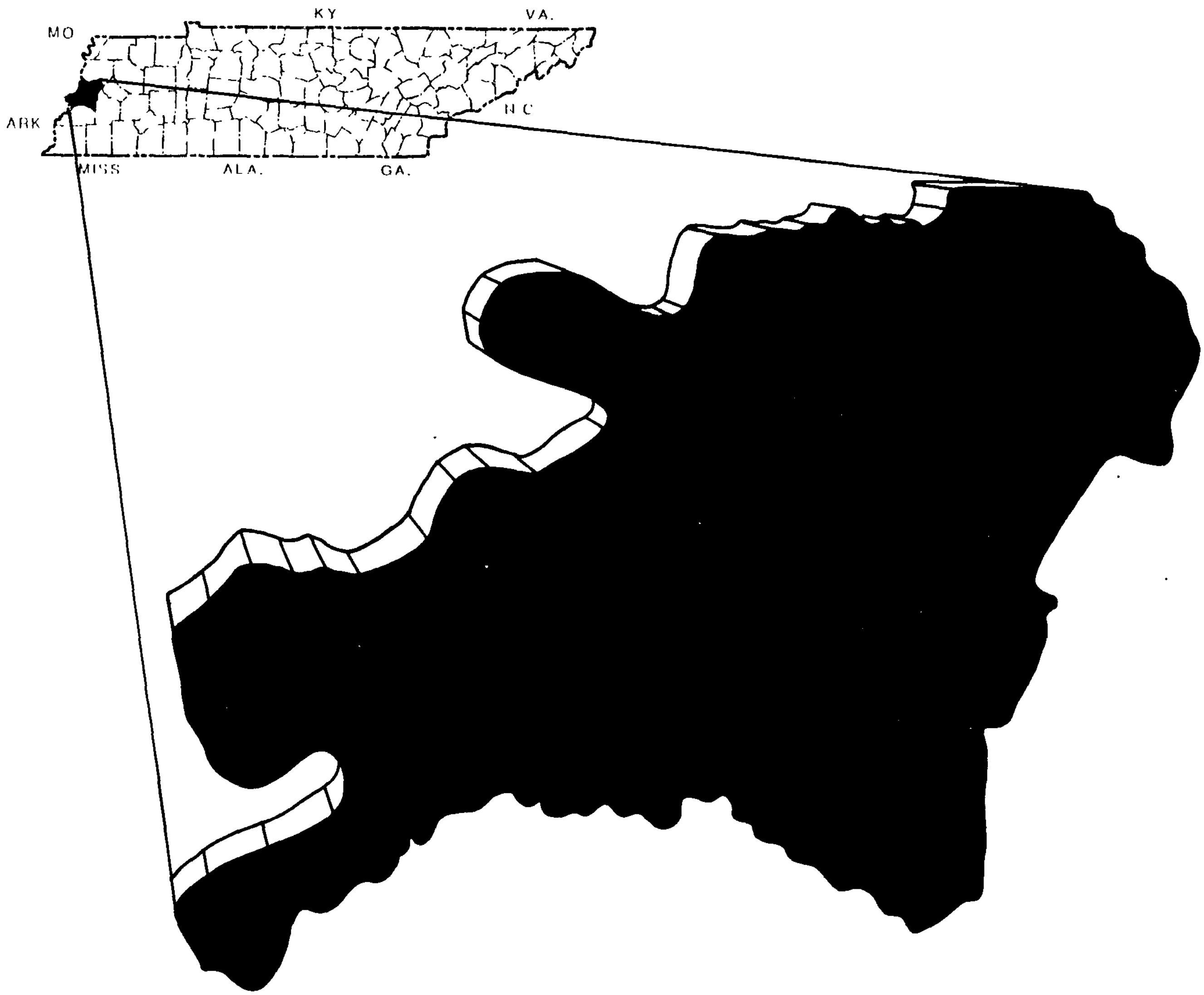
WATER-RESOURCES INVESTIGATIONS REPORT
84-4104

Preliminary Assessment of Ground-Water Resources of Lauderdale County, Tennessee



PREPARED BY

U.S. GEOLOGICAL SURVEY

IN COOPERATION WITH THE

TENNESSEE DEPARTMENT OF CONSERVATION,
DIVISION OF GEOLOGY

PRELIMINARY ASSESSMENT GROUND-WATER RESOURCES OF LAUDERDALE COUNTY, TENNESSEE

By W. S. Parks, J. K. Carmichael, and D. D. Graham

U.S. GEOLOGICAL SURVEY

Water Resources Investigations Report 84-4104

Prepared in cooperation with the

TENNESSEE DEPARTMENT OF CONSERVATION,

DIVISION OF GEOLOGY

Memphis, Tennessee
1985

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Lakewood, Colorado 80225
(Telephone: (303) 236-7476)

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

To convert inch-pound units to International System of units (SI)

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
ton, short (2,000 lb)	0.9072	metric ton
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
cubic foot per day per foot $(ft^3/d)/ft$	0.0929	cubic meter per day per meter $(m^3/d)/m$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

Well-Numbering System: Wells are identified according to the numbering system used by the U.S. Geological Survey throughout Tennessee. The well number consists of three parts: (1) an abbreviation of the name of the county in which the well is located; (2) a letter designating the 7½-minute quadrangle, or 7½-minute quadrant of the 15-minute quadrangle, on which the well is plotted; and (3) a number generally indicating the numerical order in which the well was inventoried. The symbol Ld:H-16, for example, indicates that the well is located in Lauderdale County on the "H" quadrangle and is identified as well 16 in the numerical sequence. The quadrangles are lettered from left to right, beginning in the southwest corner of the county.

PRELIMINARY ASSESSMENT OF GROUND-WATER RESOURCES OF LAUDERDALE COUNTY, TENNESSEE

By W. S. Parks, J. K. Carmichael, and D. D. Graham

ABSTRACT

The ground-water resource in Lauderdale County is in a rudimentary stage of development. Average withdrawal in 1982 was 3.1 million gallons per day by the main water-supply systems.

The principal shallow aquifers, from youngest to oldest, are the Mississippi alluvial deposits of Quaternary age and the Cockfield Formation, Memphis Sand, and Fort Pillow Sand of Tertiary age. The alluvial deposits, Cockfield, and Memphis Sand presently yield water for domestic, farm, industrial, irrigation, and public supplies. Existing wells range from less than 100 feet to as much as 800 feet in depth and pump from 5 to 1,500 gallons per minute. The deeper Fort Pillow Sand is, as yet, untapped.

Water levels fluctuate seasonally. High water-levels generally occur in the winter, spring, or early summer, and low water-levels occur in the fall or early winter. Water levels range from near land surface to as much as 275 feet below land surface--depending on the aquifer, location, and land-surface altitude.

Water from the Mississippi alluvial deposits, Cockfield Formation, and Memphis Sand is a calcium bicarbonate type and is generally of good quality. Undesirable parameters from the stand point of use are hardness and concentrations of dissolved iron and dissolved solids. Hardness is highest in the alluvial deposits (median value--from available analyses-- 354 milligrams per liter, as $CaCO_3$) and lowest in the Memphis Sand (median value-- 84 milligrams per liter, as $CaCO_3$). Dissolved iron concentrations are highest in the alluvial deposits (median value-- 11,200 micrograms per liter) and lowest in the Cockfield (median value--1,900 micrograms per liter). Dissolved solids concentrations are highest in the alluvial deposits (median value--402 milligrams per liter) and lowest in the Memphis Sand (median value--112 milligrams per liter). Although no water-quality data are available for the Fort Pillow Sand in Lauderdale County, this aquifer is known to have potential to yield a sodium bicarbonate type water of somewhat better quality than is available from the shallower aquifers.

Values of transmissivity estimated from four single-well pumping tests are 17,700 and 24,100 cubic feet per day per foot for the Mississippi alluvial deposits, 1,500 cubic feet per day per foot for the Cockfield Formation, and 8,000 cubic feet per day per foot for the Memphis Sand. Because of partial penetration of the aquifers, these values of transmissivity may not be indicative of the total thickness of the individual aquifers.

Several north-northeast and west-northwest trending faults and their approximate locations are identified by correlation of the Cook Mountain on the geophysical logs of test holes and wells.

INTRODUCTION

During the oil crises in the mid 1970's, energy companies gave new consideration to Gulf Coastal Plain lignite as an alternative source of energy. Several companies became involved in extensive exploration programs in Alabama, Arkansas, Louisiana, Mississippi, Tennessee, and Texas. Western Tennessee was a target area for some of this exploration. Luppens (1978), in a paper on exploration for Gulf Coastal Plain lignite deposits, gave a preliminary estimate of 1.0 billion tons of lignite reserves in Tennessee and some general information about its occurrence and quality.

Because of the need for information about lignite in western Tennessee for use in appraising this resource, and the need for background information about the hydrology for use in determining any effects of future mining on the hydrologic system, the Tennessee Division of Geology and the U.S. Geological Survey initiated a cooperative project to begin collecting and compiling some of these data.

Lauderdale County, in western Tennessee, is thought to be one of the most likely areas for mining to begin. Consequently, Lauderdale County was selected for this initial study. In a division of effort, according to the priority interests of each agency, the Division of Geology was to collect and compile information concerning the geologic formations and occurrence of lignite and the U.S. Geological Survey was to do likewise in regards to the water resources.

The first phase of the U.S. Geological Survey's effort was to prepare a plan to study the surface and ground-water resources of Lauderdale County. The general objectives of this planning effort were to locate and compile available hydrologic, geologic, land-use, and associated data; prepare a summary description of the surface and shallow subsurface hydrologic system; outline the need for additional background hydrologic information; and propose plans to monitor the effects of strip-mining. This phase of the study was completed with the publication of a report by Parks (1981).

Purpose and Scope

Because of the immediate need for information concerning the subsurface formations, first priority was placed on a study of the ground water rather than the surface water in Lauderdale County.

The objectives of the ground-water study were to develop a concept of the geohydrology, water quality, transmissivity, potentiometric surfaces, and water-level fluctuations of the shallow aquifers.

These objectives were met by:

- o drilling test holes and installing observation wells;
- o installing pumps on wells for conducting single-well pumping tests in observation wells and obtaining water-quality data from these wells;
- o installing shelters and recorders on observation wells for the collection of continuous water-level data;
- o locating and selecting water wells for measurement of water levels to be used in the preparation of areal water-level maps;
- o maintaining the water-level and water-quality data collection networks and preparing a progress report.

Although limited to a county area, this study has regional impact inasmuch as it involves the principal Tertiary and Quaternary aquifers that provide ground water for a large part of the northern Mississippi embayment. The information will be of use not only as comparative data in future studies assessing the effects of mining of lignite on the ground-water resources but also in planning future ground-water supplies for Lauderdale County.

Location and Size of Lauderdale County

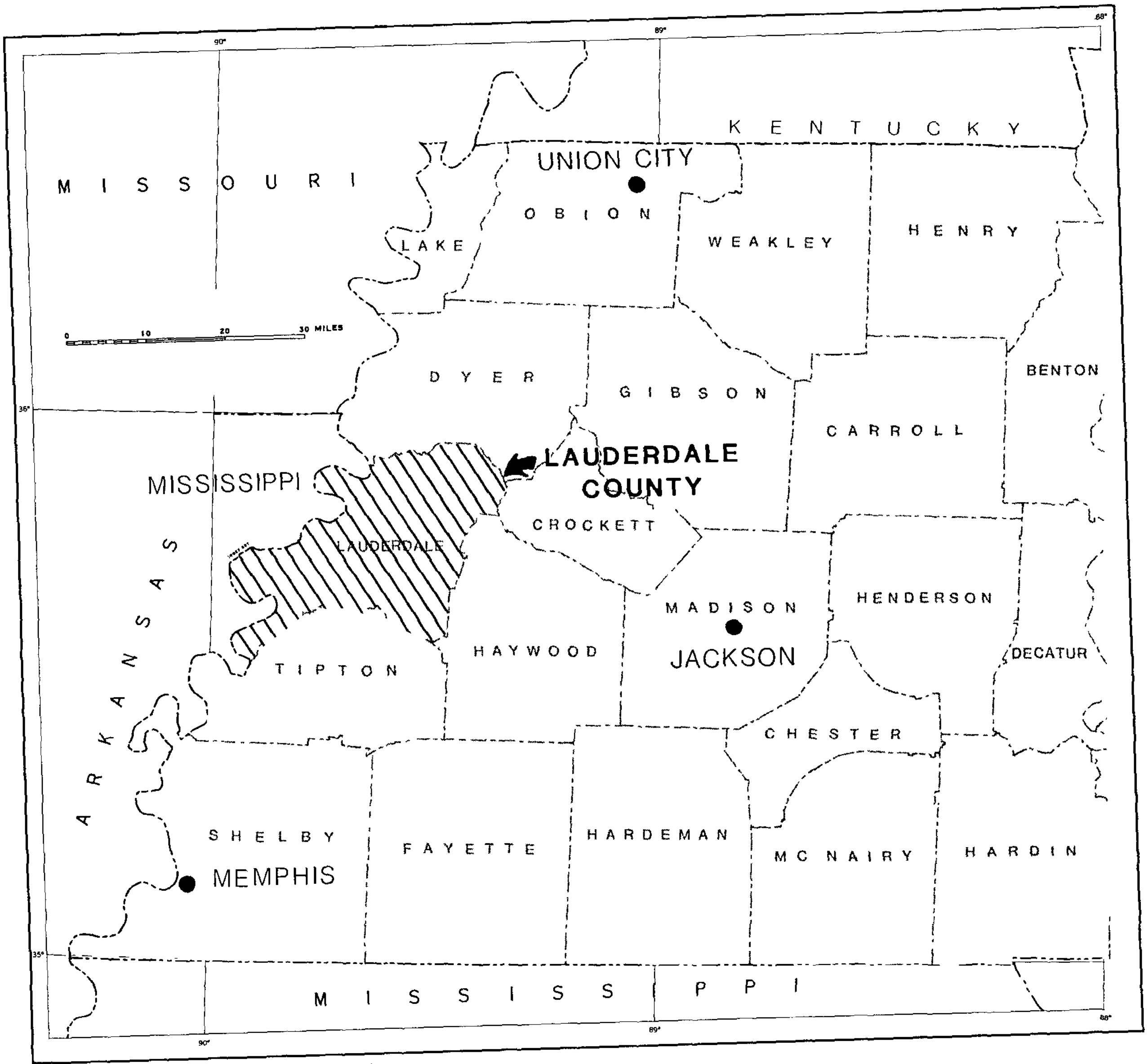
Lauderdale County is in the westernmost tier of counties in western Tennessee about midway between the Mississippi and Kentucky State lines (fig.1). The county has an area of 477 square miles and is very irregular in shape. It is bounded on the north by Dyer County, on the east by Crockett and Haywood Counties, on the south by Tipton County in Tennessee, and on the west by Mississippi County in Arkansas. Natural features that form parts of the boundary are the Mississippi River on the west, the Obion and Forked Deer Rivers on the northwest, the South Fork Forked Deer River on the northeast, and the Hatchie River on the south (fig. 2).

Previous Investigations

Glenn (1906, p. 91-96) and Wells (1933, p. 210-219) in reports describing the ground-water resources in western Tennessee on a county-by-county basis gave general information about the stratigraphy and the ground-water supplies in Lauderdale County. Although the stratigraphy is now out-of-date insofar as nomenclature is concerned, these reports provide historical data about early ground-water supplies and some information about the geology. Lanphere (1955) described the geologic source and chemical quality of public ground-water supplies in western Tennessee. That report (p. 38-40, 57-58) includes details concerning the water-supply systems at Halls, Henning, and Ripley. Strausberg and Schreurs (1958, pl. 1, 2, 4; table 4, 5) in an unpublished report on the ground-water resources of the Mississippi Valley of Tennessee included the locations of some wells in the Mississippi alluvial deposits in Lauderdale County and some data on water levels and quality of water.

Milhous (1959) compiled driller's logs and sample descriptions for Tennessee by counties. He gave logs for three early oil-test wells in the county (p. 233-239). Krinitzsky and Wire (1964) described the ground water in the alluvium of the Lower Mississippi Valley. They presented contour maps of the Tertiary surface and piezometric-surface maps for the Mississippi alluvial deposits. Moore (1965, pl. 1-8, fig. 4), in a report on the geology and hydrology of the Claiborne Group in western Tennessee, included structure-contour maps, geophysical cross sections, and a fence diagram along with maps of the apparent and potential coefficient of transmissiblity (transmissivity), the downdip changes in chemical quality of water, and the piezometric (potentiometric) surface in the "500-foot" sand (Memphis Sand). These illustrations provide some general information about the Claiborne aquifers in Lauderdale County.

The Tennessee Department of Public Health (1964-65) published a ground-water survey of western Tennessee. That report includes a summary (table 18) of the water-supply system at Ripley and gives chemical analyses and radiological data of composite raw water sampled in 1964-65. Moore and Brown (1969) give detailed information on the stratigraphy and ground-water resources gained by drilling



Base map from U S. Geological Survey 1 1,000,000,1973

Figure 1.-- Location of Lauderdale County in western Tennessee.

a 3,183-foot test hole into Paleozoic rocks within Fort Pillow State Historic Area. That report introduced some new nomenclature for the subsurface geologic units of western Tennessee and re-evaluates certain interpretations presented by Moore in his 1965 report.

