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Alluvial Aquifer of the Cache and St. Francis River Basins

Northeastern Arkansas

By

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the inch-pound units given herein to the International System of Units (SI)

Multiply inch-pound unit	By	To obtain SI unit
acre	4047	square meter
acre-foot	1233	cubic meter
acre-foot per year	1233	cubic meter per year
cubic foot	.02832	cubic meter
foot	.3048	meter
foot per day	.3048	meter per day
foot per year	.3048	meter per year
foot squared per day	.0929	meter squared per day
gallon	3.785	liter
gallon per minute	.06309	liter per second
inch	25.4	millimeter
	.0254	meter
mile	1.609	kilometer
square mile	2.590	square kilometer

ALLUVIAL AQUIFER OF THE CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

By M. E. Broom and F. P. Lyford

ABSTRACT

The alluvial aquifer underlies about 9,000 square miles of the study area. Formations of Tertiary age crop out in the alluvial plain in Crowleys Ridge, dividing the aquifer into a segment on the western side of the ridge that underlies the Cache River basin and a segment on the eastern side of the ridge that underlies the St. Francis River basin.

The aquifer is composed of sand and gravel. Maximum aquifer thickness west of Crowleys Ridge is about 150 feet and east of Crowleys Ridge, about 200 feet. Hydraulic conductivity ranges from 100 to 400 feet per day.

Well yields from the aquifer commonly range from 1,000 to 2,000 gallons per minute. Maximum specific capacity of the wells is about 100 gal-gallons per minute per foot of drawdown.

The natural direction of flow in the aquifer has been greatly altered by intensive pumping for rice irrigation in the area between the Cache River and Crowleys Ridge. Flow toward the pumping-stressed area is eastward from the Cache River and westward from the St. Francis River. The Memphis aquifer acts as a conduit through Crowleys Ridge for induced flow from the St. Francis River basin to the Cache River basin.

Most pumpage from the alluvial aquifer in the study area since the early 1900's has been for rice irrigation. Total pumpage for rice in the study area during 1978 was about 1,650,000 acre-feet, of which about 88 percent was pumped from the aquifer west of Crowleys Ridge.

Water levels in wells west of the ridge in parts of Poinsett, Cross, and Craighead Counties during 1978 were 75 feet below land surface and declining about 2 feet per year. Water levels outside the pumping-stressed area, including all the area east of Crowleys Ridge, were less than 20 feet below land surface.

The aquifer yields a calcium bicarbonate type water that has dissolved-solids concentrations of 200 to 400 milligrams per liter in most of the area. A sodium chloride type water with chloride concentrations of about 700 milligrams per liter is pumped from the aquifer at a locale west of the Black River in Independence County and at a locale near Brinkley in Monroe County. A southerly migration of the chloride water from near Brinkley is indicated by its pattern of distribution in the aquifer.

Digital-model analysis indicated that at the end of 1978 water was being removed from aquifer storage at the rate of 540,000 acre-feet per year, and streamflow, about one-half from the Cache River, was being captured at the rate of 430,000 acre-feet per year.

Projecting the 1978 pumping rate of 1,460,000 acre-feet per year, the pumping rate would have to be reduced by about 110,000 acre-feet per year by 1990 to sustain sufficient aquifer saturation for water needs through 2000 in all parts of Poinsett, Craighead, and Cross Counties west of Crowleys Ridge.

At the reduced pumping rate of 1,350,000 acre-feet per year, beginning in 1991, saturated thickness of the aquifer west of Crowleys Ridge by the end of 2000 would be less than 50 feet in most of Poinsett and Craighead Counties and a substantial part of Cross County; the rate of water removal from aquifer storage would be about 490,000 acre-feet per year, and the rate of streamflow capture would be about 860,000 acre-feet per year.

INTRODUCTION

The study area, in northeast Arkansas (fig. 1), includes about 9,000 square miles of the Mississippi Alluvial Plain and, peripherally, about 2,000 square miles of the Springfield-Salem Plateaus. The plateaus are discussed in this report only to establish boundary conditions near the juncture of the alluvial plain and the plateaus.

The study, in cooperation with the Arkansas Geological Commission, was made to provide information for planning, developing, and managing the water resources of the area. The study consisted of two phases. The first phase involved the collection and analysis of data to gain a concept of the aquifer's geometry and hydrologic properties, the location and nature of its recharge and discharge boundaries, and its relation to streams and to other aquifers. The second phase of work involved a simulation of the aquifer by a digital model that would provide estimates of response to pumping stress on the aquifer.

The study was enhanced greatly by data provided by well drillers, municipalities, and industries. The study would have been nearly impossible without the cooperation of the many farmers throughout the area who provided access to property and wells for measuring water levels, making aquifer tests, and drilling test holes.

DESCRIPTION OF THE AREA

The alluvial plain slopes southward from an altitude of about 300 feet near the State line in Clay County to an altitude of about 150 feet near the confluence of the White and Mississippi Rivers in Desha County (pl. 1). The plain has little surface relief except at boundaries of stream flood plains and terraces, and at locally occurring sandhills and ridges in the western part of the plain.

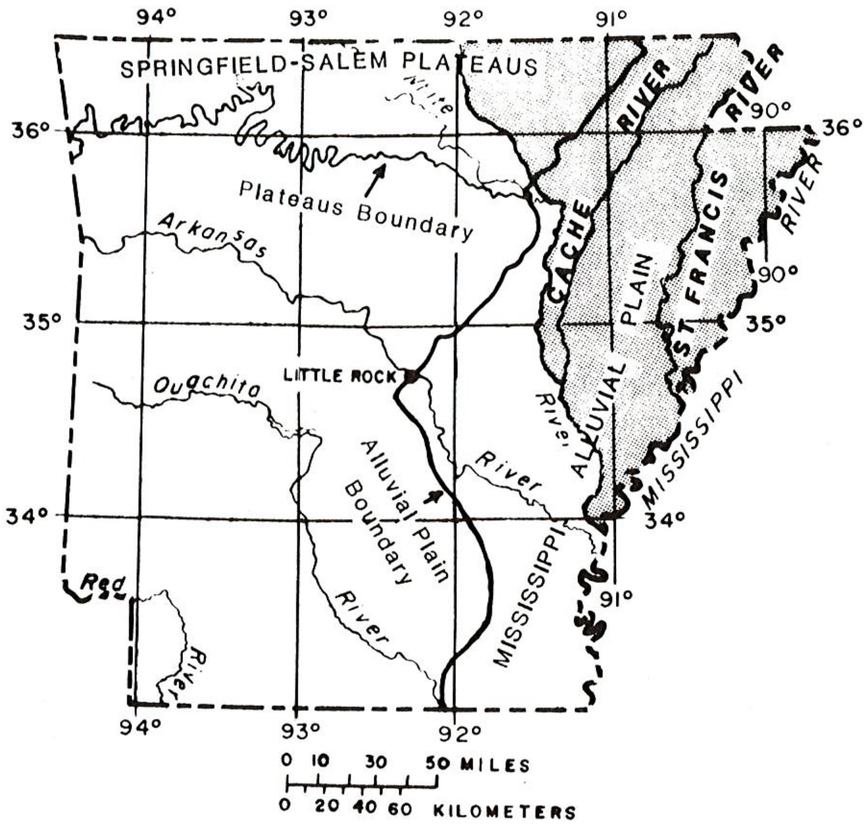


Figure 1.–Location of study area (shaded).

The greatest relief on the plain, as much as 300 feet, is at Crowleys Ridge. The ridge trends across the plain in a north-south arc, nearly bisecting the plain from Clay to Phillips County. The width of the ridge ranges from 1 to 12 miles, and altitudes along its crest commonly are 400 to 500 feet, with a maximum of about 560 feet in Greene County. Except for a breach along the course of the L'Anguille River in Lee County, the ridge is continuous from Clay County to its terminus in Phillips County.

The area in the Springfield-Salem Plateaus provides a variable terrain of rolling hills and steeply sloping valleys and ridges. The plateaus slope southeastward from an altitude of about 1,000 feet in Fulton County to an altitude of about 300 feet at the alluvial plain.

Normal annual precipitation in the area, based on an 84-year National Weather Service record at Jonesboro (Craighead County), through 1978, is 48.43 inches. Normal monthly precipitation is fairly uniform throughout the year, ranging from a minimum of 3.15 inches during August to a maximum of 5.07 inches during March. Normal annual temperature for the area is about 60°F (16°C). Normal monthly temperatures range from a low of 39°F (4°C) in January to a high of 80°F (27°C) in July.

The plain east of Crowleys Ridge is drained by the St. Francis River, tributary to the Mississippi River. In addition, a part of the plain west of the ridge drains to the St. Francis by way of the L'Anguille River through the breach in Crowleys Ridge (pl. 1). The rest of the plain west of Crowleys Ridge is drained by tributaries to the White River, including the Cache and Black Rivers and Big Creek. The plateaus area is drained primarily by the Spring and Strawberry Rivers, which are tributaries to the Black River.

The drainage system in the alluvial plain has undergone considerable alteration during the last 50 years or more by drainage-improvement projects for flood control and the conversion of hardwood-forested wetlands to highly productive farmlands for cotton, soybeans, and rice. Drainage improvements include deepening and straightening of sluggish and meandering streams, and construction of levees and ditches. To date (1980), practically all the drainage system is at least indirectly affected by drainage improvement, although forested wetlands still exist in some flood-plain areas.

GEOHYDROLOGY

Geologic units in the study area (pl. 1) are mostly on the western flank of the Mississippi embayment, a structural trough whose axis trends along the Mississippi River. From the Springfield-Salem Plateaus, the pre-Quaternary units dip toward the embayment axis and are overlain by successively younger units in the dip direction. In the alluvial plain, the pre-Quaternary units, ranging in age from Ordovician to Tertiary, are truncated and blanketed by Quaternary alluvium, except on Crowleys Ridge where Tertiary units crop out or are capped by older Quaternary deposits.

The structural and stratigraphic relation of the alluvial aquifer to adjacent geohydrologic units is shown in geohydrologic sections of plate 2. The control for the sections was provided by geophysical and lithological logs of test holes (table 1). The vertical scale of the sections is greatly exaggerated, distorting the slope of the land surface in the Crowleys Ridge area and the dip of the pre-Quaternary units. The dip of the pre-Quaternary units is only about 40 feet per mile.

Table 1.--Records of test holes used for control in geohydrologic sections

Control point	County	Driller	Depth (feet)	Date of completion	Control data
Section A-A'					
A- 1	Clay-----------	U.S. Geological Survey.	91	June 27, 1975	Lithological log.
A- 2	---do----------	Dow Chemical Co------	260	Nov. 12, 1976	Gamma-density and electrical-resistivity log.
A- 3	---do----------	---do----------------	295	-----do------	Do.
A- 4	---do----------	Layne-Arkansas Co----	1,110	Aug. 4, 1971	Driller's log, electrical log, and gamma-ray log.
A- 5	---do----------	---do----------------	1,093	May 16, 1977	Driller's log and gamma-ray log.
A- 6	Dunklin (Mo.)--	---do----------------	1,858	May 2, 1977	Driller's log, electrical log, and gamma-ray log.
A- 7	Mississippi----	---do----------------	1,440	June 5, 1970	Driller's log and electrical log.
Section B-B'					
B- 1	Randolph-------	Clay County Drilling Co.	79	July 1974	Driller's log.
B- 2	Clay-----------	Cart Well Co---------	109	May 1947	Do.
B- 3	Greene---------	Dow Chemical Co------	260	Nov. 12, 1976	Gamma-density and electrical-resistivity log.
B- 4	---do----------	Layne-Arkansas Co----	556	June 12, 1975	Driller's log, electrical log, and gamma-ray log.
B- 5	Mississippi----	---do----------------	1,083	Apr. 11, 1972	Driller's log and gamma-ray log.
B- 6	---do----------	---do----------------	1,280	July 22, 1976	Driller's log, electrical log, and gamma-ray log.
B- 7	---do----------	Carloss Well Supply Co.	1,507	Feb. 20, 1964	Electrical log.
Section C-C'					
C- 1	Lawrence-------	U.S. Geological Survey.	61	Jan. 24, 1975	Lithological log.
C- 2	---do----------	Arkansas Geological Commission.	360	Feb. 28, 1979	Do.

Table 1.--Records of test holes used for control in geohydrologic sections--Continued

Control point	County	Driller	Depth (feet)	Date of completion	Control data
		Section C-C'--Continued			
C- 3	Craighead------	Dow Chemical Co------	260	Nov. 11, 1976	Gamma-density and electrical-resistivity log.
C- 4	---do----------	---do----------------	300	Oct. 18, 1976	Do.
C- 5	---do----------	Tennark Inc----------	1,735	July 25, 1938	Electrical log.
C- 6	---do----------	Layne-Arkansas Co----	220	Mar. 8, 1978	Driller's log and gamma-ray log.
C- 7	Poinsett-------	---do----------------	1,103	Aug. 3, 1977	Driller's log and electrical log.
C- 8	---do----------	Carloss Well Supply Co.	1,606	Jan. 7, 1972	Electrical log.
C- 9	Crittenden-----	---------------------	864	Jan. 26, 1960	Gamma-ray log.
C-10	---do----------	Robert E. Ratliff----	336	Feb. 25, 1958	Electrical log.
		Section D-D'			
D- 1	Independence---	U.S. Geological Survey.	71	Jan. 17, 1975	Lithological log.
D- 2	Jackson--------	---do----------------	116	Jan. 20, 1975	Do.
D- 3	---do----------	---do----------------	805	Oct. 7, 1964	Lithological log and electrical log.
D- 4	Cross----------	Seaboard Oil Co------	2,125	July 4, 1953	Electrical log.
D- 5	---do----------	Dow Chemical Co------	295	Nov. 21, 1976	Gamma-density and electrical-resistivity log.
D- 6	---do----------	Layne-Arkansas Co----	1,528	July 24, 1974	Driller's log and gamma-ray log.
D- 7	St. Francis----	Manning and Martin Inc.	3,418	July 20, 1937	Electrical log.
D- 8	---do----------	Layne-Arkansas Co----	1,767	Oct. 6, 1976	Driller's log and electrical log.
D- 9	Crittenden-----	---do----------------	1,638	Feb. 7, 1978	Driller's log and gamma-ray log.

Table 1.--Records of test holes used for control in geohydrologic sections--Continued

Control point	County	Driller	Depth (feet)	Date of completion	Control data
Section E-E'					
E- 1	Woodruff-------	Magnolia Petroleum Co.	6,002	Sept. 15, 1954	Electrical log.
E- 2	---do----------	M. P. Taubman--------	1,599	Oct. 8, 1948	Do.
E- 3	St. Francis----	Barnwell Drilling Co.	2,672	Apr. 24, 1948	Do.
E- 4	Lee------------	Pan American Petroleum Co.	8,716	Sept. 17, 1963	Do.
E- 5	---do----------	U.S. Geological Survey.	2,400	Sept. 15, 1964	Do.
E- 6	Phillips-------	Layne-Arkansas Co----	248	June 24, 1964	Gamma-ray log.
Section F-F'					
F- 1	Prairie--------	Lilly Brothers-------	102	August 1944	Driller's log.
F- 2	Cross----------	Cross Oil Co---------	1,869	July 26, 1952	Electrical log.
F- 3	Poinsett-------	Dow Chemical Co------	300	Oct. 14, 1976	Gamma-density and electrical-resistivity log.
F- 4	---do----------	---do----------------	300	Oct. 4, 1976	Do.
F- 5	---do----------	---do----------------	300	Oct. 6, 1976	Do.
F- 6	Mississippi----	Layne-Arkansas Co----	1,317	June 27, 1975	Driller's log and gamma-ray log.

The dimensions of the stream channels on the sections are not to scale. Between the control points on the sections, the profile of the base of the alluvial aquifer was plotted from plate 3. The top of the aquifer, not shown on the sections, generally is about 20 feet below land surface but locally coincides with the land surface. The potentiometric-surface profiles of the alluvial aquifer were plotted from plate 5. The profiles of the potentiometric surface through the units across Crowleys Ridge were plotted from water levels in wells and, in places, estimated from levels of perennial streamflow and from water levels in wells located off the trace of the sections. Where the potentiometric surface is shown above land surface (pl. 2), it coincides with the water surface in stream channels and flood plains. Many of the streams in the alluvial plain were at flood stage during the spring of 1973.

The name designation and the description of the pre-Quaternary hydrologic units that follow generally are applicable in their areas of truncation and outcrop. However, the description and the name designation for some of the hydrologic units are less applicable in downdip areas because of lateral change in the rock character of the units.

Geohydrologic Units Associated With the Alluvial Aquifer

Carbonate Rock

The carbonate rock unit, the stratigraphically lowest unit associated with the alluvial aquifer, directly underlies the alluvial aquifer in area 1 (pl. 1) and crops out in the Springfield-Salem Plateaus. This geohydrologic unit includes formations, described by Caplan, 1954, pages 44-84, that extend from the base of the Jefferson City Dolomite (Lower Ordovician) to the top of the Saratoga Chalk (Upper Cretaceous). The unit consists mostly of dolomite and limestone.

The carbonate rock unit acts as a confining bed at the base of the alluvial aquifer. In its outcrop area, the unit contains shallow joints and fractures that commonly yield 5 to 10 gallons per minute of water to wells.

Nacatoch Sand Aquifer

The Nacatoch Sand aquifer, a sandy interval in the upper part of the Nacatoch Sand (formation), directly underlies the alluvial aquifer in area 2 (pl. 1). The aquifer becomes sandier along the strike, changing from a silty, fine-grained sand in Jackson County to a clean, medium- to coarse-grained sand in Lawrence, Greene, and Clay Counties. Aquifer thickness is about 200 feet.

