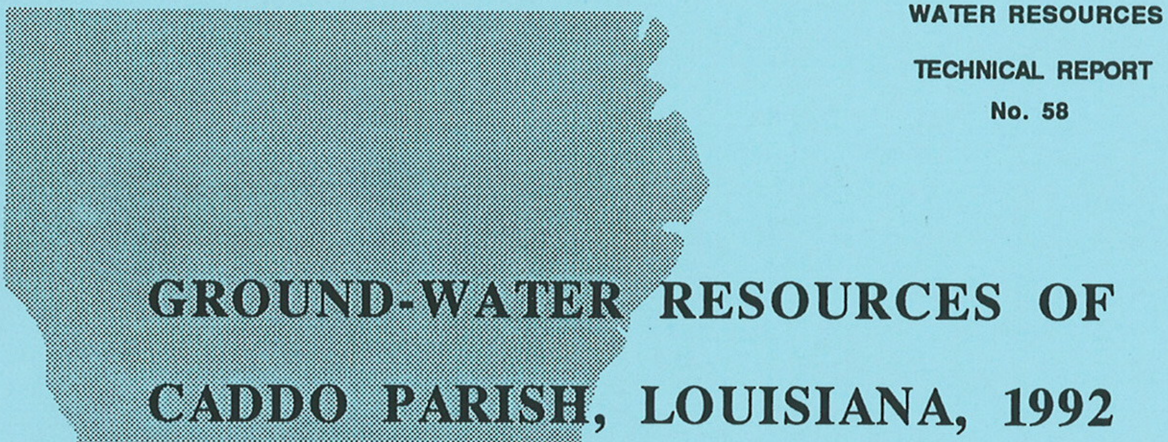
STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
PUBLIC WORKS AND FLOOD CONTROL DIRECTORATE
WATER RESOURCES SECTION

WATER RESOURCES
TECHNICAL REPORT
No. 58

GROUND-WATER RESOURCES OF CADDO PARISH, LOUISIANA, 1992



Prepared by the
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
In cooperation with the
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
and
CADDO PARISH

1996

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
PUBLIC WORKS AND FLOOD CONTROL DIRECTORATE
WATER RESOURCES SECTION
and
PARISH OF CADDO
In cooperation with the
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Water Resources
TECHNICAL REPORT NO. 58

Ground-Water Resources of Caddo Parish, Louisiana, 1992

By
Timothy R. Rapp
U.S. GEOLOGICAL SURVEY

Published by
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
Baton Rouge, Louisiana

1996

STATE OF LOUISIANA
M.J. "MIKE" FOSTER, JR., Governor

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
FRANK M. DENTON, Secretary
PUBLIC WORKS AND FLOOD CONTROL DIRECTORATE
Curtis G. Patterson, Director
WATER RESOURCES SECTION
Zahir "Bo" Bolourchi, Chief

CADDO PARISH
Judy Durham, Parish Administrator
Jim L. Willoughby, Zoning Technician

Cooperative projects with the
U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary
U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

Edward H. Martin
District Chief
U.S. Geological Survey, WRD
3535 S. Sherwood Forest Blvd., Suite 120
Baton Rouge, LA 70816
Telephone: (504) 389-0281

Zahir "Bo" Bolourchi, P.E.
Chief, Water Resources Section
Louisiana Department of
Transportation and Development
P.O. Box 94245
Baton Rouge, LA 70804-9245
Telephone: (504) 379-1434

Jim L. Willoughby
Zoning Technician
525 Marshall St., Suite 200
Shreveport, LA 71101
Telephone: (318) 226-6930

CONTENTS

Page
Abstract 1
Introduction 1
  Purpose and Scope 2
  Description of Study Area 2
  Previous Investigations 4
  Acknowledgments 4
General Hydrogeologic Setting 4
  Description of Local Structural Features 5
  Effects of Structural Features on Ground Water 8
Ground-Water Resources 11
  Red River Alluvial Aquifer 16
    Hydrogeology 16
    Water Quality 22
    Potential for Development 29
  Sparta Aquifer 31
    Hydrogeology 31
    Water Quality 33
    Potential for Development 33
  Cane River Aquifer 36
    Hydrogeology 36
    Water Quality 38
    Potential for Development 38
  Carrizo-Wilcox Aquifer 38
    Hydrogeology 41
    Water Quality 42
    Potential for Development 46
Conclusions 53
Selected References 54

Appendices:

1. Chemical analyses of water from selected wells completed in sands of Quaternary age 58
2. Chemical analyses of water from selected wells completed in sands of Tertiary age 69
3. Oil-test wells and water-test wells used for geologic correlation 88

FIGURES

Page

1. Map showing location of study area in northwestern Louisiana, water-quality sampling sites, trace of cross sections, principal surface-water bodies, and principal municipalities . . 3
2. Diagram showing stratigraphic and hydrogeologic units in Caddo Parish, Louisiana 5
3. Map showing area of Mississippi Embayment 6
4. Generalized north-south hydrogeologic section (A-A') of Caddo Parish, Louisiana. 7
5. Map showing potentiometric surface of the Carrizo-Wilcox aquifer in Caddo Parish, Louisiana 9
6. Detailed west-east hydrogeologic section (B-B') of Caddo Parish, Louisiana 10
7. Geophysical logs of water well Cd-447 and oil-test well 44498 with the base of freshwater at each well. 12
8. Detailed north-south hydrogeologic section (C-C') of northeastern Caddo Parish, Louisiana 13
9. Detailed north-south hydrogeologic section (C'-C") of east-central Caddo Parish, Louisiana 14
10. Detailed north-south hydrogeologic section (C"-C"') of southeastern Caddo Parish, Louisiana 15
11. Geologic section (D-D') showing the Red River alluvial aquifer and associated sediments near Dixie, Louisiana 17
12. Map showing altitude of the base of the Red River alluvial aquifer in eastern Caddo Parish, Louisiana. 18
13. Map showing potentiometric surface of the Red River alluvial aquifer in Louisiana, (A) February 1958, (B) May 1958, and (C) October 1958 20
14. Graph showing water levels for the Red River and observation wells Cd-335 and Cd-501 completed in the Red River alluvial aquifer, Louisiana 21

15-18. Maps showing distribution of:
   15. Sodium concentration in water from the Red River alluvial aquifer in Louisiana 23
   16. Chloride concentration in water from the Red River alluvial aquifer in Louisiana 24
   17. Dissolved-solids concentration in water from the Red River alluvial aquifer in Louisiana. 25
   18. Iron concentration in water from the Red River alluvial aquifer in Louisiana. 26

19. Map showing observation wells sampled for nitrate concentration in the Red River alluvial aquifer in Louisiana. 27
20. Box plots of selected water-quality data for the Red River alluvial aquifer in Louisiana 28

21. Graph showing distance-drawdown relation based on the Theis equation for the Red River alluvial aquifer in Louisiana for indicated pumping rates for 3 wells, a 1-year pumping period, and a transmissivity of 9,350 feet squared per day 30
22. Map showing altitude of the base of the Sparta aquifer in northern Caddo Parish, Louisiana 32
23. Map showing location of water-quality sites for wells completed in aquifers of Tertiary age in Louisiana, 1940-92 34
24. Graph showing distance-drawdown relation based on the Theis equation for the Sparta aquifer in Louisiana for indicated pumping rates for 3 wells, a 1-year pumping period, and a transmissivity of 2,500 feet squared per day 35
25. Map showing altitude of the base of the Cane River aquifer in northern Caddo Parish, Louisiana 37
26. Graph showing distance-drawdown relation based on the Theis equation for the Cane River aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 1,190 feet squared per day 39
27. Map showing altitude of the base of the Carrizo-Wilcox aquifer in Caddo Parish, Louisiana 40
28. Map of cumulative sand thickness for aquifers of Tertiary age in Louisiana 43
29. Box plots of selected water-quality data for the Carrizo-Wilcox aquifer in Louisiana 44
30. Map showing altitude of the base of freshwater in Caddo Parish, Louisiana 45
31. Detailed section (E-E') of Carrizo-Wilcox aquifer showing observation wells completed to various depths and chloride concentration in water from the wells, Caddo Parish, Louisiana 47
32-35. Graph showing distance-drawdown relation based on the Theis equation for the:
    32. Top zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 615 feet squared per day 48
    33. Bottom zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 260 feet squared per day. 49
    34. Bottom zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 2-week pumping period, and a transmissivity of 260 feet squared per day 51
    35. Bottom zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 605 feet squared per day. 52

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per foot (ft/ft)	0.3048	meter per meter
foot per mile (ft/mi)	0.1894	meter per kilometer
square foot (ft^2)	0.09290	square meter
foot squared per day (ft^2/d)	0.09290	meter squared per day
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic mile (mi^3)	4.168	cubic kilometer
pound per square inch (lb/in^2)	6.895	kilopascal
gallon per minute (gal/min)	3.785	liter per minute
gallon per day (gal/day)	3.785	liter per day
million gallons per day (Mgal/d)	3,785	cubic meters per day

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows: °C = (°F - 32)/1.8.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Transmissivity: In this report, the mathematically reduced form for transmissivity, foot squared per day (ft^2/d), is used for convenience. The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$.

Abbreviated water-quality units:

micrograms per gram (µg/g)
micrograms per kilogram (µg/kg)
micrograms per liter (µg/L)
micrometer (µm)
micromoles per gram (µmol/g)
microsiemens per meter (µS/m at 25 degrees Celsius)
microsiemens per centimeter (µS/cm at 25 degrees Celsius)
milligrams per liter (mg/L)
milliequivalents per liter (meq/L)
millimoles per liter (mmol/L)

Ground-Water Resources of Caddo Parish, Louisiana, 1992

By Timothy R. Rapp

Abstract

Four hydrogeologic units containing freshwater with substantial areal extent are present in Caddo Parish, Louisiana: the Red River alluvial, Sparta, Cane River, and Carrizo-Wilcox aquifers. Most of the ground water use in 1990 in the parish was from the Carrizo-Wilcox (2.99 Mgal/d, million gallons per day) and the Red River alluvial aquifers (0.86 Mgal/d).

Water in the Red River alluvial aquifer generally is unsuitable for domestic and industrial use due to hardness and high concentrations of iron. The Sparta aquifer crops out in northern Caddo Parish and contains water that generally is a soft, sodium bicarbonate type. The Cane River aquifer crops out in northern Caddo Parish and contains a large quantity of freshwater that generally is soft. These three aquifers are considered underdeveloped in Caddo Parish based on sand thicknesses and reported water use.

The Carrizo-Wilcox aquifer is the most important aquifer in Caddo Parish due to the aquifer's parish-wide areal extent and because the aquifer contains some freshwater at almost all locations in the parish. Water levels in the Carrizo-Wilcox aquifer have declined only slightly from 1975 levels in most areas of Caddo Parish. More than 75 percent of the chloride and iron concentrations in water from the Carrizo-Wilcox aquifer were below the secondary maximum contaminant levels of 250 milligrams per liter and 300 micrograms per liter, respectively, for drinking water. Water quality varies laterally and vertically in the Carrizo-Wilcox aquifer and is affected by hydrogeologic factors.

INTRODUCTION

Although surface water provides potable water for the city of Shreveport, La., ground water in Caddo Parish is an important source of freshwater for many of the smaller communities that rely on it for their potable and irrigation water needs (Lovelace, 1991, p. 30). To assist Caddo Parish in meeting its future water supply needs and to ensure proper development of its ground-water resources, Caddo Parish and the Louisiana Department of Transportation and Development entered into a cooperative agreement with the U.S. Geological Survey (USGS) to study the ground-water resources of the parish. In 1992, the USGS conducted a study that focused on the fresh ground-water resources of Caddo Parish. Uplifting and erosion of the sedimentary units underlying Caddo Parish have affected ground-water flow and recharge to the aquifers in the parish. This study was done to provide a better understanding of this complex hydrogeologic system and to evaluate the potential for development of the parish's ground-water resources.

Purpose and Scope

This report describes the hydrogeology, water quality, and potential for development of ground-water resources of Caddo Parish. Previously published USGS reports and maps were reviewed for the construction of this report. Reports completed by other State and Federal scientific agencies were consulted during the planning stages of this investigation. Water-quality, water-level, and geophysical-log data collected from State and Federal agencies were interpreted for this report.

The information and data are presented in graphs, cross sections, geologic-structural maps, and box plots. Water-quality information included in this report is a combination of historical data on file at the USGS and recently (1992) collected data for wells completed in aquifers in the study area. Ground-water samples were collected for analysis of common inorganic constituents and trace elements. Water levels measured in tightly cased wells completed in the Carrizo-Wilcox aquifer were used to provide information on ground-water flow patterns and development of the aquifer. Geophysical logs on file with the Louisiana Department of Conservation and the USGS were used to correlate the aquifers across the heavily faulted area of northern Caddo Parish.

Box plots of concentrations of dissolved solids and dissolved sodium, chloride, nitrate, and iron are presented. The U.S. Environmental Protection Agency's (1992) secondary maximum contaminant levels for these constituents are included with the box plots when applicable.

Description of Study Area

The study area is Caddo Parish in northwestern Louisiana (fig. 1). Caddo Parish is approximately 57 mi long (north-south) and is about 12 mi wide at its north end and 32 mi wide at its south end and has a total land area of approximately 891 mi^2. Terrain in the parish consists of rolling, hilly uplands, sloping intermediate terraces, and bottom land in the main valleys. Land surface elevations range from 465 ft in the uplands to 200 ft above sea level in the bottom lands.

Most of Caddo Parish is drained by the Red River and its tributaries. The Red River flows southeastward across northwestern Louisiana. Sediments in the Red River flood plain have created the Red River alluvial aquifer, which is hydraulically connected to the underlying sediments of Tertiary age and the Red River. The southwestern part of the parish, approximately 25 mi^2, is drained by tributaries of the Sabine River. Other major water bodies associated with the parish include Caddo, Cross, Wallace, and Black Bayou Lakes. (See Page and May, 1964.)

Normal yearly precipitation for Caddo Parish, which is measured at the Shreveport Regional Airport, is 43.8 in. Yearly average maximum and minimum temperatures for the parish were 76.2 and 54.6 °F for the period 1951-80 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1982, p. 3).

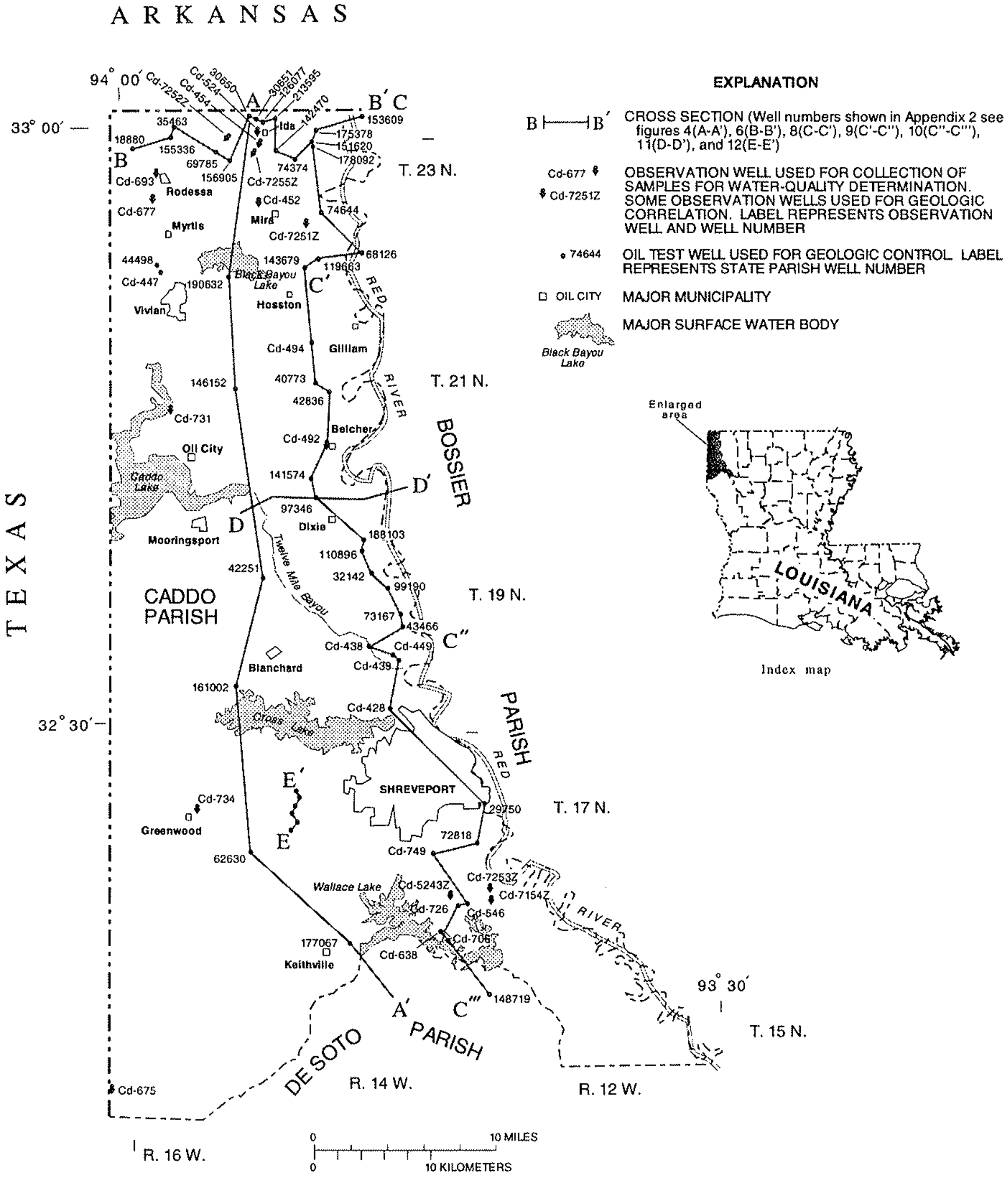


Figure 1. Location of study area in northwestern Louisiana, water-quality sampling sites, trace of cross sections, principal surface-water bodies, and principal municipalities.

Previous Investigations

Reports of previous investigations of the hydrogeologic system underlying Caddo Parish and the surrounding parishes (in Louisiana) and counties (in Arkansas and Texas) were reviewed as background for this study. Page and May (1964) described the ground- and surface-water hydrology of Caddo and Bossier Parishes and provides an overview of the ground-water system. Whitfield (1980) described the chemical characteristics of the water, hydraulic characteristics, flow, and water use for the Red River alluvial aquifer. Whitfield also discussed the effects of petroleum industry exploration and production on the water quality of the Red River alluvial aquifer and other shallow aquifers. The potential effects of lignite mining on the ground-water resources of De Soto Parish were described by Snider (1982) and Snider and Covay (1987); those reports presented more detailed information on the Carrizo-Wilcox aquifer and the hydrogeologic units that can be delineated within this aquifer. Various reports of studies by Texas and Arkansas State agencies and the USGS of the aquifers and hydrologic systems of the states bordering Caddo Parish provided additional information on water use and ground-water flow patterns in aquifers with hydraulic boundaries extending beyond the borders of the parish.

Acknowledgments

The author wishes to thank Richard P. McCulloh, Louisiana Geological Survey, for his assistance in locating a geologic outcrop map (originally constructed by Chet Smith) and interpreting the geology of Tertiary and Quaternary age of Caddo Parish. Paul Albertson, U.S. Army Corps of Engineers, greatly aided the author by procuring the reference by Smith and Russ (1974). Special thanks are due well owners in Caddo Parish for allowing the collection of water-quality samples from their wells and Sid A. Dean, Mayor of Ida, Louisiana, for his assistance and cooperation that enabled ground-water sampling in the study area. He also provided a general history of water use in the Ida area. Thanks also are due to Zahir "Bo" Bolourchi, Chief of the Water Resources Section, Louisiana Department of Transportation and Development, for his substantial contribution to the completion of this report.

GENERAL HYDROGEOLOGIC SETTING

The freshwater hydrogeologic units underlying Caddo Parish consist of sediments of Quaternary and Tertiary ages. The three hydrogeologic units in sediments of Quaternary age are the Red River alluvial aquifer, terrace deposits, and unnamed Pleistocene deposits (fig. 2). The three aquifers in sediments of Tertiary age are the Sparta, Cane River (confining unit), and Carrizo-Wilcox aquifers.

The hydrogeologic system in Caddo Parish is within a major regional geologic structural area and is affected by local structural features, including areally extensive faults. The large regional geologic structure, the Mississippi Embayment includes Louisiana and Mississippi and parts of Texas, Arkansas, Tennessee, Alabama, and other nearby states (fig. 3) (Fenneman, 1938; Hosman and others, 1968). The Mississippi Embayment is a syncline with a depositional axis that generally parallels the Mississippi River and contains sedimentary rocks that reach a maximum thickness of about 18,000 ft in southernmost regions (Cushing and others, 1964, p. B1). The sediments within a wedge-shaped part of the Mississippi Embayment that includes Caddo Parish (fig. 3) are described by Cushing and others (1964).

Description of Local Structural Features

The Sabine uplift, an asymmetric structural dome, is the principal local structural feature that affects the ground-water system of Caddo Parish. The uplift has a principal north-south axis and reaches its apex in T. 20 N., R. 15 W. The overlying sediments have a net elevation change in northern Caddo Parish of about 1,300 ft (fig. 4). The overlying sediments north of the apex dip at a rate of 50 ft/mi; south of the apex the dip is about 20 ft/mi. The sediments of the uplift dip along a secondary east-west axis with the steeper dip east of the apex.

System	Series	Group	Stratigraphic unit	Hydrogeologic unit
Quaternary	Holocene and Pleistocene	Unnamed	Terrace and alluvial deposits	Terrace deposits, Red River alluvial aquifer, and unnamed Pleistocene deposits
Tertiary	Eocene	Claiborne	Cook Mountain Formation	Cook Mountain confining unit
			Sparta Sand	Sparta aquifer
			Cane River Formation	Cane River aquifer[1]
			Carrizo Sand	Carrizo-Wilcox aquifer
		Wilcox	Undivided	
	Paleocene	Midway	Undivided	Midway confining unit

[1] Cane River confining unit has been used in previous reports.

Modified from Ryals, 1983

Figure 2. Stratigraphic and hydrogeologic units in Caddo Parish, Louisiana

At the apex of the Sabine uplift, the Midway confining unit crops out along the border of Caddo Lake. This is the only known outcrop of this confining unit in Louisiana. The Midway confining unit, which underlies the Carrizo-Wilcox aquifer (fig. 2) everywhere in Caddo Parish, is composed predominantly of marine clay and shale but includes subordinate sand and limestone beds (Cushing and others, 1964, p. B14). Although deposits of the Midway Group are predominantly clay and not considered a source of water in Caddo Parish, this clay has hydrogeologic importance because it serves as a stratigraphic marker bed and affects the direction and rate of water movement (Page and May, 1964, p. 37).

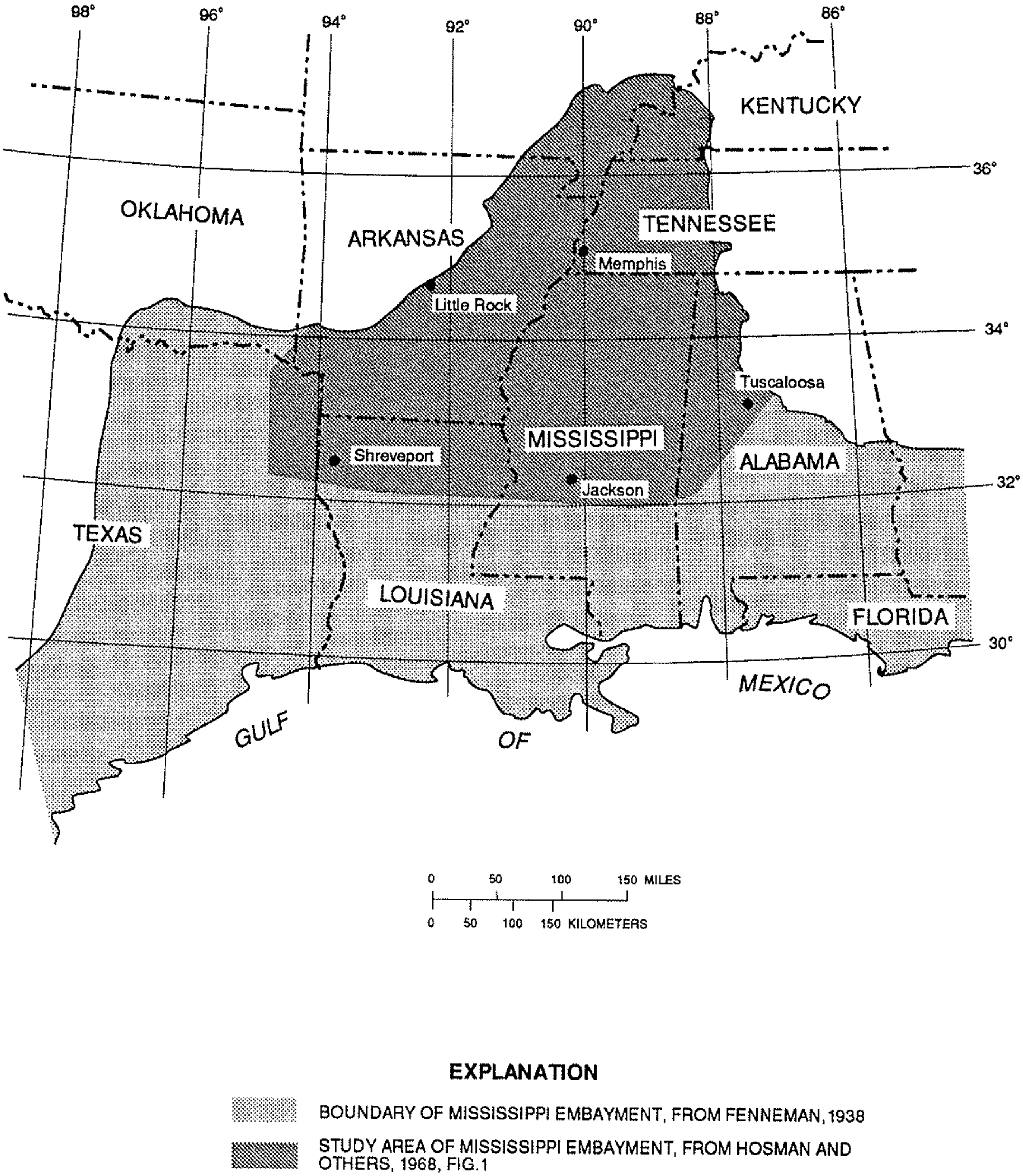


Figure 3. Area of Mississippi Embayment.

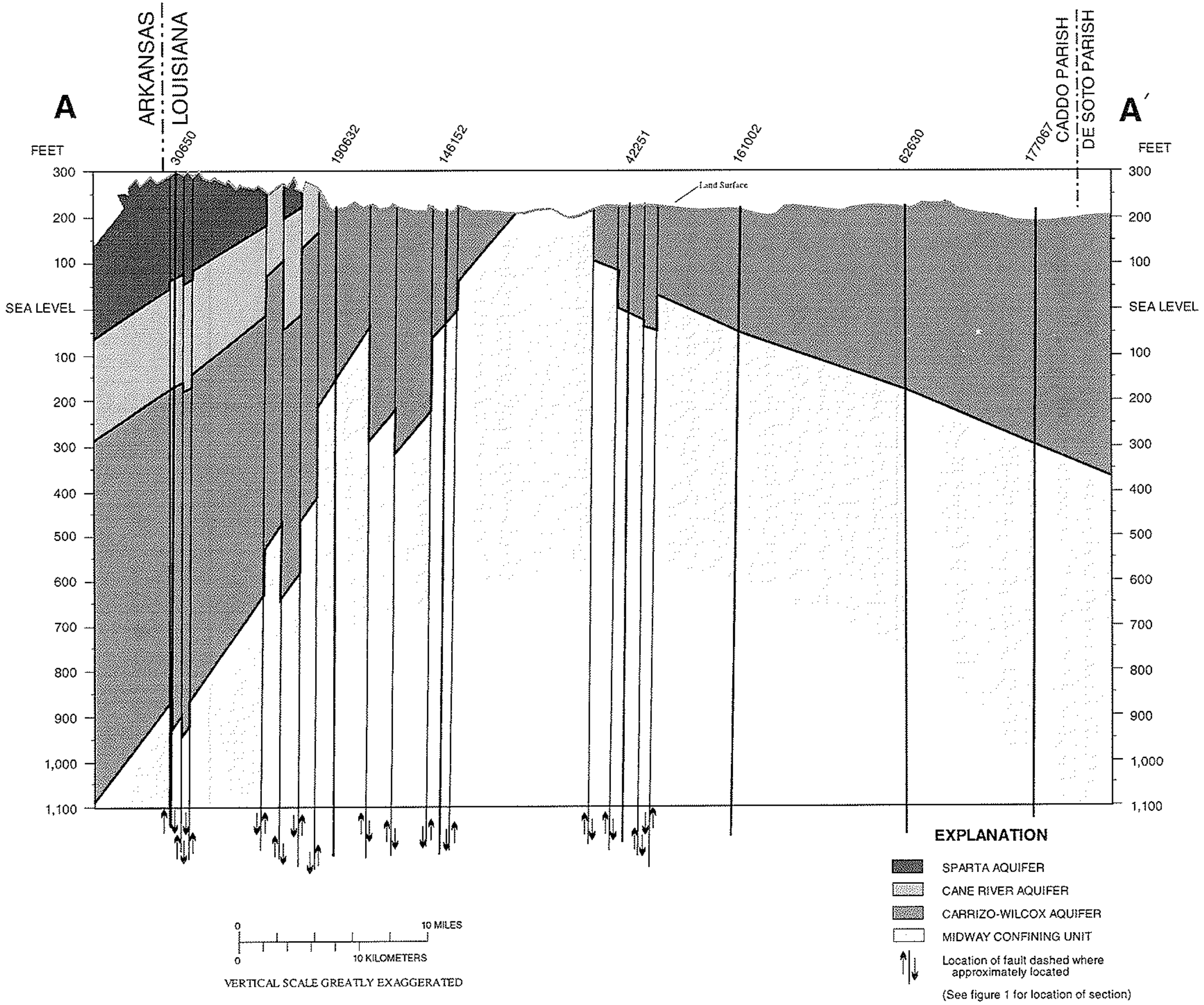


Figure 4. Generalized north-south hydrogeologic section (A-A´) of Caddo Parish, Louisiana.

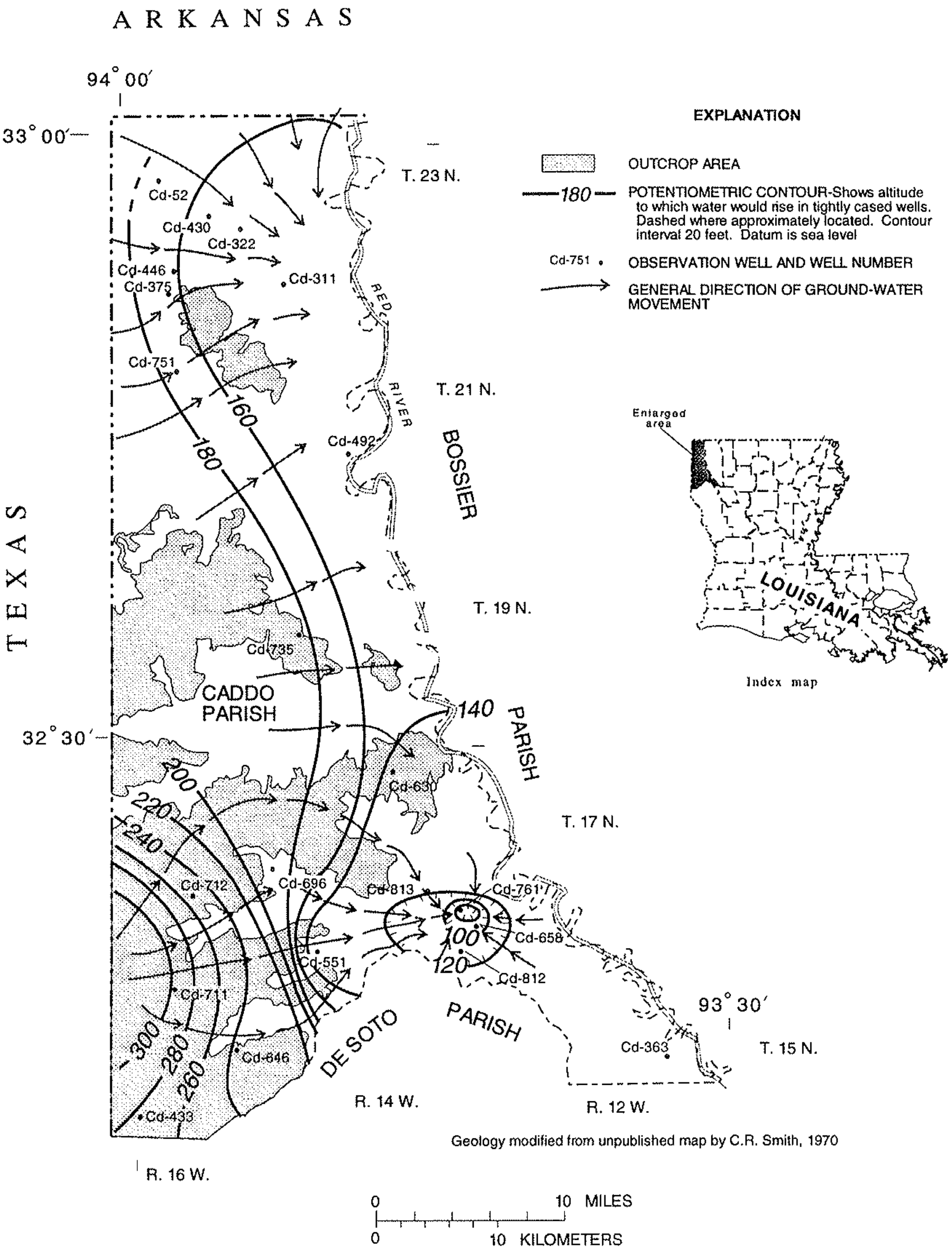
Secondary structural features that affect the hydrogeologic system underlying Caddo Parish are the complex and extensive system of faults probably resulting from stresses induced by the Sabine uplift. The hydrogeologic section in figure 4 shows a representative selection of the numerous faults in Caddo Parish. Generally, two types of faults exist in the parish. The first type of fault, referred to in the report as a major fault, shows considerable displacement at depth and has surface expression. The second type of fault, referred to in the report as a minor fault, in Caddo Parish has a large displacement at depth and a diminishing displacement near the surface. Many minor faults lie between the major faults shown in the section in figure 4.

Effects of Structural Features on Ground Water

The sedimentary units contained within Caddo Parish have been uplifted by the Sabine uplift and displaced by faults (fig. 4). The Nacatoch sand and the Arkadelphia Marl, both of Cretaceous Age, underlie the Midway confining unit. Mapping of the Nacatoch sand across Caddo Parish showed that the overlying Arkadelphia Marl and Midway confining unit had a fairly consistent combined thickness of 510 and 535 ft except at the extreme northern edge of Caddo Parish where all sedimentary units show some thickening. As can be seen on figure 4, between wells 30650 and 146152, each upthrown or downthrown block's exposed surface has the same nonweathered hydrogeologic unit thickness where mapped in Caddo Parish. This supports the theory of deposition and erosion rather than nondeposition and implies that uplifting of the sediments occurred after initial deposition followed by a period of erosion of the current land surface. It is probable that hydrogeologic units present in other areas of the Mississippi Embayment, such as the Cook Mountain confining unit, originally were present throughout Caddo Parish. The hydrogeologic units still present with substantial areal extent are the Red River alluvial, Sparta, Cane River, and Carrizo-Wilcox aquifers.

The numerous faults throughout Caddo Parish have greatly affected the hydrogeologic system. At some locations, the large vertical displacement between adjacent blocks has caused dissimilar aquifers to form continuous ground-water flow paths. An example of this can be seen on hydrogeologic section A-A' (fig. 4) between oil-test wells 30650 and 190632. This hydrogeologic section shows that at some locations the Cane River aquifer is located adjacent to the Carrizo-Wilcox aquifer. The map of the potentiometric surface of the Carrizo-Wilcox aquifer (fig. 5) shows a southeasterly component of ground-water flow across the north-central section of the parish. Comparison of hydrogeologic sections A-A' (fig. 4) and B-B' (fig. 6) indicates that large fault displacements occur along the north-south axis and smaller ones occur along the west-east axis. The increased fault displacement along the north-south axis of the Sabine uplift follows the increased rate of dip for the sediments along that axis.

Offset sand units between fault blocks slow or prevent flushing of saltwater from aquifers by freshwater flowing through the regional aquifer system. One fault block may contain saltwater sands, however a nearby upthrown block may contain freshwater sands at the same depth. This situation is generally shown in figure 4 and shown in greater detail in figure 6. Although little water-level data are available from the aquifers discussed in this report, water-quality data from geophysical logs indicate the general flow system. Saltwater in this report is defined as water having a chloride concentration greater than 250 mg/L. Saltwater typically is indicated by low resistivity values on a geophysical log.



Geology modified from unpublished map by C.R. Smith, 1970

Figure 5. Potentiometric surface of the Carrizo-Wilcox aquifer in Caddo Parish, Louisiana.