Parks (1981) in an appraisal of hydrologic information needed in anticipation of future lignite mining in Lauderdale County summarized available hydrologic information and located data sources. That report includes a summary description of the surface and shallow subsurface hydrologic system. Stearns and others (1981, p. 27-37) in a report on the impact of proposed lignite mining in western Tennessee described the geology of Lauderdale County as related to the occurrence of lignite. That report (p. 41-120) includes the results of a detailed study of the lignite, overburden, associated water, and leachate at a test site on the Fort Pillow State Prison Farm.

PHYSIOGRAPHIC SETTING

Lauderdale County is situated in two major physiographic subdivisions (fig. 2). The eastern part of the county is in the East Gulf Coastal Plain section and the western part is in the Mississippi Alluvial Plain section of the Coastal Plain province (Fenneman, 1938, p. 65-99). In Tennessee, the Gulf Coastal Plain section may be subdivided into the West Tennessee Uplands and the West Tennessee Plain (Miller, 1974, p. 7). The Gulf Coastal Plain area of the county is entirely in the West Tennessee Plain.

Gulf Coastal Plain

The Gulf Coastal Plain (or West Tennessee Plain) in Lauderdale County is characterized by gently rolling to steep topography formed as the result of erosion of geologic formations of Tertiary and Quaternary age. During the later stages of Pleistocene glaciation, this topography was covered by a relatively thick blanket of loess that makes up the present land surface. The gently rolling to steep topography is broken at many places by the flat-lying flood plains of streams that cross the area. Perhaps the most distinctive feature of the Gulf Coastal Plain is the loess covered bluffs that rise abruptly above the Mississippi Alluvial Plain at its eastern boundary. Land surface altitudes in the Gulf Coastal Plain are as low as 215 feet above sea level on the banks of the Hatchie River where it enters the Mississippi Alluvial Plain in the southwestern part of the county and are as high as 520 feet above sea level on hills near Edith in the north-central part. Maximum local relief between the Gulf Coastal Plain and the Mississippi Alluvial Plain is about 250 feet on the bluffs west of Edith.

Mississippi Alluvial Plain

The Mississippi Alluvial Plain in Lauderdale County is a flat-lying area averaging about 6 miles in width and extending about 35 miles in length in a northeast-southwest direction. The Alluvial Plain is characterized by features typical of fluvial deposition--point bars, abandoned channels, and natural levees (Saucier and others, 1964-78). Local features include alluvial fans deposited outward from the base of the bluffs where streams draining the rugged topography of the dissected Gulf Coastal Plain enter the flat-lying Alluvial Plain. Land-surface altitudes in the Alluvial Plain are as low as 210 feet above sea level on the banks of the Mississippi River in the southwestern part of the county and are as high as 290 feet above sea level on the alluvial fan of Knob Creek in the northern part. Maximum local relief is probably no more than 10 or 20 feet.

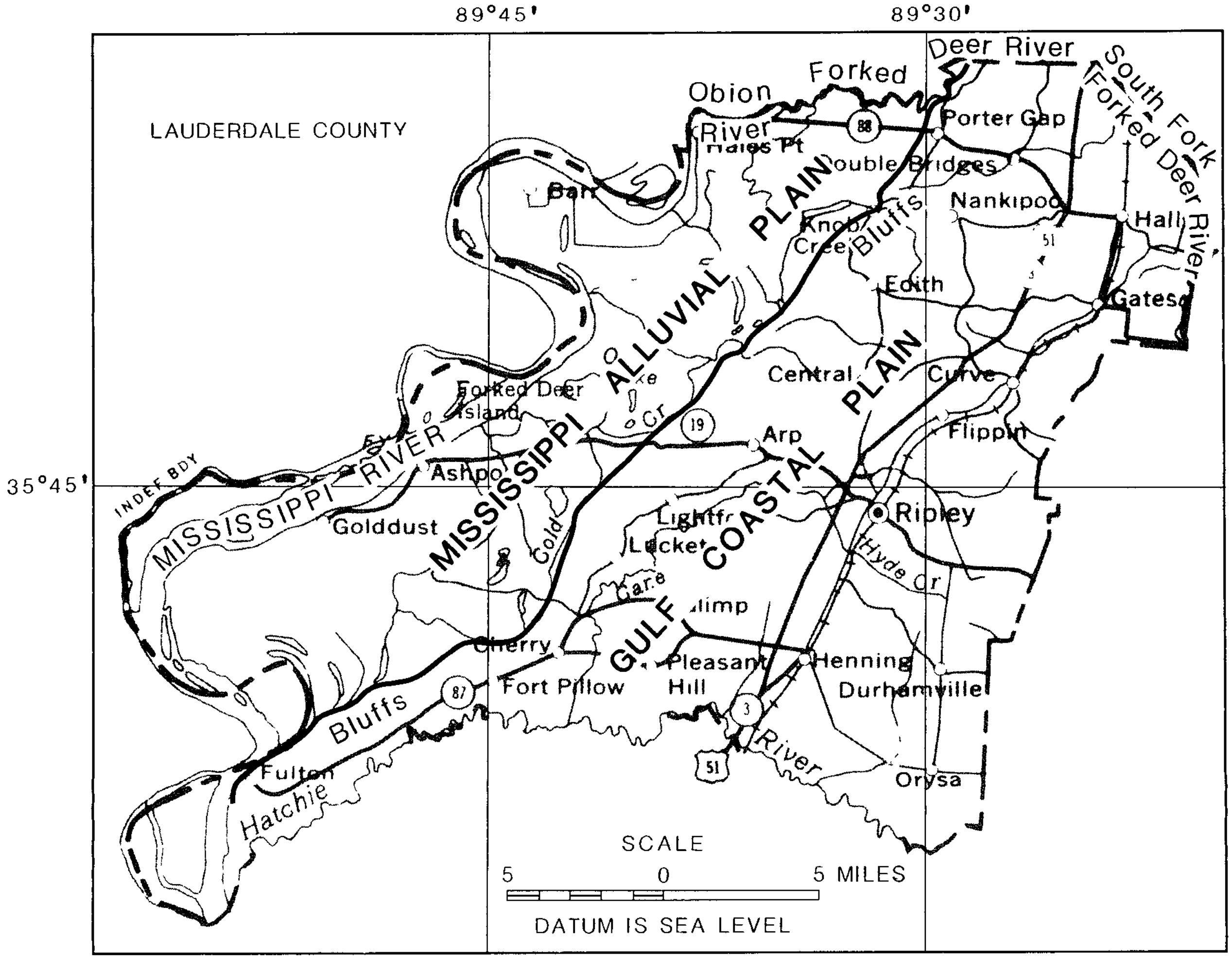
GEOLOGY

Lauderdale County is in the north-central part of the Mississippi embayment, a broad trough or syncline that plunges southward along an axis which approximates trend of the Mississippi River (Cushing and others, 1964, p. B21). This trough or syncline is filled with a wedge of several thousand feet of sediments of Cretaceous, Tertiary, and Quaternary age. These sediments make up geologic formations that dip gently westward into the embayment and southward down its axis.

Surface Geology

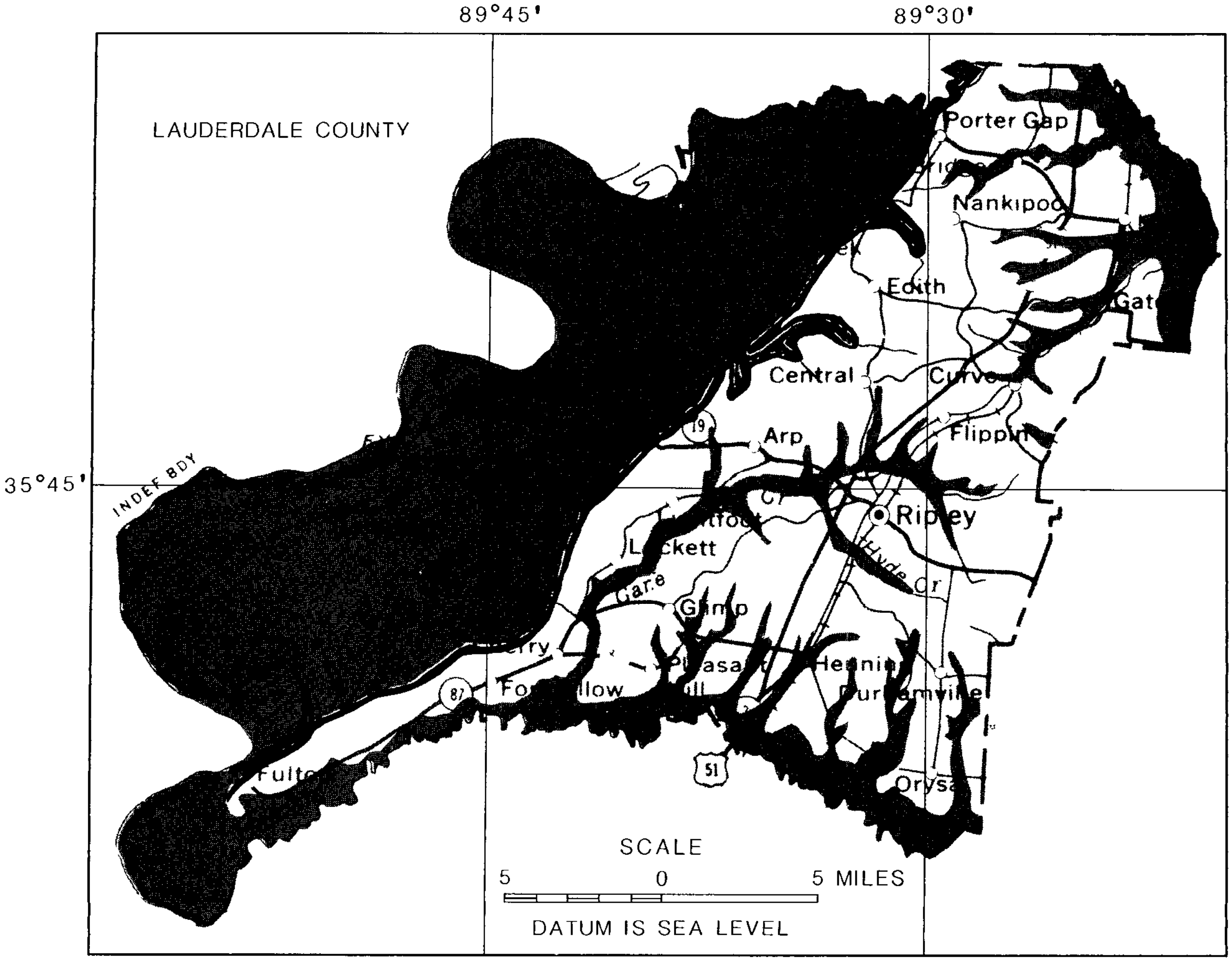
The surface geology of Lauderdale County for the most part is relatively uncomplicated. The oldest geologic units at the surface are the Cockfield Formation of the Claiborne Group and the overlying Jackson Formation (fig. 3). Because of a similarity in lithology and limited exposures, these units cannot be reliably subdivided at most places on the basis of present information. However, no great thickness of Jackson Formation is believed to be present. Most of the stratigraphic section referred to as the "Jackson (?) Formation" on the most recent geologic map of Tennessee by Hardeman and others (1966) is actually the equivalent of the Jackson and Cockfield Formations.

The Jackson and Cockfield Formations are exposed locally in the Gulf Coastal Plain in the lower parts of the bluffs and in stream channels. Above the Jackson and Cockfield are the fluvial deposits



Base from U.S. Geological
Survey 1:500,000, 1973

Figure 2.-- Major physiographic subdivisons.



Base from U.S. Geological
Survey 1:500,000, 1973

Figure 3.-- Generalized surface geology.

EXPLANATION

- Qal-- Alluvial deposits
- Ql-- Loess
- QTfjc-- Fluvial deposits, Jackson and Cockfield Formations, undivided

See table 1 for additional information.

(terrace deposits), which are erosional remnants of ancient alluvial deposits of the existing or earlier drainage systems (Russell and Parks, 1975, p. B30). The fluvial deposits are exposed locally along the bluffs, on the steep valley walls, and in sand and gravel pits. The loess, which is primarily wind-blown silt, forms the principal surface formation in the Gulf Coastal Plain. The loess covers fluvial deposits and the Jackson and Cockfield Formations at most places. The youngest geologic unit in the county are the alluvial deposits (alluvium) which underlie the Mississippi Alluvial Plain and the flood plains of streams in the county.

Subsurface Geology

Thirteen test holes were drilled during this investigation to collect information about the subsurface formations and occurrence of lignite and to locate water-bearing sands in which to install observation wells. Initially, it was planned to drill these test holes through the Cockfield Formation and terminate them in the Cook Mountain Formation, except for two shallow holes which were to be drilled only through the Mississippi alluvial deposits. The Cook Mountain was selected as the interval in which to terminate the deeper test holes because it is believed that most of the potentially mineable lignite is in the overlying Cockfield. Consequently, the Cockfield and, where present, the Mississippi alluvial deposits would be the principal shallow aquifers most affected by mining. The Cook Mountain also serves as the confining bed for the underlying Memphis Sand. As the drilling progressed, however, it was found that at some sites sand in the Cockfield was very fine, and several of the test holes had to be drilled into the Memphis Sand to find a sand suitable for the installation of observation wells. Plate 1 shows north-south and east-west geologic sections through Lauderdale County, which include selected geophysical logs of 12 of the test holes drilled during this investigation.

Based on the stratigraphic section in the Fort Pillow test well (Moore and Brown, 1969), the Cook Mountain was thought to be about 200 feet thick and to consist predominantly of clay. Consequently, it was thought that the Cook Mountain would be easy to recognize in the subsurface. During the drilling of the test holes, it became evident that the Cook Mountain is more commonly only about 60 feet thick and that at places the overlying Cockfield and the upper part of the underlying Memphis Sand contain intervals of clay that could be confused with the Cook Mountain.

To further complicate correlations between test holes, no confidence could be placed in finding the Cook Mountain at a predictable structural position, when assuming a normal, undisturbed structural setting for the area. In many of the test holes, thick intervals of clay resembling the Cook Mountain and having the expected normal stratigraphic position between the Cockfield and the Memphis Sand are either too high or too low in the section to be in the expected normal structural position of the Cook Mountain. The discordances of the Cook Mountain suggested displacement of the stratigraphic section by faults.

Investigations by Hildenbrand and others (1982) of the magnetic basement in the upper Mississippi embayment show that the eastern structural limits of the recently recognized Mississippi Valley graben crosses northeast-southwest through Lauderdale County. These investigations also identified a few principal magnetic lineaments reflecting faulting and lithologic contrasts in the magnetic basement beneath the county. Heyl and McKeown (1978) on a preliminary seismotectonic map of the cental Mississippi Valley and environs indicate two possible or hypothetical faults crossing the county. Postulation of the existance of these faults is based on subsurface data or exceptionally strong lineaments on aerial photos. One of these faults was originally recognized by Moore (1965, pl. 4).

Plate 1 in the present report shows the approximate location and the direction and amount of displacement of several faults interpreted from geophysical-log correlations during this investigation.

In summary, the difficulties in correlating the geophysical logs between test holes is the result of complexities in the stratigraphic section compounded by the existence of faults that displace the Tertiary formations. Thus, some correlations of the geophysical logs used in the preparation of this report are tentative, and the assignment of some wells to aquifers is uncertain.

GROUND-WATER SYSTEM

From about 2,500 to 3,000 feet of sand, clay, silt, gravel, and lignite ranging in age from Cretaceous to Quaternary underlie Lauderdale County above the Paleozoic rocks. Although much of this sequence is saturated with fresh water [dissolved solids concentrations less than 1,000 milligrams per liter (mg/L)], only the post-Midway units (Wilcox Group and younger) are considered in this report because these units contain the principal shallow aquifers. Table 1 gives the stratigraphic relations of the post-Midway geologic units and their hydrologic significance.

