Water Resources of Grant and Hot Spring Counties, Arkansas

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1857

Prepared in cooperation with the Arkansas Geological Commission

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By H. N. HALBERG, C. T. BRYANT, *and* M. S. HINES

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WATER RESOURCES OF GRANT AND HOT SPRING COUNTIES, ARKANSAS

By H. N. HALBERG, C. T. BRYANT, and M. S. HINES

ABSTRACT

In Grant and Hot Spring Counties the Ouachita, Saline, and Caddo Rivers yield large quantities of soft, good-quality water. Small streams in southeastern Hot Spring County and some of the small streams in the Ouachita Mountains have relatively high base flow; in Grant County small streams yield little water during dry periods. At times, sewage and mine drainage pollute the Ouachita River from the Garland County line to a point a few miles below Lake Catherine. At low flow, Hurricane Creek water is unfit for most uses.

The Sparta Sand, the principal aquifer, yields as much as 850 gpm of soft water in Grant County. The Carrizo Sand and Cane River Formation are potentially important aquifers in Grant County and southeastern Hot Spring County. The Wilcox Group yields as much as 300 gpm of fresh water in southeastern Hot Spring County and southwestern Grant County; in the rest of Grant County its water is brackish. The alluvium along the principal streams and the consolidated rocks of the Ouachita Mountains yield small quantities of water that vary in quality from place to place. Some of the water from the alluvium has high nitrate content and may be a hazard to health.

INTRODUCTION

PURPOSE AND SCOPE

The development and management of water resources to meet increasing demands of municipal, industrial, and agricultural expansion require knowledge of the occurrence and use of water. This report describes, for Grant and Hot Spring Counties, the availability and quality of ground water in both the Interior Highlands and the Coastal Plain and the lithology of the principal aquifers in the Coastal Plain. Information is given on availability of surface water, including magnitude and frequency of floods and low flows, duration of daily flows, and storage requirements for specific dependable yields of streams. The report also describes the quality of the water of the Ouachita and Saline Rivers, and of many of the tributary streams, and furnishes information about existing or potential river- and ground-water pollution.

PREVIOUS WORK

Ground-water, streamflow, and water-quality data used for this study are compiled in a report by Edds and others (1967). A report by Albin (1965) on the water resources of the Ouachita Mountains covers part of the area of this report. Reports by Patterson (1964) and Hines (1965) provide information on flood-frequency and water-supply characteristics of streams, respectively.

COOPERATION AND ACKNOWLEDGMENTS

This report was prepared in cooperation with the Arkansas Geological Commission.

The authors acknowledge, with thanks, the help and information furnished by well drillers, industrial and public agencies, and individuals. They are grateful to Mr. Bruce Gwin, Water Works Superintendent, Sheridan; Mr. Pierce Reeder, Mayor, Leola; Messrs. Tom W. Stalnaker and Glen Tindle of the Natural Gas Pipeline Co. of America; and Mr. A. J. Stephens, Prattsville, for permitting supply wells to be used for aquifer tests.

DESCRIPTION OF THE AREA

Grant and Hot Spring Counties are in central Arkansas, about 50 miles south to southwest of Little Rock, and encompass an area of 1,254 square miles (fig. 1). Western Hot Spring County lies in the Ouachita Mountains section of the Ouachita province of the Interior Highlands (fig. 2). This area is about equally divided between the Broken Bow-Benton Uplift and the Athens Piedmont Plateau. The Broken Bow-Benton Uplift is made up of a series of east-west-trending parallel ridges and valleys, underlain principally by extensively folded shales, sandstone, chert, and novaculite of Paleozoic age. The most prominent ridges consist principally of Arkansas Novaculite. The extreme northern part of the county is in the Zigzag Mountains, the northwestern part is in the Trap Mountains, and the Ouachita River flows between the two mountain ranges, in the Mazarn Basin. The Athens Piedmont Plateau consists of a series of east-west ridges that increase in height from south to north; the plateau has a maximum relief of 300 feet. (See Fenneman, 1938, p. 668–683.) The ridges continue east of the Fall Line and disappear beneath the unconsolidated deposits of the Coastal Plain.

Eastern Hot Spring County and all Grant County lie in the West Gulf Coastal Plain section of the Coastal Plain province. The sediments in the Coastal Plain consist of clay, silt, sand, gravel, and limestone of Cretaceous and Tertiary age that dip gently southeast and south; they are overlain along the streams of flood-plain deposits of Quaternary age. (See table 4.)

Hot Spring County and most of Grant County are in the Ouachita River basin. Northeastern Hot Spring County and most of Grant

County are drained by the Saline River, a principal tributary of the Ouachita. A small area in the northeast corner of Grant County is drained by the Arkansas River. (See pl. 6.) Streams that drain the area are listed in table 8.

The streams in western Hot Spring County are incised deeply in the rocks. They have steep gradients and narrow valleys, resulting in rapid runoff. Lateral movement of the streams has been restricted by resistant rocks, resulting in narrow flood plains on the larger tributaries. Streams in the remainder of the two counties drain the gently rolling hills and lowlands of the Coastal Plain.

The two counties are sparsely populated. The total number of inhabitants is about 30,000, of whom 13,000 live in cities and towns.

Forestry is the most important agricultural industry. A few acres of row crops and rice are grown, and some cattle are raised in the area. Only small acreages of crops are irrigated. Woodlands cover about 85 percent of the counties, an increase from the 50 percent coverage of 30 years ago, when small farms were much more numerous. The

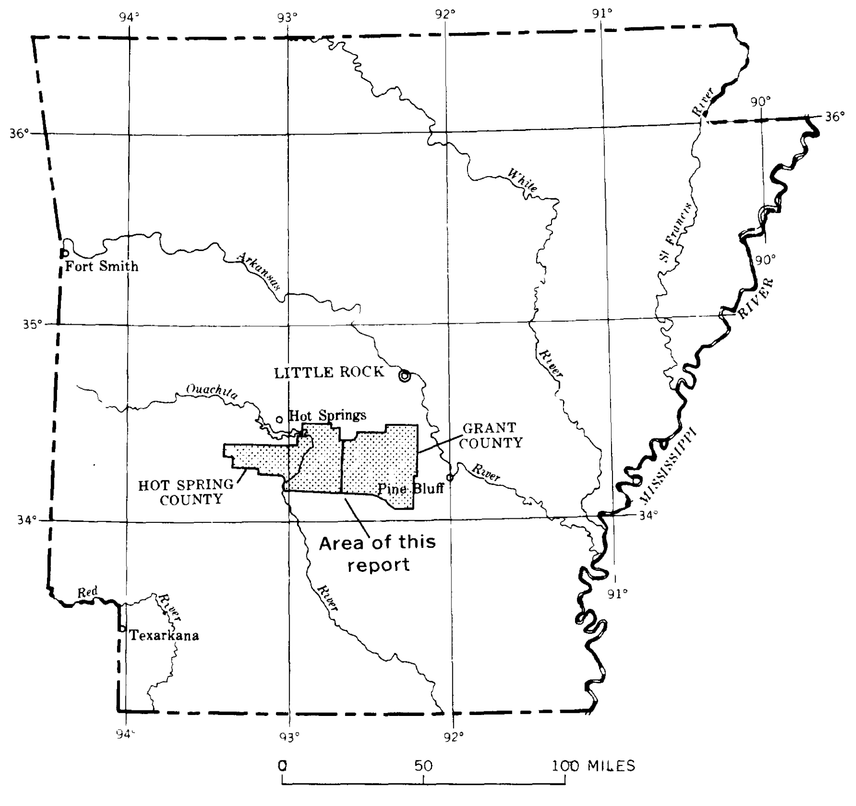

FIGURE 1.—Location of Grant and Hot Spring Counties

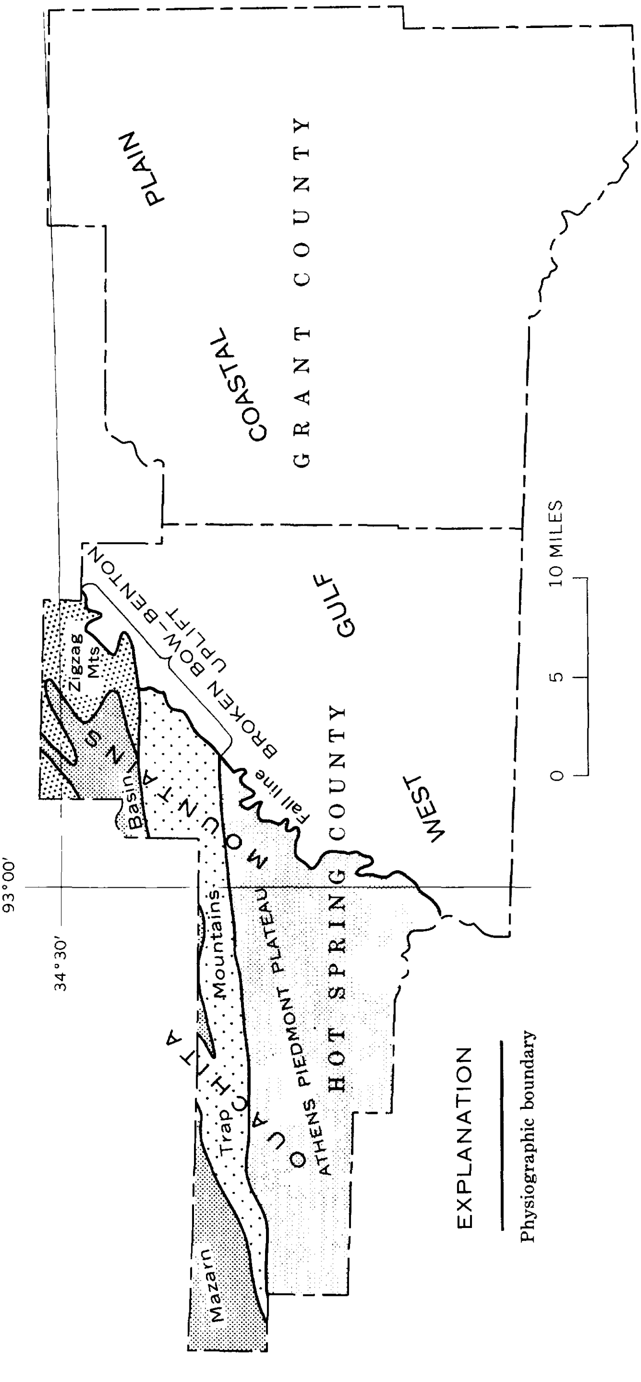

FIGURE 2.—Physiographic features. After Croneis (1930) and Fenneman (1938).

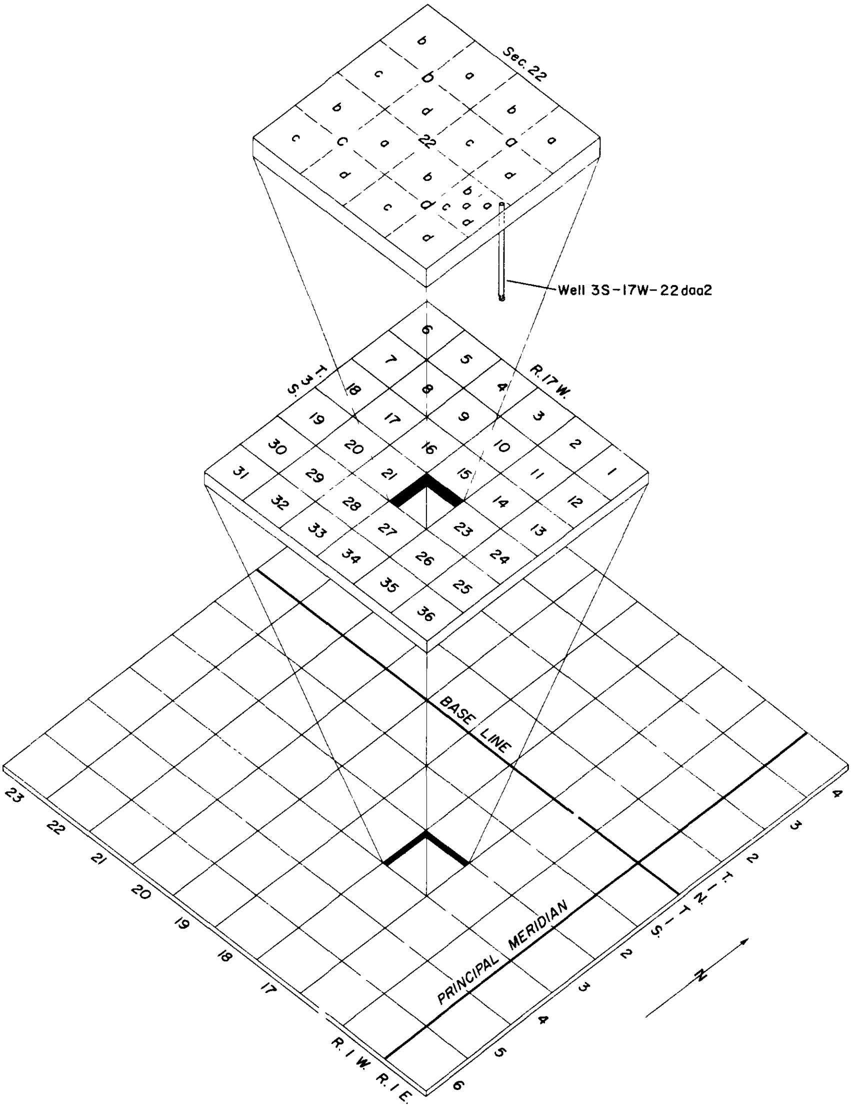

FIGURE 3.—Well-numbering system.

increase reflects the change from "dirt-farming" to growing pine for pulpwood and lumber.

Hot Spring County has three principal mineral industries. Barite is mined near Magnet for drilling mud and other barium products. Brick and tile are manufactured from the large deposits of clay near Malvern. Novaculite is mined in small quantities for the production of fine abrasive stones.

WELL-NUMBERING SYSTEM

The well and location numbers used in this report (fig. 3) are based on the Federal land-survey system as it is used in Arkansas. The township and range are written first; then the section number; then, starting in the northeast quarter section, three lowercase letters are used for the quarter section, quarter-quarter section, and quarter-quarter-quarter section. A serial number is appended if records are used for more than one well in a quarter-quarter-quarter section. Thus, the first well inventoried in the SE¼NW¼SW¼ sec. 21, T. 5 S., R. 18 W., is designated 5S–18W–21cbd1.

WATER USE

About 10 million gallons of water was used daily in 1965 for all purposes in the counties, excluding water used in the production of electric power (table 1). Fifteen percent of the 10 mgd (million gallons per day) was drawn from wells and springs and 85 percent from streams. The cities of Leola and Sheridan use ground water for their public supplies; the city of Malvern uses Ouachita River water. The public-supply systems proposed for Poyen and Prattsville will use ground water.

Practically all rural household supplies are drawn from wells. It is estimated that about 0.7 mgd was used by the 17,500 people whose water supplies were not furnished by municipal systems.

Industries used about 6 mgd, most of which was drawn from their own sources of supply (table 1). Barite mines, gravel pits, and associated plants used 1.5 mgd of surface water for cooling, but this water is available for reuse.

A small quantity of water was used for irrigation. In southern Hot Spring County, about 0.7 mgd of surface water was applied to 440

TABLE 1.—*Estimated water use in Grant and Hot Spring Counties, 1965*

[Million gallons per day]

Use	Ground water	Surface water	Total
Public supply	0.31	0.83	1.14
Rural domestic	.70		.70
Industrial, self-supplied	.06	5.57	5.63
Recreation	.02		.02
Agriculture:			
Irrigation	.09	.75	.84
Livestock	.21	.27	.48
Minnow farm	.18	.86	1.04
	1.57	8.28	9.85
Fuel-electric power		209.40	209.40
Total	1.57	217.68	219.25

acres of rice and 80 acres of cotton and pastures. In central Grant County, about 0.1 mgd of water was applied to 280 acres of cotton and pastures. The 33,000 head of livestock in the two counties used about 0.5 mgd.

The quantity of water used in the two counties is a small percentage of the available supply. The only large individual use is the 209 mgd used by a thermal-electric plant. This water is available for reuse. The following sections of the report describe the quantity, quality, and availability of water and the type and magnitude of problems that may be found. Suggested industrial water-quality tolerances are shown in table 2, and the source and significance of dissolved solids in, and physical properties of, water are shown in table 3.

APPRAISAL OF THE WATER RESOURCES

SUMMARY AND AREAL DISTRIBUTION

Large quantities of water are available throughout much of Grant and Hot Spring Counties. In isolated areas, only small quantities of water are available, and in some places, the quality of the water is poor. Most of the water is suitable for public supplies and industry after minor treatment. Practically all the water is suitable for irrigation.

The Ouachita, Saline, and Caddo Rivers are sources of large quantities of good-quality water along much of their courses in the two counties; the Ouachita is polluted from the Garland County line to a few miles below Lake Catherine. East of the Saline, large quantities of good-quality ground water are available; but the streams in this area yield little water during dry periods. Hurricane Creek can supply some water, but the water is highly polluted by industrial wastes. Between the Saline and Ouachita Rivers and in the Coastal Plain part of Hot Spring County north of Malvern, the aquifers and a few of the streams yield moderate quantities of good-quality water.

In the Ouachita Mountains, most wells yield only enough water for domestic or small farm use; the mineral composition of the water varies widely from place to place. Most of the small streams have small dependable yields of good-quality water, but not so much as can be obtained from streams between the Ouachita and Saline Rivers.

In the Coastal Plain, only the formations of Tertiary age yield large quantities of fresh water. The Sparta Sand is the most productive of the large-yielding aquifers, and its water has the best quality. The Carrizo Sand and Cane River Formation are potentially important aquifers; their water is of good quality but is harder and contains more dissolved solids than water from the Sparta Sand. The Wilcox Group is potentially important in southeastern Hot Spring County

TABLE 2.—*Suggested industrial water-quality tolerances* [1]

[Allowable limits in parts per million. Iron (Fe); limit given applies to iron (Fe) and to the sum of iron (Fe) and manganese (Mn). Other requirements; P indicates that portable water conforming to U.S. Public Health Service 1962 drinking-water standards must be used]

Use	Iron (Fe)	Manganese (Mn)	Alkylinity as HCO_3	Hydrogen sulfide (H_2S)	Dissolved solids	Hardness as $CaCO_3$	Turbidity	Color	Odor and taste	Other requirements
Air conditioning	0.5	0.5		1					Low	No corrosiveness or slime formation.
Baking	.2	.2		.2			10	10	do	P.
Brewing:										
Light beer	.1	.1	90	.2	500		10		do	P. NaCl <275 ppm, pH 6.5–7.0.
Dark beer	.1	.1	185	.2	1,000		10		do	P. NaCl <275 ppm, pH 7.0 or more.
Canning:										
Legumes	.2	.2		1		25–75	10		do	P.
General	.2	.2		1			10		do	P.
Carbonated beverages	[2].3	.2	60–120	.2	850	250	2	10	do	P. Organic color plus oxygen consumed, <10 ppm.
Confectionery	.2	.2		.2	100				do	P.
Cooling	.5	.5		5		50	50			No corrosiveness or slime formation.
Food, general	.2	.2					10		Low	P.
Ice	.2	.2					5	5	do	P. SiO_2 <10 ppm.
Laundering	.2	.2				50				
Plastics, clear, uncolored	.02	.02			200		2	2		

Paper and pulp, ground wood.	1.0	.5				180	50	20		No grit or corrosiveness.
Kraft pulp	.2	.1			300	100	25	15		
Soda and sulfite	.1	.05			200	100	15	10		
High-grade light papers.	.1	.05			200	50	5	5		
Rayon (viscose), pulp:										
Production	.05	.03	Total 50, hydroxide 8.		100	8	5	5		Al_2O_3 <8 ppm, SiO_2 <25 ppm, Cu <5 ppm.
Manufacture	.0	.0				55	.3			pH 7.8–8.3.
Tanning	.2	.2	Total 135, hydroxide 8.			50–135	20	10–100		
Textiles:										
General	.25	.25					5	20		
Dyeing	.25	.25			200		5	5–20		Constant composition. Residual alumina as Al_2O_3 <0.5 ppm.
Wool scouring	1.0	1.0						70		
Cotton bandage	.2	.2					5	5	Low	

[1] Modified from New England Water Works Assoc., 1940, p. 271. [2] Allowable limit of iron (Fe) is 0.2 ppm.

TABLE 3.—*Significance of dissolved mineral constitutents and physical properties of water*

Constituent or physical property	Source or cause	Significance
Temperature		Affects usefulness of water for many purposes. Most users desire cold water. In general, temperature of ground water at shallow depth fluctuates seasonally, but at moderate depth it is constant and is approximately the same as the mean annual air temperature. In deep wells, water temperature generally increases about 1° F for each 60- to 100-foot increment of depth.
Silica (SiO_2)	Dissolved from practically all rocks and soils, generally in small amounts, from 1–30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be dissolved from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of soluble iron in surface water generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown. Objected to in water for food processing, bottling of beverages, bleaching, brewing, dyeing, ice manufacture, papermaking, and other processes. U.S. Public Health Service (1962) drinking-water standards recommend that iron should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Manganese (Mn)	Dissolved from some rocks and soils. Not so common as iron. Large quantities commonly associated with high iron content or acid waters.	Has same objectionable features as iron. Causes dark-brown or black stain. U.S. Public Health Service (1962) drinking-water standards recommend that manganese should not exceed 0.05 ppm.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming. (See "Hardness as $CaCO_3$" below.) Waters low in calcium and magnesium are desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Found also in connate water and industrial brines, sea water, and sewage.	Large amounts, in combination with chloride, give salty taste to water. High sodium content commonly limits use of water for irrigation. Sodium salts may cause foaming in steam boilers.
Bicarbonate (HCO_3) and carbonate (CO_3).	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers, and hot-water facilities to form scale and to release corrosive carbon dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and some industrial wastes.	Large amounts have a laxative effect on some people and, in combination with other ions, give a bitter taste to water. Sulfate in water containing calcium forms a hard scale in steam boilers. U.S. Public Health Service (1962) drinking-water standards recommend that sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in sea water, connate water, and industrial brines.	Large quantity increases corrosiveness of water and, in combination with sodium, gives a salty taste to water. U.S. Public Health Service (1962) drinking-water standards recommend that chloride content should not exceed 250 ppm.

Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay in children if the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, the likelihood depending on concentration of fluoride, age of the child, amount of drinking water consumed, and susceptibility of the individual. According to U.S. Public Health Service (1962) drinking-water standards, the concentration of naturally present fluoride in water should not exceed 1.8 ppm. If the water is fluoridated, the average concentration of fluoride should be kept between 0.7 and 1.2 ppm.
Nitrate (NO_3)	Decaying organic matter, legume plants, sewage, nitrate fertilizers, and nitrates in soil.	Nitrate encourages growth of algae and other organisms that produce undesirable tastes and odors in water. Concentrations much greater than the local average may indicate pollution. U.S. Public Health Service (1962) drinking-water standards recommend that nitrate content should not exceed 45 ppm, as there is evidence that higher concentrations may cause methemoglobinemia in infants, the so-called blue-baby disease, which sometimes is fatal. Nitrate has been shown to be helpful in reducing intercrystalline cracking of boiler steel.
Phosphate (PO_4)	Dissolved from rocks containing apatite; leached from soils. Present in some fertilizers, detergents, and organic wastes. Phosphate compounds used in water treatment contribute some phosphate.	Concentrations present in natural waters are not toxic to man, animals, or fish. Phosphate stimulates growth of algae, which may cause objectionable odor.
Sulfide as H_2S	A product of reduction of sulfate by bacterial activity. Present also in some industrial wastes.	Water containing sulfides, especially hydrogen sulfide, may be undesirable because of its odor. Water containing large quantities may be corrosive. U.S. Public Health Service (1962) drinking-water standards recommend that water should have no objectionable odor. Toxicity to aquatic organisms differs for each species.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Include any organic matter and some water of crystallization.	U.S. Public Health Service (1962) drinking-water standards recommend that dissolved-solids content should not exceed 500 ppm. Water having a dissolved-solids content of more than 1,000 ppm is unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all hardness is due to calcium and magnesium. Metallic cations other than alkali metals also cause hardness.	Hard water consumes soap before lather will form, deposits soap curd on bath tubs, and forms scale in boilers, water heaters, and pipes. Hardness equivalent to bicarbonate and carbonate called carbonate hardness. Any hardness in excess of carbonate hardness called noncarbonate hardness. In general, waters having hardness of 60 ppm or less are considered soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; more than 180 ppm, very hard .
Specific conductance (micromhos at 25° C).	Mineral content of water	Specific conductance is measure of capacity of water to conduct electric current. This property varies with concentration and degree of ionization of the constituents and with temperature (therefore, reported at 25° C).
Hydrogen-ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide decrease pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates increase pH.	The pH of water is measure of activity of hydrogen ions; pH of 7.0 indicates neutral solution; pH greater than 7.0 indicates alkalinity; pH less than 7.0 indicates acidity. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline water may also attack metal.
Color	Yellow-to-brown color of some water is caused by organic matter extracted from leaves, roots, and other organic substances. Objectionable color in water also results from industrial wastes and sewage.	Water for domestic and some industrial uses should be free from perceptible color. Color objected to in water for food and beverage processing and for many manufacturing processes. U.S. Public Health Service (1962) drinking-water standards recommend that color should not exceed 15 units on the platinum-cobalt scale.

and southwestern Grant County. In the flood plains of the Ouachita and Saline Rivers, the alluvium is thin and much of it is fine grained. Wells that tap the alluvium yield only enough water to supply the needs of households, rural schools, or livestock; some of the water from the alluvium has a dangerously high nitrate content. In the two counties the sedimentary formations of Cretaceous age yield only salt water.

GROUND WATER

Grant and Hot Spring Counties are underlain by geologic formations that range in age from Ordovician to Recent (pl. 1; table 4). Most of the formations contain aquifers.

The location of, and stratigraphic relation between, the water-bearing units are shown on a geologic map pl. 1) and two sections (*A–A′* and *B–B′* on pl. 2). The outcrops of these formations, as shown on the geologic map and the sections, have been drawn principally on the basis of electric logs of oil-test wells.

The chemical quality of much of the ground water in the study area is good (table 5), but some treatment is needed to make it usable by most industries. Soft and hard water is found throughout the area. The water from most of the aquifers has a high iron content, and much of it has a low pH, indicating probable corrosiveness. Much of this slightly acidic condition is due to excess carbon dioxide; it is not due to pollution, as is true of most of the surface waters. Variations of chemical characteristics of ground water are shown on plate 3.

AQUIFIERS OF THE OUACHITA MOUNTAINS

Wells in the Ouachita Mountains tap aquifers in consolidated rocks of Paleozoic age (pl. 1; table 4). Most of the rocks are shale, sandstone, novaculite, and chert; but they include some limestone and intrusive igneous rocks. The oldest rocks are the Womble Shale and the Bigfork Chert of Ordovician age, which are tapped for water in a small area in northeastern Hot Spring County. A few wells tap the Arkansas Novaculite, which underlies the crests of the east-west-trending ridges in the northern part of the county. In the vicinity of Friendship, small quantities of water are obtained from the Jackfork Sandstone. The youngest rock is the Atoka Formation of Pennsylvanian age, which is present in a small area in the southern part of Hot Spring County; but the availability of water in this formation is unknown. The most widespread aquifer is the Stanley Shale, which underlies most of the western part of the county.

The occurrence of water in all the rocks of the Ouachita Mountains is similar and will be described as though for one rock unit. The rocks are shown as one unit on plate 1, except that the area of occurrence of the Bigfork Chert is delineated. The primary porosity of most of the rocks is so low as to be negligible, and the water is found in joints, fractures, and separations along bedding planes; hence, the amount of water available from the rocks is a function of the amount of fracturing that has taken place in them. Owing to its large degree of fracturing, the Bigfork Chert, present in northeastern Hot Spring County, is the only formation that is an aquifer throughout its area of occurrence (Purdue and Miser, 1923, p. 11). Because the systems of fractures and joints lie along east-west lines, wells of equal water-yielding capacity lie east or west of each other. Yields of wells north or south of each other generally are unrelated. Wells should not be drilled closer than 1,000 feet to prevent excessive drawdowns of water level (Albin, 1965, p. 7).

Most wells drilled into these rocks yield from 2 to 7 gpm; a few yield 20 gpm or more. The highest pumping rates measured in the Ouachita Mountains in Hot Spring County were 21 gpm from wells 3S–16W–21bdc at Glen Rose School and 3S–18W–27dca2 at Lake Catherine State Park. The highest reported yield was 40 gpm from well 5S–21W–15bac.

Specific-capacity tests were made to determine the ability of the wells to yield water (table 6). The specific capacity of a well is the discharge expressed as a rate of yield per unit of drawdown after a given time interval, generally gallons per minute per foot of drawdown at the end of a given period of pumping. Because a high initial pumping rate does not necessarily indicate that the yield will be maintained, specific capacities were determined at the end of 1 hour. The values determined ranged from 0.1 to 5.1 gpm per ft (gallons per minute per foot) of drawdown. The results indicate that there is little difference between the water-yielding characteristics of the rock units. A well that has a specific capacity of 0.5 or greater appears to furnish enough water to supply the needs of households.

Eighty percent of the wells inventoried are less than 100 feet deep, and most of the remainder are less than 130 feet deep. The deepest well inventoried (4S–20W–11bbb), however, is 640 feet deep.

The depth-to-static water level is less than 40 feet in 90 percent of the wells and less than 25 feet in 50 percent of the wells. The water levels (fig. 4) show fluctuations related only to local precipitation and use.

The chemical quality of water from wells in the Ouachita Mountains varies from a soft, sodium bicarbonate type to a hard, calcium bicarbonate type (pl. 3; table 5). Water containing excess iron is common throughout the mountains. In a few places the water is slightly acidic.

TABLE 4.—*Rock units and their water-bearing properties*

System	Series	Geologic unit		Lithology	Water-bearing properties of rock units	Symbols used on map plates
Sedimentary rocks						
Quaternary	Recent	Alluvium		Sand, silt, clay, and gravel	Yields 5–10 gpm throughout most of the two-county area, and 15 gpm in a few places. Water is soft and contains few minerals.	Qal
	Pleistocene	Terrace deposits		Sand and gravel	In southeastern Hot Spring County, wells yield 5–10 gpm. Most terrace deposits in Grant County are too thin to furnish water. Water is soft and contains few minerals.	Not shown on plate 1.
Tertiary	Eocene	Jackson Group	Redfield Formation of Wilbert (1953)	Clay and silt, lignitic, and minor amounts of fine sand.	Occurs only in eastern Grant County; yields small supplies for domestic use from shallow wells. In places, water has high sulfate content. If more than minimum quantity needed, wells should be drilled into the White Bluff or Cockfield Formation.	Tr
			White Bluff Formation of Dall (1898)	Very fine to fine argillaceous sand; fossiliferous silt and clay; in southeast corner of Grant County contains much more clay.	Occurs only in eastern Grant County; yields small quantities of water sufficient for domestic use from shallow wells. More water obtained by drilling deeper in formation. If no water obtained, it is necessary to drill into the Cockfield Formation.	Twb
		Claiborne Group	Cockfield Formation	Sand, fine to very fine, and carbonaceous clay.	Yields 5–10 gpm, enough for household supplies. No large-yielding wells to indicate maximum available yields, but should yield as much as 25 gpm in eastern Grant County. In places water has high sulfate content.	Tcf
			Cook Mountain Formation	Clay, carbonaceous, sandy; locally glauconitic; contains beds of sand 10–30 ft thick.	Yields 5–10 gpm, enough water for household supplies.	Tcm
			Sparta Sand	Sand, medium to very fine; little sandy lignitic clay. Sand occurs as beds as much as 300 ft thick in Grant County, in Hot Spring County in beds commonly 20–60 ft thick, and in places 100 ft thick.	Yields 0–25 gpm throughout its area of occurrence. In southwestern Grant County and southeastern Hot Spring County, yields 300 gpm. In central Grant County, yields 500 gpm. In eastern Grant County, yields as much as 800 gpm. Water is low in minerals, soft, acid, high in iron and hydrogen sulfide. Water is fresh throughout the two counties.	Ts

			Cane River Formation	Clay, lignitic, sandy, and fine sand. Sand occurs commonly as beds 20–60 ft thick. In places 150-ft thick.	Yields 0–25 gpm throughout its outcrop area. Should yield 100 gpm throughout Grant County and southeastern Hot Spring County.	Tcr
			Carrizo Sand	Sand, very fine to medium, and carbonaceous lignitic clay. Sand occurs commonly in beds 20–60 ft thick, in places, 150-ft thick.	Yields 0–25 gpm throughout its outcrop area. Should yield 100 gpm in Hot Spring and Grant Counties.	Tcz
		Wilcox Group		Clay, blue to tan, sandy; gray fine sand; sandy marl; contains thin limestone stringers; white fossiliferous sandy chalk.	Yields 10–25 gpm throughout its area of occurrence. Yields as much as 200 gpm in southeastern Hot Spring County. Water is soft, of the sodium bicarbonate chloride type. Yields salt water east of southwest corner of Grant County and Hot Spring County.	Tw
	Paleocene	Midway Group	Porters Creek Clay	Clay, blue to black.	Yields no water.	Tpc
			Clayton Formation	Limestone, fractured, porous; some sand.	Yields enough water to supply households. Presumably the water is a hard, calcium bicarbonate type.	Tc
Cretaceous	Upper			Clay, blue to tan, sandy; gray fine sand; sandy marl; contains thin limestone stringers; white fossiliferous sandy chalk.	Present only in the subsurface; contains salt water only.	
		Major unconformity				
Pennsylvanian, Mississippian, Devonian, Silurian, and Ordovician (rocks of Paleozoic age undifferentiated)	Undifferentiated			Shale, light-gray to black, silty, micaceous, and light-gray to dark-gray fine- to coarse-grained sandstone, mostly massive; contains some novaculite, chert, and limestone.	Yields 5–10 gpm from fractures, joints, and bedding planes, enough for households, schools, and industries; in a few places, yields as much as 20 gpm. Water is of variable quality. The Bigfork Chert is the only geologic unit that generally is an aquifer throughout its area of occurrence.	Pzu
	Bigfork Chert			Chert, gray to black, thin-bedded, much shattered, with thin layers of black shale and limestone.		Ob
	Undifferentiated					
Igneous rocks						
Cretaceous				Large bodies that include nepheline syenite, phonolite, ijolite, carbonatite, and inclusions of Arkansas Novaculite and Stanley Shale (Erickson and Blade, 1956).	Yield about 10 gpm from fractures and joints. Water is soft and of the sodium bicarbonate type (on basis of 1 analysis).	Ki

TABLE 5.—*Selected chemical analyses of ground water in Grant and Hot Spring Counties*

[Results in parts per million, except as indicated]

Well	Date of collection	Depth of well (feet)	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Sulfide as H_2S	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Alluvial deposits of Quaternary age																							
5S-15W-8aba2	4-16-64	30	61	2.5	3.6	0.1	3.3	2.7	13	1.5	10	16	20	0.0	0.2	------	0.0	80	19	11	121	5.8	5
6S-18W-3dbc	4-16-64	30	61	13	.23	.02	7.3	3.2	16	1.2	5	.4	20	.0	42	------	------	104	31	27	166	5.7	5
Terrace deposits of Quaternary age																							
6S-19W-11dba	5-11-64	30	----	21	0.05	0.01	0.6	0.8	4.3	1.8	2	0.0	6.0	0.1	11	0.00	------	46	4	3	49	4.9	1
White Bluff Formation of Dall (1898)																							
5S-12W-3aba	8-20-65	107	67	40	0.76	0.01	2.6	2.6	13	1.7	4	25	7.1	0.0	3.0	------	1.7	112	17	14	114	5.1	3
Cockfield Formation																							
3S-12W-15cda	8-6-64	78	63	23	0.00	0.00	4.8	2.9	5.6	2.3	10	3.2	6.4	0.0	25	------	------	82	24	16	86	6.5	0
3S-13W-24ada2	7-22-64	109	67	44	2.8	.04	2.8	1.1	7.5	1.1	19	4.0	8.0	.0	1.4	------	------	80	12	0	75	5.8	5
4S-13W-7daa	8-5-64	150	64	22	.17	.02	62	14	29	6.2	308	4.8	14	.0	.2	------	------	298	212	0	511	7.8	5
34adc1	8-4-64	170	66	16	.47	.00	72	12	54	7.7	203	172	9.0	.0	.4	------	------	445	229	62	690	7.4	5
5S-13W-5dbd	7-23-64	240	66	20	1.5	.1	42	5.9	50	4.7	201	69	6.0	.0	1.2	------	------	288	129	0	482	8.0	5
5S-14W-26bcc	8-5-64	170	67	30	.11	.01	1.4	.5	1.7	1.9	12	.0	2.5	.0	.2	------	------	44	6	0	27	6.3	5
6S-12W-2dcb1	5-11-64	421	67	15	.04	.02	6.0	.8	103	3.1	211	56	10	.4	.3	0.23	0.3	283	18	0	484	8.2	2
29cbc	7-30-64	140	65	37	.17	.00	26	6.1	22	4.6	146	6.4	14	.0	.2	------	------	186	90	0	289	7.4	5
7S-12W-3bbd	5-14-64	200±	65	13	7.2	.04	46	8.4	105	6.9	179	218	16	.2	2.1	.00	------	470	150	3	759	7.8	2

Cook Mountain Formation

4S-14W-31bcb	8-14-63	25	70	32	0.05	0.00	7.9	0.6	5.5	0.6	24	2.8	5.2	0.1	7.0	----	----	78	22	2	78	6.8	4

Sparta Sand

3S-14W-20dda	6-27-63	110	----	17	0.10	0.00	3.8	0.8	1.3	2.3	20	0.0	2.6	0.0	1.7	----	----	34	12	0	39	7.2	1
3S-15W-26daa	10-20-64	95	65	36	.10	.01	1.0	.6	2.8	1.5	7	2.0	3.4	.1	1.5	----	----	51	5	0	32	6.1	5
4S-12W-17dcc2	7-21-64	520	----	14	.77	.02	20	3.5	70	5.4	[1] 201	42	6.5	.3	2.6	----	----	250	64	0	433	8.4	5
4S-15W-33bca	6-20-64	138	65	24	4.2	.1	3.3	1.2	3.6	2.3	22	.0	4.0	.2	.4	----	0.4	55	13	0	53	6.7	----
5S-13W-3cda3	5-28-64	565	70	18	1.7	.01	4.4	2.2	4.9	2.7	24	6.4	6.0	.0	.0	----	.1	54	20	0	76	6.4	0
5S-14W-5cbb1	7- -64	360	68	34	2.2	.1	10	1.9	9.4	3.8	46	13	6.2	.2	.0	----	----	101	33	0	127	6.9	0
6S-15W-25ccc3	5- 7-64	106	68	16	.51	.02	16	6.5	6.0	38	122	11	7.5	.1	4.0	0.00	----	154	66	0	266	6.4	1
26aca	10-19-64	172	64	16	1.4	.02	2.2	1.0	1.2	1.4	0	13	1.0	.1	.2	----	----	37	10	10	52	4.5	5
6S-16W-7cac	8-18-64	80	65	18	.55	.1	8.8	5.4	12	2.3	3	2.2	17	.2	51	----	----	128	44	42	169	5.5	0
7S-12W-21bdb	8- 4-64	538	----	15	1.2	.01	12	4.6	13	5.2	83	7.8	6.0	.0	.3	----	----	95	49	0	175	6.8	5

Cane River Formation

5S-16W-16cdb	6-17-64	153	64	16	0.86	0.04	1.9	0.5	1.2	0.8	1	8.4	2.5	0.1	0.0	----	0.2	37	6	6	41	4.7	5

Carrizo Sand

6S-17W-34abb	6-20-63	254	66	12	1.0	0.00	4.8	1.4	44	2.8	82	5.8	33	0.2	0.2	----	0.0	142	18	0	249	8.2	2

Wilcox Group

4S-16W-8adc	5- 8-64	46	64	7.3	0.02	0.01	0.4	0.9	0.5	0.6	3	0.0	2.5	0.0	3.0	0.01	----	12	4	2	17	5.7	0
4S-17W-28acc1	6-21-63	224	69	12	.57	.00	3.3	1.5	58	2.0	[1] 165	.0	7.0	.2	.1	----	----	168	14	0	270	8.5	4
5S-17W-17aac1	5- 8-64	30	64	10	.00	.01	.5	.4	1.5	.1	2	1.0	3.0	.1	2.2	.00	----	22	2	1	21	5.0	2
18ddc	5-28-63	130	66	12	.15	.00	18	5.5	109	3.0	178	2.8	114	.4	.2	----	----	368	68	0	661	7.9	1
22ddd1 [2]	6-29-62	548	----	18	----	----	22	7	----	----	237	19	106	----	----	----	----	409	84	0	----	7.4	----
22ddd2	1-15-63	549	69	12	.48	----	23	7.8	81	5.7	238	10	50	.4	.0	----	0.0	300	90	0	508	8.1	----
6S-18W-1ddd	5- 3-63	161	66	51	9.7	.00	8.1	3.1	13	2.5	71	.4	4.4	.2	.1	----	----	132	33	0	125	7.1	1
35ccc	6- 7-63	167	66	48	2.4	.00	18	9.5	17	2.3	[1] 133	.8	9.2	.2	.2	----	.8	167	84	0	236	8.4	2

Clayton Formation

4S-17W-10aad1	12- 7-65	207	62	----	2.2	0.1	48	3.8	35	0.4	166	6.2	1.9	0.2	0.2	----	----	174	136	0	276	7.3	6
5S-18W-3aaa	5-11-64	115	65	20	.06	.04	2.1	1.6	10	.2	7	.0	12	.0	15	0.00	----	70	12	6	86	5.5	3
3ada	12- 8-65	77	62	----	.20	----	----	----	4.6	----	31	----	1.8	----	2.5	----	----	----	----	----	66	6.3	----

See footnotes at end of table.

