STATE OF LOUISIANA

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

PUBLIC WORKS AND WATER RESOURCES DIVISION

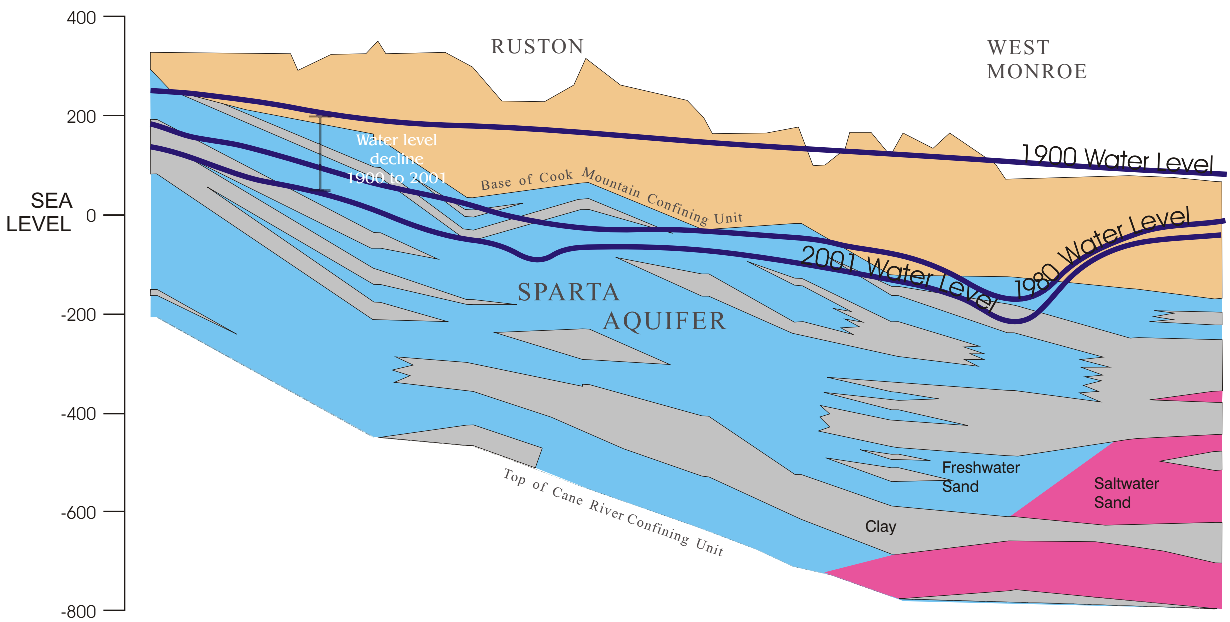
WATER RESOURCES SECTION

WATER RESOURCES

TECHNICAL REPORT

NO. 68

WATER WITHDRAWALS AND TRENDS IN GROUND-WATER LEVELS AND STREAM DISCHARGE IN LOUISIANA



Sparta aquifer in northern Louisiana

In cooperation with the

U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

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Figure modified from Brantly, Seanor, and McCoy (2002).

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Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per year (ft/yr)	0.3048	meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per year [(ft^3/s)/yr]	0.02832	cubic meter per second per year
mile	1.609	kilometer
million gallons per day (Mgal/d)	3,785	cubic meters per day

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.

WATER WITHDRAWALS AND TRENDS IN GROUND-WATER LEVELS AND STREAM DISCHARGE IN LOUISIANA

By Dan J. Tomaszewski, John K. Lovelace, *and* Paul A. Ensminger

ABSTRACT

In 2000, approximately 10,400 Mgal/d (million gallons per day) of water was withdrawn from ground- and surface-water sources in Louisiana, an increase of 10 percent from 1990. In 2000, about 16 percent (1,600 Mgal/d) of the water withdrawn was ground water. Approximately 93 percent of the ground water withdrawn was from four aquifers or aquifer systems: the Chicot aquifer system (49 percent), the Mississippi River alluvial aquifer (22 percent), the Sparta aquifer (4 percent), and the Southern Hills aquifer system (18 percent). Three of these, the Chicot aquifer system, the Sparta aquifer, and the Southern Hills aquifer system, contain areas where declines in ground-water levels from 1990-2000 are 1 ft/yr (foot per year) or greater.

The Chicot aquifer system in southwestern Louisiana is the most heavily pumped aquifer or aquifer system in the State. By 2000, water levels in areas of Calcasieu, Jefferson Davis, and Acadia Parishes had declined to 50 feet or more below sea level. Water levels in areas of largest withdrawals declined as much as 1.7 ft/yr during the period 1990-2000.