The Nacatoch Sand aquifer yields as much as 500 gallons per minute of water to wells in the Crowleys Ridge area of Greene and Clay Counties.

The Nacatoch probably would yield slightly saline to brine water in areas downdip from about Jonesboro, in Craighead County. Water from the Nacatoch contains 21,500 milligrams per liter of chloride near Brinkley, in Monroe County.

Midway-Arkadelphia Clay

The Midway-Arkadelphia clay includes chiefly the Midway Group and the Arkadelphia Marl, both described by Caplan (1954, p. 92-94). This hydrologic unit in places also includes silt and clay of the lower part of the Wilcox Group and marl and shale of the uppermost part of the Nacatoch Sand (formation).

The Midway-Arkadelphia clay directly underlies the alluvial aquifer in area 3 (pl. 1). This unit, which is about 500 feet thick and composed mainly of shale and clay, acts as a confining bed under the alluvial aquifer.

Wilcox Aquifer

The Wilcox aquifer directly underlies the alluvial aquifer in area 4 (pl. 1) and crops out along Crowleys Ridge from near Jonesboro (Craighead County) to the Missouri State line. The aquifer consists of a sandy middle part of the Wilcox Group between clayey upper and lower parts of the Wilcox Group. Plebuch (1961, p. 20) referred to this aquifer as the "Middle unit," and Hosman, Long, Lambert, and others (1968, p. D8) referred to the aquifer as the "lower Wilcox" aquifer.

The Wilcox aquifer thickens downdip from about 150 feet near areas of truncation and outcrop to about 300 feet or more in areas along the Mississippi River. The aquifer is composed of medium- to fine-grained sand with varying amounts of interbedded clay. The interbedding of clay in the aquifer generally decreases northward along the strike and in the direction of dip. Consequently, east of Crowleys Ridge, the Wilcox aquifer contains thickly bedded sand; but west of the ridge, interbeds of clay in places make up 50 percent or more of the aquifer.

The Wilcox aquifer yields 1,000 to 2,000 gallons per minute to wells east of Crowleys Ridge. Water from the Wilcox east of the ridge is a sodium bicarbonate type with dissolved-solids concentrations of about 100 to 150 milligrams per liter. West of Crowleys Ridge, the Wilcox aquifer is largely untested for well yield and water quality. However, about 10 miles downdip from area 4 (pl. 1) in parts of Poinsett, Cross, Woodruff, and Prairie Counties, Cushing (1966) mapped dissolved-solids concentrations in the Wilcox in excess of 1,000 milligrams per liter.

Wilcox Clay

The Wilcox clay, composed of the upper part of the Wilcox Group, directly underlies the alluvial aquifer in area 5 (pl. 1). The unit, composed mostly of clay, contains some lenses of lignite and silty sand. It thickens downdip from about 150 feet near its area of truncation to about 250 feet in Mississippi and Crittenden Counties. The Wilcox clay acts as a confining bed under the alluvial aquifer.

Memphis Aquifer

The Memphis aquifer directly underlies the alluvial aquifer in area 6 (pl. 1) and crops out on Crowleys Ridge in Cross, Poinsett, and Craighead Counties. This aquifer is comprised of a sandy section that makes up about the lower one-half of the Claiborne Group updip from about latitude 35° (pl. 1). Downdip from about latitude 35°, the sandy section making up the Memphis aquifer changes to alternating beds of sand and clay that Hosman, Long, Lambert, and others (1968) mapped in ascending order as the Carrizo Sand, Cane River Formation, and the Sparta Sand. Downdip from area 6, the Sparta Sand, as well as the Cane River Formation and the Carrizo Sand, has negligible hydraulic connection with the alluvial aquifer because of confining clay beds at the base of the alluvial aquifer.

The Memphis aquifer, a fine- to medium-grained sand with thin lenses of silt and clay, thickens northward along the strike of the Claiborne Group and also thickens in the dip direction. The aquifer has a maximum thickness of about 600 feet in area 6 and about 800 feet in Mississippi and Crittenden Counties.

Although extensively used at Memphis, Tenn., across the Mississippi River from Crittenden County (pl. 1), the Memphis aquifer in the study area is used little for water supply. The aquifer yields as much as 500 gallons per minute of water to wells in area 6. In Mississippi and Crittenden Counties, the aquifer probably would yield as much as 1,000 gallons per minute to wells. The water in the Memphis aquifer in area 6, is a calcium bicarbonate type with dissolved solids ranging from 200 to 500 milligrams per liter.

Jackson-Claiborne Clay

The Jackson-Claiborne clay directly underlies the alluvial aquifer in area 7 (pl. 1) and crops out on Crowleys Ridge in Cross, St. Francis, Lee, and Phillips Counties. This geohydrologic unit reaches a maximum thickness of about 500 feet. It contains the Jackson Group, mostly a dense clay, and the upper part of the Claiborne Group, a silty clay with some interbedding of thin and discontinuous beds of sand. The Jackson-Claiborne clay acts as a confining bed under the alluvial aquifer.

Crowleys Ridge Deposits

The Crowleys Ridge deposits, as a geohydrologic unit, include all Quaternary sediments on Crowleys Ridge. The sediments generally consist of clay, silt, sand, and gravel of fluvial origin. The sediments also include wind-deposited silt and sand (loess) in the uppermost part of the unit along the ridge from Poinsett to Phillips Counties.

The Crowleys Ridge deposits where saturated are used for domestic water supplies. The water generally contains less than 100 milligrams per liter of dissolved solids.

ALLUVIAL AQUIFER

Extent and Geometry

The alluvial aquifer in the study area extends from the Springfield-Salem Plateaus and the White River on the west to the Mississippi River on the east, and from the confluence of the White and Mississippi Rivers on the south to the State line on the north (pl. 1). The aquifer is separated into two segments by Crowleys Ridge. The area of the aquifer west of the ridge is about 5,300 square miles, 40 percent of which underlies the Cache River basin; the area of the aquifer east of the ridge is about 3,300 square miles, all of which underlies the St. Francis River basin.

The surface of the truncated units upon which the aquifer rests (bedrock surface) generally slopes southward at about the same rate as the land surface; consequently, the thickness of the aquifer along any given north-south line tends to be fairly uniform. But, along east-west lines, aquifer thicknesses vary extremely, from 0 to 200 feet, because of northward-southward trending bedrock valleys and the termination of the aquifer against laterally bounding units (pl. 2).

A prominent southward-trending bedrock valley is present on each side of the ridge (pl. 3). Maximum thicknesses of the aquifer where underlain by the bedrock valleys are about 150 feet on the western side of the ridge and about 200 feet on the eastern side.

Lithology

The aquifer is composed of sand and gravel in the Quaternary alluvium. The log in table 2 shows the alluvium grading from a clay at land surface to a basal gravel, which overlies the Tertiary deposits. The base of the gravel, at a depth of 178 feet, is the base of the aquifer; and the top of

Table 2.--Representative lithological log

[Augered by U.S. Geological Survey, January 14, 1975, in Cross County, Ark. Location 07N01E10BBB1]

Material	Thickness (feet)	Depth (feet)
Quaternary alluvium:		
Clay, silty, mottled yellow and gray------------	15.0	15.0
Silt, sandy, yellowish-gray----------------------	3.0	18.0
Sand, fine, silty, yellowish-gray---------------	25.0	43.0
Sand, fine to medium------------------------------	23.0	66.0
Sand, medium--	6.0	72.0
Sand, medium to coarse---------------------------	30.0	102.0
Sand, coarse to very coarse, gravelly-----------	34.0	136.0
Sand, very coarse, gravelly---------------------	14.0	150.0
Gravel, sandy--------------------------------------	28.0	178.0
Tertiary deposits (Memphis aquifer):		
Sand, fine, silty----------------------------------	8.0	186.0

the sand, at a depth of 18 feet, is the top of the aquifer. The gradational increase in particle size with depth is typical for the aquifer throughout the study area.

Clay and silt generally compose a layer, about 20 feet thick, throughout the aquifer in the interstream areas. The clay is very compact and makes up most of the layer. However, in the flood plains of the larger streams, the clay in the layer is considerably thinner and in places is absent. In the interstream areas, mostly west of the Cache River, the clay is absent locally and the aquifer is covered by a fine ridge-forming sand.

Hydraulic Properties

The hydraulic conductivity, the transmissivity, the coefficient of storage, and the specific yield are indices of an aquifer's capacity to transmit and store water. Hyraulic conductivity is the rate, in unit length per unit time, that the aquifer will transmit water at the prevailing viscosity through a cross section of unit area measured at right angles to the direction of flow, under a unit hydraulic gradient (unit hydraulic-head change per unit flow distance). Transmissivity is equal to hydraulic conductivity multiplied by the saturated thickness of the aquifer, and is the rate at which water of the prevailing viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient; the coefficient of storage is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in hydraulic head; and the specific yield is the ratio of the volume of water that the aquifer will yield by gravity to the volume of the aquifer. For a truly unconfined aquifer, the specific yield is nearly equal to the coefficient of storage.

Values of transmissivity, hydraulic conductivity, and coefficient of storage derived from aquifer tests (table 3) show transmissivity values ranging from 8,500 to 64,900 feet squared per day, hydraulic conductivity values ranging from 100 to 390 feet per day, and coefficient of storage values ranging from 4.0×10^{-4} to 2.2×10^{-2}. The tests generally were made using the well-discharge method described by Lohman (1972, p. 15). Additional values of transmissivity and hydraulic conductivity were estimated from specific-capacity tests of wells (table 4) and lithological logs of test holes, using the methods described by Bedinger and Emmett (1963, p. C188). Transmissivity values compiled from the different sources of data were used to construct a transmissivity map of the alluvial aquifer (pl. 4).

The transmissivity values, which vary directly with both the hydraulic conductivity and the saturated thickness of the aquifer, generally become larger with increased aquifer thickness. When plates 3 and 4 are compared, it is evident that transmissivity values are largest where the aquifer overlies bedrock valleys and smallest where the aquifer overlies bedrock ridges. This relationship was used in part to guide the delineation of transmissivity where data were few, particularly in the St. Francis River basin.

The storage coefficients were determined from aquifer tests of generally less than 36 hours of duration. The values reflect short-term, confined conditions that would change with time as finer grained sediments drain. Analysis of a long-term aquifer test would probably yield a storage coefficient approaching the value of specific yield for the aquifer. Although not measured in the study area, specific yields for the alluvial aquifer west of the White River ranged from 0.27 to 0.38 (Sniegocki and others, 1965, p. G8; Johnson and others, 1966, p. H23).

Table 3.--Results of aquifer tests in the alluvial aquifer

[Use test number to locate well on plate 4]

Test number	County	Pumping well number	Date	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)	Coefficient of storage
1	Clay	21N05E02CCC	Feb. 25, 1971	30,400	360	$1.1X10^{-3}$
2	do	20N09E04ACA	Mar. 17, 1970	64,900	---	--------
3	Greene	18N06E35BAA	Feb. 8, 1972	19,700	100	$1.0X10^{-3}$
4	Jackson	14N02W23BBB	Feb. 12, 1970	1/39,000	320	$2.2X10^{-2}$
5	do	12N02W28DDC	Dec. 7, 1964	10,000	100	$7.0X10^{-3}$
6	do	11N03W11ABD	May 27, 1961	8,500	---	--------
7	Craighead	14N05E24DCC	Dec. 11, 1969	36,000	280	$1.5X10^{-3}$
8	do	13N02E35DAD	Jan. 25, 1971	37,300	380	$2.2X10^{-2}$
9	Mississippi	14N10E18DBB	June 18, 1957	2/20,000	210	$9.0X10^{-4}$
10	do	13N09E30CCC	June 11, 1957	2/15,500	160	$7.0X10^{-4}$
11	do	11N09E08DBA	June 12, 1957	2/26,700	250	$7.0X10^{-4}$
12	Poinsett	10N01E06CBB	June 19, 1971	48,000	390	$1.0X10^{-3}$
13	Crittenden	08N08E09BCA	Mar. 12, 1958	3/19,300	170	$4.6X10^{-4}$
14	do	08N07E22BCC	Nov. 24, 1969	34,400	220	$1.0X10^{-3}$
15	St. Francis	05N06E18AAA	Apr. 25, 1961	4/36,000	280	$9.0X10^{-4}$
16	do	04N02E03DDD	Apr. 10, 1961	4/42,700	330	$4.0X10^{-2}$
17	Lee	02N03E35CCA	May 19, 1950	18,500	---	--------
18	do	01N03E02BBC	Nov. 18, 1969	12,700	130	$7.3X10^{-4}$
19	Monroe	02N02W01DDA	Apr. 11, 1969	23,500	---	--------
20	do	02N01W28DDD	Oct. 4, 1967	31,900	290	$4.0X10^{-4}$
21	Phillips	02S01E28CCB	Feb. 23, 1972	34,400	247	$1.0X10^{-4}$
22	do	02S03E15ACC	July 18, 1970	34,400	300	$9.8X10^{-3}$
23	do	04S02E27BAA	Feb. 1, 1972	35,500	320	$2.6X10^{-2}$

1/Albin, Hines, and Stephens (1967, p. G8).

2/Ryling (1960, p. 40)

3/Plebuch (1961, p. 38).

4/Halberg and Reed (1964, p. V15).

Table 4.--Yield and specific capacity of wells in the alluvial aquifer

[Use test number to locate well on plate 4]

Test number	County	Well number	Date	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)
1	Randolph-----	20N02E24ADD	July 26, 1973	1,720	62
2	---do--------	18N02E32CCA	July 27, 1973	920	51
3	Clay---------	21N05E17ABB	July 26, 1973	1,190	67
4	---do--------	20N06E29CDC	July 31, 1973	1,080	30
5	Greene-------	19N04E29AAA	---do--------	1,050	105
6	---do--------	18N03E06BBA	---do--------	1,020	84
7	---do--------	19N05E31BBB	July 30, 1973	1,350	90
8	---do--------	17N03E02BDB	May 2, 1973	1,400	70
9	---do--------	16N03E01ADC	Aug. 1, 1973	520	19
10	---do--------	16N03E27BBA	---do--------	890	36
11	Lawrence-----	17N02E30BBA	July 27, 1973	1,670	93
12	---do--------	16N01E13CBD	---do--------	1,290	40
13	---do--------	16N01E25CCD	Aug. 2, 1973	950	73
14	---do--------	15N01E04DBA	July 30, 1973	1,500	65
15	---do--------	15N01E23DDA	Aug. 3, 1973	1,730	108
16	Craighead----	15N03E05BBB	Aug. 1, 1973	1,080	77
17	---do--------	15N03E30BCB	Aug. 3, 1973	1,150	77
18	---do--------	14N01E09CBB	---do--------	970	35
19	---do--------	14N01E21BBB	---do--------	1,590	40
20	---do--------	13N01E05ACA	July 30, 1973	1,720	44
21	---do--------	13N02E16AAA	Aug. 3, 1973	1,680	58
22	---do--------	13N03E29AAA	---do--------	920	51
23	Jackson------	13N01W20BCD	July 30, 1973	2,285	53
24	---do--------	09N02W08BCC	Aug. 16, 1973	2,180	76
25	Poinsett-----	11N03E22DDD	Aug. 21, 1973	800	35
26	Mississippi--	13N08E24BAA	Aug. 12, 1957	740	1/39
27	---do--------	13N09E18CBD	Aug. 13, 1957	780	1/29
28	---do--------	12N09E14ACB	July 8, 1957	2,200	1/43
29	---do--------	12N09E34CDC	Aug. 14, 1957	1,920	1/43
30	---do--------	11N10E09DCC	Aug. 12, 1957	1,050	1/82
31	---do--------	11N10E16DAD	---do--------	1,000	1/61
32	---do--------	10N08E31DAB	Aug. 14, 1957	460	1/79
33	Cross--------	09N01E36BAB	June 25, 1974	990	119
34	---do--------	08N03E09DAD	---do--------	1,060	54
35	---do--------	08N03E32DDA	July 24, 1973	880	66
36	---do--------	07N01E05CDA	June 25, 1973	890	78
37	---do--------	06N03E05CDD	July 24, 1973	610	35
38	Woodruff-----	08N03W32DBB	July 18, 1973	920	46
39	---do--------	07N03W20BBB	---do--------	1,510	69
40	---do--------	06N02W10DAA	---do--------	840	53
41	---do--------	07N01W22BCA	July 19, 1973	1,800	84
42	---do--------	05N01W16BCC	June 27, 1974	940	61
43	---do--------	05N01W29AAA	July 10, 1973	470	47

1/Ryling (1960, p. 40).

Table 4.--Yield and specific capacity of wells in the alluvial aquifer--Continued

Test number	County	Well number	Date	Yield (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)
44	Prairie------	04N04W04BBB	July 18, 1973	860	89
45	St. Francis--	06N01E33ACA	July 19, 1973	970	36
46	---do--------	04N01W08ADD	July 10, 1973	1,720	59
47	---do--------	04N01W12BDD	July 11, 1973	1,430	75
48	---do--------	04N01W35CAA	July 9, 1973	1,060	71
49	Lee----------	03N01E15CCC	July 11, 1973	1,570	60
50	Monroe-------	01S01W34CAA	July 13, 1973	590	73
51	Phillips-----	01S01W24ACB	July 17, 1973	840	120
52	---do--------	06S01E16BAA	---do--------	2,320	129

Flow Boundaries

Flow boundaries, boundaries across which the alluvial aquifer either discharges or is recharged, include the boundary between the aquifer and the overlying clay layer (surface boundary), the boundaries between the aquifer and the streams (stream boundaries), and the boundaries between the alluvial aquifer and other aquifers. In addition, each well in the aquifer represents a flow boundary. Except for the wells, the flow boundaries are briefly discussed in the following paragraphs.

