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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

REGIONAL GEOHYDROLOGY OF THE NORTHERN LOUISIANA SALT-DOME BASIN,

PART I, CONCEPTUAL MODEL AND DATA NEEDS

By G. N. Ryals

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Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.9290	meter squared per day (m^2/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	3.785×10^{-3}	cubic meter per minute (m^3/min)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

To convert temperature in degree Celsius (°C) to degree Fahrenheit (°F), multiply by 9/5 and add 32.

REGIONAL GEOHYDROLOGY OF THE NORTHERN LOUISIANA SALT-DOME BASIN, PART I, CONCEPTUAL MODEL AND DATA NEEDS

By G. N. Ryals

ABSTRACT

As part of the National Waste Terminal Storage Program, the U.S. Geological Survey is conducting a regional study of the geohydrology of the northern Louisiana salt-dome basin and developing a regional multilayered ground-water flow model to determine regional flow paths.

In the salt-dome basin the Tokio Formation and Brownstown Marl (Austin aquifer in this report), and Nacatoch Sand of Late Cretaceous age and the Wilcox Group, Carrizo Sand, Sparta Sand, and Cockfield Formation of Tertiary age contain regional aquifers within the maximum potential repository depth of 3,000 feet. The Cretaceous units contain saltwater throughout the basin. The Tertiary units contain freshwater to varying distances downdip from outcrop areas in the basin. Natural flow directions and rates of movement of ground water have been changed in the salt-dome basin by the withdrawal of freshwater and by the injection of wastes (principally oil-field brines) into saline aquifers. Except for the Sparta aquifer, ground-water flow directions are not well known because of a lack of potentiometric data.

A regional test-drilling program, to collect the data needed to document concepts of the flow system and to quantify inputs to the planned ground-water flow model, has been proposed. The Sparta aquifer is being modeled first because data are available for the unit. As regional test drilling provides data on other units, those units will be added to the model developed for the Sparta aquifer.

INTRODUCTION

The Department of Energy (DOE), formerly the Energy Research and Development Administration, in 1976 began an expanded waste-management program for both defense and commercially produced radioactive waste. The National Waste Terminal Storage (NWTS) program is an effort by DOE to locate and develop sites in various parts of the country for disposal or storage of commercially produced radionuclides in deeply buried geologic formations. The Office of Nuclear Waste Isolation, Battelle Memorial Institute, at Columbus, Ohio, administers the NWTS program for DOE. As part of the program, salt domes in the Gulf Coast Region of Texas, Mississippi, and Louisiana (the northern Louisiana salt-dome basin) are being considered for their suitability as repositories. Law Engineering Testing Co. (LETCO) served as the Geologic Project Manager coordinating study activities and data acquisition for the Gulf Coast Region, 1977-81. In Louisiana, the U.S. Geological Survey's participation in the NWTS Program, in cooperation with DOE, has been to describe the regional geohydrology of the northern Louisiana salt-dome basin and to develop a regional multilayered ground-water flow model. This report presents a brief conceptual model of the ground-water flow system of the northern Louisiana salt-dome basin, a discussion of the modeling effort, and outlines data needs to accomplish the modeling.

Location

The northern Louisiana salt-dome basin has an area of about 3,000 mi^2 and includes all or parts of 11 parishes in north-central and northwestern Louisiana. The area of interest for the ground-water flow model shown in figure 1 is considerably larger than the northern Louisiana salt-dome basin, as most of the aquifers have regional extent, and ground-water flow within the basin is part of regional patterns. Model boundaries will extend beyond the principal area of interest to incorporate aquifer boundary conditions.

Repository Site Selection

The Office of Nuclear Waste Isolation, (ONWI) in the overall program to select a repository site, is using a four-phase approach in which successively more detailed studies are conducted on successively smaller study areas. The first phase consists of regional broad-based evaluations of multistate regions to identify areas that may be suitable for repositories. In the second phase, area studies of about 1,000 mi^2 lead to the selection of locations for further study. The location phase consisting of approximately 30 mi^2 study areas will lead to the identification of a site for an exploratory shaft of a potential repository site or sites in a region. Finally, these potential sites will be studied in detail (10 mi^2 study areas), and one or more sites will be chosen for a test facility leading ultimately to a repository.

In the Gulf Coast Region studies, the four characterization phases are called Regional, Area, Location, and Detailed Site Characterization. In the Regional Characterization studies, 8 of 263 known salt domes were chosen for study in the Area Characterization phase (Law Engineering Testing Company, 1978). Rayburns and Vacherie salt domes in Louisiana (fig. 2) were two of the eight domes chosen for study in the Area phase. The Area Characterization studies, completed in 1980 (Law Engineering Testing Company, 1980a, b, c, d), provided the data for ONWI to select four of the eight salt domes (Office of Nuclear Waste Isolation, 1980) for further study in the Location Characterization phase. Vacherie dome is one of the four domes selected. Currently, plans for Location and Detailed Site Characterization studies are being developed.

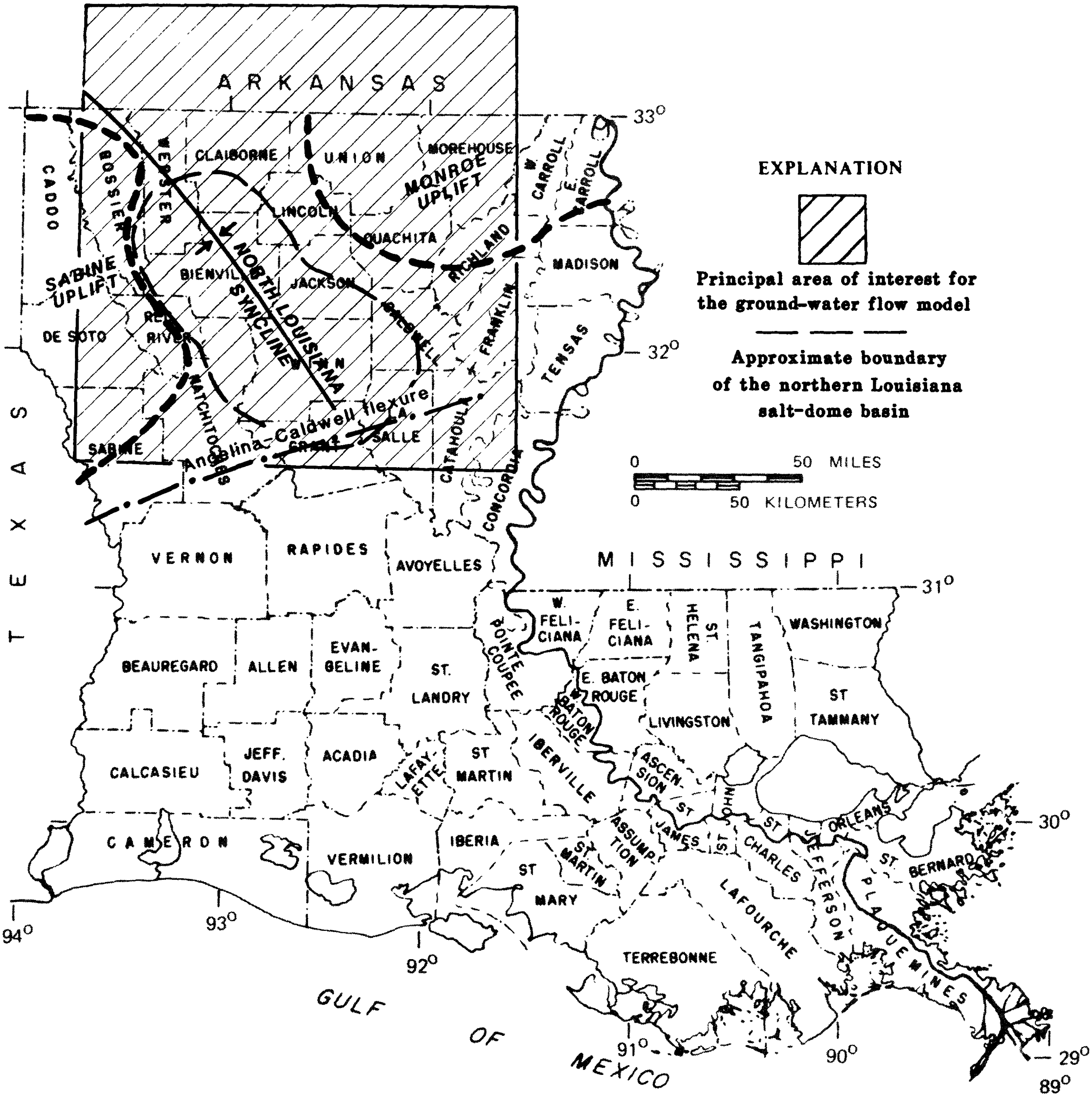


Figure 1.--Location of northern Louisiana salt-dome basin.