The Sparta aquifer in north-central Louisiana is the fourth most heavily pumped aquifer in the State. Approximately 68.2 Mgal/d was withdrawn in 2000. Water levels in the aquifer declined to more than 200 feet below sea level in the Monroe area by 1997. During 1990-2000, water level declines ranged from 0.1 to 5.2 ft/yr at monitor wells screened in the aquifer.

The Southern Hills aquifer system of southeastern Louisiana is composed of numerous freshwater aquifers. This aquifer system is the third most heavily pumped aquifer or aquifer system in the State (291 Mgal/d in 2000). By the 1970’s, saltwater encroachment had been documented in major aquifers in the Baton Rouge area. Water levels in deep aquifers having largest withdrawals declined about 0.2 to 3.5 ft/yr or more during the period 1990-2000.

In 2000, about 84 percent (8,700 Mgal/d) of the water withdrawn in Louisiana was surface water. Stream discharge data were analyzed for 59 continuous discharge stations. Eleven stations on nine streams had decreasing mean annual discharge during the period 1990-2000.

INTRODUCTION

Although Louisiana has abundant supplies of fresh ground and surface water, there have been recent concerns about the increasing withdrawals of water and the effects of these withdrawals on water resources. During the 1999 Regular Session of the Louisiana Legislature, Senate Concurrent Resolution No. 113 (State of Louisiana, 1999) requested that the Louisiana Department of Transportation and Development (DOTD) study the long-term effects of taking water from public sources to be used for commercial purposes. To provide some basic hydrologic information relevant to this issue, a cooperative study between the U.S. Geological Survey (USGS) and the DOTD was initiated to summarize water withdrawals and recent (1990-2000) trends in streamflow and ground-water levels. Results of that study are presented herein.

In 2000, approximately 10,400 Mgal/d of water was withdrawn from ground- and surface-water sources in Louisiana; 16 percent was ground water, and 84 percent was surface water (B.P. Sargent, U.S. Geological Survey, written commun., 2001) (fig. 1). Total water withdrawals in the State increased by 10 percent from 1990 to 2000 (Lovelace and Johnson, 1996; B.P. Sargent, U.S. Geological Survey, written commun., 2001). Water-use data referred to as “2000 water use” in this report (with the exception of irrigation data) were compiled in 1999 and are representative of 1999 water use. Irrigation data were compiled 1999-2000. Data presented in this report, as well as more detailed water-use data for ground- and surface-water resources throughout Louisiana, are on file at the USGS office in Baton Rouge, La.

Water-use data presented are based on a complete survey of water use in Louisiana conducted by the USGS during 1999-2000. A survey of major water users in Louisiana was conducted during 2000 to determine the amount of water being exported from Louisiana. Major water users are defined as public-supply, industrial, power-generation, or commercial facilities that withdraw an average of 1 Mgal/d or more of water. Major water users withdraw approximately 84 percent of all water withdrawn in Louisiana.

Data on trends in stream discharge and ground-water levels are based on data from monitoring networks maintained by the USGS in cooperation with various Federal, State, and local agencies. Trends over the period 1990-2000 were statistically determined to identify ground- and surface-water resources that are declining.

Louisiana Department of Transportation and Development-U.S. Geological Survey Water Resources Cooperative Program

