haugh of the District office is the project chief.



Hypothesis of secondary permeability in the Manchester aquifer and the effects of dewatering at the J4 test cell on water levels in the shallow, Manchester, and Fort Payne aquifers at Arnold Air Force Base.

Hydrogeologic Investigation of the Fort Campbell Military Reservation, Kentucky

The USGS in cooperation with the U.S. Army at Fort Campbell, Directorate of Public Works, Environmental Division is conducting an investigation of the hydrogeology of the Fort Campbell Military Reservation and adjacent parts of Christian and Trigg Counties, Kentucky; and Montgomery and Stewart Counties, Tennessee. The broad objective of the study is to better understand the occurrence and movement of ground water in the Fort Campbell area. A specific objective is to delineate the recharge area of Boiling Spring. Fort Campbell pumps approximately 6 million gallons of water per day from Boiling Spring, the primary source of drinking water for the Reservation. Developing an understanding of the source and recharge area of ground water pumped from Boiling Spring will allow Reservation officials to manage and protect the water supply from potential sources of pollution.

The hydrologic investigation at Fort Campbell involves a multidisciplinary approach. Major components of the investigation include:

- Well construction
- Dye-trace studies
- Ground-water level measurements
- Geophysical studies
- Stream discharge measurements
- Water chemistry analyses.

Notable findings of the investigation include the existence of deep, water-bearing openings in rock beneath the alluviated valley near Boiling Spring, and the direct hydraulic connection between surface streams and Boiling Spring. Well drilling identified the existence of the deep, water-bearing openings in bedrock. Five wells drilled into bedrock beneath the alluviated valley near Boiling Spring intercepted water-bearing openings at depths greater than 100 feet below land surface and had yields exceeding 35 gallons per minute. At four of these wells, yields from these deep openings exceeded 200 gallons per minute.

Dye-trace studies and discharge measurements verified the hydraulic connection between surface streams and Boiling Spring during low baseflow conditions. Dye placed in a stream reach adjacent to Boiling Spring was detected less than 2 hours later in water pumped from the spring. Simultaneous discharge measurements in the stream reach confirmed infiltration of surface water into the ground near Boiling Spring.

The multidisciplinary approach of this investigation involves the efforts of several hydrologists and hydrologic technicians from both the Tennessee and Kentucky offices of the USGS. Gregg Hileman, hydrologist from the Nashville office, is project chief. Chuck Taylor, hydrologist from the Louisville office, is responsible for the dye-trace component of the investigation. Data collection is scheduled for completion in the summer of 1995.

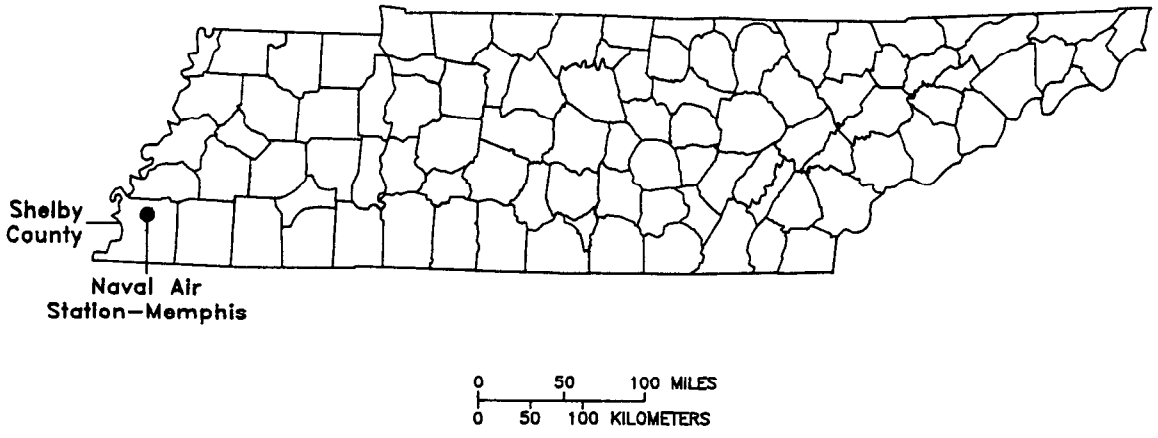
Investigation of the Hydrogeology of the Naval Air Station-Memphis near Millington in Shelby County, Tennessee