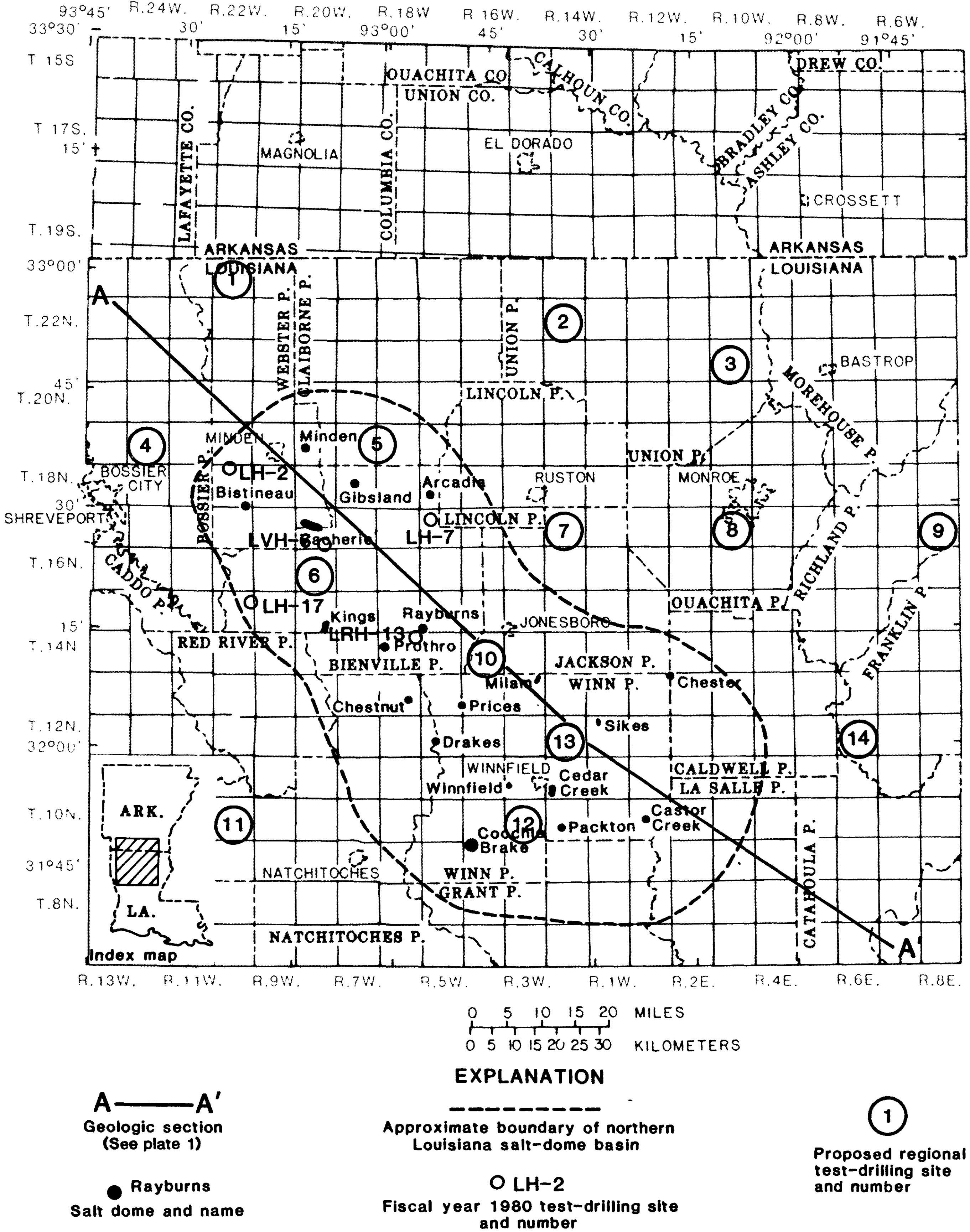


Figure 2.--Location of salt domes, fiscal year 1980 test-drilling sites, and proposed regional test-drilling sites.

The four-phase approach for selecting repository sites seems to be advantageous for geologic formations of large areal extent. Granite, tuff, basalt, and bedded-salt are rock types of large areal extent currently being considered as hosts for a repository. For these rock types, the focus is from regional studies to the most suitable site for a potential repository in the formation as the four-phase program proceeds. As the study areas decrease in size, the regional-flow system is studied in less detail and the local flow system in more detail. However, in formations having large areal extent, the local ground-water flow regime probably would be an integral part of the regional flow system, whereas the salt domes in the Gulf Coast probably are not.

Salt domes are the only geologic formations of small areal extent that are being considered as repositories. During dome development, salt domes have pierced thousands of feet of Cretaceous and Tertiary sediments that contain thick aquifers. Many of these are major aquifers that extend into several states. In a regional setting, the salt domes appear as local anomalies. As a result of the approach of studying successively smaller areas, more detailed attention is given to these anomalous areas for comparing one to another. Because of the complexity of domal areas, localized detailed studies are needed. The regional flow system in the vicinity of the salt domes and related structures has been modified. Therefore, regional as well as local flow systems must be known in detail. As pointed out by Hosman (1978), both regional and local geohydrologic conditions will control movement should a contaminant escape from a salt dome.

Participation by the Geological Survey

In this investigation, the objective of the U.S. Geological Survey in Louisiana is to study the regional geohydrology. The Survey has not participated in the selection of domes for further study, nor does the Survey plan to participate in selecting a specific dome for a potential repository. However, the Survey has cooperated with ONWI and LETCO during the Regional and Area Characterization studies by providing data and preparing specific reports needed for the site selection process. During the Regional Characterization phase, the general geohydrology of the northern Louisiana salt-dome basin was described by Hosman (1978) using existing data. As part of the Area Characterization phase, completed in 1980, a total of 16 test wells were completed at 5 sites in Louisiana (fig. 2). The test-drilling program was planned and managed by LETCO; however, the Survey participated in the selection of sidewall-core depths and screen intervals, sampled test wells for water-quality determinations, and analyzed aquifer tests. Maps of the base of fresh ground water and the potentiometric surface of the Sparta and Wilcox-Carrizo aquifers were prepared (Ryals, 1980a, b, c). In addition, hydrologic data from the vicinity of the Vacherie and Rayburns salt domes were compiled (Ryals and Hosman, 1980).

CONCEPTUAL MODEL OF AQUIFER SYSTEM

General Geohydrologic Framework

The main structural feature in north-central Louisiana is the north Louisiana syncline (fig. 1). The syncline encompasses two structural basins (evident on structure maps of Cretaceous units) that are referred to as the northern Louisiana salt-dome basin (fig. 2) because of the presence of 19 known salt domes. The basin is bounded on the east by the Monroe uplift and on the west by the Sabine uplift. The southern part of the basin is bounded by the Angelina-Caldwell flexure, which is at the northern edge of Miocene deposits. To the north the basin becomes less distinct.

A repository in a salt dome probably will be within a depth range of 1,000 to 3,000 ft below land surface (Office of Nuclear Waste Isolation, 1981). Geologic units above 3,000 ft in the northern Louisiana salt-dome basin are of Late Cretaceous, Tertiary, and Quaternary age (table 1). The Upper Cretaceous units consist of marine chalk, marl, limestone, clay, and sand. The Tertiary units consist of alternating marine clays and nonmarine sands. The Cretaceous and Tertiary units generally dip and thicken to the southeast (pl. 1). The Quaternary deposits consist of clay, sand, and gravel and are nearly flat lying. They were deposited on an irregular, eroded Tertiary surface. Table 1 gives a brief description of the lithology and an indication of the water-bearing characteristics of the geologic units. Detailed discussions of regional geology and hydrology can be found in Boswell and others (1965), Cushing and others (1964 and 1970), Hosman and others (1968), Hosman (1978), and Payne (1968, 1970, 1972, and 1975).

In 1980 as part of the Area Characterization studies, a total of 16 test wells were completed at five test-drilling sites (fig. 2) and the data collection needed for describing the regional as well as near-dome hydrology began. Sites LVH-6, LH-7, and LRH-13 are near salt domes. Data collected from these sites are probably more indicative of near-dome hydrology than of regional hydrology. However, data from sites LH-2 and LH-17 are indicative of regional conditions. Table 2 gives the results of aquifer tests and other pertinent information for the 16 test wells, and chemical analyses of water samples from various aquifers are given in tables 4, 5, and 6. Detailed presentations of the data collected from the Area Characterization test-drilling activities were published as well-completion reports by Law Engineering Testing Company, Marietta, Ga. (1981a, b, c, d, e).

In the salt-dome basin between a depth of 3,000 ft and land surface, six geologic units contain regional aquifers. From oldest (deepest) to youngest, the aquifers are in the Tokio Formation and Brownstown Marl (Austin aquifer in this report), and Nacatoch Sand of Late Cretaceous age, and the Wilcox Group, Carrizo Sand, Sparta Sand, and Cockfield Formation (southeastern part of basin) of Tertiary age. The Wilcox is hydraulically interconnected with the overlying Carrizo; therefore, the

Carrizo and the Wilcox are treated as one hydrologic unit, the Wilcox-Carrizo aquifer. The aquifers are separated by confining layers that retard water movement. Water in each unit is confined under artesian pressure, except in the outcrop where water-table conditions prevail.

In general, under natural-flow conditions, water moves from points of recharge in the outcrop areas downdip to discharge areas in the subsurface. In discharge areas water moves upward into the overlying units because the head increases with depth.