Table 1.--Post-Midway geologic units underlying Lauderdale

System	Series	Group	Stratigraphic unit	Thickness (ft)
Quaternary	Holocene and Pleistocene		Alluvial deposits (alluvium)	0-180
Quaternary	Pleistocene		Loess	0-65
Quaternary and Tertiary (?)	Pleistocene and Pliocene (?)		Fluvial deposits (terrace deposits)	0-70
Tertiary	Eocene		Jackson Formation ?	0-100
Tertiary	Eocene	Claiborne	Cockfield Formation	35-270
Tertiary	Eocene	Claiborne	Cook Mountain Formation	45-100
Tertiary	Eocene	Claiborne	Memphis Sand ("500-foot" sand)	650-770
Tertiary	Eocene	Wilcox	Flour Island Formation	150-200
Tertiary	Eocene ?	Wilcox	Fort Pillow Sand ("1400-foot" sand)	160-300
Tertiary	Paleocene	Wilcox	Old Breastworks Formation	90-280

County and their hydrologic significance

Lithology and hydrologic significance
Sand, gravel, silt, clay, and reworked lignite. Underlie the Mississippi River Alluvial Plain and flood plains of other streams. Thickest beneath the Alluvial Plain, where they commonly are between 100 and 150 feet thick. Probably no more than 50 feet thick elsewhere. Provides water for domestic, farm, and irrigation supplies, particularly in the Alluvial Plain.
Silt, silty clay, and minor sand. Is principal geologic unit at the surface in the Gulf Coastal Plain. Thickest on the bluffs that border the Mississippi Alluvial Plain. Not an aquifer. Tends to retard downward movement of water recharging the water-table aquifers.
Sand, gravel, and minor clay. Commonly underlie the loess in the Gulf Coastal Plain, but are absent in many areas. Thickest and contain the most gravel in the highly dissected area north of Ripley. Thickness highly variable because of erosional surfaces at top and base. Locally provide water for domestic, farm, and public supplies.
Sand, silt, clay, and lignite. Because of similarities in lithology, the Jackson and Cockfield Formations cannot be reliably subdivided based on available information. Preserved section mostly Cockfield, but at places is overlain by the Jackson. Thicknesses are estimates based on tentative geophysical log correlations. The Cockfield provides water for domestic, farm, industrial, and public supplies.
Clay, silt, sand, and lignite. Believed to consist predominately of clay and silt and to be more commonly about 60 feet thick. Locally may contain fine sand and lignite. Could be confused with clay and silt beds in the lower part of the Cockfield or upper part of the Memphis Sand. Serves as the confining bed between the Cockfield and Memphis Sand.
Sand, silt, and clay. Consists of a thick body of sand containing lenses of clay and silt at various stratigraphic horizons. Locally upper part contains much clay and silt similar to that in the overlying Cook Mountain. Thickest in the southern part of the county. Provides water for public supplies where shallower aquifers do not yield enough water for installation of large-capacity wells.
Silt, clay and sand. Not an aquifer. Serves as lower confining bed for the Memphis Sand and upper confining bed for Fort Pillow Sand. Thickest in the southern part of the county.
Sand and minor clay. Relatively deep aquifer not presently used in the county because of the availability of water at shallower depths. May have potential for supplying water of better quality than available from shallower aquifers, but specific information on water quality is not available. Thickest in the northern part of the county.
Silt, clay, sand, and lignite. Not an aquifer. Thickest in the southern part of the county. Serves as the lower confining bed of the Fort Pillow Sand, along with the underlying Porters Clay of the Midway Group.

The principal shallow aquifers in Lauderdale County are: (1) Mississippi alluvial deposits, (2) Cockfield Formation, (3) Memphis Sand ("500-foot" sand), and (4) Fort Pillow Sand ("1400-foot" sand). The fluvial deposits (terrace deposits) that drape over the hills into valleys, the Jackson Formation which is preserved locally, and the alluvial deposits (alluvium) beneath the flood plains of the streams in the Gulf Coastal Plain provide water to some shallow wells. These deposits are not a principal source of ground-water supply; therefore, they are not described in detail in this report.

Mississippi Alluvial Deposits

The Mississippi alluvial deposits underlie the Mississippi Alluvial Plain in western Lauderdale County. In general these deposits consist of fine sand, silt, and clay in the upper part and coarse sand and gravel in the lower part. At places, however, the lower part consists largely of sand. The alluvial deposits locally may be as much as 180 feet thick, but probably are more commonly between 100 and 150 feet thick. The basal sand and gravel is about nine-tenths to three-quarters of the thickness of the alluvial deposits and provide a source of water for domestic, farm, and irrigation supplies.

Wells in the Mississippi alluvial deposits range from about 10 to 120 feet in depth. For domestic and farm supplies these wells are typically of small capacity, pumping from 5 to 25 gal/min. However, this aquifer has potential to yield 1,500 to 4,000 gal/min to large capacity wells (Strausberg and Schreurs (1958, p. 4). Recently, a 120-foot deep irrigation well (Ld:S-4) with a reported capacity to pump 1,500 gal/min was installed in the alluvial deposits at Knob Creek (table 2).

Figure 4 shows the approximate altitude of the base of the Mississippi alluvial deposits and the thickness of this aquifer in test holes. Using altitudes shown in figure 4 and extremes in altitude of the topography in the Mississippi Alluvial Plain, it is estimated that wells drilled to the base of the aquifer would range from about 50 to 180 feet in depth.

Cockfield Formation

The Cockfield Formation underlies the Jackson Formation, the fluvial deposits, or the loess in the Gulf Coastal Plain, and the Mississippi alluvial deposits in the Mississippi Alluvial Plain. This unit consists of lenticularly bedded sand, silt, clay, and lignite. Not much specific information is available on which to base a range in thickness for the Cockfield, but where the full thickness is preserved, it probably is about 250 to 270 feet thick. At most places, the full thickness is not preserved and as little as 35 feet is present beneath the Mississippi alluvial deposits in the south-central part of the county. This is the principal aquifer utilized in the Gulf Coastal Plain for domestic and farm supplies and for some industrial and public supplies.

Wells in the Cockfield Formation are generally less than 350 feet deep and most are less than 200 feet deep. Sands range from very fine to coarse, but commonly are of the finer sizes. These sands yield water to small and moderate capacity wells pumping from about 5 to 300 gal/min.

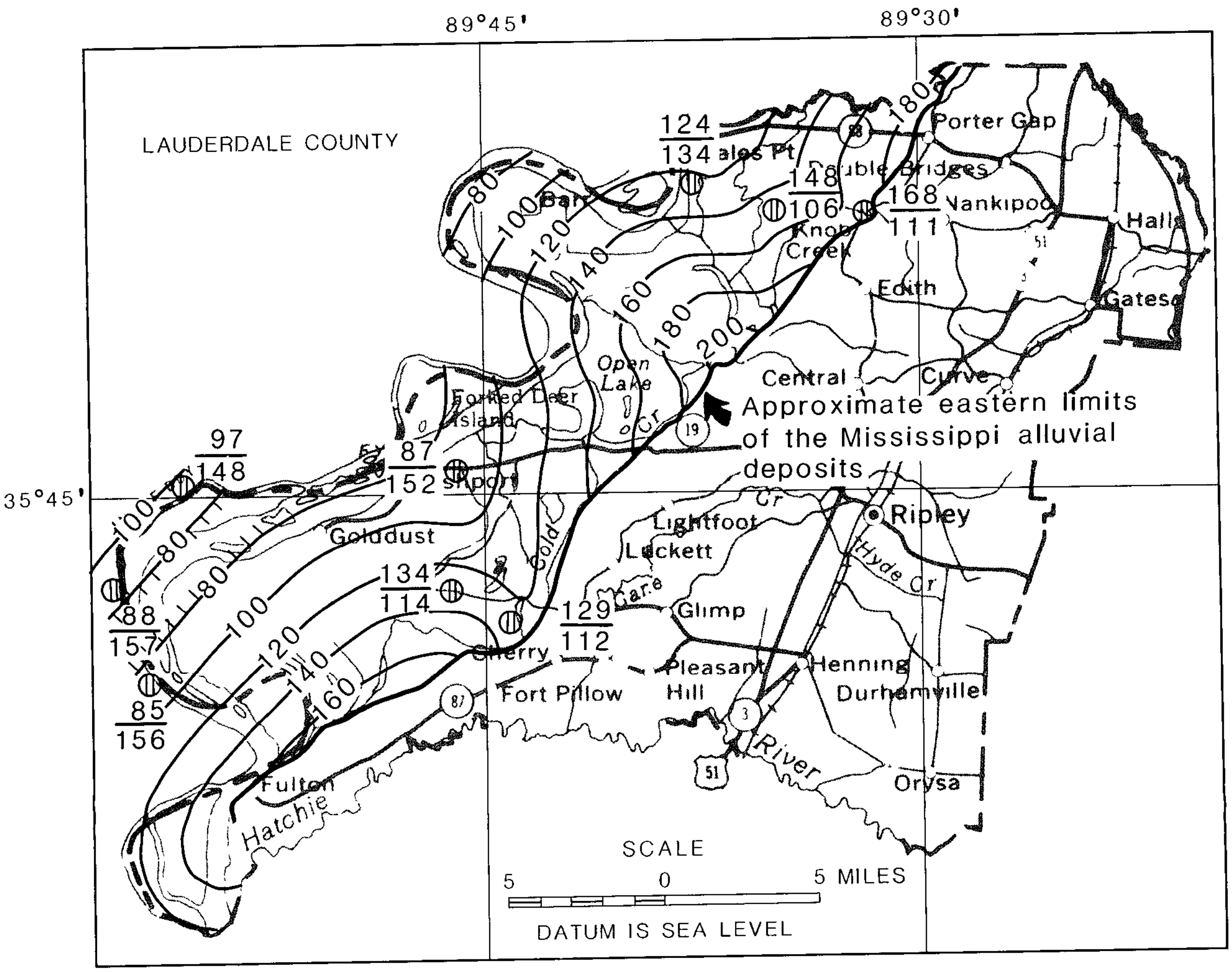
Figure 5 shows the approximate altitude of the base of the Cockfield Formation, the thickness of this aquifer in test holes and wells, and the faults shown on plate 1. Using altitudes shown in figure 5 and extremes in altitude of the topography in the county, it is estimated that wells drilled to the base of the aquifer would range from about 100 to 500 feet in depth.

Memphis Sand

The Memphis Sand is a widespread and very important aquifer in western Tennessee. It is the principal aquifer supplying water to the City of Memphis, about 50 miles south of Lauderdale County (Criner and Parks, 1976, p. 5).

In Lauderdale County, the Memphis Sand consists chiefly of a thick body of sand containing subordinate lenses or beds of clay and silt at various stratigraphic horizons. This aquifer is about 660 feet thick in the northern part of the county in the vicinity of Gates and about 760 feet thick in the southern part in the Fort Pillow State Historic Area. The Memphis Sand is presently being used for public supplies where the sands of the shallower aquifers do not yield sufficient water for large-capacity wells.

Wells in the Memphis Sand range from about 400 to 800 feet in depth. The sands range from very fine to coarse and supply water to moderate and large capacity wells, pumping from 60 to 1,120 gal/min. The upper part of the Memphis Sand consists of interlensed sand, silt, and clay with fine or fine-to-medium sand predominant. At some places, the sand in the upper part of the aquifer may be thick enough and coarse enough to supply moderate-capacity wells. Commonly, however, it is necessary to drill to the middle or lower parts of the aquifer to find a sand suitable for large-capacity wells.



Base from U.S. Geological Survey 1:500,000, 1973

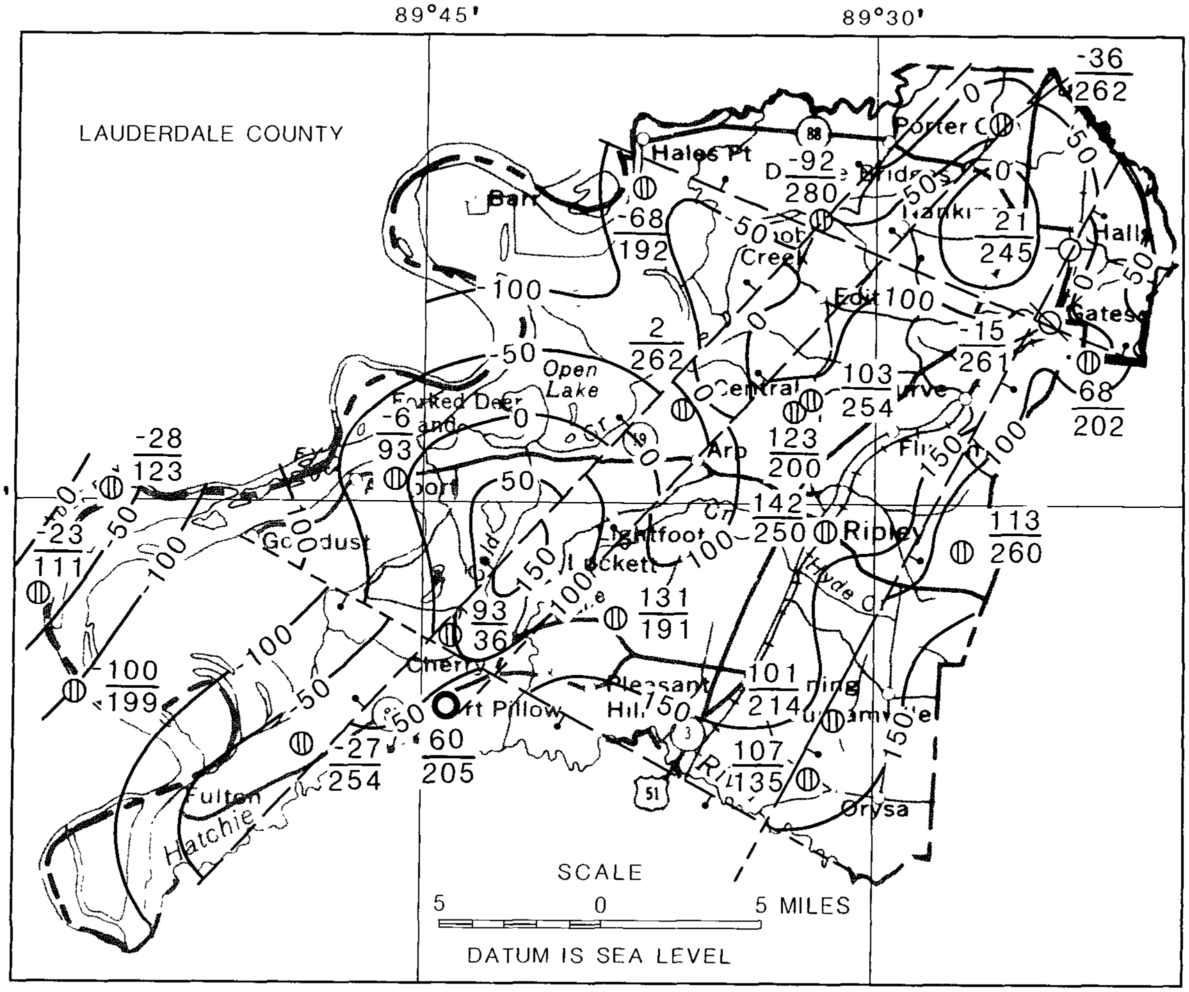
Figure 4.-- Altitude of the base of the Mississippi alluvial deposits.

EXPLANATION

—120— STRUCTURE CONTOUR-- Shows altitude of base of aquifer. Contour interval 20 feet.

97 — Altitude of base
148 — Thickness of aquifer

Test hole



Base from U.S. Geological Survey 1:500,000, 1973

Figure 5.-- Altitude of the base of the Cockfield Formation and faults shown on plate 1.

EXPLANATION

—— -100 —— STRUCTURE CONTOUR-- Shows altitude of base of aquifer. Contour interval 50 feet.

- Fault
- Fault, approximately located
- Inferred fault
- Fault, ball and bar on downthrown side
- -6 — Altitude of base
- 93 — Thickness of aquifer
- Observation well
- Test hole
- Oil test well
- Public-supply well

Figure 6 shows the approximate altitude of the base of the Memphis Sand and the thickness of the aquifer in several test holes and an oil test well. Using altitudes shown in figure 6 and extremes in altitude of tne topography in the county, it is estimated that wells drilled to the base of the Memphis Sand would range from about 750 to 1,300 feet in depth.

Fort Pillow Sand

The Fort Pillow Sand is a widespread and important aquifer in western Tennessee, second only to the Memphis Sand. The Fort Pillow Sand, however, is not widely used as a source of ground water (1983) because in most areas adequate supplies for most needs are available from aquifers at shallower depths. The Fort Pillow Sand is presently used for some industrial and public supplies in a narrow belt adjacent to its outcrop area, and for part of one industrial supply at Memphis.

In Lauderdale County, the character of the Fort Pillow Sand is known only from the logs of early oil test wells in the vicinity of Gates and Halls and the deep stratigraphic test hole drilled in the Fort Pillow State Historic Area. From the geophysical logs of the Raymond Gear, Lee No. 1 oil test well and the Fort Pillow test hole, the Fort Pillow Sand is about 300 feet thick near Gates and about 160 feet thick in the Fort Pillow State Historic Area. According to a description of the samples from the Fort Pillow test hole, the sand in the Fort Pillow Sand is very fine to coarse and is moderately well sorted (Moore and Brown, 1969).

In general, the Fort Pillow Sand is at greater depths than the Memphis Sand, is not as thick, and does not contain as much coarse sand. Thus, the Fort Pillow Sand probably would not yield as much water as the Memphis Sand. The Fort Pillow Sand is, as yet, untapped as a source of ground-water supply in the county.

Figure 7 shows the approximate altitude of the base of the Fort Pillow Sand. Using the altitudes shown in figure 7 and extremes in altitude of the topography in the county, it is estimated that wells drilled to the base of the aquifer would range from about 1,250 to 1,700 feet in depth.