The alluvial aquifer discharges at the surface boundary by water loss to evaporation and plants (evapotranspiration). Along with climatological and vegetal factors, the rate of discharge to evapotranspiration is controlled by the depth to the water table in the alluvium. Most discharge to evapotranspiration is greater in the flood-plain areas of the larger streams where the water table generally is within reach of plants (less than 10 feet). The aquifer is recharged at the surface boundary by infiltration of water from rainfall, irrigation, and ponds. However, the clay layer greatly retards recharge at the surface boundary in the interstream areas. Rice fields and manmade ponds are selectively located so that the clay layer will cause infiltration losses to be minimal.

The greatest quantities of natural aquifer recharge and discharge occur along stream boundaries where streams incise the alluvial aquifer. The principal stream boundaries include the White, Black, Mississippi, Cache, and St. Francis Rivers. Mostly, the streams recharge the aquifer during periods of high stage and drain the aquifer during periods of low stage. However, in areas of extensive pumping, streams function as year-round sources of aquifer recharge.

The location and extent of the boundaries between the alluvial aquifer and other aquifers (pls. 1 and 2) have been previously discussed. The rate and direction of flow between the alluvial aquifer and the connecting aquifers are dependent upon their respective hydraulic properties and hydraulic heads. The significance of flow between the alluvial aquifer and other aquifers is discussed in subsequent sections of this report dealing with model design and assumptions.

Hydraulic-Head Conditions and Distribution, and Direction of Flow

The hydraulic-head distribution in an aquifer is represented by its potentiometric surface, an imaginary surface that either coincides with the water table in the aquifer or connects points to which water in the aquifer will rise naturally above the aquifer in tightly cased wells. In the first instance the aquifer is unconfined, and the water occurs under water-table conditions; in the second instance the aquifer is confined, and the water occurs under artesian conditions.

Water in the alluvial aquifer occurs under both water-table and artesian conditions. In some areas, the conditions change seasonally in response to changes in stream stage and pumpage. Water-table conditions generally prevail in areas of significant withdrawals from the aquifer.

The potentiometric surface of the alluvial aquifer for the spring and fall of 1973 is shown in plates 5 and 6. Water-level measurements in wells, the primary control for the potentiometric-surface maps, were made shortly before and after the rice-growing season, which usually begins in late May and ends in early September. Stream-stage records were used to supplement the water-level control.

Flow in the alluvial aquifer generally is southward, always in the slope direction of the potentiometric surface or from areas of recharge to areas of discharge. Along stream boundaries, the direction of flow is commonly southeastward and southwestward, away from the streams during the spring and toward the streams during the fall (pls. 5 and 6).

The greatest deviation in the general flow direction occurs in and around the elongated potentiometric-surface depression centered between the Cache River and Crowleys Ridge in Craighead, Poinsett, Cross, Lee, and Monroe Counties (pls. 5 and 6). This depression is caused by large water withdrawals from the alluvial aquifer for rice irrigation. Water moves eastward into the depression from the Cache River and its Bayou DeView tributary; and water moves westward into the depression from the St. Francis River basin, with the Memphis aquifer acting as a conduit through Crowleys Ridge in Craighead, Poinsett, and Cross Counties.

The depressions in the potentiometric surface of the alluvial aquifer in the confluent areas of the Mississippi-White Rivers and the Mississippi-St. Francis Rivers during the spring of 1973 (pl. 5) did not result from ground-water withdrawals, but from high stage of the Mississippi River and backwater conditions in the lower reaches of the White and St. Francis Rivers. During the fall of 1973, when the Mississippi River was at low stage, potentiometric-surface highs were present in the confluent areas (pl. 6).

Use of Water

Use of water from the alluvial aquifer in the study area, dating from the early 1900's to the present, has been predominantly for rice irrigation. From 1910 to 1935, annual rice acreage increased from 10,000 to 30,000 acres; during the same period, annual pumpage increased from 25,000 to 75,000 acre-feet. From 1935 to 1953, rice acreage increased to nearly 300,000 acres and pumpage to nearly 750,000 acre-feet. Rice-acreage controls were instituted during 1954 and were continued during the next 20 years; annual pumpage fluctuated between 375,000 and 675,000 acre-feet in response to varying annual rice-acreage allotments. Elimination of rice-acreage controls during 1975 caused total annual pumpage in the study area to increase from 675,000 acre-feet during 1974 to about 1,650,000 acre-feet during 1978. Thus far, the rice production has been confined mainly to the area west of Crowleys Ridge, with the greatest concentration between the ridge and the Cache River.

The uses of water from the alluvial aquifer in the study area during 1973 are shown in table 5. The values in table 5 represent both consumed and unconsumed water. The table does not include any use for irrigation of crops other than rice, because the use for other crops during 1973 was not significant. However, use for other crops, mostly for soybean and cotton, can be as much as 5 percent of the annual pumpage during abnormally dry summers. Irrigation for crops other than rice in any year before the severe drought of the 1950's was nil.

The values of use for rice irrigation and fish farms (table 5) were generally based on a water-use study by Halberg (1977). Halberg reported annual application rates on rice in the study area west of Crowleys Ridge to be about 31 inches and east of Crowleys Ridge to be about 39 inches. Also, Halberg reported an annual application rate of 84 inches for catfish and minnows and 36 inches to "rough" fishponds and fishing lakes. Fish farming in the study area dates from the early 1960's. Values for municipal

Table 5.--Use of water from the alluvial aquifer, in acre-feet, 1973

County	Rice irrigation	Fish farms	Municipal and industrial	Rural domestic and livestock	Total
Clay	25,100	400	500	800	26,800
Craighead	56,700	600	5,000	200	62,500
Crittenden	21,400	1,300	------	500	23,200
Cross	108,500	2,600	3,000	200	114,300
Desha	0	0	0	0	[1]0
Greene	17,600	800	------	500	18,900
Independence	1,300	300	------	200	1,800
Jackson	59,400	4,400	3,700	900	[2]68,400
Lawrence	28,300	2,000	1,500	300	32,100
Lee	25,200	300	------	700	26,200
Mississippi	2,000	1,000	------	900	3,900
Monroe	36,600	200	------	400	[3]37,200
Phillips	15,700	400	------	600	16,700
Poinsett	120,400	1,800	100	600	122,900
Prairie	2,200	------	------	100	[4]2,300
Randolph	4,500	200	100	100	4,900
St. Francis	55,700	1,700	3,000	700	61,100
Woodruff	66,100	7,000	700	300	74,100
Subtotal	646,700	25,000	17,600	8,000	697,300

[1]South of the Arkansas River, outside the project area, about 60,000 acre-feet of water was pumped from the alluvial aquifer in Desha County during 1973.

[2]West of the White River, outside the project area, an additional 6,000 acre-feet of water was pumped from the alluvial aquifer in Jackson County during 1973.

[3]West of the White River, outside the project area, an additional 9,000 acre-feet of water was pumped from the alluvial aquifer in Monroe County during 1973.

[4]West of the White River, outside the project area, an additional 100,000 acre-feet of water was pumped from the alluvial aquifer in Prairie County during 1973.

and industrial use were reported by the managers of the municipalities and industries. Values for rural-domestic and livestock use were based on population and normal consumption rates.

The 646,700 acre-feet for rice irrigation (table 5) was 93 percent of the total water used from the alluvial aquifer in the study area in 1973; it was 99 percent of all the water used for rice. The rest of the water used for rice, about 7,000 acre-feet, was diverted from the Current, Black, White, and Little Rivers.

The 25,000 acre-feet for fish farms (table 5) represented 100 percent of the water used for fish farms on the alluvial plain. In the Springfield-Salem Plateaus, about 1,300 acre-feet was diverted from streams for fish farms.

The 17,600 acre-feet for municipal and industrial use (table 5) represented 30 percent of the total water pumped for municipal and industrial use on the plain. The other water for municipal and industrial use on the plain included 24,000 acre-feet from the Wilcox aquifer, 13,000 acre-feet from the Memphis aquifer and the Sparta Sand, and 800 acre-feet from the Nacatoch Sand aquifer. No streamflow was diverted for municipal and industrial use on the plain. On the plateaus, 800 acre-feet was pumped from the carbonate rock and 1,000 acre-feet from deep Ordovician aquifers (Roubidoux Formation and Gunter Sandstone Member of Van Buren Formation) for municipal and industrial use. Also, in the plateaus, 1,200 acre-feet of streamflow was diverted for municipal and industrial use.

Water-Level Fluctuations and Declines

Water levels have been monitored in about 50 wells in the study area by annual or more frequent measurements since the 1950's. Other wells were added to the observation-well network during the 1960's and with the start of this project in 1973. Hydrographs from a representative selection of the observation wells are shown on plate 7.

Water levels in areas of little or no water-level decline (pl. 7) are generally within 20 feet of land surface and have an annual fluctuation of about 5 feet. Most of the fluctuation is in response to stream-stage changes, but some of the response is to recharge from precipitation and discharge to evapotranspiration and wells.

Water levels in the area of water-level decline (pl. 7) during 1978 were from about 40 to 75 feet below land surface and were declining as much as 2 feet per year in some places. Hydrograph 12 (pl. 7) indicates about the same rate of water-level decline in the Memphis aquifer as is indicated by hydrographs for the rate of water-level decline in the alluvial aquifer. This similarity is significant because water-level decline in the Memphis aquifer is almost entirely in response to irrigation-well discharge from the alluvial aquifer.

Water Quality

The water pumped from the alluvial aquifer is typically a calcium bicarbonate ($CaHCO_3$) type which contains appreciable amounts of magnesium (Mg) and iron (Fe). Other dissolved constituents in the water, but in comparatively small concentrations, include sodium (Na), chloride (Cl), potassium (K), sulfate (SO_4), silica (SiO_2), nitrate (NO_3), flouride (F), and manganese (Mn). Chemical analyses of the water are contained in Ryling (1960); Plebuch (1961); Lamonds, Hines, and Plebuch (1969); Hines, Plebuch, and Lamonds (1972); and Westerfield (1977).

The distribution of the dissolved-solids concentration, a measure of the total mineralization of the water, is shown on plate 8. Also indicated on this plate is the concentration, in milliequivalents per liter, of the common constituents at selected sampling sites. Dissolved solids in the alluvial aquifer (pl. 8) in most of the area ranges from 200 to 400 milligrams per liter. Larger concentrations, about 500 to 600 milligrams per liter, generally occur along some reaches of the Mississippi River and along the downstream reach of the White River. Concentrations of 400 to 500 milligrams per liter generally occur in the area coinciding with the area of greatest pumpage between the Cache River and Crowleys Ridge in Poinsett, Cross, St. Francis, and Monroe Counties. Dissolved solids that exceeded 700 milligrams per liter were found only at three sites (pl. 8). At two of the sites, one between Brinkley and Bayou DeView and the other west of the Black River in Independence County, dissolved solids were about 1,500 milligrams per liter, and the water at each of these two sites was a sodium chloride (NaCl) type. At the third site, north of Walnut Ridge, dissolved solids were about 800 milligrams per liter, and the water was a calcium sulfate ($CaSO_4$) type.

According to the classification of irrigation water by Wilcox (1948, p. 26), water in the alluvial aquifer that contains less than 500 milligrams per liter of dissolved solids is excellent to good; 500 to 1,000 milligrams per liter, good to permissible; 1,000 to 1,500 milligrams per liter, permissible to doubtful; and more than 1,500 milligrams per liter, doubtful to unsuitable. Only at the two sites where the water contained 1,500 milligrams per liter of dissolved solids would the water be considered doubtful to unsuitable. At these two sites, crop production was reported to be impaired by the use of the water.

Hardness and dissolved iron in the water of the alluvial aquifer generally limit its use for municipal, industrial, and domestic supplies unless it is treated. The water commonly contains hardness concentrations of about 100 to 300 milligrams per liter (hard to very hard) and dissolved-iron concentrations of about 1 to 5 milligrams per liter. Dissolved-iron concentrations of more than only about 0.3 milligrams per liter are undesirable in a water supply for public use and many industrial uses.

The patterns of mineralization of the water in the alluvial aquifer generally appear consistent with the principle that ground water tends to increase in mineralization in the direction of flow. For example, as water moves eastward from the Cache River and westward from the St. Francis River toward the area of extensive pumping in Poinsett and Cross Counties (west of Crowleys Ridge), dissolved solids increase from about 200 to 500 milligrams per liter (pl. 8).

The small concentration of dissolved solids (100 milligrams per liter or less) along the eastern edge of Crowleys Ridge in Craighead, Greene, and Clay Counties (pl. 8) is attributed to flow of very dilute water from the Crowleys Ridge deposits to the alluvial aquifer.

The anomalously large concentrations of dissolved solids (1,500 milligrams per liter) at the site between Brinkley and Bayou DeView in Monroe County (pl. 8) results from a sodium chloride water that has a chloride concentration of 700 milligrams per liter. Hosman, Long, Lambert, and others (1968) reported a similar concentration of chloride occurring in the Sparta Sand in the same vicinity. Also, in the same vicinity, a sample of water collected in 1950 from a flowing oil-test well drilled to the Nacatoch Sand had a chloride concentration of 21,500 milligrams per liter. The oil-test well was plugged and covered after the water sampling.

The concentration of the sodium chloride in both the alluvial aquifer and the Sparta Sand in the Brinkley vicinity seems to be increasing. The city of Brinkley began reducing municipal pumpage from the Sparta Sand in the area of concern in 1975 and located new wells in the Sparta Sand north of Brinkley and west of Bayou DeView. A southward migration of the sodium chloride water is indicated (pl. 8), and this indication is consistent with reports of deteriorating water quality in the alluvial aquifer by irrigators south of Brinkley.

The data are insufficient for a firm explanation of the occurrence of the sodium chloride water in the alluvial aquifer and the Sparta Sand aquifer near Brinkley. Possibly, the saltwater originates in a deeper unit, such as the Nacatoch Sand, and gains access to the shallow aquifers through a vertically extensive zone of large hydraulic conductivity in the strata between the source unit and the shallow aquifers. If the saltwater actually has an access route from a deeper source unit, any increased lowering of the hydraulic head in the shallow aquifers in the area of concern would tend to increase the rate of flow of saltwater from the source unit.

DIGITAL MODEL OF THE ALLUVIAL AQUIFER

Design and Assumptions

A two-dimensional digital model, described by Trescott, Pinder, and Larson (1976), was used for this study. The model uses a block-centered grid to spacially distribute those parameters that define the aquifer and its flow system. The strongly-implicit procedure (SIP) was chosen to solve the finite-difference approximations of the differential flow equations. Model options used included water-table simulation and aquifer recharge.

The model grid (pl. 9) was oriented so that the columns approximately parallel the principal streams, namely the White, Black, Cache, St. Francis, and Mississippi Rivers. The dimensions of the grid are 30 rows by 50 columns with uniform spacing of 3 miles. The intersection of each row and column forms a block at the center of which a node is located.

A no-flow boundary (impermeable nodes), inherent in the model design, was placed around the border of the grid (pl. 9). For modeling convenience, impermeable nodes were placed between the grid border and the White and Mississippi Rivers. Actually, the modeled areas west of the White River and east of the Mississippi River are underlain by extensions of the alluvial aquifer. However, the effects of any stress on the aquifer west of the White River and east of the Mississippi River were canceled in the study area by modeling the two rivers as constant hydraulic-head sources.

The placement of the northern and southern borders of the grid causes small parts of the study area underlain by the alluvial aquifer to be excluded from the model. The placement of the northern border of the grid additionally causes a small part of the Missouri "boot heel," also underlain by the alluvial aquifer, to be included in the model. The alluvial aquifer in the parts of the study area excluded from the model is only slightly stressed by pumping, and therefore the exclusion of these parts would not materially affect model calibration and predictions. Likewise, as previously indicated, the alluvial aquifer within the modeled area east of Crowleys Ridge, including the part in Missouri, is only slightly stressed.

It was assumed that boundary conditions at the north and south boundaries of the model would be adequately controlled by the constant hydraulic-head stream sources. The flow actually crossing the north and south boundaries of the modeled area was estimated to be about 14,000 acre-feet per year across the north boundary and 2,000 acre-feet per year across the south boundary. These values would represent, respectively, about 6 percent and 1 percent of the total simulated recharge rate in the model, and therefore are not significant for model calibration.

The impermeable nodes placed along the boundary of the alluvial aquifer in the northwestern part of the modeled area (pl. 9) simulate the only actual barrier to lateral flow in the model. There, the alluvial aquifer wedges out against the carbonate rock unit.

Constant hydraulic-head nodes (pl. 9) were placed along the entire reaches within the modeled area of the White, Black, Cache, St. Francis, and Mississippi Rivers, and along the downstream reaches of some of the smaller streams, including Bayou DeView, Big Creek, and the L'Anguille River. The upstream reaches of the mentioned smaller streams are in areas of intensive pumping, where the ground-water levels are considerably below the stream beds. In addition, the upstream reaches of these smaller streams do not entirely penetrate the alluvial-clay layer, and therefore the recharge rates along their upper reaches were assumed to be the same as in the interstream areas.

Average stream stages from gaging stations (pl. 9) having more than 10 years of record provided the constant hydraulic-head values at stream boundaries. The modeled streams were assumed to be fully penetrating, and it was assumed that the streams always had water at the simulated constant hydraulic-head nodes. It was further assumed that for long-term simulations, the constant hydraulic head at stream boundaries represented the average ground-water levels near the streams.