The USGS, in cooperation with the U.S. Department of the Navy, Southern Division Naval Facility Engineering Command (SOUTHDIV), Charleston, South Carolina, is providing technical assistance in hydrogeologic investigations under the Navy's Corrective Action Program at the Naval Air Station (NAS) Memphis near Millington in Shelby County, Tennessee. The project currently has two components. The first and highest priority component focuses on investigations within the NAS Memphis North Complex, which is scheduled to close and begin being reaccessed by the City of Millington in 1995 under the Base Realignment and Closure Act of 1990. The second component focuses on the NAS Memphis South Complex, which will be retained by the Navy, but will undergo realignment from a training facility to the headquarters for the Navy's Bureau of Personnel. The objectives of the USGS investigation are to:

- Prepare reports that describe the general hydrogeology of the area,
- Assist in the preparation and review of work plans and final reports that describe planned and completed field work, respectively, and
- Conduct Resource Conservation Recovery Act Facility Investigations at several Solid Waste Management Units (SWMU) to determine the possible occurrence and extent of contamination of soil, sediment, and ground water.

As part of the work performed at the NAS Memphis, the USGS has conducted soil-gas and surface-geophysical investigations at several of the SWMU's and has provided technical oversight of contractors in the use of Direct Push Technology and installation of stratigraphic test holes and monitoring wells by Rotosonic and other more-conventional drilling techniques. The USGS also has analyzed ground-water samples for tritium as an aid in determining the contamination potential of the Memphis aquifer which supplies some of the water used by the NAS Memphis and the City of Millington. Other investigative techniques that are planned include ground-water-level monitoring, borehole geophysics, additional surface geophysics, and aquifer testing. The USGS also has developed a series of modular computer programs linking various geographic-information-system coverages.

The computer programs are designed to simulate the ground-water flow system. The USGS-led parts of the investigations are under the direction of John K. Carmichael of the District office.



Location of the Naval Air Station-Memphis in Shelby County, Tennessee.

Potential for Interaquifer Leakage in the Memphis Area, Tennessee

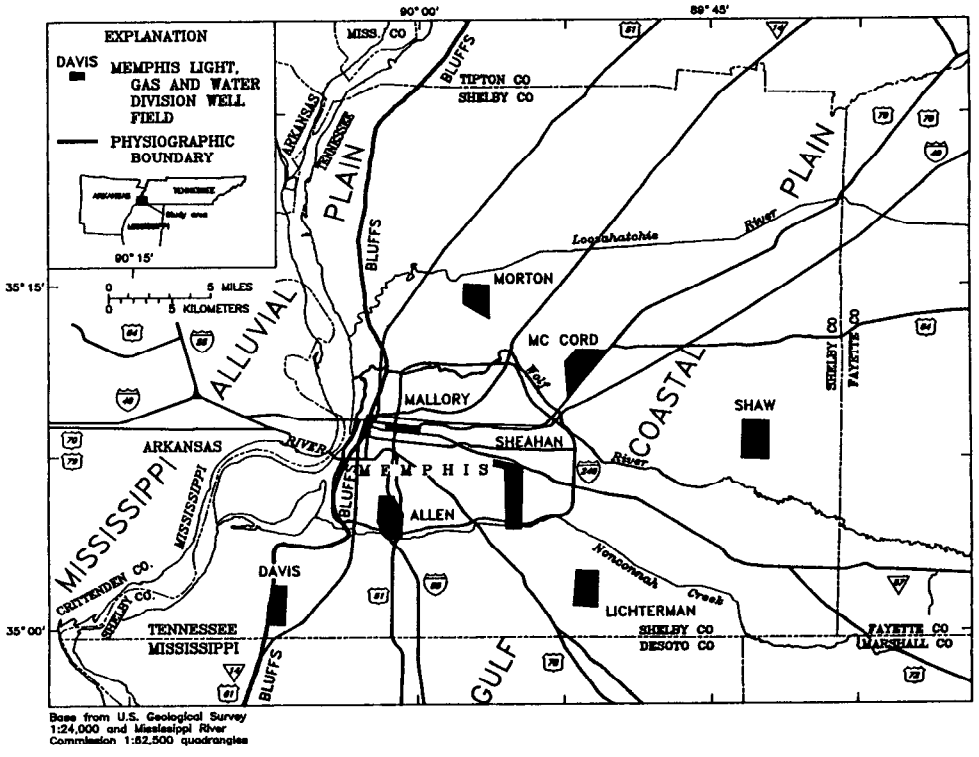
The USGS, in cooperation with the Memphis Light, Gas and Water Division of the City of Memphis, conducted a hydrogeologic investigation of the greater Memphis area from 1990 to 1992. The study focused on the hydrogeology and geologic structure of two principal aquifers underlying a 1,500-square-mile area in southwesternmost Tennessee and adjacent areas of Arkansas and Mississippi. The study was conducted in response to concerns that contaminants at or near land surface could be transported downward in water to degrade water in the Memphis aquifer, the principal source of public water supply for the Memphis area.