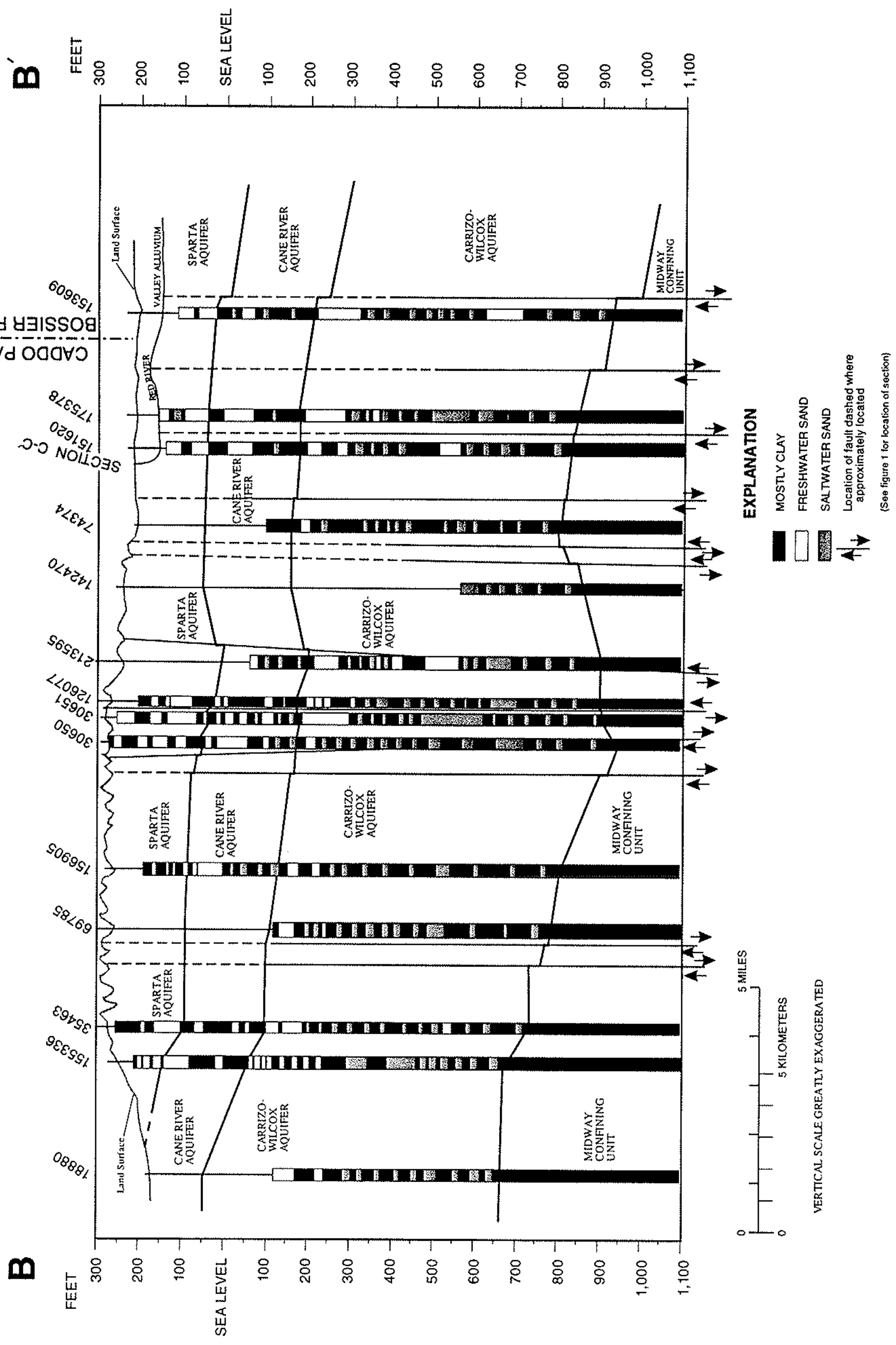


Figure 6. Detailed west-east hydrogeologic section (B-B′) of Caddo Parish, Louisiana.

The disruptive effect of faults on ground-water flow is illustrated in the comparison of oil-test well 44498 (fig. 7) completed in a downthrown fault block and water well Cd-447 completed in the adjacent upthrown block near the town of Myrtis, La. (fig. 1). The geophysical log of well Cd-447 shows ground water with resistivity of about 7 ohm-meters below a depth about 238 ft below land surface (fig. 7). About 1.5 mi west, at oil-test well 44498 the geophysical log resistivity curve indicates that freshwater is present to a depth approximately 530 ft below land surface (fig. 7). Hydrogeologic sections C-C', C'-C'', and C''-C''' (figs. 8, 9, and 10) show the freshwater section of the hydrologic system along the eastern border of Caddo Parish. In hydrogeologic section C-C' (fig. 8), the result of reduced freshwater recharge through aquifers due to displaced sand units along a fault plane can be seen between oil-test wells 74644 and 68126. Although a thick section of freshwater is located north of well 74644, geophysical logs south of the major fault between wells 74644 and 68126 indicate that saltwater is present in this area.

Although that section of Caddo Parish located between oil wells 30650 and 190632 in hydrogeologic section A-A' (fig. 4) is a heavily faulted area of the parish, the extreme northern end of the parish has a thick section of freshwater. This thick freshwater section can be seen in hydrogeologic section B-B' (fig. 6). Very few wells have penetrated the deep Carrizo-Wilcox aquifer in this area, but geophysical well-log data indicate that the sands contain both fresh and high-chloride water. High-chloride ground water is found in sands that have not been flushed with fresh ground water from the regional flow system. The sands containing high-chloride ground water may have been hydraulically isolated from the regional flow system due to faulting. Figure 5 illustrates that flow through northwest and north-central Caddo Parish generally is from west to east, which is also the axis along which fault displacement is minimized. The thick aquifer sands of northern Caddo Parish allow substantial quantities of flow despite numerous faults in that area.

GROUND-WATER RESOURCES

Of the three aquifers of Quaternary age in Caddo Parish, the Red River alluvial, terrace, and unnamed Pleistocene deposits, the Red River alluvial aquifer has the greatest areal extent and provides more than 20 percent of all ground water used in the parish (calculated from Lovelace, 1991).

The aquifers containing potable water that were sampled during this study include the Red River alluvial aquifer of Quaternary age, and the Sparta, Cane River, and Carrizo-Wilcox aquifers of Tertiary age. Two other aquifers of Quaternary age of lesser importance in the area are the terrace and unnamed Pleistocene deposits. These two aquifers provide less than 4 percent of the ground water used in the parish (calculated from Lovelace, 1991), and this amount is expected to diminish as municipal water systems expand in response to economic growth (S.A. Dean, Mayor of Ida, La., oral commun., 1992). Due to their diminishing importance to water users, the terrace and unnamed Pleistocene deposits are not discussed further in this report. All aquifers that contain potable water within Caddo Parish crop out in the parish.

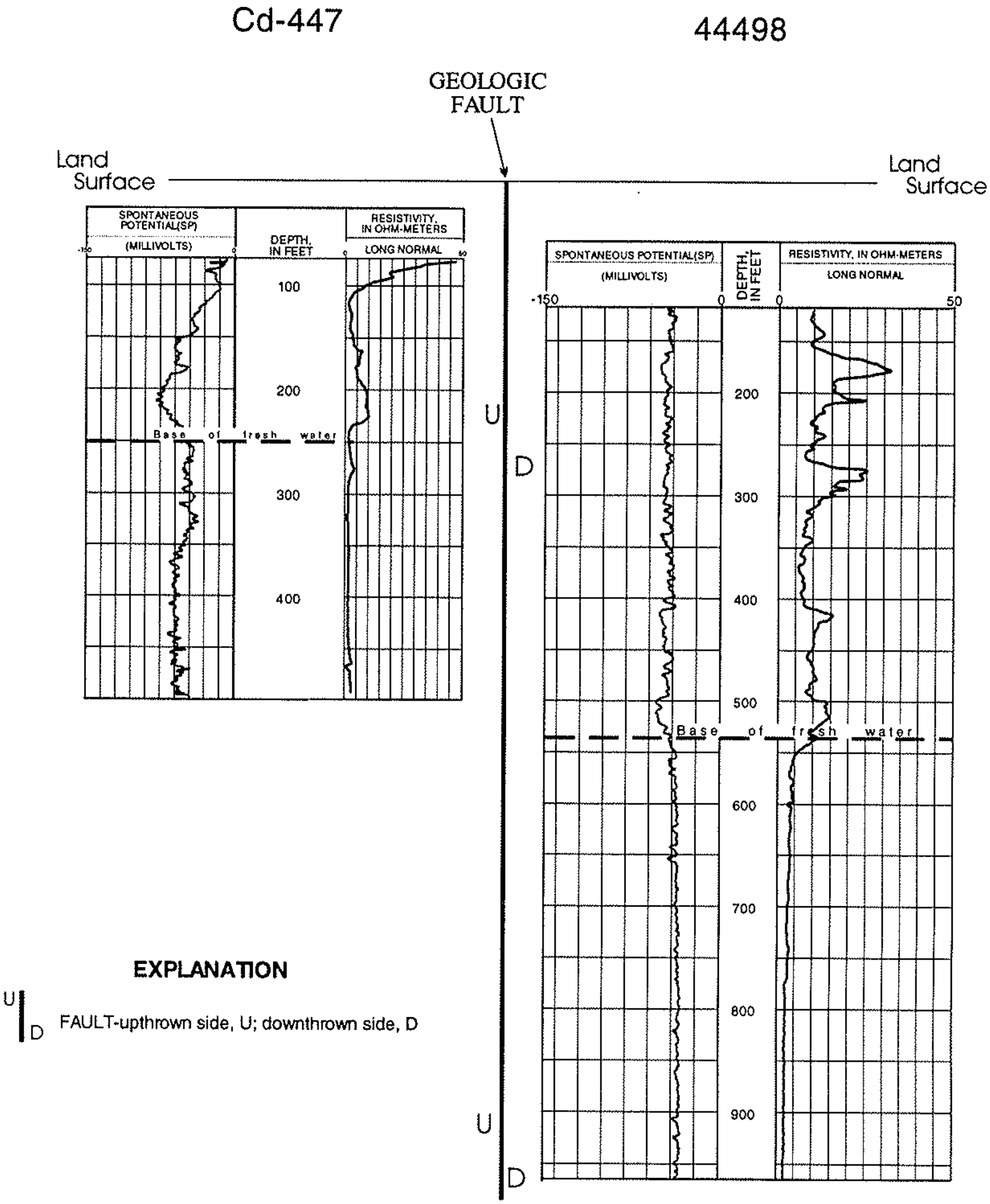


Figure 7. Geophysical logs of water well Cd-447 and oil-test well 44498 with the base of freshwater at each well.

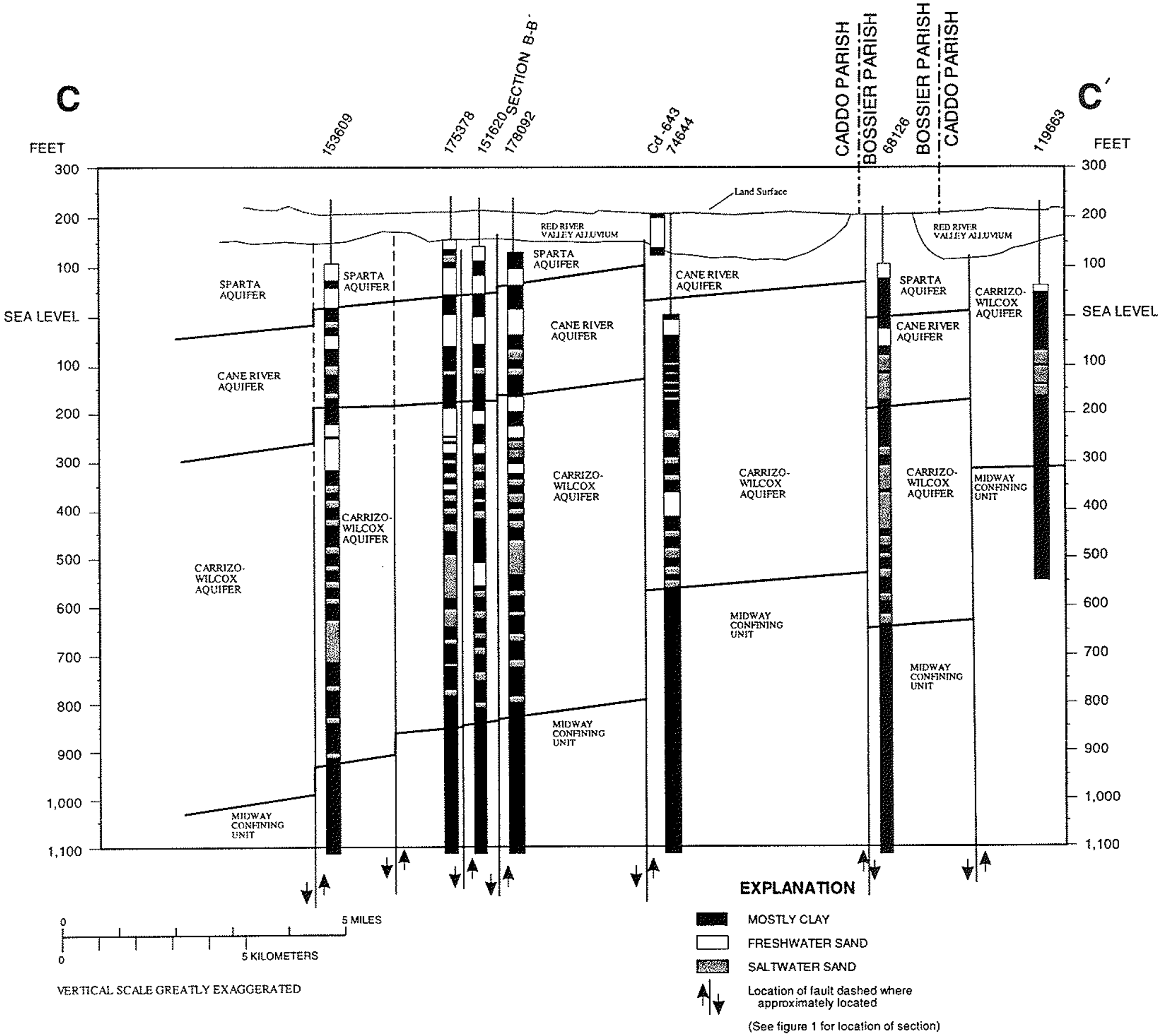


Figure 8. Detailed north-south hydrogeologic section (C-C′) of northeastern Caddo Parish, Louisiana.

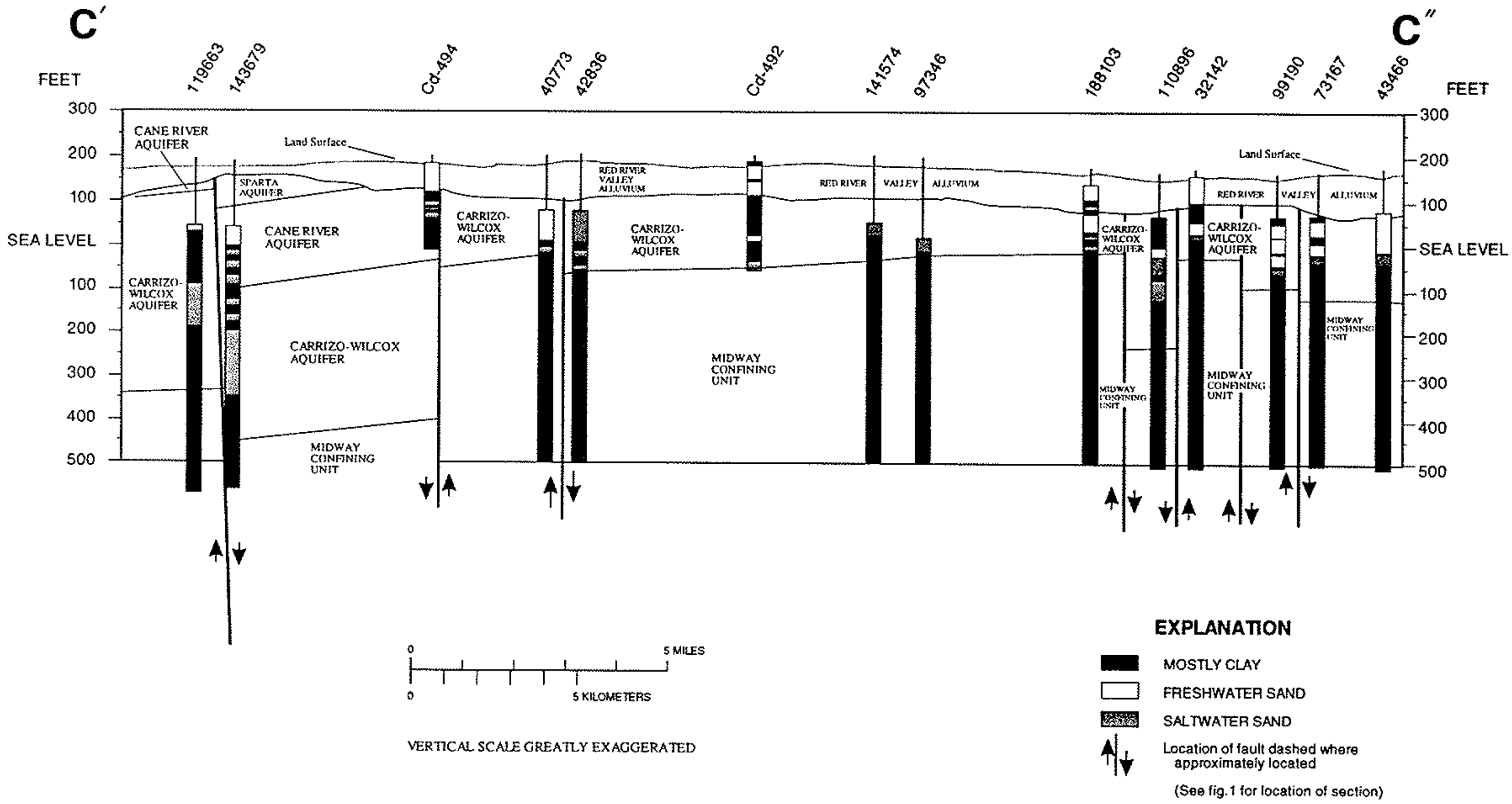


Figure 9. Detailed north-south hydrogeologic section (C′-C″) of east-central Caddo Parish, Louisiana.

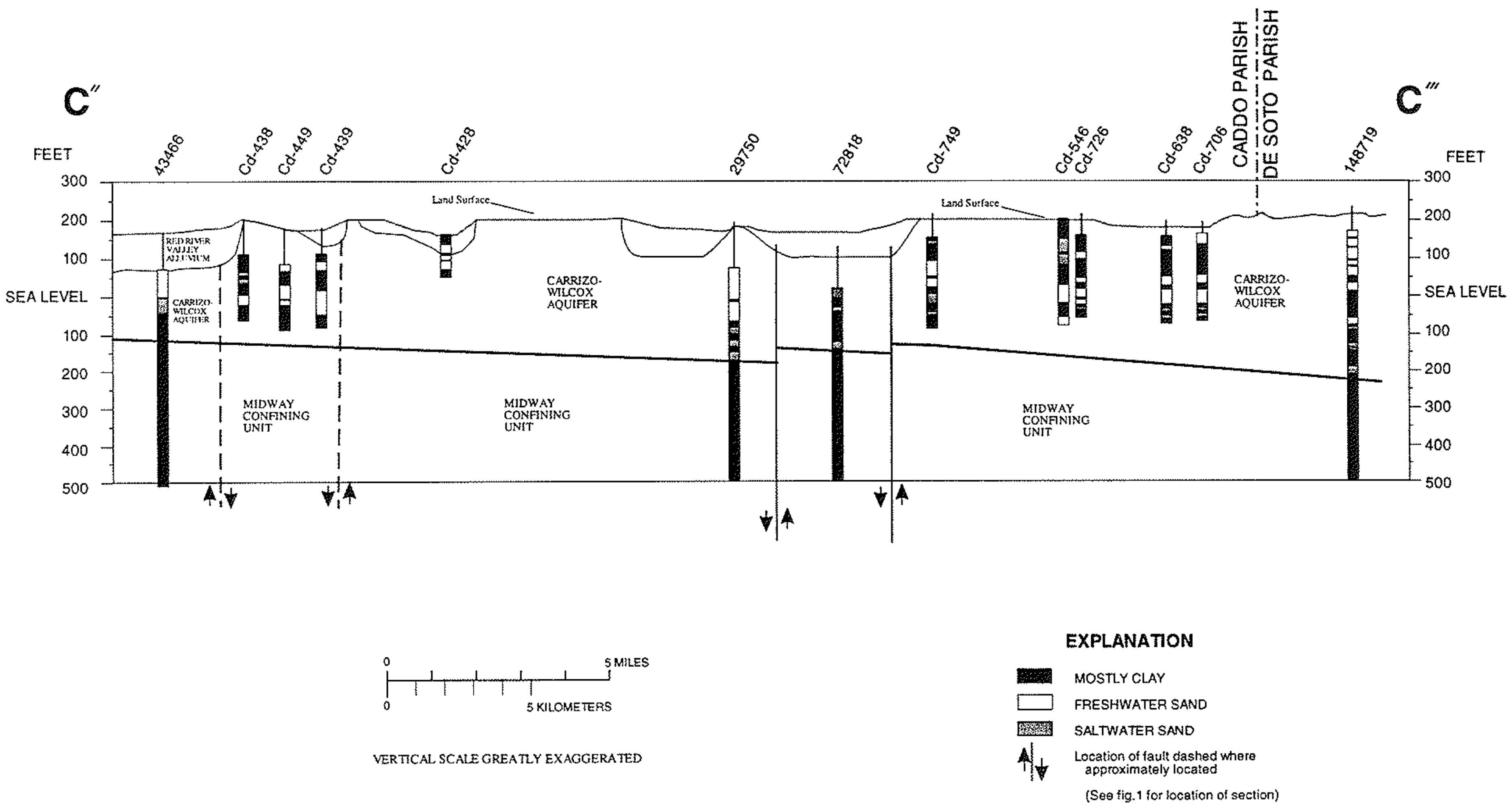


Figure 10. Detailed north-south hydrogeologic section (C″-C‴) of southeastern Caddo Parish, Louisiana.

Of the three aquifers of Tertiary age in Caddo Parish (the Sparta, Cane River, and Carrizo-Wilcox aquifers), the Carrizo-Wilcox aquifer is the oldest and has the greatest areal extent. The Carrizo-Wilcox aquifer contains freshwater throughout the parish and provides the largest percentage of potable water. These aquifers of Tertiary age provide more than 75 percent of ground water used in the parish (calculated from Lovelace, 1991) and are the principal future sources of fresh ground water for the parish. Although the Sparta and Cane River aquifers are presently (1992) underdeveloped in Caddo Parish (based on sand thickness and water-use data), these aquifers are important sources of supply to water users in areas adjacent to Caddo Parish. Development of these aquifers outside of Caddo Parish has provided hydrologic data needed to estimate aquifer yields and other ground-water production factors.

Red River Alluvial Aquifer

The Red River flows southeastward across the northwestern part of Louisiana. Pre-levee sedimentation during floods in the Red River flood plain has created the Red River alluvial aquifer, which covers underlying Tertiary age sediments. The alluvial aquifer is hydraulically connected with the Red River (Newcome, 1960, p. 6). This aquifer is an important source of freshwater for agriculture and rural domestic well owners in the Red River Valley (Whitfield, 1980, p. 24, 26).

Hydrogeology

The Red River alluvial aquifer is the product of a complex depositional and erosional history. Although the alluvial aquifer can be considered to have fairly homogeneous hydrologic characteristics relative to other aquifers in the study area, much lateral and vertical variability is seen in hydrologic characteristics of the aquifer. Detailed mapping of the alluvial aquifer by the U.S. Army Corps of Engineers (Albertson, 1992) shows that a variety of sedimentary units, indicating various depositional environments, can be mapped across the Red River Valley. Nonpermeable, highly organic, backswamp clay deposits substantially affect recharge and flow in the alluvial aquifer. These clay deposits overlie sections of alluvial sand and gravel (fig. 11). These clay deposits locally restrict infiltration of precipitation to the alluvial aquifer.

The Red River Valley alluvium is the product of large scale erosion and deposition during the Pleistocene and Recent epochs (Boswell and others, 1970a, p. E2). Alluvial deposits consist of clay, silt, sand, and gravel and characteristically have a uniform sedimentary sequence with grain size increasing with depth. The base of the formation generally consists of very coarse sand and gravel with smoothly rounded pebbles of chert found locally (Page and May, 1964, p. 53). The thickness of the alluvial deposit is irregular and ranges from 25 to 100 ft (Newcome, 1960, pl. 1). Transmissivity of the alluvial aquifer, based on aquifer tests, ranges from 4,000 to 15,000 ft^2/d. Hydraulic conductivity ranges from 140 to 260 ft/d (Newcome, 1960, table 1, p. 13).

The Red River Valley alluvium lies at the lowest point between the uplift ridge in central Caddo Parish to the west and a line of ridges immediately to the east of the Red River (fig. 1). The alluvial deposits vary in width across the study area and approach a maximum width of 10 mi near Belcher, La. As the Red River meandered across the basin, the river eroded a complex system of channels in the underlying deposits of Tertiary age deposits (fig. 12). The ridges and troughs

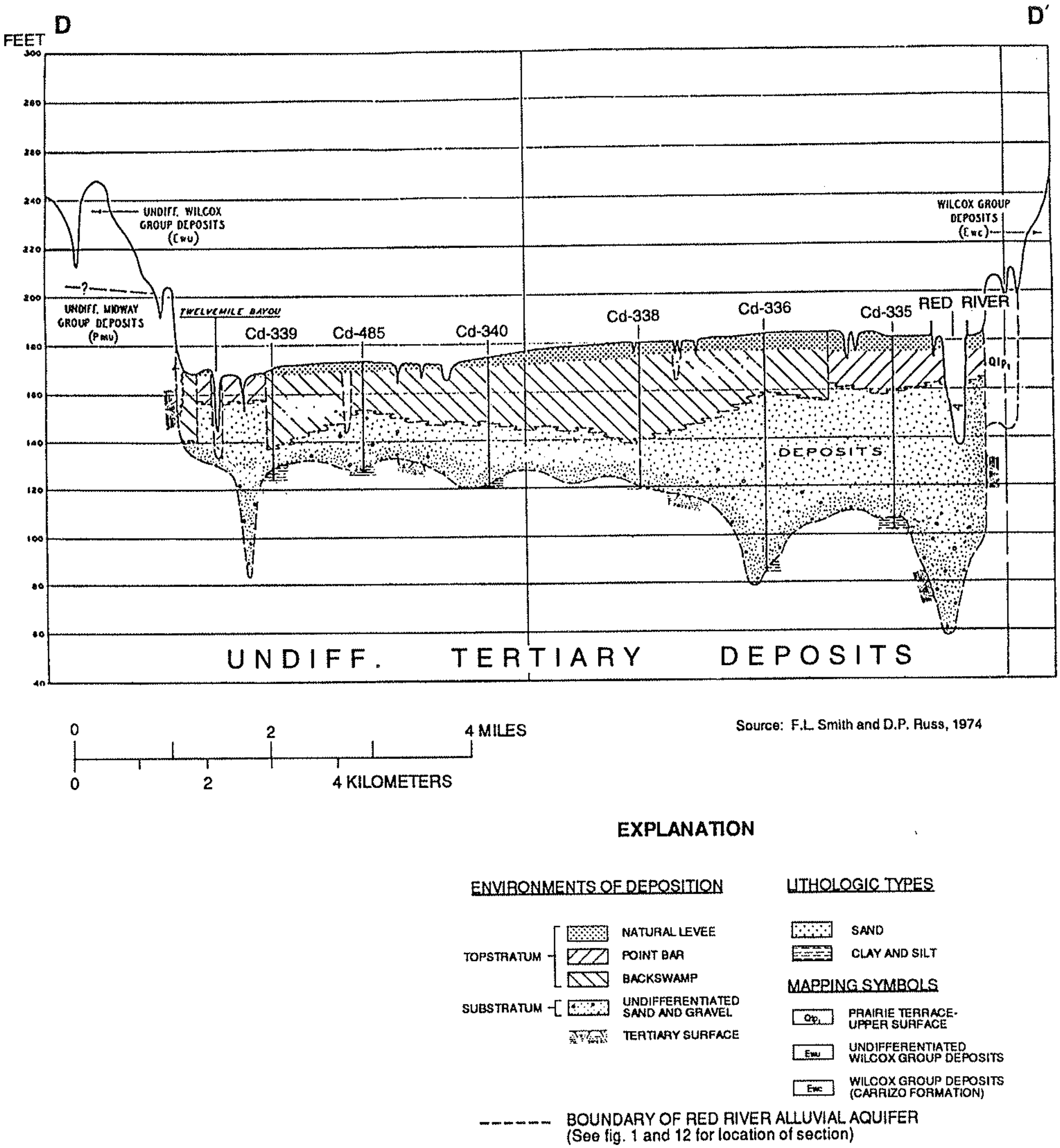


Figure 11. Geologic section (D-D′) showing the Red River alluvial aquifer and associated sediments near Dixie, Louisiana.

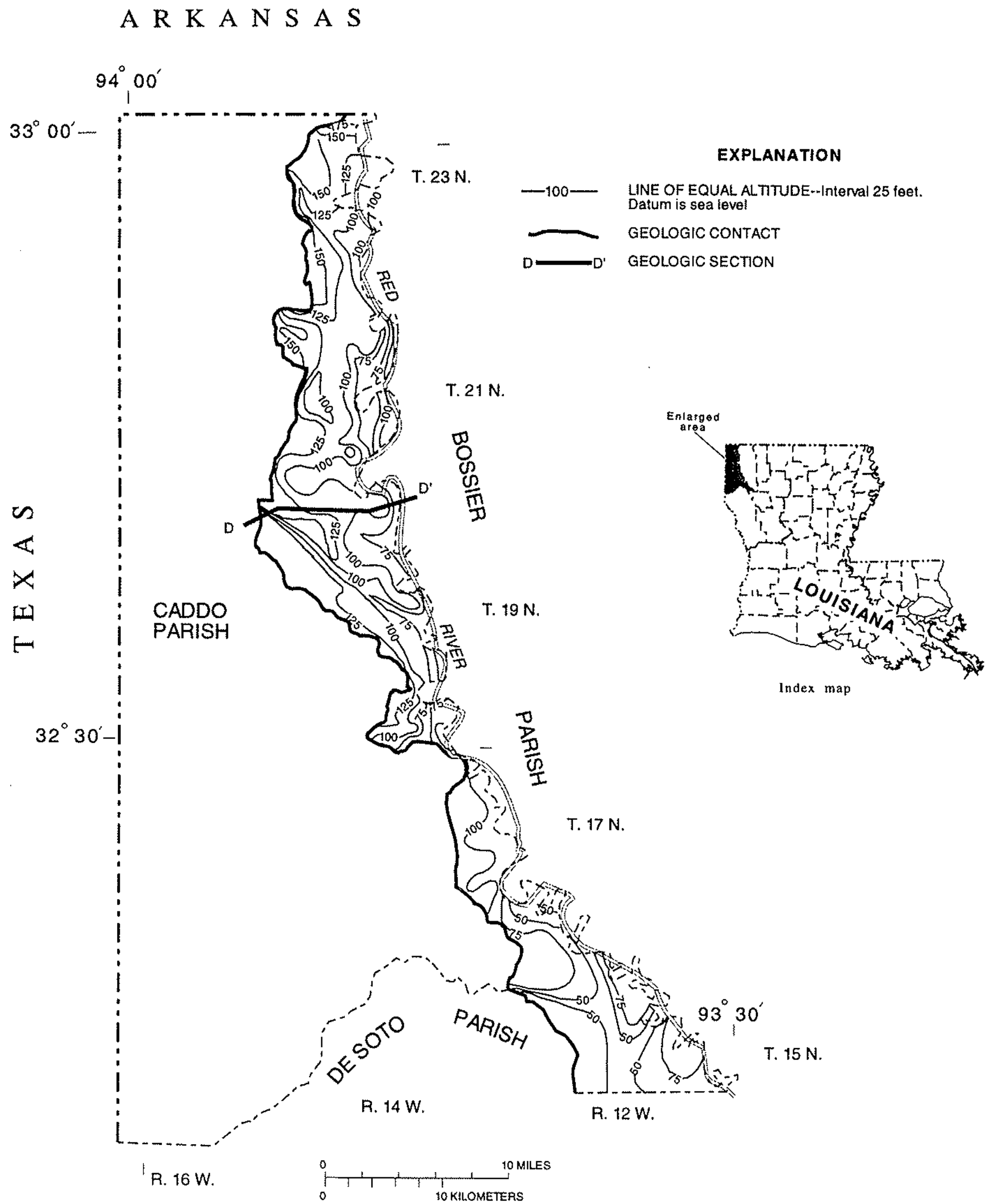


Figure 12. Altitude of the base of the Red River alluvial aquifer in eastern Caddo Parish, Louisiana.

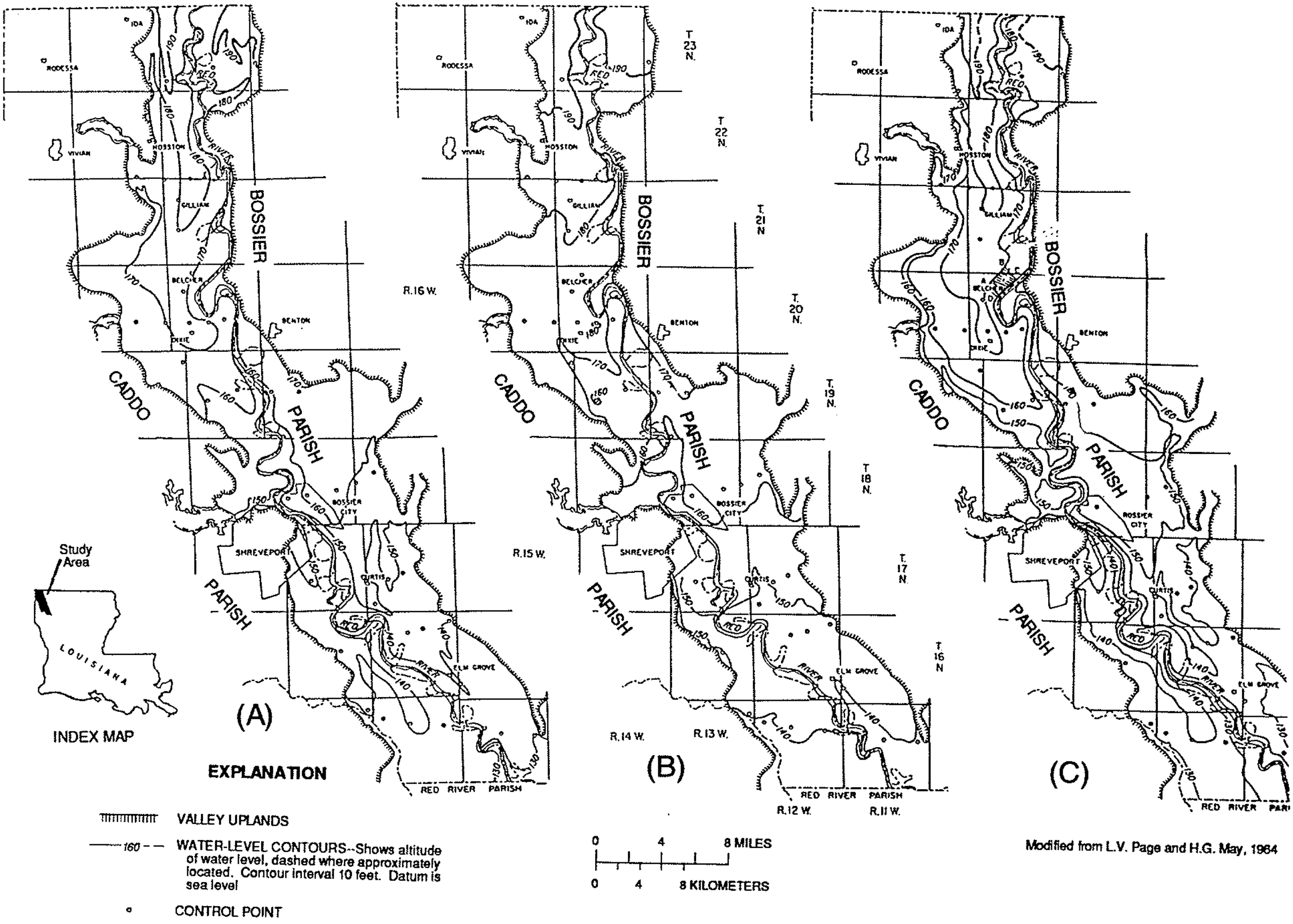
eroded into the underlying units of Tertiary age act as natural flow paths for water movement in the aquifer and as former depositional lows for the accumulation of coarser grained sediments. Because the underlying deposits of Tertiary age are predominantly clayey materials, water in the alluvial aquifer tends to flow downdip under the control of gravity and along troughs cut in the base of the aquifer where alluvial deposits are thicker and coarser grained.

Water levels in the alluvial aquifer fluctuate seasonally in response to rainfall, natural discharge to streams, and withdrawals of water from the aquifers. Recharge to the alluvial aquifer is chiefly by precipitation that infiltrates the surficial silty soil. Discharge from underlying aquifers of Tertiary age is a secondary source of recharge to the aquifer (Page and May, 1964). Although water levels in the aquifer fluctuate with time, seasonal variations in water levels (fig. 13) and flow are similar from year to year. Occasionally in the immediate vicinity of the stream, recharge from the stream to the alluvial aquifer occurs when the water level in the stream is higher than the water level in the aquifer (Page and May, 1964, p. 55).