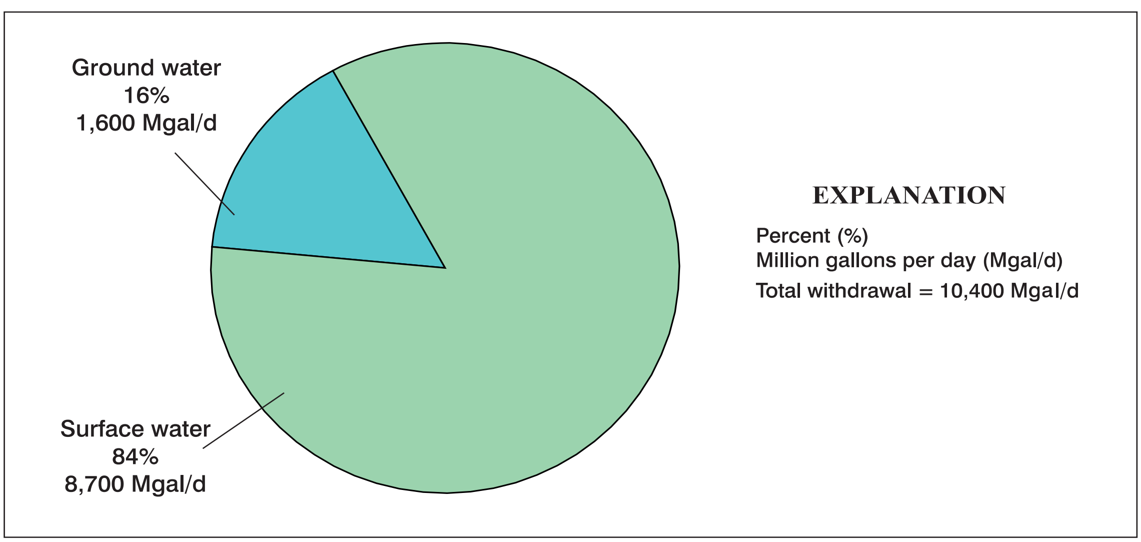


Figure 1. Ground- and surface-water withdrawals in Louisiana, 2000.

Purpose and Scope

This report summarizes:

1. use of ground water and surface water in Louisiana, 2000,

2. trends in ground-water levels in monitor wells screened in selected aquifers in Louisiana for the approximate period 1990-2000, and

3. trends in streamflow from the statewide network of discharge stations during 1990-2000.

The report focuses chiefly on one aquifer and two aquifer systems in Louisiana (figs. 2, 3) that had regional water-level declines for the period 1990-2000. The Chicot aquifer system, Sparta aquifer, and Southern Hills regional aquifer system (hereinafter referred to as Southern Hills aquifer system) are three of the four most heavily pumped aquifers and aquifer systems in Louisiana. Although about 354 Mgal/d is withdrawn from the Mississippi River alluvial aquifer, no significant declines in water levels were noted in monitor wells screened in this aquifer. Therefore, the Mississippi River alluvial aquifer is not discussed in detail.