Detailed study was made of the Memphis Sand and Fort Pillow Sand, which represent the Memphis aquifer and Fort Pillow aquifer, respectively. Both formations are composed primarily of sand. More than 500 geophysical logs of wells were examined to make stratigraphic correlations of the formations underlying the area and to prepare structure-contour maps and geologic sections. Structure-contour maps and geologic sections show that the strata are broken by many faults with vertical displacements ranging from about 50 to 150 feet. In areas where the characteristic clay deposit between the surface aquifers and the Memphis aquifer is thin, upward displacement of fault blocks may have enhanced erosion of parts of the clay deposit, resulting in the formation of "windows" in the clay. The windows are areas where downward leakage of water from the water-table aquifers to the Memphis aquifer can occur.

The investigation was conducted by James A. Kingsbury and William S. Parks of the Memphis Subdistrict office.

PUBLICATION

Kingsbury, J.A., and Parks, W.S., 1993, Hydrogeology of the principal aquifers and relation of faults to interaquifer leakage in this Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4075, 18 p.



Location of the study area.

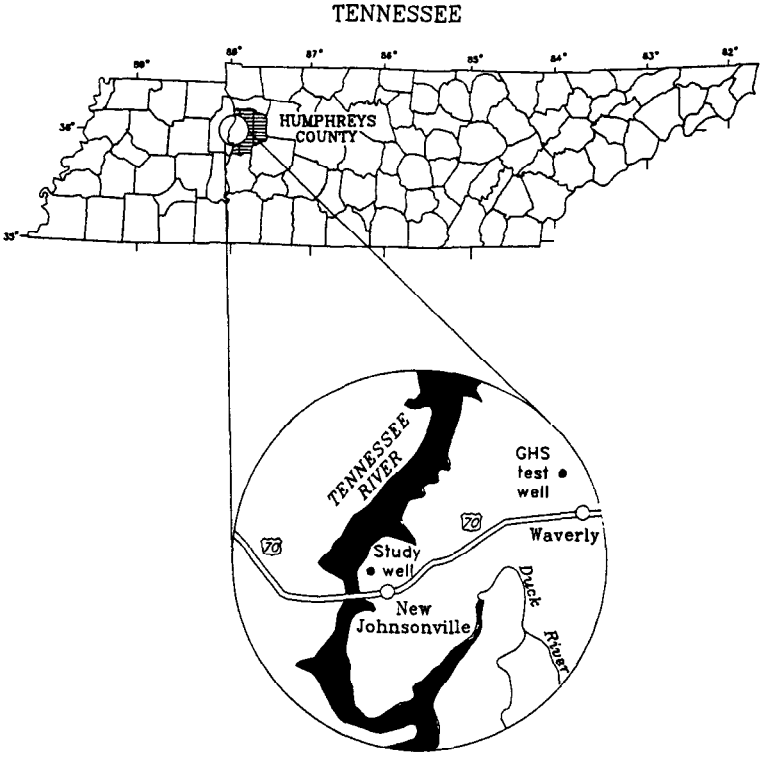
Geology and Hydrology of Deeper Rocks in West-Central Tennessee

Relatively few wells in west-central Tennessee have been drilled to depths greater than a few hundred feet; consequently, the geologic and hydrologic characteristics of the deeper rock in the region are known for the most part in general terms only. Recently, a study well was completed at a depth of 8,765 feet at the E.I. du Pont de Nemours & Company (Du Pont) titanium-dioxide processing plant in New Johnsonville, Humphreys County. The well fully penetrated the strata of sedimentary origin and terminated in basement rock of igneous origin. The purpose of the well was to provide geologic and hydraulic information about the deeper formations underlying the plant, particularly those formations below a depth of 3,000 feet.