Water enters the Cretaceous aquifers in outcrop areas in southern Arkansas and eastern Texas. Discharge areas for the Cretaceous aquifers have not been well established. Because the sand facies of the Nacatoch Sand (the Nacatoch Sand aquifer) (fig. 3) occurs only in the northwestern part of the project area, that area probably is the discharge area for the unit. The Tertiary aquifers crop out discontinuously in the salt-dome basin and north of the basin. Water discharges from these units into the Mississippi River alluvial aquifer. In the salt-dome basin, Quaternary deposits, which occur as alluvial fill and terrace remnants, are recharged locally by precipitation. In some areas, downward leakage from Quaternary deposits recharges Tertiary aquifers; but most of the discharge from the Quaternary deposits occurs by lateral movement to streams.

Saline water in the aquifers is flushed and displaced by freshwater moving downdip from recharge areas to replace water discharged vertically. Saline water has not been flushed from the Cretaceous sands in the study area but has been flushed to varying degrees in the Tertiary sands. Plate 2 shows the occurrence of freshwater in the study area and the extent of flushing in various units. In general, flushing has progressed from outcrop areas in the basin to about 20 mi downdip in the Wilcox-Carrizo aquifer and more than 100 mi downdip in the Sparta aquifer. Abrupt and large differences in the base of freshwater occur at the downdip limit of freshwater as the base changes from one aquifer to another.

Direction of Ground-Water Flow in the Major Aquifers

Man's activities in the salt-dome basin since the early 1900's have modified the natural flow system. The Wilcox-Carrizo and Sparta aquifers yield water for domestic, public-supply and industrial use; parts of the Wilcox-Carrizo, and the Nacatoch Sand and Austin aquifers are used for disposal of industrial wastes, principally oil-field brines. Some oil and gas is produced from the Austin. Recharge by injection wells has caused local potentiometric-high areas, but discharge (withdrawal) from wells in other areas has caused local and widespread cones of depression. The direction and rate of movement of ground water is controlled by the gradient of the potentiometric surface and by the geometry and hydrologic properties of the aquifers. The relatively simple gradients of the natural flow system have been modified to form a relatively complex flow system.

Table 1.--Generalized post-Lower Cretaceous stratigraphic column for northern Louisiana salt-dome basin and vicinity

Erathem	System	Series	Group	Formation	Description	Aquifer	Hydrologic characteristics
Cenozoic	Quaternary	Holocene and Pleistocene			Terrace remnants alluvial valley fill. Coarse, graveliferous at base grading upward to sand, silt, and clay. Thickness about 50 to 150 ft.	Quaternary aquifers	Contains freshwater. Used locally for rural supplies and some public supplies. Yields range from a few gal/min for small domestic supplies to several thousand gal/min for large irrigation wells. Hydraulic conductivity ranges from 100 to 300 ft/d.
	Tertiary	Miocene	Undivided	Undivided	Interbedded sand and clay. Thickness 400 to 800 ft.	Miocene aquifers	Contains freshwater and saltwater. Hydraulic conductivity ranges from about 25 ft/d to more than 100 ft/d.
		Oligocene	Vicksburg	Undivided	Mostly clay. Thickness 400 to 700 ft.		Generally not water bearing. Local sands yield small quantities of water to wells.
		Eocene	Jackson	Undivided			
			Claiborne	Cockfield Formation	Fine lignitic sand and carbonaceous clay. Thicker sands in lower part. Thickness about 500 to 600 ft.	Cockfield aquifer	Contains freshwater and saltwater. Used mostly for small rural supplies. Hydraulic conductivity ranges from less than 15 ft/d to more than 40 ft/d.
				Cook Mountain Fm.	Clay, partly sandy and glauconitic. Thickness about 100 ft.		Generally not water bearing. Local sands yield small quantities of water to wells.
				Sparta Sand	Fine to medium sand with clay interbeds; lignitic. Thickness 500 to 700 ft.	Sparta aquifer	Contains freshwater and saltwater. Principal aquifer of north-central Louisiana. Large withdrawals by domestic, municipal, and industrial wells. Hydraulic conductivity ranges from 30 ft/d to more than 100 ft/d.
				Cane River Fm.	Mostly clay; some marl. Thickness 200 to 300 ft.		Not water bearing.
				Carrizo Sand	Fine to medium sand; discontinuous. Thickness 0 to 150 ft.	Wilcox-Carrizo aquifer	Contains freshwater and saltwater. Penetrated only by a few shallow wells, mostly in the outcrop. Hydraulic conductivity about 25 ft/d.
		Eocene / Paleocene	Wilcox	Undivided	Interbedded sand, clay, and silt; lignitic. Thickness 500 to 1,500 ft.		Contains freshwater and saltwater. Penetrated mostly by small-yielding rural wells. Larger supplies developed locally where sands are thick. Hydraulic conductivity about 15 ft/d.

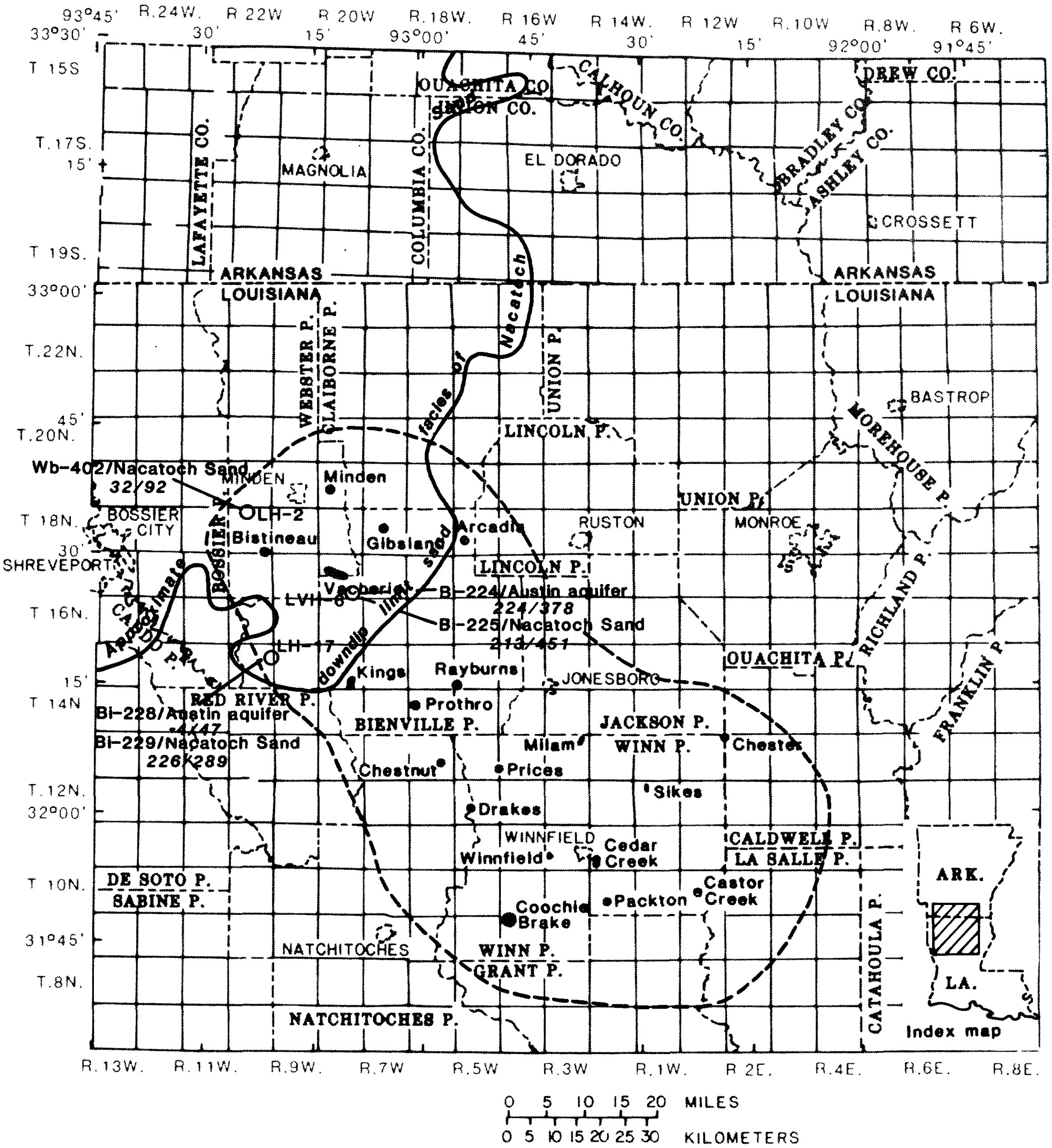
		Paleocene	Midway	Porters Creek Clay, Clayton Fm.	Marine clay with thin calcareous basal unit. Thickness about 600 ft.		Not water bearing.
Mesozoic	Cretaceous	Upper Cretaceous		Arkadelphia Marl	Dark-gray marl, partly chalky. Thickness about 200 ft (60 m).		Not water bearing.
				Nacatoch Sand	Shale, sandy, calcareous; sand facies in upper part. Total thickness 250 to 350 ft (75 to 105 m). Sand thickness 100 to 200 ft (30 to 60 m).	Nacatoch Sand aquifer	Saltwater bearing in sand facies.
				Saratoga Chalk	White fossiliferous chalk; some marl. Thickness about 50 ft (15 m).		Not water bearing.
				Marlbrook Marl	Marl, fossiliferous, chalky. Some glauconitic sand. Thickness 150 to 200 ft (45 to 60 m).		Not water bearing.
				Annona Chalk	Fossiliferous chalk; marl in lower part. Thickness 200 to 250 ft (60 to 75 m).		Not water bearing.
				Brownstown Marl	Calcareous clay and some sand. Thickness about 100 ft (30 m).	Austin aquifer	Not water bearing.
				Tokio Formation	Poorly sorted sands with silt, ash, shale; lignitic, calcareous. Thickness about 300 ft (90 m).		Saltwater bearing.
				Eagle Ford Shale	Micaceous shale with some micaceous and calcareous sandstone. Thickness about 200 ft (60 m).		Not water bearing.
				Woodbine Formation	Interbedded shales and poorly sorted sands; trace of gravel at base. Thickness less than 200 ft (60 m).		Saltwater bearing.