This report summarizes year 2000 water use data for the Chicot aquifer system, the Sparta aquifer, and the Southern Hills aquifer system in Louisiana. Brief discussions of development of the aquifer and aquifer systems are summarized from previous investigations. Hydrographs for selected wells are used to describe water-level trends in the aquifer.

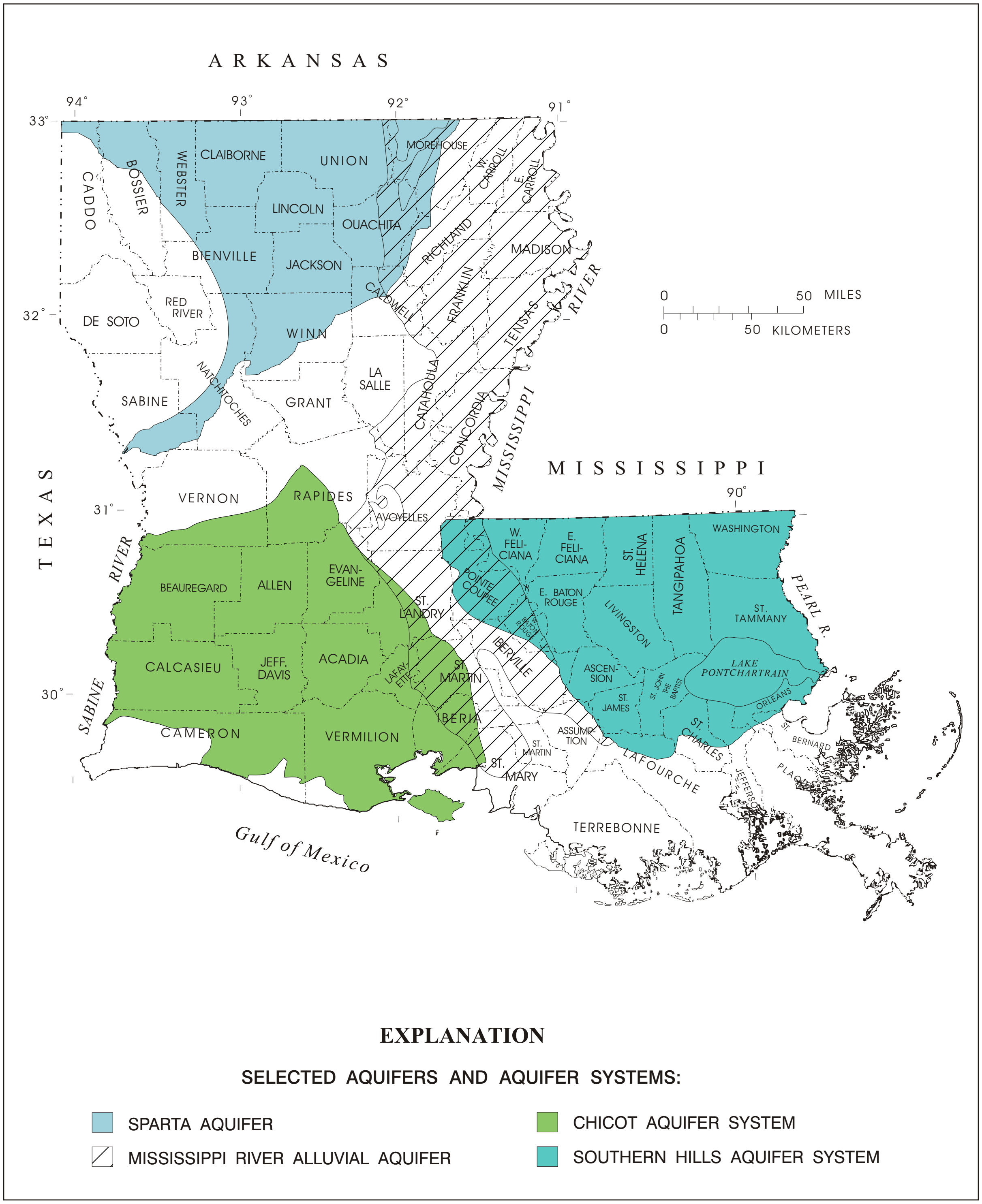
The rate and areal extent of water-level decline for the Chicot aquifer system, Sparta aquifer, and Southern Hills aquifer system are described in illustrations and tables. The maps are based on data from network wells and show generalized regional trends. The extent and rate of decline are based on data collected from network wells, analyzed for the approximate period 1990-2000. Water-level data are stored in the USGS National Water Information System data base.

