DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS, VICKSBURG DISTRICT
and
THE ARKANSAS GEOLOGICAL COMMISSION

WATER-RESOURCES INVESTIGATIONS REPORT 85-4029

INTRODUCTION

The Mississippi River Valley alluvial aquifer, herein referred to as the alluvial aquifer, is a major source of water supply in the Boeuf-Tensas basin, in southeastern Arkansas. Agriculture, which comprises about 85 percent of the land use in the basin, is heavily dependent on the aquifer for irrigation. In 1980, approximately 238 Mgal/d were withdrawn from the aquifer for this purpose (Holland and Ludwig, 1981). This represents a fivefold increase over 1960 water-use estimates.

Occurrence of saltwater in the alluvial aquifer has been of increasing concern for several years. The presence of saltwater in Lincoln and Desha Counties was documented as early as 1961 (Bedinger and Reed), and in Chicot County as early as 1955 (Onellion and Criner). In recent years, withdrawals from the aquifer in some areas have been suspended, as a result of increasing salinity.

While the existence of areas containing saltwater has been known, the areal extent and degree of contamination within the entire basin has not been determined. In 1983, the U.S. Geological Survey entered into a cooperative program with the Vicksburg District, Corps of Engineers and the Arkansas Geological Commission with the principal objective of determining the extent and magnitude of saltwater in the alluvial aquifer within the Boeuf-Tensas basin, Arkansas. A secondary objective was to examine the potential source and avenue of intrusion of the saltwater.

BASIN DESCRIPTION

The project area is located in the southeastern corner of Arkansas (fig. 1), and lies entirely within the alluvial flood plain of the Mississippi River. The area is bounded by drainage divides of Bayou Bartholomew and the Arkansas and Mississippi Rivers to the west, north and east, respectively, and the Arkansas-Louisiana State line to the south. The basin in Arkansas covers an area of about 1,375 mi^2, and includes most of Chicot and Desha Counties, and parts of Ashley, Lincoln and Drew Counties.

The interior drainage system in the basin is typified by sluggish meandering streams. Other surface features include abandoned meanders, oxbow lakes, natural levees and irrigation ditches. Surface topography is generally flat, with altitudes ranging from 185 feet above sea level in the northern part of the basin to about 100 feet above sea level in the southern part.

The climate in the area is characterized by hot and relatively dry summers, and mild winters. Approximately 60 percent of the average annual precipitation of about 50 inches, occurs during the months of December through May.

HYDROGEOLOGIC SETTING

Major geologic units which control the flow of freshwater in the basin are described by generalized geologic cross section A-A' in figure 2. The Sparta Sand contains freshwater in the northern part of the basin, and is utilized there for public supply. The formation contains saltwater in the southern part of the basin in Chicot County. The Sparta Sand is overlain by the Cook Mountain Formation, a confining unit.

The Cockfield Formation is a source of water for public and domestic supply throughout much of the basin. The formation yields freshwater except in areas within the southern part of the basin.

The Jackson Formation directly underlies the alluvial aquifer. According to Krinitzsky and Wire (1964), the surface of the Jackson Formation is irregular due to erosion by streams which formed a system of entrenched valleys during the Pleistocene glacial stages. The unit acts as a confining unit between the Cockfield Formation and the alluvial aquifer.

The uppermost unit in the basin is the Quaternary alluvium deposits of the Mississippi and Arkansas Rivers. These deposits, which lie unconformably on the irregular surface of the Jackson Formation, generally grade from coarse sand and gravel at the base, to silt and clay at the surface. The upper part of the alluvium consists of clay and silt, ranging in thickness from less than 5 feet to about 40 feet. This fine-grained material generally functions as a semi-confining bed over the alluvial aquifer (Broom and Reed, 1973). The alluvial aquifer is located in the middle and lower parts of the alluvium, and is made up of fine to coarse sand and gravel. The aquifer ranges in thickness from 50 to 175 feet. Flow within the alluvial aquifer is in the direction of the hydraulic gradient, generally to the south-southeast. The potentiometric surface ranges from about 170 to 175 feet above sea level in the northern part of the basin to about 80 to 85 feet near the Arkansas-Louisiana State line. Differences in direction of movement exist locally due to surface-water drainage.