The alluvial aquifer was treated as a homogeneous unit with an average hydraulic conductivity of its combined sand-and-gravel components. Also, to stay within a two-dimensional design, the hydrologic units in Crowleys Ridge were treated as a zone of variable hydraulic conductivity between the eastern and western segments of the alluvial aquifer.

The hydrologic units underlying the alluvial aquifer, except the Memphis aquifer, were treated as impermeable units. There was no reason to treat the carbonate rock unit, the Arkadelphia-Midway clay, the Wilcox clay, and the Claiborne-Jackson clay otherwise. But, treating the Nacatoch Sand aquifer and the Wilcox aquifer as impermeable units was based on analytical solutions that showed that flow crossing their boundaries with the alluvial aquifer was was negligible.

Where the alluvial aquifer is underlain by the Memphis aquifer, the Memphis aquifer had to be treated as if it provided additional thickness to the alluvial aquifer in order to achieve nonsteady model calibration. Perfect hydraulic connection was therefore assumed between the Memphis aquifer and the alluvial aquifer in the area of truncation of the Memphis aquifer. The same boundaries, mainly stream (constant hydraulic head), that apply to the alluvial aquifer were assumed to apply where the alluvial aquifer and the Memphis aquifer were combined as a unit. The Memphis aquifer was terminated in the model at its downdip boundary of truncation, or where it becomes confined by the Jackson-Claiborne clay (pl. 1). Analytical solutions showed that flow from the confined part of the Memphis was negligible.

Evapotranspiration was not modeled because most discharge from evapotranspiration occurs in the flood plains of rivers that are modeled with constant hydraulic-head nodes. Discharge at the constant hydraulic-head nodes includes ground-water discharge to both streamflow and evapotranspiration.

It was assumed that all the unconsumed part of the water applied to rice was diverted to streams. In most areas of rice production, this is a reasonable assumption because the clay layer over the alluvial aquifer greatly retards infiltration or return of any of the applied water to the aquifer. Finally, it was assumed that recharge to the aquifer was constant with time, unaffected by the amount of water applied to the rice in any given year.

Calibration

Selected hydrologic parameters and adjustment of their values to achieve model calibration are discussed in the following.

Recharge in interstream areas--Calibration was achieved with a recharge value of 0.03 foot per year in all areas except in the sandy area west of the Cache River, where a recharge value of 0.16 foot per year was necessary for calibration. The most critical area for the value of the recharge estimate was in the stressed area between the Cache River and Crowleys Ridge, but the 0.03 foot per year used there could have been twice as much without materially affecting steady-state calibration.

Specific yield--Calibration was achieved with a specific yield value of 0.3, a value consistent with the specific yield for the alluvial aquifer in the Grand Prairie, adjacent to the study area, reported by Engler, Thompson, and Kazmann (1945); Sniegocki (1964); and Johnson, Mosten, and Versau (1966). The specific yield could range from 0.25 to 0.35 in the study area.

Hydraulic conductivity--The final value used in the model for the alluvial aquifer was 270 feet per day. For the connecting layer through Crowleys Ridge, a hydraulic conductivity of 130 feet per day was used for that part of the layer made up by the Memphis aquifer. Hydraulic conductivities used for the other units making up the layer through the ridge ranged from 3 to 15 feet per day.

Steady-State Results

Calibration of the steady-state model involved a simulation of the flow system as it existed prior to about 1911, when the aquifer was virtually unstressed by pumping. Steady-state calibration was achieved by adjusting hydrologic parameters until the model-derived potentiometric surface compared reasonably well with water-level data representative of initial conditions.

The potentiometric surface derived for steady-state conditions is shown on plate 10. Generally, the model-derived hydraulic heads were within 5 feet of the measured and reported hydraulic heads. Exceptions are in two areas of several square miles; one area is south of Marianna (Lee County) and the other is near Brinkley (Monroe County). The model-computed hydraulic heads were 10 to 20 feet lower than measured hydraulic heads in the Marianna area and 10 feet higher than measured hydraulic heads in the Brinkley area. In both areas, substantial improvement in model calibration could not be achieved with justifiable adjusting of the parameter values insofar as the flow system is conceived at this time.

The mass balance of the model under steady-state conditions is as follows.

Recharge:

At surface boundary = 250,000 acre-feet per year

At stream boundaries = 66,000 acre-feet per year

Discharge:

At stream boundaries = 316,000 acre-feet per year (includes discharge to streams and to evapotranspiration)

At stream boundaries, steady-state analysis showed net discharges of 72,000 acre-feet per year along the Cache River, 31,000 acre-feet per year along the St. Francis River, and 4,000 acre-feet per year along the L'Anguille River. A net recharge of 1,500 acre-feet per year was shown along Bayou DeView.

Nonsteady-State Results

Calibration of the nonsteady model involved simulating changes in the flow system of the aquifer resulting from pumping stress, the dominant stress on the system. The calibration period was from the beginning of 1911 to the end of 1978. The model was considered calibrated when it could approximate the potentiometric surfaces of 1938 and 1953 (Counts and Engler, 1954), and the potentiometric surface of 1973 (pl. 5).

It would have been desirable for additional validity of calibration to match measured streamflow losses, or streamflow capture, resulting from ground-water pumping. However, streamflow records did not lend themselves for a quantification of stream gains and losses because of a number of factors, mainly of which include: (1) Streamflow is dominated by surface runoff about 99 percent of the time, and (2) there is considerable interbasin movement of ground water and surface water. These conditions generally prevail throughout the areas of intensive rice production in the alluvial plain in eastern Arkansas.

The historically minor pumpage east of Crowleys Ridge was negligible as a long-term stress; therefore, pumpage was simulated only in the area west of Crowleys Ridge. The pumpage west of the ridge, estimated from water requirements for rice production, was simulated at the average pumping rate for each of four time spans between 1911 and 1978 (fig. 2). One pumping node was used to approximate pumping from each 36 square miles for the 1911-37, 1938-52, and 1953-72 time spans. During 1973-78, the pumping rate approximately doubled that of 1953-72. Additional pumping nodes were added in the area significantly stressed during 1973-78. The extra pumping nodes were added to prevent unrealistically large model drawdowns from occurring at some nodes.

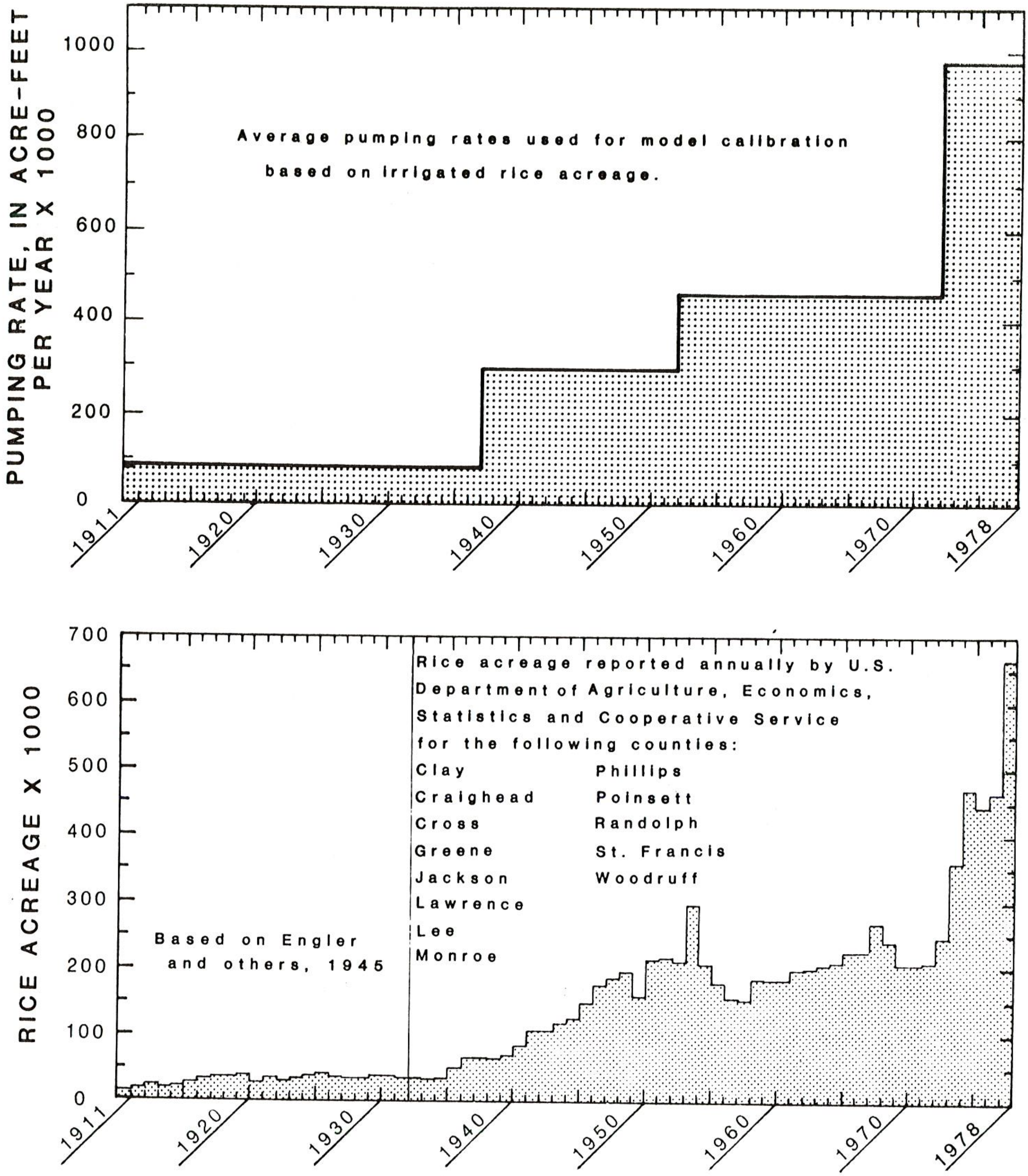


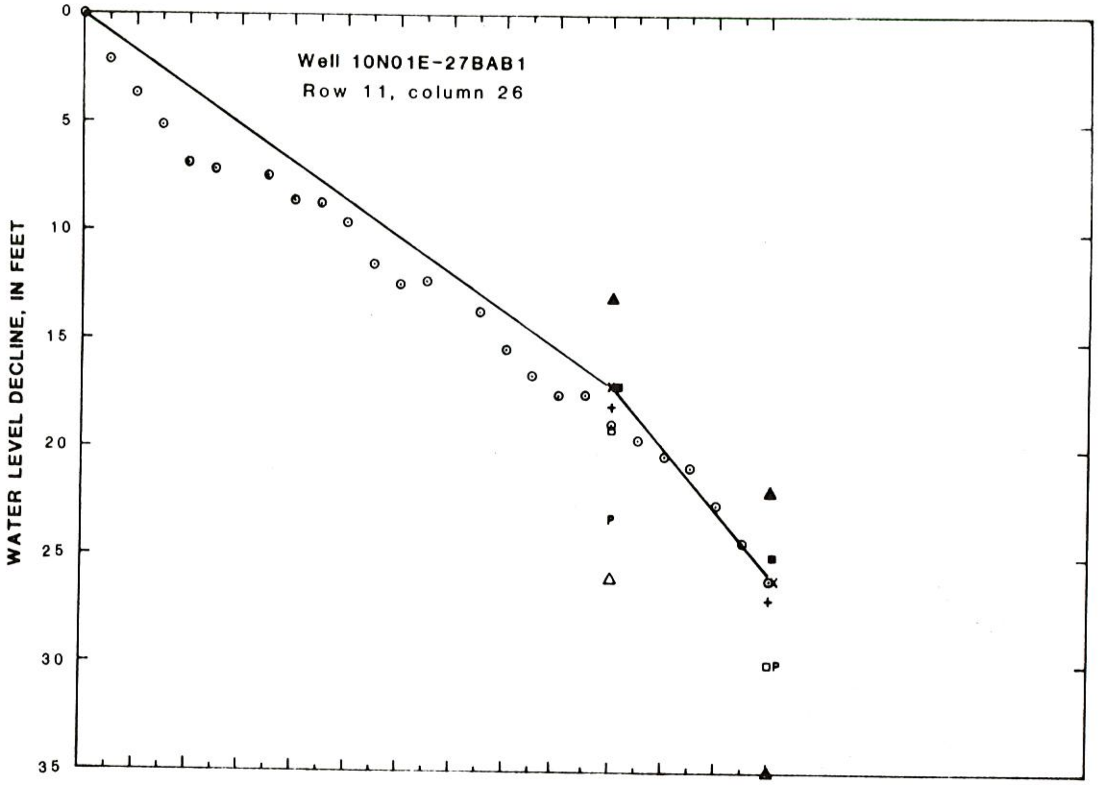
Figure 2.--History of rice acreage and pumping rates for rice irrigation west of Crowleys Ridge, 1911-78.

The model-generated potentiometric surface for the spring of 1973, and the distribution of pumping nodes, is shown on plate 11. The modeled hydraulic heads were generally within about 5 feet of the measured hydraulic heads in the stressed area between the Cache River and Crowleys Ridge, and elsewhere the modeled hydraulic heads were generally within about 10 feet of the measured hydraulic heads. The largest mismatches of the hydraulic heads occurred along streams and were partly attributable to the higher-than-normal stream stages and ground-water levels during 1973. Some mismatches of hydraulic heads, particularly in the stressed area, could be attributed to the inexact method of assigning pumping centers. As expected, modeled hydraulic heads northwest of Brinkley were about 10 feet too high, reflecting the high initial hydraulic heads in the same area.

The calibrated-model decline at two locations in the stressed area and, for comparison, the measured decline at approximately the same locations are shown in figure 3. The measured and modeled declines generally are within 5 feet of each other for the period of comparison (1953-78).

The sensitivity of the model to selected parameter-value changes during the nonsteady phase of calibration also is indicated in figure 3. For example, with the hydraulic conductivity of the alluvial aquifer increased to one and one-half times the calibrated value of 270 feet per day for the alluvial aquifer, the model decline at both locations (fig. 3) would be about 4 feet less for 1973 and 1979.

In general, the smaller hydraulic conductivities gave drawdowns that were excessive by about 10 feet. Smaller specific-yield values and larger pumping rates gave drawdowns that were excessive by about 5 feet. The pumping rates were varied in the sensitivity test because pumpage at the pumping



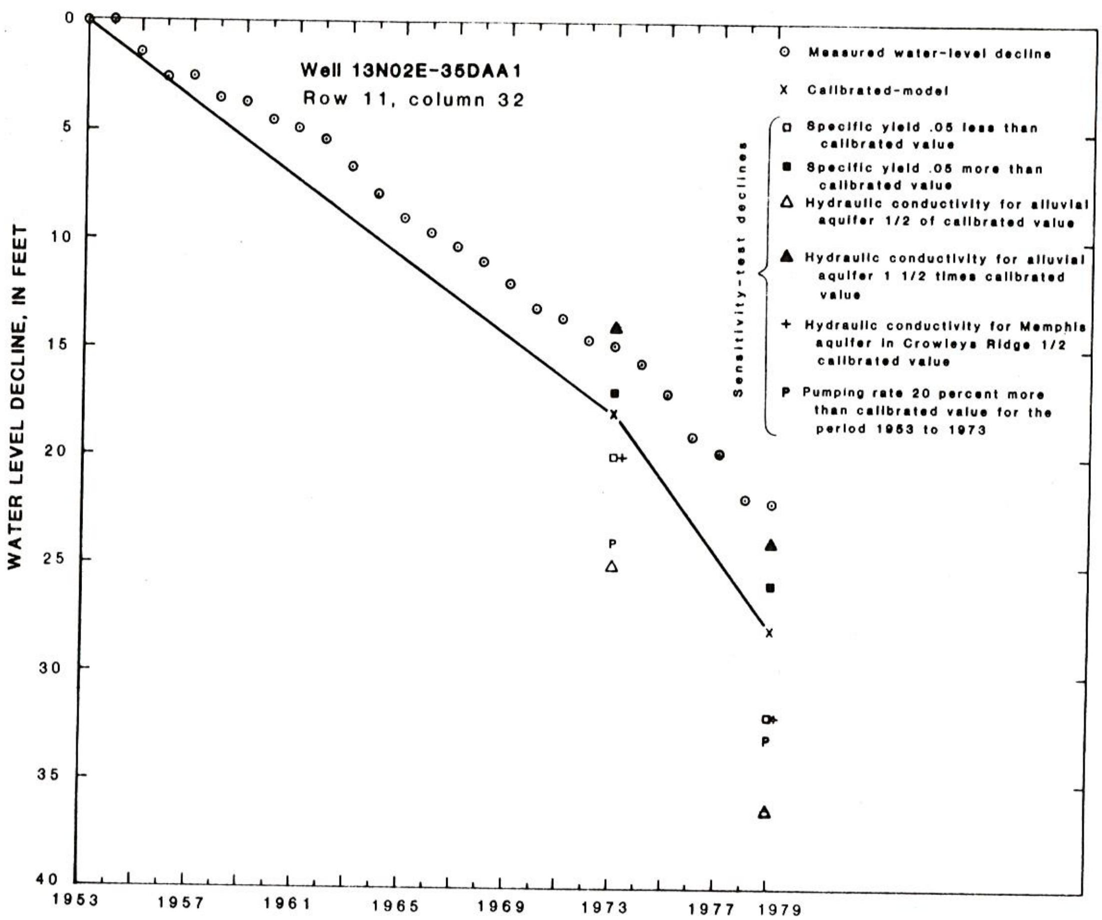


Figure 3.--Measured water-level declines, calibrated-model declines, and sensitivity-test declines.

nodes could be in error by as much as 10 percent because of the manner of estimating and distributing the pumpage. The model was relatively insensitive to larger hydraulic conductivities and larger specific yields. In some places, these increased values actually improved modeled and measured fits, but not enough to warrant additional refinement of the model.