Table 2.--Results of aquifer tests, fiscal year 1980 test-drilling program

Well No.		Location			Screened interval (ft below land-surface datum)	Aquifer	Sand thickness (ft)	Date of test (1980)	Yield (gal/min)	Hydraulic conductivity (ft/d)
USGS	LETCO	Sec.	T. (N.)	R. (W.)						
Wb-401	LH- 2WS	3	18	10	62- 134	Sparta/Terrace---	131	3/17- 3/19	41	----1/
Wb-402	LH- 2A	3	18	10	1,663-1,795	Nacatoch Sand----	120	3/24- 3/26	29	1
Wb-403	LH- 2B	3	18	10	659- 740	Wilcox-Carrizo---	76	3/13- 3/16	86	3
SITE LH-7										
Bi-217	LH- 7WS	8	17	5	[477- 549; 579- 590]	Sparta-----------	89	5/28- 5/30	70	66
Bi-218	LH- 7A	5	17	5	[1,480-1,500; 1,520-1,561]	Wilcox-Carrizo---	55	5/11- 5/13	16	.1
Bi-219	LH- 7B	8	17	5	[943- 959; 976-1,047]	Wilcox-Carrizo---	91	5/16- 5/18	78	8
SITE LRH-13										
Bi-220	LRH-13WS	1	14	6	78- 192	Sparta-----------	183	6/24- 6/26	40	----1/
Bi-221	LRH-13A	1	14	6	[1,047-1,108; 1,118-1,215]	Wilcox-Carrizo---	133	7/ 9- 7/15	36	.4
Bi-222	LRH-13B	1	14	6	564- 662	Wilcox-Carrizo---	94	6/19- 7/22	84	8
SITE LVH-6										
Bi-223	LVH- 6WS	35	17	8	32- 94	Sparta-----------	90	7/29- 7/31	55	----1/
Bi-224	LVH- 6A	35	17	8	[2,537-2,577; 2,582-2,697]	Austin-----------	85	9/ 3- 9/ 7	35	----2/
Bi-225	LVH- 6B	35	17	8	1,831-1,918	Nacatoch Sand----	81	8/21- 8/25	5	<.1
Bi-226	LVH- 6C	35	17	8	909- 970	Wilcox-Carrizo---	65	7/23- 7/27	83	7
SITE LH-17										
Bi-227	LH-17WS	12	15	10	294- 428	Wilcox-Carrizo---	152	9/ 9- 9/16	44	4
Bi-228	LH-17A	12	15	10	1,993-2,022	Austin-----------	26	10/20-10/22	9	----2/
Bi-229	LH-17B	12	15	10	1,312-1,373	Nacatoch Sand----	56	10/ 7-10/ 9	4	<.1

1/Aquifer properties determined from the tests are much lower than values determined from other tests in the area. Because of water-table conditions, the wells probably were not pumped long enough for the determination of aquifer properties.

2/Because of the large amount of gas present, current methods of aquifer-test analysis probably are not capable of calculating reliable aquifer properties. Permeabilities determined from sidewall cores ranged from 6-1,350 millidarcies.



EXPLANATION

Approximate boundary of northern Louisiana salt-dome basin

● Rayburns
Salt dome and name

O LH-2
Area characterization test-drilling site and number

Bi-225/Nacatoch Sand
Well number/stratigraphic unit or aquifer

213/451
Altitude of measured head/measured head corrected to equivalent fresh water head. National Geodetic Vertical Datum of 1929, in feet. (Measured head could be in error because of gas content of water and density differences in water column in well)

Figure 3.--Potentiometric data for the Austin and Nacatoch Sand aquifers.

Austin and Nacatoch Sand Aquifers

Five test wells were completed in sands of the Austin and Nacatoch Sand aquifers during the 1980 test drilling; these are the only known hydrologic-test wells completed in the Cretaceous in northern Louisiana. Aquifer testing (table 2) showed that the two units have relatively poor water-transmitting capabilities. Regional potentiometric-surface maps to define gradients of the two units cannot be constructed at this time because of insufficient data. The potentiometric data that are presented in figure 3 indicate that injection wells in the Nacatoch Sand aquifer and petroleum production from the Austin aquifer may have modified the natural system in the aquifers, because head no longer increases with depth. The data indicate a potential for downward flow from the Nacatoch Sand aquifer through the confining layers to the Austin aquifer. However, site LH-17 (fig. 3) is the only regional site where both the Nacatoch and Austin are screened. Measured water levels may be in error because of the gas content of the water and density differences in the water columns of the test wells. In addition, the sands of the Austin may not be interconnected. Discharge from or recharge to a particular sand bed may not be reflected in other sands of the Austin; thus, water-level comparisons may not be valid.

Wilcox-Carrizo Aquifer

Potentiometric data from seven test wells in the Wilcox-Carrizo resulting from the 1980 drilling program were incorporated with other water-level data to construct a generalized potentiometric-surface map of the Wilcox-Carrizo aquifer (fig. 4). The map indicates that the potentiometric surface slopes away from a high south of Ringgold, La. In the part of the study area where the unit contains saline water, potentiometric data are available for only a few points. Most of the potentiometric data for the Wilcox-Carrizo are within the area where the unit contains freshwater and overlies the sand facies of the Nacatoch (fig. 4). Comparing the few data shown in figures 3 and 4, the head in the Nacatoch is at a higher elevation than the Wilcox-Carrizo; thus, upward flow from the Nacatoch, through the confining layer, to the Wilcox-Carrizo may be occurring. Where the sand facies of the Nacatoch is absent, data are not available to compare water levels of the Wilcox-Carrizo and the underlying Austin aquifer.

Ground-water gradients in the Wilcox-Carrizo have been changed locally by injection of oil-field brines. Data from two 1980 test wells may illustrate these effects. Well Bi-218 screened in the lower part of the Wilcox at site LH-7 has a much higher water level than well Bi-219 screened in the upper part of the unit at the same site (fig. 4). Well Bi-219 has a water level that is consistent with regional levels. A nearby injection well is screened in the Wilcox-Carrizo in the same interval as Bi-218. Well Bi-219 is probably not responding to the stress of the injection well at this time because interverning clay beds retard the vertical movement of injection water.