Study of the strata by Du Pont and its contractors yielded considerable information useful for refining knowledge of the geology of this area, and is complementary to on-going studies of the U.S. Geological Survey (USGS) in the region. To provide earth-science information of public interest, Humphreys County, in cooperation with the USGS, published an atlas summarizing the significant geologic and hydraulic findings of the study. An atlas was compiled by both Du Pont and USGS personnel from information contained in an unpublished site report provided by DuPont.

Some of the findings of the study are:

- The well penetrated 32 named stratigraphic units between land surface and the top of basement rock.
- The interval from 769 feet deep (the top of the interval studied) to 7,342 feet deep consists primarily of limestone and dolomite.
- Sandstone predominates from 7,342 to 7,513 feet deep.
- Basement rock consists of interlayered felsic tuff and diabase gabbro (7,513 to 8,227 feet deep), followed by gabbro (8,227 feet to terminal depth of 8,765 feet).
- No fractures were identified above the Wells Creek Formation (top, 1,582 feet deep); a few fractures were identified in that unit, and numerous fractures were identified in underlying formations.
- The two most permeable formations in the column are the Mascot Dolomite (1,927 to 3,093 feet deep) and the Copper Ridge Dolomite (4,057 to 5,409 feet deep).



Location of the New Johnsonville-site study well.

David Webster of the District office represented the USGS in the effort.

PUBLICATION

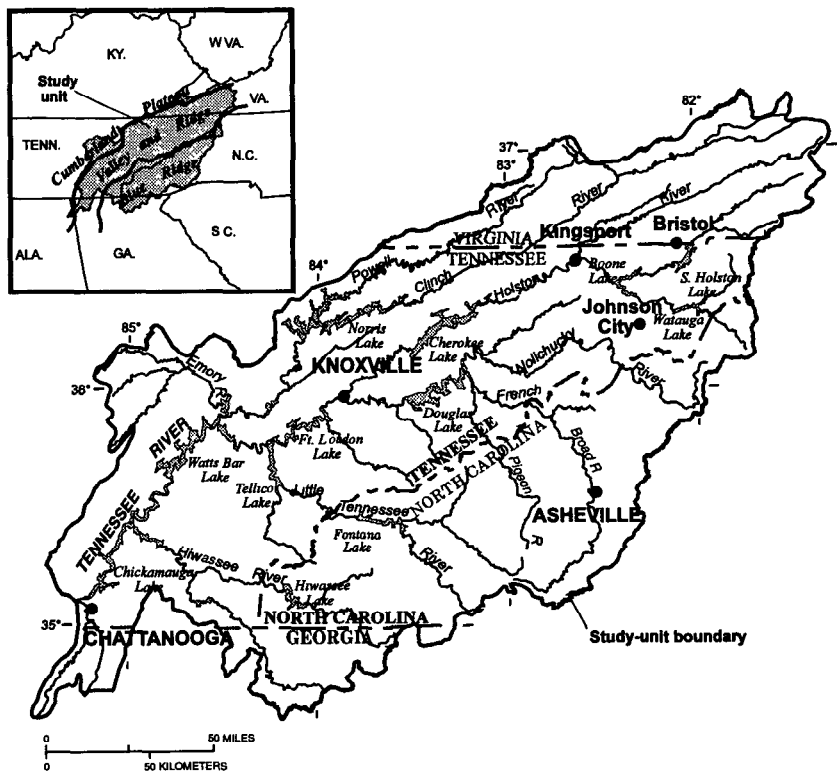
Webster, D.A., Macconi, J.R., Stehle, D.E., and Collins, D.J., compilers, 1993, Subsurface geology and hydraulic data from 769- to 8,765-feet depth at the Johnsonville-site study well, Humphreys County, Tennessee: Humphreys County, Tennessee, unnumbered atlas, 1 sheet.

Upper Tennessee River Basin Study Unit of the National Water-Quality Assessment Program

The National Water Quality Assessment (NAWQA) Program was established to (1) describe, in a nationally consistent manner, the status of and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to (2) provide a sound, scientific understanding of the principal natural and human-related factors affecting the quality of these resources. The program is expected to produce water-quality information needed by policy makers and water managers at State, Federal, and local levels.