Model Estimates and Projections

Pumpage from the alluvial aquifer west of Crowleys Ridge at the end of the 1973-78 period was removing water from aquifer storage at the rate of 540,000 acre-feet per year and capturing streamflow, about one-half from the Cache River, at the rate of 430,000 acre-feet per year.

Two pumping rates were simulated to project the potentiometric surface of the alluvial aquifer through 2000. It was assumed that the distribution of wells and rice acreage would remain the same for both projections of pumping rates.

Pumping rate 1 was 970,000 acre-feet per year, or the average 1973-78 pumping rate for the rice acreage shown in figure 2. The projected potentiometric surface through 2000 at pumping rate 1 is shown on plate 12. For 2000, the potentiometric surface would be at an altitude of less than 150 feet in the stressed area, centered mostly in Poinsett, Craighead, and Cross Counties. At places within the stressed area, the saturated thickness of the aquifer would be reduced to less than 50 feet (pl. 12).

Pumping rate 2 was initially 1,460,000 acre-feet per year, or the 1978 pumping rate for rice (fig. 2), but the pumping rate had to be reduced by 110,000 acre-feet per year during 1990 to prevent aquifer dewatering in parts of Poinsett, Craighead, and Cross Counties. At the reduced pumping rate (1,350,000 acre-feet per year) beginning in 1991, the projected potentiometric surface of the aquifer for 2000 would be at an altitude of less than 125 feet (pl. 13) in the stressed area, indicating a saturated-aquifer thickness of less than 50 feet in most of Poinsett and Craighead Counties and a substantial part of Cross County; the rate of water removal from aquifer storage would be about 490,000 acre-feet per year, and the rate of streamflow capture would be about 860,000 acre-feet per year.

Model estimates of the rate of streamflow capture from selected streams during 1911-78 are shown in figure 4, with projected rates of capture from the streams through 2000 at pumping rates 1 and 2. The Cache River would be the largest source of capture, contributing about 320,000 acre-feet per year for pumping rate 1 and 420,000 acre-feet per year for pumping rate 2.

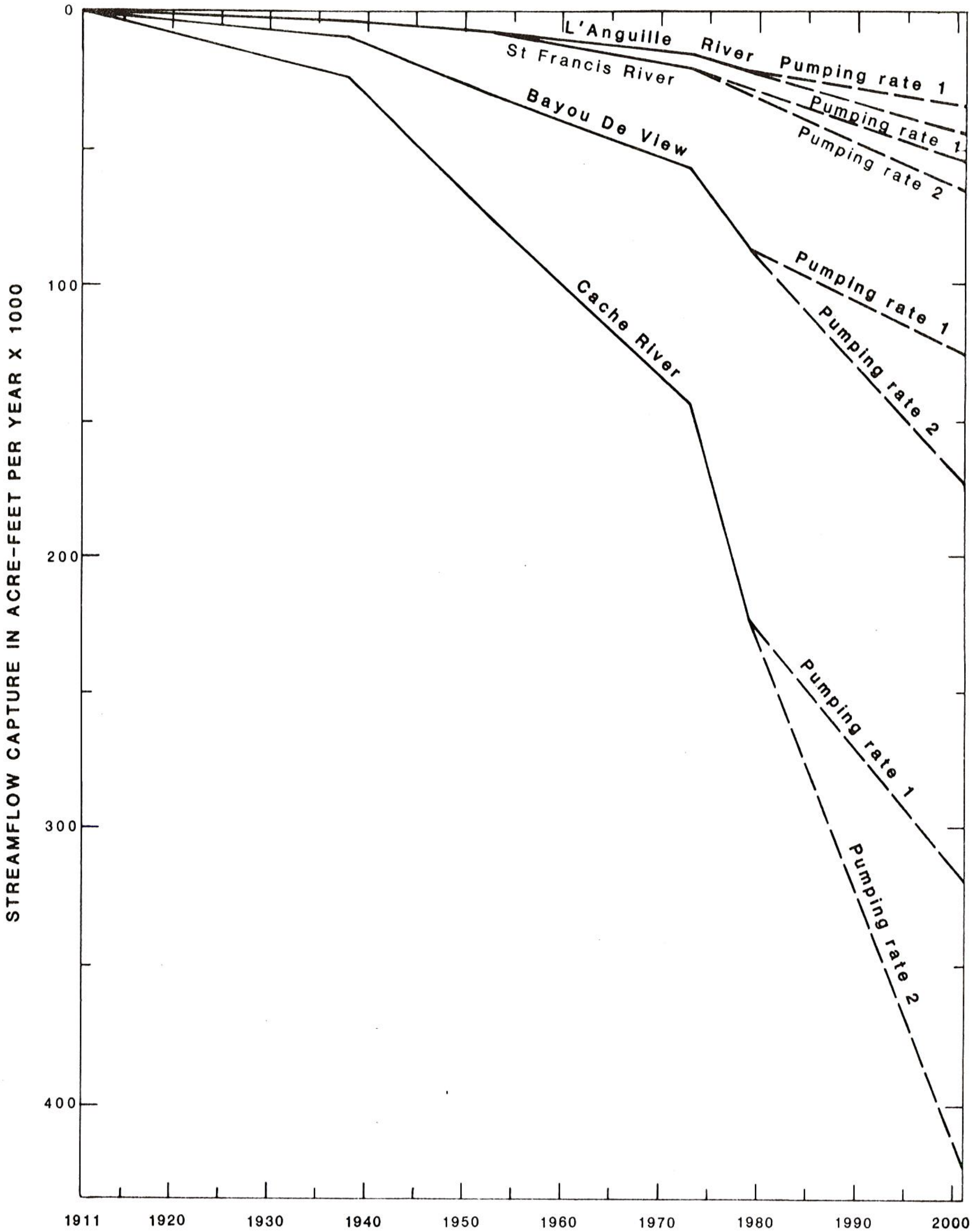


Figure 4.--Streamflow capture by ground-water pumping.

SUMMARY AND CONCLUSIONS

The aquifer is composed of sand and gravel, grading downward from fine- to coarse-particle size. Maximum aquifer thickness west of Crowleys Ridge is about 150 feet and east of Crowleys Ridge, about 200 feet.

Hydraulic conductivity of the aquifer is from about 100 to 400 feet per day and storage coefficient from about $4.0X10^{-4}$ to $2.0X10^{-2}$; however, for long-term drawdown computations, a specific yield of about 0.25 to 0.35 is more applicable than the storage coefficient. Well yields from the aquifer commonly are from 1,000 to 2,000 gallons per minute. Maximum specific capacity of wells is about 100 gallons per minute per foot of drawdown.

The natural direction of flow in the aquifer has been greatly altered by intensive pumping for rice irrigation in the area between the Cache River and Crowleys Ridge. The flow from the west largely reflects streamflow capture from the Cache River; the flow from the east reflects leakage from units on Crowleys Ridge and induced flow through the ridge from the alluvial aquifer east of the ridge. The Memphis aquifer acts as a conduit for the induced flow through the ridge.

Water use from the alluvial aquifer in the study area since the early 1900's has been mostly for rice irrigation on the alluvial plain west of Crowleys Ridge. Pumpage west of the ridge during 1978 for rice was 1,460,000 acre-feet or 88 percent of all the pumpage for rice in the study area.

Water levels in wells in parts of Poinsett, Cross, and Craighead Counties during 1978 were 75 feet below land surface, and declining about 2 feet per year. Water levels in wells outside the pumping-stressed area, including all the area east of Crowleys Ridge, were less than 20 feet below land surface.

The aquifer yields a hard to very hard calcium bicarbonate type water that has dissolved-solids concentrations of 200 to 400 milligrams per liter in most of the area. Iron concentrations of 1 to 5 milligrams per liter are common in water from the aquifer. A sodium chloride type water with chloride concentration of about 700 milligrams per liter is present in the aquifer at a locale west of the Black River in Independence County and at a locale near Brinkley in Monroe County. A southward migration of the chloride water from the locale near Brinkley is indicated.

The alluvial aquifer was simulated using a digital model to provide estimates of aquifer-recharge rates and rates of water removal from aquifer storage, and to project the effects of future pumping from the aquifer.

The alluvial aquifer was modeled as a single layer that included connecting hydrologic units through Crowleys Ridge. Except for the connecting units through the ridge, the layer was simulated with a hydraulic conductivity of 270 feet per day and a specific yield of 0.3. In the truncated area of the Memphis aquifer, the layer was modeled with the combined thickness of the alluvial aquifer and the Memphis aquifer in order to obtain adequate nonsteady calibration.

Annual average stream stages at stream boundaries were simulated with constant-head nodes. A recharge of 0.03 foot per year was simulated in most of the interstream areas.

Pumping nodes were distributed in the model only for the aquifer segment west of Crowleys Ridge; the historically minor pumpage east of the ridge was assumed negligible as a long-term stress. Pumping rates were based on use requirements for rice, about 30 inches per year in most of the area but as much as 42 inches per year on some of the plain west of the Cache River.

Digital-model analysis indicated that at the end of 1978 water was being removed from aquifer storage at the rate of 540,000 acre-feet per year, and streamflow, about one-half from the Cache River, was being captured at the rate of 430,000 acre-feet per year.

Projecting the 1978 pumping rate of 1,460,000 acre-feet per year, the pumping rate would have to be reduced by about 110,000 acre-feet per year by 1990 to sustain sufficient aquifer saturation for water needs through 2000 in all parts of Poinsett, Craighead, and Cross Counties west of Crowleys Ridge. At the reduced pumping rate of 1,350,000 acre-feet per year, beginning in 1991, saturated thickness of the aquifer west of Crowleys Ridge by the end of 2000 would be less than 50 feet in most of Poinsett and Craighead Counties and a substantial part of Cross County; the rate of water removal from aquifer storage would be about 490,000 acre-feet per year, and the rate of streamflow capture would be about 860,000 acre-feet per year.

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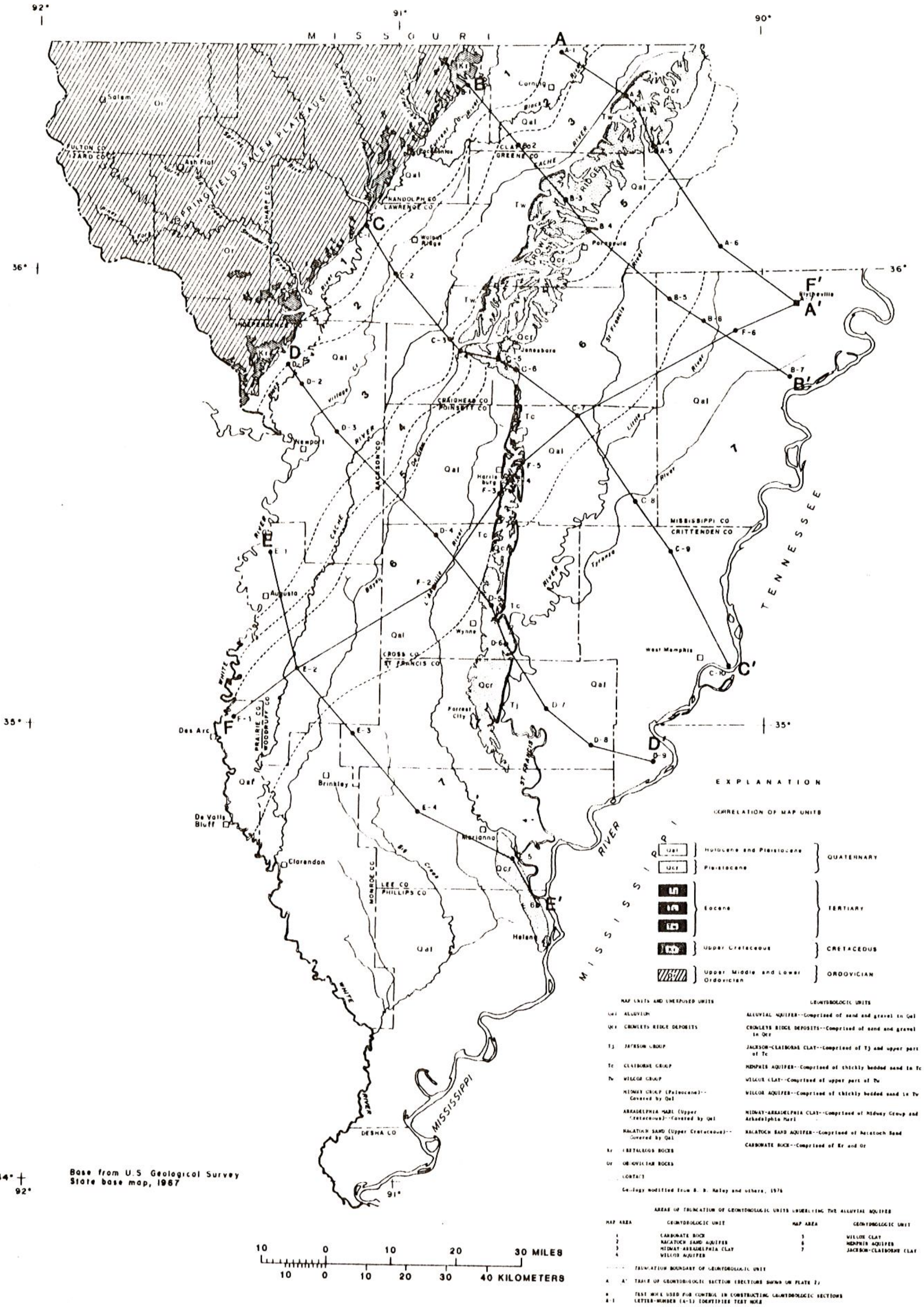
PLATES 1 to 13

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION

OPEN-FILE REPORT 81-476
PLATE 1



EXPLANATION

CORRELATION OF MAP UNITS

Unit	Epoch	Period
Qal	Holocene and Pleistocene	QUATERNARY
Qcr	Pleistocene	QUATERNARY
Tj, Tc, Tw	Eocene	TERTIARY
Kr	Upper Cretaceous	CRETACEOUS
Or	Upper Middle and Lower Ordovician	ORDOVICIAN

MAP UNITS AND UNEXPOSED UNITS	GEOHYDROLOGIC UNITS
Qal ALLUVIUM	ALLUVIAL AQUIFER--Comprised of sand and gravel in Qal
Qcr CROWLEYS RIDGE DEPOSITS	CROWLEYS RIDGE DEPOSITS--Comprised of sand and gravel in Qcr
Tj JACKSON GROUP	JACKSON-CLAIBORNE CLAY--Comprised of Tj and upper part of Tc
Tc CLAIBORNE GROUP	MEMPHIS AQUIFER--Comprised of thickly bedded sand in Tc
Tw WILCOX GROUP	WILCOX CLAY--Comprised of upper part of Tw
MIDWAY GROUP (Paleocene)--Covered by Qal	WILCOX AQUIFER--Comprised of thickly bedded sand in Tw
ARKADELPHIA MARL (Upper Cretaceous)--Covered by Qal	MIDWAY-ARKADELPHIA CLAY--Comprised of Midway Group and Arkadelphia Marl
NACATOCH SAND (Upper Cretaceous)--Covered by Qal	NACATOCH SAND AQUIFER--Comprised of Nacatoch Sand
Kr CRETACEOUS ROCKS	CARBONATE ROCK--Comprised of Kr and Or
Or ORDOVICIAN ROCKS	

CONTACT

Geology modified from B. R. Haley and others, 1976

AREAS OF TRUNCATION OF GEOHYDROLOGIC UNITS UNDERLYING THE ALLUVIAL AQUIFER

MAP AREA	GEOHYDROLOGIC UNIT	MAP AREA	GEOHYDROLOGIC UNIT
1	CARBONATE ROCK	5	WILCOX CLAY
2	NACATOCH SAND AQUIFER	6	MEMPHIS AQUIFER
3	MIDWAY-ARKADELPHIA CLAY	7	JACKSON-CLAIBORNE CLAY
4	WILCOX AQUIFER		

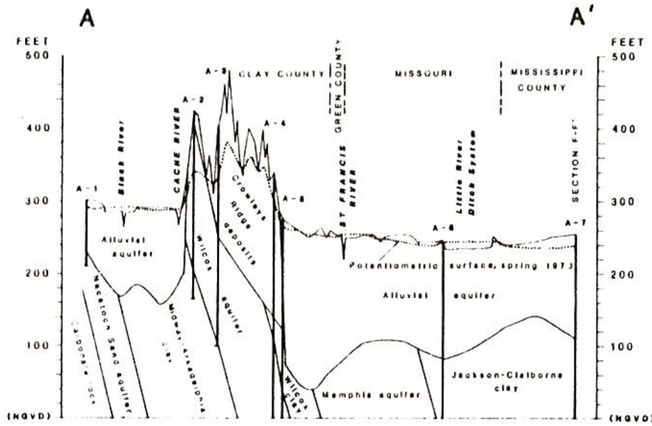
TRUNCATION BOUNDARY OF GEOHYDROLOGIC UNIT