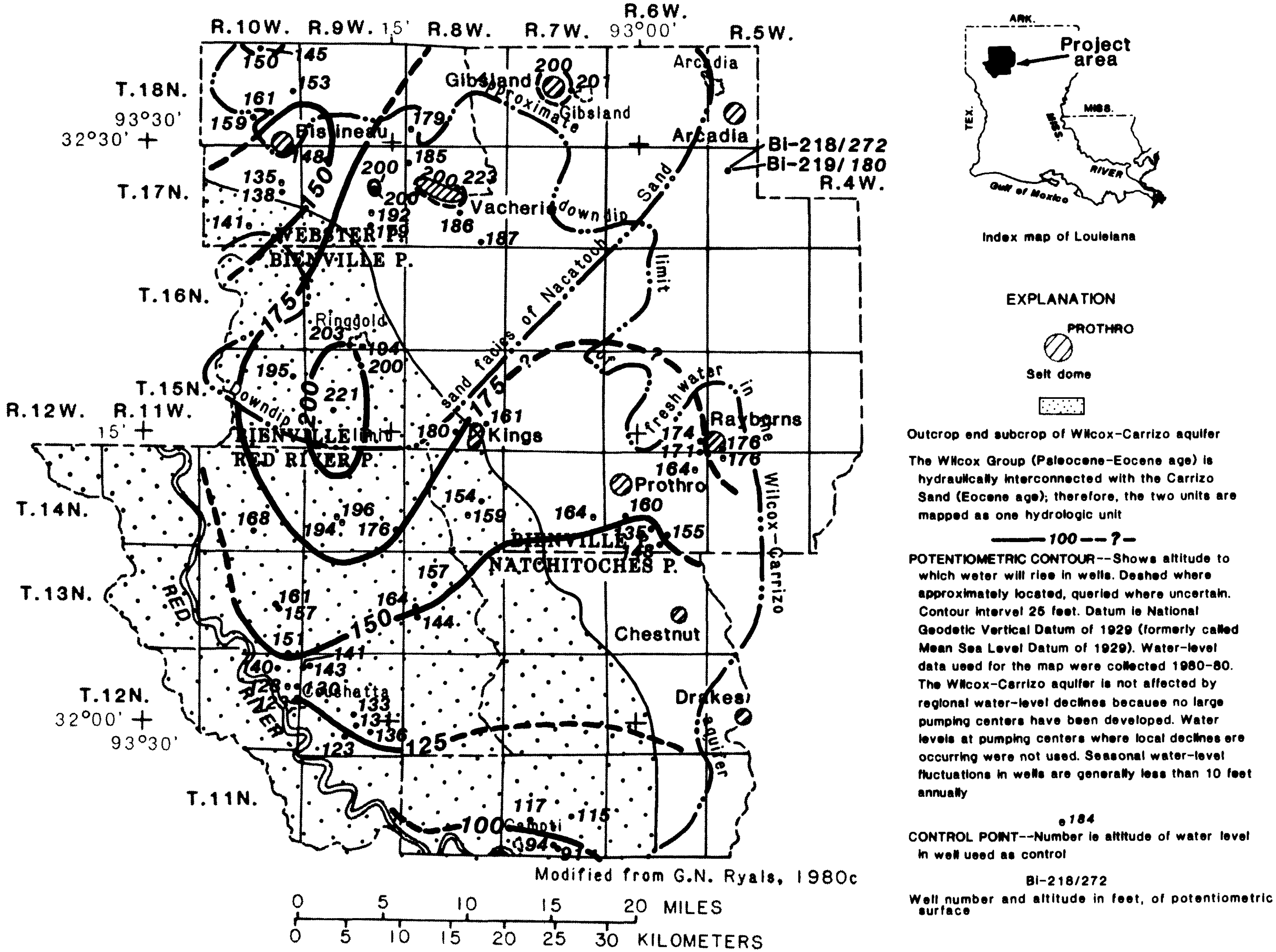


Figure 4.--Potentiometric surface of the Wilcox-Carrizo aquifer; Bienville, Red River, northern Natchitoches, and southern Webster Parishes, La.

Sparta Aquifer

More potentiometric data are available for the Sparta aquifer than for any other water-bearing unit in the study area because of the extent and development of the aquifer. Widespread and intensive pumping of the unit has caused development of numerous cones of depression and a regional lowering of water levels. As shown on the 1980 potentiometric-surface map (fig. 5), major cones of depression are centered at El Dorado, Ark., and Monroe, La. The natural pattern of easterly flow of ground water from outcrop areas to discharge areas in the Mississippi Valley has been significantly modified. Water levels have been lowered below the top of the Sparta in much of northern Louisiana and southern Arkansas. Because of the lack of potentiometric data for the Wilcox-Carrizo, regional flow relations between the Sparta and Wilcox-Carrizo are not well documented. However, because of extensive lowering of water levels in the Sparta, upward flow probably is occurring from the Wilcox-Carrizo toward the Sparta in most of the area.

Under natural flow conditions, movement of water was from the overlying Cockfield Formation (where present) downward through the Cook Mountain confining layer to the Sparta, except in the Mississippi Valley where the Cockfield discharges into the overlying alluvium. The Cook Mountain confining layer contains a discontinuous basal sand bed in parts of the area. Because of the lowering of the water levels in the Sparta, water drains from this sand bed of the Cook Mountain into the Sparta.

MODELING APPROACH AND DATA NEEDS

The multilayered ground-water flow model planned by the Geological Survey for this study will simulate flow in and between aquifers. Regional flow paths and time of travel along any flow path then can be determined under current and projected conditions. Should a contaminant excape from a salt dome, the regional flow model could be used to identify endangered areas and provide information to help cope with the contaminant. The planned model will also provide the basis for a subsequent solute-transport model should one be necessary to solve complex solute-transport problems. Thus, after the regional model is completed, solute-transport modeling techniques, which take into consideration sorptive properties and fluid density, could be incorporated.

The Wilcox-Carrizo, Sparta, and Cockfield aquifers are the principal units to be simulated by the flow model. Because the tentative boundaries of the flow model extend well beyond the salt-dome basin, the Cockfield is included in the model to aid in simulating flow into or out of the top of the Sparta. The Nacatoch Sand may also be an important aquifer to include in the model to aid in simulating flow into or out of the base of the Wilcox-Carrizo. The Austin aquifer is not included in potential modeling plans at this time. Water in the unit, based on data from the 1980 test-drilling program, had a very high gas content and Law Engineering Testing Company (1980c) indicates that there is oil and gas production from the unit. Because the unit may be a multiphase system in the study area, current modeling techniques may not be suitable for simulating flow in the unit.

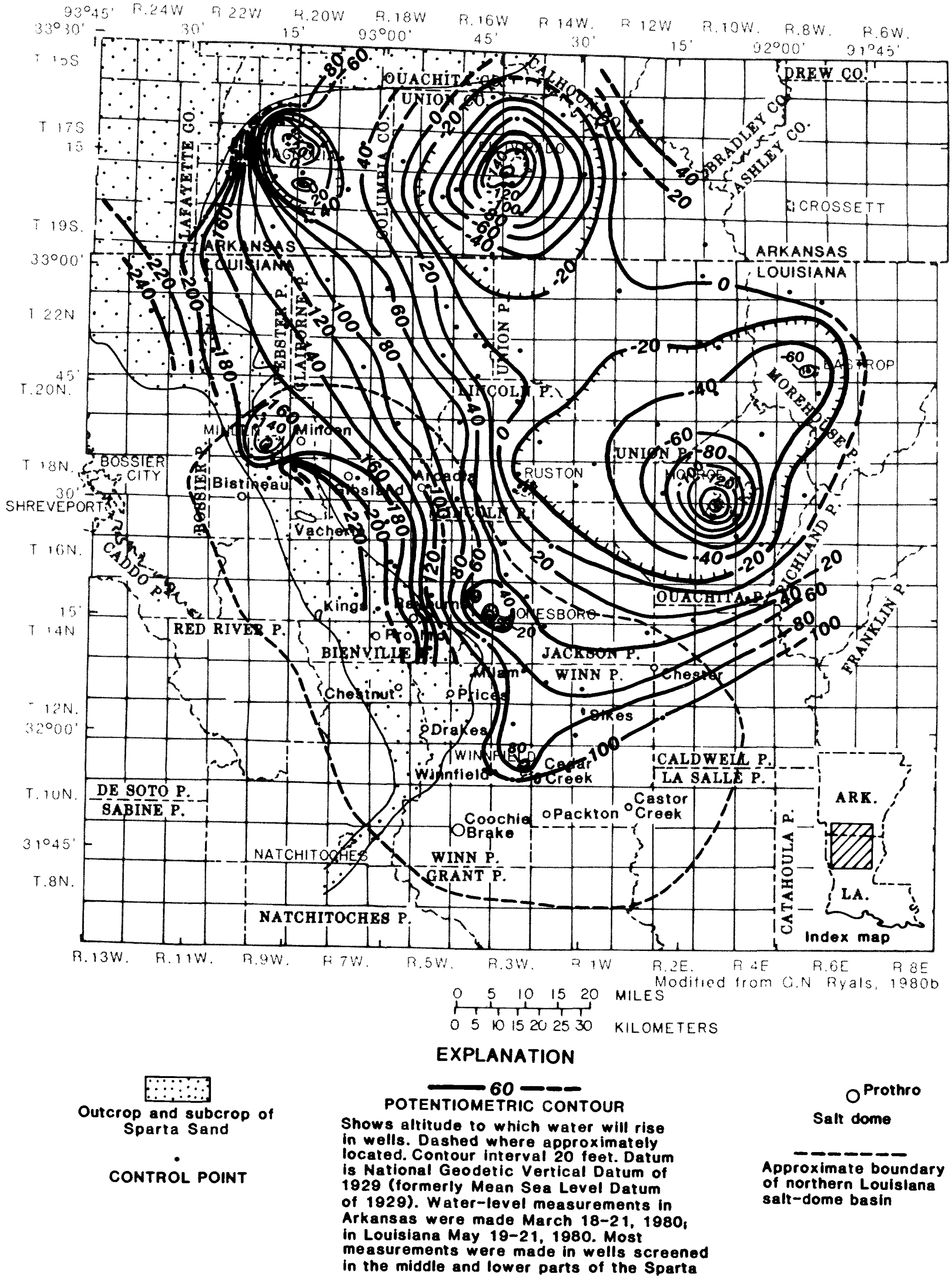


Figure 5.--Potentiometric surface of the Sparta aquifer, northern Louisiana and southern Arkansas, spring 1980.

A three-dimensional model of the Sparta aquifer is being developed to provide a foundation from which to build a detailed model as additional data are collected from regional test holes that are proposed. Additional layers will be added and input into the Sparta model will be refined as more data become available.

Four types of data needed for input to the ground-water flow model and to further develop concepts of the flow system are summarized below. The first is hydraulic properties of the aquifers, such as hydraulic conductivity, transmissivity, and storage coefficient. The second is potentiometric data to define the direction and rate of ground-water flow, both within and between aquifers. The third type of data, hydraulic conductivity of the confining layers, is needed to establish rates of movement between aquifers. No hydraulic conductivity values are known to have been determined for any confining unit in the area. The fourth data category where data is deficient is water chemistry. Ultimately, water chemistry will be very important if a dome is chosen as a repository and solute-transport techniques are used to simulate the ground-water flow system.