In Mississippi County, Arkansas, across the Mississippi River from Lauderdale County, a cost benefit is realized by drilling deep wells to the Fort Pillow Sand rather than by treating water of less desirable quality from the Memphis Sand. For discussion of the water quality in the Fort Pillow Sand in Mississippi County, Arkansas, see General Characteristics under the section on Water Quality in this report.

Present Resource Development

The ground-water resource in Lauderdale County is now in a rudimentary stage of development. According to statistics compiled by the Tennessee Department of Health and Environment for 1982, average withdrawal to supply the principal water systems in the county totals about 3.1 Mgal/d. This compares with an average withdrawal in 1980 of 193 Mgal/d by public and industrial users in the Memphis area (Graham, 1982, p. 10).

The water use statistics for Lauderdale County are as follows:

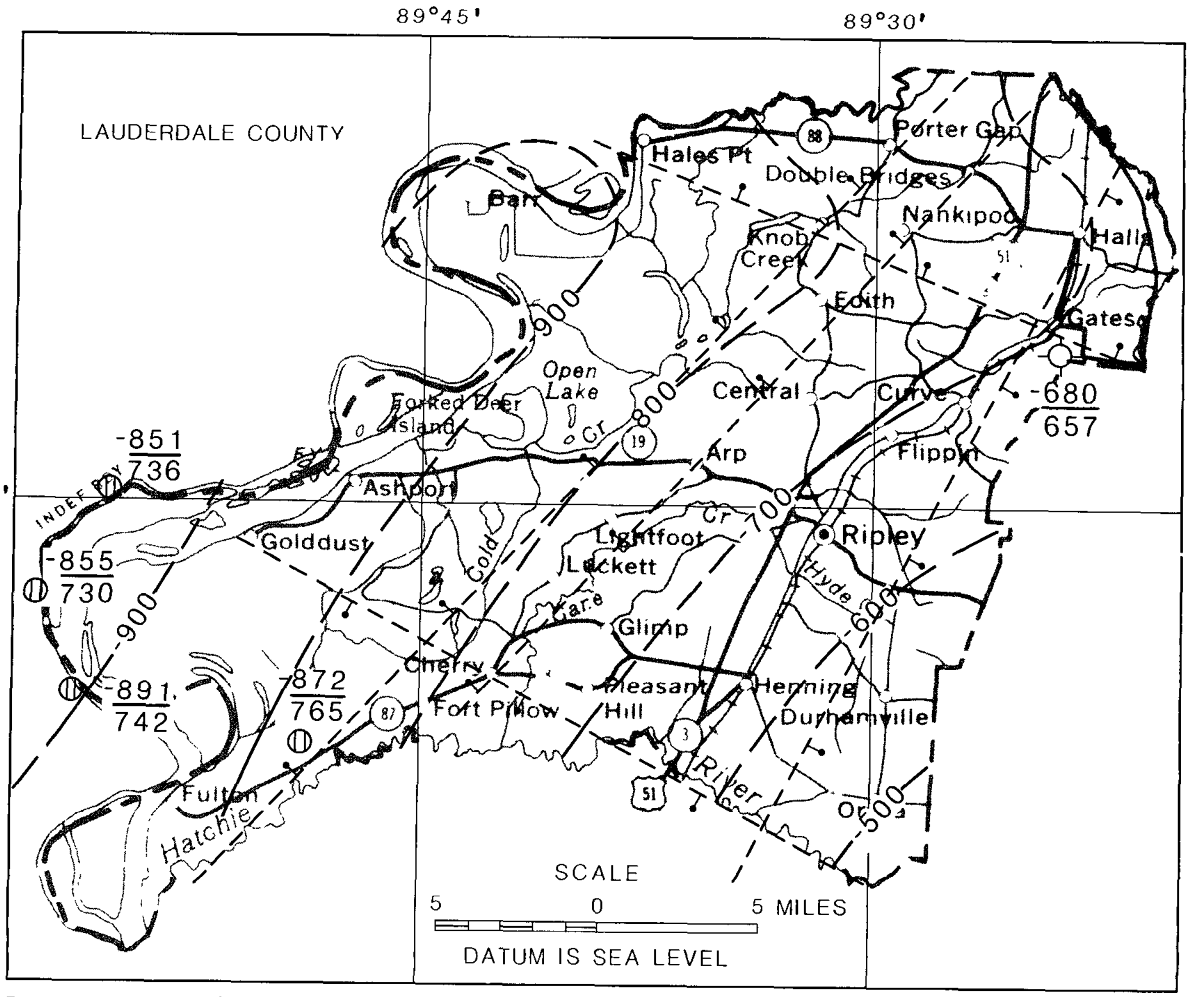
Halls Water System	0.525 Mgal/d
Henning Water Department	0.092 Mgal/d
Fort Pillow State Prison Farm	0.436 Mgal/d
Gates Water Department	0.050 Mgal/d
Lauderdale County Water Association	0.432 Mgal/d
Ripley Water System	1.569 Mgal/d
Total	3.104 Mgal/d

The water supply at Gates and part of the supply at Halls is from the Cockfield Formation. The supply at Fort Pillow State Prison Farm, Lauderdale County Water Association, Ripley and part of the supply at Halls and Henning is from the Memphis Sand. Part of the supply at Henning is from shallow wells about 70 feet deep which are in the fluvial deposits.

Records of approximately 650 water wells installed in Lauderdale County since 1963 are on file with the Tennessee Department of Health and Environment. These wells were installed to provide water for a variety of uses, but most are domestic and farm wells. Table 2 gives records of 29 selected water wells in the county, including those wells currently supplying water for industrial and public uses. Their locations are shown in figure 8.

In 1963, the two wells (Ld:N-10 and Ld:N-11) were installed to provide water for the Lauderdale County Water Association (formerly Arp-Central Water Association). Since then this system has been expanded to four wells and the service area extended throughout most rural areas of the county. Some water used by customers of the Lauderdale County Water Association is purchased from the City of Ripley.

It is not known how many of the 650 wells installed since 1963 are still in use. No doubt many wells are still in service for farm use or to supplement water provided by the Lauderdale County Water Association.



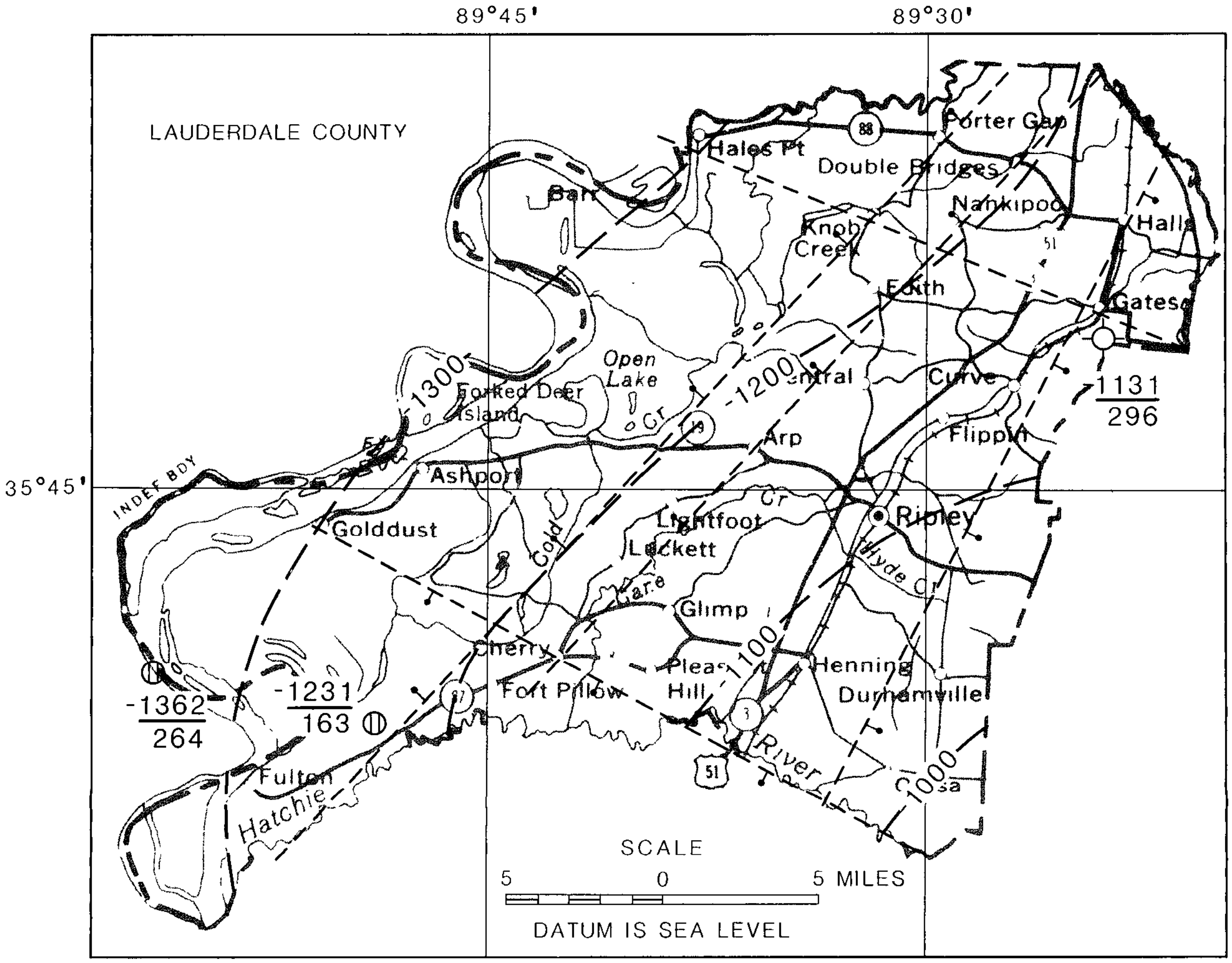
Base from U.S. Geological Survey 1:500,000, 1973

Figure 6.-- Altitude of the base of the Memphis Sand.

EXPLANATION

—— -900 —— —— STRUCTURE CONTOUR-- Shows altitude of base of aquifer. Dashed where approximately located. Contour interval 100 feet.

—⊥— —	Inferred fault, ball and bar on downthrown side
-851 ——	Altitude of base
736 ——	Thickness of aquifer
ⓘ	Test hole
-◇-	Oil test well



Base from U.S. Geological Survey 1:500,000, 1973

Figure 7.-- Altitude of the base of the Fort Pillow Sand.

EXPLANATION

— -1300 — STRUCTURE CONTOUR-- Shows altitude of base of aquifer. Dashed where approximately located. Contour interval 100 feet.

Inferred fault, ball and bar on downthrown side

-1362 — Altitude of base
264 — Thickness of aquifer

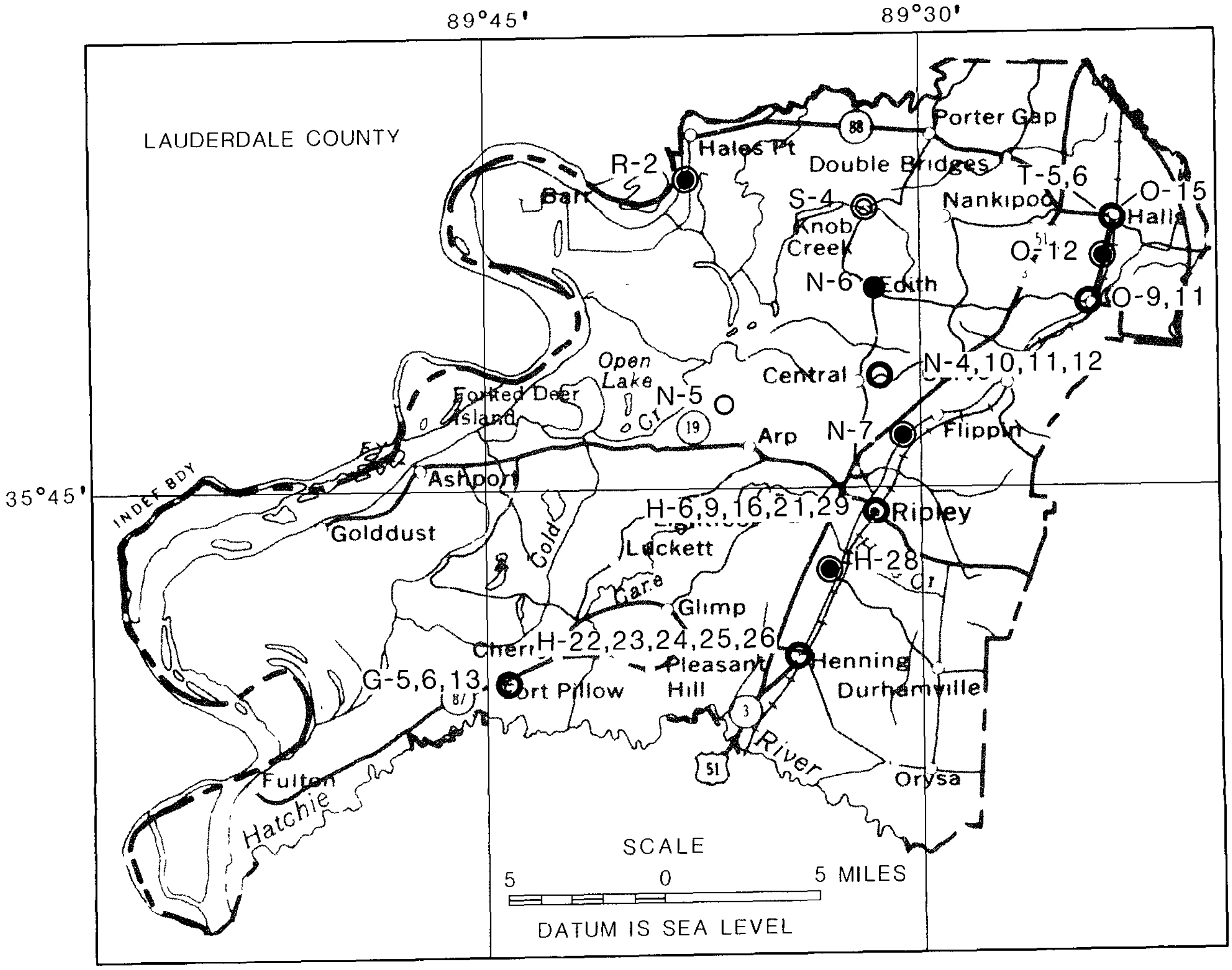
Test hole

Oil test well

Table 2.--Records of selected water-supply wells in Lauderdale County, Tennessee

Well No.	Well owner	Driller	Date drilled	Altitude (ft)[1]	Well depth (ft)	Water-bearing unit[2]	Well diameter (in.)	Screen length (ft)	Water level[3] below land surface Depth(ft)	Date	Pumping rate (gal/min)	Use of water[4]
Ld:G-5	Fort Pillow State Prison Farm (#2)	Layne-Central Co.	1957	275	656	Tm	10x6	50	27.74	10-21-83	600	P
Ld:G-6	Fort Pillow State Prison Farm (#1)	Carloss Well Supply	1959	281	665	Tm	12x8	52	46	1959	530	P
Ld:G-13	Fort Pillow State Prison Farm (#3)	Layne-Central Co.	1966	280	659	Tm	12x8	50	44	1966	850	P
Ld:H-6	City of Ripley (#2)	Layne-Central Co.	1951	419	755	Tm	12	50	142	1953	400	P
Ld:H-9	City of Ripley (#1)	Layne-Central Co.	1958	430	700	Tm	12	60	157	1958	480	P
Ld:H-16	City of Ripley (#4)	Layne-Central Co.	1966	416	737	Tm	12x8	60	150.35	10-19-83	618	P
Ld:H-21	City of Ripley (#5)	Layne-Central Co.	1982	430	730	Tm	18x12	80	158	1982	1,119	P
Ld:H-22	City of Henning (#2)	---	---	298	---	QTf	4	--	--	--	--	P
Ld:H-23	City of Henning (#4)	Layne-Central Co.	1979	323	570	Tm	8x6	50	52.91	10-19-83	335	P
Ld:H-24	City of Henning (#1)	Thorpe Well Supply	1967	328	67	QTf	4	7	57	1967	20	P
Ld:H-25	City of Henning (#5)	Thorpe Well Supply	1967	299	70	QTf	6	10	57	1967	25	P
Ld:H-26	City of Henning (#3)	Thorpe Well Supply	1967	302	70	QTf	6	10	57	1967	25	P
Ld:H-28	Tennessee Electro-Plating Co.	Genson Drilling Co.	1968	362	289	Tcf(?)	6	60	66	1968	170	I
Ld:H-29	City of Ripley (#3)	Layne-Central Co.	1966	410	737	Tm	12x8	60	145	1966	618	P
Ld:N-4	Lauderdale County Water Assoc. (#4)	Layne-Central Co.	1979	479	514	Tm	12x8	51	196	1978	500	P
Ld:N-5	Walnut Grove Catfish Farm	Genson Drilling Co.	1969	341	801	Tm	10x8	52	83.47	10-21-83	650	F
Ld:N-6	Edith Baptist Church	G. H. Mize	1965	511	181	Tj	2½x1½	6	160	1965	15	D
Ld:N-7	S & R of Tennessee	Bob Smith	1979	360	272	Tcf(?)	6x3	50	90	1979	150	I
Ld:N-10	Lauderdale County Water Assoc. (#1)	Layne-Central Co.	1963	482	495	Tm	10x8x6	32	206.27	10-21-83	150	P
Ld:N-11	Lauderdale County Water Assoc. (#2)	Layne-Central Co.	1963	480	491	Tm	10x8x6	30	198	1963	150	P
Ld:N-12	Lauderdale County Water Assoc. (#3)	Layne-Central Co.	1975	469	511	Tm	12x8	40	196	1975	500	P
Ld:O-9	City of Gates (#2)	Layne-Central Co.	1959	338	353	Tcf	8x6	30	61	1959	100	P
Ld:O-11	City of Gates (#3)	Wilson, Inc.	1981	338	345	Tcf	10x6	30	64	1981	225	P
Ld:O-12	Tupperware Co.	Robert W. Wilson	1968	330	285	Tcf	6	20	100	1968	200	I
Ld:O-15	City of Halls (#2)	Genson Drilling Co.	---	315	196	Tcf	16x10	42	42	1983	375	P
Ld:R-2	Continental Grain Co.	Genson Drilling Co.	1976	257	75	Qal	4	4	23	1976	20	I
Ld:S-4	Fletcher Gin Co.	Wilson, Inc.	1982	278	120	Qal	16	60	25.11	10-21-83	1,500	Ir
Ld:T-5	City of Halls (#3)	Layne-Central Co.	1968	311	514	Tm	12	60	34.45	10-11-83	600	P
Ld:T-6	City of Halls (#1)	Layne-Central Co.	1960	315	197	Tcf	10x6	35	35	1983	320	P

[1] Altitude above sea level; altitudes determined from well locations on 7½-minute topographic quadrangle maps.
[2] Water-bearing units: Qal, Mississippi alluvial deposits; QTf, fluvial (terrace) deposits; Tj, Jackson Formation; Tcf, Cockfield Formation; Tm, Memphis Sand.
[3] Water levels reported by the driller, except for those measured to a hundredth of a foot by the U.S. Geological Survey.
[4] Use of water: D, domestic; F, farm; I, industrial; Ir, irrigation; P, public supply.