Wells included in this report were chosen based on the following data criteria: (1) the wells were part of an established water-level monitoring network in Louisiana; (2) a minimum of at least 10 water-level measurements were documented during the approximate period 1990-2000; (3) the screened interval was known; (4) the wells were screened in one of three selected aquifers or aquifer systems; and (5) wells screened in the Southern Hills aquifer system were located north of the Baton Rouge fault.

Water-level data from 123 wells were analyzed for trends to determine if a net change (increase or decrease) occurred over a selected time interval (generally 1990-2000). Water-level trends were grouped by aquifer and plotted on maps to determine if areas with regional water-level declines in the aquifers could be identified.

A brief summary of the development of the Chicot aquifer system, the Sparta aquifer, and the Southern Hills aquifer system are included. Water-level graphs are shown for the full period of record at selected sites to indicate historical impacts of withdrawals on ground-water levels.

Stream discharge data were summarized for the period 1990-2000. To determine trends in streamflow, discharge data were analyzed for 59 surface-water stations during the approximate period 1990-2000.



(Modified from Stuart and others, 1994)

Figure 2. Locations of freshwater resources in selected aquifers and aquifer systems in Louisiana.

System	Series	Stratigraphic Unit		Hydrogeologic Unit: Northern Louisiana — Aquifer or confining unit	Central and southwestern Louisiana — Aquifer system or confining unit	Central and southwestern Louisiana — Aquifer or confining unit: Lake Charles area	Central and southwestern Louisiana — Aquifer or confining unit: Rice growing area	Southeastern Louisiana	Southeastern Louisiana — Aquifer system or confining unit	Southeastern Louisiana — Aquifer[1] or confining unit: Baton Rouge area	Southeastern Louisiana — Aquifer[1] or confining unit: St. Tammany, Tangipahoa, and Washington Parishes	Southeastern Louisiana — Aquifer[1] or confining unit: New Orleans area and lower Mississippi River parishes
Quaternary	Pleistocene		Red River alluvial deposits Mississippi River alluvial deposits Northern Louisiana terrace deposits Unnamed Pleistocene deposits	Red River alluvial aquifer or surficial confining unit Mississippi River alluvial aquifer or surficial confining unit Upland terrace aquifer or surficial confining unit	Chicot aquifer system or surficial confining unit	"200-foot" sand "500-foot" sand "700-foot" sand	Upper sand unit Lower sand unit	Southern Hills regional aquifer system	Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Ponchatoula aquifer	Gramercy aquifer[2] Norco aquifer[2] Gonzales-New Orleans aquifer[2] "1,200-foot" sand[2]
Tertiary	Pliocene — ? — Miocene	Fleming Formation	Blounts Creek Member	Pliocene-Miocene aquifers are absent in this area	Evangeline aquifer or surficial confining unit			Southern Hills regional aquifer system	Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Ponchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
Tertiary	Miocene	Fleming Formation	Castor Creek Member		Castor Creek confining unit			Southern Hills regional aquifer system	Unnamed confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
Tertiary	Miocene	Fleming Formation	Williamson Creek Member Dough Hills Member Carnahan Bayou Member		Jasper aquifer system or surficial confining unit	Williamson Creek aquifer Dough Hills confining unit Carnahan Bayou aquifer		Southern Hills regional aquifer system	Jasper equivalent aquifer system or surficial confining unit			
Tertiary	Miocene	Fleming Formation	Lena Member		Lena confining unit			Southern Hills regional aquifer system	Unnamed confining unit			
Tertiary	— ? — Oligocene		Catahoula Formation		Catahoula aquifer			Southern Hills regional aquifer system	Catahoula equivalent aquifer system or surficial confining unit			
Tertiary	Oligocene		Vicksburg Group, undifferentiated	Vicksburg-Jackson confining unit	No freshwater occurs in older aquifers							
Tertiary	Eocene		Jackson Group, undifferentiated									
Tertiary	Eocene	Claiborne Group	Cockfield Formation	Cockfield aquifer or surficial confining unit								
Tertiary	Eocene	Claiborne Group	Cook Mountain Formation	Cook Mountain aquifer or confining unit								
Tertiary	Eocene	Claiborne Group	Sparta Sand	Sparta aquifer or surficial confining unit								
Tertiary	Eocene	Claiborne Group	Cane River Formation	Cane River aquifer or confining unit								
Tertiary	Eocene	Claiborne Group	Carrizo Sand — ? —	Carrizo-Wilcox aquifer or surficial confining unit								
Tertiary	Paleocene		Wilcox Group, undifferentiated									
Tertiary	Paleocene		Midway Group, undifferentiated	Midway confining unit								

[1]Clay units separating aquifers in southeastern Louisiana are discontinuous and unnamed.
[2]Four aquifers as a group are called the New Orleans aquifer system.

Figure 3. Hydrogeologic column of aquifers and aquifer systems in Louisiana (modified from Stuart and others, 1994).

Acknowledgments

Special thanks are extended to Zahir “Bo” Bolourchi, Chief, Water Resources Programs, Louisiana Department of Transportation and Development, who contributed substantially to the design and format of the report. Thanks are given to Don C. Dial, Director, Capital Area Ground Water Conservation Commission, who provided information on the five-parish area under his jurisdiction.

GROUND-WATER WITHDRAWALS AND WATER-LEVEL TRENDS

In 2000, about 16 percent (1,600 Mgal/d) of the water withdrawn in Louisiana was ground water (fig. 1). Approximately 93 percent of the ground water withdrawn was from four aquifers or aquifer systems: the Chicot aquifer system (49 percent), Mississippi River alluvial aquifer (22 percent), Sparta aquifer (4 percent), and Southern Hills aquifer system (18 percent) (fig. 4). Three of these, the Chicot aquifer system, Sparta aquifer, and Southern Hills aquifer system, contain areas where declines in ground-water levels were 1 ft/yr or greater during the period 1990-2000. Nearly all of the ground water withdrawn was utilized in the State of Louisiana; less than 0.3 percent was exported. Approximately 87 percent of ground-water withdrawals was for irrigation, public supply, and industry (fig. 5). Because large amounts of ground water have been used the past few decades, and withdrawals may increase in future decades, there is concern about declining ground-water levels and that water is being withdrawn faster than it is being recharged.

Several factors cause ground-water levels to fluctuate. Water levels naturally rise and fall during a given year in response to seasonal climate patterns and to seasonal withdrawals for agriculture and industry. Long-term changes in ground-water levels also may occur because of climate and pumping changes.

Ground-water levels are affected by pumping from wells. As water is pumped from a well, water levels in the aquifer are drawn down, and a cone-shaped depression is formed on the water-level surface of the aquifer. This cone-shaped depression is maintained as long as the well is pumping. This depression on the water-level surface can be very localized, or can extend many miles when several high-capacity wells are pumping in the same area.