A more detailed description of the geologic and aquifer flow characteristics within the basin are given in Onellion and Criner (1955), Bedinger and Reed (1961), and Broom and Reed (1973).

METHODOLOGY

The extent and magnitude of saltwater in the alluvial aquifer was largely determined through collection and analysis of aquifer water-quality data. During 1982-84, water samples were collected from 275 irrigation wells that tap the alluvial aquifer within the basin, and analyzed for chloride concentration and specific conductance. Well locations and chloride concentrations are shown in figure 3. In the southern part of the basin, terrain conductivity measurements using the electromagnetic suface geophysical method (Stewart, 1982) were made to augment chloride concentration data. Six traverses ranging in length from 3/4 to 2 1/2 miles were made. Terrain conductivity readings were made at intervals of 300, 600 or 750 feet during each traverse. Traverse locations are shown in figure 3.

The extent of saltwater occurrence in the alluvial aquifer is illustrated in figure 3 by means of lines of equal chloride concentration. These lines are based on data collected during 1982-84. Intervals used are 50, 100, and 200 milligrams per liter (mg/L). For convenience, that part of the aquifer which contains chloride concentrations of greater than 50 mg/L is considered affected by saltwater intrusion. The actual affected part of the alluvial aquifer is probably greater than that indicated by the 50 mg/L line, since the native water concentration is less than 50 mg/L, at least in some areas. Similarly, the term saltwater as used in this report refers to water which contains chloride concentrations of 50 mg/L or greater. This 50 mg/L threshold concentration has no significance regarding the use of water withdrawn from the aquifer. The secondary drinking water standard for chloride concentration is 250 mg/L (U.S. Environmental Protection Agency, 1979). Tolerable limits for agricultural crops are variable, depending largely on soil properties, and individual crop tolerance. Irrigation of agricultural crops with water from the alluvial aquifer containing chloride concentrations greater than 50 mg/L occurs throughout much of the basin.

As part of this investigation, a test well tapping the alluvial aquifer was constructed in the vicinity of an abandoned oil and gas test well and sampled to investigate the abandoned well's potential for being a source of contamination. More detailed analyses of major ions and trace metals were also made from this and other selected wells in an effort to determine the saltwater source.

AREAL EXTENT AND DEGREE OF SALTWATER OCCURRENCE

The occurrence of saltwater in the alluvial aquifer within the Boeuf-Tensas basin is shown in figure 3. Actual chloride concentrations from wells sampled are also shown in figure 3, and range from less than 5 mg/L to greater than 1,300 mg/L. Variations in other chemical constituents are given in table 1.

As shown, a band of water containing chloride concentrations of 50 mg/L or greater extends from near the northern limits of the Boeuf-Tensas basin southward to the Arkansas-Louisiana State line, and comprises approximately 50 percent of the areal extent of the aquifer within the basin. The most severely affected part of the aquifer is in the southern part of the basin in Chicot County, where chloride concentrations as high as 1,360 mg/L were found. Terrain conductivity data indicate that water containing the highest salinity levels in this area occurs in the form of a narrow, meandering band located within the 1,200 mg/L chloride concentration line. Areas containing chloride concentrations greater than 200 mg/L are also evident in Desha and Lincoln Counties. Highest chloride concentrations found within any of these areas were 3C0 mg/L.

Movement of saltwater away from the source area(s) in the basin is largely controlled by ground-water flow patterns in the aquifer; some spreading would also occur through dispersion. The south-southeast hydraulic gradient restricts movement of the saltwater plume westward, as evidenced by the relatively steep chloride concentration gradient in places. Similarly, movement of the saltwater plume eastward is also affected by localized gradient patterns influenced by the Mississippi River and interior drainage. Movement of saltwater from the apparent source area(s) northward, particularly evident in the southern part of the basin in Chicot County, may be the result of a localized reversal of the hydraulic gradient due to seasonal withdrawals for irrigation.