The upper Tennessee River basin study unit is one of 60 such study units in the Nation. It encompasses the Tennessee River drainage basin upstream of Chattanooga, and includes parts of Tennessee, North Carolina, Virginia, and Georgia. This study unit began assessment activities in 1994. Activities have included many meetings with public and private agencies to discuss and coordinate the NAWQA program. These meetings have resulted in an identification and prioritization of several water-quality issues of regional and local interest, a determination of sources of water-quality data and other information, and assistance in the design and scope of project elements.

The study, under the direction of Paul S. Hampson of the Knoxville office, is scheduled to continue for several years.



Location of the upper Tennessee River basin NAWQA study unit.

Effects of Contaminants from an Abandoned Wood-Preserving Plant site on the Quality of Ground Water and Surface Water at Jackson, Tennessee

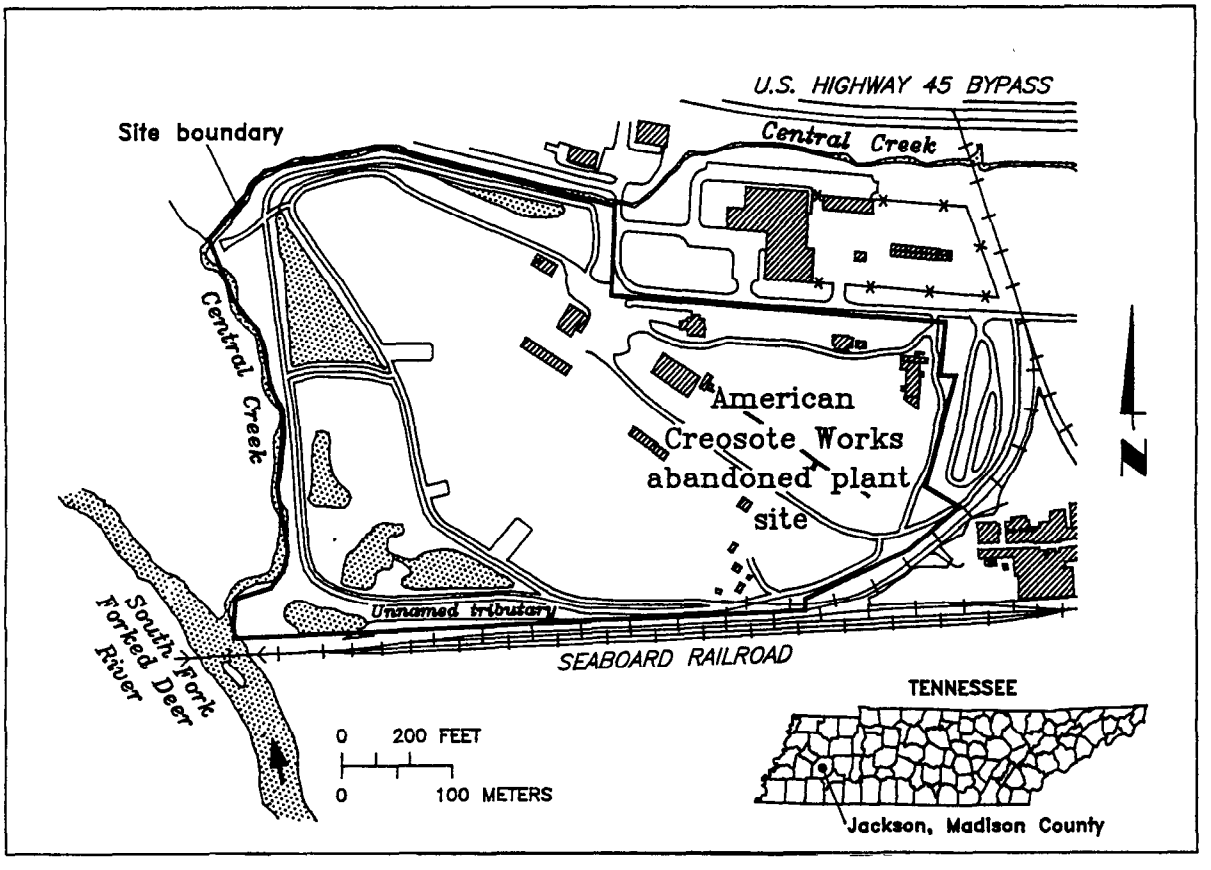
The USGS, in cooperation with the North Superfund Remedial Branch, Waste Management Division of the U.S. Environmental Protection Agency (USEPA), Region IV, conducted an investigation to determine the effects of contaminants from the American Creosote Works, Inc. abandoned plant site at Jackson, Tennessee, upon the water resources of the surrounding area. This facility, used for impregnating wood with preservatives, was operated for about 50 years and was closed in 1981. Operations at the plant site resulted in the soils, ground water, and nearby streams becoming contaminated with significant levels of wood-preserving chemicals. In 1984, the site was designated a Superfund site by the USEPA and placed on the National Priorities List.