TABLE 5.—*Selected chemical analyses of ground water in Grant and Hot Spring Counties*—Continued

[Results in parts per million, except as indicated]

Well	Date of collection	Depth of well (feet)	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potasium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Sulfide as H_2S	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Jackfork Sandstone																							
6S-18W-5bad1	5- 6-63	142	63	14	0.19	0.00	8.3	4.0	28	1.7	14	8.8	54	0.2	4.7	------	------	140	37	26	237	7.1	1
6S-19W-10dab	5- 3-63	121	----	33	13	.00	7.6	3.7	8.5	2.8	62	.2	4.2	.3	.2	------	0.1	102	34	0	114	8.0	3
11abc1	8-19-64	450-500	66	9.8	.66	.2	4.8	2.4	10	1.3	27	5.6	9.0	.0	7.9	------	------	66	22	0	98	6.8	5
Stanley Shale																							
3S-17W-21dca2	8- 9-62	110	71	25	0.26	0.00	20	4.8	15	3.6	112	12	2.5	0.3	0.1	------	------	146	70	0	214	8.1	3
4S-21W-17bdc	8-20-64	75	64	46	2.4	.5	10	5.1	14	.4	88	2.6	3.0	.3	.0	------	------	128	46	0	142	7.4	5
4S-22W-17dcb	6-25-64	110	65	25	.48	.3	51	11	26	.8	189	7.8	47	.2	.0	------	------	278	172	17	473	7.7	0
30acd	5-15-64	75	61	21	1.3	.04	1.6	.8	5.3	.7	9	4.4	5.0	.0	2.4	0.00	------	44	7	0	59	5.8	3
5S-19W-5adb	5-11-64	85	63	42	.32	.2	4.9	1.4	11	.7	34	6.8	7.0	.2	.5	.08	------	85	18	0	92	6.4	2
5S-20W-8bca2	5-11-64	160	64	33	.00	.3	53	11	20	.7	213	26	12	.2	.1	.11	------	254	177	2	415	7.6	1
5S-22W-24dca1	8-20-64	86	65	21	3.2	.3	38	6.6	12	1.0	156	13	6.8	.0	.8	------	------	179	122	0	280	7.8	0
Arkansas Novaculite																							
3S-16W-21bda	6-16-64	317	65	9.7	0.43	0.03	31	7.2	28	3.4	191	0.0	12	0.3	0.3	------	------	196	107	0	330	8.1	0
3S-17W-10dca	5-28-64	200	64	8.4	.12	.1	2.8	.8	1.1	.4	8	4.8	2.0	.1	1.3	------	------	24	10	4	36	5.4	0
Bigfork Chert																							
2S-16W-31cac	3-13-66	102	63	12	0.37	0.01	0.5	0.1	1.8	0.0	[3]0	5.0	2.2	0.0	0.0	------	------	24	2	2	35	4.42	3

[1] Includes equivalent of 4 ppm carbonate (CO_3).
[2] Analysis by Natural Gas Pipeline Co. of America, Joliet, Ill.
[3] Sample contained immediate acidity of 0.4 ppm as H^+.

TABLE 6.—*Summary of specific-capacity tests*

[Specific capacity of a well is the discharge in gallons per minute per foot of drawdown at the end of a given period of pumping]

Well	Owner	Depth of well below land surface (feet)	Static depth to water below land surface (feet)	Well yield during test (gpm)	Drawdown of water level at end of 1 hour (feet)	Specific capacity (gpm per foot)	Remarks
Alluvium of Quaternary age							
4S-17W-27cdb	Malvern Nursing Home.	37	9.02	5.8	4.14	1.4	
5S-15W-5abb2	E. F. Channell	32	17.81	4.9	1.18	4.1	30-min test—water level stopped falling in 3 min.
6S-18W-3dbc	W. E. Davis	30	4.69	4.7	5.29	.9	15-min test—projected to 1 hr.
Cockfield Formation							
3S-12W-15cda	Mrs. C. E. Emery	78	34.85	4.4	4.39	1.0	30 min test—projected to 1 hr.
18bca	S. B. Dorr, Jr	126	43.27	2.2	13.43	.2	Water level stopped falling in 16 min.
4S-13W-7daa	Roland Taylor	70	23.33	4.1	21.98	.2	
11cda	Bob Rowe	125	49.12	2.1	13.50	.2	Water level stopped falling in 8 min.
5S-13W-1bdb	Joe Woddle	296	56.96	10.7	2.64	3.9	
5dbd	International Paper Co.	240	118.74	4.7	9.72	.5	
5S-14W-26bcc	J. C. Warren	170	55.85	3.6	5.69	.6	
6S-12W-29cbc	O. M. Taylor	140	24.06	6.5	8.59	.8	30-min test—projected to 1 hr.
Sparta Sand							
3S-14W-20adb	J. W. Hicks	70	28.90	5.2	6.23	0.8	30-min test—water stopped falling in 9 min.
3S-15W-26daa	W. H. Tull	95	42.77	4.7	6.15	.8	36-min test—projected to 1 hr.
4S-12W-17dcc2	Louis Jackson	520	35.12	4.2	31.69	.1	
5S-13W-3cda3	Sheridan Water Works.	564	83.64	550	25	22	See table 7.
5S-14W-18ddb	W. R. Stephens	448	38.30	150	12	12.5	Reported by driller.
6S-14W-8bcd	Jenkins Ferry State Park.	86	8.60	15.4	10.59	1.5	
6S-15W-26aaa	Leola Schools	70	39.20	3.8	.55	6.9	9-min test—water stopped falling in 30 sec.
26aca	Leola Water Works.	172	63.25	257	22.32	11.5	See table 7.
6S-16W-7cac1	Clarence Tankersley.	80	62.82	2.4	8.99	.3	
Cane River Formation							
5S-16W-16cdb	Malvern Country Club.	153	48.24	18.6	13.65	1.4	

TABLE 6.—*Summary of specific-capacity tests*—Continued

[Specific capacity of a well is the discharge in gallons per minute per foot of drawdown at the end of a given period of pumping]

Well	Owner	Depth of well below land surface (feet)	Static depth to water below land surface (feet)	Well yield during test (gpm)	Drawdown of water level at end of 1 hour (feet)	Specific capacity (gpm per foot)	Remarks
			Carrizo Sand				
6S-17W-34abb	Texas Eastern Transmission Corp.	254	96.91	47.8	22.93	2.1	See table 7.
			Wilcox Group				
4S-16W-19bcd	Perla School	185	48.90	5.2	4.19	1.2	
4S-17W-28aac1	Malvern Brick and Tile Co.	208	8.08	4.5	17.89	.3	
5S-17W-17aac1	Central School	22	14.76	6.9	1.84	3.8	
18ddc	Luther Griffin	110	49.48	5.6	4.74	1.2	
22ddd2	Natural Gas Pipeline Co. of America.	548	----------	157	----------	----------	See table 7.
			Clayton Formation				
5S-18W-3aaa	Social Hill School	115	19.05	8.4	3.30	2.5	
			Jackfork Sandstone				
6S-19W-11abc	G. C. Spurlin	500	36.32	5.5	10.75	.5	
			Stanley Shale				
3S-17W-21dca2	Magnet Cove School.	110	3.79	12.7	38.29	.3	
3S-18W-27dca2	Lake Catherine State Park.	157	72.98	21.0	8.15	2.6	
4S-17W-3bdc	Homer Sharpe	173	31.09	4.1	8.89	.5	
4S-18W-19dbc	Charles Kirk	95	26.32	6.2	8.93	.7	
4S-19W-36bdc	Jeff Davis	102	14.43	2.8	31.37	.1	
4S-20W-14bbc	John Kelley	93	18.43	5.7	10.50	.5	
4S-21W-17bdc	Kenneth Looper	75	31.25	2.2	11.24	.2	Well yield decreased near end of test.
4S-22W-17dcb	J. P. Bozman	110	31.88	2.2	21.91	.1	
30acd	Seventh Day Adventist School.	75	17.80	6.2	27.05	.2	49-min test.
5S-20W-8cbb	Clinton Ivy	86	29.40	8.1	4.77	1.7	
5S-21W-15bac	C. O. Shuffield	117	59.80	3.6	1.27	2.8	
			Arkansas Novaculite				
3S-16W-21bda	Glen Rose School	317	4.92	21.4	4.16	5.1	
3S-17W-10dca	Magnet Cove Barium Corp.	200	35.84	12.8	56.41	.2	
			Bigfork Chert				
2S-16W-31cac	E. C. Cash	102	69.02	5.1	9.97	0.5	Well is in Saline County.
			Womble Shale				
3S-16W-7aaa	C. R. Taylor	70	16.07	6.1	7.47	0.8	

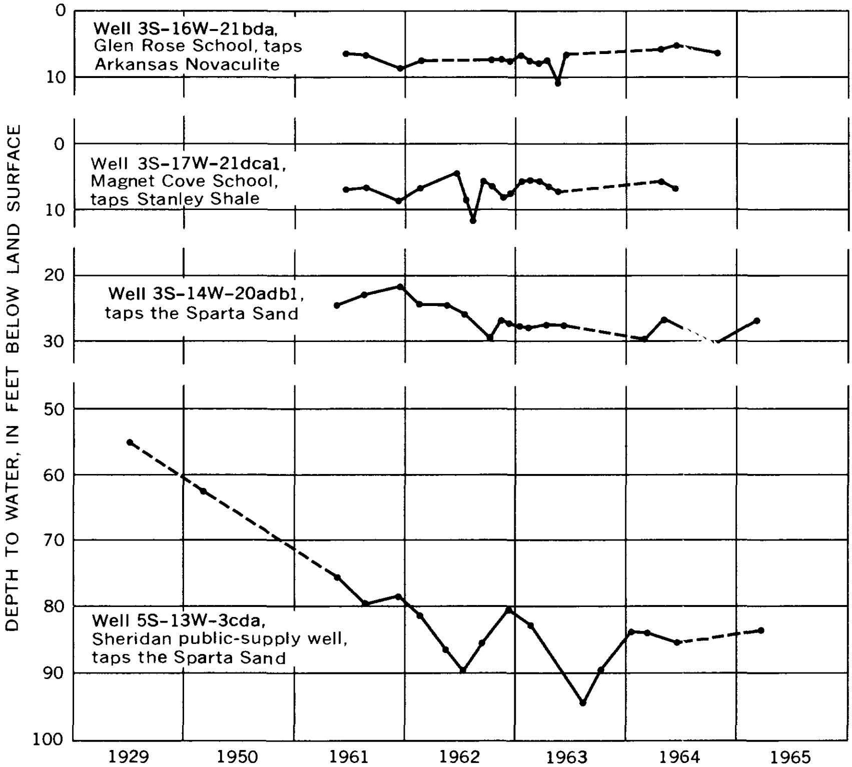

FIGURE 4.—Fluctuations of water levels in selected wells.

AQUIFERS OF THE COASTAL PLAIN

The Coastal Plain part of the two-county area is underlain principally by unconsolidated deposits of clay, silt, sand, and gravel, which range in age from Cretaceous to Recent. The sea invaded the area many times, and deposition of the sediments was both marine and continental. The only consolidated-rock unit is the Clayton Formation of Early Tertiary age, which is a limestone in some places along the Fall Line (pl. 1).

The oldest unconsolidated deposits in the Coastal Plain are of Late Cretaceous age. These deposits occur only at depth beneath the land surface, and are composed of clay, silt, sand, gravel, marl, and limestone. They yield no fresh water in the two counties and therefore will not be described further.

The only aquifers that yield large quantities of fresh water are those in the formations of Tertiary age. In southeastern Hot Spring County and southwestern Grant County, sand beds in the Wilcox and

Claiborne Groups yield fresh water in quantities adequate for industrial or public use. In the rest of Grant County, only alluvium and formations of the Claiborne Group yield fresh water.

Most of the alluvium of Quaternary age that underlies the flood plains of the streams yields small quantities of water.

The water-bearing properties of the units of Tertiary age have been described graphically (pl. 4). The maximum depth at which fresh water is available and the formation from which the water is obtained have been determined from electric logs of oil-test wells. The lower limit of fresh water is in either the Carrizo Sand or the Wilcox Group (pl. 4).

To determine the ability of the aquifers to yield and to transmit water, aquifer tests were made using wells that draw water from the Sparta Sand, Carrizo Sand, and Wilcox Group (table 7). The nonequilibrium method described by Theis (1935) was used to determine the transmissibility and storage coefficients. The basic data used in the tests are given in Edds and others (1967).

To supplement the aquifer tests, specific-capacity tests were run, using domestic, school, and industrial wells that have small yields. The results of the specific-capacity tests are given in table 6 of this report and in the basic-data report by Edds and others (1967).

TABLE 7.—*Summary of aquifer tests*

[The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent (Ferris and others, 1962, p. 72). The coefficient of storage is the volume of water released from, or taken into, storage per unit surface area of aquifer per unit change in head component normal to that surface (Wenzel, 1942, p. 87)]

Well	Owner	Aquifer	Thickness of aquifer	Field coefficient of transmissibility (gpd per foot)	Coefficient of storage
5S-13W-3cda3	Sheridan Water Works.	Sparta Sand.	95	90,000	1.4×10^{-4}
5S-14W-5cbb1	A. J. Stephens	do	[1] 59	23,000	
5S-14W-18ddb	W. R. Stephens	do	[2] 170	[3] 29,000	
6S-15W-26aca	Leola Water Works.	do	67	[3] 34,000	
6S-17W-34abb	Texas Eastern Transmission Corp.	Carrizo Sand.	40	3,600	
5S-17W-22ddd2	Natural Gas Pipeline Co. of America.	Wilcox Group.	40	19,000	1.4×10^{-5}

[1] From log of test well 0.3 mile southwest.
[2] From electric log.
[3] Determined from specific capacity.

The alluvium of Quaternary age, the Sparta Sand, and the Wilcox Group provide the best quality ground water in the two counties. The water from all three aquifers is soft to moderately hard. For most industrial uses, the only treatment needed is adjustment of the pH of the water and removal of the iron. Water from other aquifers is usable but requires other treatment in addition to reduction of the acidity and removal of the iron. Selected chemical analyses of ground water are listed in table 5. A report by Edds and others (1967) contains detailed ground-water data.

MIDWAY GROUP

CLAYTON FORMATION

The Clayton Formation is the only aquifer in the Midway Group in the two-county area. It is exposed between the Fall Line and the alluvium of the Ouachita River (pl. 1). Northeast of U.S. Highway 270, the Clayton is present only in the subsurface (R. V. Browne, oral commun. 1963).

The Clayton Formation consists mainly of limestone, calcareous sand, and sandstone; it is of marine origin, and in places is very fossiliferous. The formation is not a major aquifer in the two-county area. It is tapped by wells in the area of outcrop and a short distance downdip, and yields sufficient water for household supplies. Most of the wells are less than 100 feet deep.

Analyses of water from wells 4S–17W–10aad1 and 5S–18W–3ada indicate that the water from the Clayton Formation varies from a calcium bicarbonate type to a sodium chloride type (table 5). In Hot Spring County northeast of U.S. Highway 270, where the Clayton is a limestone, water from well 4S–17W–10aad1 has a moderately high dissolved-solids content and is hard. Farther south the water from well 5S–18W–3ada, which taps a part of the formation that is composed of sand and clay, has a low dissolved-solids content and is soft. A sample of water from another well, 5S–18W–3aaa1, at the Social Hill School, indicates that the water at that point is a sodium chloride type (table 5). This sample must indicate only local conditions, and does not represent the quality of water in the Clayton throughout Hot Spring County. In some places the water in the formation is corrosive, and the iron content is higher than the maximum of 0.3 ppm recommended for drinking water by the U.S. Public Health Service (1962).

The other formation of the Midway Group, the Porters Creek Clay, is a blue-black clay; it overlies the Clayton and is not an aquifer in Arkansas.

WILCOX GROUP

The Wilcox Group is exposed in a narrow band from Donaldson to the northeast corner of Hot Spring County (pls. 1, 4). It contains fresh water only in southeastern Hot Spring County and in southwestern Grant County. The top of the Wilcox dips southeast and reaches a depth of about 1,000 feet below the surface in southwestern Grant County. At the interface between fresh and salt water, the Wilcox is about 300–400 feet thick.

In the area where the Wilcox contains fresh water, the group is composed of clay—some of which is carbonaceous, lignite, and fine to medium sand. As shown by electric logs, the group contains one thick sand member in much of the area of fresh water. The sand ranges in thickness from 30 to 140 feet and thins to the east to about 30 feet close to the interface between fresh and salt water (pl. 2).

The hydraulic characteristics of the Wilcox Group were determined by an aquifer test on well 5S–17W–22ddd2, which yields 157 gpm from a 40-foot bed of sand at a depth of 509 feet. Values of 19,000 gpd per ft. (gallons per day, per foot) for the transmissibility and 1.4×10^{-5} for the coefficient of storage of the aquifer were obtained (table 7). These values were used to prepare figure 5, which can be used to determine well spacing east of the pumped well, that is, in a direction in which the aquifer is laterally extensive. However, an impermeable boundary about 6,000 feet from the pumped well, probably to the northwest, increases the drawdown of water level in the direction of the boundary (fig. 5). This necessitates greater spacing of wells so that they will not interfere with one another. For example, the drawdown 1,000 feet from a well pumping 200 gpm continuously for 100 days would be about 13 feet (fig. 5). However, because of the boundary, the data collected during the pumping test indicate that the drawdown 1,000 feet northwest of the pumped well will be about 20 feet.

The aquifer test was supplemented by short-duration specific-capacity tests in low-capacity wells, which indicate the magnitude of yields that can be obtained from domestic wells that tap the Wilcox (table 6). A test on well 5S–17W–28aac1 indicates a specific capacity of 0.24 gpm per ft. Thus, if the water level declined 100 feet below the static water level, the well would yield 24 gpm.

About 200–300 gpm is available from individual wells in the Wilcox Group in southeastern Hot Spring County and southwestern Grant County. In northern Hot Spring County, quantities of water adequate for household supplies or other small needs are available.

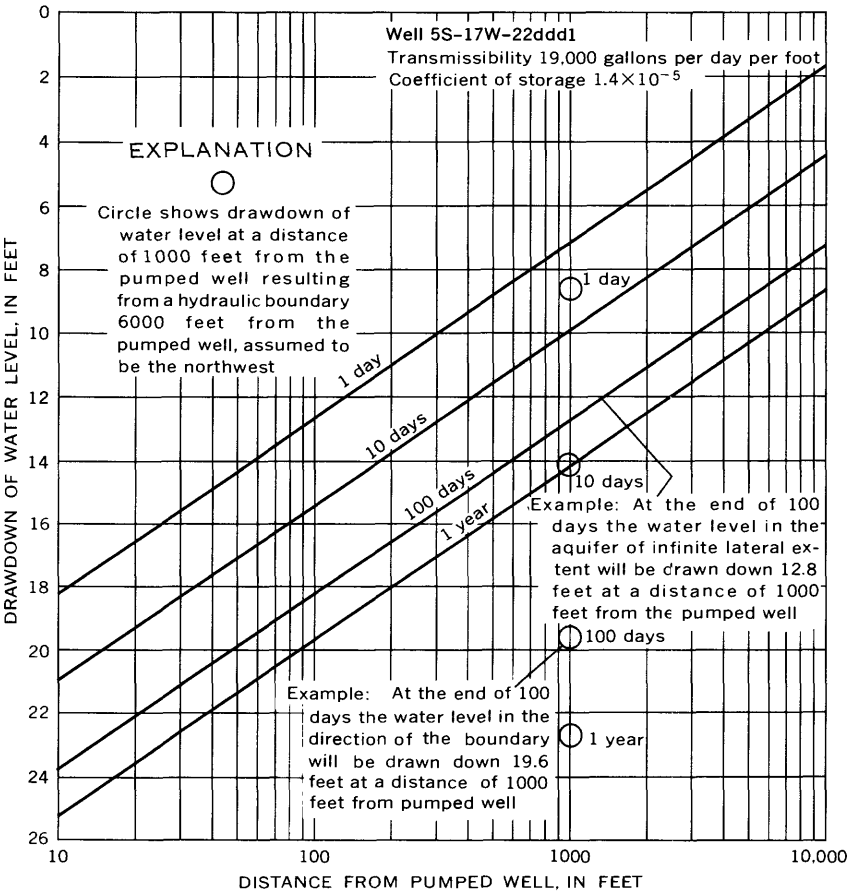

FIGURE 5.—Theoretical decline of water level at different intervals of time and at different distances from a well pumping 200 gpm from a 40-foot-thick bed of sand in the Wilcox Group.

Along U.S. Highway 67, in T. 5 S., R. 17 W., surficial gravel deposits, underlain by clay, are drained by seepage springs that flow westward toward the Ouachita River. These springs yield moderate quantities of water; one, in sec. 4, flows 15 gpm from one of two openings and supplies water for a minnow hatchery, a restaurant, and several residences.

Water levels in the Wilcox are controlled by topography and stream patterns. Near U.S. Highway 67, water levels slope westward toward the Ouachita River; but farther east in Hot Spring County, where the streams flow east, water levels also slope east.

Most of the water from the Wilcox Group is suitable for household use and some industries. From the Saline County line south to an east-west line about 4 or 5 miles south of Malvern, water from the Wilcox Group is a soft, sodium bicarbonate type. South of this line the water is a mixed calcium sodium bicarbonate type that is slightly harder and contains more dissolved solids. (See pl. 3; table 5.)

The iron content of most water from the Wilcox Group is high, and water from some of the shallow wells is slightly acidic (Edds and others, 1967).

CLAIBORNE GROUP

CARRIZO SAND

The Carrizo Sand supplies water in eastern Hot Spring County and is a potential aquifer from its outcrop east across Grant County (pls. 1, 4). In most of Grant County it is the deepest unit of Tertiary age that contains fresh water (pl. 4). The formation is exposed in Hot Spring County in a narrow band that extends southwestward from a point a few miles east of Malvern. From the outcrop, it dips southeast. The top is about 1,500 feet below the land surface near the southeast corner of Grant County. The Carrizo Sand is a relatively thin aquifer, as compared with the Sparta Sand. The Carrizo ranges in thickness from about 20 to 85 feet in southeastern Hot Spring and southwestern Grant Counties. In much of the rest of Grant County, it is about 100 feet thick, and thickens to more than 200 feet in the southeastern part of the county. It consists almost entirely of sand.