The net change in salinity levels in the aquifer with time are not entirely known. A comparison of the lines of equal chloride concentration in this report with those based on data collected between 1952-58 (Bedinger and Reed, 1961) for Lincoln and Desha Counties indicates that salinity levels have increased in some areas. A similar historical representation of salinity levels in the remainder of the project area is not available.

POTENTIAL SOURCE AND AVENUE OF SALTWATER TO THE ALLUVIAL AQUIFER

Saltwater in the alluvial aquifer can potentially be attributed, at least in part, to both influent seepage from the Arkansas River, and upward intrusion from deeper aquifers. The Arkansas River historically has contained varying degrees of saltwater, ultimately derived from the dissolution of salts from Permian beds in Oklahoma. Prior to the construction of navigational control structures in about 1967, mean monthly chloride concentrations in the river varied seasonally from about 150 mg/L during periods of high flow to about 275 mg/L during periods of low flow. Completion of the navigational control structures resulted in a general decrease in salinity levels, with chloride concentrations in the river ranging between about 35 and 135 mg/L.

Saltwater intrusion would occur when the hydraulic gradient relationship between the river and aquifer is such that the river serves as a source of recharge to the aquifer. According to Bedinger and Reed (1961), prior to 1967 the Arkansas River alternated seasonally as a drain and a source of recharge to the aquifer. After about 1967 when the river stage was artificially raised, the river, above dam no. 2 (fig. 3), became a source of recharge most of the time (Broom and Reed, 1973). The proximity of lines of equal chloride concentration to the Arkansas River in two places and the fact that chloride concentrations in these areas are within the range of those concentrations generally found in the Arkansas River, suggests that at least some of the saltwater in the northern part of the basin is a result of influent seepage from the river. The total extent of the saltwater in the northern part of the basin that has resulted from intrusion from the Arkansas River is not known.

Potential sources of saline ground water occur at varying intervals beneath the alluvial aquifer. Cushing (1966) indicates that all water-bearing formations beneath the Sparta Sand contain saltwater throughout the basin. Payne (1968) shows the Sparta Sand containing saltwater in the southern part of the basin, where dissolved solids concentrations exceed 3,000 mg/L, in places. Recent data also indicates that saltwater occurs locally in the Cockfield Formation in the southern part of the basin where concentrations as high as 1,800 mg/L were found.

The specific mechanism through which the intrusion of this saline ground water to the alluvial aquifer occurs is probably the result of one or more of the following:

1. Upward leakage into the alluvial aquifer where the Jackson confining unit is thinned or absent,
2. Leakage into the alluvial aquifer directly or indirectly along a fault, and
3. Movement through abandoned oil and gas test holes which were drilled throughout the basin.

The degree of maximum chloride concentrations found in the southern part of the basin (1,360 mg/L) suggest that the source of the saltwater in that area is from deeper aquifers. However, actual salinity levels in any of these deeper formations within the area of maximum contamination are not known.

The avenue of upward intrusion to the alluvial aquifer in Chicot County is also indeterminate. The nature of intrusion in this area suggests a line source, rather than a point source such as a well. A likely avenue for the intrusion in the area is movement through the Jackson Formation where that unit has been thinned by erosion, or along a fault. Krinitzsky and Wire (1964) indicate that thinning of the Jackson surface through channel erosion has occurred within the area of contamination. The apparently meandering character of the saltwater band in the alluvial aquifer, also suggests such channeling. However, site specific information showing the effectiveness of the Jackson Formation as a confining unit and the hydraulic gradient relationships between the alluvial aquifer and the Cockfield Formation are not available. The occurrence of saltwater in the Mississippi River alluvial aquifer in Mississippi and Louisiana has also been attributed to the upward movement from the Cockfield Formation where the Jackson Formation is absent or of a less confining character.

Upward movement of the saltwater along a fault is also plausible. The location of a fault near the area of intrusion is shown in Hewitt and others (1949). However, the presence of a fault coinciding with the high chloride levels in Chicot County cannot be substantiated.