The objectives of the investigation were to determine and document toxological effects of the spills and leakages on nearby streams, to identify and delineate the extent of off-site contaminants in ground water, and to assess the potential for transport of contaminants now in ground water to wells used for water supply within a 2-mile radius of the site.

The study was completed in 1993, and results have been published in four reports. Some of the highlights are:

- A small creek along the western site boundary contained pentachlorophenol, a wood preservative, in concentrations greater than Tennessee's criterion maximum for fish and aquatic life, and naphthalene, the most abundant single constituent of coal tar used in creosote.

- Fish from the creek contained small concentrations of creosote.



Base modified from S&ME, Inc., 1989.
Location of abandoned wood-preserving plant at Jackson, Tennessee.

- The bottom sediment of both the creek and the receiving stream (the North Fork Forked Deer River) contained large concentrations of numerous organic chemicals associated with past plant operations. Elutriates of the sediment were slightly to highly toxic to various aquatic test organisms.

- Direct Push Technology was evaluated and found successful as a method for obtaining lithologic data and ground-water samples.

- Gas chromatography with photo-ionization detection and high-performance liquid chromatography proved to be more effective for detecting creosote components, pentachlorophenol, and other organic compounds than the CHEMetrics phenol method of analysis or microtox toxicity bioassays.

- Most of the organic-compound contaminants detected in ground water were in samples from wells tapping the shallow aquifer. Concentrations were below the State's primary contaminant levels for drinking water.

- Low concentrations of six organic compounds were detected in wells screened in the deeper aquifer, including wells operated by the city of Jackson, but compounds that commonly characterize contamination from wood-preserving processes were not detected. This implies that the compounds identified were from a source other than the abandoned plant.

This investigation was under the direction of William S. Parks of the Memphis Subdistrict office and John K. Carmichael of the District office.

PUBLICATIONS

Bradfield, A.D., Flexner, N.M., and Webster, D.A., 1993, Water quality, organic chemistry of sediment, and biological conditions of streams near an abandoned wood-processing plant site at Jackson, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4148, 50 p.

Parks, W.S., Carmichael, J.K., and Mirecki, J.E., 1993, Evaluation of subsurface exploration, sampling, and water-quality analysis methods at an abandoned wood-preserving plant site at Jackson, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4108, 22 p.

Parks, W.S., Mirecki, J.E., and Kingsbury, J.A., 1993, Hydrogeology, ground-water quality, and potential for water-supply contamination near an abandoned wood-preserving plant site at Jackson, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4170, 76 p.

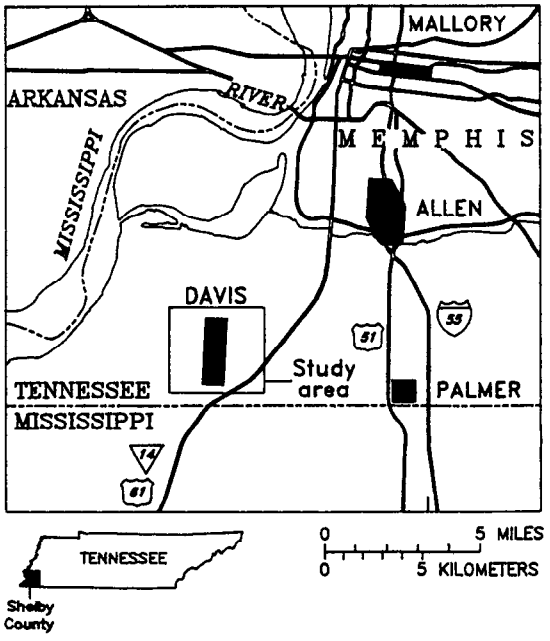
Yanosky, T.M., and Carmichael, J.K., 1993, Element concentrations in growth rings of trees near an abandoned wood-preserving plant site at Jackson, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4223, 68 p.