Little is known about the availability of water in the Carrizo Sand. It should yield adequate supplies for many industries. In a pumping test, well 6S–17W–34abb yielded 48 gpm with a drawdown of 23 feet at the end of 1 hour (table 6), from a bed, 40 feet thick, of sand whose top is at a depth of 215 feet. Its transmissibility is 3,600 gpd per ft (table 7). East of the study area, at Pine Bluff, an exploratory well drilled into the Carrizo entered a bed of sand 150 feet thick at a depth of 1,950 feet. This well has been pumped at 102 gpm with a drawdown of about 15 feet. The transmissibility of the aquifer at Pine Bluff, estimated from the specific capacity, is about 16,000 gpd per ft. These two values are probably lower than the value would be if determined from more comprehensive tests, but they indicate the order of magnitude of transmissibilities of the formation.

No information is available to determine the spacing of wells in the Carrizo Sand, but because its transmissibility is lower than that of the Wilcox Group (table 7), wells that tap the Carrizo should be spaced farther apart than those that tap the Wilcox.

Water levels range from 80 to 100 feet below land surface in southeastern Hot Spring County. The water level in the well at Pine Bluff mentioned above is 15 feet below land surface.

Water from the Carrizo Sand is a soft, sodium bicarbonate type (pl. 3) and, according to analysis of a sample from well 6S–17W–34abb, is not corrosive (table 5). Water from the Carrizo in eastern Grant County may have a high chloride content; this conclusion is based on an analysis of water from the well at Pine Bluff, which showed that the water contains 280 ppm of chloride. The iron content of water from both wells is high (1.0 ppm).

CANE RIVER FORMATION

The Cane River Formation crops out in southeastern Hot Spring County and dips southeast. Its top is about 900 feet below land surface in the southeast corner of Grant County (pl. 4). The thickness increases from about 200 feet near the outcrop to more than 500 feet at the Jefferson County line.

The Cane River consists of beds of sand, mixed sand and clay, and clay, which range in thickness from 10 to 30 feet. However, electric logs indicate that the formation contains a bed of sand that ranges in thickness from about 50 to 125 feet in much of the area of occurrence (pl. 2). In parts of the area this bed is at the top of the formation and is in contact with, or may be a part of, a bed of sand in the overlying Sparta.

A short distance downdip from the outcrop, the formation should furnish enough water for many industrial needs. The electric log of a test well drilled in sec. 2, T. 5 S., R. 14 W. (pl. 2), shows a bed of sand 125 feet thick at a depth of 645 feet, which could supply the needs of the city of Sheridan. The formation is tapped by a few domestic wells in and near its area of outcrop. The wells range in depth from 32 to 290 feet and yield as much as 19 gpm (table 6); water levels in them range from 15 to 50 feet below land surface.

Water from the Cane River Formation is very soft, and its dissolved-solids content is low (table 5). Its iron content is high; much of the water is acidic enough to be corrosive.

SPARTA SAND

The Sparta Sand is the highest yielding and most heavily pumped aquifer in the two counties and is the only one used for public supply. The Sparta supplies water to the cities of Sheridan and Leola, and it probably will be tapped by the proposed public-supply wells at Prattsville and Poyen. The Sheridan public-supply well

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produced 865 gpm during an installation test in 1965, and the city well at Leola yields 250 gpm. The Sparta is tapped by an irrigation well, 3 miles south of Prattsville, which is reported to have been pumped at the rate of 500 gpm. The Sparta is the uppermost of the high-yield aquifers and therefore the most accessible.

The Sparta Sand crops out in southeastern Hot Spring and southwestern Grant Counties, west of the Saline River, and in the vicinity of Tull (in T 3 S., R. 14 W.) in the northwest corner of Grant County (pls. 1, 4). The formation dips southeastward, and at the east edge of Grant County its top is 500–600 feet below land surface (300 ft below sea level).

Regionally, the Sparta increases in thickness downdip, or southeastward. In the study area it reaches a thickness of about 300 feet along a north-south line midway between Poyen and Prattsville and more than 500 feet in the southeast corner of Grant County.

Much of the Sparta Sand is composed of thick beds of fine to medium sand and minor amounts of sandy clay or clay. Electric logs indicate that 40–85 percent of the formation is composed of beds of sand.

Downdip from the outcrop area, the Sparta Sand is an artesian aquifer, and water levels in wells that tap the aquifer rise above the top of the water-bearing sand. The shape of the piezometric surface in the vicinity of the Saline River indicates that ground water in the Sparta flows toward the river. In the eastern part of Grant County, there is apparently no relation between streamflow and ground-water movement. Regional conditions control the pattern of ground-water movement, which is east and southeast. The piezometric high about 5 miles north of Sheridan is in an interstream area and may indicate that ground water contributes to streamflow. The depression at Sheridan is the result of pumpage. (See pl. 4.)

About 25 miles east of Sheridan, in the vicinity of Pine Bluff, in Jefferson County, a large quantity of water (43 mgd in 1965) is pumped from the Sparta Sand. The water-level contour map (pl. 4) indicates that withdrawals at Pine Bluff have lowered water levels along the eastern edge of Grant County.

To aid in the installation of wells, plate 4 shows the depth to which wells must be drilled to penetrate the Sparta Sand and the depth below land surface that water will stand in the wells. For example, at Prattsville the top of the Sparta Sand is about 125 feet below land surface, and the water in a well that taps the Sparta will stand between 60 and 100 feet below land surface.

Water levels in wells that tap the Sparta Sand show only seasonal fluctuations, except where they are affected by heavy pumpage (fig. 4). The hydrograph for well 3S–14W–20adbl indicates that the water level is affected only by seasonal fluctuations, whereas the hydrograph for the Sheridan public-supply well (5S–13W–3cda) indicates the effect of heavy pumpage. Since 1929 the water level in the Sheridan well has declined 30 feet. This decline does not indicate a critical condition; however, it does demonstrate the effect of withdrawals on ground-water levels.

The results of an aquifer test on one of the public-supply wells at Sheridan indicate that in that area the Sparta Sand has a transmissibility of 90,000 gpd per ft and a storage coefficient of 1.4×10^{-4} (table 7). Figure 6, developed from these values, can be used to determine well spacing. The figure shows that the drawdown of water level at the end of 100 days of continuous pumping at the rate of 800 gpm is about 10 feet at a distance of 1,000 feet from the pumping well. At Prattsville and Leola, aquifer and specific-capacity tests indicate that the Sparta Sand has a transmissibility ranging from about 20,000 to 35,000 gpd per ft (table 7).

To supplement the information obtained from the aquifer tests, specific-capacity tests were run on small-capacity wells scattered throughout the two counties (table 6). The yields of the wells ranged from 2.4 to 15 gpm, and the specific capacities ranged from 0.1 to 6.9 gpm per ft.

In most of Grant County the Sparta Sand can supply large quantities of water. It is tapped for industrial, public, domestic, stock, and irrigation supplies. The wells range in type and depth from dug domestic wells 30 feet deep near the western edge of the outcrop of the formation to drilled public-supply and domestic wells more than 500 feet deep in eastern Grant County; yields range from 2 gpm from some domestic wells to 865 gpm from a public-supply well.

The water in the Sparta Sand is suitable for irrigation and for most industrial uses if properly treated. It is a soft, calcium sodium bicarbonate type and the dissolved-solids content ranges from low to moderately high (pl. 3; table 5). Much of the water has a high iron content, and some of it is acidic.

COOK MOUNTAIN FORMATION

The Cook Mountain Formation yields small quantities of water in central Grant County east of the Saline River. In its outcrop in the vicinity of Prattsville (pl. 1), it is tapped by many drilled and dug wells that supply water for domestic use.

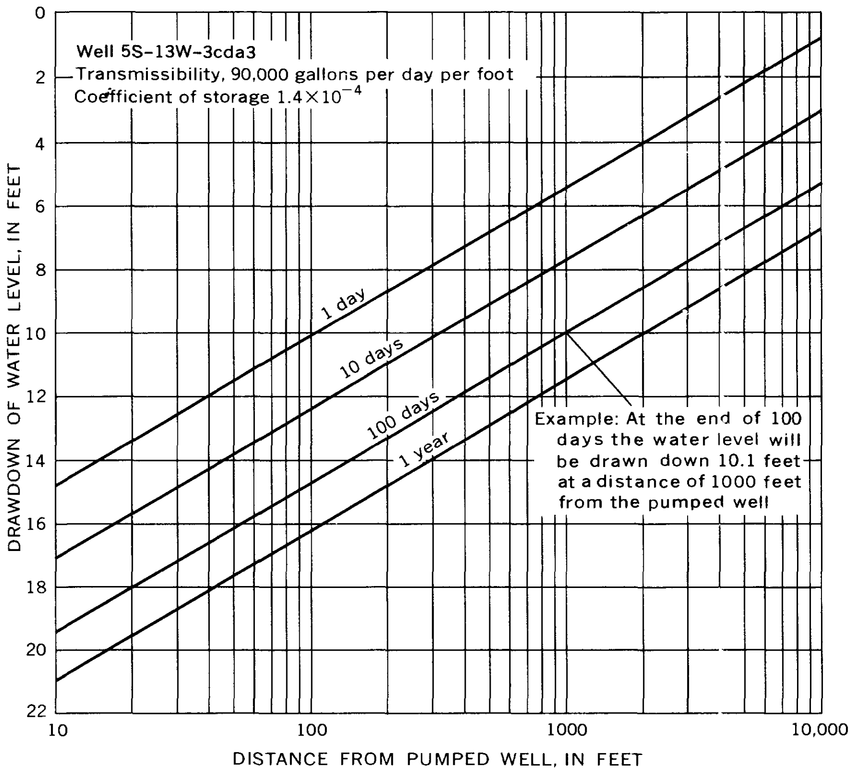

FIGURE 6.—Theoretical decline of water level at different intervals of time and at different distances from a well pumping 800 gpm from a bed of sand, 95 feet thick, in the Sparta Sand, assumed to be of infinite lateral extent.

The Cook Mountain dips southeastward beneath the Cockfield Formation and is tapped for water only in the outcrop area. The Cook Mountain is about 100–150 feet thick in the area between the outcrop and the Grant-Jefferson County line (pl. 2). In the vicinity of Prattsville it is composed of carbonaceous clay, much lignite, and lenticular beds of sand a few inches to a few feet thick. From the layers of sand, enough water can be obtained for domestic supplies. However, because water may be pumped from the wells faster than the aquifers can supply it, large-diameter wells are used to store water for use during long periods of pumping. In the area southwest of the Saline River alluvium, most of the deposits are sand, and the Cook Mountain grades imperceptibly into the Sparta Sand. Together, they constitute one water-bearing unit.

The water is a soft, calcium bicarbonate type and has low dissolved-solids content. It has a low iron content, and in some places is acidic enough to be corrosive (table 5).

COCKFIELD FORMATION

The Cockfield Formation crops out in central Grant County in a band that extends from the Saline River alluvium to the northeast corner of the county; the belt passes between Prattsville and Sheridan (pls. 1, 4). The formation dips southeastward at the rate of about 20–25 feet per mile; its top is at land surface at the northern end of the Grant-Jefferson County line and is about 200 feet below land surface at the southern end. The formation is about 250 feet thick in the southeast corner of Grant County. In places in the eastern part of the county, the top of the formation cannot be distinguished from the overlying Jackson Group.

The Cockfield consists of beds of carbonaceous clay and silt, mixed clay and sand, and fine to very fine sand; few of the beds are more than 20–30 feet thick. (See electric log at sec. 21, T. 6 S., R. 12 W., in cross section *A–A′*, pl. 2.) These beds of sand are discontinuous and are presumably lenses of small lateral extent. According to local information, the depth to which wells must be drilled to obtain water varies greatly and is difficult to predict.

Most of the wells are small-capacity wells that furnish enough water for the needs of households. Wells that were test pumped produced from 2 to 10 gpm, and specific capacities of most of the wells were 1.0 gpm per ft. or less (table 6).

Water in the Cockfield Formation flows southeast from the high ground in northern Grant County. According to the shape of the ground-water contours north of Sheridan, Hurricane Creek receives water from the Cockfield (pl. 4). From the hills in the northeast corner of the county, water flows north and northeast into Pulaski and Jefferson Counties. Plate 4 shows the depth below land surface that water stands in wells that tap the formation.

Water in the Cockfield Formation varies from a soft, sodium bicarbonate type to a hard, calcium sodium bicarbonate type and generally has a greater dissolved-solids content than water from the other formations (pl. 3; table 5). Near and southeast of Sheridan the sulfate content is high, which may indicate that water migrates downward from the overlying Jackson Group. Much of the water has a high iron content, and in a few places the water is corrosive.

JACKSON GROUP

The Jackson Group makes up the surficial deposits in most of Grant County east of Sheridan and underlies the alluvium along the streams in that area. From its area of outcrop, it dips eastward and is about 250 feet thick at the Jefferson County line east of Sheridan and about 200 feet thick at the southeast corner of Grant County. The Jackson Group consists of two formations—the White Bluff Formation of Dall (1898), which is of marine origin; and the Redfield Formation of Wilbert (1953), which is of continental origin. (See pl. 1 and Wilbert, 1953.)

WHITE BLUFF FORMATION OF DALL (1898) [1]

Most of the White Bluff Formation in Grant County is composed of fine to very fine clay, silty clay, and clay, much of which is fossiliferous. In places it contains hardened ferruginous layers a few inches thick. In southeastern Grant County the formation is predominantly clay, but south of Grapevine the uppermost beds consist principally of very fine sand interbedded with silt and silty clay (Wilbert, 1953, p. 78).

The White Bluff Formation is tapped for domestic supplies by dug wells less than 50 feet deep in its outcrop and by a few deeper drilled wells (125–204 ft. deep). The yield of the formation to wells is small in much of its area of occurrence; therefore, where larger supplies are needed, wells must be drilled through the entire Jackson Group into the underlying Cockfield Formation or the Sparta Sand.

Analysis of one water sample from the White Bluff Formation indicates that the water is a dilute, sodium sulfate type, is slightly acidic, and has a high iron content (table 5). In Jefferson County, water from the Jackson Group ranges from a sodium bicarbonate type to a sodium sulfate type, is not acidic, and its iron content range from 0.15 to 2.0 ppm (Klein and others, 1950). The water in the formation in Grant County probably has similar characteristics. The water sample from Grant County contained 1.7 ppm of sulfides as hydrogen sulfide (H_2S).

REDFIELD FORMATION OF WILBERT (1953)

In Grant County the Redfield Formation of Wilbert (1953, p. 24, 80) is a very low-yielding aquifer. It constitutes the surficial deposits in Grant County east of the outcrop of the White Bluff Formation of Dall (1898) and consists primarly of interbedded lignitic silts and

[1] The White Bluff Marl of Dall (1898, p. 343, and table opposite p. 334), as resurrected and emended by Wilbert (1953, p. 23, 37).

clay, plus a little fine sand. The formation is tapped by many shallow wells, most of which are dug wells at rural residences where electric pumps have not been installed. None of the beds of sand are thick enough to supply more than very small quantities of water.

DEPOSITS OF QUATERNARY AGE

TERRACE DEPOSITS

Terrace deposits consisting principally of fine to coarse gravel cap much of the high ground in the Coastal Plain parts of the two counties. Most of the deposits are less than 5 feet thick, but in a few places they are as much as 10 feet thick. In many places the terrace deposits blend into or mix with the underlying deposits of Tertiary age, so that they are not a separate aquifer. In this report, therefore, the wells in most areas underlain by these deposits are considered as tapping deposits of Tertiary age as the principal aquifer.

ALLUVIUM

Most of the flood plains of the Ouachita and Saline Rivers and their principal tributaries are underlain by alluvium of Quaternary age (pl. 1), which lies unconformably on deposits of Tertiary age. The alluvium, whose total thickness seldom exceeds 35–40 feet, is composed principally of silt, some clay, and thin beds of fine to very fine sand. Most of the sand is at the bottom of the section. In a few places the sand is coarser and makes up most of the section. Representative geologic sections across the Saline and Ouachita Rivers are given on plate 5.

The depth to water in the alluvium ranges from a few feet to about 25 feet and fluctuates with the season and with precipitation. Where the alluvium is coarse enough and is in hydraulic continuity with the stream, the water level fluctuates with the stream stage.

Throughout the two-county area, the alluvium is the principal source of water for small towns and dwellings on the flood plains. The residents of Poyen and Donaldson depend entirely on the alluvium for their water supplies. The alluvium does not yield enough water for large industrial needs or for irrigation, but it supplies enough water for rural schools.

The results of short-duration specific-capacity tests at Donaldson, Malvern, and Poyen were used as the basis for determining the maximum yields of wells that tap the alluvium (table 6). For example, well 4S–17W–27cdb yielded 1.3 gpm for each foot of drawdown. If the water were drawn down to 30 feet, theoretically, the yield of the well would be about 25 gpm, which is about the maximum that can be obtained from wells that tap the alluvium in the two counties.

Water from the alluvium is a soft, sodium bicarbonate-sodium chloride type and has a low dissolved-solids content (table 5). The iron content of much of the water is greater than the maximum of 0.3 ppm recommended for drinking water by the U.S. Public Health Service (1962). Some of the water is corrosive.

A problem that may be met in water from the alluvium is a high concentration of nitrate. The nitrate content of water samples from shallow wells in Donaldson ranged from 5.0 to 49 ppm in 1963 and 1964 (fig. 12). The association of methemoglobinemia and nitrate content of water is discussed under "High nitrate content of water from shallow wells in flood plains."

SURFACE WATER

Water is perennially available in Grant and Hot Spring Counties from the Ouachita and Saline Rivers, Hurricane Creek, and several tributary streams in the south-central and western parts of the two-county area (table 8). The Caddo River, which flows along the southwestern boundary of Hot Spring County, is a dependable source of large quantities of water. A more uniform supply of water will be available after DeGray Reservoir is completed.

The quality of the water in the Ouachita and Saline Rivers is excellent, except locally. Many of the small streams contain water of good quality. (See plate 6 for areal variation of water quality, and tables 9 and 10 for more detailed information.)

The average yields of streams in the Interior Highlands range from about 1.3 cfs per sq mi (cubic feet per second per square mile) near the Ouachita River to about 1.6 cfs per sq mi in the western end of Hot Spring County. Yields of streams in the Coastal Plain range from about 1.2 cfs per sq mi in the southeastern part of Grant County to about 1.3 cfs per sq mi in the northern part of the two counties and in Hot Spring County near the Ouachita River.

The area of the two counties, 1,254 square miles, has an average runoff of about 1,600 cfs. Streamflow entering the two counties is about 3,100 cfs, of which 2,300 cfs and 800 cfs are contributed by the Ouachita and Saline Rivers, respectively.

Although there is an abundance of streamflow in the counties, the amount of water available for use varies considerably from time to time and from place to place. Because of the variation of flow, the dependable amount of water available from streams is limited to their minimum flow, unless storage facilities are provided. The following discussion describes the amounts of streamflow available without storage.

LOW-FLOW FREQUENCY

Because of the variation of low flows, no single observed flow value can be used for design purposes; instead, low-flow values are treated statistically to determine the frequency of occurrence of given minimum flows (fig. 7).

Analyses of frequency of low flows, based on records collected for Ouachita River at Arkadelphia, 1930–51, and Saline River at Benton, 1950–57, and at Rye, 1938–51 (table 11), have been used in conjunction with base-flow measurements to estimate data on low-flow frequency for other points on these streams and for other streams in the two counties. Frequency data for Benton and Rye have been adjusted to represent hydrologic conditions during 1929–57. Information on low-flow frequency available for Ouachita River at Arkadelphia is based on records collected prior to completion of Lake Ouachita (fig. 7). However, additional refinement of the Arkadelphia data is necessary because of regulation at Lake Ouachita. This amounts tc a significant increase in low-flow values for the Ouachita River, the magnitude of which depends on water released from Lake Ouachita. The data for Arkadelphia are applicable along the Ouachita River upstream to the mouth of the Caddo River. For points above the Caddo (table 11), the values of low-flow frequency must be reduced because of the absence of the high base flow of the Caddo. After completion of DeGray Reservoir the regimen of the Caddo will be changed, and the low flow of the Ouachita River at Arkadelphia will increase.

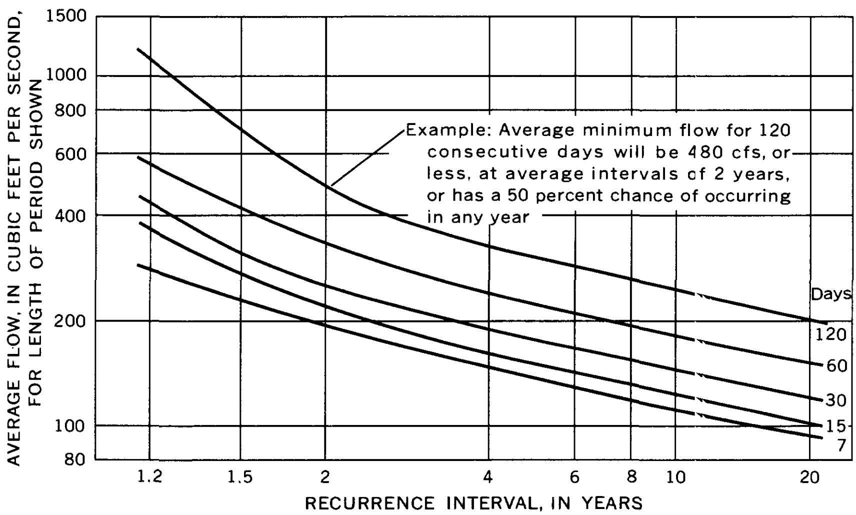

FIGURE. 7.—Magnitude and frequency of anual low flow of Ouachita River at Arkadelphia, 1930–51.