In areas where surface materials are not permeable, rainfall cannot percolate downward rapidly, and water-level rise in the Red River alluvial aquifer is slower and less complete than in areas that are not capped with low permeable materials (Boswell and others, 1970a, E13). Water levels for two observation wells completed in the Red River alluvial aquifer and for the Red River are shown in figure 14. Well Cd-335 had the highest water levels shown in figure 14 and is about 0.5 mi from the Red River. Well Cd-501, located about 1 mi west of well Cd-335, has lower water levels than well Cd-335. The water levels in figure 14 showing the widest variation in magnitude correspond to the Red River stage height. Ground water is highest in the area of well Cd-335 due to the highly permeable alluvial material at land surface at this location, and ground water is flowing from this high point towards the river and also to well Cd-501. Water levels for well Cd-501 are low because the well is screened below a clay layer that restricts the infiltration of local precipitation.

Ground-water flow into the alluvial aquifer from underlying aquifers contributes to the natural base flow of streams. Most streams in Louisiana are effluent streams that receive ground-water flow from underlying hydrogeologic units (Speer and others, 1966a, p. G25). The important factors that influence the natural base flow of streams are (1) the permeability and porosity of the adjacent hydrogeologic units, (2) accessibility of ground water to stream channels, (3) elevation of the water surface in the streams relative to the elevation of the water table and to the altitude of the base of the aquifers, (4) slope of the water table, and (5) rate of evapotranspiration (Speer and others, 1966b, p. F11).

The water level in well Cd-414, located near Gilliam, La., completed in the Carrizo-Wilcox aquifer, was 190 ft above sea level in 1956. The water level in well Cd-344, completed in the Red River alluvial aquifer near Cd-414, was measured 178 ft above sea level in December 1956. The higher water level in the deeper aquifer allows water to flow upward into the overlying alluvial aquifer. This recharged water from underlying aquifers spreads along the base of the alluvial aquifer and is slowly discharged to the Red River. Due to pumping, current (1992) water levels in aquifers of Tertiary age in this area are too low to induce flow into the overlying alluvial aquifer, but water already discharged into alluvial sands from earlier periods would probably still be contained at the base of the alluvial aquifer.



Modified from L.V. Page and H.G. May, 1964

Figure 13. Potentiometric surface of the Red River alluvial aquifer in Louisiana, (A) February 1958, (B) May 1958, and (C) October 1958.

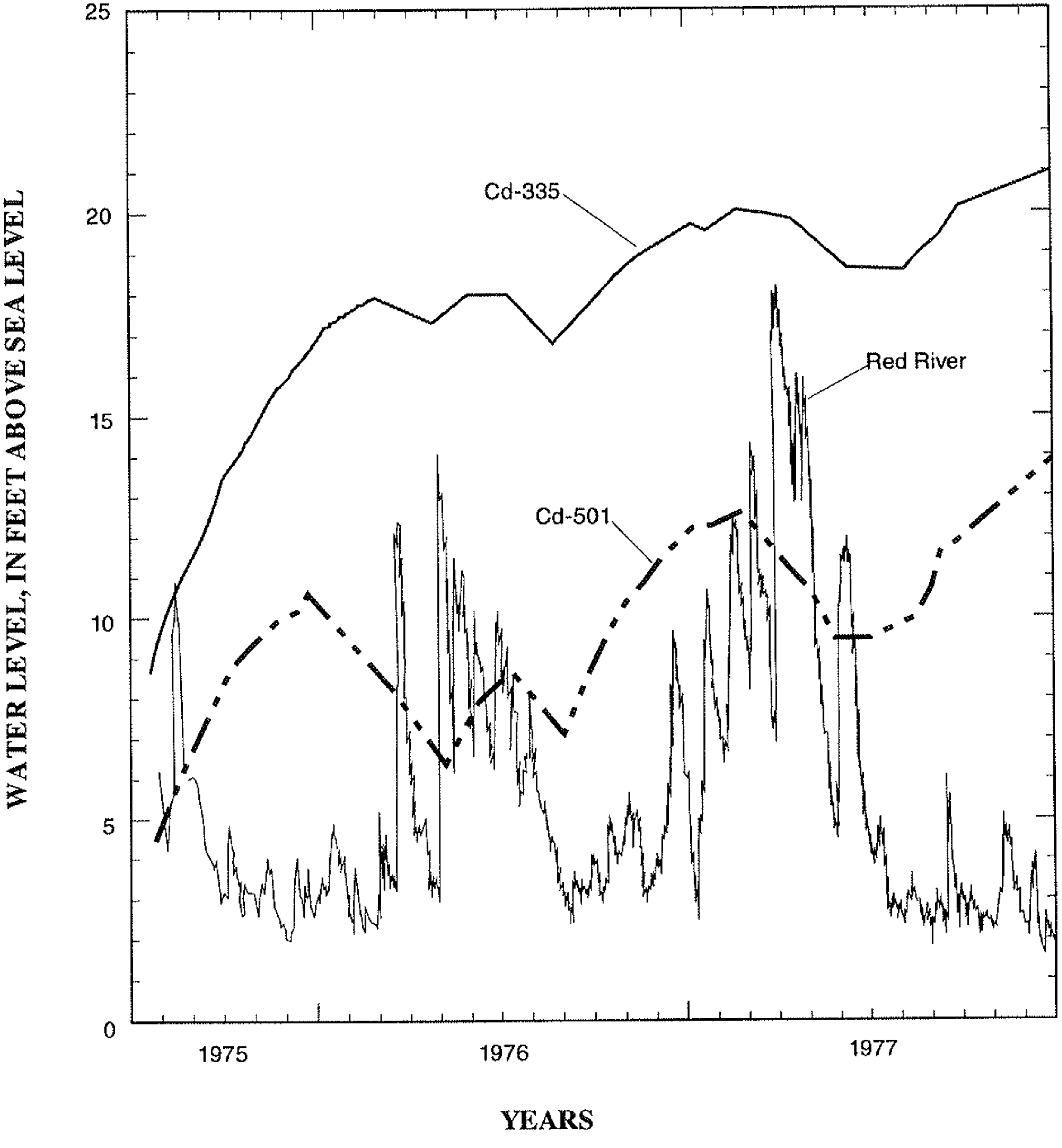


Figure 14. Water levels for the Red River and observation wells Cd-335 and Cd-501 completed in the Red River alluvial aquifer, Louisiana.

Water Quality

The distribution of sodium, chloride, dissolved-solids, and iron concentrations in water from 38 wells completed in the alluvial aquifer is shown in figures 15 to 18. Water recharge to the alluvial aquifer from the underlying aquifers may have affected the water quality in four or five areas as shown in the figures. Nitrate concentrations are shown in figure 19 but data were insufficient to illustrate distribution.

Box plots of concentrations for the above listed constituents are shown in figure 20, because the range of these constituents generally is of interest to water users. A list of selected physical properties and chemical constituents for wells completed in the Red River alluvial aquifer is in Appendix 1. Generally, only water-quality data representing the freshwater section of the Red River alluvial aquifer were used to generate the box plots shown in figure 20. Most of the anomalously high or low values were excluded from the distribution plots to enhance the usefulness of the plots to water users. Some of these extremely high values, especially chloride, may represent local contamination that has occurred in the exploration and production of oil and gas in this area.

Water in the Red River alluvial aquifer may be classed as generally unsuitable for domestic, municipal, and industrial use because of the high concentrations of iron (greater than 300 µg/L) and high hardness[2] of water (Page and May, 1964, p. 33). Generally, concentrations of sodium in water from the alluvial aquifer are less than 20 mg/L, although five areas have been mapped (fig. 15) where sodium concentrations exceed 50 mg/L. Although chloride concentrations at specific locations in the alluvial aquifer exceed 350 mg/L, more than 90 percent of the chloride-concentration data are less than the secondary maximum contaminant level of 250 mg/L (fig. 20). More than 75 percent of all wells sampled for dissolved-solids concentrations exceeded the secondary maximum contaminant level of 500 mg/L. More than 90 percent of all the water sampled from wells in the alluvial aquifer had dissolved-iron concentrations that exceeded the secondary maximum contaminant level of 300 µg/L (fig. 20). Generally, concentrations of nitrate in water from the alluvial aquifer are less than the secondary maximum contaminant level of 10 mg/L as N.

All properties and constituents discussed in preceding paragraphs indicate high concentrations in four or five areas of the alluvial aquifer. In the past, petroleum industry exploration and development activities have been a source of high chloride and sulfate concentrations that have affected Caddo Parish water resources (Whitfield, 1980, p. 21). These activities include drainage from saltwater disposal pits, leaky well casings, and gas blowouts. Large volumes of drilling mud and saltwater can be moved upward from deeper zones by gas pressure and create local areas of contamination. Although increased regulation of the petroleum industry and advanced well-field technology has greatly reduced the effects of oil-field exploration and production on the ground-water resources of Caddo Parish, abandoned oil, oil-test, and saltwater wells can develop leaks and contaminate sands locally (Whitfield, 1980, p. 23). An area of the Red River alluvial aquifer near Gilliam that borders the deep freshwater sands of northern Caddo Parish (fig. 8) has elevated concentrations of dissolved inorganic ions. This area also has experienced much oil and gas exploration of the hydrocarbon reservoirs located near geologic faults. Water sampled from well Cd-513, completed in the Red River alluvial aquifer near Gilliam, had a chloride concentration of 980 mg/L and dissolved-iron concentration of 5,800 µg/L.

---

[2] See Hem, 1985, p. 159.

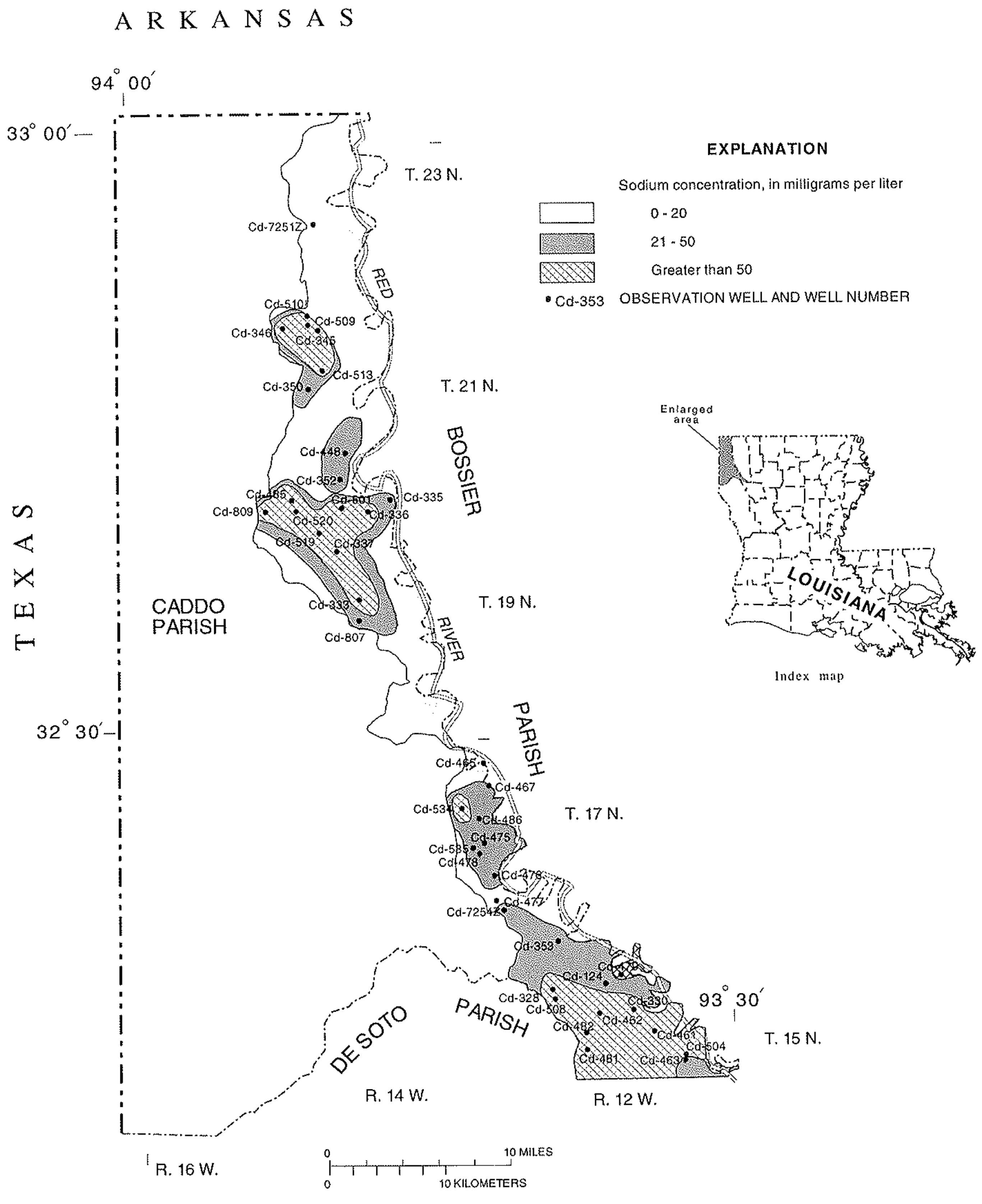


Figure 15. Distribution of sodium concentration in water from the Red River alluvial aquifer in Louisiana.

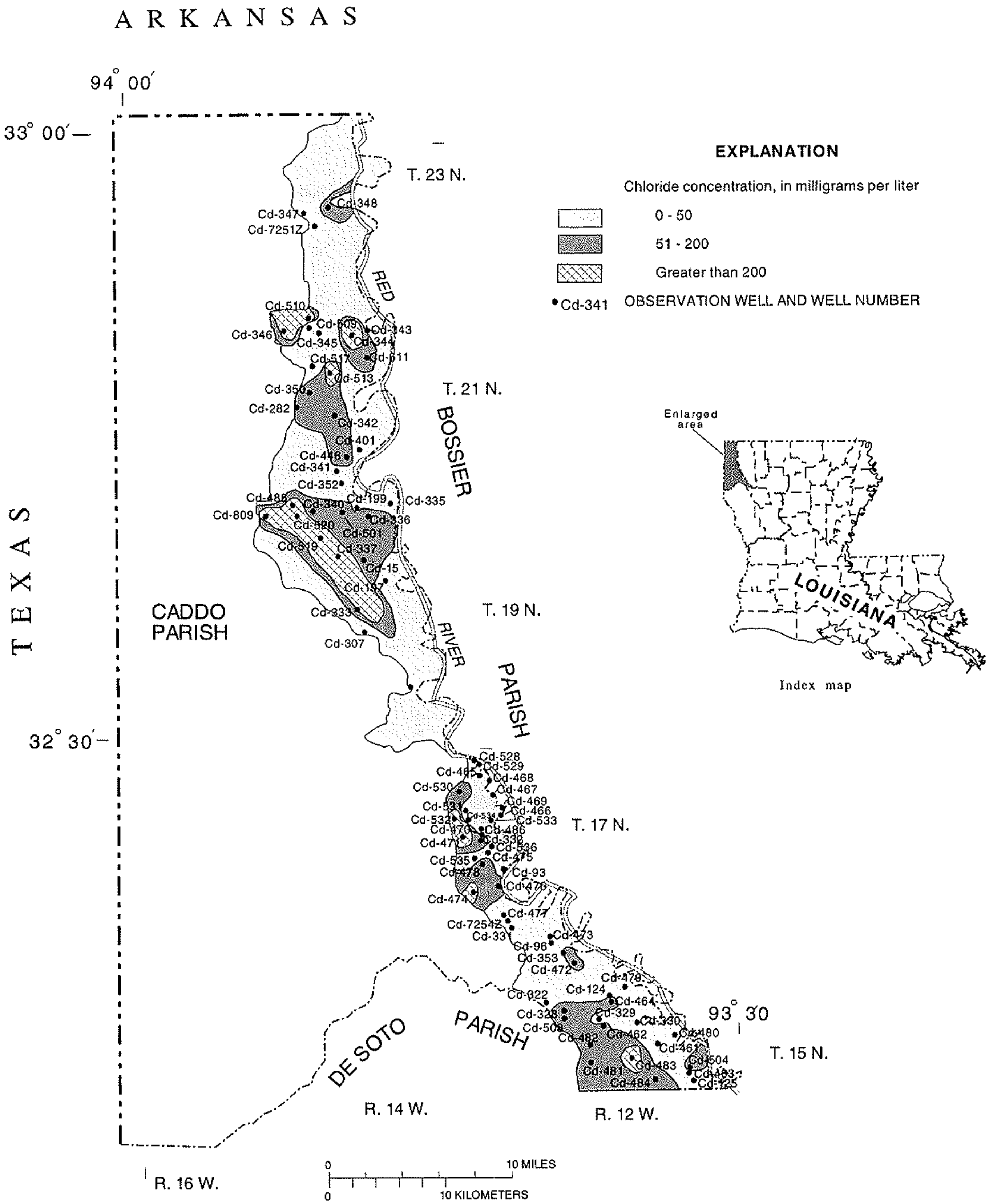


Figure 16. Distribution of chloride concentration in water from the Red River alluvial aquifer in Louisiana.

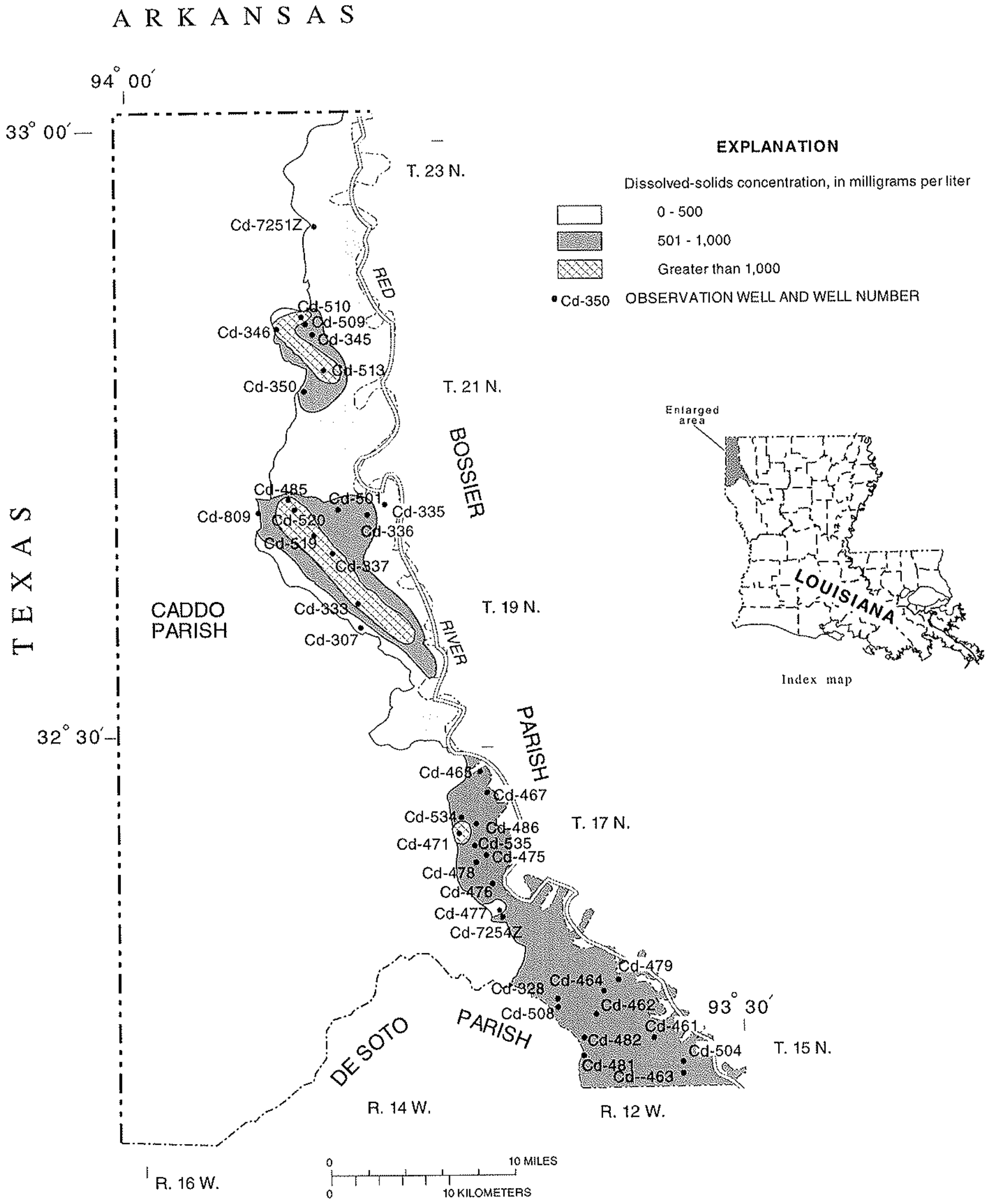


Figure 17. Distribution of dissolved-solids concentration in water from the Red River alluvial aquifer in Louisiana.

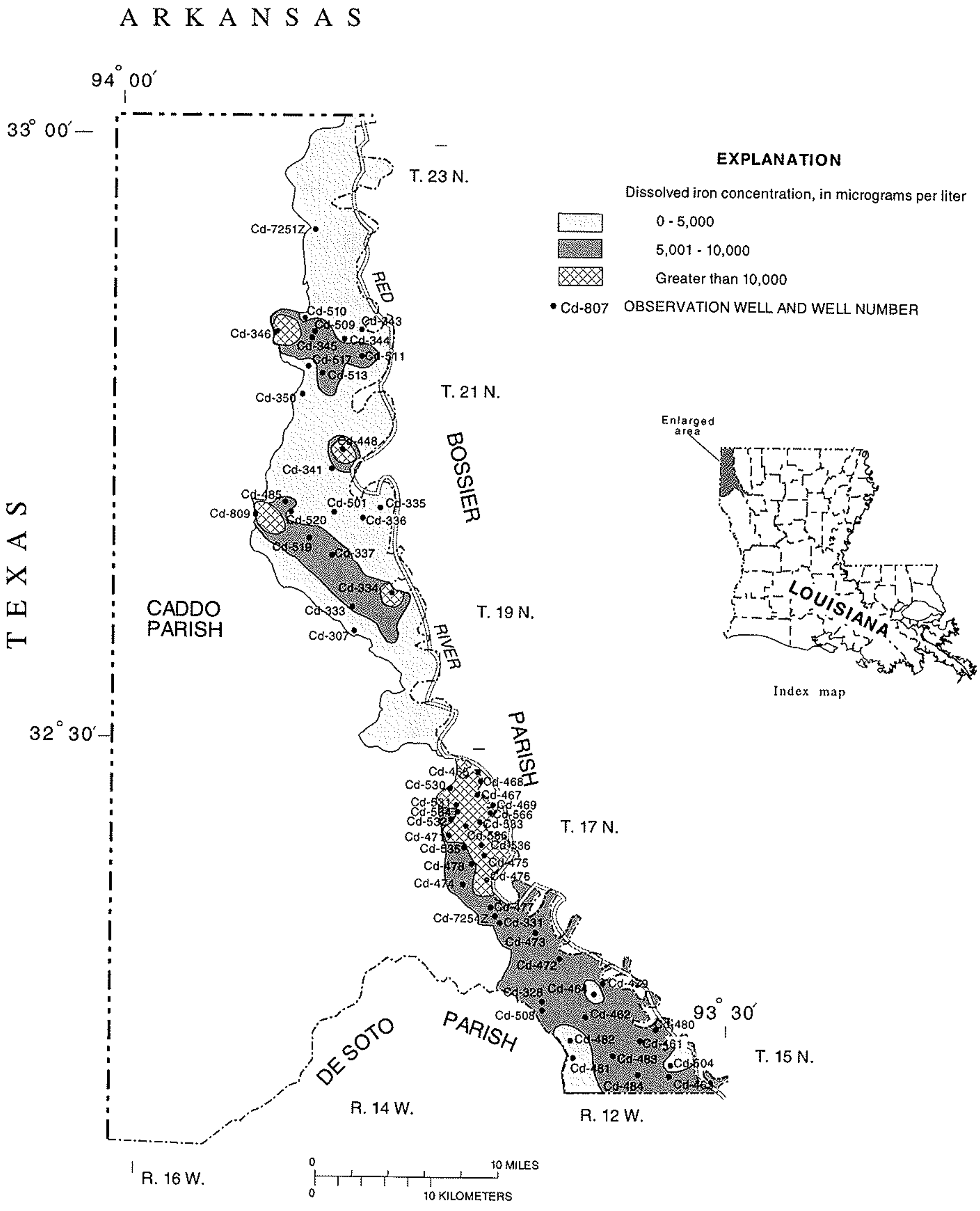


Figure 18. Distribution of iron concentration in water from the Red River alluvial aquifer in Louisiana.

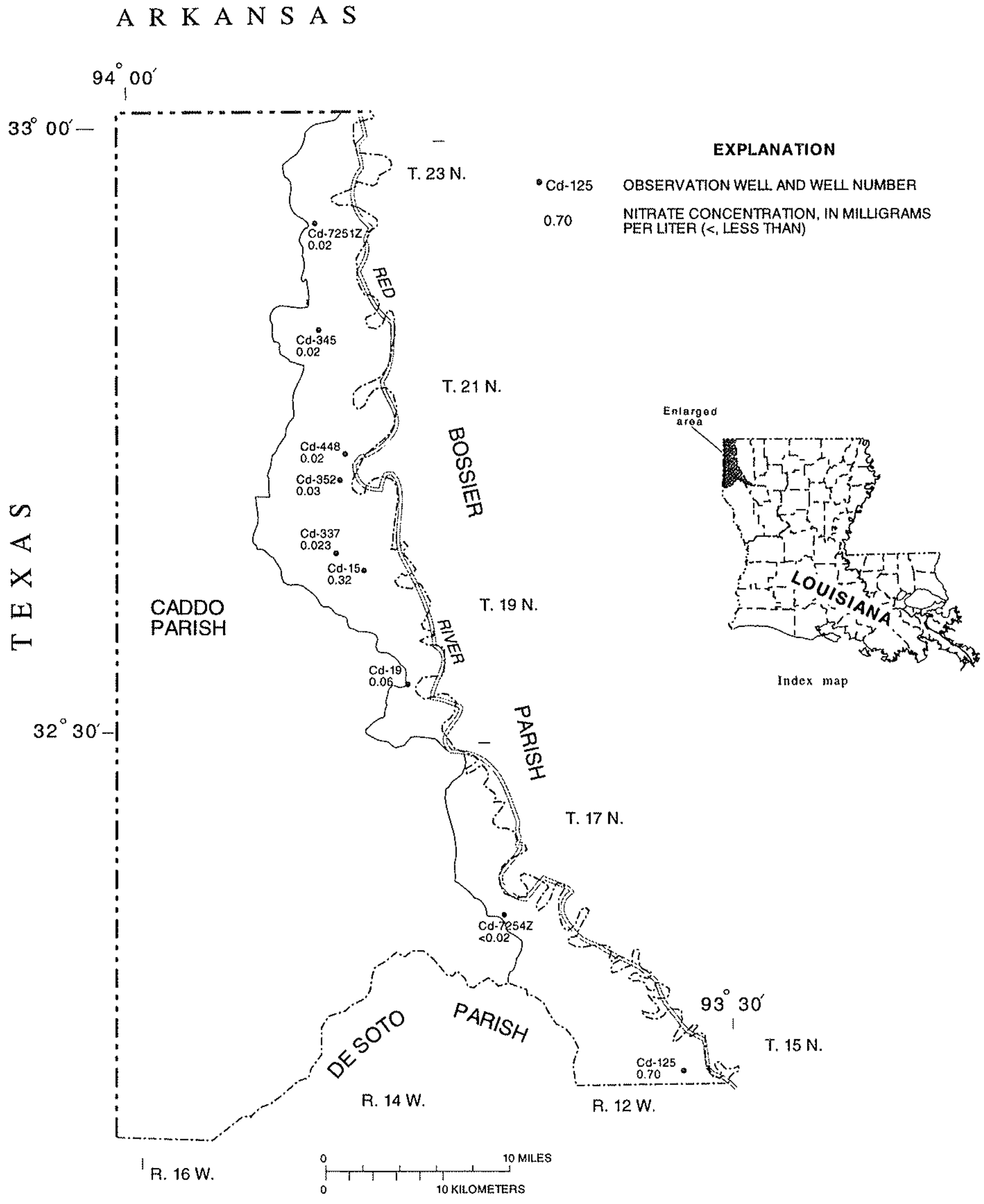


Figure 19. Observation wells sampled for nitrate concentration in the Red River alluvial aquifer in Louisiana.

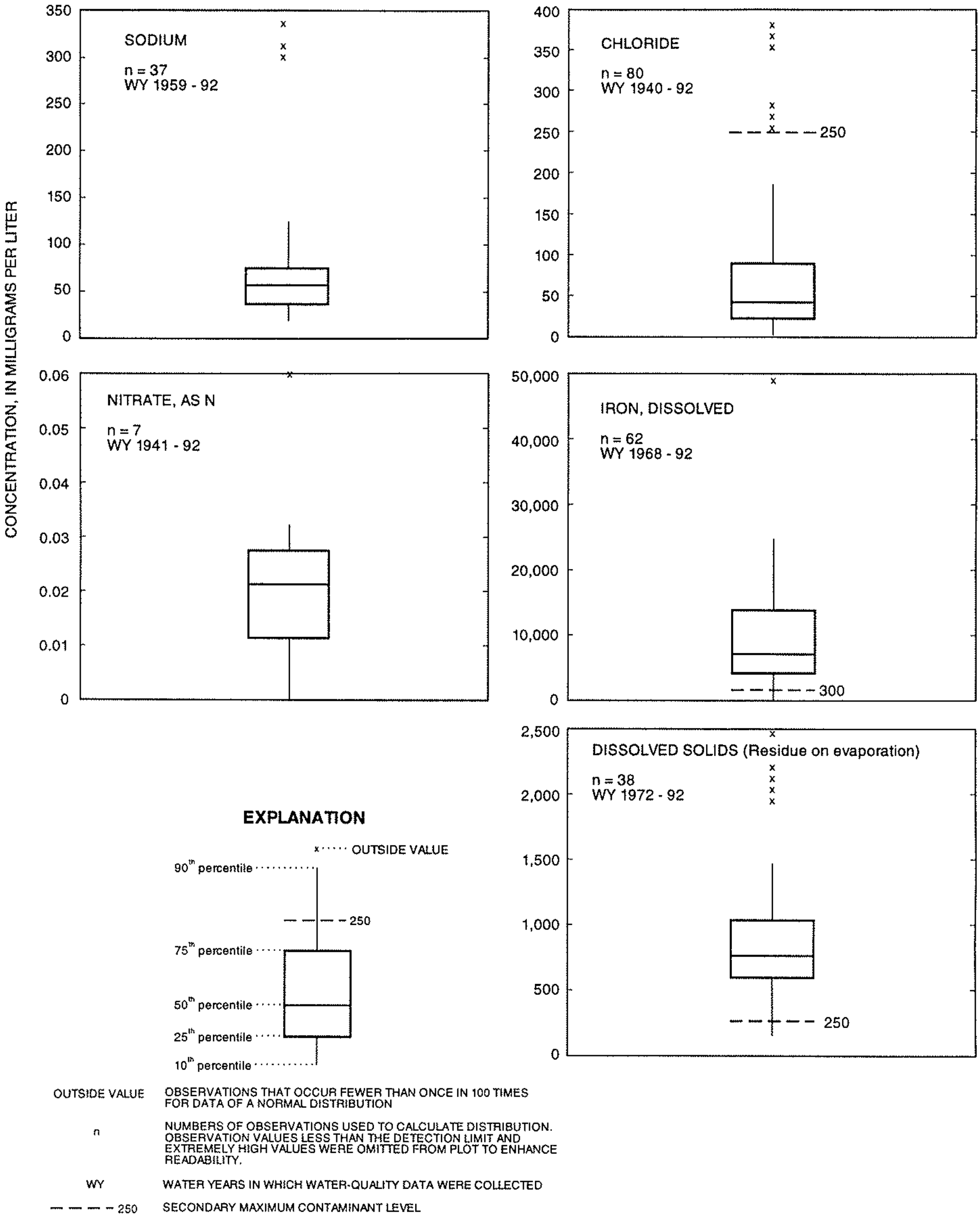


Figure 20. Box plots of selected water-quality data for the Red River alluvial aquifer in Louisiana.

These areas that have elevated concentrations of dissolved inorganic ions also may have received recharge from underlying aquifers of Tertiary age that contain high concentrations of chloride, iron, and other constituents (Whitfield, 1980, p. 10). Generally, the areas of higher mineralization have the following common features: deposits of backswamp clay materials overlie the alluvial aquifer and sands are thinner than at other locations in the alluvial aquifer; brackish water from underlying aquifers discharges into the overlying alluvial aquifer; and often the altitude of the base of the alluvial aquifer is low relative to the surrounding area.

At many locations in Caddo Parish, the deeper aquifers have been completely flushed of saltwater, although at some locations seepage of saltwater from the underlying aquifers may continue. The freshwater in these aquifers of Tertiary age is more suitable for domestic and industrial use than the overlying alluvial water. Figure 12 can be used to determine the approximate thickness of the alluvial aquifer at a point. The line of equal elevation at a particular site can be subtracted from the land surface elevation value to give the approximate thickness of the alluvial aquifer at that point. Hydrogeologic sections (figs. 8 to 10) indicate the approximate depth to the next freshwater sand below the base of the alluvial aquifer.

Potential for Development

Due to the high transmissivities (Page and May, 1964, p. 57) of the Red River alluvial aquifer, large volumes of water can be pumped from a single water well. Of the seven Louisiana parishes that withdraw water from the Red River alluvial aquifer, in 1990 Caddo Parish was the second largest user of alluvial water; Caddo Parish withdrew 0.86 Mgal/d, 22 percent of total measured withdrawals from study area aquifers (Lovelace, 1991, p. 89). Of the total volume of water withdrawn from the Red River alluvial aquifer, 0.53 Mgal/d was used for irrigation. The remaining 0.33 Mgal/d was used for rural water systems, domestic, and other agricultural water uses.

Locally, water in the alluvial aquifer is generally under artesian pressure, although such a definite classification is not always valid because of the variable thickness and permeability of the confining material and the fluctuation of water levels in the aquifer (Page and May, 1964, p. 54). The effect of pumping (at 100, 1,000 and 5,000 gal/min) on water-level drawdown for an average transmissivity of 9,350 ft^2/d, which is typical for the alluvial aquifer, is shown in figure 21. An average transmissivity of 9,350 ft^2/d corresponds to a sand thickness of 64.48 ft with an average hydraulic conductivity of 145 ft/d (Page and May, 1964, p. 54). Pumping 1,000 gal/min continuously for 1 year would cause water levels 10,000 ft from the pumped well to decline about 12 ft from their original pre-pumped levels (fig. 21).

The curves in figure 21 can be used to estimate the amount of drawdown in the alluvial aquifer water surface at varying distances from the location of the pumping well. These curves were derived using the Theis equation (Lohman, 1979, p. 15). The following assumptions were made regarding the alluvial aquifer when the curves were constructed: (1) a constant aquifer thickness, (2) horizontal flow, (3) confined aquifer between impermeable formations on top and bottom, (4) infinite in horizontal extent, and (5) homogeneous and isotropic with respect to its hydrogeological parameters (Freeze and Cherry, 1979, p. 315).