Base from U.S. Geological
Survey 1:500,000, 1973

Figure 8.-- Selected water-supply wells.

EXPLANATION

N-6 ● Domestic well and number

N-5 ○ Farm well and number

G-5 **O** Public well and number

R-2 ◉ Industrial well and number

S-4 ◎ Irrigation well and number

Ld: prefix is not shown (See page v)

WATER LEVELS

Twelve observation wells were installed during this investigation to monitor water levels in the principal shallow aqifers. Two were completed in the Mississippi alluvial deposits, six in the Cockfield Formation, and four in the Memphis Sand. An observation well (Ld:F-4) in the Memphis Sand already existed in the Fort Pillow State Historic Area (Moore and Brown, 1969). Completion data for the 13 observation wells are given in table 3, and their general locations are shown in figure 9.

Fluctuations and Trends

Recorders were installed on four of the new observation wells--Ld:S-2 in the Mississippi alluvial deposits, Ld:L-2 and Ld:J-5 in the Cockfield Formation, and Ld:G-12 in the Memphis Sand. Water levels in the other eight new wells were measured monthly. Water levels have been monitored continuously in well Ld:F-4 since April 1966, except for a period between December 1969 and February 1973 when no recorder was on this well. The record of water levels from the new observation wells is too short to show long-term trends but does give some indication of seasonal fluctuations.

Water levels in the Mississippi alluvial deposits generally are high from February to June and generally are low from September to December (fig. 10). High ground-water levels are related to high stages of the Mississippi River and backwater flooding of the Mississippi Alluvial Plain. During an earlier investigation, Strausberg and Schreurs (1958, p. 37) concluded that water levels in the Mississippi alluvial deposits as far as 3 miles away from the Mississippi River fluctuate in response to seasonal or long-term changes in the stage of the river.

Water levels in the Cockfield Formation generally are high from April to September and generally are low from December to January (fig. 10). The record of well Ld:L-2 may not indicate typical seasonal trends for the Cockfield in Lauderdale County because of the proximity of the well to the Mississippi River. As a consequence, high water levels in Ld:L-2 may be related to high stages of the river.

Water levels in the Memphis Sand are high from February to August, and commonly are highest during the period from April to June (figs. 10 and 11). Water levels in this aquifer are low from September to January and commonly are lowest in November.

The hydrograph of well Ld:F-4, 2.5 miles from the Mississippi River, shows a very definite correlation with large changes in stage of the Mississippi River (fig. 11). This correlation is most evident during long periods of sustained high stage on the Mississippi River and backwater flooding of parts of the Mississippi Alluvial Plain as was the condition during April 1978.

Because the Memphis Sand is an artesian aquifer, the changes in water level in the aquifer that can be correlated with changes in river stage probably are due to a loading effect. That is, the water level rises or falls in wells in response to similar changes of stage in the river. This loading effect would be the result of increased or decreased pressure in the aquifer caused by the weight of the river water superimposed on the aquifer system.

No water-level data are available for the Fort Pillow Sand in Lauderdale County from which to establish water-level trends in the area.

Areal Configuration

To supplement data from the observation well network, water levels were measured in many water wells for the purpose of making generalized maps showing the areal configuration of the water-level (potentiometric) surfaces in the principal shallow aquifers. These maps, given in figures 12 through 15, show the altitude in feet at which water would have stood in tightly cased wells open to the aquifers in October 1983.

Water in the Mississipppi alluvial deposits may be under unconfined (water table) conditions at most places at most times of the year, but at times of high water levels, water in this aquifer locally is under confined (artesian) or semi-confined conditions. This change in condition is probably the result of the aquifer becoming completely filled so that the water becomes confined by the finer sediments (clay, silt, and fine sand) which overlie and form a cap on the coarser sediments (sand and gravel) which make up the main aquifer. This filling of the aquifer above its normal recharge level is probably the result of lateral recharge from high stages in surface water bodies such as the Mississippi River.

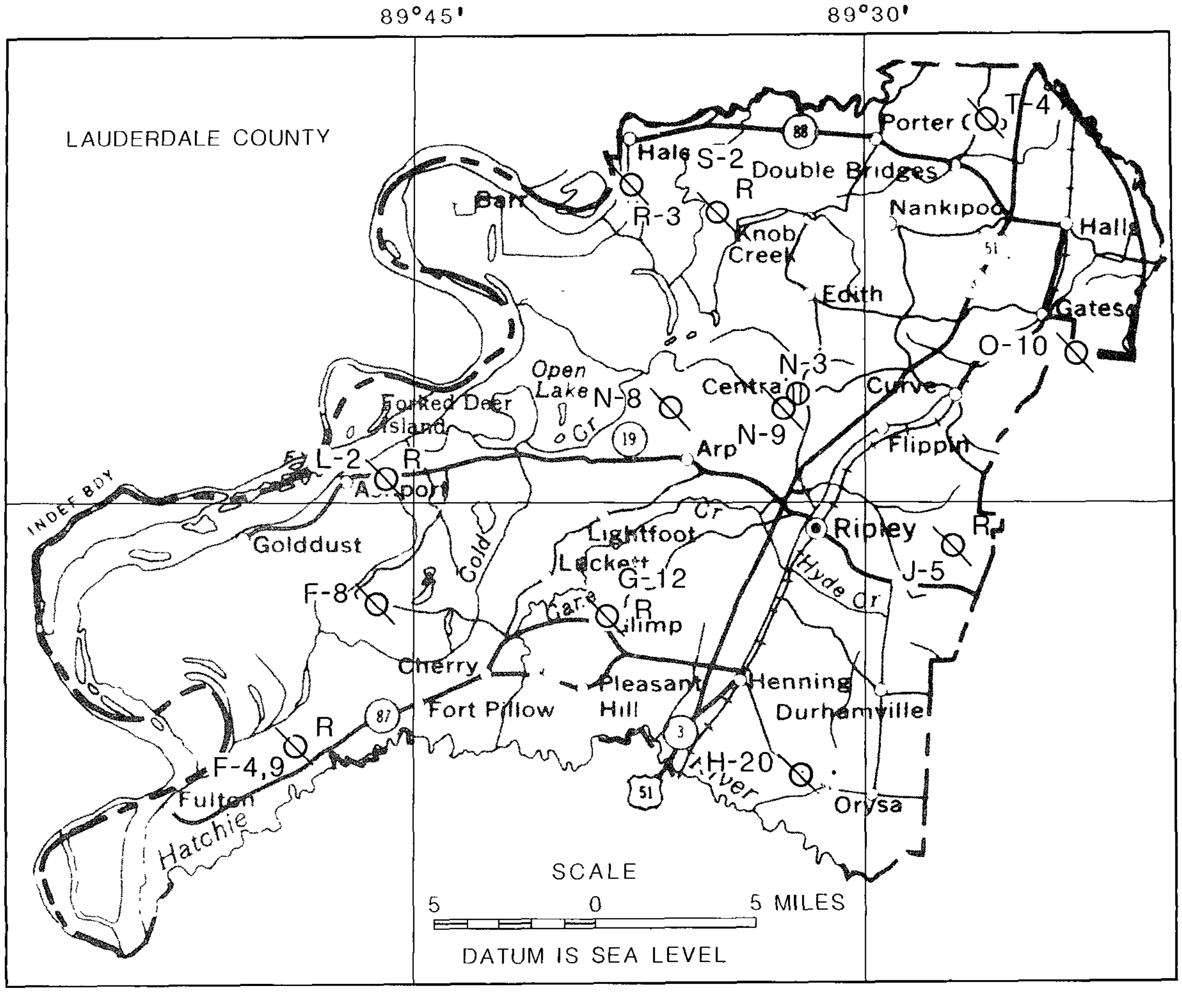
Using altitudes shown in figure 12 and extremes in altitude of the topography in the Mississippi Alluvial Plain, it is estimated that water levels in the Mississippi alluvial deposits range from slightly above land surface to about 35 feet below land surface.

The configuration of the water-level surface in the Cockfield Formation in the Gulf Coastal Plain area of Lauderdale County is a subdued replica of the topography. That is, the water-level surface follows the contour of the land surface. Water levels are at higher altitudes but

Table 3.--Completion data for test holes and observation wells in Lauderdale County, Tennessee

Well No.	Property owner	Driller	Date completed (month-year)	Altitude (ft)[1]	Depth of test hole (ft)	Depth of observation well (ft)	Observation well diameter (in.)	Screened interval (ft)	Aquifer[2]	Initial static water level (ft below land surface)	Date of measurement
Ld:F-4	Tenn. Dept. of Conser., Div. of Parks and Rec.	Robert W. Ratliff	11-65	437	3,183	897	6x3	869-879	Tm	197.97	11-10-65
Ld:F-8	Hobson M. Wakefield	Wilson, Inc.	10-80	248	140	110	6	90-110	Qal	15.62	10-21-80
Ld:F-9	Tenn. Dept. of Conser., Div. of Parks and Rec.	Parker and Jackson	3-83	437	380	380	6	360-380	Tcf	114.10	4-19-83
Ld:G-12	James F. Hopper	Wilson, Inc.	10-80	360	500	440	6	420-440	Tm	105.57	10-24-80
Ld:H-20	Milton B. Rice	Parker and Jackson	12-81	305	450	445	6	425-445	Tm	36.18	12-10-81
Ld:J-5	Charles W. Guthrie	Parker and Jackson	12-81	469	460	277	6	257-277	Tcf	131.46	2-17-82
Ld:L-2	Clifford R. Sweat	Wilson, Inc.	10-80	239	320	245	6	225-245	Tcf	14.57	10-24-80
Ld:N-3	Lauderdale County	Parker and Jackson	1-82	491	590	---	-	---	---	---	---
Ld:N-8	Don Holcomb	Parker and Jackson	2-83	342	480	340	6	320-340	Tcf	87.98	4-18-83
Ld:N-9	Mrs. Jane Hathcock	Parker and Jackson	6-83	387	410	420	6	400-420	Tm	109.52	6-22-83
Ld:O-10	Bernard Lewis	Parker and Jackson	1-82	308	470	394	6	374-394	Tm	29.18	2-17-82
Ld:R-3	Charles O. Viar	Parker and Jackson	1-83	258	600	250	6	230-250	Tcf	12.21	2-23-83
Ld:S-2	Leon & Roger Meadows	Wilson, Inc.	10-80	254	120	100	6	80-100	Qal	9.08	10-25-80
Ld:T-4	Raymond L. Kelly	Parker and Jackson	1-83	368	540	365	6	345-365	Tcf	92.69	1-27-83

[1]Altitude above sea level; altitudes determined from well locations on 7½-minute topographic quadrangle maps.
[2]Aquifer: Qal, Mississippi alluvial deposits; Tcf, Cockfield Formation; Tm, Memphis Sand.



Base from U.S. Geological
Survey 1:500,000, 1973

Figure 9.-- Locations of test holes and observation wells.

EXPLANATION

N-3 Test hole and number

F-8 Observation well and number

L-2 R Observation well with recorder and number

Test holes were drilled at sites of each observation well.

Ld: Prefix is not shown (See page v)

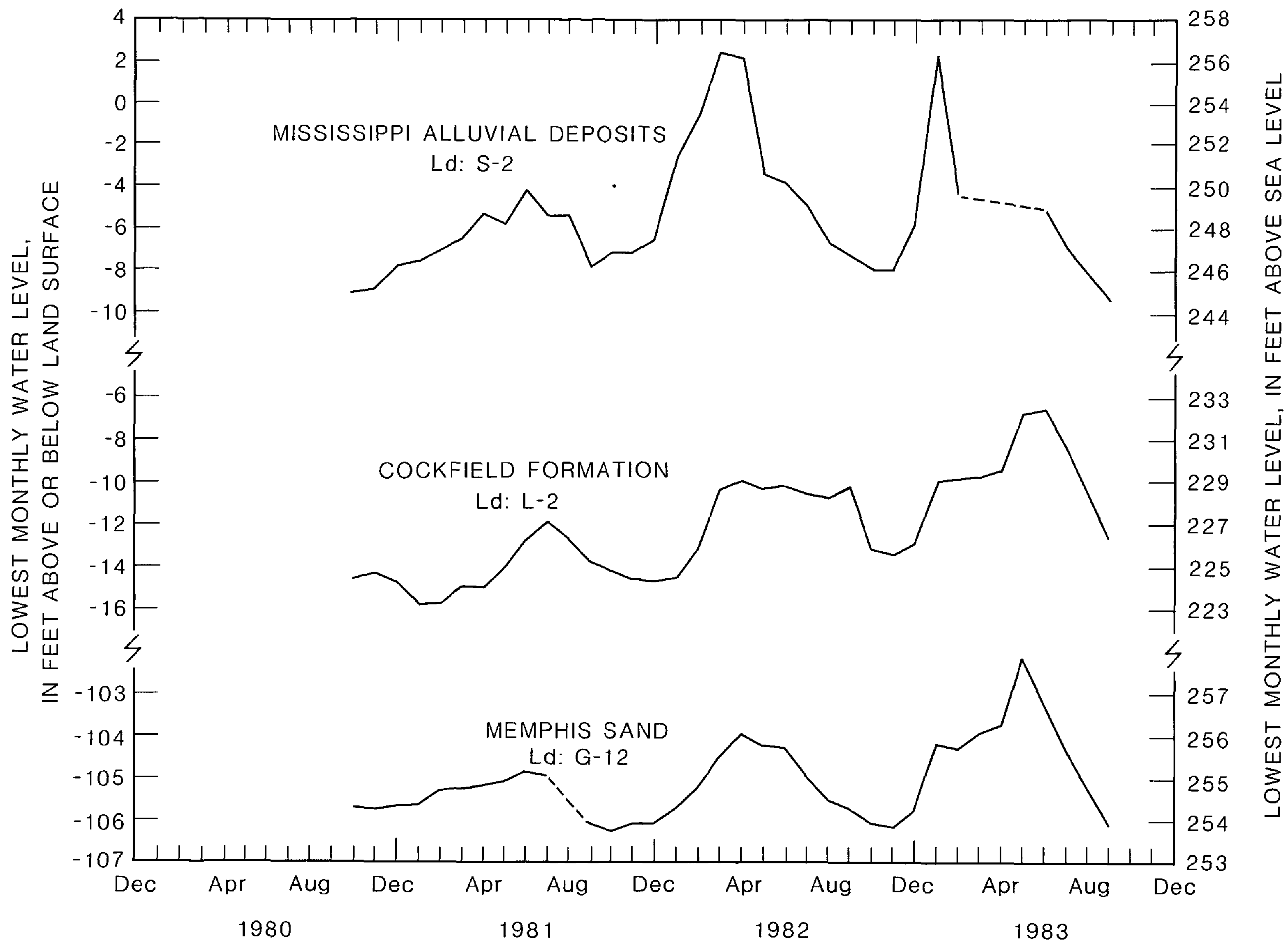


Figure 10.-- Short-term water-level changes in the Mississippi alluvial deposits, Cockfield Formation, and Memphis Sand.