A review of known abandoned oil and gas test well sites in this area, revealed one site as a potential source of contamination. However, a water-quality analysis from a well constructed in the alluvial aquifer (well E, fig. 3) adjacent to this test well location yielded water containing chloride concentrations (800 mg/L) considerably less than the maximum concentration (1,360 mg/L) which was found in a nearby well.

Occurrence of saltwater in Lincoln and Desha Counties, at least in part, may also potentially be a result of upward intrusion, although existing data indicate no evidence of saltwater occurrence in the Cockfield or Sparta Sand Formations. Intrusion in these areas could conceivably occur from intrusion of saltwater-bearing formations beneath the Sparta Sand through abandoned oil and gas test wells.

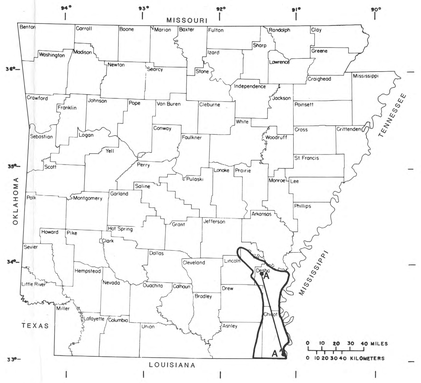

Figure 1.--Location of the Boeuf-Tensas basin in Arkansas and cross section A-A'.

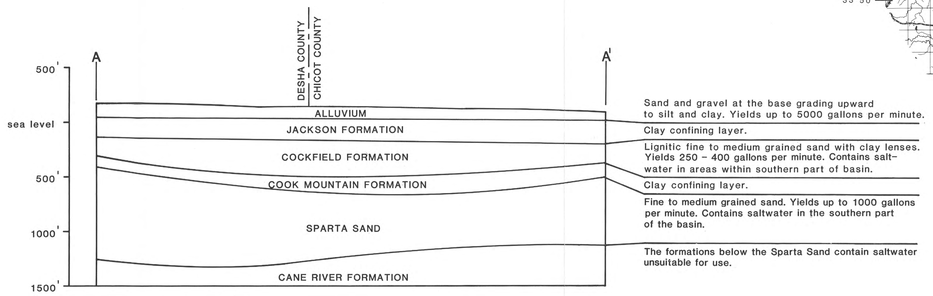

Figure 2.--Generalized geologic cross section A-A' (see figure 1 for location) in the Boeuf-Tensas basin, southeastern Arkansas.

Table 1.—Chemical analyses of water in the alluvial aquifer in the Boeuf-Tensas basin, southeastern Arkansas

[Five digit numbers in parentheses are STORET parameter codes used for computer storage of data]