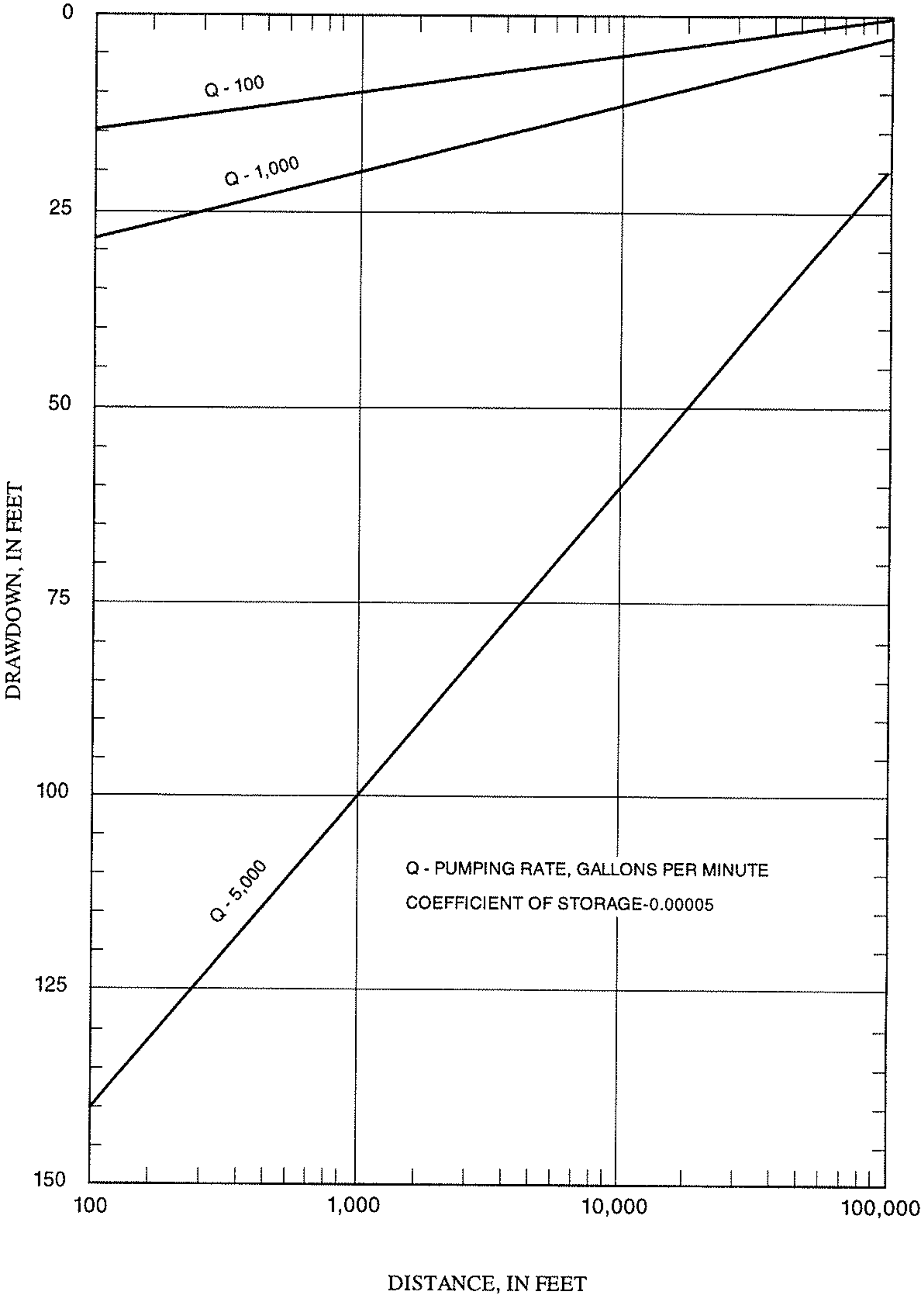


Figure 21. Distance-drawdown relation based on the Theis equation for the Red River alluvial aquifer in Louisiana for indicated pumping rates for 3 wells, a 1-year pumping period, and a transmissivity of 9,350 feet squared per day.

The actual aquifer differs from an ideal aquifer; therefore, the calculated withdrawals and their effects on water levels will differ from actual withdrawals and their effects. Because the alluvial aquifer's confining material varies in thickness and permeability, and water levels are often only slightly higher than the elevation of the confining unit, heavy pumping causes the aquifer to change from a confined to an unconfined condition in the vicinity of the pumping well (Page and May, 1964, p. 54). When this occurs, water-level drawdown with distance changes substantially from the curves in figure 21. After the water levels in the alluvial aquifer near the pumping well decline below the upper confining unit elevation, the water changes from confined to unconfined, and more water can be pumped from the aquifer while water levels are only slightly lowered (Freeze and Cherry, 1979, p. 61).

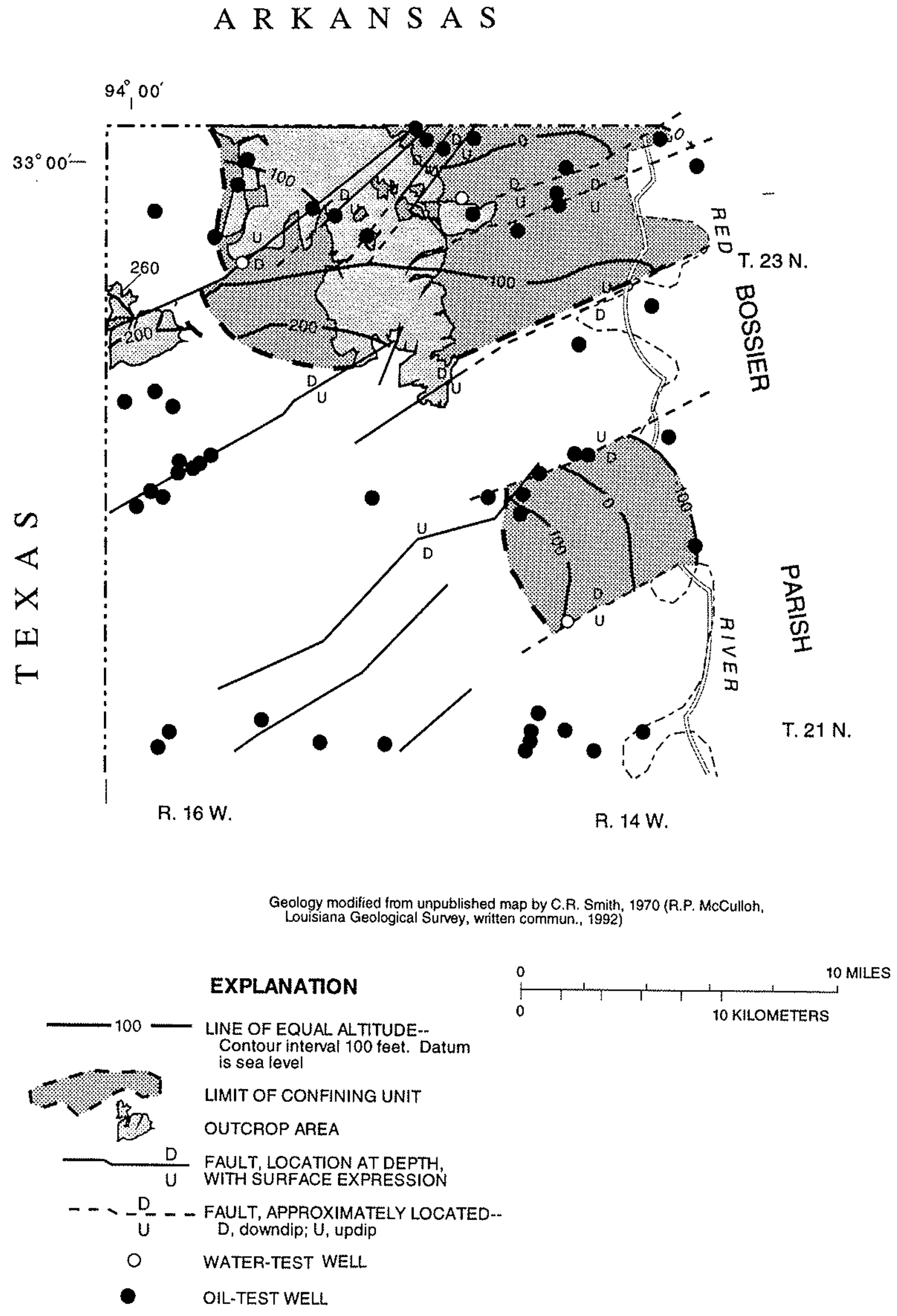
Sparta Aquifer

The Sparta aquifer overlies the Cane River aquifer (fig. 2) in most of the western part of the Mississippi Embayment, crops out on both the west and east sides of the embayment, and dips toward the embayment's axis and southward to the Gulf of Mexico (Hosman and others, 1968, p. D18). Except for a thin section of the aquifer buried beneath the Red River alluvial aquifer near Hosston, La., the Sparta aquifer crops out only in northern Caddo Parish (fig. 22).

Hydrogeology

The Sparta aquifer is highly variable in lithology both laterally and vertically and ranges from 250 to 275 ft in thickness at the Louisiana-Arkansas border. The aquifer consists primarily of beds of fine to medium sand in the lower half and beds of sand, clay, and lignite in the upper half. A geophysical log of oil-test well 30650 in hydrogeologic section B-B' (fig. 6) shows four sands ranging from 15 to 45 ft in thickness. Payne (1968, p. A3) attributes the existing pattern of well-developed lineations of sand concentrations in the aquifer to the depositional processes of a system of braiding, constantly shifting stream channels, and other depositional environments associated with a large deltaic, fluvial plain. Average values of transmissivity and hydraulic conductivity for the Sparta aquifer, based on aquifer tests completed in Louisiana, are 3,600 ft^2/d and 50 ft/d, respectively (Martin and Early, 1987, p. 7).

The approximate thickness of the Sparta aquifer can be estimated from the altitude of the base of the aquifer (fig. 22). In the areas where the aquifer crops out, subtracting the elevation of the land surface from the altitude of the base of the aquifer will give the approximate thickness of the aquifer at that site. The oil-test wells and water wells used to construct this figure and other similar figures in this report are listed in Appendix 3. In those areas outside of the outcrop the Sparta aquifer is overlain by unnamed Pleistocene alluvial deposits of small local streams that vary in depth from 15 to 45 ft. An average alluvial deposit thickness of 25 ft can be subtracted from the elevation at any point to approximate the depth to the top of the unit in that area.



Geology modified from unpublished map by C.R. Smith, 1970 (R.P. McCulloh, Louisiana Geological Survey, written commun., 1992)

Figure 22. Altitude of the base of the Sparta aquifer in northern Caddo Parish, Louisiana.

Water Quality

Water in the Sparta aquifer generally is a soft sodium bicarbonate type. The dissolved-solids concentrations across the Mississippi Embayment range from 20 to 1,510 mg/L, but the median value of 218 mg/L indicates that the water generally is moderately mineralized (Hosman and others, 1968, p. 19). Water withdrawn from the Sparta aquifer west of Caddo Parish in Sabine and San Augustine Counties in Texas is so highly mineralized that further development of the aquifer in this area has been limited (Baker and others, 1963a, p. 43-44). Water from observation well Cd-7255Z in extreme northern Caddo Parish (fig. 1) had a dissolved-solids concentration of 74 mg/L and a pH of 6.0. A pH of 6.0 in water from the well was slightly acidic, which is expected for a well completed in an aquifer's recharge area. Ground water pumped from an aquifer's recharge area tends to have slightly higher levels of organic acids in solution due to dissolution of buried organic matter (Freeze and Cherry, 1979, p. 241). As with the Red River alluvial aquifer, local petroleum industry activity related to exploration and production could have a substantial effect on water quality in shallow Sparta sands (Whitfield, 1980, p. 23).

A list of the properties and constituents for wells completed in the Sparta aquifer and wells completed in aquifers of Tertiary age is provided in Appendix 2. These wells, shown in figure 23, were grouped on the basis of geologic age rather than aquifer to simplify presentation of the water-quality data. A statistical analysis of water-quality data was not performed because of insufficient data.

Potential for Development

The earliest known pumping of water from the Sparta aquifer in the Mississippi Embayment began in the Pine Bluff area of east-central Arkansas in 1898 (Klein and others, 1950). Pumping from the aquifer in Arkansas has increased as a result of industrial development and agricultural use, and in the late 1970’s, water use peaked at 252 Mgal/d (McWreath and others, 1991, p.11). Water use from the Sparta aquifer in the Texas counties adjoining Caddo Parish is small, (Baker and others, 1963b, p. 43-44). Pumping from the aquifer in Arkansas and Texas affects water levels in the Sparta aquifer in Caddo Parish, although this effect is limited to the aquifer's recharge area, where water levels are more affected by infiltration than by distant pumping (Hosman and others, 1968, p. 20). Water use from this aquifer (in Caddo Parish) is estimated to be 0.02 Mgal/d, less than 1 percent of total measured withdrawals from study area aquifers (Lovelace, 1991, p. 100). Based on the sand thicknesses shown in hydrogeologic section B-B' (fig. 6) and available water use data for this area, this aquifer is underdeveloped in northern Caddo Parish.

The assumptions used to calculate drawdown in a Sparta Sand similar in thickness to those shown in section B-B' are the same as were discussed in the section "Red River Alluvial Aquifer, Potential for Development" for a similar set of curves. Although sand thicknesses greater than 50 ft are shown on hydrogeologic section B-B', the Sparta aquifer has not sustained enough development in northern Caddo Parish to indicate how these sands vary in thickness or interconnect across geologic faults; thus, a conservative sand thickness of 50 ft was chosen for the analysis. A hydraulic conductivity value of 50 ft/d was chosen as a representative value for calculations (Martin and Early, 1987, p. 7). The effect of pumping (at 100, 500 and 1,000 gal/min) on water-level drawdown for an average transmissivity of 2,500 ft^2/d is shown in figure 24. Pumping for 1 year at a rate of 100 gal/min would cause water levels 10,000 ft from the pumped well to decline about 3.3 ft from their original pre-pumped levels (fig. 24).

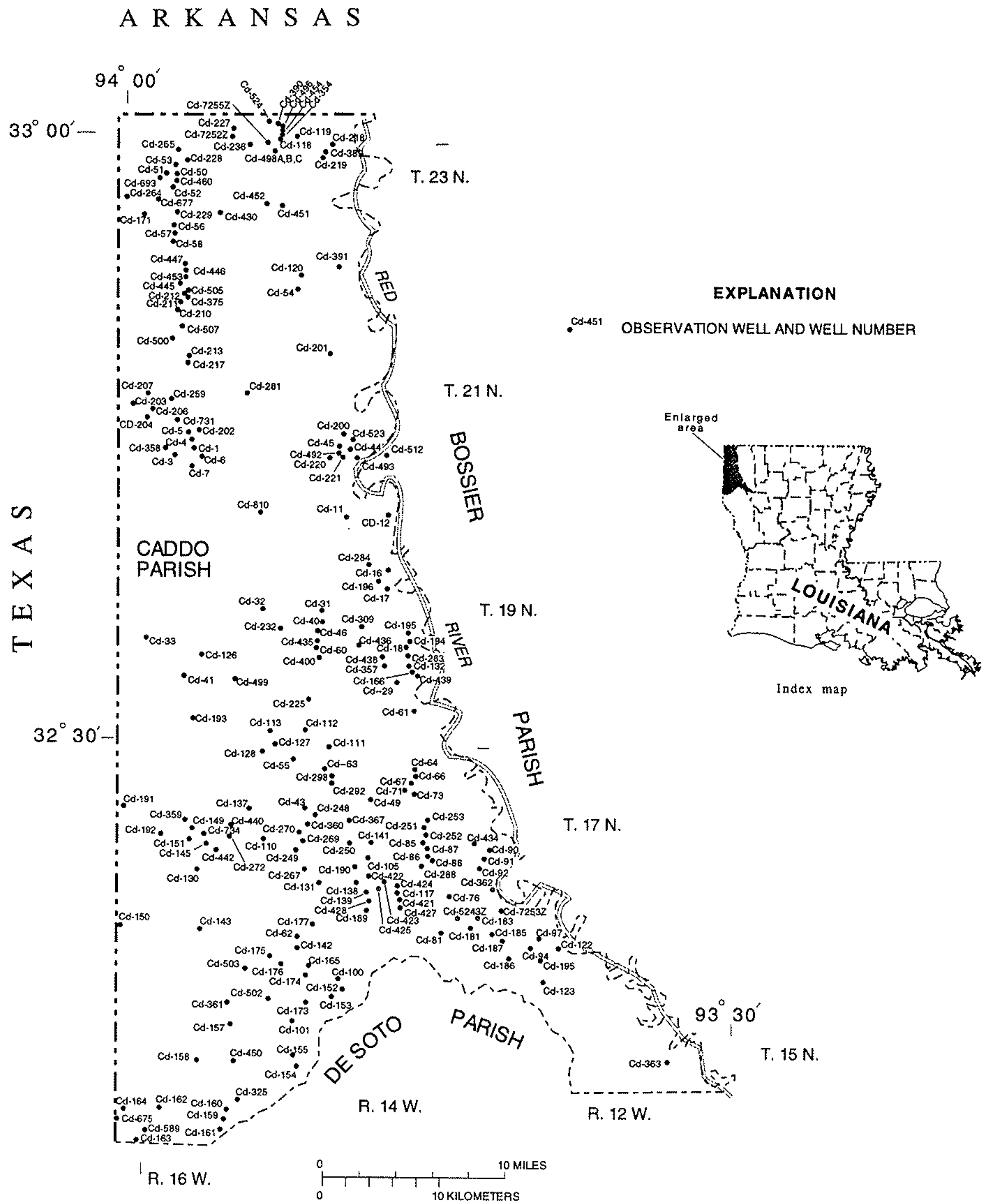


Figure 23. Location of water-quality sites for wells completed in aquifers of Tertiary age in Louisiana, 1940-92.

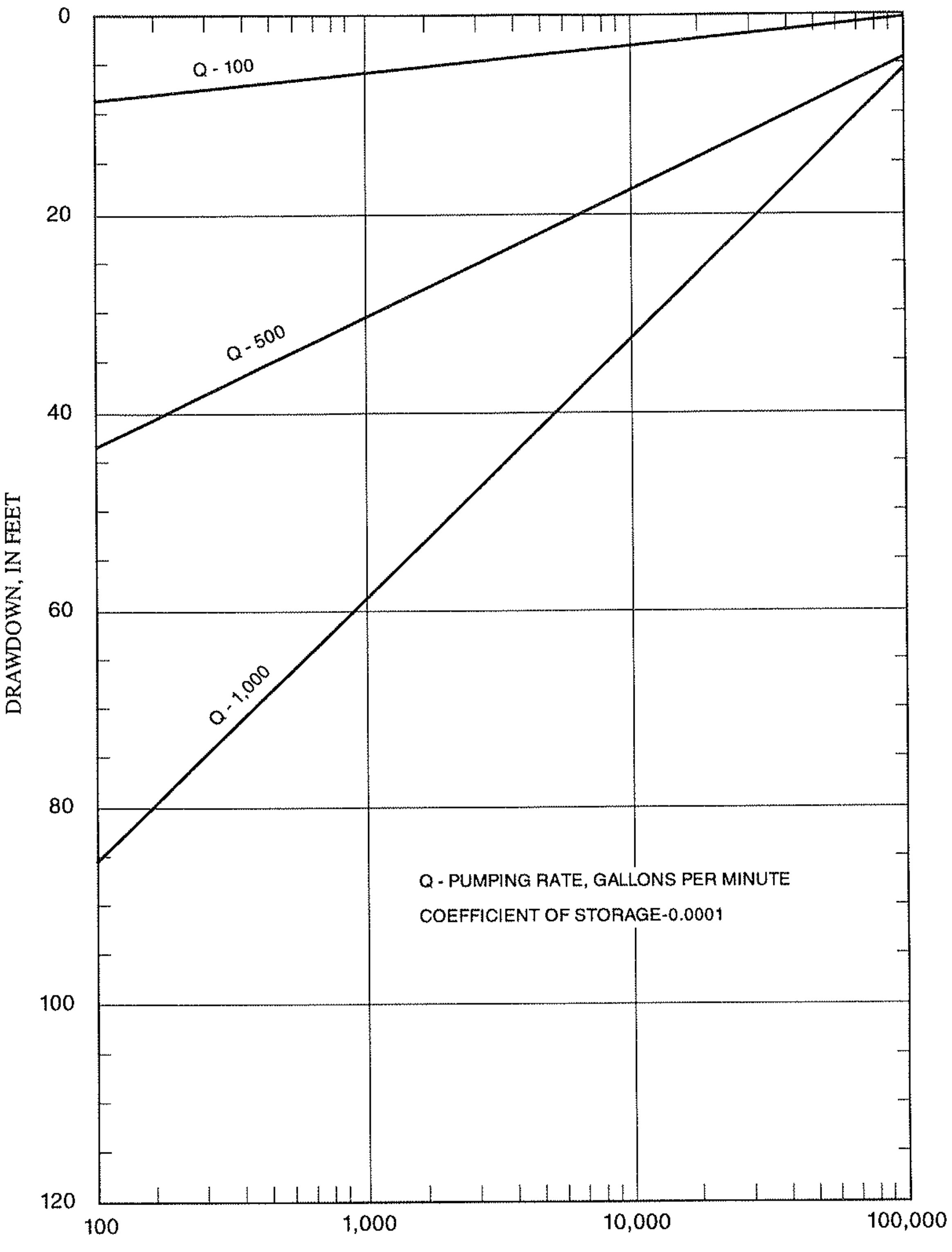


Figure 24. Distance-drawdown relation based on the Theis equation for the Sparta aquifer in Louisiana for indicated pumping rates for 3 wells, a 1-year pumping period, and a transmissivity of 2,500 feet squared per day.

Cane River Aquifer

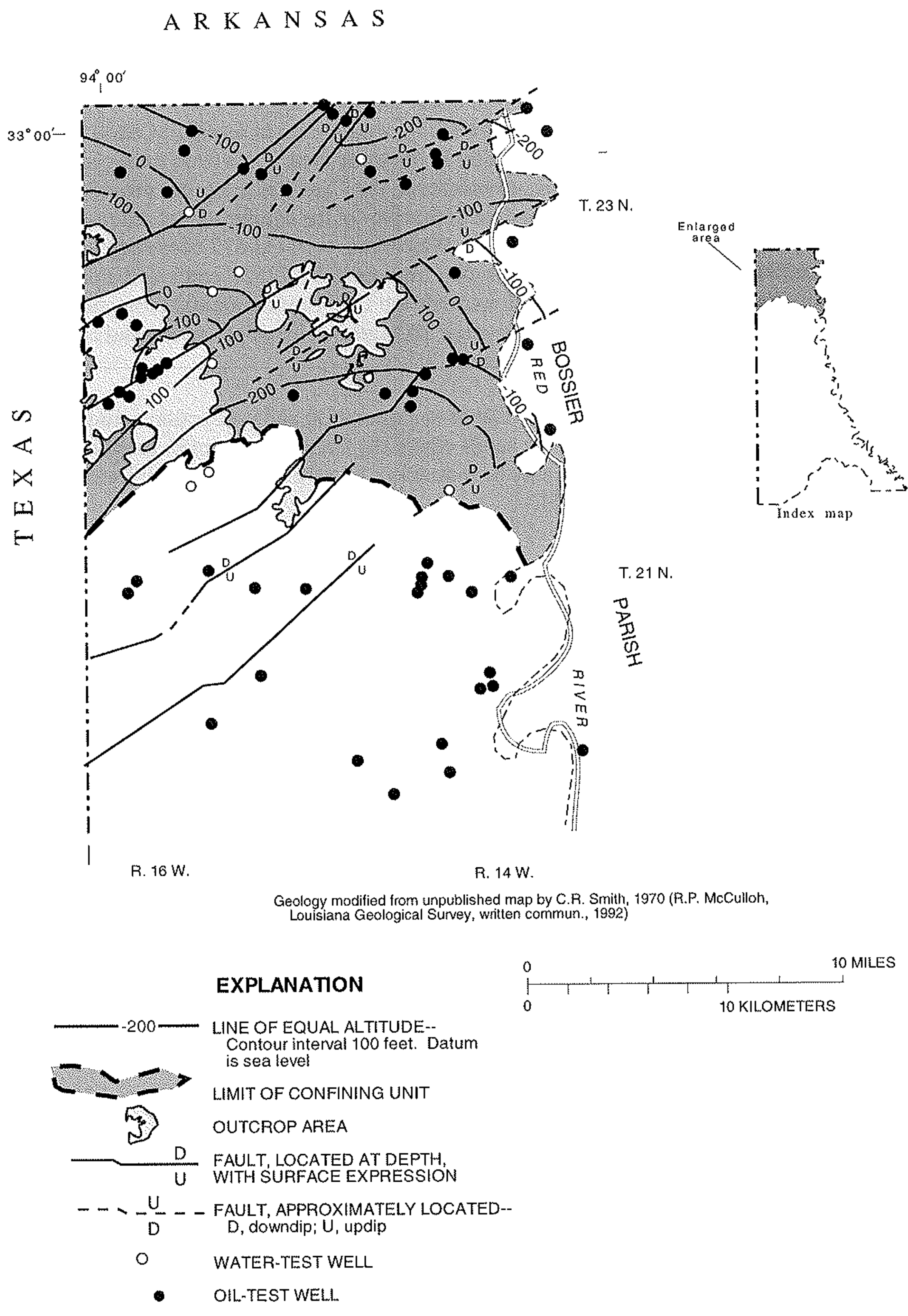
The Cane River aquifer in northwestern Louisiana (usually referred to as the Cane River confining unit in Louisiana) in this report is the interfingered sands of the Cane River confining unit. The Cane River confining unit throughout most of the subsurface of Louisiana and Arkansas is a massive, nonpermeable marine clay formation separating the underlying Carrizo-Wilcox aquifer and the overlying Sparta aquifer. However, in the updip section on the west side of the Mississippi Embayment the Cane River (confining unit) becomes increasingly sandy. The Queen City aquifer, the stratigraphic equivalent of the Cane River aquifer confining unit in Louisiana, is an important source of freshwater in Texas. In Louisiana, based on sand thickness and available water-use data, the aquifer is underdeveloped in Caddo Parish (Hosman and others, 1968, p. 18).

Hydrogeology

The Cane River aquifer (confining unit) in Louisiana and Arkansas is equivalent to the Reklaw Formation, Queen City Sand, and Weches Greensand of Tertiary age in Texas. The Cane River confining unit ranges from 200 to 500 ft in thickness in the Mississippi Embayment and dips toward the axis of the embayment (Hosman and others, 1968, p. D15). The Cane River aquifer consists of gray, fine- to medium-grained sand with interbedded gray sandy shale. Minor amounts of glauconitic sand are present locally within the aquifer (Baker and others, 1963a, p. 39). This aquifer in northern Caddo Parish (fig. 25) ranges in thickness from 30 to 80 ft where the aquifer is buried under Red River alluvium (figs. 8 and 9). The Cane River aquifer is thin where it crops out because of erosion. This aquifer is composed of thick freshwater sands in northern Caddo Parish (fig. 6).

Reported hydraulic conductivity values for the Queen City aquifer in Wood County, Tex., northwest of Caddo Parish, range from 12 to 18 ft/d (Baker and others, 1963a, p. 41). This range is similar to a range reported for the Carrizo Sand of the Carrizo-Wilcox aquifer (Martin and Early, 1987, p. 7). This similarity is expected because these two aquifers are grouped within the same stratigraphic unit and tend to interfinger and combine at different areas across the Mississippi Embayment (Hosman and others, 1968, p. D12). Because development of the Cane River aquifer in northern Caddo Parish is limited, values for hydraulic conductivity from this area are not available and, for purpose of analysis, have been approximated using the hydraulic conductivity value for the Carrizo Sand. This analysis is included in the section titled "Cane River Aquifer, Potential for Development."

The approximate altitude of the base of the Cane River aquifer is shown in figure 25. The top of the Cane River aquifer, where it does not crop out, is overlain by the Sparta aquifer or unnamed alluvial deposits. The top of the Cane River aquifer is the base of the Sparta aquifer shown in figure 22. A thickness of 25 ft can be estimated for an unnamed alluvial aquifer for all other areas where the Cane River aquifer is not exposed at the surface. Hydrogeologic section B-B' (fig. 6) shows the sands encountered in selected oil-test wells and can be used as a general guide to aquifer character near the line of section.



Geology modified from unpublished map by C.R. Smith, 1970 (R.P. McCulloh, Louisiana Geological Survey, written commun., 1992)

Figure 25. Altitude of the base of the Cane River aquifer in northern Caddo Parish, Louisiana.

Water Quality

Water from wells completed in the Cane River aquifer generally is clear and soft, but sometimes high concentrations of iron occur locally (Page and May, 1964, p. 45). Because this aquifer has experienced little development by water users in northern Caddo Parish, few water-quality data are available for this aquifer in the study area. Data from three producing water wells, Cd-212, Cd-677, and Cd-7252Z, completed in the Cane River aquifer provide water-quality information that may be representative of that part of the aquifer within the study area. No analysis for iron was available for well Cd-212. Water from well Cd-677 contained a dissolved-iron concentration of 39 μg/L. Water sampled from well Cd-7252Z contained a dissolved-iron concentration of 1,500 μg/L, which exceeds the U.S. Environmental Protection Agency's secondary maximum contaminant level of 300 μg/L. A list of properties and constituents for water from these wells is included in Appendix 2.

Petroleum industry activity related to exploration and production could have a substantial effect on water quality in shallow sands where the Cane River aquifer crops out in Caddo Parish. Highly mineralized water also may be introduced into the aquifer at other locations by leaking well casings (Whitfield, 1980, p. 23).

Potential for Development

Although no data are available that describe the extent of development of the Cane River aquifer in northern Caddo Parish, it is believed that development is relatively modest when sand thicknesses of the hydrologic system in northern Caddo Parish are considered. Water-quality data derived from geophysical logs indicate that faults have partially isolated areas of the Cane River aquifer from freshwater recharge by the regional hydrologic flow system. This would affect development of these partially isolated sands that contain freshwater.

The assumptions used to calculate drawdown in the Cane River aquifer are the same as those discussed in the section "Red River Alluvial Aquifer, Potential for Development" for a similar set of curves. Although an average sand thickness of 70 ft and hydraulic conductivity of 17 ft/d was assumed for the analysis, varying thickness of sands in northern Caddo Parish and the effect of faults may limit the areal extent of the aquifer and cause the observed drawdowns due to pumping to differ from these predicted values. The effect of pumping (at 100, 500 and 1,000 gal/min) on water-level drawdown for an average transmissivity of 1,190 ft^2/d, is shown in figure 26. Pumping for 1 year at a rate of 100 gal/min would cause water levels 10,000 ft from the pumped well to decline about 6.5 ft from their original pre-pumped levels (fig. 26).

Carrizo-Wilcox Aquifer

The Carrizo-Wilcox aquifer is the most important aquifer in Caddo Parish due to its parish-wide extent and because at almost all locations in the parish the aquifer contains some freshwater. The variation in quantity of freshwater available from this aquifer results from hydrogeologic factors that restrict freshwater recharge. The limitation of freshwater recharge to the aquifer is compounded by the parish-wide system of faults. The altitude of the base of the Carrizo-Wilcox aquifer is shown in figure 27.

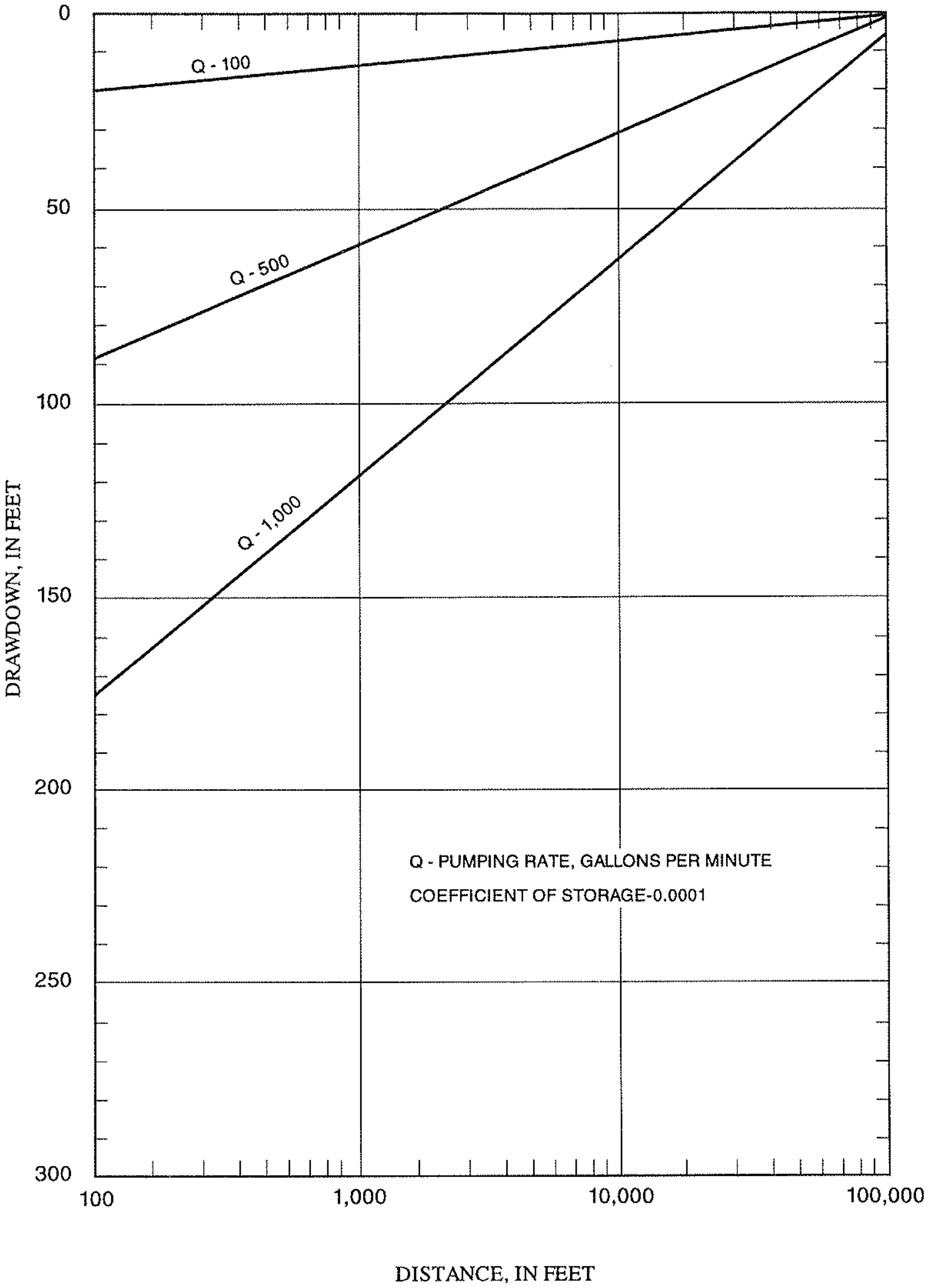


Figure 26. Distance-drawdown relation based on the Theis equation for the Cane River aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 1,190 feet squared per day.

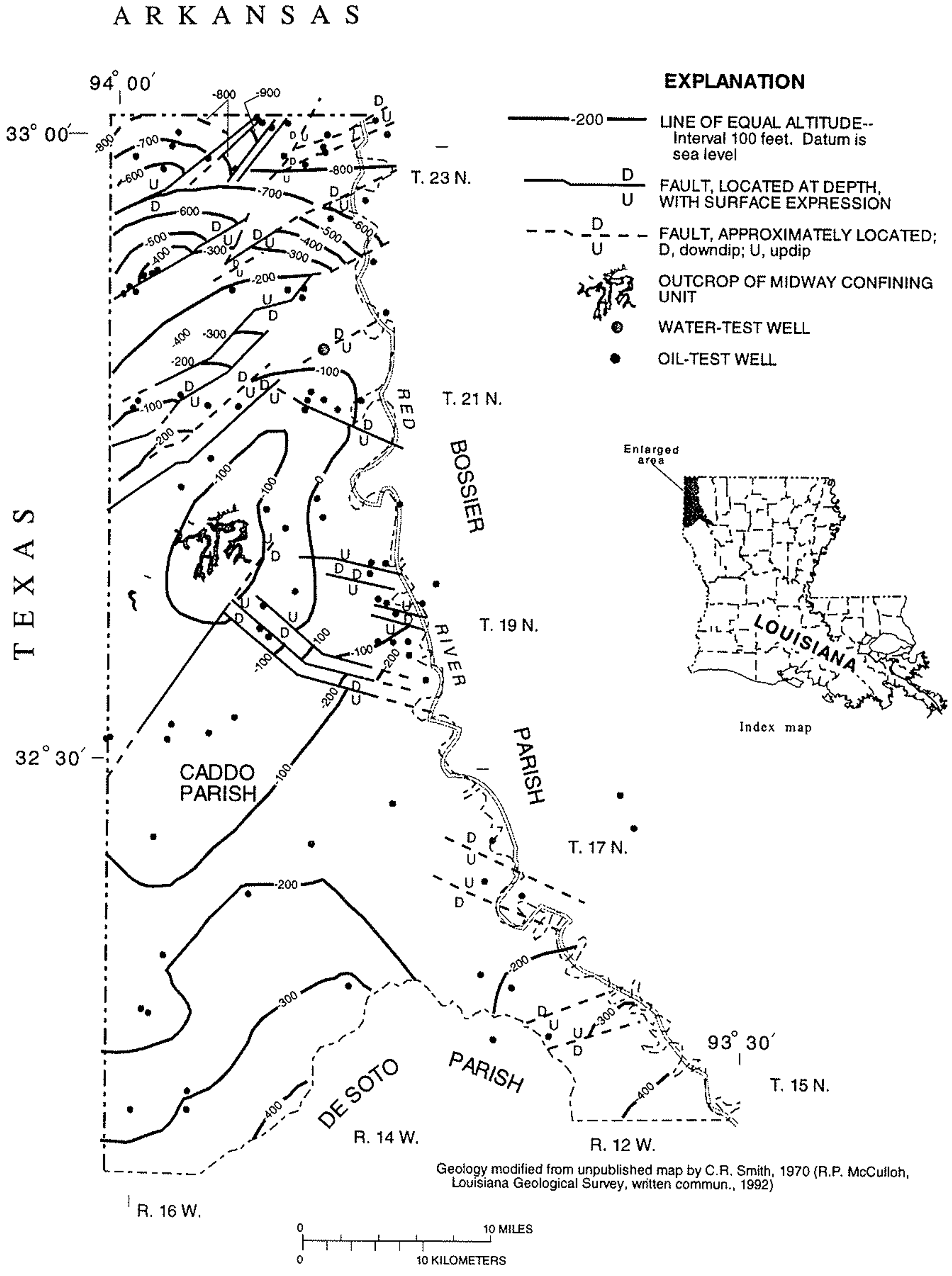


Figure 27. Altitude of the base of the Carrizo-Wilcox aquifer in Caddo Parish, Louisiana.