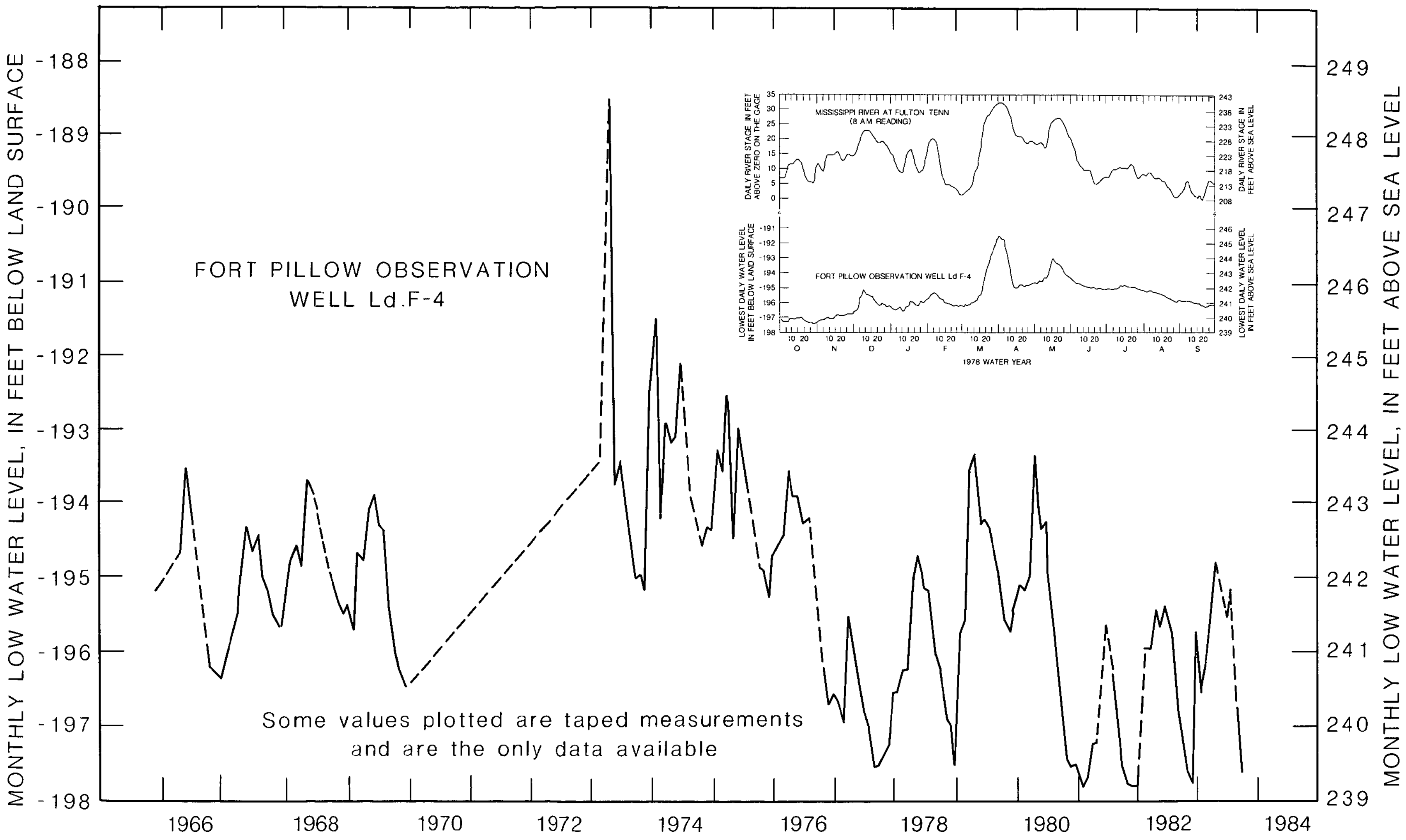
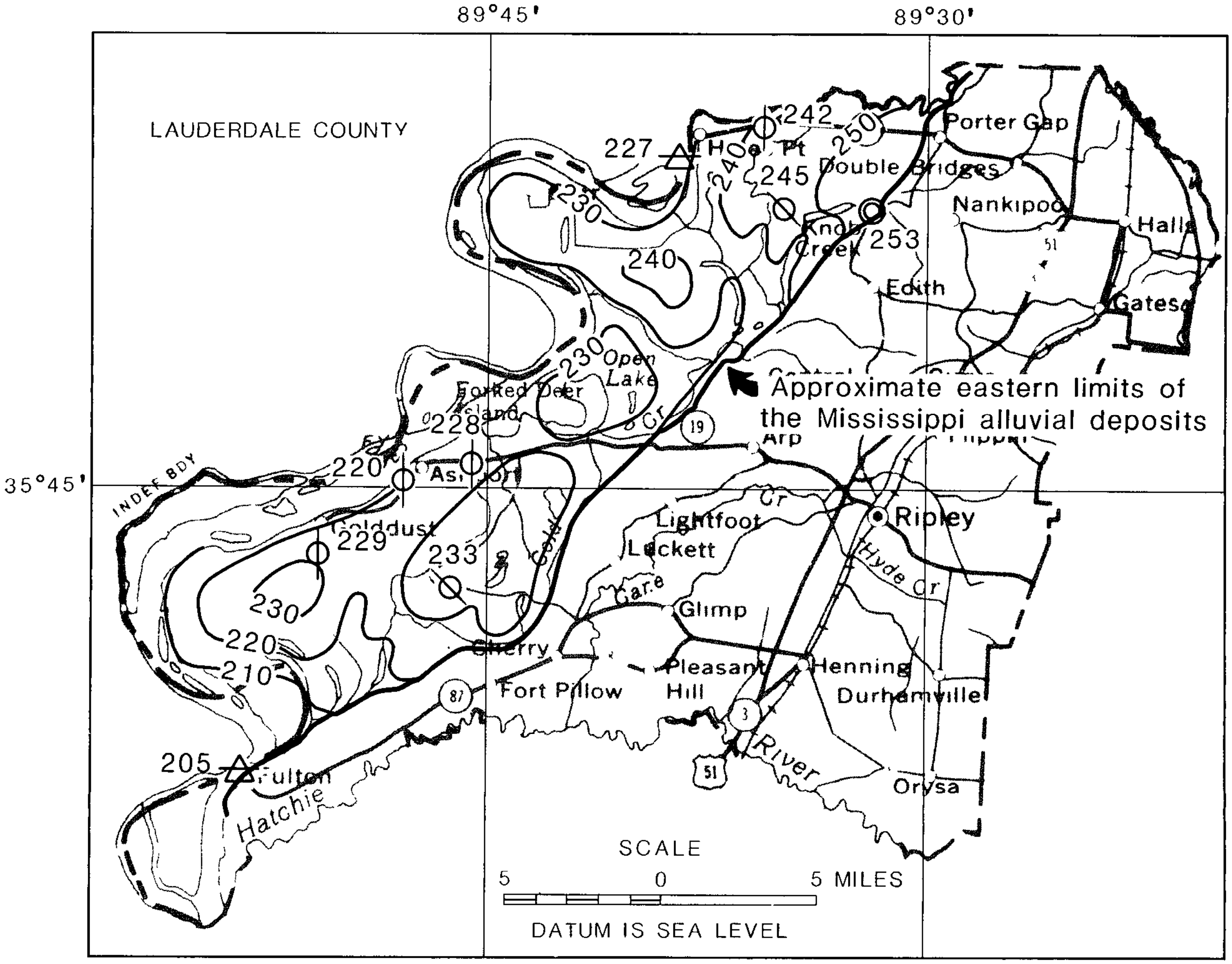


Figure 11.-- Long-term water-level changes in the Memphis Sand, and a correlation between water-level changes in the Memphis Sand and stages of the Mississippi River.



Base from U.S. Geological Survey 1:500,000, 1973

Figure 12.-- Altitude of the water-level surface in the Mississippi alluvial deposits, October 1983 (General configuration of water-level surface modified from Krinitzsky and Wire, 1964).

EXPLANATION

—230— WATER-LEVEL CONTOUR-- Shows altitude at which water level would have stood in tightly cased wells. Contour interval 10 feet.

242 Unused well

245 Observation well

253 Irrigation well

227 Low-flow at staff gage

Number at each site is altitude of water level.

greater depths beneath the hills and ridges and at lower altitudes but lesser depths beneath the valleys and flood plains.

Water in the Cockfield may be unconfined, semi-confined, or confined, depending on local conditions. Large differences in the altitude of the water-level surface in the Cockfield exist between the uplands of the Gulf Coastal Plain and the lowlands of the Mississippi Alluvial Plain at their juncture along the bluffs. Consequently, water from the Cockfield probably provides significant recharge to the Mississippi alluvial deposits laterally along the front of the bluffs and some recharge as upward leakage under the Mississippi Alluvial Plain. These large differences in the water-level surface also may be the cause of water being semi-confined or confined under pressure where clay beds or lenses in the aquifer serve as local confining beds.

Using altitudes shown in figure 13 and extremes in altitude of the topography in the county, it is estimated that water levels in the Cockfield Formation range from near land surface to as much as 150 feet below land surface, depending on location and altitude.

Water in the Memphis Sand probably is confined at most places by the Cook Mountain Formation. Where the Cook Mountain is displaced by faults, the Memphis Sand and Cockfield may be in direct hydraulic connection. Differences between the water-level surfaces shown by figures 13 and 14 indicate a potential for downward leakage of water from the Cockfield to the Memphis Sand in most of the county. It is also possible that in some areas the upper part of the Memphis Sand is separated from the lower part by clay beds or lenses which effectively act as confining beds, resulting in differences in water levels between these two parts of the aquifer.

Because of complications in the stratigraphy of the upper part of the aquifer and upper confining bed and of the existence of faults, the water-level surface of the Memphis Sand in Lauderdale County may be more complex than is shown in figure 14.

The configuration of the water-level surface in the Memphis Sand slopes gently to the west. Using altitudes shown in figure 14 and extremes in altitude of the topography in the county, it is estimated that water levels range from near land surface at the lower altitudes in the Mississippi Alluvial Plain to as much as 250 feet below land surface at the higher altitudes in the Gulf Coastal Plain.

Although no wells are available for water-level for measurement in the Fort Pillow Sand in Lauderdale County, the generalized configuration of the water-level surface can be estimated from the regional water-level configuration (Hosman and others, 1968) and measurements made in Mississippi County, Arkansas.

Water in the Fort Pillow Sand is confined by thick relatively impermeable confining beds above and below. According to Criner and others (1964, p. 037), aquifer tests at Memphis indicate that the Fort Pillow Sand, hydraulically, is almost an ideal artesian aquifer.

The water-level surface slopes gently towards the southwest towards pumpage centers in Mississippi County, Ark. Using altitudes shown in figure 15 and extremes in altitude of the topography in the county, it is estimated that water levels range from near land surface at the lowest altitudes in the Mississippi Alluvial Plain to as much as 275 feet below land surface at the highest altitudes in the Gulf Coastal Plain.

WATER QUALITY

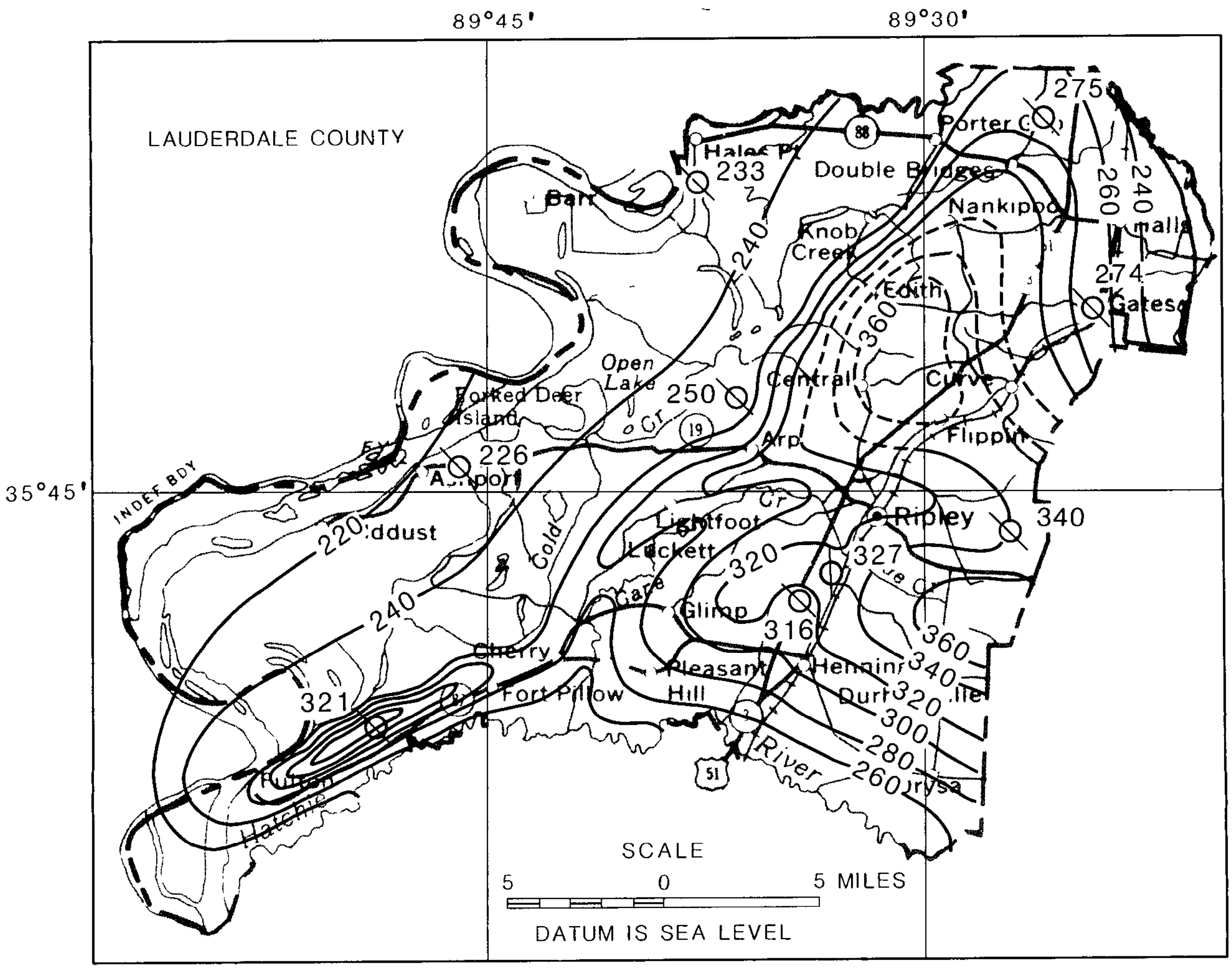
Over the years the Geological Survey has collected some water-quality information for the aquifers in Lauderdale County. Between 1929 and 1965, 20 wells were sampled--most during the 1950's. This water was analyzed for selected common constituents and properties, and the analyses were published by Parks (1981, table 4).

During the present investigation an additional 19 wells were sampled, including a representative selection of currently producing industrial and public supply wells. This water was analyzed for selected common constituents and properties and also selected trace constituents. These analyses are published in the Survey's annual reports, "Water Resources Data for Tennessee," for the 1980, 1981, and 1982 water years and are not repeated here.

For this report, a statistical summary was compiled using the data from analyses for 34 wells in the Mississippi alluvial deposits, Cockfield Formation, and Memphis Sand. Analyses of water from three shallow, public supply wells in the fluvial deposits at Henning and two wells in the Jackson Formation at Edith were excluded in the summary inasmuch as the fluvial deposits and the Jackson Formation are not considered principal shallow aquifers. A short discussion is given of the general chemical constituents of the Fort Pillow Sand based on data from outside the county.

General Characteristics

Statistical data for selected common constituents and properties of water from



Base from U.S. Geological Survey 1:500,000, 1973

Figure 13.-- Altitude of the water-level surface in the Cockfield Formation, October 1983.