Geologic data are available for all of the stratigraphic units, but hydrologic data are sparse. As shown in other sections of the report, hydrologic data are available for areas where the Wilcox-Carrizo, Sparta, and Cockfield aquifers contain freshwater (pl. 2). Electrical logs of wells available in northern Louisiana and southern Arkansas made it possible to define the area of occurrence of freshwater. Hydraulic characteristics of the freshwater section have been determined from test wells and from tests of public-supply and private wells. Most of the pertinent reports that discuss the hydraulic characteristics of the freshwater section are listed in the selected references. Few hydrologic data are available for the saline parts of the Wilcox-Carrizo, Sparta Sand, and Cockfield aquifers and for the Austin and Nacatoch Sand aquifers in the project area.

In 1977 the U.S. Geological Survey in Louisiana proposed a regional test-drilling program to collect the additional data needed for the model. The program was revised in 1978 in coordination with other proposed drilling. The proposed drilling locations are shown in figure 2; table 3 gives anticipated aquifer depths at the test-drilling sites. Because of the 1980 drilling program and other test wells completed in the area since 1978, sites 4, 11, and 12 can be eliminated from the proposed drilling program. Of the remaining locations, sites 2, 7, 8, 9, and 13 have the highest priority as they are needed to provide data for modeling the Wilcox-Carrizo, Sparta, and Cockfield aquifers. Site 1 may prove to be important in establishing potentiometric gradients in the Nacatoch Sand aquifer from outcrop areas in Arkansas to the northwestern part of the salt-dome basin. Should the Austin aquifer be included in the model, the need for additional information at existing drilling sites and at proposed sites will need to be evaluated.

Table 3.--Depth intervals anticipated for aquifers at proposed regional test-drilling sites

Site No.	Parish	Location	Aquifer	Aquifer depth interval (ft below land-surface datum)
1	Webster------	T. 23 N., R. 10 W.	Sparta Sand----	100- 500
			Wilcox-Carrizo-	700-1,200
			Nacatoch Sand--	1,900-2,100
2	Union--------	T. 22 N., R. 2 W.	Sparta Sand----	200- 800
			Wilcox-Carrizo-	1,000-1,500
3	Union--------	T. 21 N., R. 3 W.	Sparta Sand----	200- 800
			Wilcox-Carrizo-	1,100-1,600
4	Bossier------	T. 19 N., R. 12 W.	Wilcox-Carrizo-	100- 500
			Nacatoch Sand--	1,000-1,200
5	Claiborne----	T. 19 N., R. 6 W.1/	Sparta Sand----	200- 800
			Wilcox-Carrizo-	900-1,600
			Nacatoch Sand--	2,200-2,500
6	Bienville----	T. 16 N., R. 8 W.	Sparta Sand----	0- 400
			Wilcox-Carrizo-	500-1,100
			Nacatoch Sand--	1,700-2,000
7	Jackson------	T. 17 N., R. 2 W.	Sparta Sand----	300-1,000
			Wilcox-Carrizo-	1,200-1,800
8	Ouachita-----	T. 17 N., R. 3 E.	Sparta Sand----	200-1,000
			Wilcox-Carrizo-	1,200-1,800
9	Richland-----	T. 17 N., R. 8 E.	Sparta Sand----	700-1,400
			Wilcox-Carrizo-	1,700-2,600
10	Jackson------	T. 14 N., R. 4 W.	Sparta Sand----	0- 350
			Wilcox-Carrizo-	600-1,800
11	Natchitoches-	T. 10 N., R. 10 W.	Wilcox-Carrizo-	200- 600
12	Winn---------	T. 10 N., R. 3 W.	Cockfield------	0- 300
			Sparta Sand----	400-1,100
			Wilcox-Carrizo-	1,300-3,500
13	Winn---------	T. 12 N., R. 2 W.2/	Cockfield------	0- 300
			Sparta Sand----	400-1,100
			Wilcox-Carrizo-	1,300-1,500
14	Franklin-----	T. 12 N., R. 6 E.	Cockfield------	200-1,000
			Sparta Sand----	1,200-2,000
			Wilcox-Carrizo-	2,300-3,500

1/NW/4 of T. 19 N., R. 6 W. or SE/4 of T. 19 N., R. 7 W.

2/Changed from T. 12 N., R. 1 E. in 1978 U.S. Geological Survey drilling proposal.

SUMMARY AND CONCLUSIONS

The method of approach that is being used to select a salt dome for a repository, studying smaller and smaller areas in greater detail, has emphasized the collection of data near potential repository sites. Progress on developing a ground-water flow model to simulate the regional flow system under current and projected conditions has been slowed by a lack of data, particularly for the aquifers that contain saline water. Planned regional geohydrologic studies will define the direction and rate of movement of ground water, which would be necessary information should a contaminant escape from a repository in a salt dome.

In the northern Louisiana salt-dome basin, the interval between land surface and the potential maximum repository depth of 3,000 ft includes the Tokio Formation and Brownstown Marl (Austin aquifer in this report), Nacatoch Sand, Wilcox Group, Carrizo Sand, Sparta Sand, and Cockfield Formation, all of which contain important regional aquifers. The Wilcox Group and Carrizo Sand are interconnected and are treated as one hydrologic unit. Freshwater occurs in parts of the Wilcox-Carrizo, Sparta, and Cockfield aquifers, but the Austin and Nacatoch Sand aquifers contain saline water throughout the basin. Clay and marl units confine the aquifer and produce artesian conditions, except in the outcrop where water-table conditions prevail.

Conceptually, under natural conditions regional ground-water flow is from recharge areas of the aquifers downdip toward the southeast. Natural flow patterns have been altered because of man's activities since the early 1900's. Rates and directions of movement have been changed because of freshwater-production wells in the Wilcox-Carrizo, Sparta, and Cockfield aquifers and because of injection wells in the saline aquifers and the saline part of the Wilcox-Carrizo aquifer. Except for the Sparta, potentiometric data are not available to define regional directions of water movement in the aquifers.

Data from test-drilling in 1980 provided some indication of the potential for vertical movement. Water may be moving downward from the Nacatoch Sand aquifer to the Austin aquifer and upward from the Nacatoch (where present) to the Wilcox-Carrizo. Because of extensive development of the Sparta aquifer, water levels have been lowered below the top of the unit in many areas; thus, water probably moves upward from the Wilcox-Carrizo in most of the area. Under natural conditions water movement probably was from the Cockfield to the Sparta, except in discharge areas in the Mississippi River valley.

Concepts of present conditions of regional flow are based on sparse data. Data are available for the freshwater parts of the aquifers; however, for the saline parts, the Austin and the Nacatoch Sand aquifers, few data are available. Data needed to refine the conceptual model and to develop the ground-water flow model include aquifer properties, potentiometric data, hydraulic conductivity of confining beds, and water chemistry. A comprehensive regional test-drilling program has been proposed to obtain the needed data. Sufficient data are available for the Sparta aquifer to develop a limited ground-water flow model. As data from the regional test-drilling program become available, the Sparta model can be expanded and refined to define and evaluate the regional flow system.

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Table 4.--Chemical analyses of water from fiscal year 1980 test wells

Well No.	Location Sec.	Location T.	Location R.	Site No.	Depth of well (feet)	Date of sample (1980)	Specific conductance (µmhos)	pH (units)	Temperature (°C)	Color (platinum-cobalt units)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
SPARTA AQUIFER															
WB-401[1/]	3	18N	10W	LH- 2	134	3-18	320	6.2	19.5	5	68	0	17	6.2	36
BI-217	8	17N	5W	LH- 7	590	5-29	250	6.2	----	30	54	0	17	2.8	25
BI-220	1	14N	6W	LRH-13	192	6-25	76	5.1	19.0	5	22	0	6.3	1.5	3.9
BI-223	35	17N	8W	LVH- 6	94	7-30	20	4.6	18.0	50	4	0	.9	.3	4.1
WILCOX-CARRIZO AQUIFER															
WB-403	3	18N	10W	LH- 2	740	3-15	6,500	6.7	27.0	5	120	0	33	10	1,300
BI-218	5	17N	5W	LH- 7	1,561	5- 7	12,900	7.9	31.5	0	89	0	20	9.3	2,700
BI-219	8	17N	5W	LH- 7	1,047	5-17	4,460	8.0	22.0	30	21	0	5.0	2.0	960
BI-221	1	14N	6W	LRH-13	1,215	7-10	719	8.3	29.5	30	19	0	6.6	.5	150
BI-222	1	14N	6W	LRH-13	662	6-20	656	8.3	25.0	60	8	0	2.7	.4	160
BI-226	35	17N	8W	LVH- 6	970	7-24	7,700	8.4	28.5	5	42	0	11	3.5	1,500
BI-227	12	15N	10W	LH-17	428	9-10	340	7.6	22.5	0	98	-----	30	5.6	33
NACATOCH SAND AQUIFER															
WB-402	3	18N	10W	LH- 2	1,795	3-23	-------	7.2	38.5	20	2,700	2,500	650	260	17,000
BI-225	35	17N	8W	LVH- 6	1,918	8-22	183,000	7.0	----	40	4,300	4,100	1,100	370	85,000
BI-229	12	15N	10W	LH-17	1,373	10- 7	45,400	7.9	28.5	--	1,800	1,600	440	160	10,000
AUSTIN AQUIFER															
BI-224	35	17N	8W	LVH- 6	2,697	9- 4	154,000	6.6	42.0	15	6,600	6,500	1,800	510	39,000
BI-228	12	15N	10W	LH-17	2,022	10-21	66,200	7.5	33.0	--	2,700	2,600	800	180	15,000