Investigation of Water-Quality Changes at Davis Well Field in Memphis, Tennessee

In cooperation with the Memphis Light, Gas and Water Division (MLGW) and Memphis State University (the University of Memphis since July 1994), the USGS conducted an investigation of the water-quality changes at the Davis well field. Significant water-quality changes have taken place in the wells screened in the Memphis aquifer at the Davis well field located in southwest Memphis, where withdrawals began in 1971. The largest changes have been increases in alkalinity and hardness, which occurred at five wells on the western margin of the well field. The objectives of the investigation were to characterize the water quality in the three hydrogeologic units (the alluvium, fluvial deposits, and Memphis Sand) at the Davis well field and to determine the source of the water causing the changes in water quality.

The investigation was conducted from 1992-94. The water quality of each aquifer was characterized by analyzing water samples from many wells, 12 of which were constructed for this study. The source of water causing changes in water quality was determined by observations noted during drilling, analysis of geophysical logs of wells, chemical data, and a computer model of the geochemistry of the aquifer system. Drilling observations and geophysical logs indicated that the protective clay deposit between the water-table aquifers and the Memphis aquifer is absent at some of the wells drilled. A comparison of constituents, including isotopes of hydrogen and carbon, in water samples from the water-table and the Memphis aquifers indicated that younger, more mineralized water in the Mississippi River Valley alluvial aquifer is flowing downward to the Memphis aquifer. A computer simulation showing the effects of mixing water from the two aquifers indicated that water from the well most affected by water-quality changes represented a mixture of about 3 to 18 percent alluvial aquifer water and 97 to 82 percent Memphis aquifer water.

The investigation was completed in 1994. It was under the direction of William S. Parks of the Memphis Subdistrict office.



Location of study area.

Ground-Water Quality of the Upper Knox Aquifer, Middle Tennessee

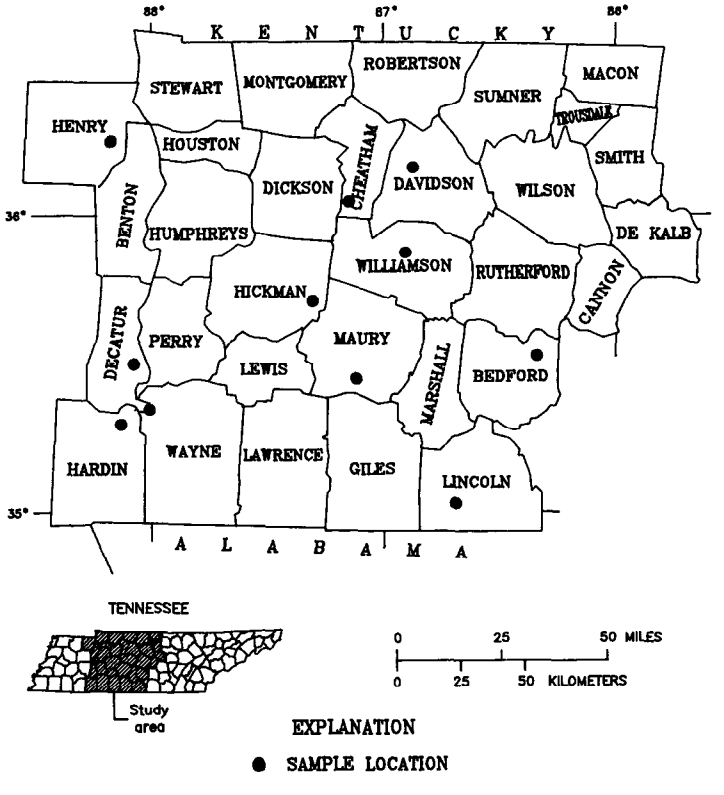
The upper Knox aquifer in Middle Tennessee consists of a paleokarst system that occurs in the upper 200 to 300 feet of the Mascot Dolomite of the Knox Group. Water from the upper Knox aquifer in parts of Middle Tennessee is used for rural, domestic supply. An investigation was conducted by the USGS in cooperation with Humphreys County to determine recharge and discharge areas and to evaluate the water quality of this aquifer, using historical data and water samples collected from about 10 wells throughout Middle Tennessee. These water samples were analyzed for major constituents and trace metals, and for carbon-14 and chlorine-36 to determine the apparent age of the ground water.