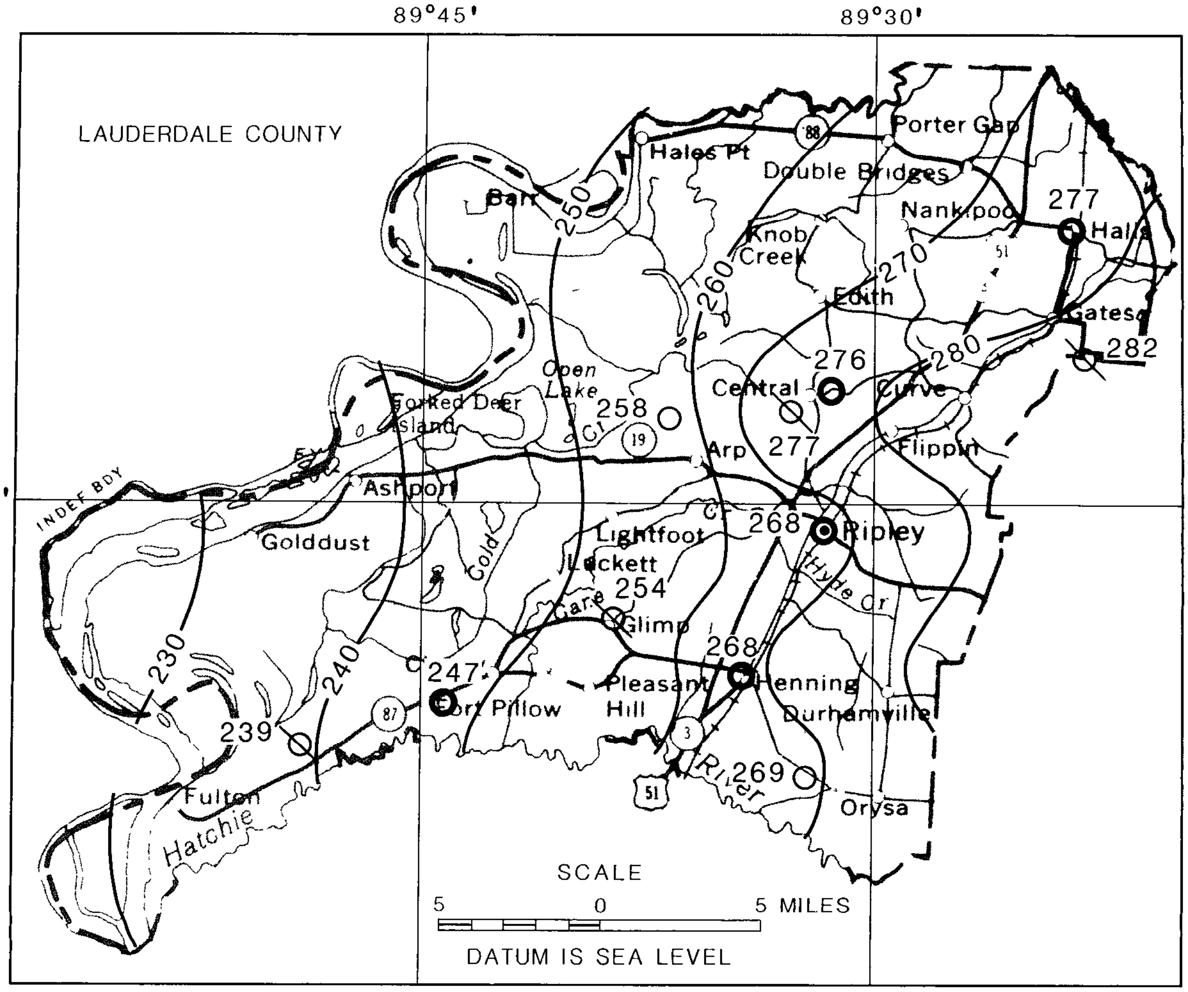
EXPLANATION

— 220 — WATER-LEVEL CONTOUR-- Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 20 feet.

327 Unused well

226 Observation well

Number at each site is altitude of water level.



Base from U.S. Geological
Survey 1:500,000, 1973

Figure 14.-- Altitude of the water-level surface in the Memphis Sand, October 1983.

EXPLANATION

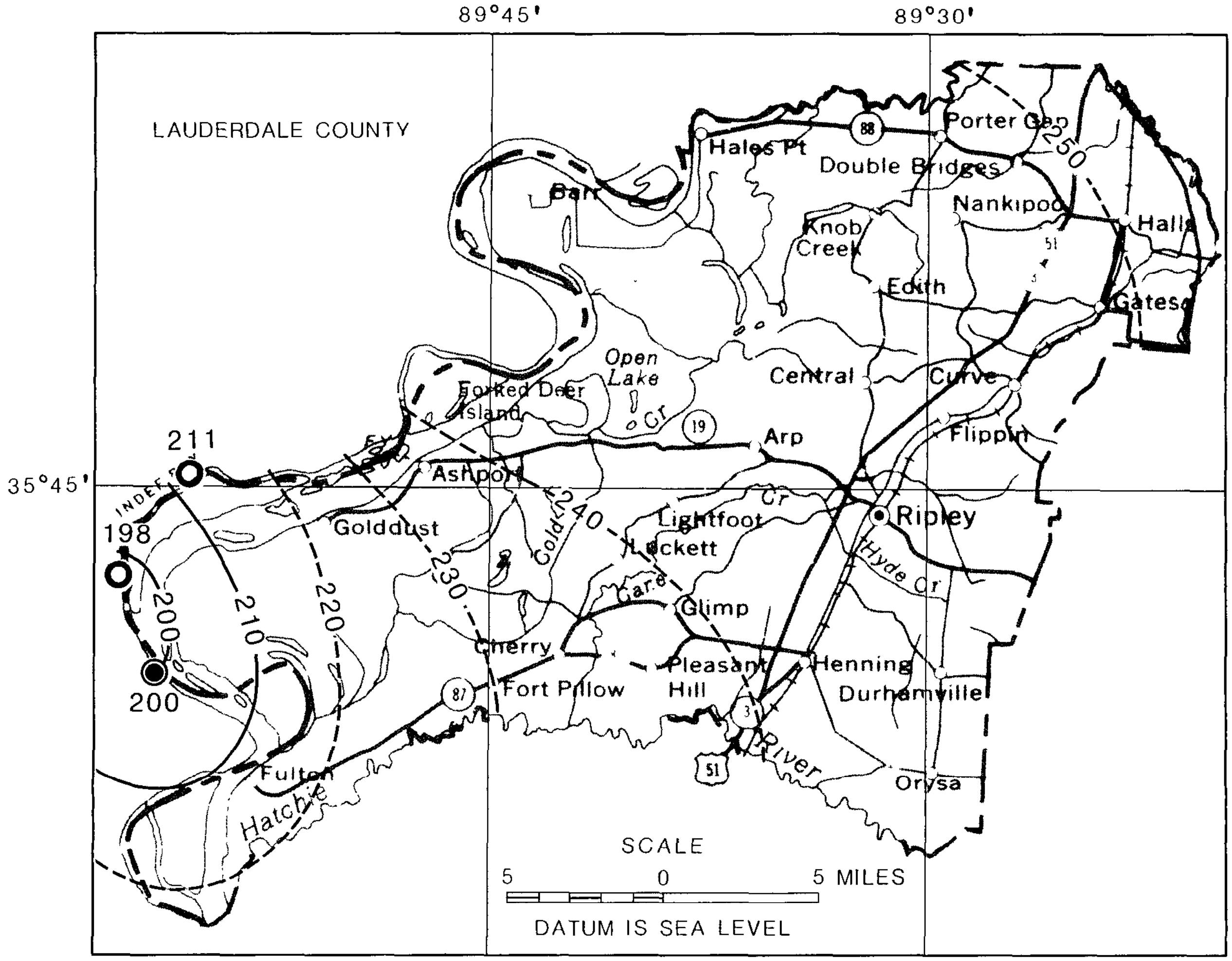
— 240 — WATER-LEVEL CONTOUR-- Shows altitude at which water level would have stood in tightly cased wells. Contour interval 10 feet.

○ 258 Farm well

⦰ 254 Observation well

O 247 Public-supply well

Number at each site is altitude of water level



Base from U.S. Geological Survey 1:500,000, 1973

Figure 15.-- Altitude of the water-level surface in the Fort Pillow Sand, October 1983 (General configuration of the water-level surface modified from Hosman and others 1968, plate 4).

EXPLANATION

—220 — — WATER-LEVEL CONTOUR-- Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 10 feet.

O 211 Public-supply well

◉ 200 Industrial-supply well

Number at each site is altitude of water level.

the Mississippi alluvial deposits, Cockfield Formation, and Memphis Sand in Lauderdale County are given in table 4. In general, these data show that water in these three aquifers is a calcium bicarbonate type.

The highest median concentrations of most of the common constituents and properties are in water from the Mississippi alluvial deposits; thus, this aquifer contains the most mineralized water of the three aquifers. Iron, manganese, potassium, and total organic carbon are lowest in the Cockfield with median values of 1,900 micrograms per liter (ug/L), 106 ug/L, 1.7 mg/L, and 0.5 mg/L, respectively. Water temperature increases with depth. Median values are 16.0°C for the Mississippi alluvial deposits, 17.0°C for the Cockfield Formation, and 18.0°C for the Memphis Sand.

With the exception of the parameters discussed above, the median concentrations of the selected common constituents and properties of ground water generally decrease with increasing depth. In general, the water from the three principal shallow aquifers is of good quality. Undesirable parameters from standpoint of use, though not detrimental to health, are high hardness, high concentrations of dissolved iron, and moderate concentrations of dissolved solids.

Water from the Mississippi alluvial deposits is characteristically very hard (median value--354 mg/L as $CaCO_3$) and has high concentrations of iron (median value--11,200 ug/L) and moderate concentrations of dissolved solids (median value--402 mg/L). Locally, shallow wells less than 25 feet deep provide somewhat softer water with lower concentrations of iron and dissolved solids. The lower degree of mineralization is probably due to recharge from surface sources (rainfall, nearby streams, or lakes).

Water from the Cockfield Formation is hard (median value--127 mg/L as $CaCO_3$), and has lower concentrations of dissolved iron (median value--1,900 ug/L) and dissolved solids (median value--142 mg/L) than the Mississippi alluvial deposits, but it has higher dissolved solids concentrations than the Memphis Sand. This water is commonly treated to remove iron.

Water from the Memphis Sand is moderately hard (median value--84 mg/L as $CaCO_3$) has lower dissolved solids concentrations (median value--112 mg/L) than the Mississippi alluvial deposits and the Cockfield, but it has higher dissolved iron concentrations (median value--5,800 ug/L) than the Cockfield. Treatment for iron removal commonly includes aeration, sedimentation (or coagulation and sedimentation), and filtration.

Although no water-quality data are available for the Fort Pillow Sand in Lauderdale County, this aquifer is worthy of discussion because it is the next deepest aquifer beneath the Memphis Sand that has potential for development. The Fort Pillow Sand is untapped in Lauderdale County, but because of the quality of its water, this aquifer is used exclusively as the principal source of water for public and industrial supplies across the Mississippi River in Mississippi County, Arkansas.

According to Ryling (1960, p. 57) the Fort Pillow Sand (Wilcox Formation in his report) contains sodium bicarbonate type water that is uniformly low in mineralization. Analyses given by Ryling (1960, table 14) of water from supply wells at Blytheville, Burdette, Luxora, and Osceola, show that the dissolved solids concentrations in water from the Fort Pillow Sand equivalent in Mississippi County, Arkansas, are about the same as those from the Memphis Sand in Lauderdale County. Of significance though is the fact that the water from the Fort Pillow Sand is soft (16 to 28 mg/L as $CaCO_3$) and dissolved iron concentrations are lower (180 to 1,600 ug/L) than in the Memphis Sand in Lauderdale County. The quality of water from the Fort Pillow Sand in Lauderdale County would have to be confirmed by test wells. Water from the Fort Pillow Sand can be expected to be somewhat warmer (21.0° to 26.0° C) than that from the Memphis Sand.

Trace Constituents

Statistical data for selected trace constituents in water from the principal shallow aquifers are given in table 5. Of these trace constituents, arsenic and zinc are the only ones that are consistently present in the samples analyzed. The concentrations of arsenic are greatest in water from the Mississippi alluvial deposits having a median value of 6 ug/L and a maximum value of 14 ug/L. Very small concentrations of arsenic are present in the Cockfield and Memphis Sand with maximum values of 1 ug/L and 2 ug/L, respectively, for these aquifers.

Zinc is present in small concentrations in water from all three aquifers. Locally, however, the Memphis Sand may contain what seems to be anomalously high concentrations of zinc. Zinc concentration was 240 ug/L in water from the observation well (Ld:G-12) in the Memphis Sand at Glimp.

The other trace constituents determined--cadmium, chromium, copper, lead, mercury, and selenium--either were below the limits of detection for the analytical techniques used or were present in very small concentrations.

The values of the selected trace constituents are all well below the maximum concentrations recommended by the U.S. Environmental Protection Agency (1979) for drinking water supplies.

Short-term Changes

To provide background information on short-term changes in water quality, two wells--Ld:F-8 in the Mississippi alluvial deposits and Ld:N-4 in the upper part of the Memphis Sand--were sampled monthly for 12 months and twice at 6-month intervals thereafter. These analyses have or are being published in the Survey's "Water Resources Data for Tennessee" for the 1981, 1982, and 1983 water years, and are not repeated here.

The analyes show slight variations in the values for the common constituents and properties and for the selected trace constituents over this short-term period, but the variations do not seem to show any correlation between seasonal high and low water-levels. These variations may be the result of differences in the quality of the water in the aquifers as received at the wells or in the sampling procedures or analytical techniques.

AQUIFER CHARACTERISTICS

Single-well pumping tests were made in four observation wells installed during the present investigation. Of these, two were in the Mississippi alluvial deposits, one in the Cockfield Formation, and one in the Memphis Sand. Estimated values of transmissivity made from these tests may not be indicative of the transmissivity of the individual aquifers because of excessive drawdown due to water entrance losses to the wells and partial penetration of the aquifers. The few aquifer tests (multiple-well pumping tests) previously made in the county and in nearby areas may provide a more reliable indication of aquifer characteristics than the single-well pumping tests. However, any test is valid only for the immediate area of the test site.

Single well pumping tests in wells Ld:S-2 and Ld:F-8, both in the Mississippi alluvial deposits, provided estimated values of transmissivity of about 17,700 and 24,100 $(ft^3/d)/ft$, respectively. Ld:S-2 was screened for 20 feet in a sand and gravel about 100 feet thick, and Ld:F-8 was screened for 20 feet in a fine to medium sand about 90 feet thick. The results of four aquifer tests made in wells in the alluvial deposits in Mississippi County, Arkansas, indicated values of transmissivity ranging from about 16,100 to 38,900 $(ft^3/d)ft$ (Ryling, 1960, table 9). The values estimated for wells Ld:S-2 and Ld:F-8 are within this range and may be a reliable indication of transmissivity of the alluvial deposits at these sites. Values of storage determined from the Arkansas tests ranged from $5x10^{-4}$ to $9x10^{-4}$.

A single-well pumping test made in well Ld:L-2 in the Cockfield Formation provided an estimated value of transmissivity of about 1,500 $(ft^3/d)/ft$. An aquifer test made in 1961 at the U.S. Military Reservation near Halls, involving two wells screened in the Cockfield indicated a transmissivity of about 2,500 $(ft^3/d)/ft$ (Moore, 1965, fig. 4). The 1,500 $(ft^3/d)/ft$ from the test in Ld:L-2 may represent the transmissivity of the 46-foot fine sand in which the 20-foot screen was set. If so, the hydraulic conductivity of this sand would be about 32 $(ft^3/d)/ft^2$ which seems a reasonable value for such a sand. The test at the U.S. Military Reservation indicated a storage of $3x10^{-4}$ for the Cockfield.

A single-well pumping test made in well Ld:G-12 in the upper part of the Memphis Sand provided an estimated value of transmissivity of about 8,000 $(ft^3/d)/ft$. An aquifer test made in 1961 at Ripley, involving two municipal wells screened in the lower part of the Memphis Sand indicated a transmissivity of about 22,400 $(ft^3/d)/ft$ (Moore, 1965, plate 7). The 8,000 $(ft^3/d)/ft$ from the test in Ld:G-12 may represent the transmissivity of the 170-foot fine or fine to medium sand in which the 20-foot screen was set. If so, the hydraulic conductivity of this sand would be about 47 $(ft^3/d)/ft^2$ which seems like a reasonable value for such a sand. No value of storage was determined from the test at Ripley, but tests at Memphis indicate a value of $3x10^{-3}$ for the Memphis Sand (Criner and others, 1964, p. 30).

No aquifer test data are available for the Fort Pillow Sand in Lauderdale County. An aquifer test made at the Blytheville Air Force Base in Mississippi County, Arkansas, indicated a transmissivity of about 21,400 $(ft^3/d)/ft$ and storage of $2x10^{-4}$ for this aquifer (Ryling, 1960, table 9). Criner and others (1964, p. 037) give ranges of transmissivity from about 12,100 to 18,800 $(ft^3/d)/ft$ and storage from $1.5x10^{-4}$ to $4x10^{-4}$ for this aquifer at Memphis. The above values should provide a guide to transmissivity and storage to be expected for this aquifer in Lauderdale County.