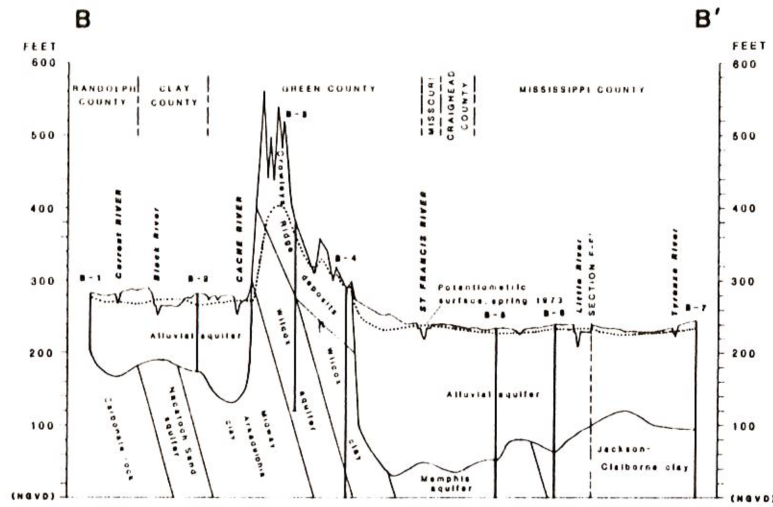
A A' TRACE OF GEOHYDROLOGIC SECTION (SECTIONS SHOWN ON PLATE 2)

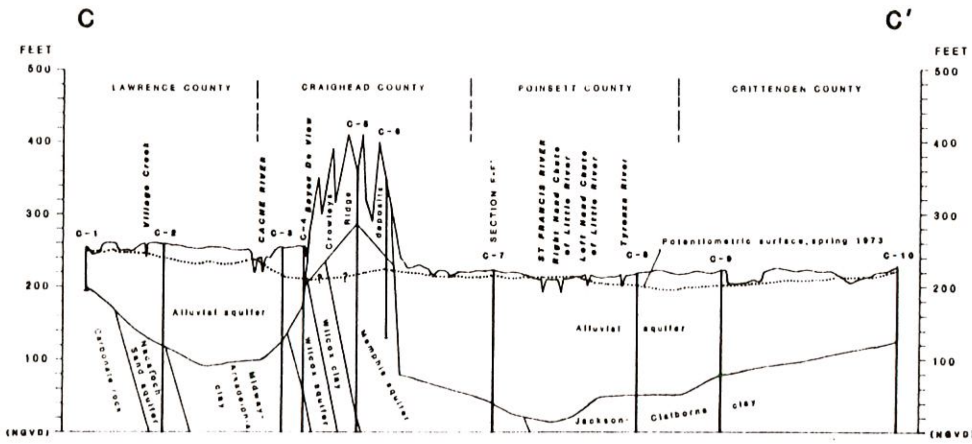
• TEST HOLE USED FOR CONTROL IN CONSTRUCTING GEOHYDROLOGIC SECTIONS
A-1 LETTER-NUMBER (A-1) IDENTIFIES TEST HOLE

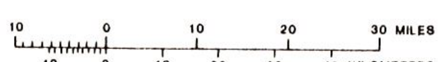
WHITE RIVER-BLACK RIVER DRAINAGE DIVIDE

GEOHYDROLOGIC MAP OF THE CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS





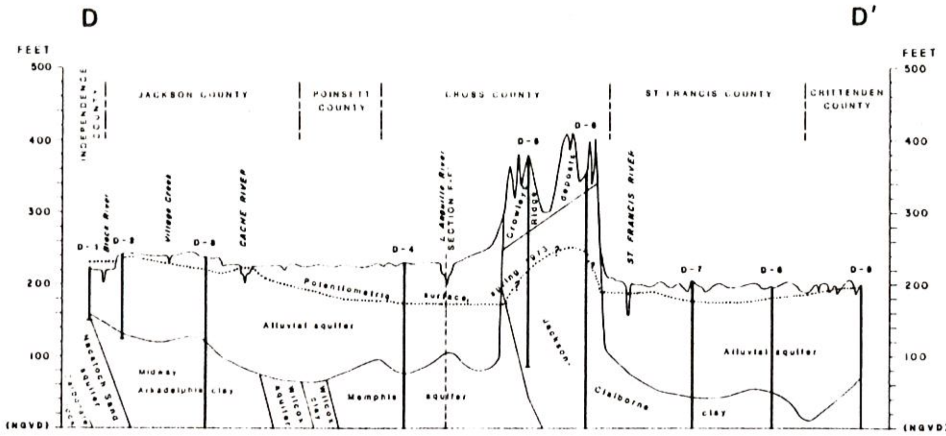


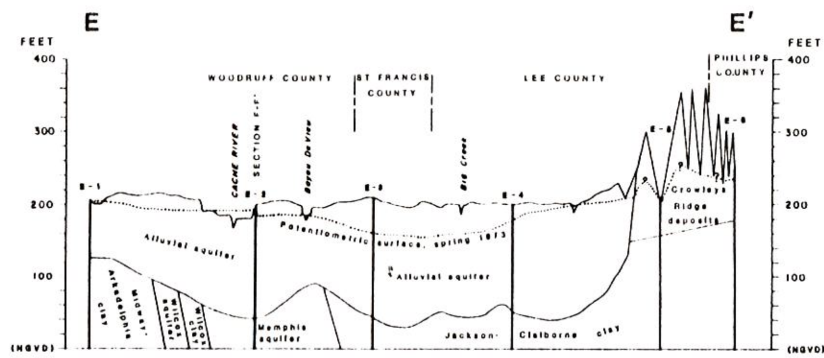


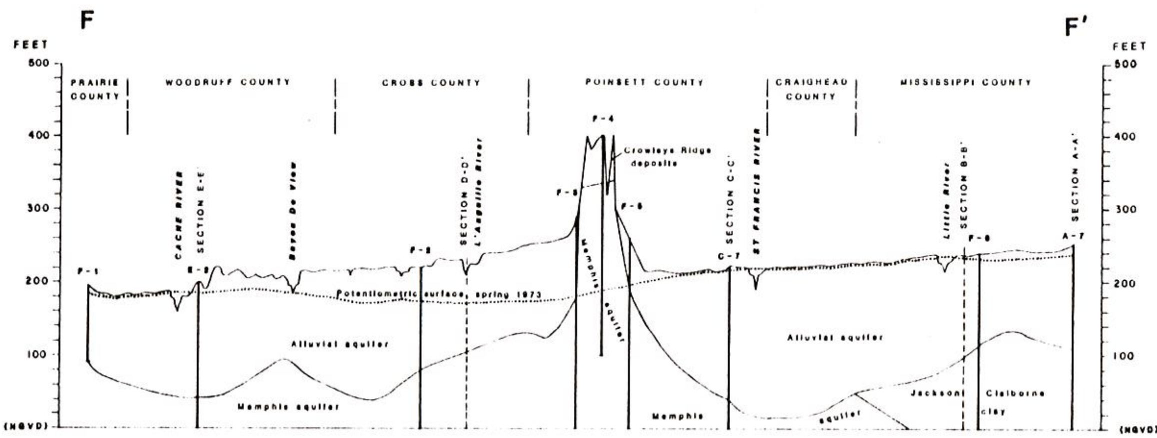
VERTICAL SCALE GREATLY EXAGGERATED

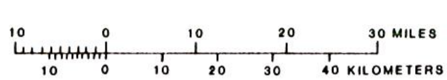
NGVD IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOHYDROLOGIC SECTIONS, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS





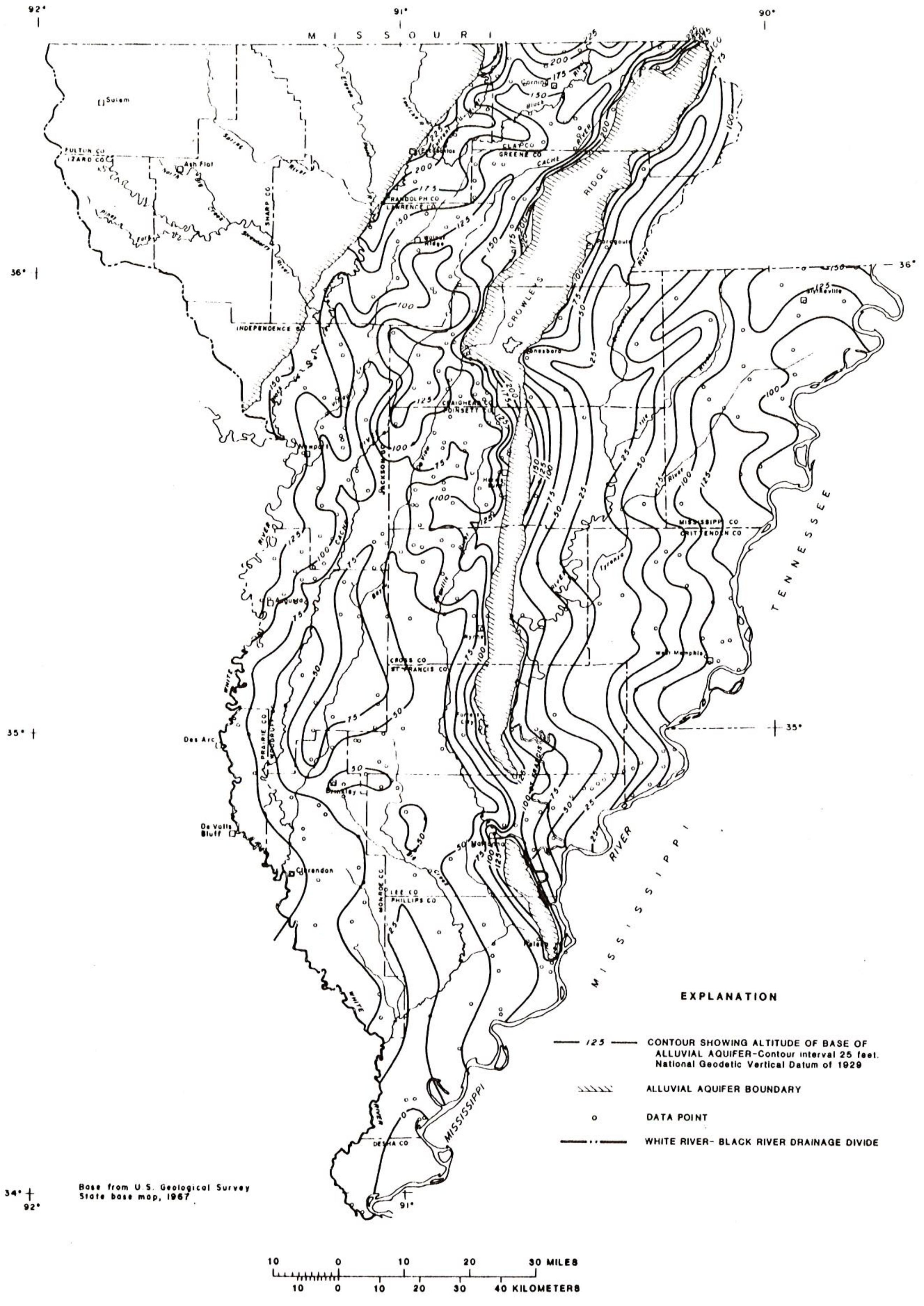




VERTICAL SCALE GREATLY EXAGGERATED

NGVD IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOHYDROLOGIC SECTIONS, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

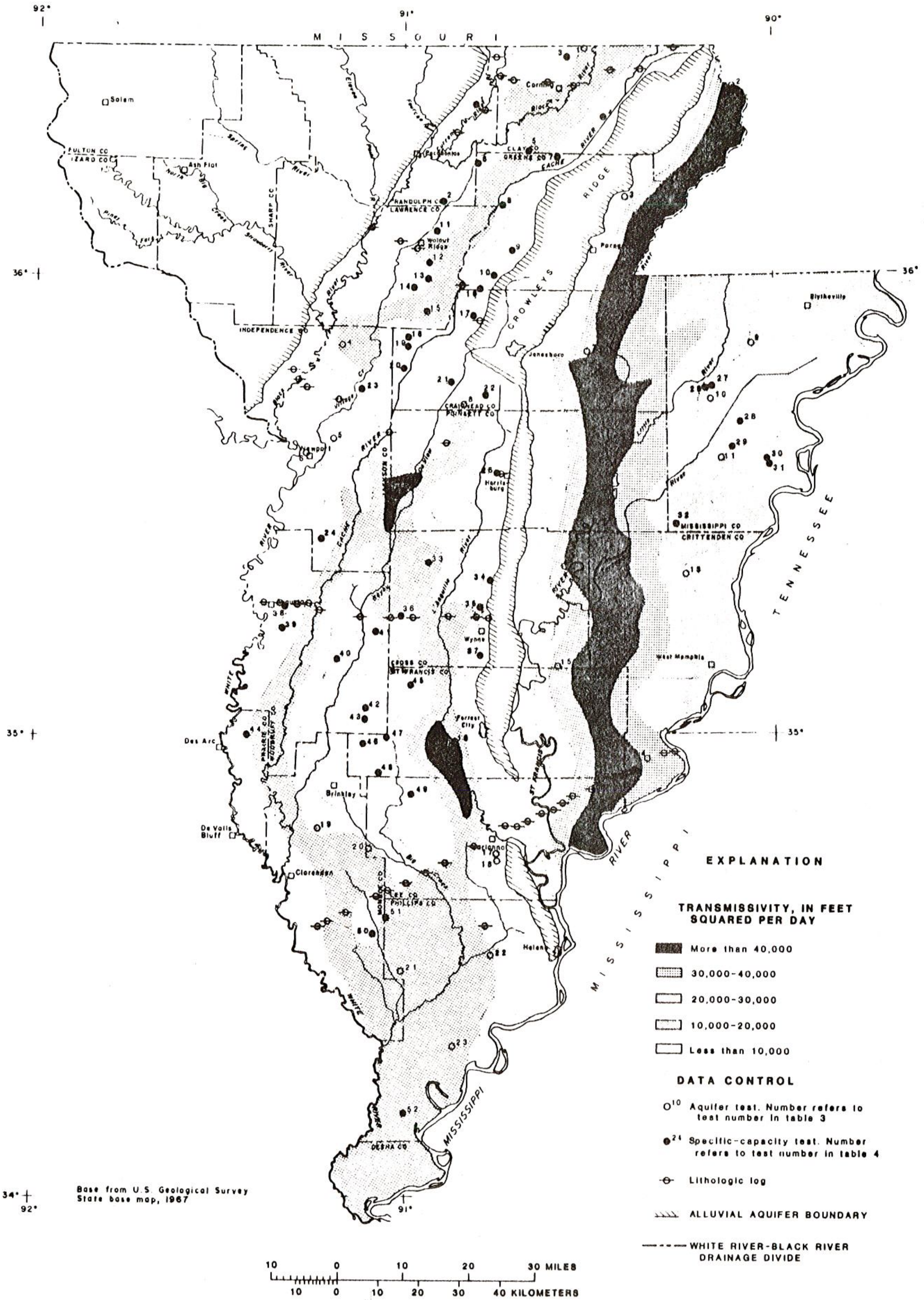


MAP SHOWING ALTITUDE OF THE BASE OF THE ALLUVIAL AQUIFER, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

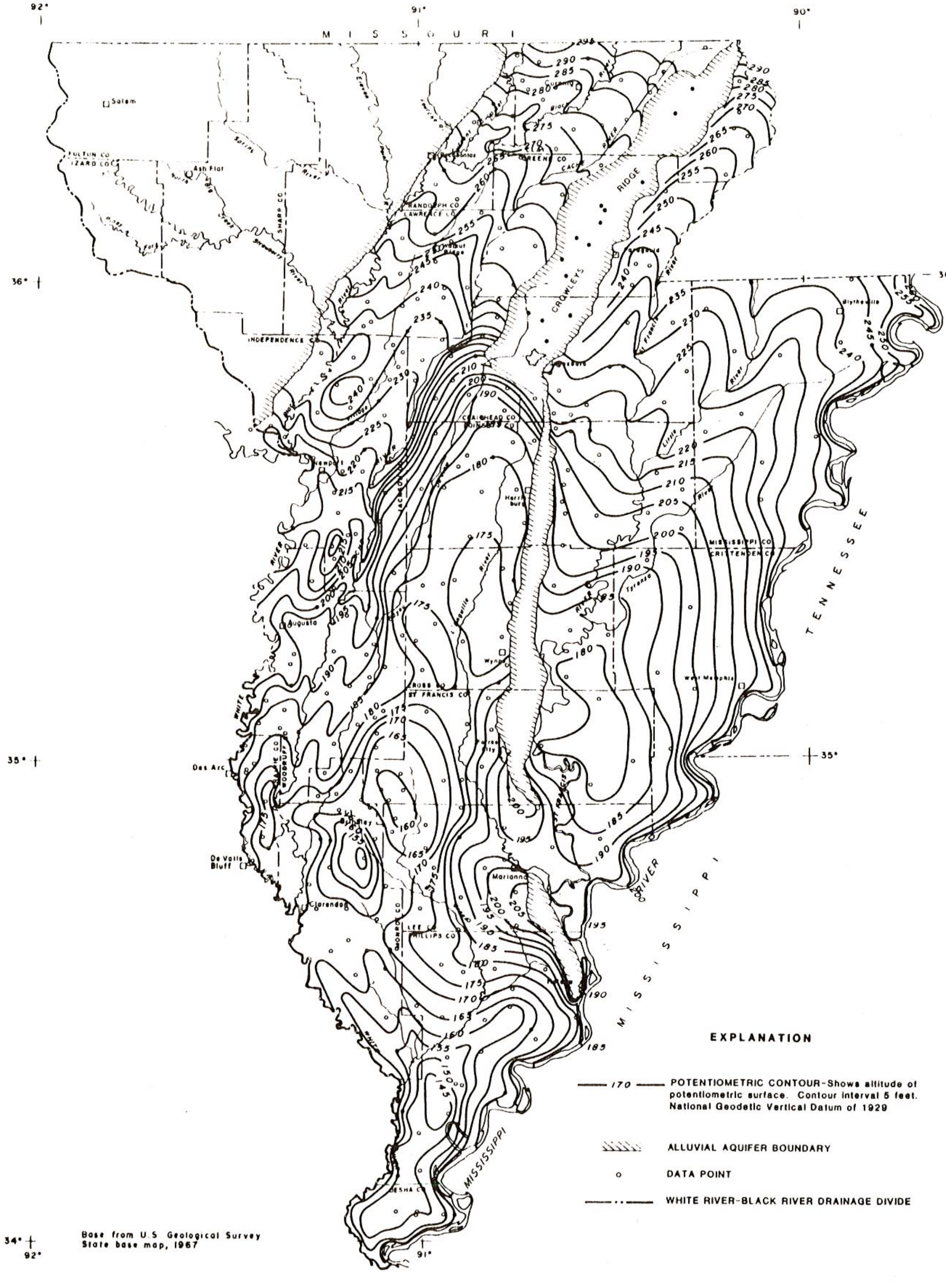
PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION

OPEN-FILE REPORT 81-476
PLATE 4



MAP SHOWING TRANSMISSIVITY OF THE ALLUVIAL AQUIFER, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION



EXPLANATION

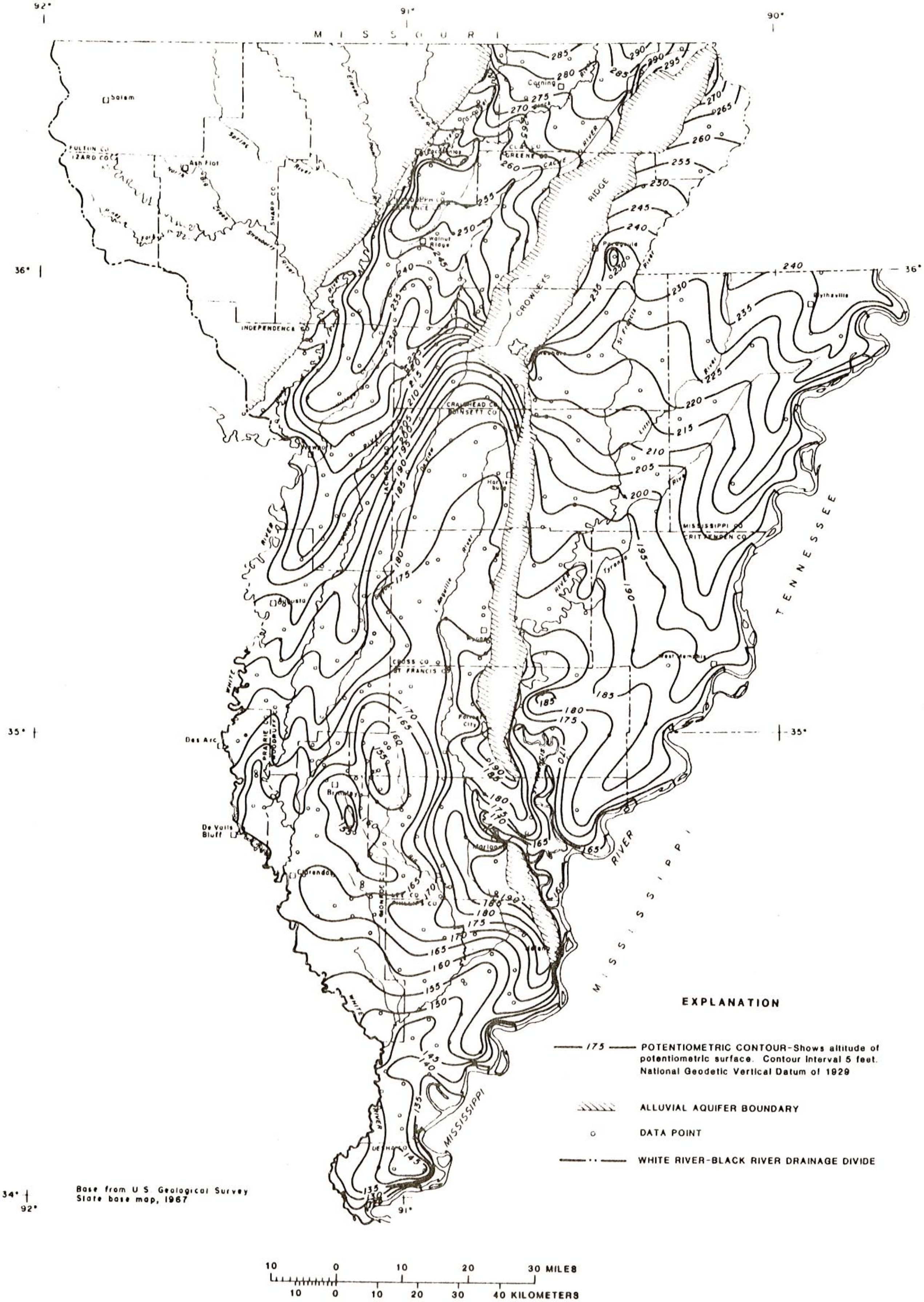
170 — POTENTIOMETRIC CONTOUR–Shows altitude of potentiometric surface. Contour interval 5 feet. National Geodetic Vertical Datum of 1929

ALLUVIAL AQUIFER BOUNDARY

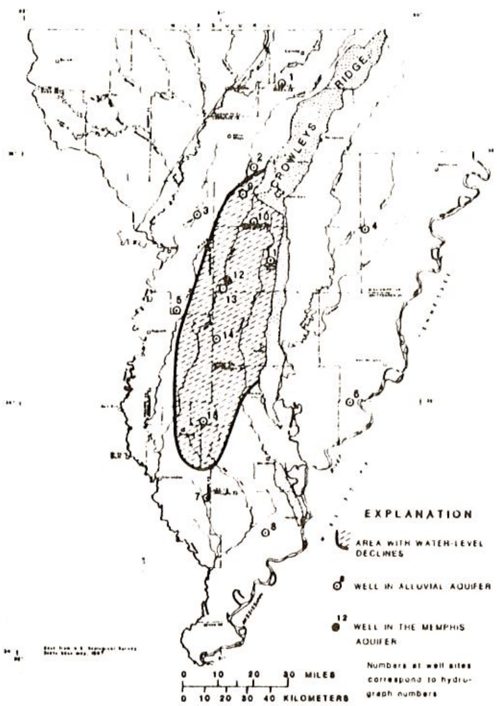
o DATA POINT

WHITE RIVER–BLACK RIVER DRAINAGE DIVIDE

MAP SHOWING POTENTIOMETRIC SURFACE OF THE ALLUVIAL AQUIFER, SPRING OF 1973, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

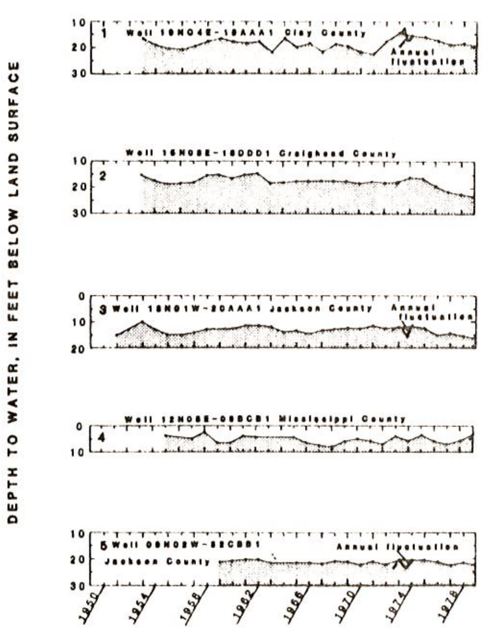


MAP SHOWING POTENTIOMETRIC SURFACE OF THE ALLUVIAL AQUIFER, FALL OF 1973, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

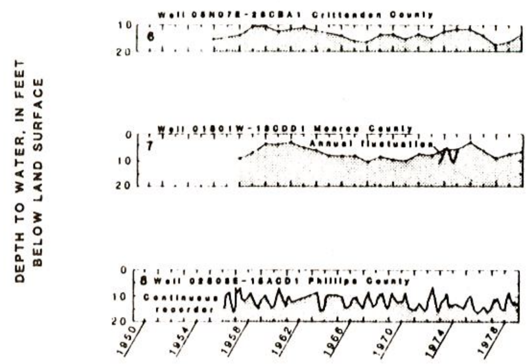


Index map

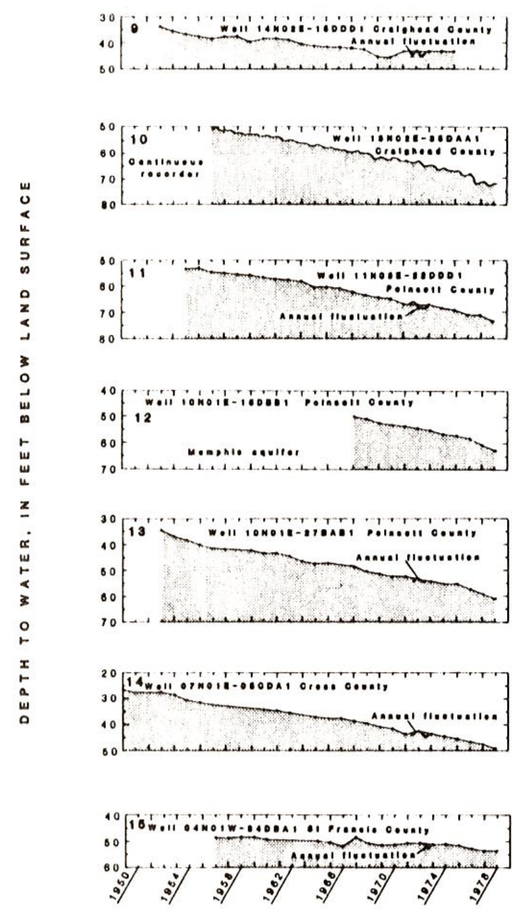
Wells with little or no water-level declines



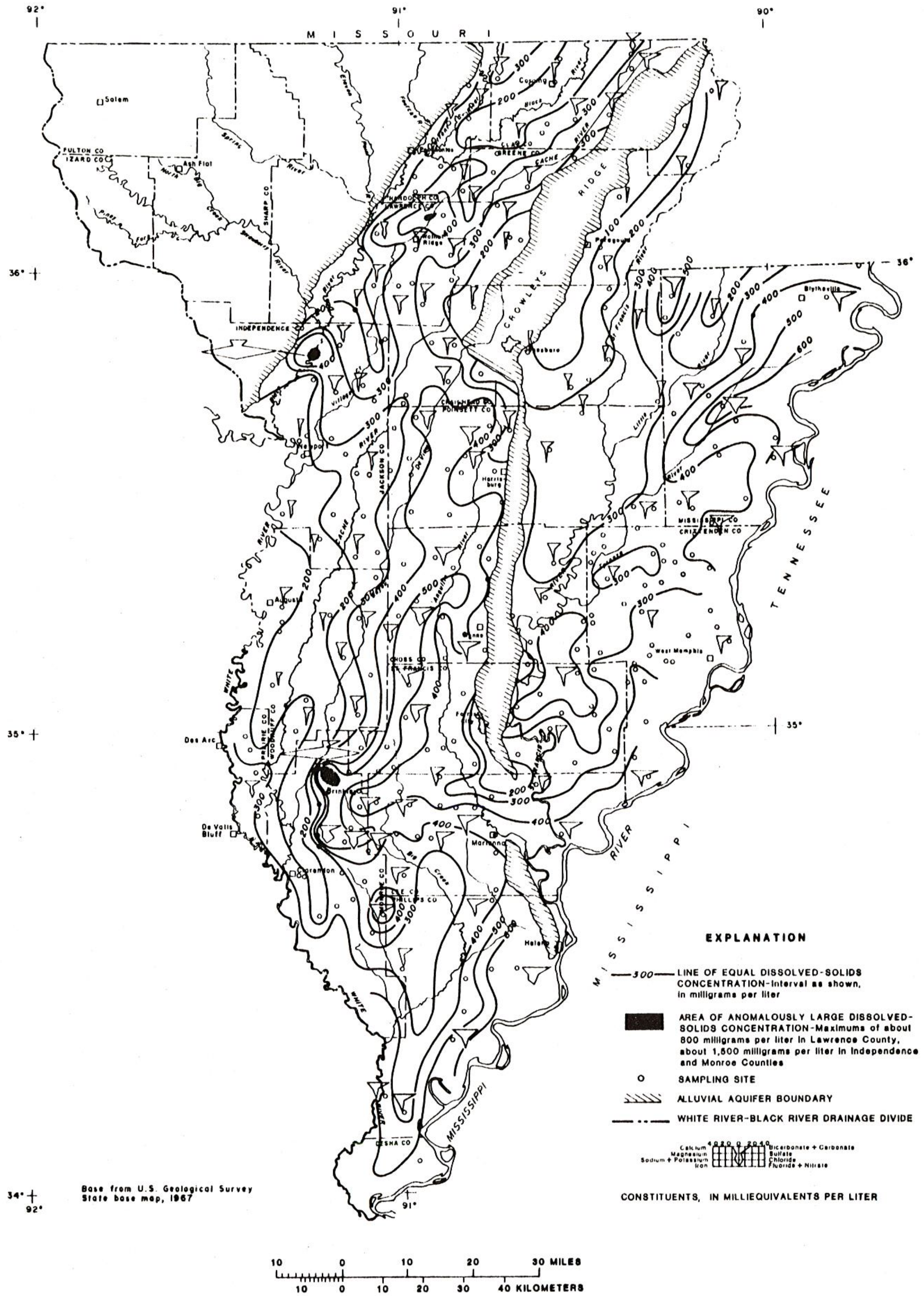
Wells with little or no water-level declines, continued