Hydrogeology

The Carrizo-Wilcox aquifer is composed of a top zone (Carrizo) of coarse-grained and relatively clay-free sand and a much thicker bottom zone (Wilcox) that is composed of fine-grained sand interbedded with thin clay beds. The Carrizo Sand, referred to in this report as the top zone of the Carrizo-Wilcox aquifer, is considered the basal unit of the Claiborne Group in Arkansas, Louisiana, and Texas (Hosman and others, 1968, p. D12). The Carrizo Sand is hydraulically interconnected with the underlying Wilcox Group; therefore, the Wilcox Group and Carrizo Sand are considered to be a single hydrologic unit (Ryals, 1983, p. 3). The top zone of the Carrizo-Wilcox aquifer is in the area of northern Caddo Parish between the Sabine uplift and the Louisiana-Arkansas border. South of the Sabine uplift's apex, the top zone of the Carrizo-Wilcox aquifer has been eroded along with part of the underlying bottom zone. North of the Sabine uplift's apex the Carrizo-Wilcox aquifer has a net vertical change in elevation of about 1,400 ft (fig. 4). South of the apex the Carrizo-Wilcox aquifer base has a net vertical change in elevation of about 400 ft.

Martin and Early (1987, p. 7) reported a hydraulic conductivity of 17 ft/d for the Carrizo Sand. The thickness of the top zone of the Carrizo-Wilcox aquifer varies widely in the northern part of the study area. At well Cd-447, north of Vivian, La. (fig. 1), this top zone is about 70 to 75 ft thick. At oil-test well 74374, as shown in hydrogeologic section B-B' (fig. 6), this zone has a thickness of about 25 ft. At its outcrop the aquifer is approximately 35 ft thick. Although the top zone of the Carrizo-Wilcox aquifer contains freshwater in Caddo Parish, the variability in thickness will result in variability in well yields.

The bottom zone of the Carrizo-Wilcox aquifer contains freshwater and makes up the bulk of the sands. Hydraulic conductivity for this zone averages 10 ft/d (Ryals, 1983, p. 6). Transmissivity values based on aquifer tests of wells in southern Caddo Parish for wells Cd-707 and Cd-706 completed in the bottom zone of the Carrizo-Wilcox aquifer are 250 and 260 ft^2/d, respectively. Although some thick sands are present in the bottom zone north of the Sabine uplift's apex, poorly interconnected thin sand beds interbedded with clay (Hosman and others, 1968, p. D10) are common for the bottom zone of the Carrizo-Wilcox aquifer and are present throughout the study area. South of the Sabine uplift's apex the aquifer is comprised of poorly interconnected thin sand beds interbedded with clay. Because these poorly interconnected fine grained sands resist flushing by freshwater, the entire aquifer has never been completely flushed of saltwater at any point in the study area.

South of the uplift's apex, a single extensive sand that ranges in thickness from 75 ft at oil-test well 60890 to 24 ft at well Cd-706 provides a conduit for ground-water flow across the area. Thin sand units located at higher elevations receive freshwater recharge from this single deep sand having a higher hydraulic head. The saltwater contained in these thin fine-grained sands has not been flushed due to poor sand interconnections. Most of the mapped geologic faults occur north of the Sabine uplift's apex (fig. 27). The extensive faults and large scale displacements that occur north of the Midway confining unit generally do not occur in southern Caddo Parish; however, some faults have been documented in southern Caddo Parish, and like the hydrologic system north of the Sabine uplift's apex, there are probably additional, unmapped faults located in this area. These minor faults would not greatly affect the massive sands of northern Caddo Parish but could greatly affect water flowing through poorly interconnected thin sands.

Recharge to the Carrizo-Wilcox aquifer is generally from the west (fig. 5). The closely spaced contour intervals in the southwestern part of the parish indicate a steeper hydraulic gradient than in adjacent areas of Caddo Parish. Assuming a constant hydraulic conductivity, ground-water flow velocity increases as the distance between contour intervals decrease, which indicates a high flow velocity in the southwestern part of the parish. The increased flow in this area probably is facilitated by the Carrizo-Wilcox aquifer of southern Caddo Parish having a cumulative sand thickness greater than that of northern Caddo Parish (fig. 28). The potentiometric low areas in the southeastern and northeastern parts of the parish probably result from pumping by municipal water supplies. The bending of the potentiometric contours toward those areas indicates increased flow toward the pumping center.

Water Quality

More than 75 percent of the chloride and iron concentrations for the Carrizo-Wilcox aquifer in the study area were below the U.S. Environmental Protection Agency's secondary maximum contaminant levels (fig. 29). More than 90 percent of the nitrate concentrations were below the U.S. Environmental Protection Agency's secondary maximum contaminant level. Dissolved-solids concentrations for the Carrizo-Wilcox aquifer were not plotted due to insufficient data. Water from fewer than 25 percent of all wells sampled that were completed in the Carrizo-Wilcox aquifer contained chloride concentrations greater than 600 mg/L. These high chloride concentrations were in water from wells completed in the bottom-zone sands that have not been flushed with freshwater. A substantial percentage of the Carrizo-Wilcox aquifer has not been flushed of saltwater; therefore, few wells have been completed in these saltwater sands. The box plot (fig. 29) represents the statistical distribution of chloride concentrations from wells completed in the freshwater section of the Carrizo-Wilcox aquifer. A list of properties and constituents of water for wells completed in the Carrizo-Wilcox aquifer is provided in Appendix 1.

Water quality varies both laterally and vertically in the Carrizo-Wilcox aquifer as a result of hydrogeologic factors that affect freshwater recharge from the regional flow system. North of the Sabine uplift's apex a general trend of increasing chloride with depth is indicated by the geophysical logs of oil-test wells completed in the area. Water samples from the few water wells completed in the deep Wilcox sands had chloride concentrations exceeding the U.S. Environmental Protection Agency's secondary maximum contaminant level of 250 mg/L (for seven samples, the maximum concentration was 510 mg/L). A general trend of decreasing resistivity with increasing depth was apparent in these deep sands; however, close inspection of oil-test well geophysical logs indicates some deep sands are receiving higher rates of flow from freshwater recharge than nearby sands and have low dissolved-solids concentrations (high resistivity water). Geophysical data for oil-test well 178092 in hydrogeologic section C-C' (fig. 8) indicate that two freshwater sands at 250 and 330 ft are separated by two saltwater sands that have not been completely flushed by freshwater.

Although many of the sand units shown on hydrogeologic section B-B' (fig. 6) are identified as containing saltwater, the geophysical log data which were used to construct these hydrogeologic sections provide only approximate water-quality information. The approximate base of freshwater, as determined from geophysical-logs and water-quality data, is shown in figure 30. These deep sands of northern Caddo Parish may contain freshwater or water with slightly elevated chloride concentrations (50-200 mg/L) that could be developed as a water supply.

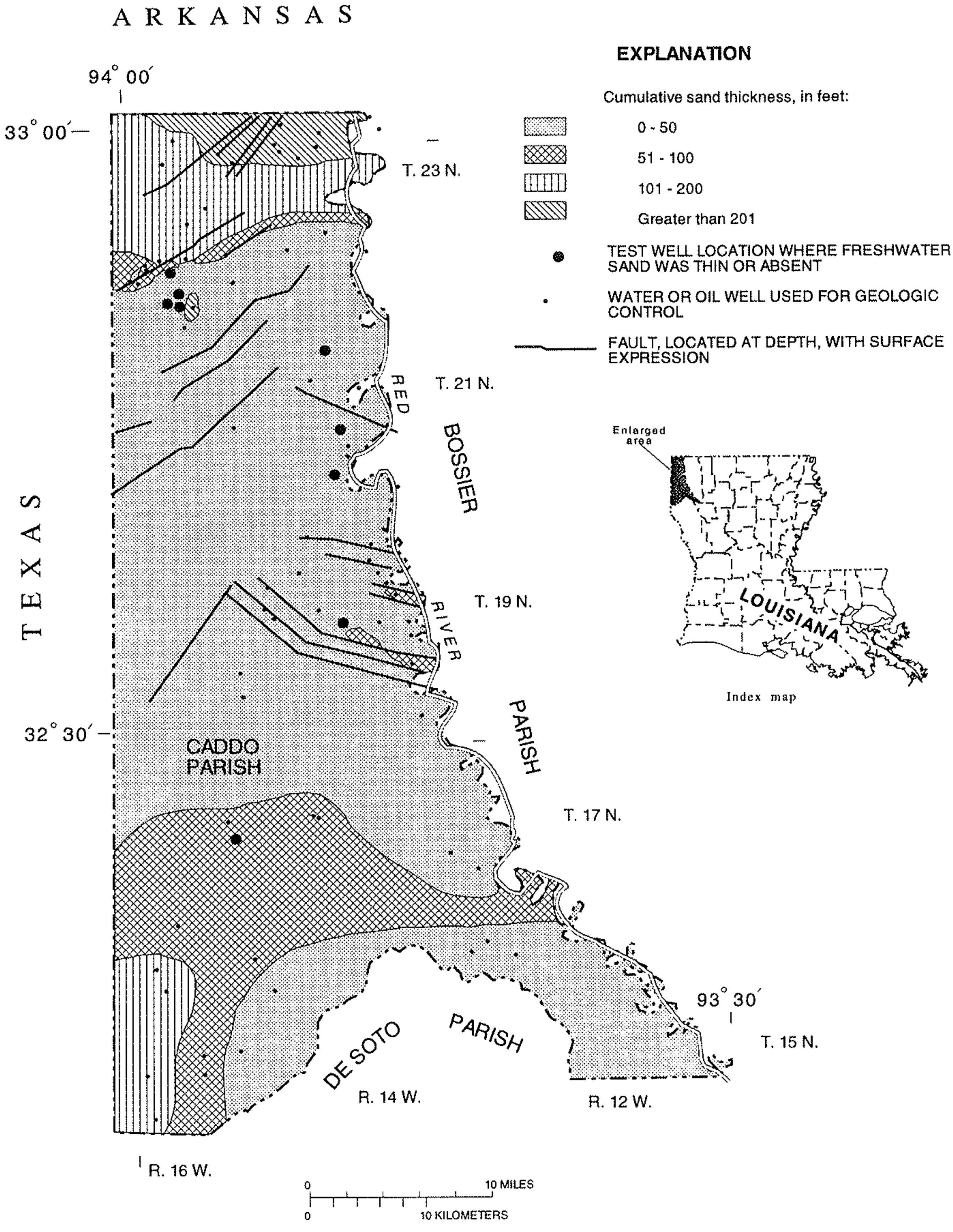


Figure 28. Cumulative sand thickness for aquifers of Tertiary age in Louisiana. Minimum sand thickness used to construct map is 10 feet.

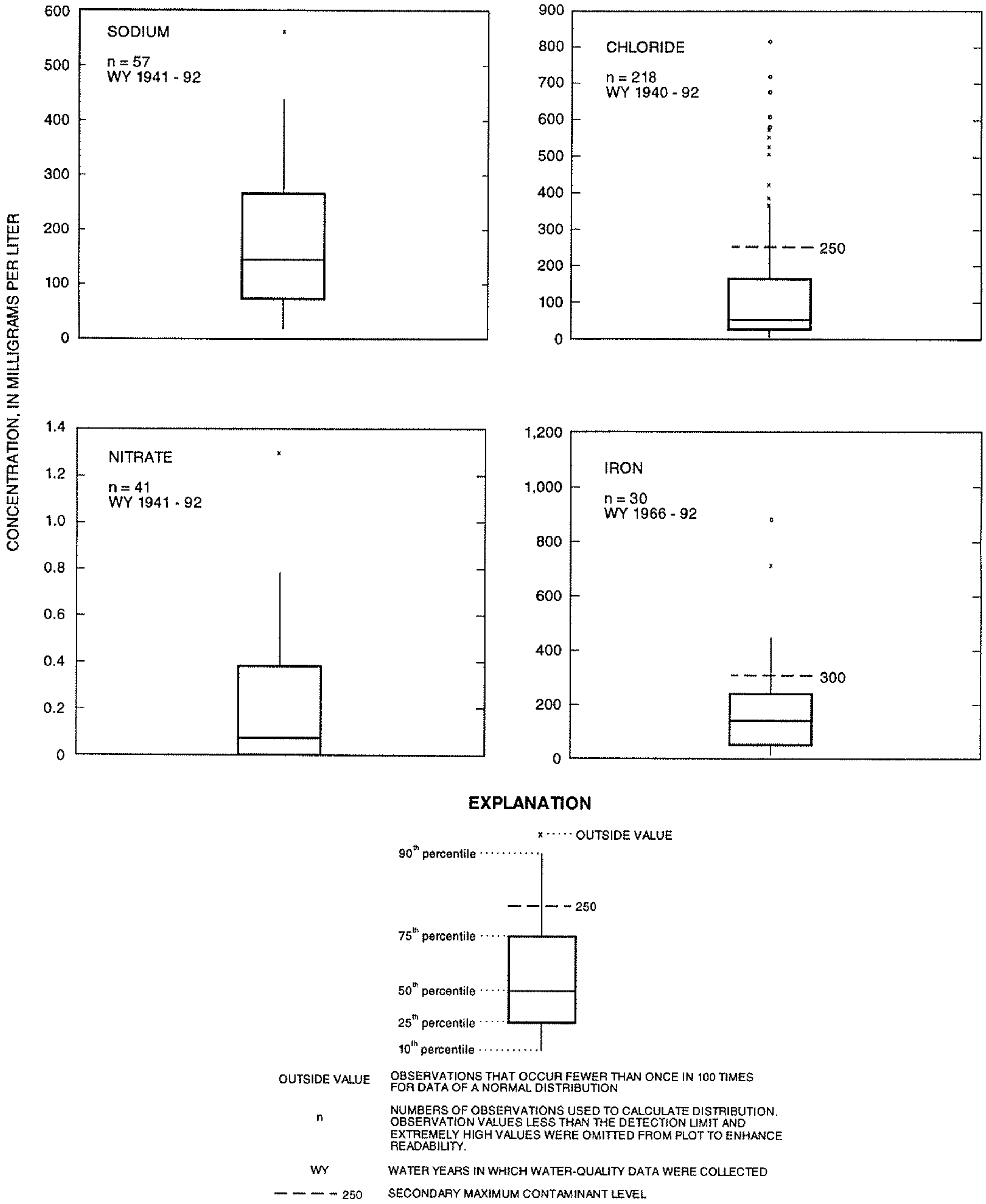


Figure 29. Box plots of selected water-quality data for the Carrizo-Wilcox aquifer in Louisiana.

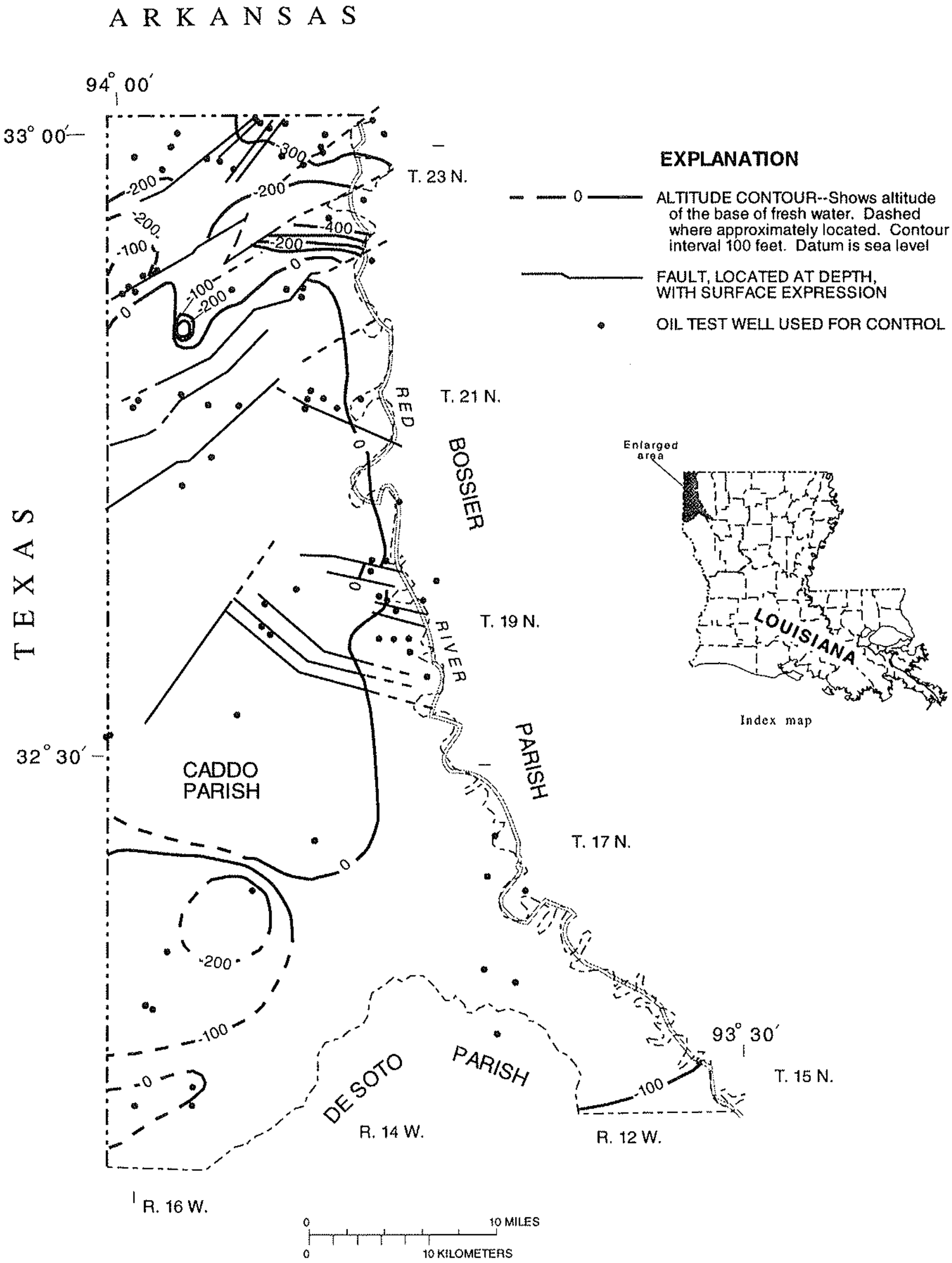


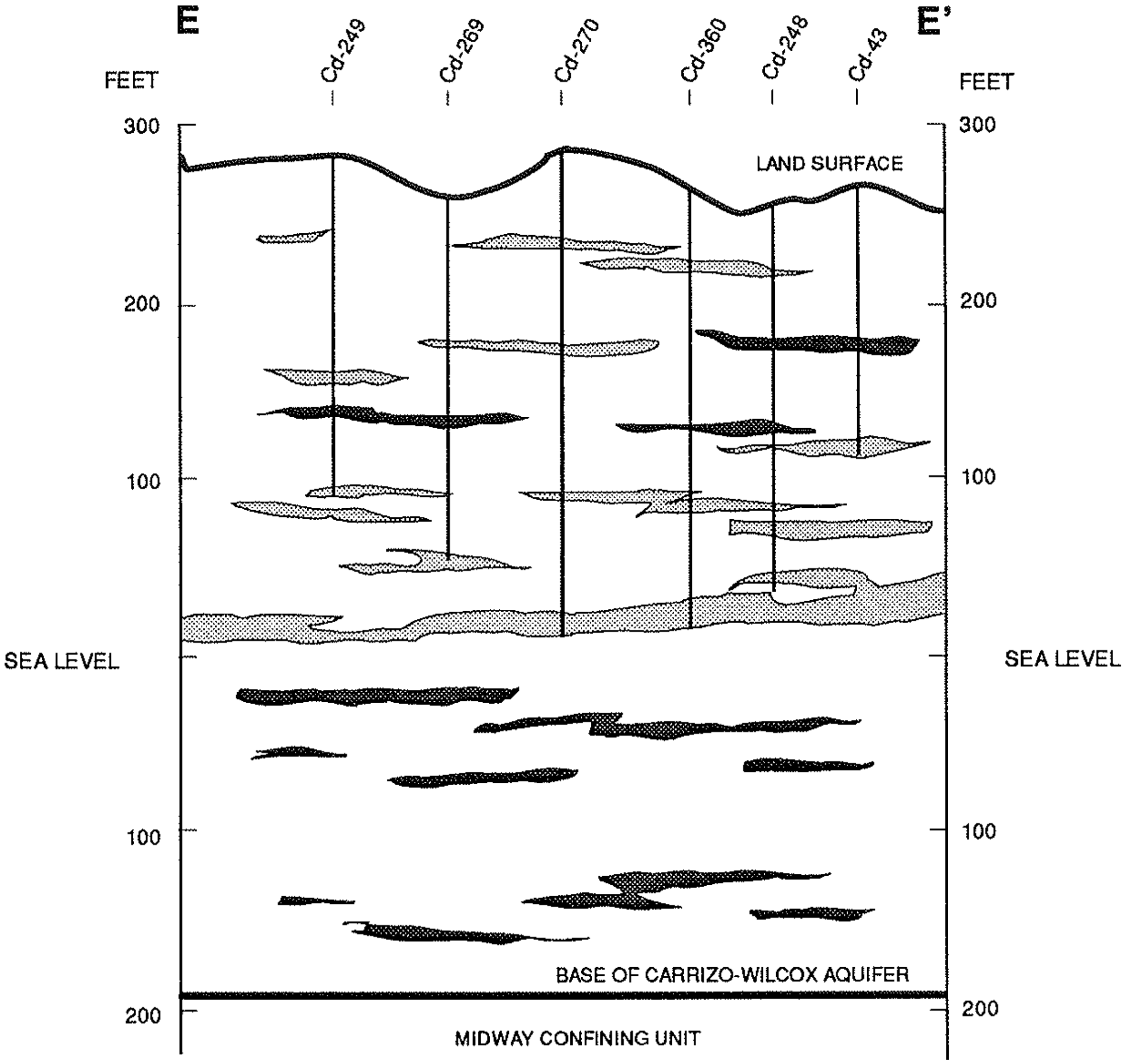
Figure 30. Altitude of the base of freshwater in Caddo Parish, Louisiana.

The trend of increasing salinity of ground water in the deeper sands is reversed south of the Sabine uplift's apex due to recharge moving through the deep sand unit in southern Caddo Parish. The geophysical log of well Cd-450 completed southwest of Keithville, La., shows the presence of a deep freshwater sand thinning in that area and ground water with progressively lower resistivity in the Carrizo-Wilcox aquifer above it. Hydrogeologic section E-E' (fig. 31) shows six observation wells completed at various depths in different sands of the Carrizo-Wilcox aquifer bottom zone. Also included in figure 31 is a table listing chloride concentrations for each well at the various depths. Although geophysical logs from wells completed in the Carrizo-Wilcox aquifer in southern Caddo Parish indicate that water is increasingly mineralized vertically in both directions from the primary deep sand in southern Caddo Parish, chloride concentrations increase fairly randomly among the sands of hydrogeologic section E-E' with no apparent general trend. This randomness in chloride concentrations is evidence of the random hydraulic interconnections of the sands and resulting random pattern of flushing of the original saltwater by freshwater recharge.

Potential for Development

Caddo Parish uses 2.99 Mgal/d of water from the Carrizo-Wilcox aquifer (77 percent of total measured withdrawals from study area aquifers), which is the single largest user of water from the Carrizo-Wilcox aquifer in Louisiana. The parish uses 22 percent of the total 13.32 Mgal/d of water pumped from the aquifer in Louisiana (Lovelace, 1991, p. 101). The southeastern part of Caddo Parish has had a decline in water levels of 40 to 60 ft from adjacent water levels in response to pumping. This area has little aquifer sand thickness, which limits its production of water. No other area of the Carrizo-Wilcox aquifer has substantial disruption of the potentiometric surface due to pumping. Curves similar to those produced for the other hydrogeologic units discussed in this report have been generated for the top and bottom zones of the Carrizo-Wilcox aquifer. Because the hydraulic conductivity of the top zone of the Carrizo-Wilcox aquifer is one and a half times larger than the hydraulic conductivity of the bottom zone, separate curves have been produced for the two zones of the Carrizo-Wilcox aquifer.

The assumptions used to calculate drawdown in the top and bottom zones of the Carrizo-Wilcox aquifer are the same as those discussed in the section "Red River Alluvial Aquifer, Potential for Development" for a similar set of curves. The variation in the hydraulic conductivity between the top and bottom zones of the Carrizo-Wilcox aquifer substantially affects aquifer water-level response to pumping, as seen by comparing figures 32 and 33. Distance-drawdown curves were produced with an assumed average top zone thickness of 36 ft for figure 32 and 26 ft for figure 33. Comparison of the effect of pumping at 500 gal/min on water-level drawdown shows that water-level drawdown in the bottom zone sand is more than twice that of the top zone sand. This doubling of water-level decline occurs for every pumping rate shown on these two figures.



Chloride concentration in water from wells included in hydrogeologic section E-E'

Parish well number	Chloride concentration, in milligrams per liter	Well depth, in feet
Cd-43	50	104
Cd-248	30	25
Cd-360	110	8
Cd-270	50	2
Cd-269	120	54
Cd-249	20	90

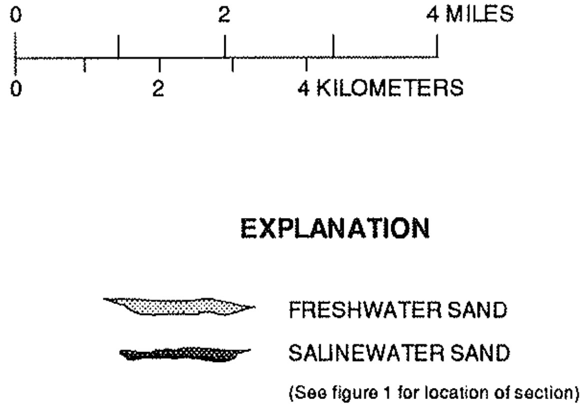


Figure 31. Detailed section (E-E') of Carrizo-Wilcox aquifer showing observation wells completed to various depths and chloride concentration in water from the wells, Caddo Parish, Louisiana.

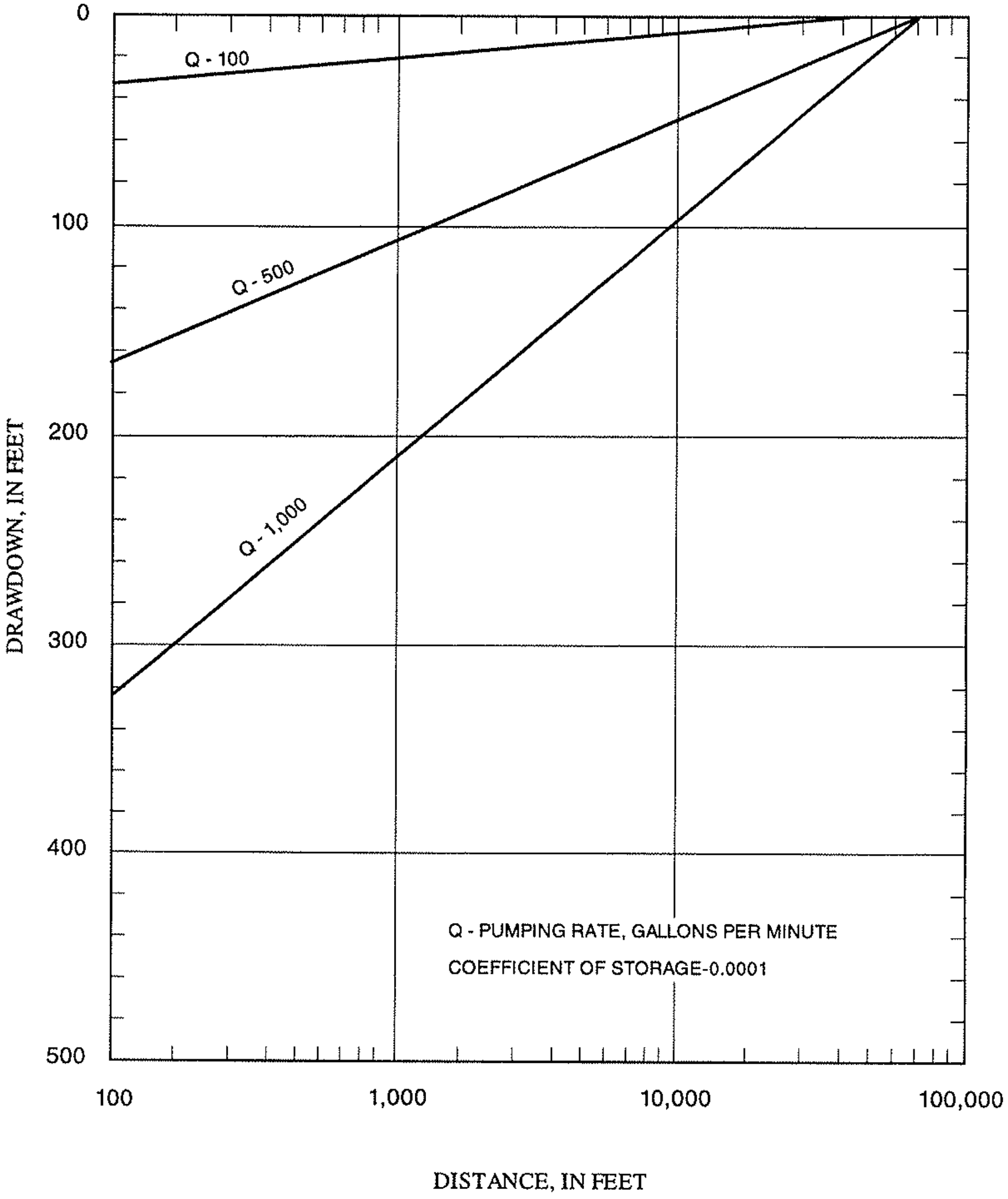


Figure 32. Distance-drawdown relation based on the Theis equation for the top zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 615 feet squared per day.

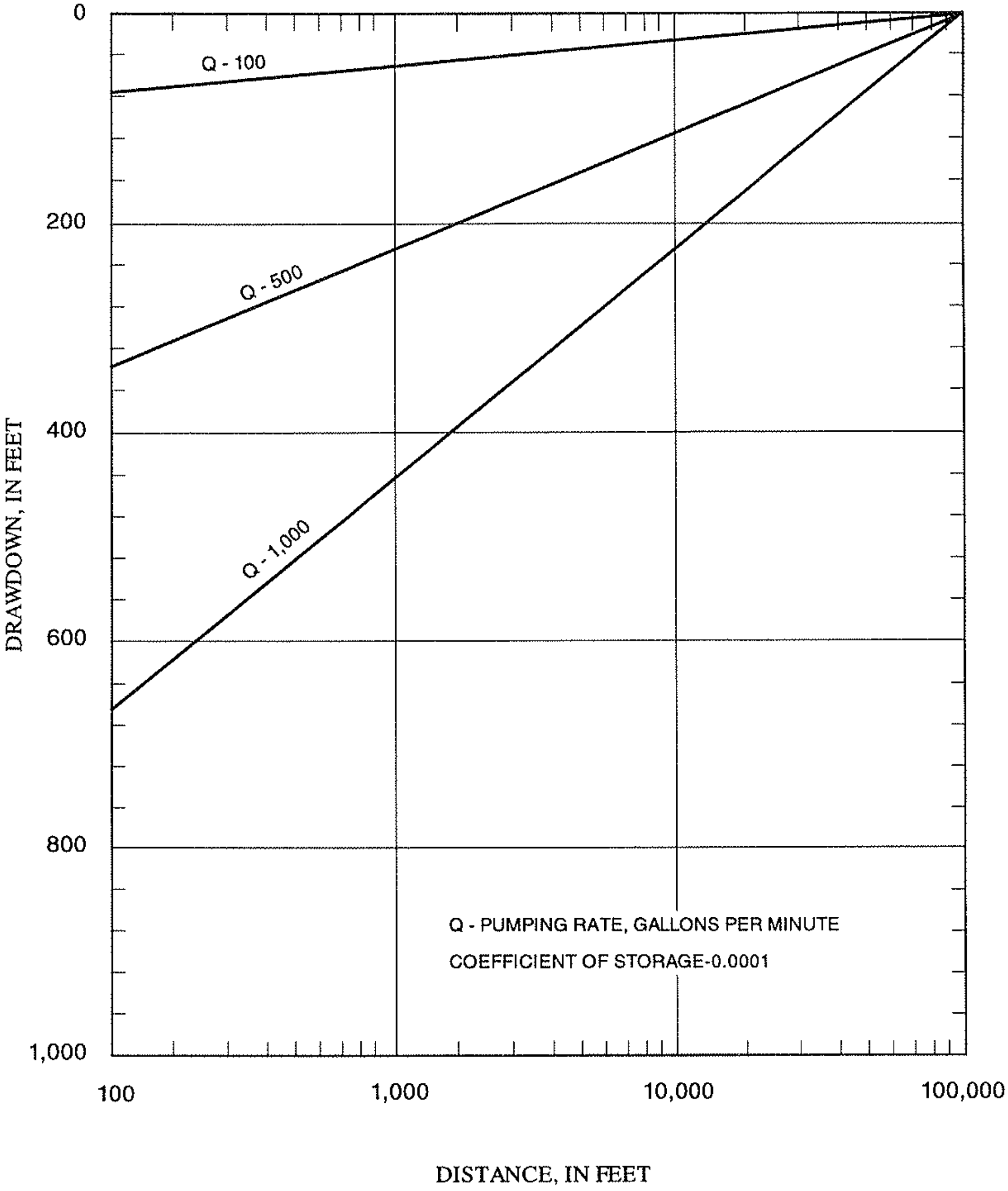


Figure 33. Distance-drawdown relation based on the Theis equation for the bottom zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 260 feet squared per day.

A notable characteristic of all bottom zone sands of the Carrizo-Wilcox aquifer is the steep cone of depression generated in the water-level surface during pumping. The effect of pumping (at 100, 500 and 1,000 gal/min) on water-level drawdown for an average transmissivity of 260 ft^2/d and a 2-week pumping period, is shown in figure 34. This bottom zone sand thickness is similar to that at well Cd-706 or Cd-707. Pumping for 2 weeks at a rate of 500 gal/min would cause water levels 1,000 ft from the pumped well to decline about 130 ft from their original pre-pumped levels (fig. 34). The water-level drawdown 10,000 ft from the well is 11 ft and the average potentiometric gradient of the water-level surface between these two points is 0.013 ft/ft. After a year of continuous pumping, water levels in the same well 1,000 and 10,000 ft away measure 226 and 91 ft, for an average potentiometric gradient of 0.015 ft/ft (fig. 34).

The gradient of the potentiometric surface generated by the pumped well discussed in the previous paragraph increases as the cone of depression deepens and as the cone moves outward from the pumping center. The large pumpage rate would stress the Carrizo-Wilcox aquifer at the pumping center and would generate increased vertical flow gradients in addition to the expected increased horizontal flow gradients. The effect of pumping (at 100, 500, and 1,000 gal/min) on water-level drawdown for the thicker bottom zone sands of the Carrizo-Wilcox aquifer that are north of the Sabine uplift's apex are calculated in figure 35. Distance-drawdown curves were produced for a bottom zone sand thickness of approximately 60.5 ft and a transmissivity of 605 ft^2/d. These Carrizo-Wilcox bottom zone sands develop steep cones of depression as a result of pumpage similar to bottom zone sands south of the Sabine uplift's apex.

Because bottom-zone sands of the Carrizo-Wilcox aquifer typically develop steep cones of depression, extended pumping in most areas where the freshwater section is bounded above and below by saltwater would cause high-chloride water to move into the well from surrounding sands. When observation well Cd-7253Z was drilled, the well owner indicated that a bed of lignite was penetrated just above where the well was screened and when the well was pumped continuously for more than an hour, the water would darken as water from the lignite deposit would move downward into the well screen. This water-quality change associated with reduced water levels in a pumped Carrizo-Wilcox Sand unit represents the primary potential problem caused by overdevelopment of the Carrizo-Wilcox aquifer.

Water levels in the Carrizo-Wilcox aquifer have declined only slightly in most areas of Caddo Parish from 1975 levels (R.C. Seanor and C.W. Smoot, U.S. Geological Survey, written commun., 1992). This small water-level decline could indicate that the natural hydrogeologic system is not greatly stressed and that additional pumping in most areas of Caddo Parish is possible. North of the Sabine uplift's apex thick sections of freshwater sand are available for further development. Because the Carrizo-Wilcox aquifer receives recharge from the north and west, the aquifer sands north of the Sabine uplift's apex may be affected by pumping in Arkansas or Texas, although such effects may be small due to large distances between pumping centers.