Based on the chemical data, it appears that most recharge to the upper Knox aquifer occurs in the Central Basin. The ground water reacts with the aquifer matrix to become more mineralized along flow paths. Regional ground-water flow appears to be primarily to the west.

In the recharge areas, ground water in the upper Knox aquifer is primarily of the calcium sulfate bicarbonate type and typically has less than 1,000 milligrams per liter dissolved solids. The dissolved-solids concentration increases and the water type changes toward the west. West of the Tennessee River, water from the upper Knox aquifer in Henry County is a sodium bicarbonate type with more than 5,000 milligrams per liter dissolved solids.

In the southwestern Highland Rim, the quality of water from the upper Knox aquifer remains similar to that in the recharge area. This might indicate that water flows more rapidly to discharge points which could be near the Tennessee River.

The investigation was conducted under the direction of Michael W. Bradley of the District office.



Location of study area.

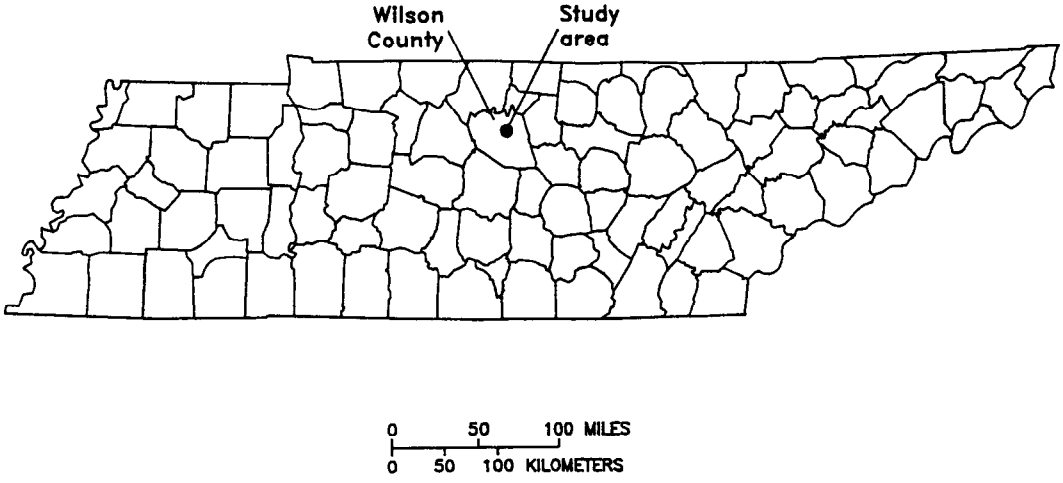
Occurrence of Bacteria in Ground Water near Lebanon, Tennessee

The USGS, at the request of the U.S. Environmental Protection Agency, investigated the possible occurrence of bacteria in ground water near the Cedars of Lebanon State Park in Lebanon, Tennessee. The study area is underlain by a karst limestone aquifer that has numerous caves and sinkholes. Water samples were collected from six sites in June 1992 and analyzed for total coliform, fecal coliform, and fecal streptococci bacteria.

A background water sample was collected from a local supply well that obtains water from solution openings in the limestone aquifer. The water sample from this site contained 350 colonies per 100 milliliters (cols./mL) total coliform, 45 cols./100 mL fecal coliform, and 64 cols./100 mL fecal streptococci bacteria. Other water samples were collected from a small seep, streams within two cave systems, and a local pond.

Samples from two tributary streams in one of the caves also contained bacteria. Separate streams occurred in two branches of this cave system. The water sample collected from one branch contained 48 cols./100 mL total coliform, about 6 cols./100 mL fecal coliform, and about 9 cols./100 mL fecal streptococci bacteria. The water sample collected from the second branch contained 4,900 cols./100 mL total coliform, about 270 cols./100 mL fecal coliform, and 50 cols./100 mL streptococci bacteria.

Michael W. Bennett of the Nashville Subdistrict office was in charge of field operations.



Location of study area in Wilson County, Tennessee.