Well No.	Potassium, dissolved (mg/L as K)	Alkalinity, field (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SIO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
SPARTA AQUIFER--Continued													
WB-401[1/]	2.7	107	130	0	131	2.1	40	0.1	37	196	206	760	30
BI-217	3.9	82	100	0	91	35	7.9	.1	60	193	199	2,500	70
BI-220	2.8	24	40	0	508	4.0	2.7	.3	26	68.0	64.0	1,200	20
BI-223	1.1	8.0	10	0	49	2.1	3.2	.2	16	37.0	33.0	40	2
WILCOX-CARRIZO AQUIFER--Continued													
WB-403	8.8	359	438	0	140	7.0	2,000	.4	15	3,360	3,590	90	80
BI-218	12	513	626	0	13	28	4,000	1.6	15	---------	7,100	190	40
BI-219	4.4	990	1,210	0	19	.1	880	3.0	13	2,460	2,460	150	0
BI-221	1.9	250	310	-	2.5	24	61	.2	17	441	412	50	10
BI-222	1.3	320	408	0	3.1	4.3	10	.3	15	403	388	1,600	90
BI-226	5.5	404	493	1	3.0	3.6	2,100	.8	60	3,760	3,930	150	30
BI-227	2.1	165	-----	-	-----	.6	8.0	.2	28	215	206	260	70
NACATOCH SAND AQUIFER--Continued													
WB-402	77	157	192	0	19	77	30,000	.5	14	51,100	48,200	2,500	100
BI-225	31	146	178	-	28	2,400	130,000	.2	4.1	223,000	219,000	18,000	450
BI-229	37	124	-----	-	3.0	31	17,000	.7	11	28,200	27,800	4,300	170
AUSTIN AQUIFER--Continued													
BI-224	160	99	-----	-	-----	150	5,600	.3	9.0	113,000	97,700	7,500	1,000
BI-228	66	-----	-----	-	-----	31	27,000	.7	13	43,800	43,200	8,100	370

1/Terrace deposits also screened in this well.

Table 5.--Trace-metal analyses of water from fiscal year 1980 test wells

Well No.	Location Sec.	T.	R.	Site No.	Depth of well (feet)	Date of sample (1980)	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)
							SPARTA AQUIFER						
WB-401[1/]	3	18N	10W	LH- 2	134	3-18	10	1	0	100	0	0	0
BI-217	8	17N	5W	LH- 7	590	5-29	0	0	1	90	<1	<1	0
BI-220	1	14N	6W	LRH-13	192	6-25	0	0	1	100	<1	<1	10
BI-223	35	17N	8W	LVH- 6	94	7-30	0	0	0	20	<1	<1	10
							WILCOX-CARRIZO AQUIFER						
WB-403	3	18N	10W	LH- 2	740	3-15	10	2	0	700	0	0	0
BI-218	5	17N	5W	LH- 7	1,561	5- 7	30	2	0	800	10	0	10
BI-219	8	17N	5W	LH- 7	1,047	5-17	10	0	0	100	0	0	10
BI-221	1	14N	6W	LRH-13	1,215	7-10	0	0	1	80	1	<1	10
BI-222	1	14N	6W	LRH-13	662	6-20	10	0	1	40	<1	<1	10
BI-226	35	17N	8W	LVH- 6	970	7-24	0	0	0	100	10	1	10
BI-227	12	15N	10W	LH-17	428	9-10	10	1	0	200	<1	<1	10
							NACATOCH SAND AQUIFER						
WB-402	3	18N	10W	LH- 2	1,795	3-23	10	3	0	8,800	20	0	30
BI-225	35	17N	8W	LVH- 6	1,918	8-22	0	1	0	1,200	--	0	190
BI-229	12	15N	10W	LH-17	1,373	10- 7	0	1	1	7,000	10	0	40
							AUSTIN AQUIFER						
BI-224	35	17N	8W	LVH- 6	2,697	9- 4	0	0	0	7,500	0	0	60
BI-228	12	15N	10W	LH-17	2,022	10-21	0	1	0	6,000	10	0	70

Well No.	Cobalt, dissolved (µg/L as CO)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)
				SPARTA AQUIFER--Continued							
WB-401[1/]	0	0	760	0	20	30	0.0	0	2	0	130
BI-217	<3	0	2,500	0	20	70	.0	<10	0	1	440
BI-220	<3	1	1,200	3	10	20	.1	<10	7	0	610
BI-223	<3	0	40	1	6	2	.0	<10	0	0	490
				WILCOX-CARRIZO AQUIFER--Continued							
WB-403	0	0	90	0	70	80	.2	0	2	0	80
BI-218	1	0	190	0	200	40	.3	1	3	0	240
BI-219	0	0	150	2	50	0	.2	1	2	0	40
BI-221	<3	0	50	1	10	10	.0	<10	0	0	<3
BI-222	<3	0	1,600	0	8	90	.1	<10	4	0	<3
BI-226	0	0	150	2	70	30	.2	1	0	0	40
BI-227	<3	0	260	0	20	70	.0	<10	0	0	80
				NACATOCH SAND AQUIFER--Continued							
WB-402	0	1	2,500	0	820	100	.0	0	1	0	2,400
BI-225	0	0	18,000	16	240	450	.1	1	2	0	8,400
BI-229	3	5	4,300	2	640	170	.4	2	2	0	560
				AUSTIN AQUIFER--Continued							
BI-224	0	0	7,500	1	700	1,000	.5	0	0	0	1,800
BI-228	2	3	8,100	1	320	370	1.0	0	1	0	1,600

1/Terrace deposits also screened in this well.

Table 6.--Concentrations of radioactive elements in water from fiscal year 1980 test wells

Well No.	Location Sec.	T.	R.	Site No.	Depth of well (feet)	Date of sample (1980)	Gross alpha, dissolved (pCi/L as U-natural)	Gross alpha, suspended total (pCi/L as U-natural)	Gross beta, dissolved (pCi/L as Cs-137)	Gross beta, suspended total (pCi/L as Cs-137)	Gross beta, dissolved (pCi/L as Sr/Yt-90)	Gross beta, suspended total (pCi/L as Sr/Yt-90)
SPARTA AQUIFER												
WB-401[1/]	3	18N	10W	LH- 2	134	3-18	2.3	----	4.3	---	4.4	---
BI-217	8	17N	5W	LH- 7	590	5-29	<1.8	----	2.0	---	1.9	---
BI-220	1	14N	6W	LRH-13	192	6-25	<.4	----	3.0	---	2.8	---
BI-223	35	17N	8W	LVH- 6	94	7-30	<.3	----	1.0	---	.9	---
WILCOX-CARRIZO AQUIFER												
WB-403	3	18N	10W	LH- 2	740	3-15	<49	----	<39	---	<40	---
BI-218	5	17N	5W	LH- 7	1,561	5- 7	<82	----	<80	---	<77	---
BI-219	8	17N	5W	LH- 7	1,047	5-17	<26	----	<20	---	<19	---
BI-221	1	14N	6W	LRH-13	1,215	7-10	<4.1	----	<3.5	---	<3.4	---
BI-222	1	14N	6W	LRH-13	662	6-20	<3.1	----	3.3	---	3.1	---
BI-226	35	17N	8W	LVH- 6	970	7-24	<66	----	<46	---	<44	---
BI-227	12	15N	10W	LH-17	428	9-10	<2.7	----	<1.6	---	<1.6	---
NACATOCH SAND AQUIFER												
WB-402	3	18N	10W	LH- 2	1,795	3-23	<750	----	<560	---	<580	---
BI-225	35	17N	8W	LVH- 6	1,918	8-22	<2,400	----	<2,200	---	<2,100	---
BI-229	12	15N	10W	LH-17	1,373	10- 7	310	6.7	<300	1.4	<280	1.4
AUSTIN AQUIFER												
BI-224	35	17N	8W	LVH- 6	2,697	9- 4	<1,400	----	<1,200	---	<1,100	---
BI-228	12	15N	10W	LH-17	2,022	10-21	610	19	<520	8.0	<500	7.6

Well No.	Cesium 137, dissolved (pCi/L)	Potassium 40, dissolved (pCi/L as K-40)	Potassium 40, total (pCi/L)	Radium 226, dissolved, planchet count (pCi/L)	Radium 226, dissolved, radon method (pCi/L)	Strontium 90, dissolved (pCi/L)	Tritium, total (pCi/L)	Uranium natural, dissolved (µg/L as U)	Uranium, dissolved, extraction (µg/L)
SPARTA AQUIFER--Continued									
WB-401[1/]	<1.0	--	---	---	0.43	<0.4	<24	<0.6	-----
BI-217	<1.0	--	---	---	.16	<.4	<20	<.6	-----
BI-220	<1.0	--	---	---	.15	<.4	<30	<.6	-----
BI-223	<1.0	--	---	---	.11	<.4	37	---	<.70
WILCOX-CARRIZO AQUIFER--Continued									
WB-403	<2.0	--	---	---	.83	<.4	<24	<.6	-----
BI-218	<1.0	--	---	---	2.6	<.4	<20	<.6	-----
BI-219	<1.0	--	3.3	---	.55	<.4	<20	---	<.50
BI-221	<1.0	--	---	---	.12	<.4	<30	<.6	-----
BI-222	<1.0	--	---	---	.04	<.4	<30	<.6	-----
BI-226	<1.0	--	---	---	.79	<.4	<30	---	<.60
BI-227	<1.0	--	---	---	.30	.4	<10	---	<.60
NACATOCH SAND AQUIFER--Continued									
WB-402	<2.0	--	---	---	67	1.5	<24	---	<14
BI-225	<1.0	--	---	---	120	.7	<10	---	<5.0
BI-229	<1.0	28	---	---	26	<.4	<20	<1.6	-----
AUSTIN AQUIFER--Continued									
BI-224	<1.0	--	---	140	---	3.5	<10	---	<5.0
BI-228	<1.0	49	---	65	65	<.4	<20	<1.6	-----

1/Terrace deposits also screened in this well.