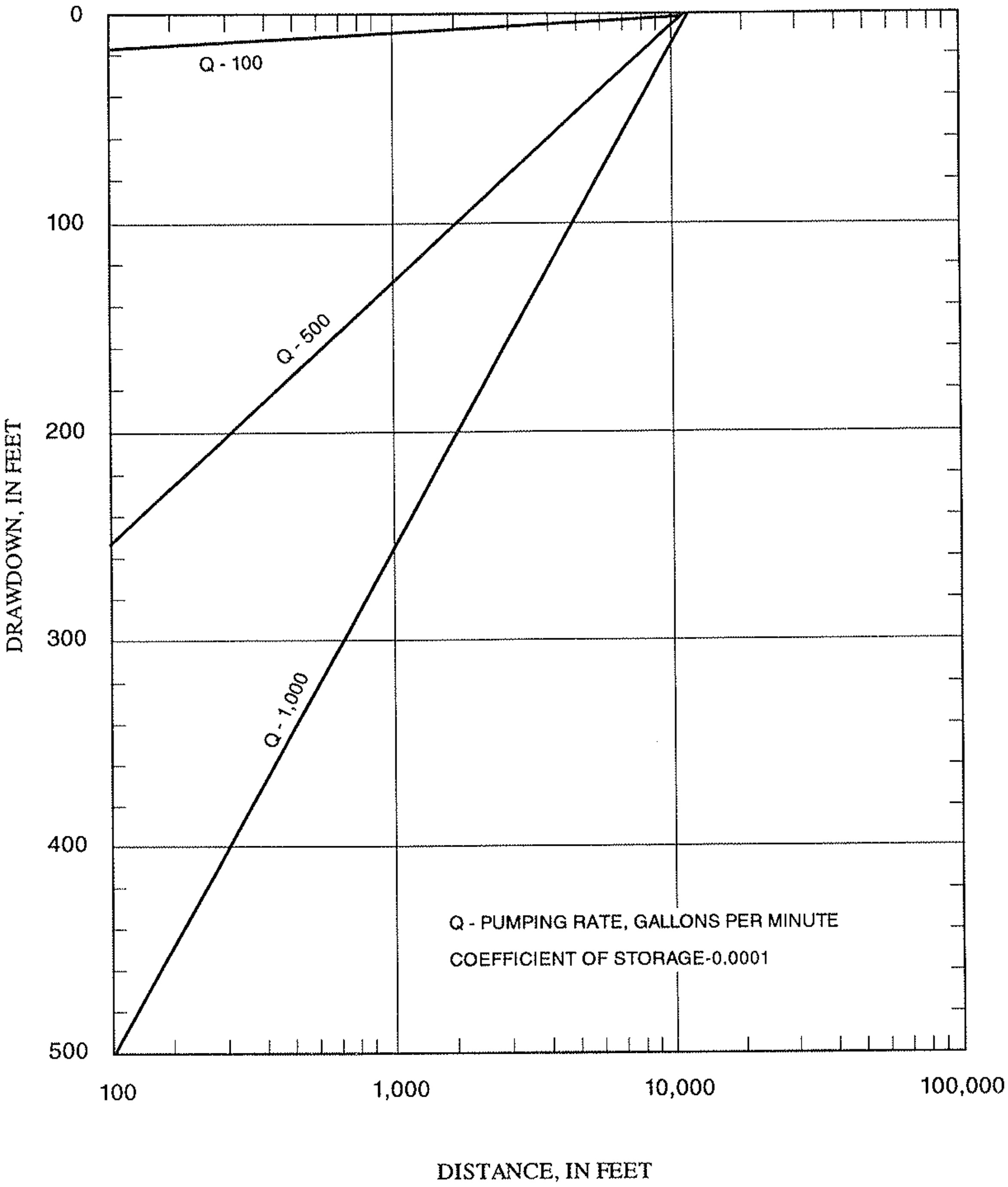


Figure 34. Distance-drawdown relation based on the Theis equation for the bottom zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 2-week pumping period, and a transmissivity of 260 feet squared per day.

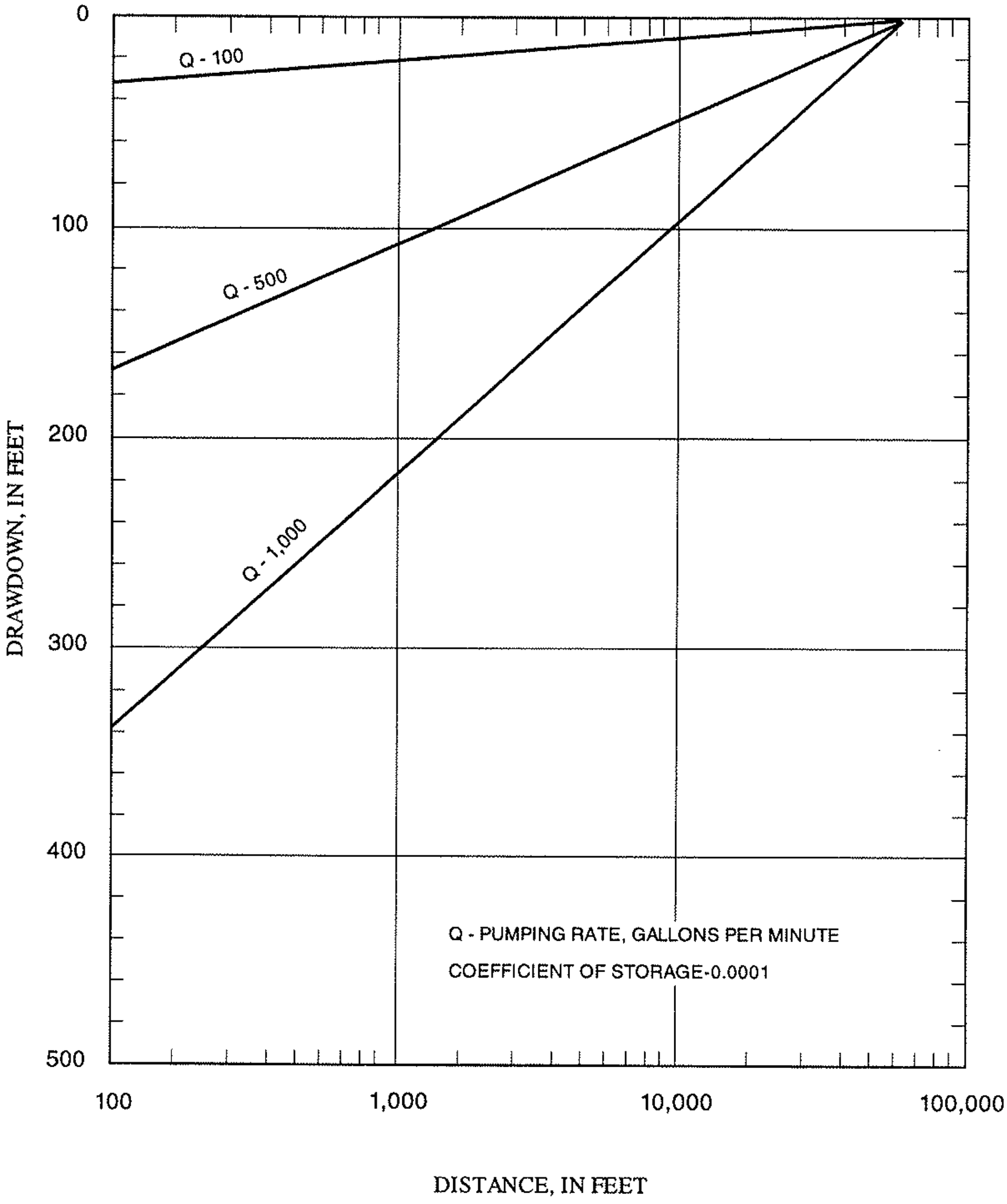


Figure 35. Distance-drawdown relation based on the Theis equation for the bottom zone of the Carrizo-Wilcox aquifer in Louisiana for indicated pumping rates, a 1-year pumping period, and a transmissivity of 605 feet squared per day.

CONCLUSIONS

As a result of the effects of uplifting and erosional processes, only four hydrogeologic units containing freshwater with substantial areal extent are present in Caddo Parish: the Red River alluvial, Sparta, Cane River, and Carrizo-Wilcox aquifers. Water use in 1989 in Caddo Parish was 0.86 Mgal/d from the Red River alluvial aquifer, 0.02 Mgal/d from the Sparta aquifer, 0.04 Mgal/d from the Cane River aquifer, and 2.99 Mgal/d from the Carrizo-Wilcox aquifer.

Of these aquifers, the Red River alluvial aquifer has the most complex depositional and erosional history. Water in the alluvial aquifer generally is unsuitable for domestic and industrial use without treatment due to hardness and to high concentrations of iron. The Sparta aquifer crops out in northern Caddo Parish and contains water that generally is a soft, sodium bicarbonate type. The Cane River aquifer crops out in northern Caddo Parish and contains a large quantity of freshwater that generally is soft. These three aquifers are considered underdeveloped in Caddo Parish based on sand thicknesses and reported water.

The Carrizo-Wilcox aquifer is the most important aquifer in Caddo Parish due to the aquifer's parish-wide areal extent and because the aquifer contains some freshwater at almost all locations in the parish. The Carrizo-Wilcox aquifer is composed of a top zone (Carrizo) of coarse-grained and relatively clay-free sand and a bottom zone (Wilcox) that makes up the bulk of the freshwater sands. Although some thick sands are present in the bottom zone north of the apex of the Sabine uplift, poorly interconnected thin sand beds interbedded with clay are common in the Carrizo-Wilcox aquifer bottom zone throughout Caddo Parish. Because these sands resist flushing by freshwater, the entire aquifer has never been completely flushed of saltwater at any point in the parish. South of the apex of the Sabine uplift a single major Carrizo-Wilcox sand provides a conduit for ground-water recharge.

More than 75 percent of the chloride and iron concentrations of water from the Carrizo-Wilcox aquifer were below the secondary maximum contaminant levels of 250 milligrams per liter and 300 micrograms per liter, respectively, established by the U.S. Environmental Protection Agency for drinking water. Water quality varies laterally and vertically in the Carrizo-Wilcox aquifer and is affected by hydrogeologic factors.

Although Caddo Parish uses more water from the Carrizo-Wilcox aquifer than any other parish in northwestern Louisiana, water levels in the Carrizo-Wilcox aquifer have declined only slightly from 1975 levels in most areas of Caddo Parish. North of the apex of the Sabine uplift, thick sections of freshwater sand are available for further development. Sands of the Carrizo-Wilcox in Caddo Parish have not been completely flushed of saltwater, and greatly lowered water levels in the deep freshwater sands can be expected to bring poor quality water down from sands of higher elevation.

SELECTED REFERENCES

Albertson, P.E., 1992, Geologic reconnaissance of the Shreveport, Louisiana, to Daingerfield, Texas Reach, Red River Waterway: Vicksburg, Mississippi, U.S. Army Corps of Engineers Waterways Experiment Station, Technical Report GL-92-1, 10 pl.

Baker, B.B., Dilliard, J.W., Souders, V.L., and Peckham, R.C., 1963, Reconnaissance investigation of the ground-water resources of the Sabine River Basin, Texas: Texas Water Commission Bulletin 6307, 57 p.

Baker, E.T., Jr., Long, A.T., Jr., Reeves, R.D., and Wood, L.A., 1963, Reconnaissance investigation of the ground-water resources of the Red River, Sulphur River, and Cypress Creek Basins, Texas: Texas Water Commission Bulletin 6306, 127 p.

Baker, E.T., Jr., and Wall, J.R., 1976, Summary appraisals of the Nation's ground-water resources, Texas-Gulf Region: U.S. Geological Survey Professional Paper 813-F, 29 p.

Boswell, E.H., Cushing, E.M., and Hosman, R.L., 1970, Quaternary aquifers in the Mississippi Embayment, *with a discussion of* Quality of the water, by H.G. Jeffery: U.S. Geological Survey Professional Paper 448-E, 15 p.

Boswell, E.H., Moore G.K., Lambert T.W., and others, 1970, Cretaceous aquifers of the Mississippi Embayment, *with a discussion of* Quality of the water, by H.G. Jeffery: U.S. Geological Survey Professional Paper 448-C, 37 p.

Broadhurst, W.L., 1942, Harrison County, Texas: Records of wells and springs, drillers' logs, and water analyses, and map showing locations of wells and springs: Texas State Board of Water Engineers Report, 43 p.

Broadhurst W.L., and Breeding, S.D., 1943, Water resources of Harrison County, Texas: Texas State Water Resources Report, 55 p.

Broadhurst, W.L., and White, W.N., 1942, Water supply near Woodall, in southwestern corner of Harrison County, Texas: U.S. Geological Survey Open-File Report, 21 p.

Broom, M.E., 1971, Ground-water resources of Cass and Marion Counties, Texas: Texas Water Development Board Report 135, 73 p.

Broom, M.E., and Myers, B.N., 1966, Ground-water resources of Harrison County, Texas: Texas Water Development Board Report 27, 74 p.

Cushing E.M., Boswell, E.H., and Hosman, R.L., 1964, General geology of the Mississippi Embayment: U.S. Geological Survey Professional Paper 448-B, 28 p.

Duffin, G.L., and Elder, G.R., 1979, Variations in specific yield in the outcrop of the Carrizo Sand in south Texas as estimated by seismic refraction: Austin, Texas Department of Water Resources, Report 229, 61 p.

Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill Book Company, 714 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Fitzpatrick, D.J., Kilpatrick, J.M., and McWreath, H.C. III, 1990, Geohydrologic characteristics and simulated response to pumping stresses in the Sparta aquifer in east-central Arkansas: U.S. Geological Survey Water-Resources Investigations Report 88-4201, 50 p.

Follett, C.R., and White, W.N., 1942, Cass County, Texas: Records of wells and springs, drillers' logs, water analyses, and map showing locations of wells and springs: Texas State Board of Water Engineers Report, 41 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall Inc., 604 p.

Garza, Sergio, Jones, B.D., and Baker, E.T., Jr., 1987, Approximate potentiometric surfaces for the aquifers of the Texas coastal uplands system, 1980: U.S. Geological Survey Hydrologic Atlas HA-704, 1 sheet, 1:1,500,000.

Grubb, H.F., 1985, Overview of the Gulf Coast Regional Aquifer-System Analysis, south-central United States: American Water Resources Association Monograph no. 9, p. 101-118.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p., 3 pls. in pocket.

Hosman, R.L., 1978, Geohydrology of the northern Louisiana salt-dome basin pertinent to the storage of radioactive wastes--A progress report: U.S. Geological Survey Water-Resources Investigations Report 78-104, 27 p.

———1982, Outcropping Tertiary units in southern Arkansas: U.S. Geological Survey Miscellaneous Investigation Series I-1405, 1 p.

Hosman R.L., Long A.T., Lambert T.W., and others, 1968, Tertiary aquifers in the Mississippi Embayment, *with discussions of* Quality of the water, by H.G. Jeffery: U.S. Geological Survey Professional Paper 448-D, 29 p.

Jones, P.H., Stevens, P.R., Wesselman, J.B., and Wallace, R.H., Jr., 1976, Regional appraisal of the Wilcox Group in Texas for the subsurface storage of fluid wastes: Part I - Geology: U.S. Geological Survey Open-File Report 76-394, 107 p.

Klein, Howard, Baker, R.C., and Billingsly, G.A., 1950, Ground-water resources of Jefferson County, Arkansas: University of Arkansas, Institute of Science and Technology, Research Series no. 19, 44 p.

Lohman, S.W., 1979, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p.

Lovelace, J.K., 1991, Water use in Louisiana, 1990: Louisiana Department of Transportation and Development Water Resources Special Report no. 6, 131 p.

Ludwig, A.H., and Terry J.E., 1980, Methods and applications of digital-model simulation of the Red River alluvial aquifer, Shreveport to the mouth of the Black River, Louisiana: U.S. Geological Survey Water-Resources Investigations Report 79-114, 103 p.

Martin, Angel, Jr., and Early, D.A., 1987, Statistical analysis of aquifer-test results for nine regional aquifers in Louisiana: U.S. Geological Survey Water-Resources Investigations Report 87-4001, 26 p.

McWreath, H.C., III, Nelson, J.D., and Fitzpatrick, D.J., 1991, Simulated response to pumping stresses in the Sparta aquifer, northern Louisiana and southern Arkansas: Louisiana Department of Transportation and Development Water Resources Technical Report no. 51, 51 p.

Mesko, T.O., Williams, T.A., Ackerman, D.J., and Williamson, A.K., 1990, Ground-water pumpage from the Gulf Coast aquifer systems, 1960-85, south-central United States: U.S. Geological Survey Water-Resources Investigations Report 89-4180, 177 p.

Nelson, J.D., and Herbert, M.A., 1986, Geostatistical estimation of parameters for the Sparta Sand aquifer--north Louisiana: Proceedings of the Focus Conference on Southeastern Ground Water Issues, Dublin, Ohio, National Water Well Association, p. 263-286.

Newcome, Roy, Jr., 1960, Ground-water resources of the Red River Valley alluvium in Louisiana: Department of Conservation, Louisiana Geological Survey, and Louisiana Department of Public Works Water Resources Pamphlet no. 7, 21 p.

Page, L.V., and May, H.G., 1964, Water Resources of Bossier and Caddo Parishes, Louisiana: Department of Conservation, Louisiana Geological Survey, and Louisiana Department of Public Works Water Resources Bulletin no. 5, 105 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.

———1972, Hydrologic significance of lithofacies of the Cane River Formation or equivalents of Arkansas, Louisiana, Mississippi, and Texas: U.S. Geological Survey Professional Paper 569-C, 17 p.

———1975 [1976], Geohydrologic significance of lithofacies of the Carrizo Sand of Arkansas, Louisiana, and Texas and the Meridian Sand of Mississippi: U.S. Geological Survey Professional Paper 569-D, 11 p.

Petersen, J.C., and Broom, M.E., 1985, Geohydrologic units in the Gulf Coastal Plain in Arkansas: U.S. Geological Survey Water-Resources Investigations Report 85-4116, 20 p.

Pettijohn, R.A., Weiss, J.S., and Williamson, A.K., 1988, Distribution of dissolved-solids concentrations and temperature in ground water of the Gulf Coast aquifer systems, south-central United States: U.S. Geological Survey Water-Resources Investigations Report 88-4082, 5 sheets.

Ryals, G.N., 1980, Potentiometric surface of the Wilcox-Carrizo aquifers; Bienville, Red River, northern Natchitoches, and southern Webster Parishes, Louisiana: U.S. Geological Survey Open-File Report 80-1179, 1 sheet.

———1983, Regional geohydrology of the northern Louisiana salt-dome basin, part III, potentiometric levels of the Wilcox-Carrizo and Sparta aquifers: U.S. Geological Survey Water-Resources Investigations Report 83-4131, 10 p.

———1984, Regional geohydrology of the northern Louisiana salt-dome basin, part II, geohydrologic maps of the Tertiary aquifers and related confining layers: U.S. Geological Survey Water-Resources Investigations Report 83-4135, 6 p.

Ryder, P.D., 1988, Hydrogeology and predevelopment flow in the Texas Gulf Coast aquifer systems: U.S. Geological Survey Water-Resources Investigations Report 87-4248, 109 p.

Smith, C.R., 1970, Unpublished geologic map of Caddo Parish, Louisiana: Louisiana Geological Survey open file, 1 sheet, scale 1:62,500.

Smith, F.L., and Russ, D.P., 1974, Geological investigation of the Lower Red River-Atchafalaya Basin Area, Louisiana: Vicksburg, Miss., Waterways Experiment Station, Geotechnical Laboratory Technical Report S-74-5, 57 pls.

Smoot, C.W., 1983, Records of water-level measurements and lithologic logs, Red River Valley, Louisiana, 1975-80: Louisiana Department of Transportation and Development, Office of Public Works Water Resources Basic Records Report no. 12, 197 p.

Smoot, C.W., and Guillot, J.R., 1988, Water-level measurements 1981-85 and chemical analyses 1978-85, Red River alluvial aquifer, Red River Valley, Louisiana: U.S. Geological Survey Open-File Report 87-541, 261 p.

Snider, J.L., 1982, Premining hydrology of the lignite area in southeastern De Soto Parish, Louisiana: Louisiana Department of Transportation and Development, Office of Public Works Water Resources Technical Report no. 29, 40 p.

———1983, Ground-water resources of the Fillmore-Haughton-Red Chute area, Bossier and Webster Parishes, Louisiana: Louisiana Department of Transportation and Development, Office of Public Works Water Resources Technical Report no. 32, 21 p.

Snider, J.L., and Covay, K.J., 1987, Premining hydrology of the Logansport lignite area, De Soto Parish, Louisiana: Louisiana Department of Transportation and Development Water Resources Technical Report no. 41, 65 p.

Speer, P.R., Hines, M.S., and Calandro, A.J., and others 1966, Low-flow characteristics of streams in the Mississippi Embayment in southern Arkansas, northern Louisiana, and northeastern Texas, *with a section on* Quality of the water, by H.G. Jeffery: U.S. Geological Survey Professional Paper 448-G, 40 p.

Speer, P.R., Hines, M.S., and Jansen, M.E., 1966, Low-flow characteristics of streams in the Mississippi Embayment in northern Arkansas, and in Missouri: U.S. Geological Survey Professional Paper 448-F, 25 p.

Stephens, J.W., 1976, Records of wells, water-level measurements, and drillers' logs, Red River Valley, Louisiana: Baton Rouge, La., U.S. Geological Survey Open-File Report 76-759, 335 p.

Sundstrom, R.W., 1941, Water supply in the vicinity of Hughes Springs, Cass County, Texas, and Daingerfield, Morris County, Texas: U.S. Geological Survey Open-File Report, 7 p.

Terry, J.E., Bryant, C.T., Ludwig, A.H., and Reed, J.E., 1979, Water-resources appraisal of the south-Arkansas lignite area: U.S. Geological Survey Open-File Report 79-924, 162 p.

Tukey, J.W., 1977, Exploratory data analysis, Addison-Wesley Pub., Reading, Mass., 506 p.

Turcan, A.N., Jr., 1962, Estimating water quality from electrical logs, *in* Short papers in geology and hydrology, articles 60-119: U.S. Geological Survey Professional Paper 450-C, article 116, p. C135-C136.

U.S. Department of Commerce, 1982, Normals, means, and extremes, annual summary with comparative local climatological data: Shreveport, Louisiana; National Oceanic and Atmospheric Administration, p. 3.

U.S. Environmental Protection Agency, 1992, Final rule, National primary and secondary drinking water regulations--Synthetic organic chemicals and inorganic chemicals (sections 141.12, 141.32, 141.50, 141.51, 141.61, and 141.62 of part 141 and 143.3 of part 143) U.S. Federal Register, v. 57, no. 138, July 17, 1992, p. 31, 776-31, and 849.

Weiss, J.S., 1987, Determining dissolved-solids concentrations in highly mineralized ground water of the Gulf Coast aquifer systems using electric logs: American Water Resources Association Monograph no. 8, p. 139-150.

Weiss, J.S., and Williamson, A.K., 1985, Subdivision of thick sedimentary units into layers for simulation of ground-water flow: Ground Water, v. 23, no. 6, p. 767-774.

Westerfield, P.W., 1990, Ground-water levels in Arkansas, spring 1990: Little Rock, Arkansas, U.S. Geological Survey Open-File Report 90-377, 62 p.

Whitfield, M.S., Jr., 1980, Chemical character of water in the Red River alluvial aquifer, Louisiana: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-1018, 95 p.

Williamson, A.K., 1987, Preliminary simulation for ground-water flow in the Gulf Coast aquifer systems, south-central United States: American Water Resources Association Monograph no. 9, p. 119-137.

Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf Coast aquifer systems, south-central United States--a preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 89-4071, 124 p.

Woodward, D.G., 1989, Flow pattern in regional aquifers and flow relations between the lower Colorado River Valley and regional aquifers in six counties of southeastern Texas: U.S. Geological Survey Water-Resources Investigations Report 88-4154, 24 p.

APPENDIX 1

Chemical Analyses of Water from Selected Wells Completed in Sands of Quaternary Age

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age

[Geologic unit: RRVA, Red River alluvial aquifer. Cd, Caddo Parish; --, no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg. C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Well number	Latitude	Longitude	Date	Time	Depth (feet)	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)
Cd- 2	32 46 18 N	93 54 45 W	10-22-40	--	37	RRVA	--	--
Cd- 8	32 44 47 N	93 58 14 W	04-25-41	--	60	RRVA	--	--
Cd- 15	32 39 53 N	93 49 05 W	01-15-41	--	40	RRVA	--	--
Cd- 19	32 33 43 N	93 46 25 W	01-15-41	--	48	RRVA	--	--
Cd- 93	32 29 13 N	93 41 51 W	03-24-41	--	75	RRVA	--	--
Cd- 96	32 21 30 N	93 38 34 W	03-24-41	--	65	RRVA	--	--
Cd-124	32 18 54 N	93 35 17 W	04-26-41	--	65	RRVA	--	--
Cd-125	32 15 00 N	93 30 35 W	03-26-41	--	65	RRVA	--	--
Cd-197	32 38 52 N	93 47 52 W	04-24-71	--	40	RRVA	--	--
Cd-199	32 42 11 N	93 49 30 W	04-24-41	--	50	RRVA	--	--
Cd-263	32 46 24 N	93 56 47 W	05-15-45	--	60	RRVA	--	--
Cd-282	32 47 13 N	93 53 04 W	06-02-41	--	60	RRVA	--	--
Cd-327	32 18 37 N	93 38 53 W	06-06-57	--	43	RRVA	--	--
Cd-328	32 18 06 N	93 37 50 W	02-03-72	--	75	RRVA	1,160	--
Cd-329	32 17 46 N	93 35 54 W	06-06-57	--	75	RRVA	--	--
Cd-330	32 17 40 N	93 33 44 W	07-31-59	--	64	RRVA	774	--
Cd-331	32 22 13 N	93 40 47 W	09-21-76	1400	64	RRVA	270	--
Cd-332	32 26 37 N	93 42 32 W	03-09-60	--	76	RRVA	--	--
Cd-333	32 37 38 N	93 49 10 W	03-31-76	1330	54	RRVA	1,910	7.1
Cd-334	32 38 09 N	93 47 06 W	06-06-57	--	65	RRVA	--	--
Cd-335	32 42 21 N	93 47 36 W	04-08-92	0935	64	RRVA	812	7.1
Cd-336	32 42 07 N	93 48 48 W	06-12-90	1200	86	RRVA	1,460	7.1
Cd-337	32 40 02 N	93 50 35 W	04-08-92	0755	44	RRVA	2,800	7.1
Cd-340	32 42 09 N	93 51 48 W	02-15-57	--	43	RRVA	--	--
Cd-341	32 44 09 N	93 50 40 W	10-31-74	1500	65	RRVA	768	7.2
Cd-342	32 46 51 N	93 50 44 W	06-26-57	--	64	RRVA	--	--
Cd-343	32 50 54 N	93 48 53 W	06-08-76	2015	43	RRVA	899	--
Cd-344	32 50 51 N	93 49 47 W	06-08-76	1900	64	RRVA	881	--
Cd-345	32 50 45 N	93 51 37 W	04-26-77	1655	54	RRVA	960	7.0
Cd-346	32 50 53 N	93 53 40 W	12-15-76	1430	44	RRVA	3,850	6.6
Cd-347	32 56 32 N	93 52 30 W	06-27-57	--	43	RRVA	--	--
Cd-348	32 56 49 N	93 51 06 W	01-23-57	--	43	RRVA	--	--
Cd-350	32 47 55 N	93 52 12 W	05-27-76	1230	90	RRVA	1,110	--
Cd-352	32 43 36 N	93 50 22 W	11-25-59	--	60	RRVA	814	7.0
Cd-353	32 20 52 N	93 37 47 W	03-18-60	--	71	RRVA	1,120	7.2
Cd-401	32 45 06 N	93 49 21 W	12-18-59	--	86	RRVA	--	--
Cd-448	32 45 03 N	93 50 02 W	09-04-75	--	106	RRVA	--	--
Cd-461	32 16 39 N	93 32 32 W	03-31-92	1535	47	RRVA	--	7.2
Cd-462	32 17 43 N	93 35 42 W	08-26-92	1300	64	RRVA	1,370	6.9
Cd-463	32 15 16 N	93 30 50 W	04-01-92	0915	52	RRVA	960	7.0

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Date	Temperature, water (deg. C)	Color, (platinum-cobalt units)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Cd- 2	10-22-40	--	--	40	--	--	--	--
Cd- 8	04-25-41	--	--	110	--	--	--	--
Cd- 15	01-15-41	19.5	--	600	--	--	--	--
Cd- 19	01-15-41	--	--	32	--	--	--	--
Cd- 93	03-24-41	--	--	--	--	--	--	--
Cd- 96	03-24-41	--	--	--	--	--	--	--
Cd-124	04-26-41	--	--	100	--	--	--	--
Cd-125	03-26-41	--	--	460	--	--	--	--
Cd-197	04-24-71	--	--	350	--	--	--	--
Cd-199	04-24-41	--	--	500	--	--	--	--
Cd-263	05-15-45	19.0	--	200	--	--	--	--
Cd-282	06-02-41	--	--	--	--	--	--	--
Cd-327	06-06-57	20.5	--	230	--	--	--	--
Cd-328	02-03-72	--	5	590	130	65	70	4.0
Cd-329	06-06-57	--	--	460	--	--	--	--
Cd-330	07-31-59	--	15	340	42	57	50	1.2
Cd-331	09-21-76	--	--	120	--	--	--	--
Cd-332	03-09-60	19.5	--	420	--	--	--	--
Cd-333	03-31-76	20.5	15	780	220	57	120	2.2
Cd-334	06-06-57	--	--	710	--	--	--	--
Cd-335	04-08-92	20.0	--	420	97	43	23	2.1
Cd-336	06-12-90	--	0	660	170	58	60	2.4
Cd-337	04-08-92	19.0	--	1,100	170	170	240	2.9
Cd-340	02-15-57	--	--	590	--	--	--	--
Cd-341	10-31-74	--	--	440	--	--	--	--
Cd-342	06-26-57	--	--	450	--	--	--	--
Cd-343	06-08-76	20.0	--	460	--	--	--	--
Cd-344	06-08-76	--	--	300	--	--	--	--
Cd-345	04-26-77	19.5	--	420	--	--	--	--
Cd-346	12-15-76	--	5	980	210	110	400	6.0
Cd-347	06-27-57	--	--	80	--	--	--	--
Cd-348	01-23-57	--	--	530	--	--	--	--
Cd-350	05-27-76	--	5	560	140	51	30	2.0
Cd-352	11-25-59	20.0	10	410	100	40	27	1.6
Cd-353	03-18-60	19.5	5	540	150	39	48	1.1
Cd-401	12-18-59	19.0	--	480	--	--	--	--
Cd-448	09-04-75	--	--	790	--	--	--	--
Cd-461	03-31-92	20.0	--	530	95	72	50	.9
Cd-462	08-26-92	20.5	--	570	130	59	69	2.2
Cd-463	04-01-92	20.5	--	450	130	31	31	3.0

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Date	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	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 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)
Cd- 2	10-22-40	--	--	60	--	--	--	--
Cd- 8	04-25-41	221	10	99	1.1	--	--	--
Cd- 15	01-15-41	358	200	52	.0	--	--	--
Cd- 19	01-15-41	40	3.0	15	.0	--	--	--
Cd- 93	03-24-41	--	--	30	--	--	--	--
Cd- 96	03-24-41	--	--	25	--	--	--	--
Cd-124	04-26-41	--	--	60	--	--	--	--
Cd-125	03-26-41	478	130	20	.8	--	--	--
Cd-197	04-24-71	--	--	15	--	--	--	--
Cd-199	04-24-41	--	--	20	--	--	--	--
Cd-263	05-15-45	--	--	530	--	--	--	--
Cd-282	06-02-41	--	--	60	--	--	--	--
Cd-327	06-06-57	--	--	27	--	--	--	--
Cd-328	02-03-72	512	74	84	.0	15	790	759
Cd-329	06-06-57	--	--	46	--	--	--	--
Cd-330	07-31-59	403	31	8.8	.8	22	485	455
Cd-331	09-21-76	--	4.2	3.6	--	--	--	--
Cd-332	03-09-60	--	--	90	--	--	--	--
Cd-333	03-31-76	558	260	170	.2	26	1,300	1,200
Cd-334	06-06-57	--	--	36	--	--	--	--
Cd-335	04-08-92	431	37	7.4	.4	23	474	495
Cd-336	06-12-90	633	110	50	.2	20	822	850
Cd-337	04-08-92	686	620	260	.5	21	1,970	1,900
Cd-340	02-15-57	--	--	110	--	--	--	--
Cd-341	10-31-74	--	20	3.2	--	--	--	--
Cd-342	06-26-57	--	--	63	--	--	--	--
Cd-343	06-08-76	--	48	19	--	--	--	--
Cd-344	06-08-76	--	2.4	57	--	--	--	--
Cd-345	04-26-77	--	39	37	--	--	--	--
Cd-346	12-15-76	207	450	820	<.1	23	2,480	2,190
Cd-347	06-27-57	--	--	34	--	--	--	--
Cd-348	01-23-57	--	--	72	--	--	--	--
Cd-350	05-27-76	396	33	130	.4	18	592	643
Cd-352	11-25-59	414	44	12	.3	15	490	488
Cd-353	03-18-60	503	80	25	.7	1.8	689	674
Cd-401	12-18-59	--	--	30	--	--	--	--
Cd-448	09-04-75	--	--	520	--	--	--	--
Cd-461	03-31-92	604	33	8.2	.7	19	628	645
Cd-462	08-26-92	518	88	120	.4	20	788	808
Cd-463	04-01-92	521	10	24	.3	25	544	580

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Latitude	Longitude	Date	Time	Depth (feet)	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)
Cd-464	32 18 50 N	93 35 15 W	03-31-92	1315	64	RRVA	860	7.6
Cd-465	32 29 30 N	93 42 02 W	05-14-75	1410	63	RRVA	1,230	--
Cd-466	32 27 31 N	93 41 21 W	06-09-76	1330	53	RRVA	1,000	--
Cd-467	32 28 29 N	93 41 46 W	06-09-76	1615	50	RRVA	1,070	--
Cd-468	32 28 41 N	93 41 23 W	06-09-76	1520	47	RRVA	966	--
Cd-469	32 28 12 N	93 41 08 W	06-09-76	1430	47	RRVA	974	--
Cd-470	32 26 36 N	93 42 28 W	07-21-71	--	42	RRVA	--	--
Cd-471	32 26 34 N	93 43 24 W	03-16-77	1505	49	RRVA	2,230	--
Cd-472	32 20 31 N	93 37 15 W	08-05-75	1820	63	RRVA	1,370	--
Cd-473	32 21 43 N	93 38 37 W	09-21-76	1310	63	RRVA	--	--
Cd-474	32 24 03 N	93 42 55 W	06-08-76	1545	48	RRVA	1,270	--
Cd-475	32 25 17 N	93 41 35 W	06-19-75	0950	42	RRVA	1,250	--
Cd-476	32 24 04 N	93 41 29 W	09-21-76	1540	48	RRVA	1,470	--
Cd-477	32 22 48 N	93 41 12 W	09-21-76	1430	47	RRVA	671	--
Cd-478	32 25 15 N	93 42 22 W	06-19-75	0835	57	RRVA	1,330	--
Cd-479	32 19 24 N	93 34 26 W	08-26-92	1030	56	RRVA	925	7.8
Cd-480	32 16 53 N	93 31 33 W	03-30-76	1215	52	RRVA	888	--
Cd-481	32 15 48 N	93 36 20 W	06-08-76	1215	47	RRVA	1,410	--
Cd-482	32 16 37 N	93 36 25 W	06-08-76	1320	48	RRVA	1,310	--
Cd-483	32 15 58 N	93 34 04 W	03-30-76	1635	47	RRVA	990	--
Cd-484	32 14 58 N	93 32 40 W	03-10-75	1505	64	RRVA	1,200	--
Cd-485	32 42 21 N	93 53 10 W	04-08-92	1115	42	RRVA	3,810	7.3
Cd-486	32 26 37 N	93 42 24 W	09-22-76	1025	64	RRVA	1,120	--
Cd-501	32 42 08 N	93 50 18 W	04-10-90	1210	58	RRVA	1,250	8.0
Cd-504	32 15 16 N	93 30 50 W	10-07-87	1730	87	RRVA	--	--
Cd-508	32 18 06 N	93 37 49 W	06-08-76	1415	75	RRVA	1,170	--
Cd-509	32 51 15 N	93 52 11 W	05-26-76	1230	35	RRVA	1,020	--
Cd-510	32 51 16 N	93 52 16 W	05-26-76	1315	90	RRVA	3,310	--
Cd-511	32 49 35 N	93 48 55 W	05-26-76	1545	35	RRVA	1,350	--
Cd-513	32 48 53 N	93 51 03 W	10-29-76	0930	35	RRVA	3,810	--
Cd-514	32 46 11 N	93 54 53 W	05-27-76	1530	35	RRVA	1,560	--
Cd-515	32 45 57 N	93 57 00 W	05-27-76	1800	24	RRVA	157	--
Cd-516	32 45 55 N	93 57 03 W	05-27-76	1700	42	RRVA	599	--
Cd-517	32 49 06 N	93 52 00 W	05-27-76	1115	35	RRVA	747	--
Cd-518	32 46 16 N	93 54 39 W	05-27-76	1430	101	RRVA	2,650	--
Cd-519	32 40 54 N	93 51 37 W	05-28-76	1345	31	RRVA	4,650	--
Cd-520	32 42 10 N	93 52 56 W	05-28-76	1500	45	RRVA	2,950	--
Cd-528	32 30 05 N	93 42 50 W	12-06-79	1355	74	RRVA	--	--
Cd-529	32 29 24 N	93 42 32 W	04-04-80	0845	75	RRVA	--	--
Cd-530	32 28 38 N	93 43 42 W	04-04-80	1030	60	RRVA	935	--