TABLE 8.—*Low-flow characteristics of streams in Grant and Hot Spring Counties*

[Adjusted to period 1929–57]

No. on pl. 6	Station name	Annual low flow, in cubic feet per second, for indicated number of days and recurrence interval: 7-day, Recurrence interval, in years			30-day, Recurrence interval, in years			Daily mean flow, in cubic feet per second which will be exceeded the indicated percentage of time			Remarks
		2	5	10	2	5	10	95	90	80	
	Ouachita River basin										
2	Fourche a Loupe Creek near Hot Springs.	0.16	0.08	[1] 0.06	0.24	0.12	0.08	0.18	0.27	0.52	Perennial flow.
5	Prairie Bayou near Social Hill.	.16	.10	[1] .08	.21	.13	.10	.16	.22	.34	No flow at times.
6	Ten Mile Creek near Donaldson.	[1] .10	.02	[1] <.01	.26	[1] .05	[1] .01	[1] .09	.35	1.4	No flow at times in most years.
7	De Lisle Creek near Friendship.	[1] <.01	0	0	[1] <.01	0	0	0	0	[1] <.01	Do.
8	Bayou de Roche near Friendship.	[1] <.01	0	0	.15	[1] <.01	0	[1] <.01	.01	.09	Do.
9	Point Cedar Creek near Lambert.	.23	.15	.12	.31	.19	.14	.24	.33	.50	Perennial flow.
12	White Oak Creek at Witherspoon.	[1] .03	[1] .01	[1] <.01	[1] .08	[1] .02	[1] .01	[1] .01	[1] .08	.57	Do.
13	L'Eau Frais Creek at Joan.	1.6	[1] .71	[1] .41	2.8	1.2	[1] .63	1.7	3.1	7.1	Do.

	Saline River basin										
15	Reyburn Creek near Perla.	.05	.02	[1] <.01	.09	.03	.01	.05	.11	.27	No flow at times.
16	Francois Creek near Poyen.	.10	.02	<.01	.28	.05	.02	.10	.38	1.4	Perennial flow.
17	Rhinehart Branch near Perla.	.17	.15	.13	.18	.16	.14	.17	.19	.22	Do.
18	Big Creek at Poyen----	2.1	1.2	[1] .82	2.9	1.7	[1] 1.2	2.1	3.1	4.7	Do.
19	Saline River near Leola.	17	[1] 8.4	[1] 5.8	25	[1] 12	[1] 7.7	15	27	55	Do.
20	Lost Creek near Sheridan.	0	0	0	0	0	0	0	0	0	No flow at times in most years.
21	Hurricane Creek near Belfast.	1.1	.49	.25	1.8	.82	.46	1.1	2.1	4.0	Flow during dry periods is effluent from bauxite-processing plant.
23	Hurricane Creek near Sheridan.	1.5	.62	.30	2.6	1.1	.58	1.5	3.1	6.2	No flow at times.
25	Derrieusseaux Creek near Grapevine.	[1] <.01	0	0	[1] <.01	0	0	0	0	[1] <.01	No flow at times in most years.

[1] Estimated.

TABLE 9.—*Summary of chemical constituents of water from major streams in Grant and Hot Spring Counties*

[Results in parts per million, except as indicated]

Period of record	Mean daily discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Ouachita River near Malvern																			
1947–50																			
Maximum	--------	----	12	0.16	10	6.2	12	1.8	41	48	6.5	0.6	8.5	88	50	48	140	8.7	60
Minimum	--------	----	3.3	.01	1.6	.9	2.1	.1	3	2.5	.2	.0	.4	21	8	0	37	5.5	4
Average	--------	----	7.5	.03	6.7	1.8	4.3	1.0	26	6.1	3.1	.1	2.0	48	24	3	67	7.4	14
High-flow sample	28,530	----	----	----	6.0	1.8	[1] 2.6	----	21	6.0	2.8	----	.9	41	22	5	55	----	26
Low-flow sample	154	----	----	----	7.6	2.2	[1] 6.6	----	34	7.5	4.0	----	1.4	50	28	0	97	----	----
Ouachita River at Arkadelphia																			
1949–64																			
Maximum	--------	99	34	0.37	18	4.0	93	5.2	76	34	140	3.2	6.7	283	85	66	559	8.5	80
Minimum	--------	35	.9	.00	2.7	.3	1.5	.2	10	1.2	.2	.0	.1	26	10	0	27	6.2	0
Average	--------	65	5.4	.03	7.5	1.9	4.4	1.0	27	6.6	7.7	.2	1.3	56	27	4	83	7.1	12
High-flow sample	64,060	----	6.6	.12	2.8	1.0	1.5	.7	10	3.5	2.0	.0	.9	42	11	3	32	7.0	80
Low-flow sample	163	----	----	----	13	2.0	8.7	----	36	12	10	----	.8	84	40	10	24	7.7	4

Saline River at Benton

1950-53																			
Maximum	----	91	16	0.11	21	8.0	8.7	3.4	82	9.1	12	0.5	6.2	96	74	15	204	8.2	45
Minimum	----	32	5.9	.00	5.3	1.7	1.0	.5	24	1.6	1.0	.0	.4	29	22	0	32	6.6	3
Average	----	62	----	----	14	3.6	2.5	1.5	55	5.2	2.9	----	1.5	70	50	5	108	7.5	14
High-flow sample	7,340	----	----	----	8.0	1.8	1.9	----	32	3.1	2.8	----	1.3	53	27	1	65	7.2	32
Low-flow sample	10.7	----	----	----	19	3.7	3.3	----	73	4.0	5.0	----	1.0	88	63	3	142	7.6	12

Hurricane Creek near Sheridan

1950-55																			
Maximum	----	89	15	0.70	133	11	562	21	[2] 794	669	65	55	14	1,680	370	290	2,540	9.9	65
Minimum	----	32	.4	.00	1.4	.1	5.1	.4	3	14	1.8	.1	.0	41	4	0	34	5.1	1
Average	----	64	----	----	23	3.2	93	5.9	97	168	12	3.6	1.1	374	72	26	564	7.5	15

[1] Sodium and potassium calculated.

[2] Includes equivalent of 284 ppm of carbonate (CO_3).

TABLE 10.—*Chemical analyses of water from selected streams in Grant and Hot Spring Counties*

[Results in parts per million, except as indicated]

Date of collection	No. on pl. 6	Instantaneous discharge (cfs)	Temperature (° F)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Fourche a Loupe Creek near Hot Springs																						
Oct. 14, 1964	2	0.577	--------	9.0	------	------	0.00	2.1	0.6	1.7	0.4	9	2.4	1.4	0.0	0.0	27	8	0	27	7.3	8
Cove Creek at Jones Mill																						
Apr. 14, 1964	3	30.3	58	13	5.6	2.9	8.2	67	2.3	0.4	1.2	2	166	9.0	0.4	1.0	282	177	175	397	4.8	5
July 21, 1964		1.36	82	24	13	.37	31	128	28	9.0	3.6	10	534	1.7	1.6	1.3	1,020	435	435	1,160	4.3	------
Ouachita River near Malvern																						
July 21, 1964	4	99	79	2.5	------	0.04	0.02	7.5	1.8	2.2	0.8	30	5.4	2.0	0.0	0.2	36	26	2	67	7.3	5
Prairie Bayou near Social Hill																						
July 21, 1964	5	0.18	95	5.2	------	0.24	0.00	3.6	1.5	3.8	1.0	22	2.4	4.0	0.0	0.4	34	15	0	51	7.0	5
June 22, 1965		----------	--------	8.4	------	.06	.00	2.5	1.6	3.4	.6	19	3.0	1.2	.3	.0	21	12	0	40	7.3	6
Point Cedar Creek near Lambert																						
July 21, 1964	9	0.23	88	9.4	------	0.23	0.00	3.8	1.6	4.2	1.2	26	2.8	3.0	0.0	0.2	36	16	0	56	7.3	5
June 23, 1965		3.94	--------	8.4	------	.08	.00	4.9	2.4	4.3	.9	31	2.6	1.7	.3	.1	35	22	0	61	7.2	4
White Oak Creek at Whitherspoon																						
June 19, 1963	12	0.60	72	25	------	2.0	0.00	3.8	1.6	21	1.5	50	2.6	15	0.1	0.2	92	16	0	134	7.3	12
Sept. 26, 1963		.17	--------	30	------	1.2	.01	3.5	2.0	26	1.8	61	2.0	17	.2	.6	119	16	0	157	7.1	42

L'Eau Frais Creek near Joan																					
Sept. 6, 1960	13	2.73	----	----	----	0.00	----	1.7	0.5	1.3	0.8	7	1.2	2.0	0.3	0.6	34	6	0	23	6.3	15
Aug. 13, 1962		3.94	----	6.3	----	.04	----	1.9	.6	1.7	1.0	6	2.8	3.0	.2	.6	----	7	2	26	6.4	5
July 21, 1964		2.14	79	7.9	----	.56	0.00	1.4	.8	1.3	1.1	7	3.0	3.0	.0	.5	32	6	1	26	6.6	40
Saline River near Tull																					
Apr. 16, 1964	14	[2] 570	64	6.5	----	0.41	0.00	13	3.2	2.3	0.7	48	9.2	3.5	0.1	0.3	58	46	6	107	7.3	5
July 20, 1964		[2] 9.8	83	4.2	----	.15	.00	17	4.0	5.2	1.4	67	12	5.0	.0	.2	76	59	4	148	7.3	9
Reyburn Creek near Perla																					
Apr. 14, 1964	15	14.8	56	8.8	----	0.68	0.9	8.6	4.1	14	1.2	2	59	5.0	0.2	0.4	104	38	37	169	4.9	----
July 21, 1964		.03	77	11	----	.15	1.5	15	3.8	39	2.3	0	132	3.5	.3	.0	217	53	53	366	4.5	0
Francois Creek near Poyen																					
Sept. 20, 1969	16	[3] 0.05	----	1.6	----	----	----	6.4	1.3	9.0	2.0	16	23	3.0	0.1	0.3	68	22	8	109	6.3	7
June 27, 1961		5.24	----	5.9	----	----	----	6.4	1.9	9.4	1.1	10	36	1.0	.0	.6	100	24	16	107	6.4	5
Big Creek at Poyen																					
July 20, 1964	18	----	78	8.9	----	0.56	0.00	1.8	0.6	1.1	0.7	6	5.2	1.5	0.0	0.5	30	7	2	30	6.1	40
June 23, 1965		21.7	----	9.2	----	.40	.00	1.2	1.5	1.3	.7	3	3.0	1.3	.3	.8	26	9	6	25	5.6	42
Saline River near Leola																					
Apr. 16, 1964	19	----	66	7.1	----	0.54	0.00	10	2.5	2.3	0.7	37	6.8	4.5	0.1	0.4	51	35	4	89	7.2	20
July 20, 1964		29.8	86	6.4	----	.31	.00	11	3.3	3.4	.8	43	8.2	4.0	.0	.3	61	41	6	100	7.4	20
Hurricane Creek near Belfast																					
June 20, 1963	21	4.6	74	1.4	----	0.08	0.00	9.8	0.9	248	7.8	[4] 196	361	9.2	14	0.1	736	28	0	1,190	8.8	5
Aug. 13, 1963		2.13	82	1.4	38	.15	.00	3.4	.0	496	17	[5] 786	598	9.6	32	.9	1,560	8	0	2,230	9.4	30
Sept. 26, 1963		1.41	----	5.4	----	.02	.01	53	5.1	210	8.0	92	480	11	9.7	3.8	856	153	78	1,260	7.8	5
Apr. 15, 1964		----	67	9.3	.1	1.8	.8	22	4.9	64	3.2	20	184	6.0	1.6	.6	319	76	59	487	6.7	5
July 20, 1964		1.67	82	1.9	1.2	.00	.00	38	4.5	350	6.6	185	644	7.6	20	.1	1,250	114	0	1,840	8.1	6
Hurricane Creek near Sheridan																					
Apr. 15, 1964	23	[6] 268	65	12	1.3	0.93	0.00	11	2.2	27	2.0	47	50	5.5	1.1	0.6	152	36	0	212	7.2	40
July 20, 1964		.92	81	3.1	.9	.19	.00	30	1.9	350	9.5	252	574	9.4	18	.1	1,200	83	0	1,770	8.2	6

[1] Sample contained immediate acidity of 1.6 ppm as H^+.
[2] Mean daily discharge at Benton.
[3] Estimated.
[4] Includes equivalent of 9 ppm carbonate (CO_3).
[5] Includes equivalent of 185 ppm carbonate (CO_3).
[6] Mean daily discharge.

TABLE 11.—*Frequency of low flows and duration of daily flows*

Station name	Period in days	Annual low flow, in cubic feet per second, for indicated recurrence interval, in years				
		1.2	2	5	10	20
Ouachita River at Arkadelphia.	7	280	195	137	112	94
	15	360	220	150	123	104
	30	430	255	175	142	118
	60	550	330	220	178	150
	120	1, 110	480	305	245	200
Ouachita River above mouth Caddo River.	7	242	177	126	105	89
	15	317	199	138	115	97
	30	379	228	161	132	111
	60	459	294	203	165	141
	120	905	411	274	223	184
Saline River at Benton	7	28	12	5. 3	2. 7	1. 4
	15	34	15	6. 8	3. 6	1. 9
	30	48	20	9. 0	5. 0	2. 7
	60	75	28	11	6. 9	4. 5
	120	194	65	26	18	12
Saline River at Rye	7	56	26	13	9. 0	6. 6
	15	70	30	15	10	7. 7
	30	101	39	18	12	9. 0
	60	161	56	25	17	12
	120	428	133	50	34	24

Station name	Daily flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of time								
	Percentage of time								
	99	95	90	80	60	40	20	5	1
Ouachita River at Arkadelphia.	126	187	250	385	920	2, 270	4, 500	14, 200	37, 500
Ouachita River above mouth Caddo River.	116	168	221	335	796	1, 920	3, 530	10, 500	25, 500
Saline River at Benton.	2. 3	12	23	44	118	328	890	3, 500	11, 400
Saline River at Rye.	11	23	41	84	287	1, 190	4, 090	11, 100	23, 600

Information on low-flow frequency for the Saline River in Grant County may be determined by adjusting data for gaging stations at Benton and Rye (table 11) on the basis of drainage-area relationships. For example, assume that it is desired to determine the 7-day 2-year low flow (the flow below which the average discharge for 7 consecutive days can be expected to fall on the average of once every other year) of Saline River near Leola. The drainage areas at Benton, Leola, and Rye are 569, 900, and 2,062 square miles, respectively. From table 11, the 7-day 2-year low flows at Benton and Rye are 12 cfs and 26 cfs, respectively. The 7-day 2-year low flow at Leola, based on records at Benton, is computed as 19.0 ($\frac{900}{569} \times 12 = 19.0$). The 7-day 2-year low flow at Leola, based on records at Rye, is computed as 11.4 cfs ($\frac{900}{2,062} \times 26 = 11.4$). The average of these computed values is 15 cfs. This compares favorably with the value of 17 cfs (table 8) obtained for this site on the basis of measurements of base-flow discharge.

Information on low-flow frequency for small streams, for which continuous records have not been collected (table 8), has been determined by use of base-flow measurements and indicates the dependable flow without storage. The 7-day 2-year low flow is considered to be the average minimum flow and is a useful value in appraising the dependable water-supply potential of a stream. For example, the table shows that at a point near Hot Springs the 7-day 2-year low flow of Fourche a Loupe Creek is 0.16 cfs (103,000 gpd) and that the flow will be less than this amount for a short period of time on the average of once in 2 years. A more complete discussion of methods of determining low-flow frequencies is given in a report by Hines (1965).

The analysis of low-flow frequency indicates the average time interval in years between selected low flows, but it does not indicate what percentage of time a given quantity of streamflow will be available. This time distribution of flow can be determined by a flow-duration analysis.

FLOW DURATION OF STREAMS

A flow-duration analysis (fig. 8) shows the percentage of time that the flow (daily mean flow) of a stream is equal to, or greater than, a certain quantity. The curve can be used to estimate the quantity of water available for various percentages of time, provided hydrologic conditions do not change. The analysis for the Ouachita River consists of two curves. The difference between the two is primarily the result of the effect of regulation of Lake Ouachita. Other flow-duration data, based on records collected for several years at gaging stations on the Ouachita and Saline Rivers, are given in table 11. These data may be used to estimate the flow duration at other points on these streams on the basis of drainage-area ratios. When this is done, careful consideration should be given to hydrologic factors affecting streamflow in the intervening watershed and the estimate should be modified as necessary.

Flow-duration information has been determined for small streams (table 8) by the use of base-flow measurements; hence, the determinations are limited to periods of low flow. For example, the table shows that 95 percent of the time the flow of Fourche a Loupe Creek near Hot Springs is 0.18 cfs or greater. The analysis of low-flow frequency indicates that the 7-day 2-year low flow of the stream is

0.16 cfs. To summarize: The minimum average flow in Fourche a Loupe Creek near Hot Springs for 7 consecutive days will be equal to, or less than, 0.16 cfs at average intervals of 2 years; the daily flow will be equal to, or greater than, 0.18 cfs 95 percent of the time (or less than 0.18 cfs 5 percent of the time).

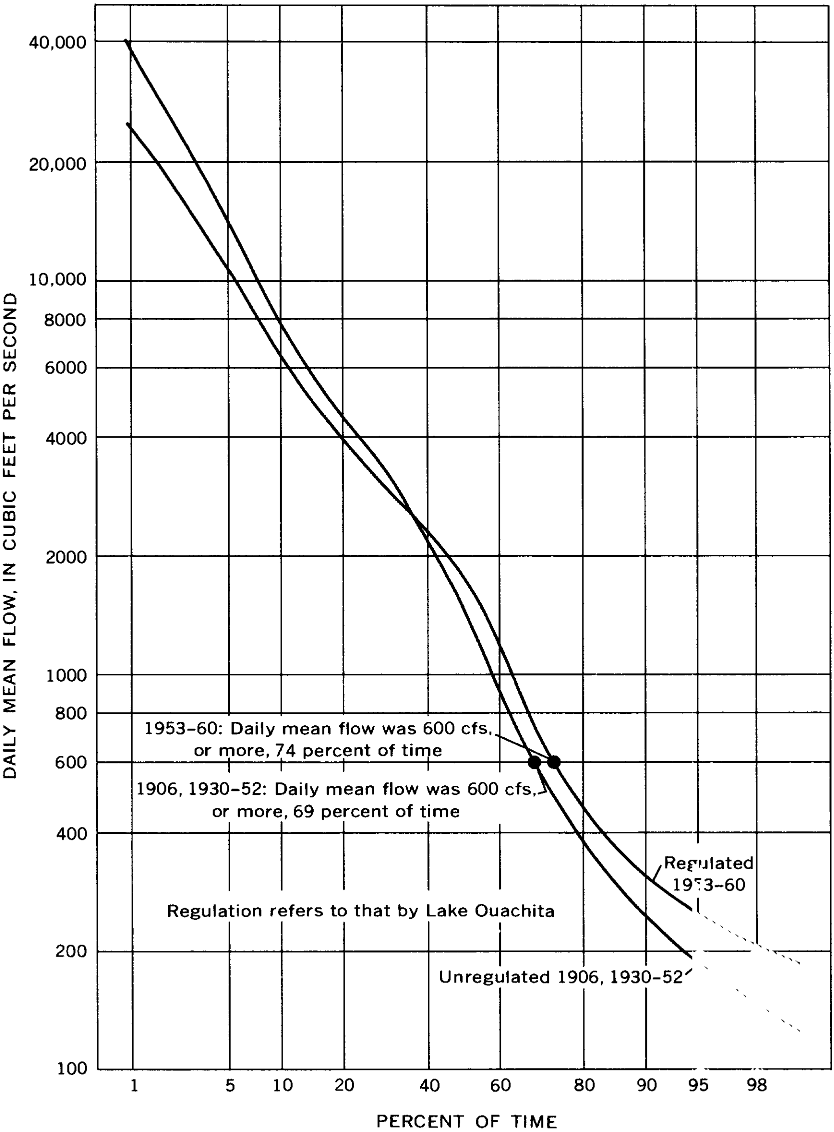

Figure 8.—Duration of daily mean flow of Ouachita River at Arkadelphia, 1906, 1930–52, 1953–60.

STORAGE

Only a small percentage of the average runoff (discharge) of 1.3 cfs per sq mi of most of the streams in Grant and Hot Spring Counties is available for use during droughts. The dependable yields of the streams can be greatly increased by storing high flows. There are many good reservoir sites in the Interior Highlands; but, because of the minor relief, there are few good sites in the Coastal Plain. Figure 9 can be used to determine the storage requirements for specific draft rates. The graphs are based on drought conditions having a 20-year recurrence interval. This means that storage requirements will be deficient on the average of once in 20 years, or that there is a 5 percent possibility that storage will be deficient in any year.