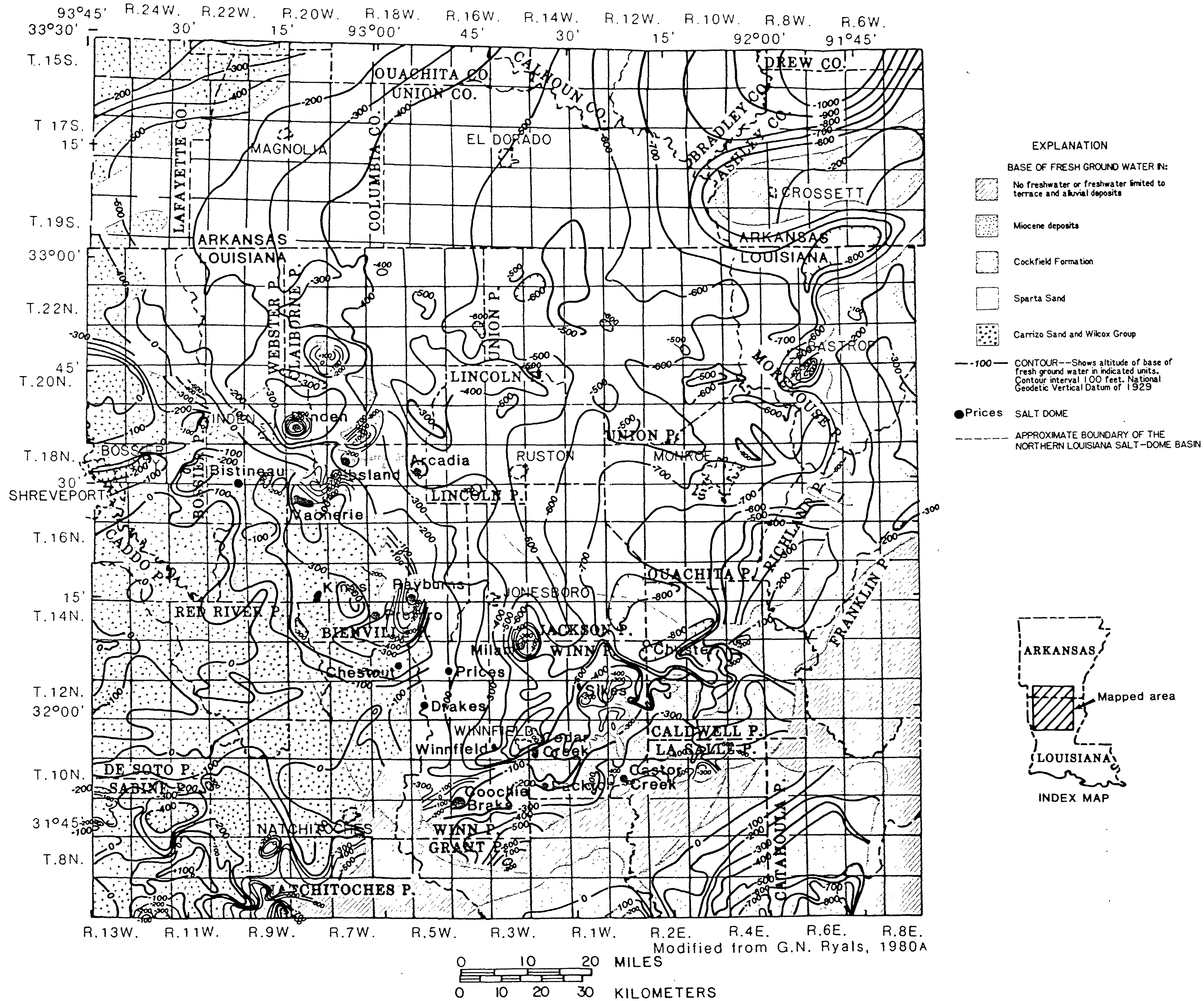

PLATE 2. MAXIMUM DEPTH OF OCCURRENCE OF FRESHWATER, NORTHERN LOUISIANA SALT-DOME BASIN AND VICINITY.

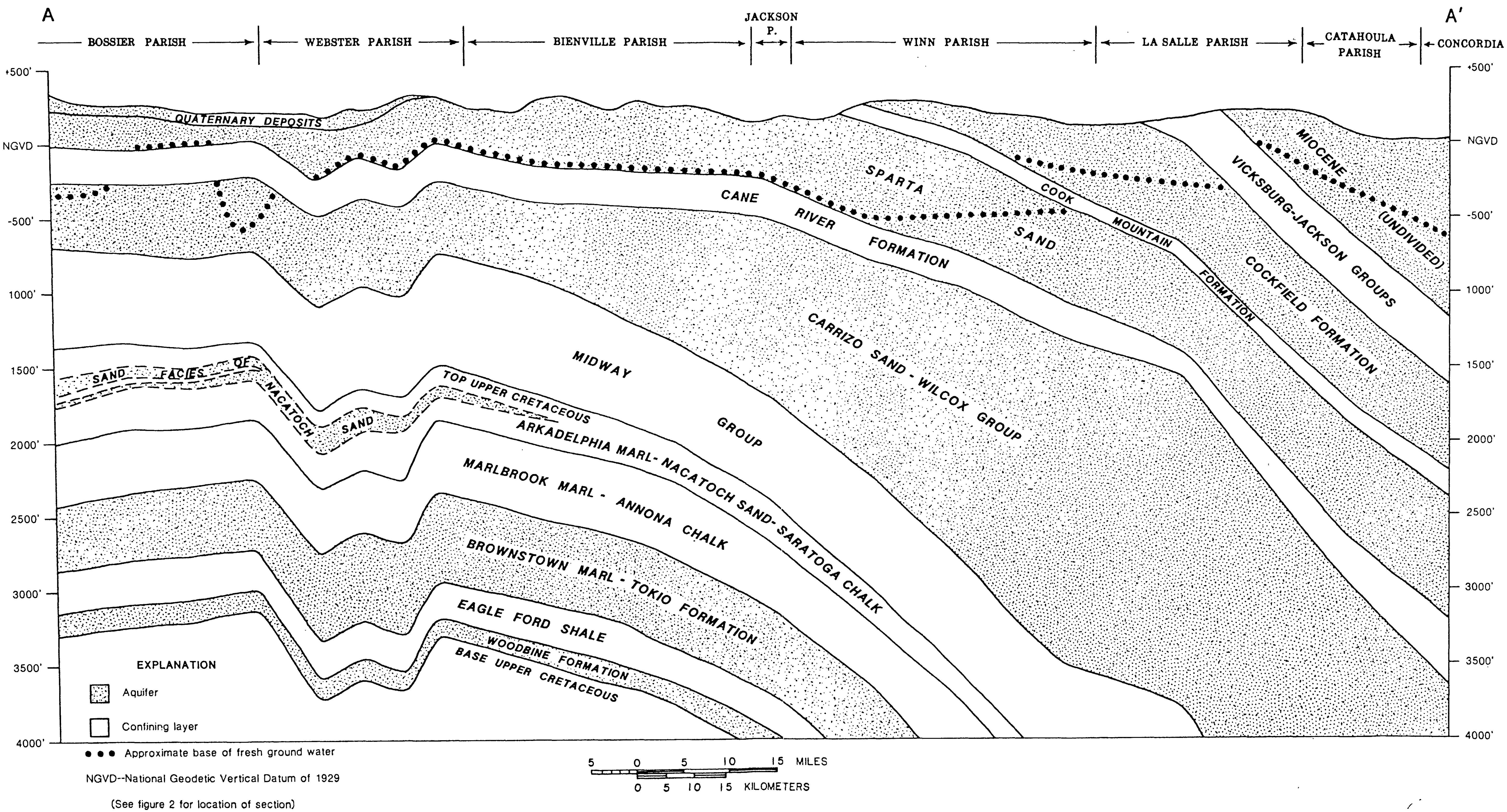

PLATE 1. GENERALIZED NORTHWEST-SOUTHEAST GEOLOGIC SECTION, NORTHERN LOUISIANA SALT-DOME BASIN.