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Date	Temperature, water (deg. C)	Color (platinum-cobalt units)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Cd-464	03-31-92	21.5	--	420	100	42	21	1.7
Cd-465	05-14-75	21.0	5	540	150	41	16	1.3
Cd-466	06-09-76	20.0	--	550	--	--	--	--
Cd-467	06-09-76	19.5	10	560	170	33	25	2.7
Cd-468	06-09-76	20.0	--	550	--	--	--	--
Cd-469	06-09-76	19.5	--	420	--	--	--	--
Cd-470	07-21-71	--	--	1,900	--	--	--	--
Cd-471	03-16-77	--	--	920	--	--	--	--
Cd-472	08-05-75	--	--	600	130	68	--	--
Cd-473	09-21-76	--	--	410	--	--	--	--
Cd-474	06-08-76	--	--	520	--	--	--	--
Cd-475	06-19-75	--	--	620	--	--	--	--
Cd-476	09-21-76	--	--	680	--	--	--	--
Cd-477	09-21-76	--	--	380	--	--	--	--
Cd-478	06-19-75	--	0	600	120	72	69	1.5
Cd-479	08-26-92	20.5	--	410	90	44	57	1.0
Cd-480	03-30-76	--	--	380	--	--	--	--
Cd-481	06-08-76	--	--	590	120	70	100	1.6
Cd-482	06-08-76	--	5	510	100	63	88	2.5
Cd-483	03-30-76	--	--	450	--	--	--	--
Cd-484	03-10-75	20.5	--	580	--	--	--	--
Cd-485	04-08-92	21.0	--	--	--	--	440	6.0
Cd-486	09-22-76	--	0	570	160	42	33	2.7
Cd-501	04-10-90	20.0	0	620	110	84	53	1.3
Cd-504	10-07-87	--	0	750	200	62	95	2.7
Cd-508	06-08-76	20.0	--	530	--	--	--	--
Cd-509	05-26-76	--	5	520	120	54	20	1.5
Cd-510	05-26-76	--	10	50	14	3.6	700	6.0
Cd-511	05-26-76	18.5	--	680	--	--	--	--
Cd-513	10-29-76	18.0	10	590	160	46	560	2.8
Cd-514	05-27-76	19.5	5	680	170	61	88	2.0
Cd-515	05-27-76	18.5	5	35	7.3	4.1	12	2.8
Cd-516	05-27-76	19.5	5	130	31	13	68	5.2
Cd-517	05-27-76	--	--	460	--	--	--	--
Cd-518	05-27-76	--	0	140	29	16	480	11
Cd-519	05-28-76	19.0	0	2,000	250	330	480	3.3
Cd-520	05-28-76	20.0	5	1,100	220	130	300	3.5
Cd-528	12-06-79	--	--	430	--	--	--	--
Cd-529	04-04-80	--	--	370	--	--	--	--
Cd-530	04-04-80	--	--	420	--	--	--	--

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Date	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SO_2)	Solids, residue at 180 deg. C, dis-solved (mg/L)	Solids, sum of constit-uents, dis-solved (mg/L)
Cd-464	03-31-92	425	61	15	0.3	19	518	520
Cd-465	05-14-75	509	15	25	.2	26	631	601
Cd-466	06-09-76	--	<1.0	20	--	--	--	--
Cd-467	06-09-76	572	1.2	12	.4	24	649	630
Cd-468	06-09-76	--	.20	13	--	--	--	--
Cd-469	06-09-76	--	.20	11	--	--	--	--
Cd-470	07-21-71	--	--	32	--	--	--	--
Cd-471	03-16-77	--	310	260	--	--	--	--
Cd-472	08-05-75	--	77	120	--	--	--	--
Cd-473	09-21-76	--	18	26	--	--	--	--
Cd-474	06-08-76	--	190	45	--	--	--	--
Cd-475	06-19-75	--	110	17	--	--	--	--
Cd-476	09-21-76	--	130	81	--	--	--	--
Cd-477	09-21-76	--	28	6.4	--	--	--	--
Cd-478	06-19-75	614	24	71	.4	26	767	759
Cd-479	08-26-92	522	48	5.6	.5	21	562	588
Cd-480	03-30-76	--	12	180	--	--	--	--
Cd-481	06-08-76	516	140	88	.5	17	825	848
Cd-482	06-08-76	491	33	140	.5	17	747	742
Cd-483	03-30-76	--	52	57	--	--	--	--
Cd-484	03-10-75	--	34	66	--	--	--	--
Cd-485	04-08-92	604	1,200	390	.5	18	3,030	--
Cd-486	09-22-76	601	<1.0	14	.3	24	637	633
Cd-501	04-10-90	637	50	56	.4	24	666	765
Cd-504	10-07-87	633	93	140	.2	21	989	1,000
Cd-508	06-08-76	--	76	57	--	--	--	--
Cd-509	05-26-76	502	30	25	.8	24	588	581
Cd-510	05-26-76	437	23	810	.9	10	1,830	1,830
Cd-511	05-26-76	--	98	84	--	--	--	--
Cd-513	10-29-76	463	2.2	980	.4	24	2,090	2,060
Cd-514	05-27-76	477	150	140	.3	18	1,010	916
Cd-515	05-27-76	14	12	18	<.1	12	104	79
Cd-516	05-27-76	8	14	180	<.1	16	387	341
Cd-517	05-27-76	--	30	40	--	--	--	--
Cd-518	05-27-76	206	<1.0	730	.7	11	1,420	1,410
Cd-519	05-28-76	669	1,900	350	.8	18	4,010	3,740
Cd-520	05-28-76	492	790	270	.2	19	2,200	2,030
Cd-528	12-06-79	--	18	26	--	--	--	--
Cd-529	04-04-80	--	--	17	--	--	--	--
Cd-530	04-04-80	--	3.8	82	--	--	--	--

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Latitude	Longitude	Date	Time	Depth (feet)	Geo- logic unit	Spe- cific con- duct- ance (µS/cm)	pH (stand- ard units)
Cd-531	32 27 48 N	93 43 17 W	11-08-79	1440	59	RRVA	--	--
Cd-532	32 27 16 N	93 43 59 W	12-06-79	1215	56	RRVA	281	--
Cd-533	32 27 20 N	93 41 54 W	11-08-79	1615	59	RRVA	--	--
Cd-534	32 27 17 N	93 43 15 W	03-31-92	0845	61	RRVA	1,290	7.4
Cd-535	32 25 36 N	93 42 31 W	03-31-92	1050	62	RRVA	920	7.5
Cd-536	32 25 44 N	93 41 51 W	11-09-79	1000	53	RRVA	--	--
Cd-806	32 35 20 N	93 47 00 W	08-25-92	1450	51	RRVA	786	7.6
Cd-807	32 36 27 N	93 49 03 W	09-12-91	0810	55	RRVA	688	7.7
Cd-809	32 41 59 N	93 54 41 W	04-08-92	1205	40	RRVA	11,500	7.5
Cd-7254Z	32 22 42 N	93 40 08 W	06-29-92	0830	90	RRVA	887	7.6

Well number	Date	Temper- ature, water (deg. C)	Color (plat- inum- cobalt units)	Hard- ness, total (mg/L as $CaCO_3$)	Calcium, dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved- (mg/L as Na)	Potas- sium, dis- solved (mg/L as K)
Cd-531	11-08-79	--	--	600	--	--	--	--
Cd-532	12-06-79	--	--	62	--	--	--	--
Cd-533	11-08-79	--	--	480	--	--	--	--
Cd-534	03-31-92	21.5	--	610	160	52	56	2.3
Cd-535	03-31-92	22.0	--	450	110	43	41	1.5
Cd-536	11-09-79	20.5	--	560	--	--	--	--
Cd-806	08-25-92	22.5	35	390	84	43	22	1.2
Cd-807	09-12-91	--	5	320	66	37	34	<1.0
Cd-809	04-08-92	--	--	430	91	49	190	3.4
Cd-7254Z	06-29-92	19.0	--	420	110	34	37	3.4

Well number	Date	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	Sulfate, dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as Cl)	Fluo- ride, dis- solved (mg/L as F)	Silica, dis- solved (mg/L as SiO_2)	Solids, residue at 180 deg. C, dis- solved (mg/L)	Solids, sum of constit- uents, dis- solved (mg/L)
Cd-531	11-08-79	--	3.6	22	--	--	--	--
Cd-532	12-06-79	--	23	36	--	--	--	--
Cd-533	11-08-79	--	.40	9.4	--	--	--	--
Cd-534	03-31-92	704	.20	44	0.20	19	740	769
Cd-535	03-31-92	463	43	25	.40	17	552	565
Cd-536	11-09-79	--	1.0	14	--	--	--	--
Cd-806	08-25-92	412	27	8.2	.40	21	386	457
Cd-807	09-12-91	350	21	14	.30	27	400	--
Cd-809	04-08-92	338	30	310	.60	17	972	898
Cd-7254Z	06-29-92	347	120	34	.20	26	572	581

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geo-logic unit	Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)
Cd-335	32 42 21 N	93 47 36 W	04-10-90	64	RRVA	<0.02
Cd-336	32 42 07 N	93 48 48 W	04-08-92	86	RRVA	<.02
Cd-337	32 40 02 N	93 50 35 W	04-08-92	44	RRVA	.03
Cd-461	32 16 39 N	93 32 32 W	04-03-91	47	RRVA	<.02
Cd-462	32 17 43 N	93 35 42 W	08-26-92	64	RRVA	<.02
Cd-463	32 15 16 N	93 30 50 W	04-01-92	52	RRVA	<.02
Cd-464	32 18 50 N	93 35 15 W	04-03-91	64	RRVA	<.02
Cd-465	32 29 30 N	93 42 02 W	05-14-75	63	RRVA	<.10
Cd-477	32 22 48 N	93 41 12 W	05-13-75	47	RRVA	.30
Cd-479	32 19 24 N	93 34 26 W	08-26-92	56	RRVA	<.02
Cd-485	32 42 21 N	93 53 10 W	10-06-87	42	RRVA	[a]1.20
Cd-501	32 42 08 N	93 50 18 W	04-08-92	58	RRVA	.02
Cd-504	32 15 16 N	93 30 50 W	10-07-87	87	RRVA	[a].66
Cd-534	32 27 17 N	93 43 15 W	03-31-92	61	RRVA	<.02
Cd-535	32 25 36 N	93 42 31 W	03-31-92	62	RRVA	<.02
Cd-806	32 35 20 N	93 47 00 W	08-25-92	51	RRVA	.24
Cd-807	32 36 27 N	93 49 03 W	09-12-91	55	RRVA	.57
Cd-809	32 41 59 N	93 54 41 W	09-12-91	40	RRVA	<.02
Cd-7254Z	32 22 42 N	93 40 08 W	06-29-92	90	RRVA	<.02

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geologic unit	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
Cd-328	32 18 06 N	93 37 50 W	02-03-72	75	RRVA	9,900	360
Cd-333	32 37 38 N	93 49 10 W	03-31-76	54	RRVA	9,700	860
Cd-334	32 38 09 N	93 47 06 W	05-06-71	65	RRVA	16,000	--
Cd-335	32 42 21 N	93 47 36 W	04-10-90	64	RRVA	3,600	310
Cd-336	32 42 07 N	93 48 48 W	04-08-92	86	RRVA	7,200	220
Cd-337	32 40 02 N	93 50 35 W	04-08-92	44	RRVA	8,200	380
Cd-341	32 44 09 N	93 50 40 W	10-31-74	65	RRVA	2,200	400
Cd-343	32 50 54 N	93 48 53 W	06-08-76	43	RRVA	360	70
Cd-344	32 50 51 N	93 49 47 W	06-08-76	64	RRVA	3,700	140
Cd-345	32 50 45 N	93 51 37 W	04-26-77	54	RRVA	7,300	150
Cd-346	32 50 53 N	93 53 40 W	12-15-76	44	RRVA	49,000	1,100
Cd-350	32 47 55 N	93 52 12 W	05-27-76	90	RRVA	800	260
Cd-448	32 45 03 N	93 50 02 W	07-23-68	106	RRVA	6,000	--
Cd-461	32 16 39 N	93 32 32 W	04-03-91	47	RRVA	5,100	900
Cd-462	32 17 43 N	93 35 42 W	08-26-92	64	RRVA	7,900	420
Cd-463	32 15 16 N	93 30 50 W	04-01-92	52	RRVA	12,000	1,800
Cd-464	32 18 50 N	93 35 15 W	04-03-91	64	RRVA	4,100	140
Cd-465	32 29 30 N	93 42 02 W	05-14-75	63	RRVA	18,000	3,100
Cd-466	32 27 31 N	93 41 21 W	06-09-76	53	RRVA	15,000	640
Cd-467	32 28 29 N	93 41 46 W	06-09-76	50	RRVA	16,000	2,200
Cd-468	32 28 41 N	93 41 23 W	06-09-76	47	RRVA	18,000	2,700
Cd-469	32 28 12 N	93 41 08 W	06-09-76	47	RRVA	17,000	2,700
Cd-471	32 26 34 N	93 43 24 W	03-16-77	49	RRVA	13,000	520
Cd-472	32 20 31 N	93 37 15 W	08-05-75	63	RRVA	8,100	1,000
Cd-473	32 21 43 N	93 38 37 W	08-05-75	63	RRVA	3,400	330
Cd-474	32 24 03 N	93 42 55 W	06-08-76	48	RRVA	6,300	360
Cd-475	32 25 17 N	93 41 35 W	06-19-75	42	RRVA	17,000	2,100
Cd-476	32 24 04 N	93 41 29 W	06-08-76	48	RRVA	13,000	1,800
Cd-477	32 22 48 N	93 41 12 W	05-13-75	47	RRVA	5,200	1,400
Cd-478	32 25 15 N	93 42 22 W	06-19-75	57	RRVA	6,800	400
Cd-479	32 19 24 N	93 34 26 W	08-26-92	56	RRVA	7,400	560
Cd-480	32 16 53 N	93 31 33 W	03-30-76	52	RRVA	40	80
Cd-481	32 15 48 N	93 36 20 W	06-08-76	47	RRVA	720	1,100
Cd-482	32 16 37 N	93 36 25 W	06-08-76	48	RRVA	2,900	850
Cd-483	32 15 58 N	93 34 04 W	03-30-76	47	RRVA	9,200	690
Cd-484	32 14 58 N	93 32 40 W	03-10-75	64	RRVA	11,000	1,100
Cd-485	32 42 21 N	93 53 10 W	10-06-87	42	RRVA	5,800	1,600
Cd-486	32 26 37 N	93 42 24 W	09-22-76	64	RRVA	24,000	2,500
Cd-501	32 42 08 N	93 50 18 W	04-08-92	58	RRVA	3,200	650
Cd-504	32 15 16 N	93 30 50 W	10-07-87	87	RRVA	8,500	1,200
Cd-508	32 18 06 N	93 37 49 W	06-08-76	75	RRVA	6,000	170
Cd-509	32 51 15 N	93 52 11 W	05-26-76	35	RRVA	4,000	770
Cd-510	32 51 16 N	93 52 16 W	05-26-76	90	RRVA	90	20
Cd-511	32 49 35 N	93 48 55 W	05-26-76	35	RRVA	10,000	610
Cd-513	32 48 53 N	93 51 03 W	10-29-76	35	RRVA	5,800	260

Appendix 1. Chemical analyses of water from selected wells completed in sands of Quaternary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geologic unit	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
Cd-514	32 46 11 N	93 54 53 W	05-27-76	35	RRVA	290	490
Cd-515	32 45 57 N	93 57 00 W	05-27-76	24	RRVA	2,300	<10
Cd-516	32 45 55 N	93 57 03 W	05-27-76	42	RRVA	9,200	130
Cd-517	32 49 06 N	93 52 00 W	05-27-76	35	RRVA	2,900	90
Cd-518	32 46 16 N	93 54 39 W	05-27-76	101	RRVA	140	20
Cd-519	32 40 54 N	93 51 37 W	05-28-76	31	RRVA	3,700	1,400
Cd-520	32 42 10 N	93 52 56 W	05-28-76	45	RRVA	1,300	1,400
Cd-530	32 28 38 N	93 43 42 W	04-04-80	60	RRVA	15,000	1,900
Cd-531	32 27 48 N	93 43 17 W	11-08-79	59	RRVA	18,000	600
Cd-532	32 27 16 N	93 43 59 W	12-06-79	56	RRVA	6,300	210
Cd-533	32 27 20 N	93 41 54 W	11-08-79	59	RRVA	15,000	2,900
Cd-534	32 27 17 N	93 43 15 W	03-31-92	61	RRVA	13,000	410
Cd-535	32 25 36 N	93 42 31 W	03-31-92	62	RRVA	6,300	210
Cd-536	32 25 44 N	93 41 51 W	11-09-79	53	RRVA	12,000	2,300
Cd-806	32 35 20 N	93 47 00 W	08-25-92	51	RRVA	2,000	520
Cd-807	32 36 27 N	93 49 03 W	09-12-91	55	RRVA	20	140
Cd-809	32 41 59 N	93 54 41 W	09-12-91	40	RRVA	22,000	3,900
Cd-7254Z	32 22 42 N	93 40 08 W	06-29-92	90	RRVA	7,900	270

[a] Estimated.

APPENDIX 2

Chemical Analyses of Water from Selected Wells Completed in Sands of Tertiary Age

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age

[Geologic Unit: WLCX, Wilcox Sand, Carrizo-Wilcox aquifer; SPRT, Sparta aquifer; CRVR, Cane River Formation; CRRZ, Carrizo Sand, Carrizo-Wilcox aquifer; CLBR, Claiborne Group; WLCXU, Upper Wilcox Sand, Carrizo-Wilcox aquifer. Cd, Caddo Parish; --, no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg. C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Well number	Latitude	Longitude	Date	Depth (feet)	Geologic unit	Temperature, water (deg. C)
Cd- 1	32 45 09 N	93 58 23 W	04-23-41	92	WLCX	--
Cd- 3	32 45 16 N	93 58 29 W	10-23-40	88	WLCX	--
Cd- 4	32 45 21 N	93 58 26 W	10-23-40	92	WLCX	--
Cd- 5	32 45 29 N	93 58 30 W	10-23-40	127	WLCX	--
Cd- 6	32 45 09 N	93 58 23 W	10-23-40	95	WLCX	--
Cd- 7	32 45 09 N	93 58 23 W	10-23-40	95	WLCX	--
Cd- 11	32 41 44 N	93 49 49 W	01-14-41	118	WLCX	19.5
Cd- 12	32 41 48 N	93 47 27 W	04-24-41	200	WLCX	19.0
Cd- 16	32 39 15 N	93 47 21 W	01-15-41	175	WLCX	18.5
Cd- 17	32 38 20 N	93 47 30 W	01-15-41	190	WLCX	--
Cd- 18	32 35 26 N	93 46 26 W	01-15-41	175	WLCX	--
Cd- 29	32 34 04 N	93 46 38 W	01-15-41	125	WLCX	--
Cd- 31	32 36 41 N	93 51 20 W	05-02-41	105	WLCX	--
Cd- 32	32 37 21 N	93 54 32 W	01-07-41	240	WLCX	19.5
Cd- 33	32 36 05 N	94 01 04 W	01-16-41	56	WLCX	--
Cd- 40	32 36 37 N	93 51 07 W	01-20-41	98	WLCX	--
Cd- 41	32 34 16 N	93 58 55 W	05-03-41	110	WLCX	--
Cd- 43	32 27 20 N	93 52 03 W	01-22-41	156	WLCX	19.5
Cd- 44	32 44 52 N	93 49 54 W	04-24-41	235	WLCX	20.0
Cd- 45	32 44 55 N	93 49 59 W	01-23-41	235	WLCX	--
Cd- 46	32 36 34 N	93 51 20 W	05-02-41	150	WLCX	--
Cd- 49	32 28 11 N	93 48 25 W	05-02-41	300	WLCX	--
Cd- 50	32 58 19 N	93 59 33 W	04-28-41	310	WLCX	--
Cd- 51	32 58 19 N	93 59 33 W	04-28-41	400	WLCX	--
Cd- 52	32 58 05 N	93 59 40 W	05-22-68	660	WLCX	24.0
Cd- 53	32 58 26 N	93 59 28 W	01-29-41	381	WLCX	--
Cd- 54	32 53 05 N	93 52 35 W	01-30-41	250	WLCX	--
Cd- 55	32 30 05 N	93 52 35 W	01-30-41	250	WLCX	--
Cd- 56	32 55 25 N	93 59 35 W	04-28-41	300	WLCX	--
Cd- 57	32 55 25 N	93 59 35 W	04-28-41	558	WLCX	--
Cd- 58	32 55 23 N	93 59 35 W	04-28-41	430	WLCX	--
Cd- 60	32 35 30 N	93 51 25 W	05-01-41	168	WLCX	--
Cd- 61	32 32 41 N	93 45 59 W	02-21-41	175	WLCX	--
Cd- 62	32 21 29 N	93 52 31 W	04-17-41	326	WLCX	--
Cd- 63	32 29 34 N	93 51 10 W	03-27-41	160	WLCX	--
Cd- 64	32 29 35 N	93 45 30 W	03-20-41	145	WLCX	--
Cd- 66	32 29 13 N	93 46 11 W	03-20-41	235	WLCX	20.5
Cd- 67	32 29 13 N	93 46 11 W	04-20-41	235	WLCX	--
Cd- 71	32 28 48 N	93 46 10 W	03-21-41	153	WLCX	--
Cd- 73	32 28 42 N	93 46 14 W	03-21-41	210	WLCX	--

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
Cd- 1	04-23-41	35	--	--	50	--
Cd- 3	10-23-40	50	--	--	50	--
Cd- 4	10-23-40	40	--	--	40	--
Cd- 5	10-23-40	80	--	--	130	--
Cd- 6	10-23-40	35	--	--	40	--
Cd- 7	10-23-40	35	--	--	40	--
Cd- 11	01-14-41	160	366	1.0	290	0.2
Cd- 12	04-24-41	290	486	1.0	120	1.6
Cd- 16	01-15-41	110	327	1.0	75	.0
Cd- 17	01-15-41	180	305	15	370	.2
Cd- 18	01-15-41	180	--	--	160	--
Cd- 29	01-15-41	120	157	1.0	13	.2
Cd- 31	05-02-41	680	245	170	370	.2
Cd- 32	01-07-41	800	313	300	300	.0
Cd- 33	01-16-41	15	307	15	27	--
Cd- 40	01-20-41	50	--	--	20	--
Cd- 41	05-03-41	27	25	2.0	2.0	.1
Cd- 43	01-22-41	15	--	--	50	--
Cd- 44	04-24-41	30	383	.10	260	1.5
Cd- 45	01-23-41	60	--	--	340	--
Cd- 46	05-02-41	30	--	--	50	--
Cd- 49	05-02-41	110	165	7.0	38	.1
Cd- 50	04-28-41	35	--	--	20	--
Cd- 51	04-28-41	18	232	7.0	17	1.1
Cd- 52	05-22-68	8	335	3.6	230	.6
Cd- 53	01-29-41	20	--	--	15	--
Cd- 54	01-30-41	70	--	--	600	--
Cd- 55	01-30-41	80	--	--	570	--
Cd- 56	04-28-41	25	--	--	120	--
Cd- 57	04-28-41	21	379	2.0	220	1.2
Cd- 58	04-28-41	21	391	1.0	350	1.1
Cd- 60	05-01-41	930	101	160	810	.2
Cd- 61	02-21-41	30	--	--	200	--
Cd- 62	04-17-41	18	204	2.0	24	.2
Cd- 63	03-27-41	30	271	1.0	49	.2
Cd- 64	03-20-41	180	312	34	39	.2
Cd- 66	03-20-41	42	207	8.0	22	.0
Cd- 67	04-20-41	42	201	5.0	23	.2
Cd- 71	03-21-41	87	189	3.0	14	.2
Cd- 73	03-21-41	81	218	8.0	48	.2

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geologic unit	Temperature, water (deg. C)
Cd- 76	32 23 32 N	93 43 58 W	04-21-41	250	WLCX	--
Cd- 81	32 21 48 N	93 44 24 W	05-06-41	266	WLCX	19.5
Cd- 85	32 26 13 N	93 45 26 W	03-24-41	20	WLCX	--
Cd- 86	32 25 30 N	93 45 13 W	03-24-41	278	WLCX	--
Cd- 87	32 25 30 N	93 45 13 W	03-24-41	207	WLCX	--
Cd- 88	32 25 15 N	93 44 56 W	03-24-41	220	WLCX	--
Cd- 90	32 25 30 N	93 41 51 W	03-24-41	280	WLCX	20.0
Cd- 91	32 25 23 N	93 41 51 W	03-24-41	300	WLCX	--
Cd- 92	32 25 23 N	93 41 51 W	03-26-41	350	WLCX	--
Cd- 94	32 20 59 N	93 38 47 W	03-24-41	229	WLCX	--
Cd- 95	32 20 51 N	93 38 55 W	03-24-41	122	WLCX	19.5
Cd- 97	32 21 05 N	93 38 55 W	03-24-41	291	WLCX	19.5
Cd-100	32 19 38 N	93 50 15 W	04-15-41	334	WLCX	--
Cd-101	32 17 40 N	93 52 50 W	04-16-41	272	WLCX	20.5
Cd-105	32 25 09 N	93 48 29 W	03-26-41	260	WLCX	19.0
Cd-110	32 26 19 N	93 54 29 W	05-02-41	205	WLCX	20.0
Cd-111	32 30 43 N	93 50 48 W	03-25-41	198	WLCX	19.5
Cd-112	32 31 31 N	93 52 11 W	03-25-41	256	WLCX	19.5
Cd-113	32 31 31 N	93 53 54 W	03-25-41	143	WLCX	--
Cd-117	32 23 46 N	93 46 55 W	05-06-41	220	WLCX	--
Cd-118	32 59 57 N	93 53 37 W	04-28-41	250	WLCX	--
Cd-119	32 59 57 N	93 52 37 W	04-06-41	125	WLCX	--
Cd-120	32 53 21 N	93 52 24 W	05-01-41	234	WLCX	--
Cd-122	32 21 00 N	93 37 41 W	04-26-41	400	WLCX	--
Cd-123	32 19 23 N	93 38 34 W	03-26-41	200	WLCX	19.5
Cd-126	32 35 13 N	93 57 56 W	04-23-41	238	WLCX	19.0
Cd-127	32 30 43 N	93 53 50 W	04-27-41	162	WLCX	--
Cd-128	32 30 33 N	93 54 33 W	04-27-41	125	WLCX	--
Cd-130	32 24 55 N	93 58 10 W	05-02-41	29	WLCX	--
Cd-131	32 24 11 N	93 51 07 W	03-28-41	317	WLCX	--
Cd-132	32 34 26 N	93 46 15 W	04-00-41	191	WLCX	--
Cd-137	32 27 48 N	93 55 15 W	05-09-41	141	WLCX	--
Cd-138	32 24 14 N	93 49 18 W	04-09-41	300	WLCX	--
Cd-139	32 23 47 N	93 48 42 W	04-17-41	223	WLCX	--
Cd-141	32 26 07 N	93 48 26 W	04-10-41	235	WLCX	--
Cd-142	32 20 58 N	93 52 33 W	04-10-41	157	WLCX	--
Cd-143	32 22 07 N	93 58 03 W	04-10-41	13	WLCX	--
Cd-145	32 26 27 N	93 57 39 W	04-10-41	146	WLCX	--
Cd-149	32 26 32 N	93 58 11 W	04-22-41	15	WLCX	--
Cd-150	32 22 19 N	94 02 26 W	04-22-41	90	WLCX	--

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
Cd- 76	04-21-41	80	--	--	15	--
Cd- 81	05-06-41	100	440	3.0	120	0.2
Cd- 85	03-24-41	18	25	18	39	--
Cd- 86	03-24-41	27	278	1.0	63	.4
Cd- 87	03-24-41	110	221	1.0	51	.3
Cd- 88	03-24-41	140	194	5.0	41	.0
Cd- 90	03-24-41	21	435	1.0	350	1.4
Cd- 91	03-24-41	40	--	--	180	--
Cd- 92	03-26-41	180	--	--	120	--
Cd- 94	03-24-41	54	422	1.0	520	1.2
Cd- 95	03-24-41	130	171	1.0	6.0	--
Cd- 97	03-24-41	24	510	1.0	710	2.4
Cd-100	04-15-41	15	--	--	30	--
Cd-101	04-16-41	21	203	1.0	44	--
Cd-105	03-26-41	140	215	2.0	15	--
Cd-110	05-02-41	96	133	2.0	8.0	.2
Cd-111	03-25-41	33	205	13	86	--
Cd-112	03-25-41	48	244	6.0	61	.0
Cd-113	03-25-41	30	192	1.0	40	.0
Cd-117	05-06-41	15	266	1.0	51	.4
Cd-118	04-28-41	57	6	1.0	18	.1
Cd-119	04-06-41	240	--	--	560	--
Cd-120	05-01-41	57	493	1.0	510	2.2
Cd-122	04-26-41	150	--	--	310	--
Cd-123	03-26-41	14	604	1.0	380	4.8
Cd-126	04-23-41	33	26	4.0	5.0	.2
Cd-127	04-27-41	60	--	--	600	--
Cd-128	04-27-41	180	--	--	320	--
Cd-130	05-02-41	250	80	7.0	230	.8
Cd-131	03-28-41	15	366	1.0	420	.4
Cd-132	04-00-41	75	--	--	80	--
Cd-137	05-09-41	15	--	--	60	--
Cd-138	04-09-41	40	--	--	80	--
Cd-139	04-17-41	15	--	--	70	--
Cd-141	04-10-41	30	248	3.0	53	.5
Cd-142	04-10-41	30	--	--	30	--
Cd-143	04-10-41	110	--	--	90	--
Cd-145	04-10-41	70	--	--	30	--
Cd-149	04-22-41	90	--	--	70	--
Cd-150	04-22-41	27	25	1.0	13	.1

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geo-logic unit	Temperature, water (deg. C)
Cd-151	32 26 30 N	93 58 25 W	04-22-41	186	WLCX	--
Cd-152	32 19 25 N	93 49 47 W	04-15-41	22	WLCX	--
Cd-153	32 19 03 N	93 50 33 W	04-15-41	60	WLCX	--
Cd-154	32 15 30 N	93 52 34 W	04-15-41	68	WLCX	--
Cd-155	32 15 31 N	93 52 51 W	04-15-41	51	WLCX	--
Cd-157	32 17 31 N	93 56 22 W	04-15-41	42	WLCX	--
Cd-158	32 15 50 N	93 57 50 W	04-15-41	270	WLCX	--
Cd-159	32 13 11 N	93 56 39 W	04-15-41	28	WLCX	--
Cd-160	32 13 11 N	93 56 32 W	04-15-41	40	WLCX	--
Cd-161	32 13 09 N	93 56 47 W	04-15-41	275	WLCX	20.0
Cd-162	32 13 38 N	94 00 12 W	04-15-41	27	WLCX	--
Cd-163	32 12 22 N	94 01 34 W	04-15-41	36	WLCX	--
Cd-164	32 13 37 N	94 02 14 W	04-15-41	148	WLCX	--
Cd-165	32 19 58 N	93 52 20 W	04-15-41	9	WLCX	--
Cd-166	32 34 19 N	93 46 06 W	04-24-41	203	WLCX	19.5
Cd-171	32 56 21 N	94 01 16 W	05-17-41	300	WLCX	--
Cd-173	32 18 31 N	93 52 04 W	04-16-41	286	WLCX	--
Cd-174	32 19 54 N	93 51 45 W	04-16-41	165	WLCX	20.5
Cd-175	32 20 35 N	93 53 32 W	04-16-41	215	WLCX	--
Cd-176	32 20 34 N	93 53 30 W	04-17-41	160	WLCX	--
Cd-177	32 21 32 N	93 51 42 W	04-17-41	154	WLCX	--
Cd-181	32 22 02 N	93 42 42 W	04-18-41	262	WLCX	20.0
Cd-183	32 22 45 N	93 42 13 W	04-18-41	80	WLCX	--
Cd-185	32 21 54 N	93 41 28 W	04-18-41	196	WLCX	--
Cd-186	32 20 31 N	93 40 31 W	04-19-41	60	WLCX	--
Cd-187	32 21 22 N	93 40 51 W	04-19-41	173	WLCX	--
Cd-189	32 23 23 N	93 48 27 W	04-19-41	295	WLCX	--
Cd-190	32 24 37 N	93 49 14 W	04-19-41	256	WLCX	--
Cd-191	32 27 56 N	94 02 16 W	04-22-41	40	WLCX	--
Cd-192	32 26 39 N	93 59 59 W	04-22-41	185	WLCX	19.5
Cd-193	32 32 09 N	93 58 26 W	04-23-41	28	WLCX	--
Cd-194	32 35 47 N	93 46 14 W	04-24-41	172	WLCX	--
Cd-195	32 36 10 N	93 46 21 W	03-24-41	160	WLCX	--
Cd-196	32 38 40 N	93 47 59 W	04-24-41	300	WLCX	--
Cd-200	32 45 09 N	93 49 56 W	04-24-41	255	WLCX	--
Cd-201	32 49 36 N	93 50 43 W	04-24-41	380	WLCX	--
Cd-202	32 45 26 N	93 58 14 W	04-25-41	85	WLCX	--
Cd-203	32 47 11 N	94 01 49 W	04-25-41	240	WLCX	--
Cd-204	32 47 05 N	94 01 02 W	04-25-41	189	WLCX	--
Cd-206	32 47 10 N	94 00 45 W	04-25-41	180	WLCX	--

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
Cd-151	04-22-41	39	212	3.0	26	0.4
Cd-152	04-15-41	30	--	--	20	--
Cd-153	04-15-41	150	--	--	160	--
Cd-154	04-15-41	60	--	--	40	--
Cd-155	04-15-41	680	384	40	300	.2
Cd-157	04-15-41	54	43	10	53	.1
Cd-158	04-15-41	100	--	--	70	--
Cd-159	04-15-41	70	--	--	60	--
Cd-160	04-15-41	27	32	2.0	18	.1
Cd-161	04-15-41	130	172	1.0	6.0	.0
Cd-162	04-15-41	50	--	--	60	--
Cd-163	04-15-41	180	--	--	320	--
Cd-164	04-15-41	140	97	34	55	.0
Cd-165	04-15-41	200	--	--	220	--
Cd-166	04-24-41	39	263	1.0	76	.2
Cd-171	05-17-41	20	--	--	90	--
Cd-173	04-16-41	12	267	1.0	78	.3
Cd-174	04-16-41	42	167	4.0	50	.1
Cd-175	04-16-41	48	279	30	36	.4
Cd-176	04-17-41	21	168	2.0	27	.2
Cd-177	04-17-41	180	--	--	60	--
Cd-181	04-18-41	160	216	1.0	9.0	.5
Cd-183	04-18-41	130	--	--	20	--
Cd-185	04-18-41	100	--	--	20	--
Cd-186	04-19-41	140	--	--	50	--
Cd-187	04-19-41	60	--	--	25	--
Cd-189	04-19-41	--	--	--	140	--
Cd-190	04-19-41	66	252	2.0	96	.1
Cd-191	04-22-41	50	--	--	30	--
Cd-192	04-22-41	24	230	80	120	.2
Cd-193	04-23-41	60	--	--	50	--
Cd-194	04-24-41	90	--	--	170	--
Cd-195	03-24-41	200	--	--	75	--
Cd-196	04-24-41	80	--	--	360	--
Cd-200	04-24-41	48	463	1.0	320	1.6
Cd-201	04-24-41	340	473	34	160	.9
Cd-202	04-25-41	110	135	1.0	24	.1
Cd-203	04-25-41	27	273	1.0	68	.4
Cd-204	04-25-41	69	207	1.0	34	.4
Cd-206	04-25-41	100	--	--	50	--

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geo-logic unit	Specific conductance (µS/cm)	pH (standard units)
Cd-207	32 47 11 N	94 00 46 W	04-25-41	180	WLCX	--	--
Cd-210	32 52 07 N	93 59 18 W	09-19-62	265	WLCX	--	8.0
Cd-211	32 52 07 N	93 59 09 W	09-19-62	337	WLCX	--	8.0
Cd-212	32 52 31 N	93 58 56 W	04-25-41	82	CLBR	--	--
Cd-213	32 49 31 N	93 58 42 W	04-28-41	223	WLCX	--	--
Cd-217	32 49 21 N	93 58 44 W	04-28-41	213	WLCX	--	--
Cd-218	32 59 31 N	93 50 40 W	04-28-41	450	WLCX	--	--
Cd-219	32 58 53 N	93 51 10 W	04-28-41	456	WLCX	--	--
Cd-220	32 44 35 N	93 50 46 W	04-28-41	241	WLCX	--	--
Cd-221	32 44 34 N	93 50 01 W	05-01-41	472	WLCX	--	--
Cd-225	32 33 00 N	93 51 57 W	05-01-41	416	WLCX	--	--
Cd-227	33 00 09 N	93 56 09 W	05-01-41	450	WLCX	--	--
Cd-228	32 59 11 N	93 58 42 W	05-01-41	410	WLCX	--	--
Cd-229	32 56 23 N	93 59 21 W	05-01-41	447	CRRZ	--	--
Cd-232	32 36 20 N	93 52 34 W	05-02-41	300	WLCX	--	--
Cd-236	32 59 33 N	93 55 21 W	05-01-41	446	WLCX	--	--
Cd-248	32 27 11 N	93 51 44 W	05-07-41	125	WLCX	--	--
Cd-249	32 25 47 N	93 52 36 W	05-07-41	190	WLCX	--	--
Cd-250	32 26 06 N	93 49 36 W	05-07-41	36	WLCX	--	--
Cd-251	32 26 34 N	93 45 18 W	05-07-41	260	WLCX	--	--
Cd-252	32 26 34 N	93 45 18 W	05-07-41	260	WLCX	--	--
Cd-253	32 26 34 N	93 45 18 W	05-07-41	260	WLCX	--	--
Cd-259	32 47 30 N	93 59 41 W	05-15-41	115	WLCX	--	--
Cd-264A	32 57 12 N	94 02 15 W	09-17-60	623	WLCX	--	--
Cd-264B	32 57 12 N	94 02 15 W	05-17-41	658	WLCX	--	--
Cd-265B	32 59 13 N	93 59 23 W	05-17-41	315	WLCX	--	--
Cd-267	32 24 54 N	93 52 09 W	05-23-41	165	WLCX	--	--
Cd-269	32 26 12 N	93 52 16 W	05-23-41	204	WLCX	--	--
Cd-270	32 26 38 N	93 52 30 W	05-23-41	278	WLCX	--	--
Cd-272	32 26 29 N	93 56 42 W	05-23-41	150	WLCX	--	--
Cd-281	32 47 44 N	93 55 26 W	06-02-41	134	WLCX	--	--
Cd-283	32 35 05 N	93 46 20 W	06-02-41	300	WLCX	--	--
Cd-284	32 39 17 N	93 48 35 W	06-02-41	213	WLCX	--	--
Cd-288	32 24 58 N	93 45 35 W	06-09-41	214	WLCX	--	--
Cd-292	32 29 21 N	93 50 37 W	06-10-41	130	WLCX	--	--
Cd-298	32 29 28 N	93 50 36 W	06-11-41	128	WLCX	--	--
Cd-309	32 36 30 N	93 48 57 W	09-11-42	114	WLCX	--	7.0
Cd-325	32 13 46 N	93 55 59 W	01-23-59	203	WLCX	100	6.7
Cd-354	33 00 11 N	93 53 32 W	07-30-59	21	SPRT	181	--
Cd-355	32 54 22 N	93 53 06 W	07-30-59	32	CRVR	121	4.2