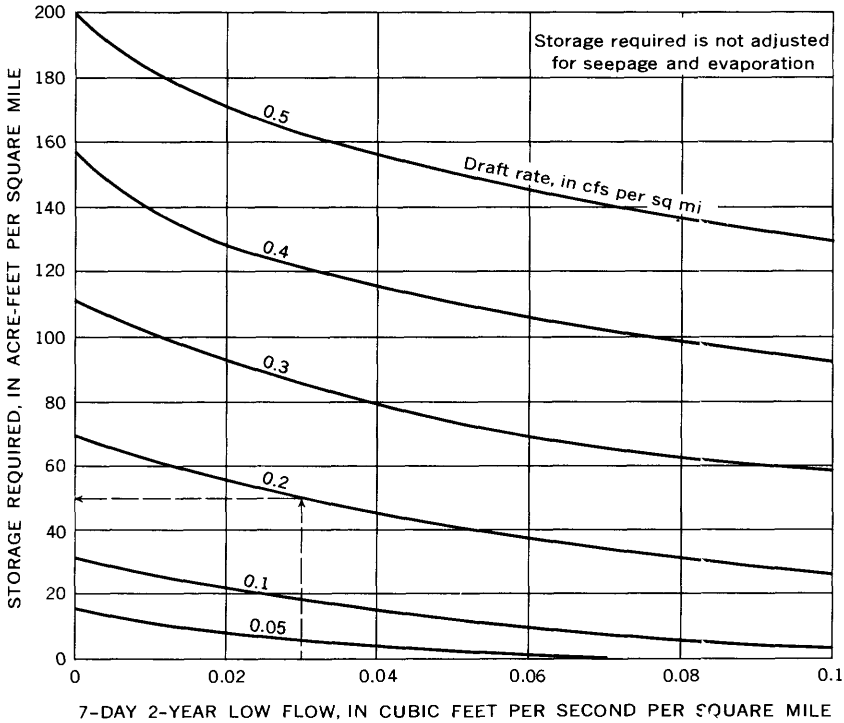

FIGURE 9.—Storage required to maintain specific draft rates, for 20-year recurrence interval, related to 7-day 2-year low flow. Prepared by J. L. Patterson.

To use the graphs, it is necessary to know the drainage area and the 7-day 2-year low flow at the proposed damsite. The 7-day 2-year low flows for 17 sites are given in table 8, and values for other sites can be determined by a correlation of base-flow measurements with concurrent streamflow data for a nearby gaging station.

The following example illustrates the use of the graphs in figure 9:

Assume that a satisfactory reservoir site has been found and that the drainage area above the damsite is 40 square miles. Let it be further assumed that the 7-day 2-year low flow at the site is determined to be 1.2 cfs. The desired draft rate is 8 cfs, and the proposed reservoir has a capacity of 3,000 acre-feet. The 7-day 2-year low flow is 0.3 cfs per sq mi (1.2/40). Entering figure 9 with the above values, the storage required is 50 acre-feet per square mile, or a total of 2,000 acre-feet, which is within the 3,000-acre-foot capacity of the reservoir.

MAGNITUDE AND FREQUENCY OF FLOODS

During periods of excessive runoff, large quantities of water can be stored for future use. Although floods of a given magnitude do not occur at regular intervals, the high-water season in Grant and Hot Spring Counties is generally between January and May.

Although floods provide an opportunity to replenish depleted stores of water, few aspects of floods are beneficial. In some places, scour, erosion, or other damage is caused by the force of the water. In other areas, damage to structures is caused by inundation.

In the Interior Highlands, most damage is caused by the high velocity of the water which deposits gravel and rocks on flood plains, washes out roads where they are overtopped, and destroys fenses and buildings. Loss due to inundation is slight, except during the growing season, and then it is limited to crop damage in the narrow flood plains.

In the Coastal Plain, streams are sluggish, and large areas in the flood plains of the Ouachita and Saline Rivers and Hurricane Creek are occasionally inundated. Flood peaks along the Ouachita River have been greatly reduced by storing water in Lake Ouachita. In effect, the drainage area of 1,105 square miles above Blakely Mountain Dam does not contribute to high-water flows in Hot Spring County.

To appraise floodflow potential, a method is presented on plate 6, and figures 10 and 11 whereby the magnitude and frequency of floods in this area can be determined. The use of the figures is explained by the following two examples. A more complete treatment of flood frequency is contained in a report by Patterson (1964).

Example 1

To determine the magnitude of the 25-year flood on Francois Creek near Poyen (drainage area, 84.1 sq mi):

The site is in hydrologic area 2 on plate 6.

From figure 10, the mean annual flood for 84.1 sq mi in area 2 is 6,800 cfs.

From figure 11, the ratio of the mean annual flood to a 25-yr flood is 2.2.

The 25-yr floodflow is 6,800 × 2.2, or 14,400 cfs.

Example 2

To determine the recurrence interval of a peak flow of 23,400 cfs on Hurricane Creek at U.S. Highway 270 near Sheridan (drainage area, 205 sq mi):

The site is in hydrologic area 2 on plate 6.

From figure 10, the mean annual flood for 205 sq mi for area 2 is 11,700 cfs.

The ratio of 23,400 cfs to the mean annual flood (11,700) is 2.00.

The recurrence interval, from figure 11, is 20 yr.

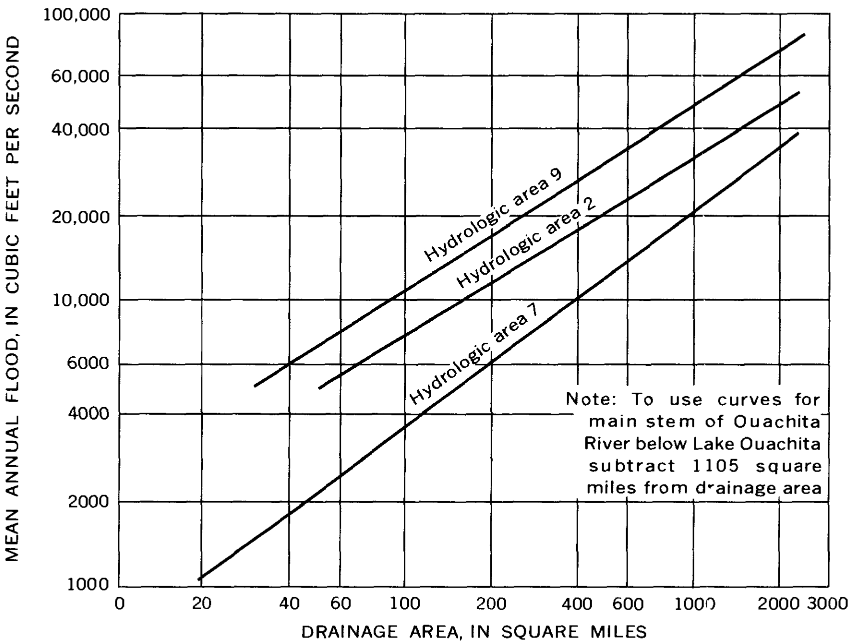

FIGURE 10.—Variation of mean annual flood with drainage area (Patterson, 1964). Hydrologic areas shown on plate 6.

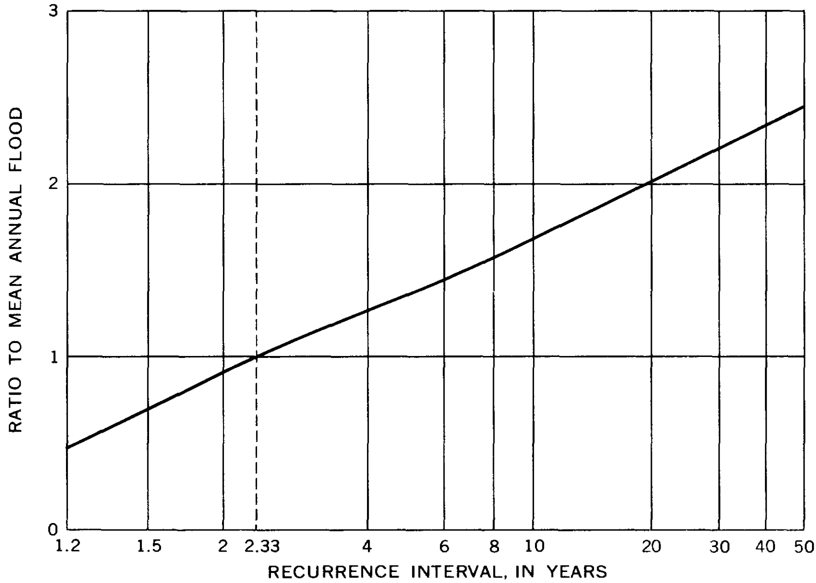

FIGURE 11.—Frequency of annual floods (Patterson, 1964).

CHEMICAL QUALITY OF SURFACE WATER

OUACHITA RIVER BASIN

The Ouachita River and most of its tributaries contain water of excellent chemical quality, except locally where untreated wastes or acid mine drainage occasionally enters the stream. Areal distribution of chemical characteristics of the water is shown on plate 6, and the pollution of the river is discussed in more detail under "Pollution of the Ouachita River."

Water from the Ouachita River is a soft, calcium bicarbonate type, and its dissolved-solids content is low (table 9). The chemical characteristics of the water have changed little since the initiation of water-quality studies in 1946. The chemical content of a sample collected near Malvern in 1964 (table 10) was about the same as the average for the period 1946 through 1950. Continuous records for Arkadelphia indicate that the quality of water there has changed little since 1949 when sampling began. The chemical quality of water at Malvern and Arkadelphia is similar, and the inflow of the Caddo River affects the quality of the water in the Ouachita River very little.

Table 9 shows maximum, minimum, and average values of princpal chemical constituents for the Ouachita River at Arkadelphia and Malvern. Detailed information on quality of water can be obtained from the water-supply papers listed in the bibliography.

The small tributaries of the Ouachita and Caddo Rivers in the Ouachita Mountains in Hot Spring County yield water that has excellent chemical quality. The water is soft, has a very low mineral content (table 10), and is suitable for most uses. The chemical quality of water from Fourche a Loupe and Point Cedar Creeks and Prairie Bayou is alike. All three streams drain areas of similar topography that are underlain by the same types of rocks.

The water of two tributaries on the east side of the Ouachita River, White Oak and L'Eau Frais Creeks, is chemically dissimilar (table 10). Water from White Oak Creek is soft and is a sodium bicarbonate type. Its dissolved-solids content is higher than that of streams in the Ouachita Mountains. White Oak Creek water contains as much as 30 ppm of silica, and during periods of low flow, the color is high. L'Eau Frais Creek water is soft and has a very low dissolved-solids content (table 10). Its color is high at times during periods of low flow.

SALINE RIVER BASIN

The Saline River is a source of large quantities of good-quality water in Grant County. The water is a calcium bicarbonate type and has a low dissolved-solids content (table 9). Its hardness varies from soft to moderately hard, and its iron content during periods of low flow has been greater than the maximum limit of 0.3 ppm recommended for drinking water by the U.S. Public Health Service (1962). A color of 45 has been recorded and has reached 40 many times during periods of high flow. The high iron content and color limit the usefulness of the water, but after minor treatment it can be used for most purposes.

The chemical quality of the water changes little as the Saline River traverses Grant County, as indicated by analysis of samples collected near Tull and Leola in 1964. The quality has remained almost unchanged since 1949. Water samples collected near Tull in 1964 had chemical characteristics similar to those determined by daily sampling at Benton (14 miles upstream) during the period 1949–53. Inflow between Benton and Tull is small, and the quality of the water at Tull is considered to be similar to that at Benton.

The chemical quality of the water of some of the tributaries of Saline River is good; in Francois and Reyburn Creeks, water is acidic because of pollution from industrial wastes.

Big Creek water is a very dilute, soft, calcium sodium bicarbonate type (pl. 6; table 10). The water is slightly acidic, its color is high, and its iron content is in excess of 0.3 ppm. The water reflects the quality of Rhinehart Branch, which receives most of its base flow from Big Spring.

The water from Francois Creek, east of Poyen (pl. 6), is much different from that of Big Creek. Francois Creek water is a soft, slightly acidic, sodium sulfate-sodium bicarbonate type; its dissolved-solids content (table 10) is much higher than that of Big Creek water. Reyburn Creek, a tributary of Francois Creek (pl. 6), yields an acidic sodium sulfate type water that has a higher dissolved-solids content than water from Big and Francois Creeks (table 10). The acidity and sulfate content of water from Francois and Reyburn Creeks are due to wastes from mining operations near Magnet a few miles north of Malvern.

Most of the time the chemical quality of Hurricane Creek water is poor, owing to introduction of wastes from bauxite mines and alumina plants near Bauxite, in Saline County (pl. 6; tables 9, 10). This pollution is discussed in more detail under "Pollution of Hurricane Creek." Only at high flows is the quality of the water similar to that of other streams in the two counties. The chemical characteristics of Hurricane Creek water have remained about the same since 1949, as indicated by the results of samples collected daily during the period 1949–55 and spot samples collected in 1964.

PUBLIC WATER SUPPLIES

The public water-supply systems in Grant and Hot Spring Counties furnish 1.1 mgd of water to about 12,400 people in the cities of Leola, Malvern, and Sheridan. The finished waters are of excellent quality (table 12) and meet all U.S. Public Health Service (1962) standards for drinking water. They are soft, have a low dissolved-solids content, and are suitable for most industrial uses. The city of Malvern takes its water from the Ouachita River; Leola and Sheridan use water from the Sparta Sand. The sources of water for all three systems are large enough to furnish much more water than was used in 1965 (table 1).

INTERRELATION OF GROUND AND SURFACE WATER

The base flow of streams in the area is supplied about 95 percent of the time by ground water from the adjacent alluvium and rocks. During, and for a short time after storms, the alluvium in the river bottoms is recharged while river stages are high. As streamflow decreases, the direction of ground-water flow reverses, and the normal condition of ground water supplying streamflow is resumed.

Deeper aquifers are supplied by precipitation that falls on their areas of outcrop and from overlying alluvium and by streams that

TABLE 12.—*Chemical analyses of water from public supplies*

[Results in parts per million, except as indicated. Water treatment: A, aeration; C, chemical dosage for coagulation; Dc, chlorination; Dh, hypochlorination; F, filtration; I, iron removal; S, sedimentation; T, activated carbon; V, fluoridation]

	Leola	Malvern	Sheridan
Population served	313	9, 566	2, 500
Source of water	Well	Ouachita River	Wells
Average use, 1965 mgd	0. 026	0. 812	0. 284
Rated plant capacity do	----------	1. 810	. 500
Treatment	Dh, F, I–A, S	C, Dc, F, S, T, V	Dh, F, I–A, S
Date of collection	10–19–64	7–15–66	5–28–64
Silica (SiO_2)	16	2. 6	17
Iron (Fe)	. 21	. 06	. 20
Manganese (Mn)	. 01	. 00	. 00
Calcium (Ca)	9. 5	11	15
Magnesium (Mg)	1. 1	2. 9	2. 3
Sodium (Na)	1. 5	2. 0	5. 0
Potassium (K)	1. 5	1. 0	2. 7
Bicarbonate (HCO_3)	21	34	54
Carbonate (CO_3)	0	0	2
Sulfate (SO_4)	13	12	6. 4
Chloride (Cl)	2. 1	2. 9	6. 5
Fluoride (F)	. 2	. 6	. 1
Nitrate (NO_3)	. 3	. 2	. 0
Disolved solids, residue at 180° C	57	62	84
Hardness as $CaCO_3$	28	40	47
Noncarbonate hardness as $CaCO_3$	11	12	0
Specific conductance micromhos at 25° C)	81	100	125
pH	7. 1	7. 5	8. 5
Color	3	0	0

cross the outcrops where the streams and aquifers are hydraulically connected.

Water levels in the alluvium respond quickly to changes in river stage. There is no apparent relation between river stages and the fluctuations of water levels in the deeper aquifers. There is, however, a long-term relation between recharge to aquifers and precipitation and streamflow.

MAJOR WATER PROBLEMS AND THEIR SOLUTIONS

The principal problems in the two counties are the poor areal distribution of the ground- and surface-water supplies and the poor quality of water in certain areas. The Ouachita and Saline Rivers can supply Hot Spring County and western Grant County with large quantities of water, but from the Garland County line to a point a few miles below Lake Catherine, the Ouachita River is polluted. Malvern is assured plenty of water from the Ouachita River for municipal and industrial expansion; however, larger treatment facilities will be needed to keep pace with industrial growth. Away from the two rivers, southeastern Hot Spring County has moderately large supplies of good-quality ground water.

East of the Saline River, surface-water yields are low during prolonged dry periods and Hurricane Creek water is unfit for most uses. However, large quantities of good-quality ground water are available, but additional wells should be spaced far enough apart so that they do not interfere with one another.

The high nitrate content of water from shallow wells in a few places in the flood plains of the principal streams introduces the problem of methemoglobinemia.

POLLUTION OF THE OUACHITA RIVER

The Ouachita River is polluted locally by municipal and domestic sewage, industrial wastes, and mine drainage (Arkansas Water Pollution Control Com., 1963, p. 6–12). During rainy seasons, excessive infiltration of ground and surface water into the sewers of the cities of Hot Springs and Malvern overloads the treatment plants, and raw sewage bypasses the plants and empties into creeks that drain into Lakes Hamilton and Catherine and the river. Added to the above are the domestic sewage and the wastes from several industries that are discharged into Lake Hamilton or from streams that flow into it.

In addition to the above, just below Lake Catherine, Cove Creek discharges the drainage from strip mines into the Ouachita River. Metallic sulfides from spoil piles combine with rainwater to produce sulfuric acid, which is the primary source of the acid water. At times the river water below Cove Creek becomes so acidic that fish die. Process water from current (1966) mining operations is treated and does not contribute significantly to the pollution of Cove Creek.

In spite of the pollution load, much of the Ouachita River is a source of large quantities of good-quality water. Dilution raises the pH of the water to acceptable levels a few miles downstream from the polluted areas.

POLLUTION OF HURRICANE CREEK

Hurricane Creek water cannot be used for most purposes during low flow because it is highly polluted. If the stream could be reclaimed, an additional source of water would be available in eastern Grant County; treatment, however, would be costly.

Two methods can be used to reduce or eliminate the pollution of Hurricane Creek. One method is more extensive treatment of wastes from alumina plants and bauxite mines before release of effluent to the stream. The second method is to increase low flows by use of a system of storage reservoirs. The second method probably would require more water than is perennially available. A combination of the two methods probably would have to be used because complete treatment is impracticable.

HIGH NITRATE CONTENT OF WATER FROM SHALLOW WELLS IN FLOOD PLAINS

High nitrate content of water that is fed to infants has been known to cause methemoglobinemia (blue-baby disease). Hem (1959, p. 239) states that several investigators link high nitrate content of domestic-water supplies with methemoglobinemia in infants whose feeding formulas are mixed with these waters. It has not been determined exactly what concentration of nitrate in water causes this poisoning, but the U.S. Public Health Service (1962, p. 7) recommends that water containing more than 45 ppm of nitrate not be used for drinking water.

In a few places in the flood plains of the Ouachita and Saline Rivers and other streams, particularly where there are concentrations of houses whose occupants draw their water from shallow wells, there is a possibility of a dangerously high nitrate content of the water. In the village of Donaldson, all domestic water supplies are drawn from wells tapping alluvium that ranges in depth from 15 to 30 feet. The land surface of the area is very flat, and drainage is poor. As shown in figure 12, there is no apparent relation between the location of wells in the village and the nitrate content. Also, there is no apparent relation between the drainage pattern and the nitrate content. Both high and low nitrate concentrations are in well waters in the center of the village and on the outskirts.

The nitrate content of water samples collected from 13 wells at Donaldson ranged from 5.0 to 49 ppm (fig. 26). A water sample from well 6S–18W–3dbc, collected in 1963, contained 36 ppm of nitrate; a year later the nitrate content had increased to 42 ppm. Although some of the nitrate may be from natural sources, most of it probably represents contamination. Individual septic tanks are probably the primary source of the nitrate. A few privies and barnyards in the village may contribute to the nitrate content of some of the well water.

Probably the only solution of the nitrate problem at Donaldson is to install a central supply system that draws water from wells or streams outside the area of contamination. Near Donaldson, only small quantities of water are available from the alluvium. Plenty of good-quality, uncontaminated water is available from deeper aquifers several miles from the village; but transporting the water would be expensive, and minor treatment would be necessary. The Ouachita River is the closest large supply of good-quality water, but the water would have to be treated and transported to the village.

The nitrate content of water from shallow wells that tap alluvium at a few other places in the two counties is high enough to cause concern. A water sample from well 5S–15W–5abb2, in Poyen, contained 45 ppm of nitrate. A sample from well 4S–17W–29dcb, which is on a farm southwest of Malvern, contained 27 ppm of nitrate; this fact indicates that nitrate contamination is not confined to thickly populated areas.

Water that has a high nitrate content is found in only a few places in the alluvium along the principal streams. The nitrate content of water from most of the alluvium is low and well within safe limits.

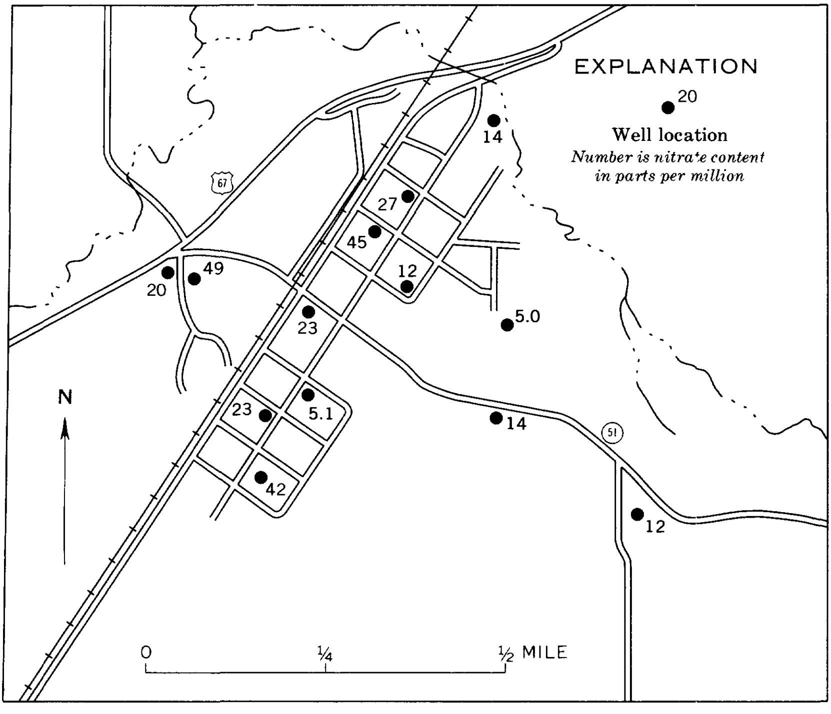

FIGURE 12.—Nitrate content of water from selected wells that tap alluvium of Quartenary age in Donaldson and vicinity.