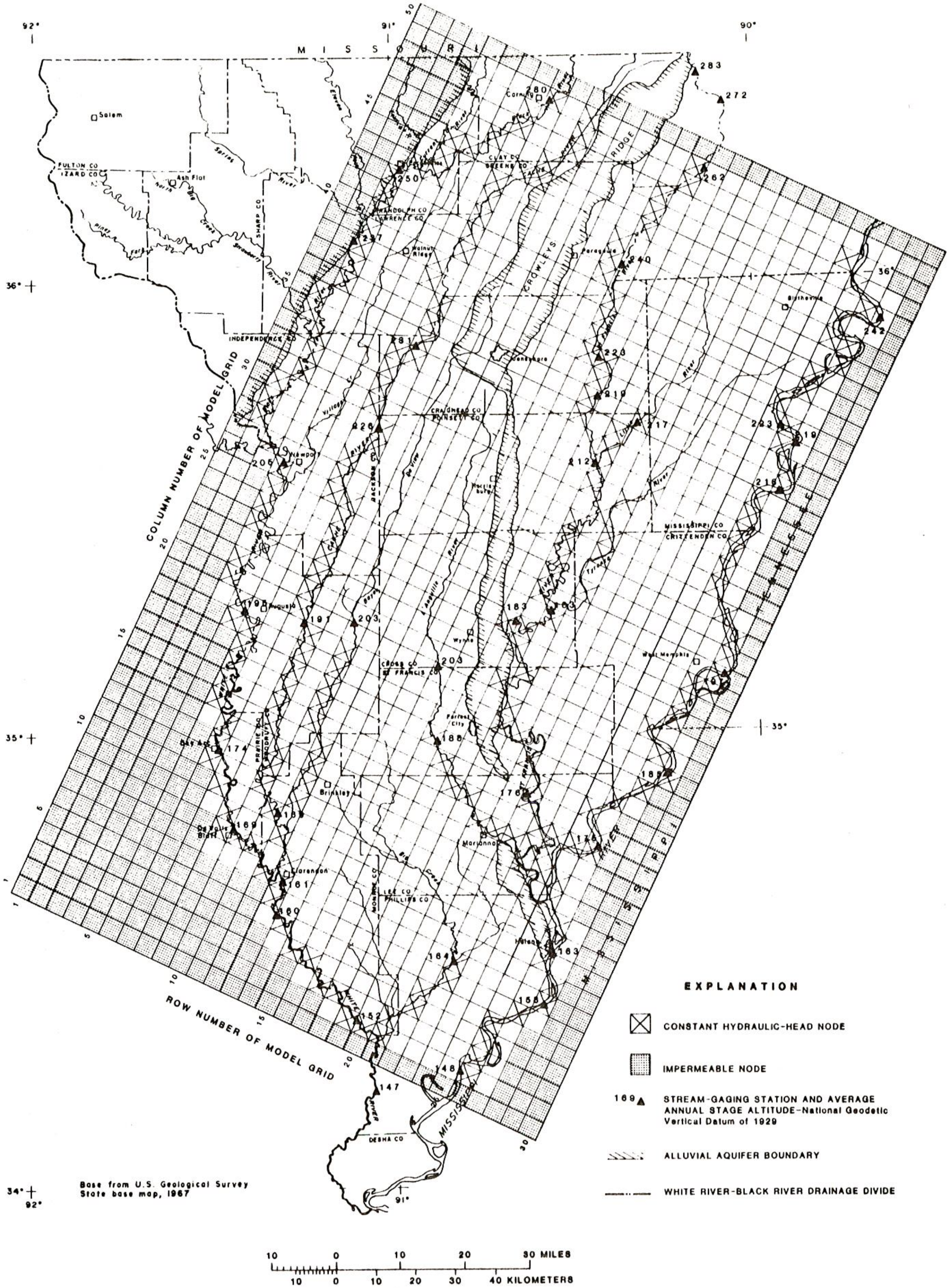
Wells with water-level declines



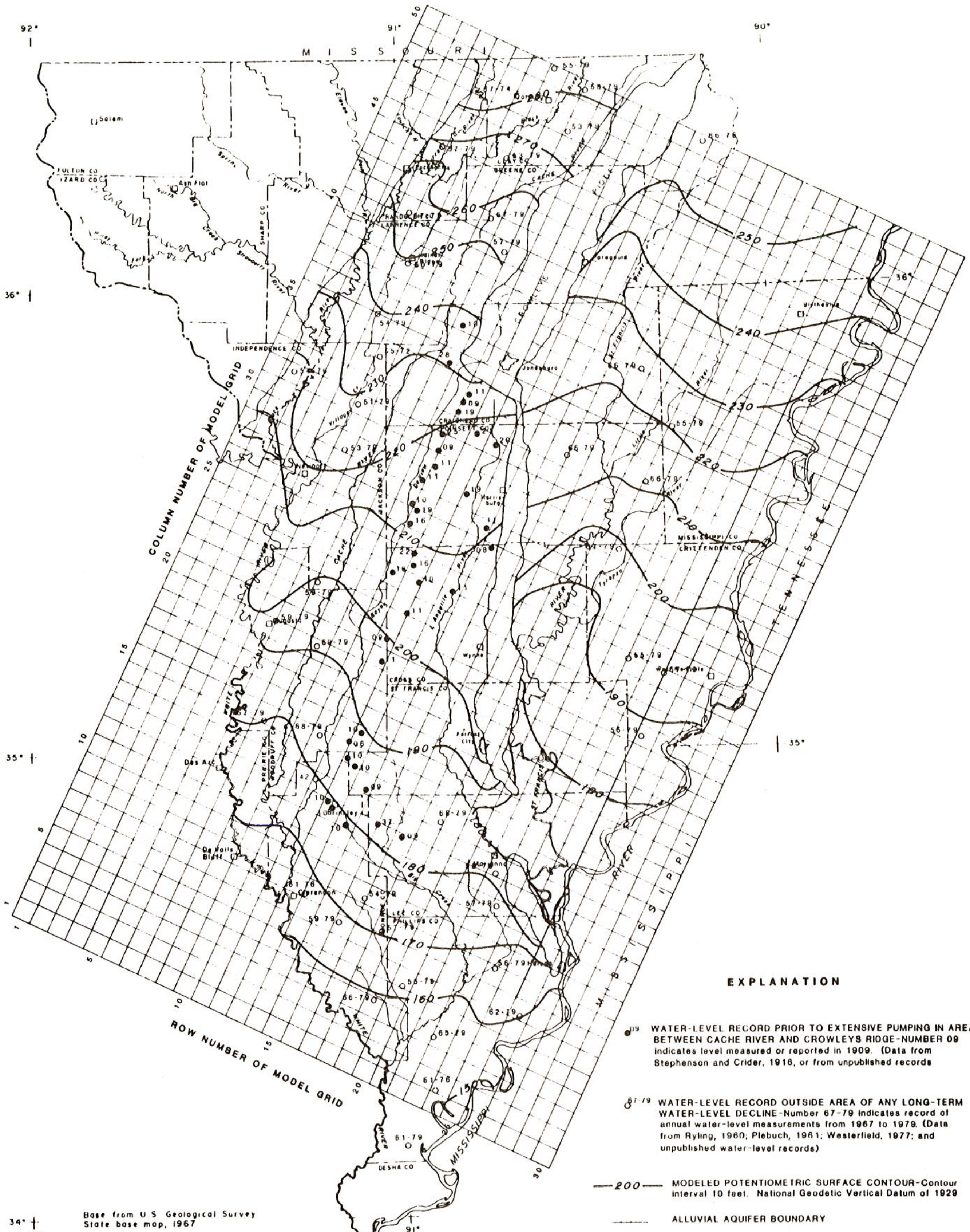
HYDROGRAPHS SHOWING WATER-LEVEL FLUCTUATIONS AND DECLINES IN SELECTED WELLS, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS



MAP SHOWING DISSOLVED-SOLIDS CONCENTRATION IN WATER FROM THE ALLUVIAL AQUIFER, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS



MAP SHOWING GRID SYSTEM OF THE MODELED AREA, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS



EXPLANATION

●09 WATER-LEVEL RECORD PRIOR TO EXTENSIVE PUMPING IN AREA BETWEEN CACHE RIVER AND CROWLEYS RIDGE-NUMBER 09 indicates level measured or reported in 1909. (Data from Stephenson and Crider, 1916, or from unpublished records

○67-79 WATER-LEVEL RECORD OUTSIDE AREA OF ANY LONG-TERM WATER-LEVEL DECLINE-Number 67-79 indicates record of annual water-level measurements from 1967 to 1979. (Data from Ryling, 1960; Plebuch, 1961; Westerfield, 1977; and unpublished water-level records)

—200— MODELED POTENTIOMETRIC SURFACE CONTOUR-Contour interval 10 feet. National Geodetic Vertical Datum of 1929

ALLUVIAL AQUIFER BOUNDARY

WHITE RIVER-BLACK RIVER DRAINAGE DIVIDE

10 0 10 20 30 MILES

10 0 10 20 30 40 KILOMETERS

MAP SHOWING MODELED POTENTIOMETRIC SURFACE OF THE ALLUVIAL AQUIFER FOR STEADY-STATE CONDITIONS, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

PREPARED IN COOPERATION WITH THE
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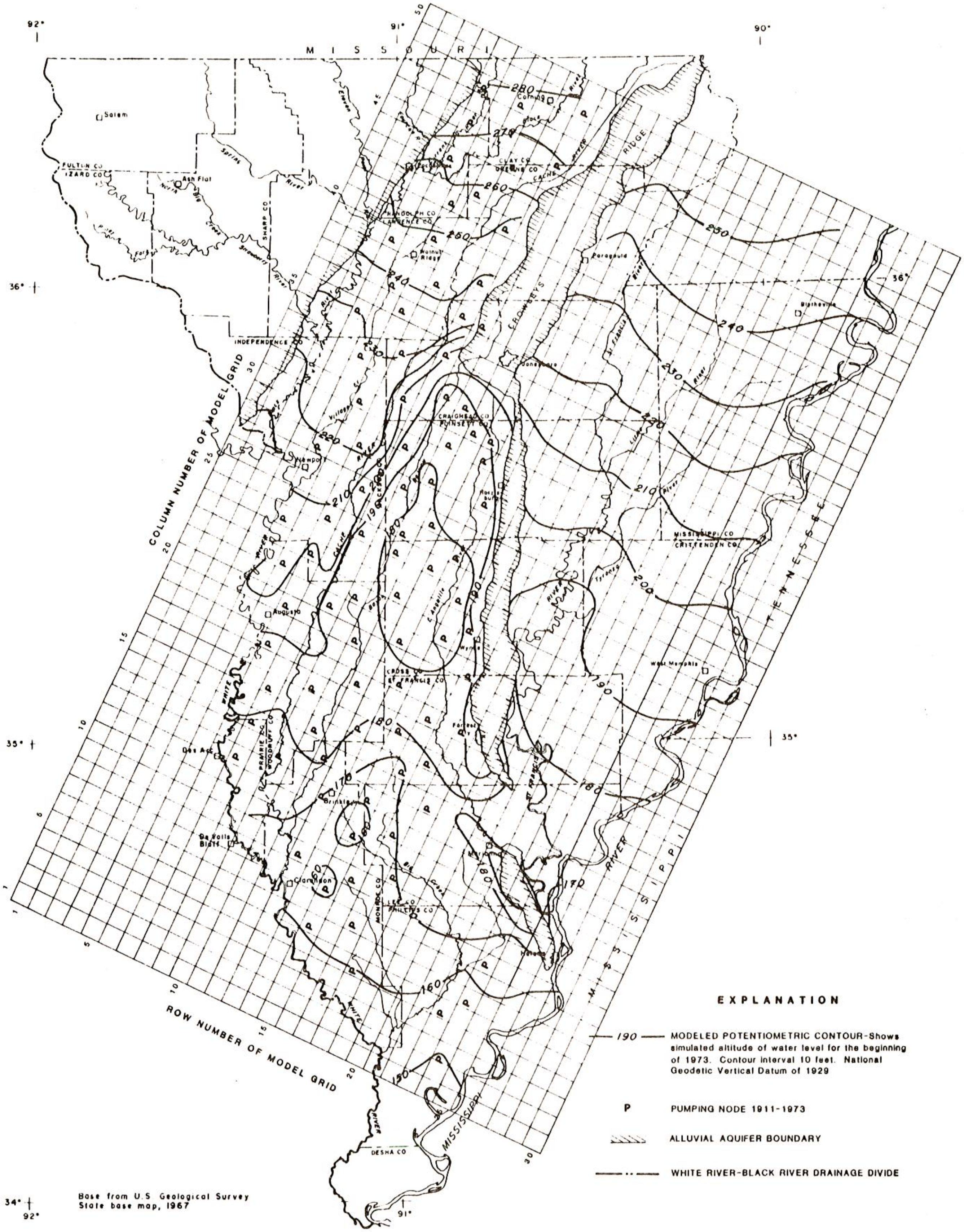


EXPLANATION

190 — MODELED POTENTIOMETRIC CONTOUR–Shows simulated altitude of water level for the beginning of 1973. Contour interval 10 feet. National Geodetic Vertical Datum of 1929

P — PUMPING NODE 1911-1973

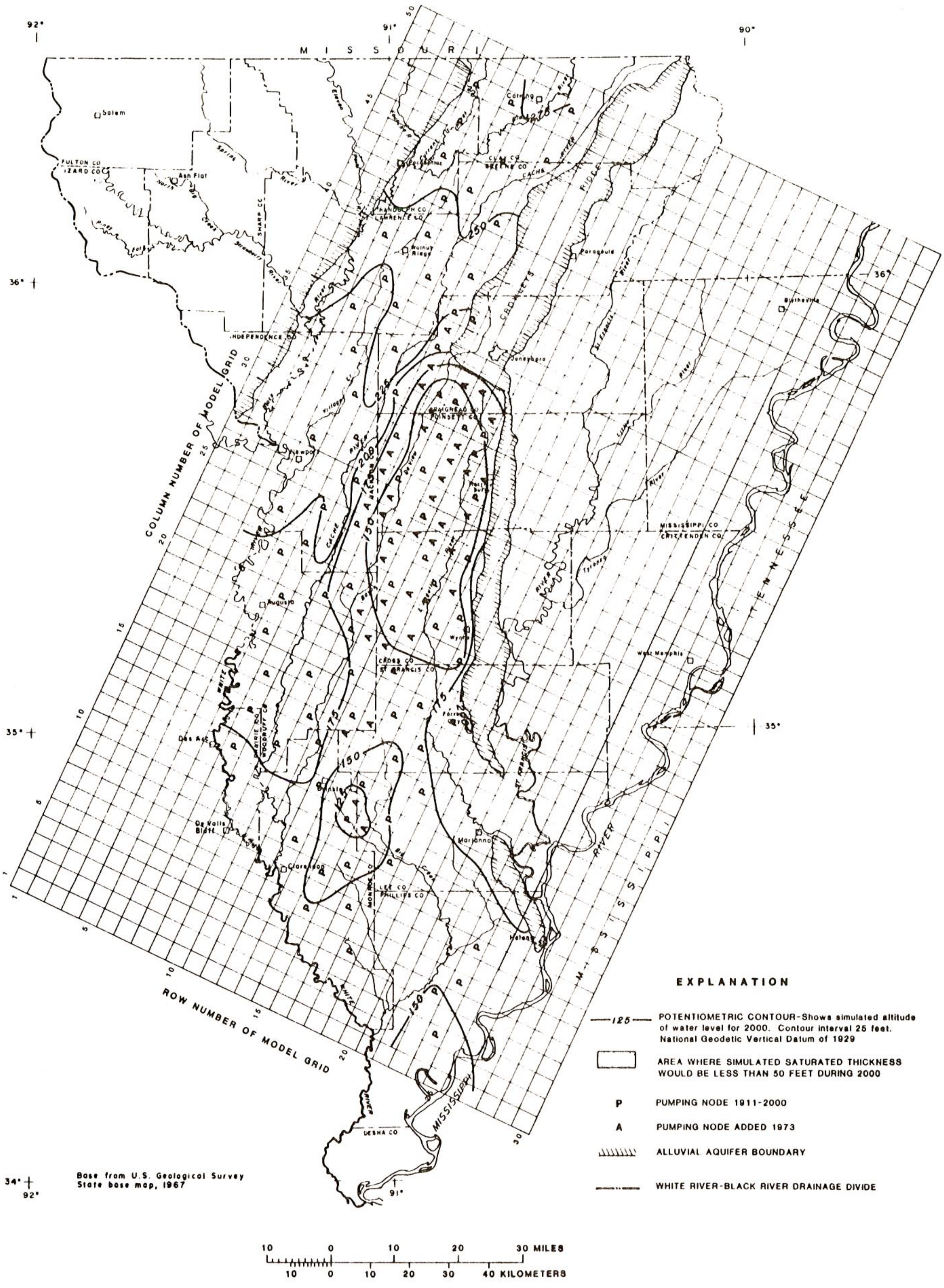
ALLUVIAL AQUIFER BOUNDARY

WHITE RIVER-BLACK RIVER DRAINAGE DIVIDE

10 0 10 20 30 MILES
10 0 10 20 30 40 KILOMETERS

MAP SHOWING MODELED POTENTIOMETRIC SURFACE OF THE ALLUVIAL AQUIFER BEFORE PUMPING DURING 1973, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION



MAP SHOWING MODELED POTENTIOMETRIC SURFACE OF THE ALLUVIAL AQUIFER FOR 2000 AT PUMPING RATE 1, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
ARKANSAS GEOLOGICAL COMMISSION

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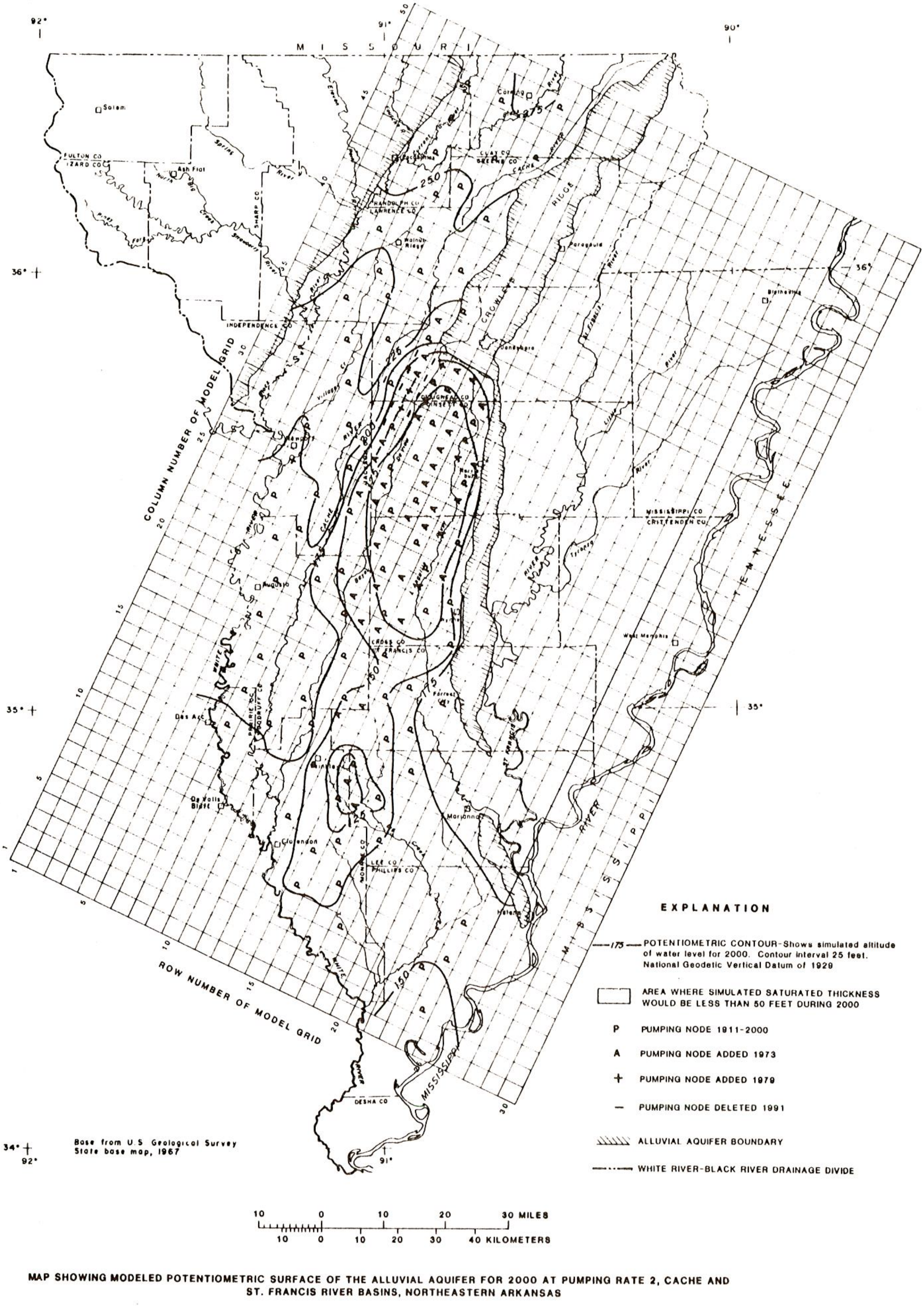
PLATE 13



MAP SHOWING MODELED POTENTIOMETRIC SURFACE OF THE ALLUVIAL AQUIFER FOR 2000 AT PUMPING RATE 2, CACHE AND ST. FRANCIS RIVER BASINS, NORTHEASTERN ARKANSAS