NEED FOR ADDITIONAL WORK

This investigation of the ground-water system in Lauderdale County closely followed the plan proposed by Parks (1981, p. 46-53). As the work progressed, however, this plan had to be modified some-

Table 4.--Minimum, median, and maximum values for selected common constituents and properties of water from aquifers in Lauderdale County[1]--Continued

	Fluoride, dissolved (mg/L as F)	Nitrate, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Carbon organic, total (mg/L as C)	Solids, residue at 180°C (mg/L)	Hardness (mg/L as $CaCO_3$)	pH (units)	Color (platinum cobalt units)	Temperature (°C)	Specific conductance (µmhos/cm)
Mississippi alluvial deposits										
Minimum	0.1	0.01	0.000	0.3	78	25	6.0	2	14.0	111
Median	0.2	0.16	0.033	2.1	402	354	6.9	6	16.0	688
Maximum	0.4	1.13	0.459	3.1	491	443	7.2	15	17.0	933
Number of analyses.[2]	9	7	9	4	9	10	9	5	10	9
Cockfield Formation										
Minimum	0.0	0.02	0.010	0.2	94	76	6.1	5	16.5	229
Median	0.2	0.10	0.020	0.5	142	127	6.5	-	17.0	255
Maximum	0.2	3.5	0.090	4.1	188	184	6.8	5	17.5	370
Number of analyses.	6	5	4	6	6	9	7	1	9	7
Memphis Sand										
Minimum	0.0	0.0	0.010	0.2	101	50	6.2	2	16.5	128
Median	0.1	0.02	0.010	0.6	112	84	6.4	3	18.0	191
Maximum	0.6	0.10	0.030	1.7	205	167	6.7	5	19.5	356
Number of analyses.[2]	10	6	6	6	12	15	11	4	12	14

[1]Values given as 0 (zero) or prefixes (less than) indicate that the constituent was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent.

[2]Two wells, one in the Mississippi alluvial deposits and the other in the Memphis Sand, were sampled monthly for a period of one year, and twice at 6-month intervals thereafter; the values for a particular constituent or property were averaged but the maximum and minimum were selected from the group; the group of analyses for a particular well was considered to be one analysis.

Table 4.--Minimum, median, and maximum values for selected common constituents and properties of water from aquifers in Lauderdale County[1]

[mg/L, milligrams per liter; ug/L, micrograms per liter; °C, degrees Celsius; umho/cm, micromhos per centimeter]

	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
Mississippi alluvial deposits										
Minimum	25	130	20	6.4	1.5	2.0	0.8	15	1.5	1.0
Median	28	11,200	150	94	27	8.2	2.0	358	14	4.1
Maximum	37	19,000	2,300	111	40	20	3.2	471	42	9.6
Number of analyses.[2]	10	10	9	10	10	10	10	10	10	10
Cockfield Formation										
Minimum	14	16	5	15	8	4.4	0.2	84	1.0	1.6
Median	19	1,900	106	28	14	7.1	1.7	140	4.0	2.2
Maximum	25	40,990	400	41	20	9.8	7.1	220	7.1	3.5
Number of analyses.	9	9	6	9	9	9	9	9	8	8
Memphis Sand										
Minimum	5	2,000	20	10	6.1	4.5	0.6	69	1.2	1.2
Median	12	5,800	110	18	9.5	6.4	2.1	98	3.4	2.0
Maximum	18	16,000	400	47	17	11	6.6	203	7.4	4.8
Number of analyses.	14	14	10	15	15	14	15	15	15	15

Table 5.--Minimum, median, and maximum values for selected trace constituents, in micrograms per liter, in water from aquifers in Lauderdale County[1]

	Arsenic, dissolved (as As)	Cadmium, dissolved (as Cd)	Chromium, dissolved (as Cr)	Copper, dissolved (as Cu)	Lead, dissolved (as Pb)	Mercury, dissolved (as Hg)	Selenium, dissolved (as Se)	Zinc dissolved (as Zn)
Mississippi alluvial deposits								
Minimum	3	<1	0	0	0	<0.1	0	10
Median	6	<1	10	1	5	<0.1	<1	20
Maximum	14	2	20	5	11	0.4	1	40
Number of analyses.[2]	4	4	4	4	4	4	4	4
Cockfield Formation								
Minimum	1	<1	<10	1	<1	<0.1	0	10
Median	1	1	10	2	4	<0.1	<1	20
Maximum	1	5	20	13	10	0.1	<1	80
Number of analyses.	6	6	6	6	6	6	6	6
Memphis Sand								
Minimum	1	<1	0	0	1	0.1	0	<10
Median	1	1	10	2	4	0.1	<1	<10
Maximum	2	5	10	7	6	0.7	<1	240
Number of analyses.[2]	7	7	7	7	7	7	7	7

[1]Values given as 0 (zero) or prefixes < (less than) indicate that the constituent was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent.

[2]Two wells, one in the Mississippi alluvial deposits and the other in the Memphis Sand, were sampled monthly for a period of 1 year and twice at 6-month intervals thereafter; the values for a particular constituent or property were averaged but the maximum and minimum were selected from the group; the group of analyses for a particular well was considered to be one analysis.

what to satisfy field conditions. Some suggested items for future work are as follows:

- o maintain the observation well network to provide the length of record necessary to establish seasonal and long-term water-level trends in the principal shallow aquifers;
- o collect additional water-level data and prepare detailed water-level maps of the aquifers to provide a better understanding of the ground-water flow system and areas of discharge and recharge;
- o install small diameter observation wells at selected depths and specified distances from several existing wells that can be pumped so that aquifer tests can be made to determine reliable values of transmissivity and storage;
- o run additional geophysical logs in test holes, new water wells, and abandoned wells to provide more geologic information to refine geologic structures, such as faults; and
- o make a comprehensive inventory of water wells to determine the present withdrawal from private wells that supply water for farm and domestic uses and to locate wells for geophysical logging and water-level measurement.

The preceding items deal specifically with additional work needed to further define the ground-water system and do not take into consideration additional work needed to further appraise the lignite resource. Nevertheless, much information about the lignite resouce could be obtained for making natural gamma and gamma-gamma (density) logs in abandoned wells of plastic casing construction. The success of this activity would require the cooperation of well owners and a way to remove the pumps from the wells.

SUMMARY AND CONCLUSIONS

Lauderdale county is situated in two major physiographic subdivisions. The eastern part is in the rolling-to-steep Gulf Coastal Plain, and the western part is in the flat-lying Mississippi Alluvial Plain. The boundary between these two subdivisions is defined by a line of bluffs, which locally have as much as 250 feet of relief.

The surface geology is, for the most part, relatively uncomplicated. The youngest geologic units at the surface are the alluvial deposits (alluvium), loess, and fluvial (terrace) deposits of Quaternary age. These surficial deposits are underlain by the Jackson Formation or the Cockfield Formation, both of Tertiary age. The Tertiary formations cannot be reliably subdivided at most places on the basis of present information.

The shallow subsurface formations underlying the Cockfield Formation are the Cook Mountain Formation and deeper Memphis Sand. Test holes drilled for this investigation show that (1) the Cook Mountain is not as thick as was expected, commonly about 60 feet; (2) the overlying Cockfield and the underlying Memphis Sand contain intervals of clay that could be confused with the Cook Mountain; and (3) the Cook Mountain commonly is not at a predictable structural position, when assuming an undisturbed structural setting for the area. These discordances of the Cook Mountain are interpreted to be the result of faulting. Several north-northeast and west-northwest trending faults and their locations are identified by correlation of the Cook Mountain on the geophysical logs of wells.

The principal shallow aquifers in the county above the Midway Group, from youngest to oldest, are: (1) the Mississippi alluvial deposits; (2) the Cockfield Formation and (3) the Memphis Sand, both of the Claiborne Group; and (4) the Fort Pillow Sand of the Wilcox Group. The Mississippi alluvial deposits are Quaternary age, and the Cockfield, Memphis Sand, and Fort Pillow Sand are Tertiary age.

The Mississippi alluvial deposits, the principal aquifer used for domestic, farm, and irrigation supplies in the Mississippi Alluvial Plain, can be as much as 180 feet thick, but generally range from 100 to 150 feet in thickness. Existing wells in this aquifer are generally less than 120 feet deep and pump from 5 to 1,500 gal/min.

The Cockfield Formation, the principal aquifer used for domestic and farm supplies and for some industrial and public supplies in the Gulf Coastal Plain, is estimated to be 250 to 270 feet thick (where completely preserved). At most places, however, this aquifer has been reduced by erosion and locally is as little as 35 feet thick. Existing wells in the Cockfield are generally less than 350 feet deep and pump from 5 to 300 gal/min.

The Memphis Sand, the principal aquifer used for public supplies in the Gulf Coastal Plain, ranges from 650 to 770 feet in thickness. This aquifer is being used where the sands of the shallower aquifers do not yield sufficient water for large-capacity wells. Existing wells range from 400 to 800 feet in depth and pump from 60 to 1,120 gal/min.

The Fort Pillow Sand is, as yet, untapped. This aquifer underlies the entire county and ranges from 160 to 300 feet in thickness. Although it is deeper and probably will not yield as much water as the Memphis Sand, the Fort Pillow Sand has potential to yield water of somewhat better quality than the shallower aquifers.

Water use statistics for 1982 show that the average withdrawal was only about 3.1 Mgal/d to supply the main water-supply systems in the county. These water-supply systems include those at Halls, Henning, Fort Pillow State Prison Farm, Gates, and Ripley. The Lauderdale County Water Association provides water to most rural areas of the county.

Water levels, fluctuate seasonally. High water-levels generally occur in the winter, spring, or early summer, and low water-levels occur in the fall or early winter. Water levels range from near land surface to as much as 275 feet below land surface. Altitudes of the water-level surfaces in the principal shallow aquifers are highest in the eastern part of the county and are lowest in the western part. However, the depth to water in a particular aquifer depends on the local altitude of the land surface. Records of observation wells close to the Mississippi River show correlations between high water levels and prolonged high stages of the river.

Water from the Mississippi alluvial deposits, Cockfield Formation, and Memphis Sand is a calcium bicarbonate type and is, in general, of good quality. Water is most mineralized in the Mississippi, alluvial deposits, and least in the Memphis Sand. Undesirable parameters from the standpoint of use are hardness and concentrations of dissolved iron and dissolved solids.

Water from the Mississippi alluvial deposits is characteristically very hard (Median value--354 mg/L as $CaCO_3$), and has high concentrations of iron (median value--11,200 ug/L) and moderate concentrations of dissolved solids (median value--402 mg/L. Water from the Cockfield Formation is hard (median value--127 mg/L as $CaCO_3$) and has lower concentrations of dissolved iron (median value--1,900 ug/L) and dissolved solids (median value--142 mg/L) than the Mississippi alluvial deposits, but it has higher concentrations of dissolved solids than the Memphis Sand. Water from the Memphis Sand is moderately hard (median value--84 mg/L as $CaCO_3$) and has lower dissolved solids concentrations (median value--112 mg/L) than the Mississippi alluvial deposits and the Cockfield, but it has higher dissolved iron concentrations (median value--5,800 ug/L) than the Cockfield.

Values of transmissivity were estimated from single-well pumping tests in four observation wells. These values for the Mississippi alluvial deposits are 17,700 and 24,100 $(ft^3/d)/ft$, for the Cockfield Formation 1,500 $(ft^3/d)/ft$, and for the Memphis Sand 8,000 $(ft^3/d)/ft$. Because of partial penetration of the aquifers, these values of transmissivity may not be indicative of the total thickness of the individual aquifers.

Items suggested for future work include (1) maintenance of the observation well network for the collection of long-term water-level data, (2) collection of additional water-level data for the preparation of detailed water-level maps of the aquifers, (3) installation of wells near existing wells for making aquifer tests, (4) geophysical logging of additional wells to provide more geologic information to refine geologic structures, and (5) a comprehensive inventory of water wells for determining the present withdrawal from private wells and for locating wells in which geophysical logs and water-level measurements could be made.

SELECTED REFERENCES

Boswell, E. H., Cushing, E. M., and Hosman, R. L., 1968, Quaternary aquifers in the Mississippi embayment, with a discussion of Quality of water by H. G. Jeffery: U.S. Geological Survey Professional Paper 448-E, p. E1-E15.

Criner, J. H., and Parks, W. S., 1976, Historic water-level changes and pumpage from the principal aquifers of the Memphis area, Tennessee: 1886-1975: U.S. Geological Survey Water Resources Investigations Report 76-67, 45 p.

Criner, J. H., Sun, P-C. P., and Nyman, D. J., 1964, Hydrology of the aquifer systems in the Memphis area, Tennessee: U.S. Geological Survey Water-Supply Paper 1779-0, p. 01-054.

Cushing, E. M., Boswell, E. H., and Hosman, R. L., 1964, General geology of the Mississippi embayment: U.S. Geological Survey Professional Paper 448-B, p. B1-B28.

Cushing, E. M., Boswell, E. H., Speer, P. R., Hosman, R. L., and others, 1970, Availability of water in the Mississippi embayment: U.S. Geological Survey Professional Paper 448-A, p. A1-A13.

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

Glenn, L. C., 1906, Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U.S. Geological Survey Water-Supply Paper 164, 173 p.

Graham, D. D., 1982, Effects of urban development on the aquifers in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 82-4024, 20 p.

Hardeman, W. D., Miller, R. A., and Swingle, G. D., compilers, 1966, Geologic map of Tennessee: Tennessee Division of Geology, scale 1:250,000, 4 sheets.

Heyl, A. V., and McKeown, F. A., 1978, Preliminary seismotectonic map of the central Mississippi Valley and environs: U.S. Geological Survey Miscellaneous Field Studies Map MF-1011, scale 1:500,000, 2 sheets.

Hildenbrand, T. G., Kane, M. F., and Hendricks, J.D., 1982, Magnetic basement in the upper Mississippi embayment region--a preliminary report: U.S. Geological Survey Professional Paper 1236-E, p. 39-53.

Hosman, R. L., Long, A. T., Lambert, and others, 1968, Tertiary aquifers in the Mississippi embayment, with discussions of Quality of water by H. G. Jeffery: U.S. Geological Survey Professional Paper 448-D, p. D1-D29.

Krinitzsky, E. L., and Wire, J. C., 1964, Ground water in alluvium of the Lower Mississippi Valley (upper and central areas): U.S. Army Engineer Waterways Experiment Station Technical Report No. 3-658 (2 v.) 100 p.

Lanphere, C. R., 1955, Geologic source and chemical quality of public ground-water supplies in western Tennessee: Tennessee Division of Geology Report of Investigation no. 1, 69 p.

Luppens, J. A., 1978, Exploration for Gulf Coast United States lignite deposits: Their distribution, quality, and reserves: Paper presented at the Second International Coal Exploration Symposium, at Denver, Colorado, October 1-4, 1978, 17 p.

Milhous, H. C., 1959, Well logs in Tennessee: Tennessee Division of Geology Bulletin 62, 606 p.

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

Moore, G. K., 1965, Geology and hydrology of the Claiborne Group in western Tennessee: U.S. Geological Survey Water-Supply Paper 1809-F, p. F1-F44.

Moore, G. K., and Brown, D. L, 1969, Stratigraphy of the Fort Pillow test well, Lauderdale County, Tennessee: Tennessee Division of Geology Report of Investigations 26, 1 sheet.

Parks, W. S., 1981, Appraisal of hydrologic information needed in anticipation of lignite mining in Lauderdale County, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 80-54, 67 p.

Russell, E. E., and Parks, W. S., 1975, Stratigraphy of the outcropping Upper Cretaceous, Paleocene, and lower Eocene in western Tennessee (including descriptions of younger fluvial deposits): Tennessee Division of Geology Bulletin 75, 118 p.

Ryling, R. W., 1960, Ground-water potential of Mississippi County, Arkansas: Arkansas Geological and Conservation Commission Water Resources Circular No. 7, 87 p.

Saucier, R. T., and others, 1964-78, Geological investigation of the St. Francis basin: U.S. Army Engineer Waterways Experiment Station Technical Report 3-659, folio of maps and cross sections published at various dates, approx. 45 sheets.

Stearns, R. G., and Wilson, C. W., Jr., 1972, Relationships of earthquakes and geology in West Tennessee and adjacent areas: Knoxville, Tennessee, Tennessee Valley Authority, 302 p.

Stearns, R. G., Wilson, J. M., and Reesman, A. L., 1981, Impact of proposed lignite mining in west Tennessee: U.S. Bureau of Mines, a minerals research report to complete contract J0100024 with Vanderbilt University and Environmental Systems Corporation of Nashville, Tennessee, 247 p.

Strausberg, S. I., and Schreurs, R. L., 1958, Ground-water resources of the Mississippi alluvial valley of Tennessee: Unpublished report on file in the Memphis office of U.S. Geological Survey and Nashville office of Tennessee Division of Geology, 49 p.

Tennessee Department of Public Health, Stream Pollution Control Board, 1964-65, Ground-water survey of western Tennessee: 49 p.

U.S. Environment Protection Agency, 1976, National interim primary drinking water regulations, Environmental Protection Agency Report 570/9-76-003, 159 p.

______1979, National interim secondary drinking water regulations: U.S. Environmental Protection Agency Report 570/9-76-000, 37 p.

U.S. Geological Survey (no date), Ground-water levels in the United States--Southeastern States: U.S. Geological Survey Water-Supply Paper(s) 1978, 2171, and 2165 (5-year summaries for 1964-68 and 1969-73) and annual summary for 1974.

______1965-83, Water resources data for Tennessee: U.S. Geological Survey Data Report. Issued annually.

Wells, F. G., 1933, Ground-water resources of western Tennessee, with a discussion of Chemical character of water by F. G. Wells and M. D. Foster: U.S. Geological Survey Water-Supply Paper 656, 319 p.