LEGAL PROBLEMS

State laws regulating the development and use of water resources have important bearing on industrial development, urban growth, and agriculture. Industrial-development leaders who are interested in promoting use of water supplies or in increasing their available supplies may find that they need to orient themselves to the existing framework of water law. Persons interested in obtaining water in areas where the supply is heavily used may wish to know how the Arkansas Supreme Court has decided various issues concerning water rights. A report by Mack (1963) summarizes statutory law in the development and use of water in Arkansas. The following paragraphs are abstracted or quoted from his summary.

Because Arkansas is blessed with an abundance of water resources, there has been little litigation of water rights. The lack of long-established rigid controls and the resulting flexible conditions of State water law are probably an advantage to the State during the period in which it is shifting from a predominantly agricultural economy to one in which industry plays a leading part. Arkansas is thus able to make a fresh start in developing its water resources and laws, and thus may benefit from the experiences of other States.

Throughout the history of the State there has been a slow but consistent growth to the body of water law. Early litigation predominantly concerned injury to property caused by excessive water. The next phase to develop showed that pollution of water gave rise to controversy. Without completing phase two, we have entered phase three concerning rights to available water and maintaining the flow of streams.

The Arkansas Supreme Court has accepted the riparian doctrine of reasonable use which essentially states that a proprietor must use water with reasonable regard to the rights of others. This general rule applies to water-courses as well as ground water. The natural flow theory of the riparian doctrine has not been abandoned, however. In addition to the riparian doctrine, the Arkansas Legislature has adopted some aspects of the appropriation doctrine whereby a State agency may allocate a fair share of water to persons where there is a shortage. The State has enabled legally responsible organizations to enter into contracts with Federal agencies for use of water from Federal reservoirs constructed under their supervision. The State may enter compacts with other States concerning interstate rivers.

Although a landowner may fend off water that washes on his land, he may not obstruct a watercourse or increase natural flow to the unreasonable detriment of another landowner. A proprietor whose land is bordered by a non-navigable stream has title to the thread of the stream but if the land is bordered by a navigable watercourse, he takes only to the high-water mark. The question of navigability is one of fact or Congressional action. Where a tract of land is bounded by a navigable or non-navigable stream, the boundary changes with the gradual change in the course of the stream but where the stream suddenly seeks a new channel, the boundary lines do not change.

Any person causing injury to another by pollution may be sued for damages or enjoined from further pollution.

In Grant and Hot Spring Counties there has been little litigation over water rights. There are no known cases relating to the utilization of ground water, presumably because there has been very little development of ground-water resources. Presently (1966), there is a legal conflict regarding release of water from a reservoir during a flash flood.

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[Italic numbers indicate major references]

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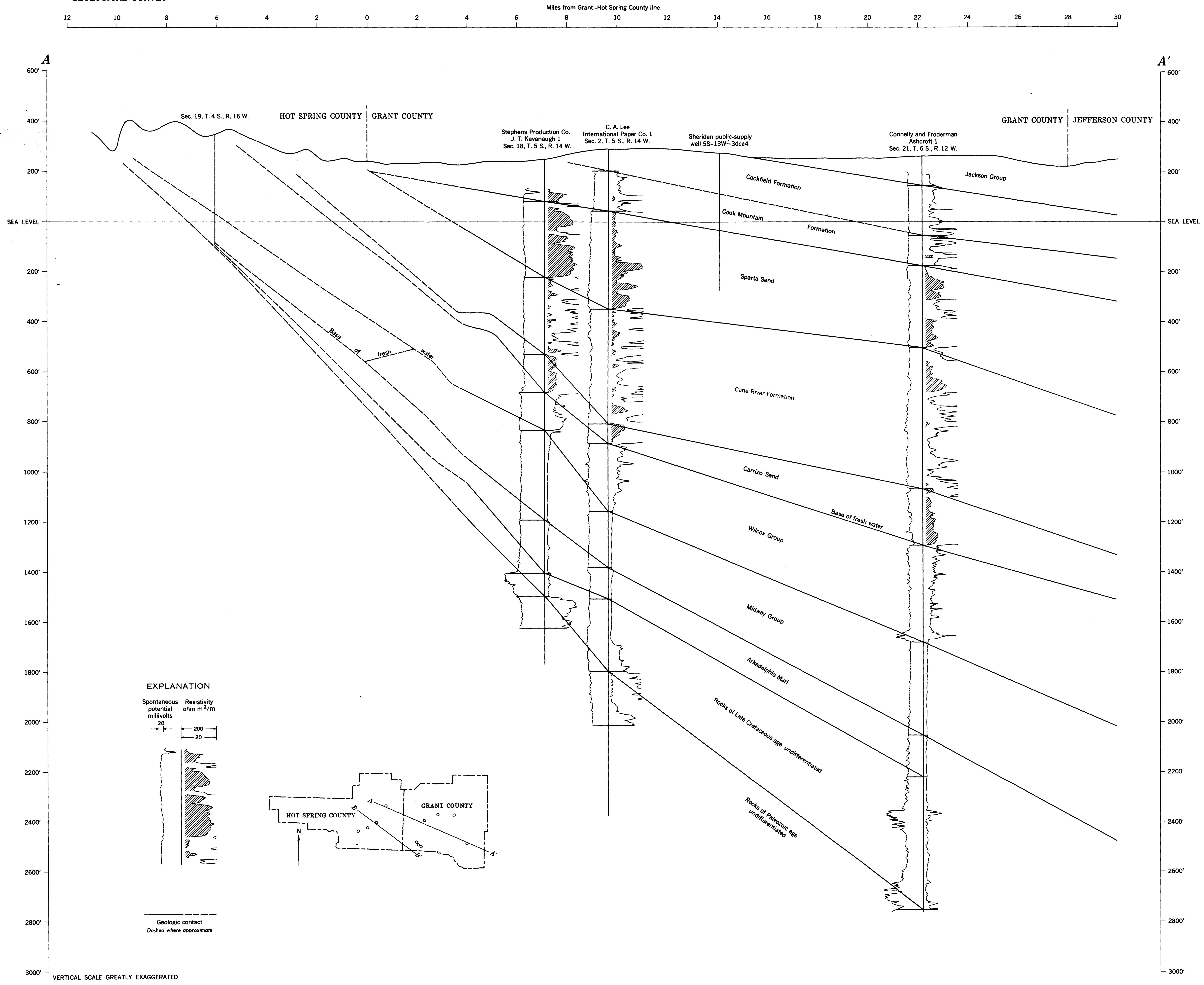
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

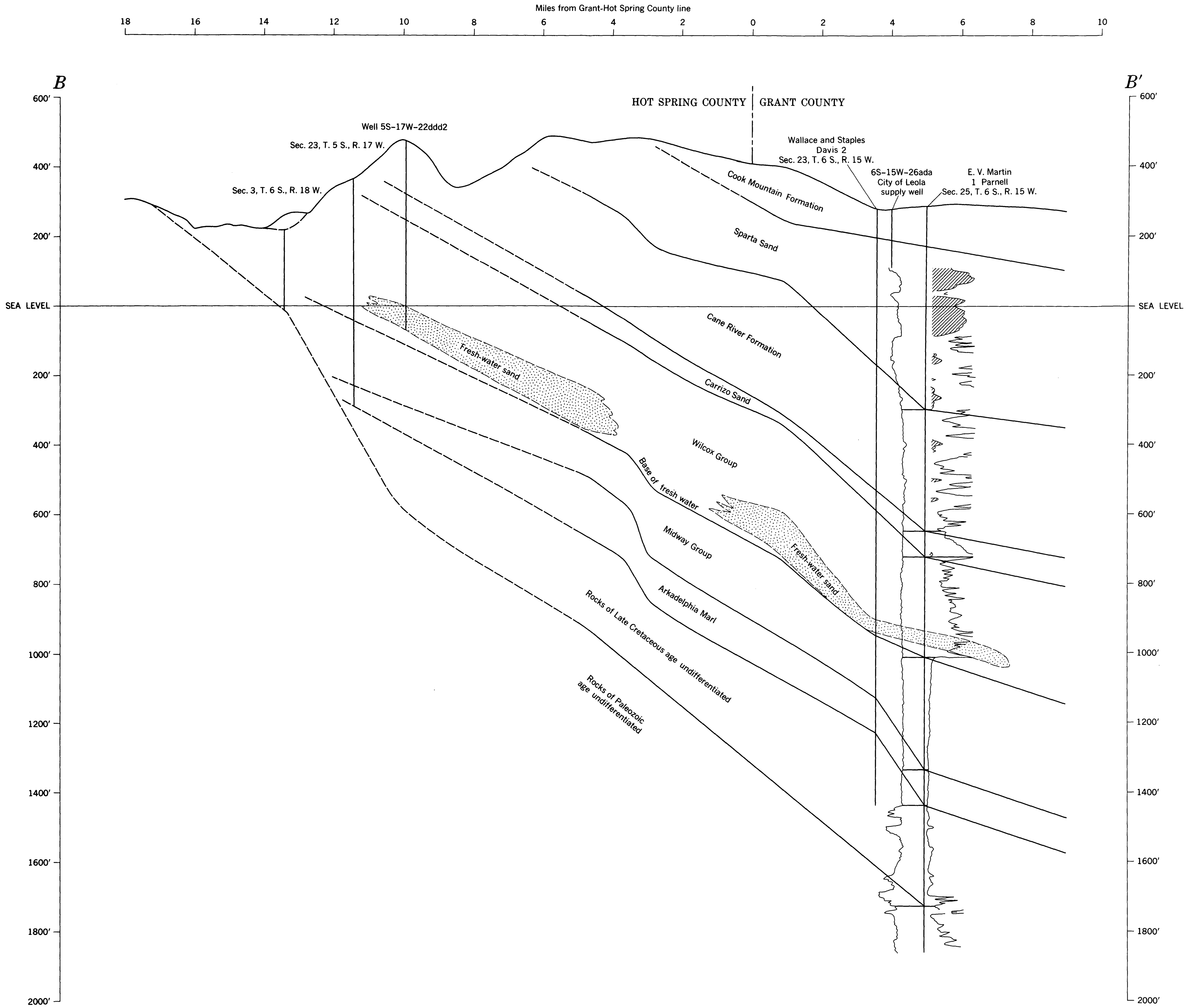
PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION

WATER-SUPPLY PAPER 1857
PLATE 1

GENERALIZED GEOLOGIC MAP OF GRANT AND HOT SPRING COUNTIES, ARKANSAS

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION





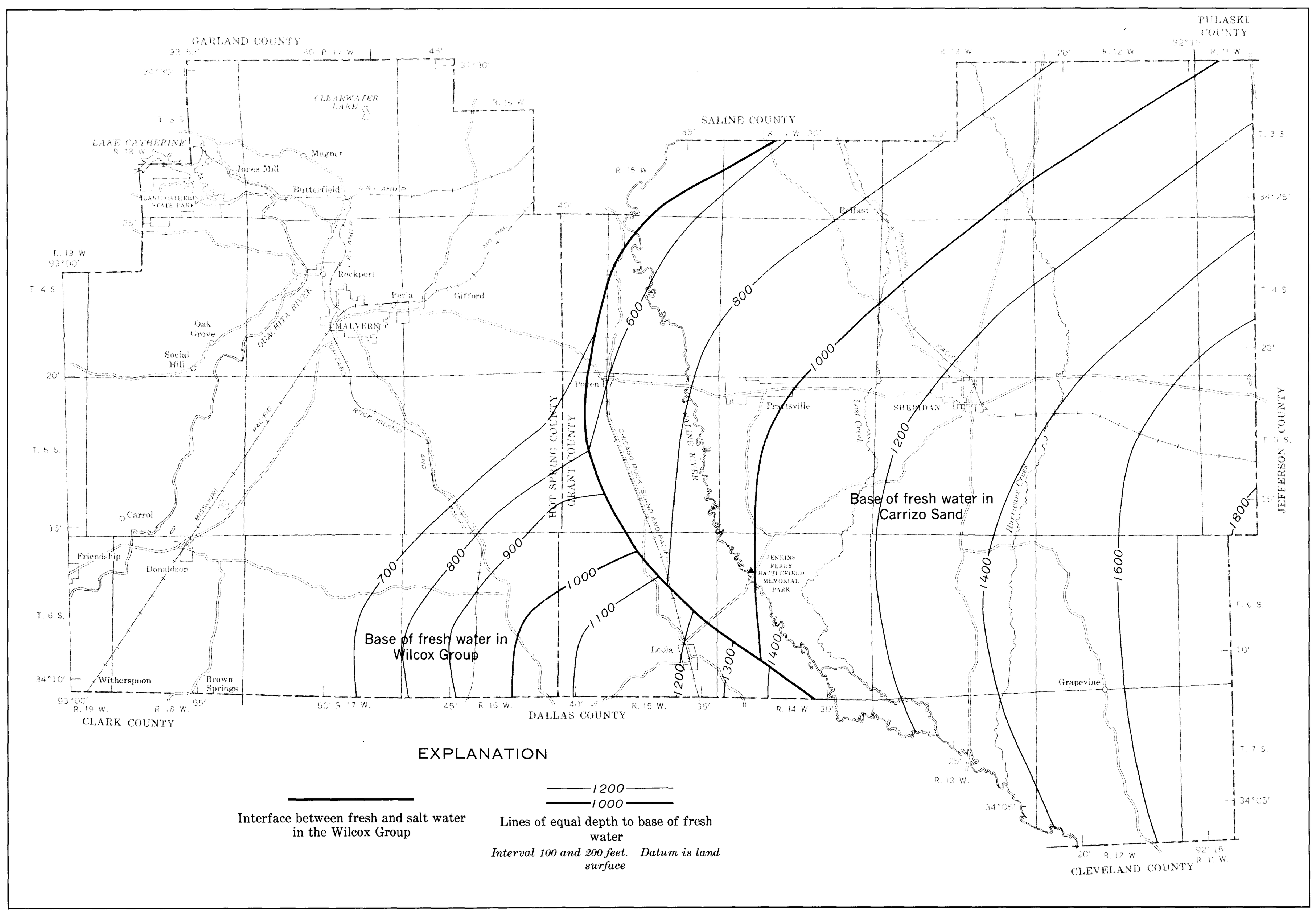
GEOLOGIC SECTIONS *A-A′* AND *B-B′*, GRANT AND HOT SPRING COUNTIES, ARKANSAS

MAP SHOWING LOCATIONS OF WELLS FOR WHICH INFORMATION ABOUT AQUIFER TESTS WATER-LEVEL FLUCTUATIONS, AND CHEMICAL CHARACTERISTICS OF THE WATER ARE AVAILABLE, GRANT AND HOT SPRING COUNTIES, ARKANSAS