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Temperature, water (deg. C)	Color, (platinum-cobalt units)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Cd-207	04-25-41	--	--	90	--	--	--	--
Cd-210	09-19-62	--	8	96	--	--	--	--
Cd-211	09-19-62	--	10	120	--	--	--	--
Cd-212	04-25-41	--	--	110	--	--	--	--
Cd-213	04-28-41	--	--	90	--	--	--	--
Cd-217	04-28-41	--	--	150	--	--	--	--
Cd-218	04-28-41	--	--	20	--	--	--	--
Cd-219	04-28-41	--	--	21	--	--	--	--
Cd-220	04-28-41	--	--	350	--	--	--	--
Cd-221	05-01-41	--	--	--	--	--	--	--
Cd-225	05-01-41	--	--	42	--	--	--	--
Cd-227	05-01-41	--	--	60	--	--	--	--
Cd-228	05-01-41	--	--	39	--	--	--	--
Cd-229	05-01-41	--	--	27	--	--	--	--
Cd-232	05-02-41	--	--	160	--	--	--	--
Cd-236	05-01-41	--	--	35	--	--	--	--
Cd-248	05-07-41	--	--	60	--	--	--	--
Cd-249	05-07-41	--	--	40	--	--	--	--
Cd-250	05-07-41	--	--	250	62	24	44	4.1
Cd-251	05-07-41	--	--	30	--	--	--	--
Cd-252	05-07-41	--	--	56	13	5.7	15	1.7
Cd-253	05-07-41	--	--	30	--	--	--	--
Cd-259	05-15-41	--	--	50	--	--	--	--
Cd-264A	09-17-60	--	--	12	--	--	--	--
Cd-264B	05-17-41	--	--	15	--	--	--	--
Cd-265B	05-17-41	--	--	25	--	--	--	--
Cd-267	05-23-41	--	--	30	--	--	--	--
Cd-269	05-23-41	--	--	50	--	--	--	--
Cd-270	05-23-41	--	--	90	--	--	--	--
Cd-272	05-23-41	--	--	50	--	--	--	--
Cd-281	06-02-41	--	--	150	--	--	--	--
Cd-283	06-02-41	--	--	30	--	--	--	--
Cd-284	06-02-41	--	--	120	--	--	--	--
Cd-288	06-09-41	--	--	120	--	--	--	--
Cd-292	06-10-41	--	--	60	--	--	--	--
Cd-298	06-11-41	--	--	60	--	--	--	--
Cd-309	09-11-42	--	20	180	--	--	--	--
Cd-325	01-23-59	24.0	0	28	8.0	1.9	12	1.2
Cd-354	07-30-59	19.5	20	12	2.2	1.6	25	.9
Cd-355	07-30-59	--	20	23	1.8	4.5	6.4	2.2

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	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 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)
Cd-207	04-25-41	--	--	30	--	--	--	--
Cd-210	09-19-62	--	--	350	0.5	--	--	1,010
Cd-211	09-19-62	--	--	320	.5	--	--	890
Cd-212	04-25-41	1	3.0	93	.0	--	--	--
Cd-213	04-28-41	266	4.0	42	.4	--	--	--
Cd-217	04-28-41	256	1.0	57	.1	--	--	--
Cd-218	04-28-41	--	--	10	--	--	--	--
Cd-219	04-28-41	389	1.0	10	1.6	--	--	--
Cd-220	04-28-41	--	--	140	--	--	--	--
Cd-221	05-01-41	403	10	56	.2	--	--	--
Cd-225	05-01-41	122	8.0	9.0	.1	--	--	--
Cd-227	05-01-41	149	1.0	9.0	.0	--	--	--
Cd-228	05-01-41	166	1.0	8.0	.0	--	--	--
Cd-229	05-01-41	222	2.0	12	.8	--	--	--
Cd-232	05-02-41	179	40	50	.3	--	--	--
Cd-236	05-01-41	--	--	10	--	--	--	--
Cd-248	05-07-41	--	--	30	--	--	--	--
Cd-249	05-07-41	--	--	20	--	--	--	--
Cd-250	05-07-41	75	2.7	120	.2	56	--	495
Cd-251	05-07-41	--	--	20	--	--	--	--
Cd-252	05-07-41	24	5.9	38	.0	57	--	156
Cd-253	05-07-41	--	--	30	--	--	--	--
Cd-259	05-15-41	--	--	15	--	--	--	--
Cd-264A	09-17-60	--	--	270	--	--	--	--
Cd-264B	05-17-41	--	--	250	--	--	--	--
Cd-265B	05-17-41	--	--	5.0	--	--	--	--
Cd-267	05-23-41	--	--	50	--	--	--	--
Cd-269	05-23-41	--	--	120	--	--	--	--
Cd-270	05-23-41	--	--	50	--	--	--	--
Cd-272	05-23-41	--	--	20	--	--	--	--
Cd-281	06-02-41	--	--	360	--	--	--	--
Cd-283	06-02-41	--	--	130	--	--	--	--
Cd-284	06-02-41	--	--	260	--	--	--	--
Cd-288	06-09-41	--	--	75	--	--	--	--
Cd-292	06-10-41	--	--	35	--	--	--	--
Cd-298	06-11-41	--	--	30	--	--	--	--
Cd-309	09-11-42	107	--	60	--	--	--	500
Cd-325	01-23-59	44	3.7	5.0	.1	67	112	126
Cd-354	07-30-59	0	1.4	35	.3	11	131	101
Cd-355	07-30-59	0	3.6	11	.3	38	150	101

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Time	Depth (feet)	Geo-logic unit	Spe-cific con-duct-ance (μS/cm)	pH (stand-ard units)
Cd-356	33 00 05 N	93 53 32 W	08-06-59	--	210	CRVR	250	7.5
Cd-357	32 34 46 N	93 47 20 W	08-06-59	--	204	WLCX	527	7.8
Cd-358	32 45 10 N	93 59 57 W	08-06-59	1200	191	WLCX	1,870	8.0
Cd-359	32 26 38 N	93 58 36 W	08-06-59	--	125	WLCX	588	8.0
Cd-360	32 27 05 N	93 51 58 W	08-07-59	--	257	WLCX	953	8.2
Cd-361	32 18 35 N	93 56 29 W	08-07-59	--	175	WLCX	313	6.6
Cd-362	32 23 54 N	93 41 28 W	08-08-59	--	194	WLCX	1,410	7.7
Cd-363	32 15 37 N	93 31 40 W	12-17-91	0900	250	WLCX	1,280	--
Cd-367	32 27 12 N	93 49 40 W	01-00-60	--	282	WLCX	--	8.1
Cd-375	32 52 15 N	93 58 55 W	05-22-68	--	275	WLCX	1,790	7.4
Cd-389	32 59 02 N	93 51 03 W	08-16-61	--	460	WLCX	417	7.6
Cd-390	33 00 16 N	93 53 38 W	12-19-59	--	535	WLCX	--	--
Cd-391	32 53 44 N	93 50 17 W	08-16-61	--	230	WLCX	1,690	7.6
Cd-400	32 35 02 N	93 51 17 W	12-28-59	--	171	WLCX	--	--
Cd-421	32 23 22 N	93 46 43 W	07-25-68	--	163	WLCX	582	7.3
Cd-422	32 24 34 N	93 48 32 W	06-00-62	--	270	WLCX	--	7.8
Cd-423	32 24 08 N	93 47 44 W	06-00-62	--	202	WLCX	--	8.2
Cd-424	32 23 53 N	93 47 03 W	06-00-63	--	296	WLCX	--	7.9
Cd-425	32 23 53 N	93 48 08 W	06-00-62	--	223	WLCX	--	7.9
Cd-427	32 23 07 N	93 46 48 W	06-00-62	--	221	WLCX	--	7.8
Cd-428	32 23 24 N	93 48 21 W	07-25-68	--	270	WLCX	593	7.4
Cd-430	32 56 20 N	93 56 56 W	02-19-60	--	574	WLCX	1,580	--
Cd-434	32 25 40 N	93 42 32 W	06-17-60	--	225	WLCX	800	8.6
Cd-435	32 36 08 N	93 51 24 W	09-13-66	--	136	WLCX	916	7.5
Cd-436	32 35 35 N	93 49 05 W	09-19-66	--	183	WLCX	829	8.7
Cd-438	32 34 50 N	93 47 25 W	05-20-67	--	216	WLCX	453	8.2
Cd-439	32 34 08 N	93 45 47 W	06-08-67	--	200	WLCX	764	8.0
Cd-440	32 26 30 N	93 56 38 W	06-12-67	--	219	WLCX	270	8.2
Cd-442	32 26 03 N	93 57 03 W	06-21-67	--	185	WLCXU	131	6.6
Cd-445	32 53 20 N	93 59 01 W	06-29-67	--	230	WLCXU	414	8.1
Cd-446	32 53 38 N	93 58 55 W	06-29-67	--	216	CRRZ	679	8.9
Cd-447	32 53 57 N	93 58 57 W	07-10-67	--	236	WLCXU	697	8.2
Cd-450	32 15 47 N	93 56 09 W	03-15-68	--	280	WLCX	435	8.4
Cd-451	32 56 47 N	93 53 29 W	07-22-68	--	210	WLCX	231	7.3
Cd-452	32 56 56 N	93 53 33 W	06-23-92	1320	210	WLCX	277	7.7
Cd-453	32 53 31 N	93 58 55 W	09-06-86	0900	228	WLCX	1,260	8.2
Cd-454	33 00 15 N	93 53 30 W	06-22-92	1800	570	WLCX	584	8.3
Cd-460	32 58 13 N	93 59 31 W	10-30-68	--	250	CRRZ	334	7.8
Cd-492	32 44 52 N	93 49 54 W	06-23-92	1630	180	WLCX	1,960	8.1
Cd-493	32 44 48 N	93 49 47 W	02-18-72	--	164	WLCX	1,500	8.1

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Temperature, water (deg. C)	Color, (platinum-cobalt units)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Cd-356	08-06-59	21.5	20	77	21	6.0	24	2.9
Cd-357	08-06-59	21.0	20	140	33	13	73	2.8
Cd-358	08-06-59	--	30	54	13	5.3	430	5.5
Cd-359	08-06-59	--	30	17	5.	1.1	130	1.1
Cd-360	08-07-59	21.5	20	11	3.5	.5	220	1.6
Cd-361	08-07-59	21.0	20	95	26	7.4	25	2.0
Cd-362	08-08-59	--	20	170	48	12	260	4.7
Cd-363	12-17-91	--	--	--	--	--	--	--
Cd-367	01-00-60	--	10	140	29	17	--	--
Cd-375	05-22-68	21.5	10	92	32	2.9	360	3.5
Cd-389	08-16-61	20.5	30	4	1.5	.1	94	1.3
Cd-390	12-19-59	19.0	--	320	--	--	--	--
Cd-391	08-16-61	21.5	10	44	15	1.6	360	8.2
Cd-400	12-28-59	20.5	--	40	--	--	--	--
Cd-421	07-25-68	20.0	10	92	24	7.8	86	1.6
Cd-422	06-00-62	--	10	61	--	--	--	--
Cd-423	06-00-62	--	15	7	--	--	--	--
Cd-424	06-00-63	--	10	61	--	--	--	--
Cd-425	06-00-62	--	15	59	--	--	--	--
Cd-427	06-00-62	--	20	9	--	--	--	--
Cd-428	07-25-68	21.0	5	2	.8	.0	140	1.4
Cd-430	02-19-60	--	20	11	4.0	.2	350	1.8
Cd-434	06-17-60	--	--	26	6.4	2.5	--	--
Cd-435	09-13-66	20.5	5	100	25	9.4	160	4.0
Cd-436	09-19-66	21.0	0	60	18	3.7	160	1.8
Cd-438	05-20-67	--	12	130	28	15	52	--
Cd-439	06-08-67	21.0	5	48	11	5.0	160	2.6
Cd-440	06-12-67	21.0	10	22	5.4	2.1	52	1.2
Cd-442	06-21-67	20.5	40	28	6.4	2.8	15	1.8
Cd-445	06-29-67	21.5	5	82	19	8.4	52	6.1
Cd-446	06-29-67	21.5	10	15	3.0	1.8	160	1.9
Cd-447	07-10-67	21.5	5	30	8.0	2.4	150	2.1
Cd-450	03-15-68	21.0	5	10	2.0	1.2	98	.2
Cd-451	07-22-68	20.5	5	6	2.0	.2	52	1.2
Cd-452	06-23-92	22.0	--	6	1.4	.5	60	1.9
Cd-453	09-06-86	21.0	--	20	6.0	1.3	260	2.3
Cd-454	06-22-92	23.0	--	4	1.2	.3	150	1.4
Cd-460	10-30-68	21.5	10	17	4.9	1.2	73	1.8
Cd-492	06-23-92	20.0	--	66	16	6.2	400	4.8
Cd-493	02-18-72	20.0	5	65	16	6.1	320	6.3

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	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 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)
Cd-356	08-06-59	105	9.6	13	0.1	12	157	153
Cd-357	08-06-59	257	15	13	.8	19	323	326
Cd-358	08-06-59	465	4.0	350	2.4	11	1,160	1,100
Cd-359	08-06-59	203	.80	69	.5	12	349	343
Cd-360	08-07-59	339	5.4	110	.6	11	586	558
Cd-361	08-07-59	92	5.8	37	.3	52	213	211
Cd-362	08-08-59	435	6.2	200	.5	16	809	811
Cd-363	12-17-91	--	--	160	--	--	--	--
Cd-367	01-00-60	168	1.2	23	<.1	--	--	--
Cd-375	05-22-68	373	2.0	360	.5	23	--	1,010
Cd-389	08-16-61	204	3.2	4.1	.2	8.7	251	236
Cd-390	12-19-59	--	--	32	--	--	--	--
Cd-391	08-16-61	521	.0	240	1.5	--	979	939
Cd-400	12-28-59	--	--	84	--	--	--	--
Cd-421	07-25-68	107	30	100	.1	29	341	343
Cd-422	06-00-62	--	--	39	--	--	--	342
Cd-423	06-00-62	--	--	25	--	--	--	280
Cd-424	06-00-63	--	--	82	--	--	--	505
Cd-425	06-00-62	--	--	24	--	--	--	355
Cd-427	06-00-62	--	--	45	--	--	--	371
Cd-428	07-25-68	230	2.8	51	.3	12	351	345
Cd-430	02-19-60	363	1.4	290	1.2	13	886	880
Cd-434	06-17-60	340	--	140	--	--	--	710
Cd-435	09-13-66	--	34	130	.2	16	517	526
Cd-436	09-19-66	--	14	120	.4	13	465	472
Cd-438	05-20-67	204	5.8	22	.3	40	--	286
Cd-439	06-08-67	--	.0	89	.2	16	439	442
Cd-440	06-12-67	--	.0	10	.1	50	196	194
Cd-442	06-21-67	--	.80	6.3	.1	64	129	132
Cd-445	06-29-67	--	53	12	.2	14	247	244
Cd-446	06-29-67	--	11	42	.6	11	406	397
Cd-447	07-10-67	--	54	20	1.4	10	419	412
Cd-450	03-15-68	162	.0	40	.2	19	258	258
Cd-451	07-22-68	106	10	4.0	.1	15	143	148
Cd-452	06-23-92	112	20	7.2	.1	15	171	173
Cd-453	09-06-86	312	27	200	.6	--	787	684
Cd-454	06-22-92	299	<.20	11	.4	10	352	--
Cd-460	10-30-68	169	.20	7.8	.3	11	204	204
Cd-492	06-23-92	426	<.20	380	1.3	10	1,080	--
Cd-493	02-18-72	--	.0	250	1.3	11	888	857

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Time	Depth (feet)	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)
Cd-496	33 00 17 N	93 53 32 W	08-01-73	0001	345	CRVR	243	6.9
Cd-498A	32 59 37 N	93 53 54 W	08-09-73	0001	142	SPRT	273	8.0
Cd-498B			08-07-73	0001	243	CRVR	259	8.0
Cd-498C			12-18-73	1430	420	CRRZ	606	8.0
Cd-499	32 34 04 N	93 56 03 W	05-06-74	1300	75	WLCX	550	7.6
Cd-500A	32 50 32 N	93 59 35 W	05-17-74	1430	273	WLCX	919	8.7
Cd-500B			05-13-74	1330	536	WLCX	1,740	8.3
Cd-502	32 18 42 N	93 54 09 W	01-15-75	1800	261	WLCX	374	6.5
Cd-503A	32 20 12 N	93 55 18 W	01-29-75	1200	198	WLCX	512	8.4
Cd-503B			01-24-75	1300	276	WLCX	529	8.0
Cd-505	32 52 28 N	93 58 46 W	10-07-75	1400	410	WLCX	1,780	8.7
Cd-507	32 50 54 N	93 59 04 W	10-15-75	1200	205	WLCX	1,410	7.8
Cd-512	32 44 39 N	93 47 32 W	05-26-76	1430	150	WLCX	2,830	--
Cd-523	32 45 00 N	93 49 55 W	06-21-83	0830	180	WLCX	1,780	7.9
Cd-524	33 00 15 N	93 53 30 W	06-23-92	0915	540	CRRZ	587	8.3
Cd-589	32 12 37 N	94 01 00 W	09-16-83	1500	270	WLCX	327	8.4
Cd-675	32 13 19 N	94 02 33 W	06-16-92	1130	145	WLCX	292	7.0
Cd-677	32 57 12 N	93 59 41 W	06-16-92	1640	160	CRVR	220	7.4
Cd-693	32 58 15 N	93 59 33 W	06-23-92	1130	400	WLCX	323	7.6
Cd-731	32 46 39 N	93 58 32 W	06-16-92	1440	175	WLCX	1,010	8.2
Cd-734	32 26 48 N	93 57 00 W	06-16-92	0940	215	WLCX	246	6.8
Cd-810	32 41 59 N	93 54 41 W	04-08-92	1245	49	WLCX	1,710	7.1
Cd-5243Z	32 22 39 N	93 42 40 W	06-15-92	1430	180	WLCX	448	7.0
Cd-7252Z	33 00 08 N	93 55 32 W	06-22-92	1215	249	CRVR	114	6.1
Cd-7253Z	32 22 42 N	93 40 08 W	06-29-92	0800	210	WLCX	753	7.6
Cd-7255Z	33 00 15 N	93 53 31 W	06-22-92	1510	36	SPRT	113	6.0

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Temperature, water (deg. C)	Color, (platinum-cobalt units)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Cd-496	08-01-73	21.0	5	5	1.0	0.6	55	1.4
Cd-498A	08-09-73	19.5	0	72	20	5.4	29	4.1
Cd-498B	08-07-73	20.5	0	11	2.0	1.5	60	1.7
Cd-498C	12-18-73	21.5	40	6	2.1	.2	160	1.4
Cd-499	05-06-74	--	0	13	3.3	1.2	130	3.2
Cd-500A	05-17-74	20.5	20	19	3.8	2.3	210	3.0
Cd-500B	05-13-74	--	5	10	3.8	.1	310	2.4
Cd-502	01-15-75	22.0	0	26	8.9	.9	71	2.5
Cd-503A	01-29-75	21.0	5	24	5.0	2.8	100	1.8
Cd-503B	01-24-75	22.0	10	1	.3	.1	120	1.1
Cd-505	10-07-75	21.0	0	86	27	4.5	360	6.0
Cd-507	10-15-75	20.5	0	56	20	1.5	300	4.3
Cd-512	05-26-76	--	10	140	27	18	560	10
Cd-523	06-21-83	20.0	20	81	19	8.2	390	3.9
Cd-524	06-23-92	23.0	--	4	1.2	.3	150	1.5
Cd-589	09-16-83	20.0	0	12	3.8	.5	70	1.4
Cd-675	06-16-92	21.0	--	22	5.9	1.8	60	1.6
Cd-677	06-16-92	19.0	--	13	3.7	1.0	50	2.1
Cd-693	06-23-92	20.5	--	16	4.2	1.3	69	2.6
Cd-731	06-16-92	20.0	--	22	6.2	1.6	240	2.8
Cd-734	06-16-92	21.0	--	17	4.0	1.6	48	1.6
Cd-810	04-08-92	--	--	429	91	49	190	3.4
Cd-5243Z	06-15-92	20.5	--	45	12	3.6	86	1.7
Cd-7252Z	06-22-92	21.0	--	34	9.6	2.5	7.2	3.2
Cd-7253Z	06-29-92	20.0	--	100	26	8.8	140	1.9
Cd-7255Z	06-22-92	18.5	--	38	13	1.3	5.4	2.2

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Date	Alkalinity, water whole total fixed end-point titration field (mg/L as $CaCO_3$)	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 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)
Cd-496	08-01-73	106	14	8.0	<0.1	13	151	157
Cd-498A	08-09-73	112	11	15	<.1	13	151	166
Cd-498B	08-07-73	125	17	4.4	<.1	13	170	175
Cd-498C	12-18-73	320	2.1	9.8	.5	8.8	387	380
Cd-499	05-06-74	203	10	52	.2	30	350	352
Cd-500A	05-17-74	367	1.6	80	1.0	9.9	536	532
Cd-500B	05-13-74	387	1.8	330	.8	12	977	893
Cd-502	01-15-75	139	4.2	26	.2	37	247	235
Cd-503A	01-29-75	198	13	35	.2	11	304	288
Cd-503B	01-24-75	181	<1.0	55	.2	11	313	298
Cd-505	10-07-75	367	<1.0	360	.5	16	1,020	980
Cd-507	10-15-75	246	66	260	.3	16	806	816
Cd-512	05-26-76	438	.2	670	1.9	11	1,550	1,560
Cd-523	06-21-83	445	1.4	320	1.4	12	1,080	1,020
Cd-524	06-23-92	306	<.2	11	.4	10	357	--
Cd-589	09-16-83	144	.4	22	.2	27	210	212
Cd-675	06-16-92	127	.4	20	.2	45	210	212
Cd-677	06-16-92	118	2.5	5.3	<.1	17	151	152
Cd-693	06-23-92	164	<.2	6.6	.2	10	191	--
Cd-731	06-16-92	340	.2	170	.2	13	639	638
Cd-734	06-16-92	99	5.3	14	.1	51	187	187
Cd-810	04-08-92	338	30	310	.6	17	972	947
Cd-5243Z	06-15-92	204	2.8	21	.3	16	268	266
Cd-7252Z	06-22-92	41	3.3	9.1	<.1	29	86	90
Cd-7253Z	06-29-92	311	<.2	60	.6	16	438	--
Cd-7255Z	06-22-92	36	4.3	9.2	<.1	13	74	77

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geologic unit	Iron dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
Cd- 52	32 58 05 N	93 59 40 W	05-22-68	660	WLCX	70	--
Cd-354	33 00 11 N	93 53 32 W	07-30-59	21	SPRT	180	--
Cd-375	32 52 15 N	93 58 55 W	05-22-68	275	WLCX	80	--
Cd-421	32 23 22 N	93 46 43 W	07-25-68	163	WLCX	370	--
Cd-428	32 23 24 N	93 48 21 W	07-25-68	270	WLCX	70	--
Cd-435	32 36 08 N	93 51 24 W	09-13-66	136	WLCX	160	--
Cd-436	32 35 35 N	93 49 05 W	09-19-66	183	WLCX	140	--
Cd-438	32 34 50 N	93 47 25 W	05-20-67	216	WLCX	700	20
Cd-439	32 34 08 N	93 45 47 W	06-08-67	200	WLCX	230	--
Cd-440	32 26 30 N	93 56 38 W	06-12-67	219	WLCX	870	--
Cd-442	32 26 03 N	93 57 03 W	06-21-67	185	WLCXU	4,100	--
Cd-445	32 53 20 N	93 59 01 W	06-29-67	230	WLCXU	50	--
Cd-446	32 53 38 N	93 58 55 W	06-29-67	216	CRRZ	30	--
Cd-447	32 53 57 N	93 58 57 W	07-10-67	236	WLCXU	20	--
Cd-450	32 15 47 N	93 56 09 W	03-15-68	280	WLCX	90	--
Cd-451	32 56 47 N	93 53 29 W	07-22-68	210	WLCX	220	--
Cd-452	32 56 56 N	93 53 33 W	06-23-92	210	WLCX	96	<5
Cd-453	32 53 31 N	93 58 55 W	09-06-86	228	WLCX	14	14
Cd-454	33 00 15 N	93 53 30 W	07-22-68	570	WLCX	330	--
Cd-460	32 58 13 N	93 59 31 W	10-30-68	250	CRRZ	410	--
Cd-492	32 44 52 N	93 49 54 W	02-15-72	180	WLCX	360	50
Cd-493	32 44 48 N	93 49 47 W	02-18-72	164	WLCX	160	20
Cd-496	33 00 17 N	93 53 32 W	07-31-73	345	CRVR	540	30
Cd-498A	32 59 37 N	93 53 54 W	08-09-73	142	SPRT	990	30
Cd-498B	32 59 37 N	93 53 54 W	08-07-73	243	CRVR	40	<10
Cd-498C	32 59 37 N	93 53 54 W	12-18-73	420	CRRZ	3,100	70
Cd-499	32 34 04 N	93 56 03 W	05-06-74	75	WLCX	440	40
Cd-500A	32 50 32 N	93 59 35 W	05-17-74	273	WLCX	40	<10
Cd-500B	32 50 32 N	93 59 35 W	05-13-74	536	WLCX	370	<10
Cd-502	32 18 42 N	93 54 09 W	01-15-75	261	WLCX	1,500	110
Cd-503A	32 20 12 N	93 55 18 W	01-29-75	198	WLCX	160	50
Cd-503B	32 20 12 N	93 55 18 W	01-24-75	276	WLCX	50	<10
Cd-505	32 52 28 N	93 58 46 W	10-07-75	410	WLCX	180	66
Cd-507	32 50 54 N	93 59 04 W	10-15-75	205	WLCX	130	40
Cd-512	32 44 39 N	93 47 32 W	05-26-76	150	WLCX	20	20
Cd-523	32 45 00 N	93 49 55 W	06-21-83	180	WLCX	150	14
Cd-524	33 00 15 N	93 53 30 W	06-23-92	540	CRRZ	45	<5
Cd-589	32 12 37 N	94 01 00 W	09-16-83	270	WLCX	20	26
Cd-675	32 13 19 N	94 02 33 W	06-16-92	145	WLCX	1,200	60
Cd-677	32 57 12 N	93 59 41 W	06-16-92	160	CRVR	39	<5
Cd-693	32 58 15 N	93 59 33 W	06-23-92	400	WLCX	98	<5
Cd-731	32 46 39 N	93 58 32 W	06-16-92	175	WLCX	34	12
Cd-734	32 26 48 N	93 57 00 W	06-16-92	215	WLCX	1,800	62
Cd-810	32 41 59 N	93 54 41 W	09-12-91	49	WLCX	3,100	340
Cd-7252Z	33 00 08 N	93 55 32 W	06-22-92	249	CRVR	1,500	30
Cd-7253Z	32 22 42 N	93 40 08 W	06-29-92	210	WLCX	7	12
Cd-7255Z	33 00 15 N	93 53 31 W	06-22-92	36	SPRT	29	<5

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geologic unit	Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolvd (µg/L as As)
Cd-452	32 56 56 N	93 53 33 W	06-23-92	210	WLCX	<0.05	0.16	<1	<1
Cd-453	32 53 31 N	93 58 55 W	09-06-86	228	WLCX	<.10	--	<1	<1
Cd-523	32 45 00 N	93 49 55 W	06-21-83	180	WLCX	<.10	--	--	--
Cd-524	33 00 15 N	93 53 30 W	06-23-92	540	CRRZ	<.05	.51	<1	<1
Cd-589	32 12 37 N	94 01 00 W	09-16-83	270	WLCX	--	--	<1	1
Cd-675	32 13 19 N	94 02 33 W	06-16-92	145	WLCX	<.05	.39	<1	<1
Cd-677	32 57 12 N	93 59 41 W	06-16-92	160	CRVR	--	--	<1	<1

Well number	Date	Barium, disolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L Pb)
Cd-452	06-23-92	26	<1	<1	1	<1	<1
Cd-453	09-06-86	46	1	3	<10	<1	<5
Cd-524	06-23-92	22	<1	<1	<1	<1	
Cd-589	09-16-83	45	<.5	<1	<10	<1	4
Cd-675	06-16-92	41	<1	<1	2	<1	<1
Cd-677	06-16-92	53	<1	<1	1	<1	<1

Well number	Date	Mercury, dis solved (µg/L as Hg)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)
Cd-452	06-23-92	<0.1	<1	<1	<1	7
Cd-453	09-06-86	<.1	1	<1	<1	4
Cd-524	06-23-92	<.1	<1	<1	<1	<5
Cd-589	09-16-83	.5	<1	<1	<1	4
Cd-675	06-16-92	<.1	<1	<1	<1	9
Cd-677	06-16-92	<.1	<1	<1	<1	<5

Appendix 2. Chemical analyses of water from selected wells completed in sands of Tertiary age--Continued

Well number	Latitude	Longitude	Date	Depth (feet)	Geo-logic unit	Iron, dissolved (µg/L as Fe)	Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)	Phos-phorus, dissolved (mg/L as P)
Cd-693	32 58 15 N	93 59 33 W	06-23-92	400	WLCX	98	<0.05	0.23
Cd-731	32 46 39 N	93 58 32 W	06-16-92	175	WLCX	34	<.05	.07
Cd-734	32 26 48 N	93 57 00 W	06-16-92	215	WLCX	1,800	<.05	.26
Cd-810	32 41 59 N	93 54 41 W	09-12-91	49	WLCX	3,100	<.02	--
Cd-7252Z	33 00 08 N	93 55 32 W	06-22-92	249	CRVR	1,500	<.05	.10
Cd-7253Z	32 22 42 N	93 40 08 W	06-29-92	210	WLCX	7	.12	.10
Cd-7255Z	33 00 15 N	93 53 31 W	06-22-92	36	SPRT	29	1.50	.02

Well number	Date	Anti-mony, dis-solved (µg/L as Sb)	Arsenic, dis-solved (µg/L as As)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cadmium, dis-solved (µg/L as Cd)	Chrom-mium, dis-solved (µg/L as Cr)	Copper, dis-solved (µg/L as Cu)
Cd-693	06-23-92	<1	<1	65	<1	<1	1	<1
Cd-731	06-16-92	<1	<1	110	<1	<1	1	<1
Cd-734	06-16-92	<1	<1	43	<1	<1	2	<1
Cd-810	09-12-91	--	--	--	--	--	--	--
Cd-7252Z	06-22-92	<1	<1	120	<1	<1	2	<1
Cd-7253Z	06-29-92	<1	<1	170	<1	<1	1	<1
Cd-7255Z	06-22-92	<1	<1	47	<1	<1	2	9

Well number	Date	Lead, dis, solved (µg/L as Pb)	Mercury, dis-solved (µg/L as Hg)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Zinc, dis-solved (µg/L as Zn)
Cd-693	06-23-92	<1	<0.1	<1	<1	<1	<5
Cd-731	06-16-92	<1	<.1	<1	<1	<1	<5
Cd-734	06-16-92	<1	<.1	<1	<1	<1	18
Cd-810	09-12-91	--	--	--	--	--	--
Cd-7252Z	06-22-92	<1	<.1	<1	<1	<1	8
Cd-7253Z	06-29-92	<1	<.1	<1	<1	<1	<5
Cd-7255Z	06-22-92	<1	<.1	<1	<1	<1	29

APPENDIX 3

Oil-Test Wells and Water-Test Wells Used for Geologic Correlation

Appendix 3. Oil-test wells and water-test wells used for geologic correlation
[Cd, Caddo Parish]

State registered well number	Location by latitude and longitude	Township, range, section
Oil-test wells		
18880	325851 934835	23N 16W 16
153609	330044 934811	23N 14W 3
30650	330101 935434	23N 15W 3
30651	330049 935416	23N 15W 3
126077	330041 935360	23N 15W 3
213595	330056 935304	23N 15W 2
151620	325926 935023	23N 24W 17
175378	325938 935028	23N 14W 8
74644	325620 935021	23N 14W 32
178092	325902 935129	23N 14W 18
970371	325844 935916	23N 16W 23
54252	330014 934652	23N 14W 11
166303	325712 934849	23N 14W 28
178438	325920 935646	23N 15W 17
69785	325920 935646	23N 15W 17
74374	325853 935830	23N 15W 13
142470	325921 935758	23N 15W 14
35463	330026 935838	23N 16W 12
155336	325953 935856	23N 16W 11
156905	325903 935528	23N 15W 16
68126	325353 934735	22N 14W 15
119663	325400 935028	22N 14W 17
143679	325331 935055	22N 14W 18
105083	325239 935156	22N 15W 24
45080	325259 935152	22N 15W 24
186105	325259 935216	22N 15W 24
44745	325354 935920	22N 16W 14
70944	325350 935910	22N 16W 14
44534	325359 935953	22N 16W 14
00000	325259 935518	22N 15W 21
190632	225259 935000	22N 15W 21
115039	325300 940030	22N 16W 22
199810	325301 940039	22N 16W 22
44498	325351 940019	22N 16W 15
44576	325340 940002	22N 16W 15
971339	325259 940132	22N 16W 21
182066	325334 940008	22N 14W 15
170248	325421 934741	22N 14W 15
150195	325209 934832	22N 14W 27
203727	325355 935006	22N 14W 17
44508	324758 934824	21N 14W 22
167037	324725 935056	21N 14W 19
40773	324749 935016	21N 14W 20
42836	324723 934929	21N 14W 21
53421	324746 935113	21N 14W 19
150072	324736 935637	21N 15W 20
160124	324807 935809	21N 16W 24
170477	324734 940044	21N 16W 22
153022	324749 940027	21N 16W 22
195180	324811 935055	21N 14W 19
53522	324736 935102	21N 14W 19
146152	324733 935454	21N 15W 21
97346	324217 935015	20N 14W 20
141574	324310 935032	20N 14W 17
57761	324348 935803	20N 16W 13
108703	324147 935209	20N 15W 25
Oil-test wells--Continued		
41479	324242 935317	20N 15W 23
117505	324507 935625	20N 15W 5
102744	324252 934726	20N 14W 23
47817	323710 935335	19N 15W 21
42251	323811 935326	19N 15W 15
162383	323849 935140	19N 15W 12
188103	324008 934813	19N 14W 4
110896	323848 934758	19N 14W 9
43466	323547 934605	19N 14W 35
73167	323605 934622	19N 14W 26
99190	323729 934641	19N 14W 23
32142	323841 934750	19N 14W 15
48682	323808 934437	19N 13W 18
50332	323908 934354	19N 13W 8
51298	323815 934438	19N 13W 18
56502	323828 934719	19N 14W 15
43668	323641 935305	19N 15W 27
11646	323655 934713	19N 14W 27
104910	323652 934804	19N 14W 28
186193	324003 934722	19N 14W 3
94186	323152 940146	18N 16W 20
63052	323153 940205	18N 16W 20
102816	323159 940204	18N 16W 20
209345	323233 935826	18N 16W 23
161002	323252 935455	18N 15W 17
56503	323153 935836	18N 16W 23
165245	323437 934456	18N 14W 1
53417	323210 935622	18N 15W 19
72818	322511 934126	17N 13W 34
45590	322702 935736	17N 15W 24
42454	322720 935917	17N 16W 22
71702	322850 934610	17N 14W 11
38813	322735 933243	17N 12W 13
970498	322908 933330	17N 12W 1
29750	322703 934033	17N 13W 23
177067	323024 934904	16N 14W 29
41900	322011 933246	16N 12W 36
39687	322148 935837	16N 16W 23
62630	322442 935402	16N 15W 4
165155	322431 933932	16N 13W 1
149778	322012 933926	16N 13W 36
69789	322050 934104	16N 13W 27
148719	321747 934023	15N 13W 11
47101	321645 935904	15N 16W 28
60643	321525 935733	15N 16W 25
60890	321642 935741	15N 16W 24
71075	321908 935924	15N 16W 3
145128	321920 935948	15N 16W 3
Water-test wells		
Cd- 435	323608 935124	
Cd- 436	323535 934905	
Cd- 437	323607 935013	
Cd- 438	323450 934725	
Cd- 439	323408 934547	