MAP IDENTIFIER	STATION NUMBER	DATE OF SAMPLE	SPECIFIC CONDUCTANCE (umhos) (00095)	PH (STANDARD UNITS) (00400)	BICARBONATE FET-FLD (mg/L AS HCO3) (00440)	HARDNESS (mg/L AS CACO3) (00900)	CALCIUM DISSOLVED (mg/L AS CA) (00915)	MAGNESIUM, DISSOLVED (mg/L AS MG) (00925)	SODIUM, DISSOLVED (mg/L AS NA) (00930)	POTASSIUM, DISSOLVED (mg/L AS K) (00935)	CHLORIDE, DISSOLVED (mg/L AS CL) (00940)	SULFATE DISSOLVED (mg/L AS SO4) (00945)	FLUORIDE, DISSOLVED (mg/L AS F) (00950)	SILICA, DISSOLVED (mg/L AS SIO2) (00955)	BARIUM, DISSOLVED (ug/L AS BA) (01005)	BORON, DISSOLVED (ug/L AS B) (01020)	IRON, DISSOLVED (ug/L AS FE) (01046)	LITHIUM DISSOLVED (ug/L AS LI) (01130)	IODIDE, DISSOLVED (mg/L AS I) (71865)	BROMIDE DISSOLVED (mg/L AS BR) (71870)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (mg/L) (70300)
CHICOT COUNTY																					
A	332613091255101	82-06-22	550	7.0	---	200	59	13	18	0.8	30	1.0	0.2	33	---	60	20,000	---	---	---	286
B	331501091152201	83-08-24	1,020	7.0	430	440	120	35	45	1.8	30	94	.3	35	300	40	4,300	16	0.034	0.18	611
C	331647091242301	83-06-22	4,810	7.3	600	1,000	270	90	570	5.4	1200	170	.3	24	---	---	---	30	<1.0	5.1	---
D	330728091234101	84-02-16	3,250	---	330	1,000	270	87	260	6.1	800	240	<1	21	200	420	70	40	.029	---	2,110
E	330638091252601	83-08-24	2,250	6.9	210	770	200	66	160	3.3	430	150	.1	28	<100	380	4,600	30	.030	<.10	1,250
DESHA COUNTY																					
F	335428091124801	83-08-23	1,920	6.8	410	620	150	60	140	2.2	200	190	0.3	29	170	70	8,200	15	0.160	0.50	1,060
G	334830091131101	83-06-22	1,280	7.3	730	500	130	42	70	3.3	85	35	.3	28	---	---	---	13	<1.0	.22	---
H	335447091243301	83-08-23	1,400	6.8	280	490	140	35	81	2.3	190	110	.2	25	730	40	9,700	14	.019	.49	776
I	333951091184001	83-08-25	1,300	7.0	440	500	130	43	84	3.0	170	110	.4	34	97	90	5,100	22	.026	.50	897
LINCOLN COUNTY																					
J	340629091393401	83-08-25	1,170	6.7	470	520	150	36	49	1.7	80	17	0.3	28	870	50	11,000	13	0.120	0.29	666
K	340046091322101	83-08-25	1,410	6.8	410	470	130	34	110	2.7	180	130	.2	27	670	40	14,000	16	.026	.52	861

SELECTED REFERENCES

Bedinger, M. S. and Reed, J. E., 1961, Geology and ground-water resources of Desha and Lincoln Counties, Arkansas: Arkansas Geological and Conservation Commission, Water Resources Circular 6, 129 p.

Broom, M. E., and Reed, J. E., 1973, Hydrology of the Bayou Bartholomew alluvial aquifer-stream system, Arkansas: U.S. Geological Survey Open-File Report 73-34, 91 p.

Cushing, E. M., 1966, Map showing altitude of the base of fresh water in coastal plain aquifers of the Mississippi embayment: U.S. Geological Survey Hydrologic Investigations Atlas HA-221, 1 sheet.

Hewitt, F. A., Baker, R. C., and Billingsley, G. A., 1949, Ground-water resources of Ashley County, Arkansas: Arkansas University Institute of Science and Technology, Research Series 16, 35 p.

Holland, T. W., and Ludwig, A. H., 1981, Use of water in Arkansas, 1980: Arkansas Geological Commission Water Resources Summary no. 14, 30 p.

Krinitzsky, E. L. and Wire, J. C., 1964, Ground-water in alluvium of the lower Mississippi valley (upper and central areas), U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, Technical Report no. 3-658, v. I and II, 100 p.

Onellion, F. E., and Criner, J. H., Jr., 1955, Ground-water resources of Chicot County, Arkansas: Arkansas Geological and Conservation Commission Water Resources Circular 3, 27 p.

Payne, J. N., 1968, Hydrologic significance of the lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi and Texas: U.S. Geological Survey Professional Paper 569-A, 17 p.

Stewart, M. T., 1982, Evaluation of electro magnetic methods for rapid mapping of saltwater interfaces in coastal aquifers: Ground water, v. 20, no. 5, p. 538-545.

U.S. Environmental Protection Agency, 1979, National secondary drinking water regulations, Office of Drinking Water, 37 p.

CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
million gallon per day (Mgal/d)	0.0438	cubic meter per second (m^3/s)
inch (in.)	25.4	millimeter (mm)
square mile (mi^2)	2.590	square kilometer (km^2)

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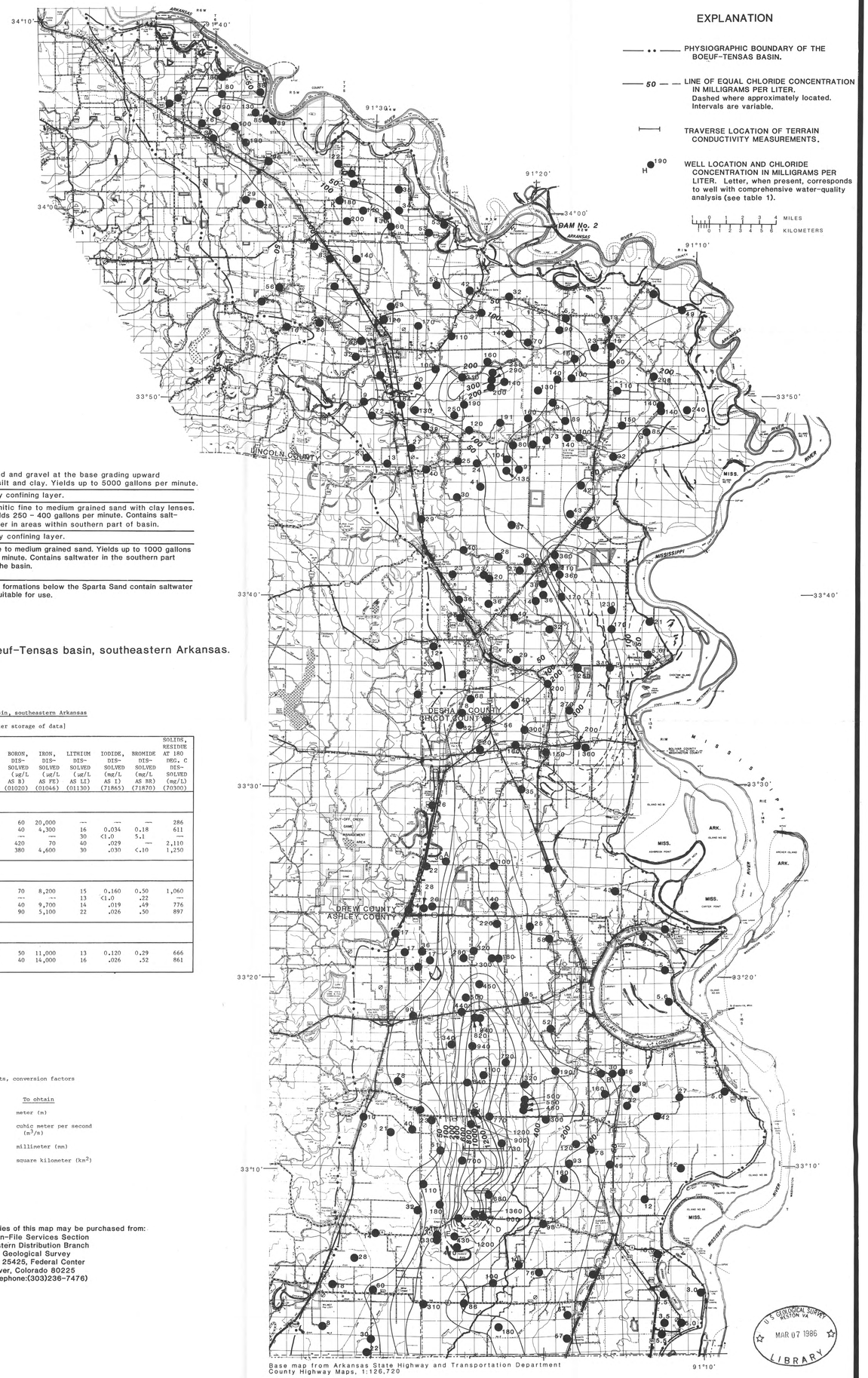

Base map from Arkansas State Highway and Transportation Department County Highway Maps, 1:126,720

Figure 3.--Occurrence of saltwater in the alluvial aquifer within the Boeuf-Tensas basin, Arkansas.

OCCURRENCE OF SALTWATER IN THE ALLUVIAL AQUIFER IN THE BOEUF-TENSAS BASIN, ARKANSAS

By Daniel J. Fitzpatrick