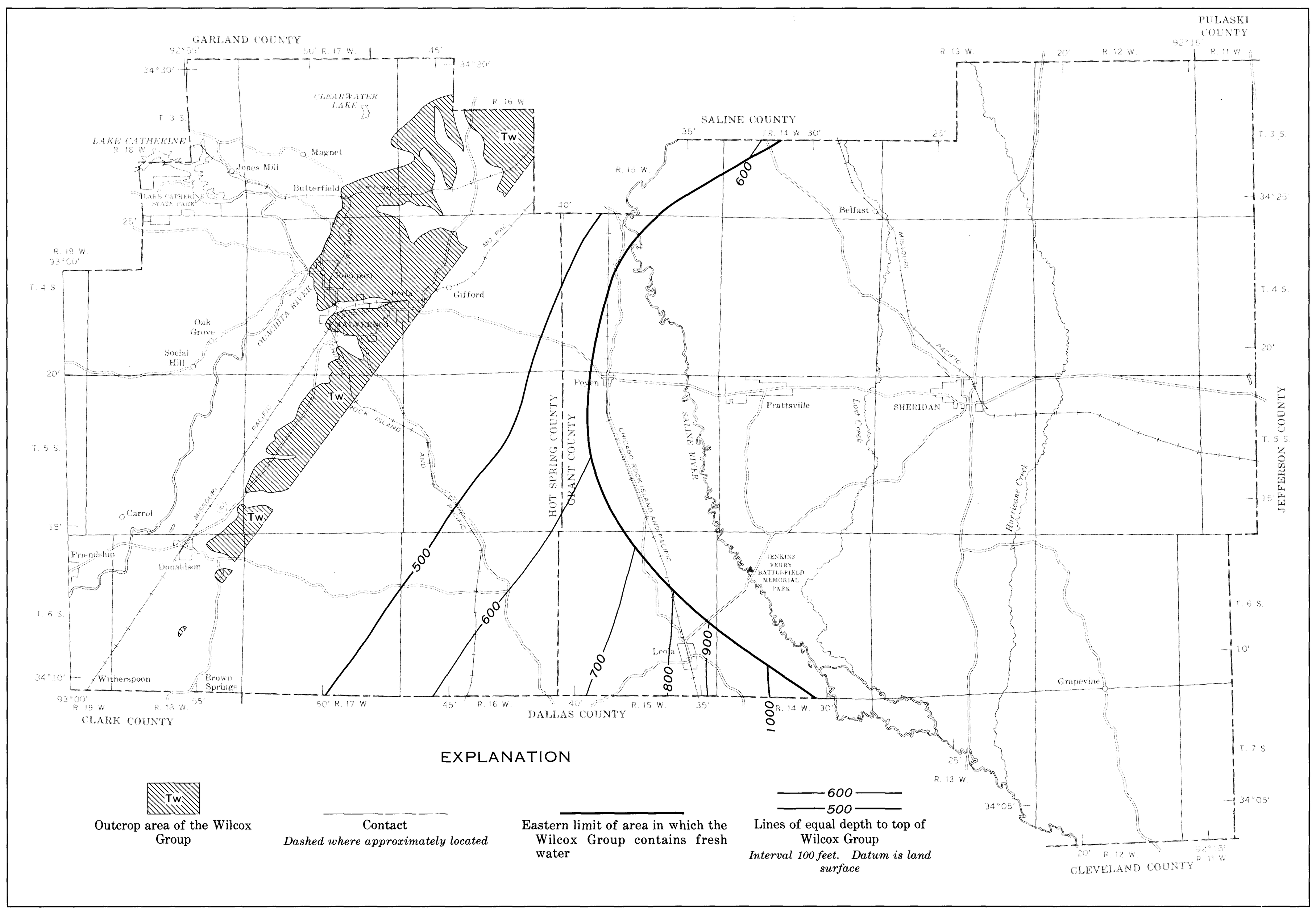
SCALE 1:125 000

2 0 2 4 6 8 10 MILES

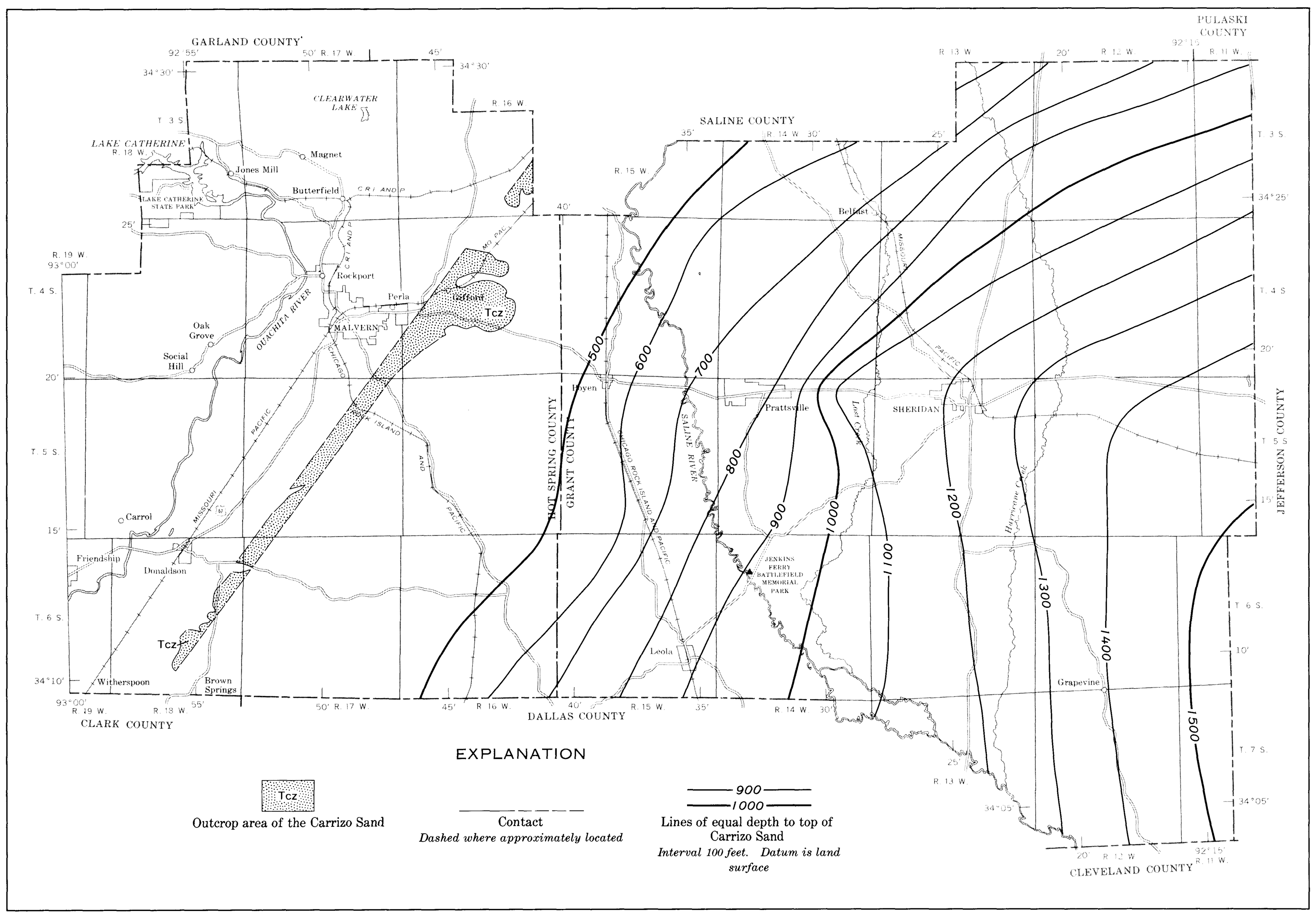
2 0 2 4 6 8 10 KILOMETERS



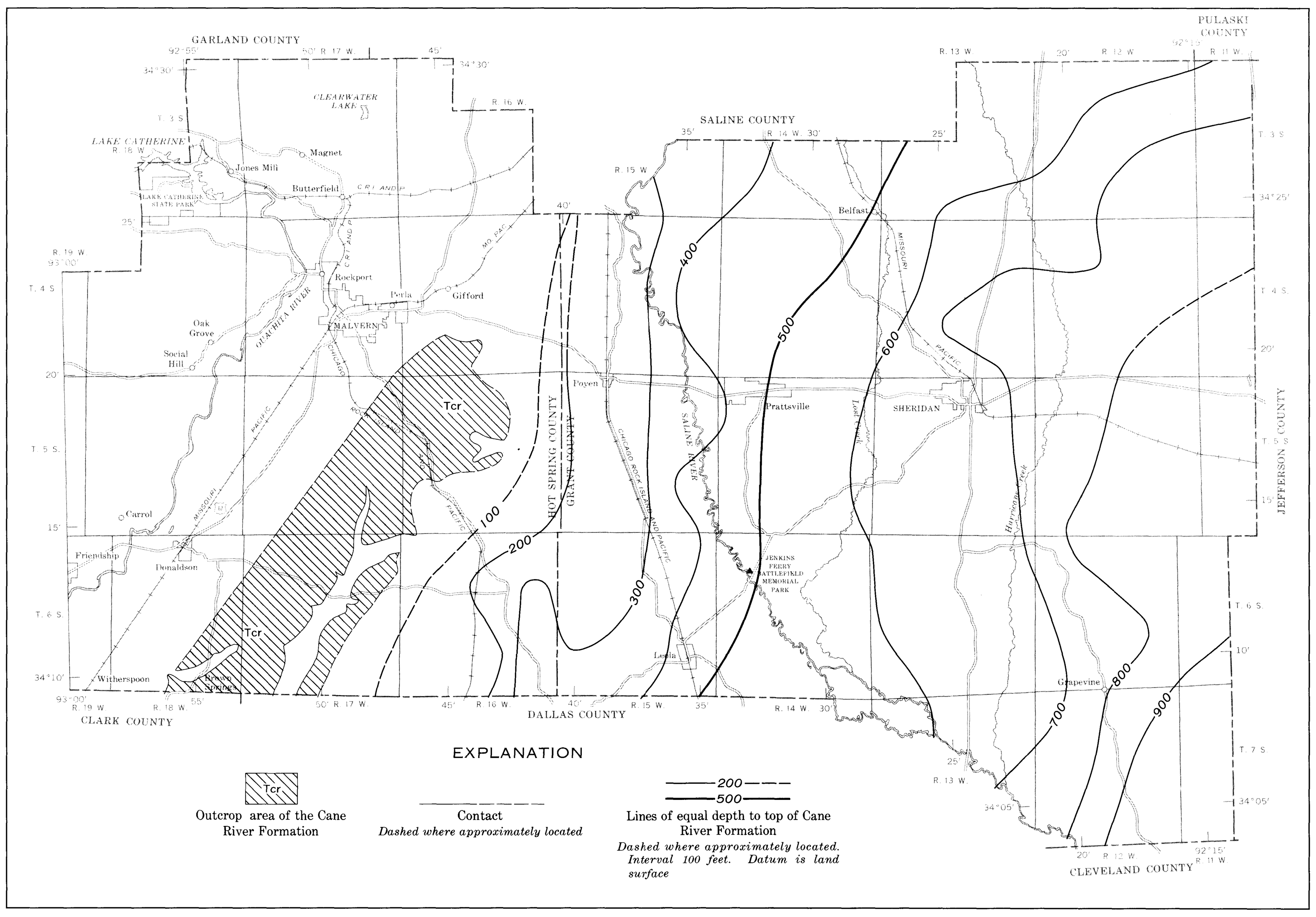
DEPTH TO BASE OF FRESH WATER



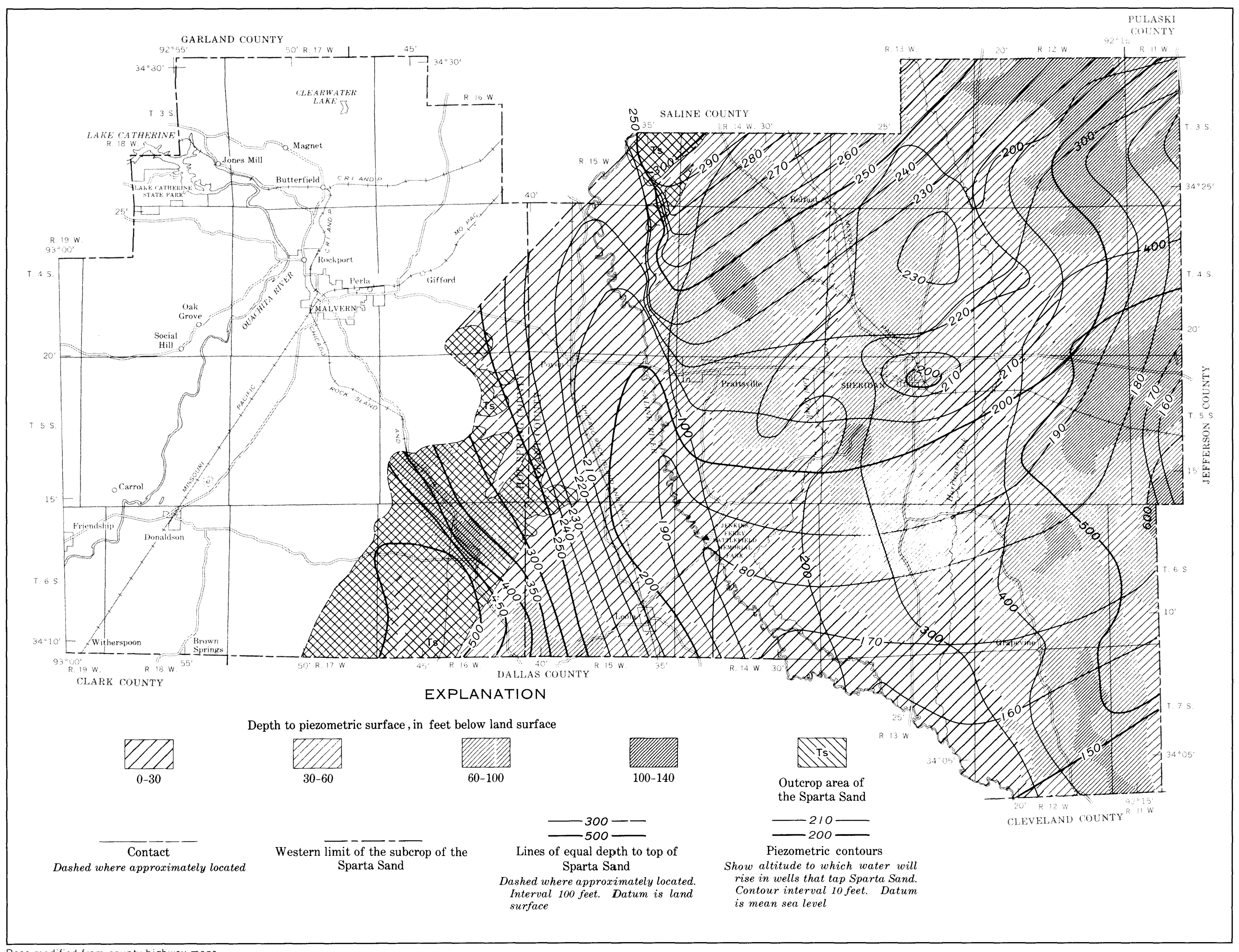
OUTCROP AREA AND DEPTH TO TOP OF WILCOX GROUP IN AREA WHERE GROUP CONTAINS FRESH WATER



OUTCROP AREA AND DEPTH TO TOP OF CARRIZO SAND

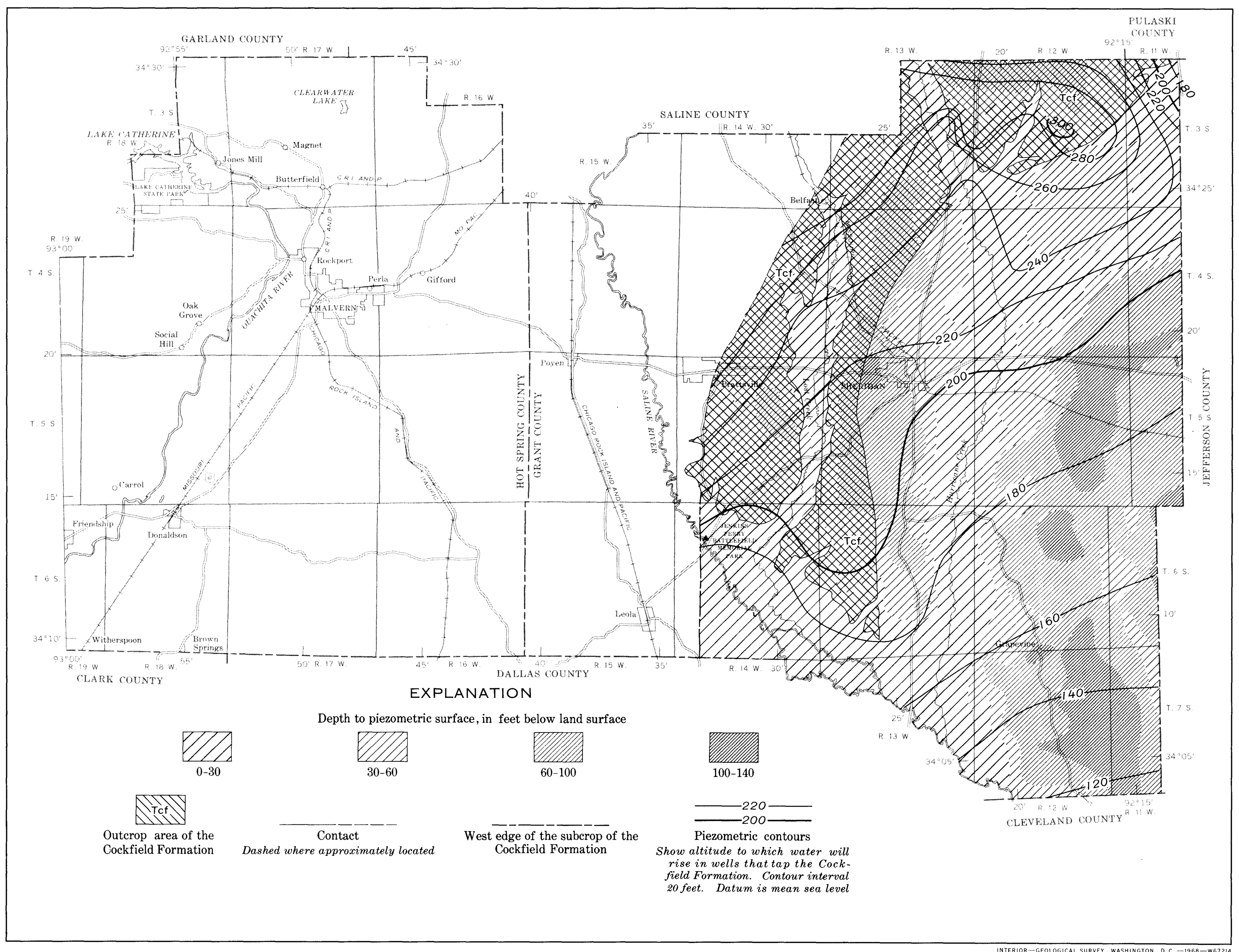


OUTCROP AREA AND DEPTH TO TOP OF CANE RIVER FORMATION



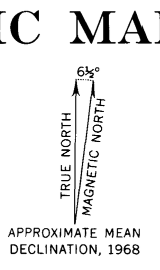
Base modified from county highway maps

OUTCROP AREA, DEPTH TO TOP OF SPARTA SAND, AND DEPTH TO AND ALTITUDE OF THE PIEZOMETRIC SURFACE



OUTCROP AREA AND DEPTH TO AND ALTITUDE OF THE PIEZOMETRIC SURFACE IN THE COCKFIELD FORMATION

GEOHYDROLOGIC MAPS OF COASTAL PLAIN AQUIFERS, GRANT AND EASTERN HOT SPRING COUNTIES, ARKANSAS



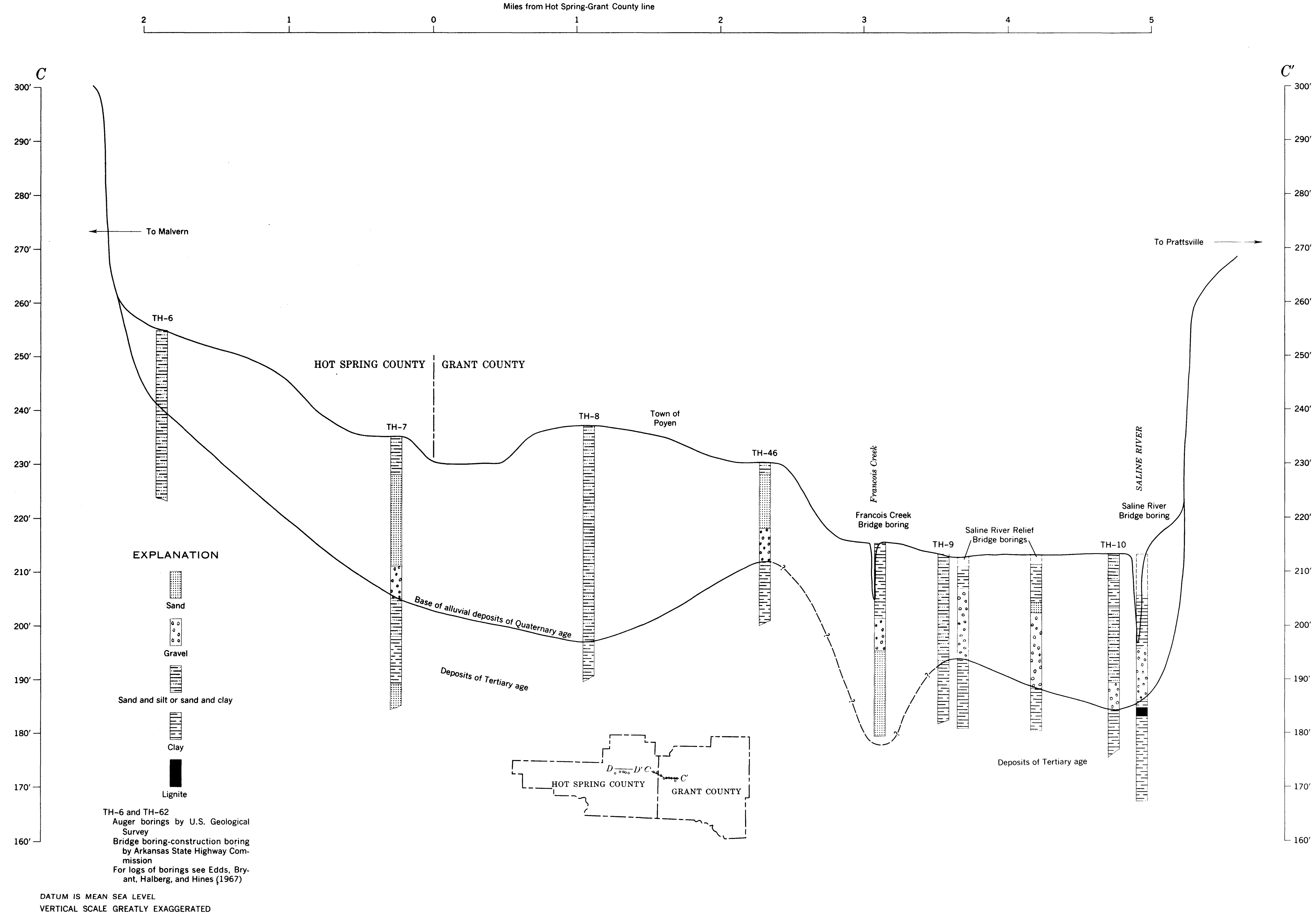
APPROXIMATE MEAN DECLINATION, 1968

SCALE 1:250 000

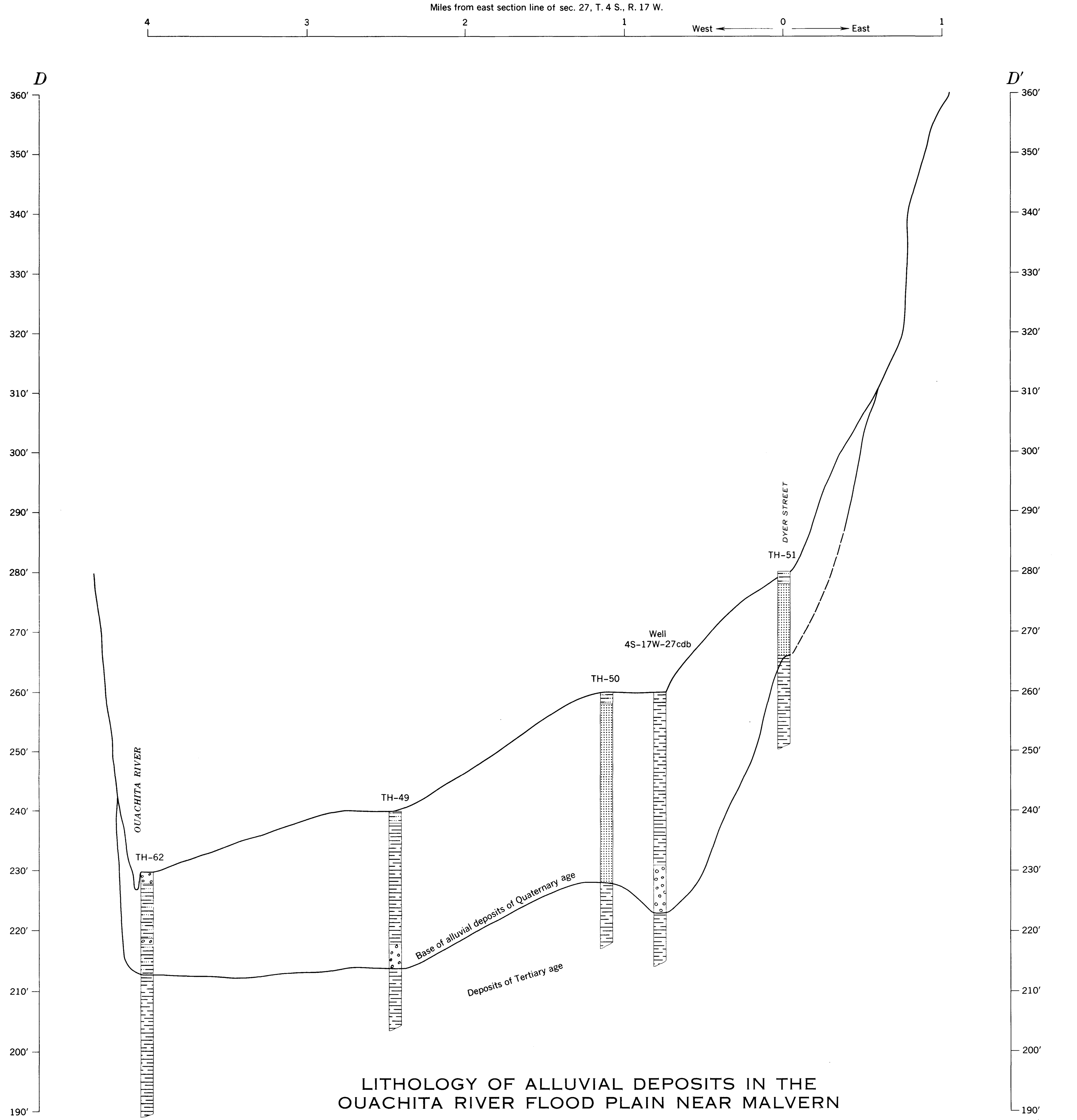
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION



LITHOLOGY OF ALLUVIAL DEPOSITS IN THE SALINE RIVER FLOOD PLAIN ALONG U.S. HIGHWAY 270



LITHOLOGY OF ALLUVIAL DEPOSITS IN THE OUACHITA RIVER FLOOD PLAIN NEAR MALVERN

GEOLOGIC SECTIONS *C-C′* AND *D-D′*, GRANT AND HOT SPRING COUNTIES, ARKANSAS

293-339 O - 68 (In pocket)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION

MAP SHOWING HYDROLOGIC AREAS, SURFACE-WATER DATA-COLLECTION POINTS, AND DIAGRAMS OF SURFACE-WATER QUALITY, GRANT AND HOT SPRING COUNTIES, ARKANSAS

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67214