As aquifers are developed and cones of depression become extensive, water levels in much of the aquifer begin to decline. When water levels continuously decline, a level may be reached that affects well use; shallower wells in the area can go dry or, more likely, the water level drops below the pump inlet. When this happens, even though the situation may be temporary, concern about the use, allocation, and availability of ground-water resources dramatically increases.

The USGS has been monitoring ground-water levels in Louisiana for about 100 years. Currently (2001), the USGS, in cooperation with the DOTD, monitors water levels quarterly in 101 wells throughout Louisiana. Additional water-level data are collected at wells throughout the State as part of special studies. In the Baton Rouge area, additional water-level data are collected by the USGS at 68 sites in cooperation with the parishes in the Capital Area Ground Water Conservation District.

Hydrographs are plots showing water-level data collected from a well over a period of time. Hydrographs from well sites in Louisiana can be used to determine:

1. seasonal fluctuations in water levels (the effects of the droughts and seasonal withdrawals), and

2. long-term trends in water-levels (effects of decades of ground-water withdrawals for irrigation, industry, and public supplies).

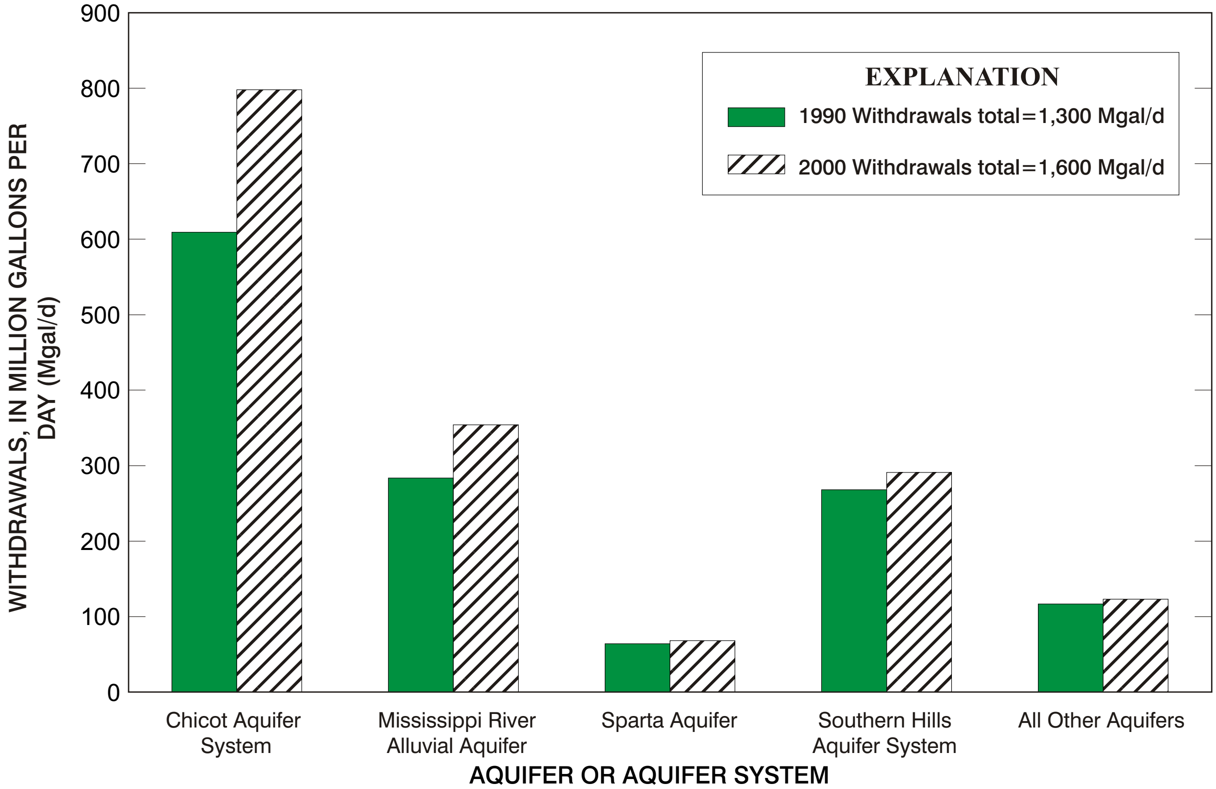


Figure 4. Ground-water withdrawals in Louisiana, by aquifer or aquifer system, 1990 and 2000.

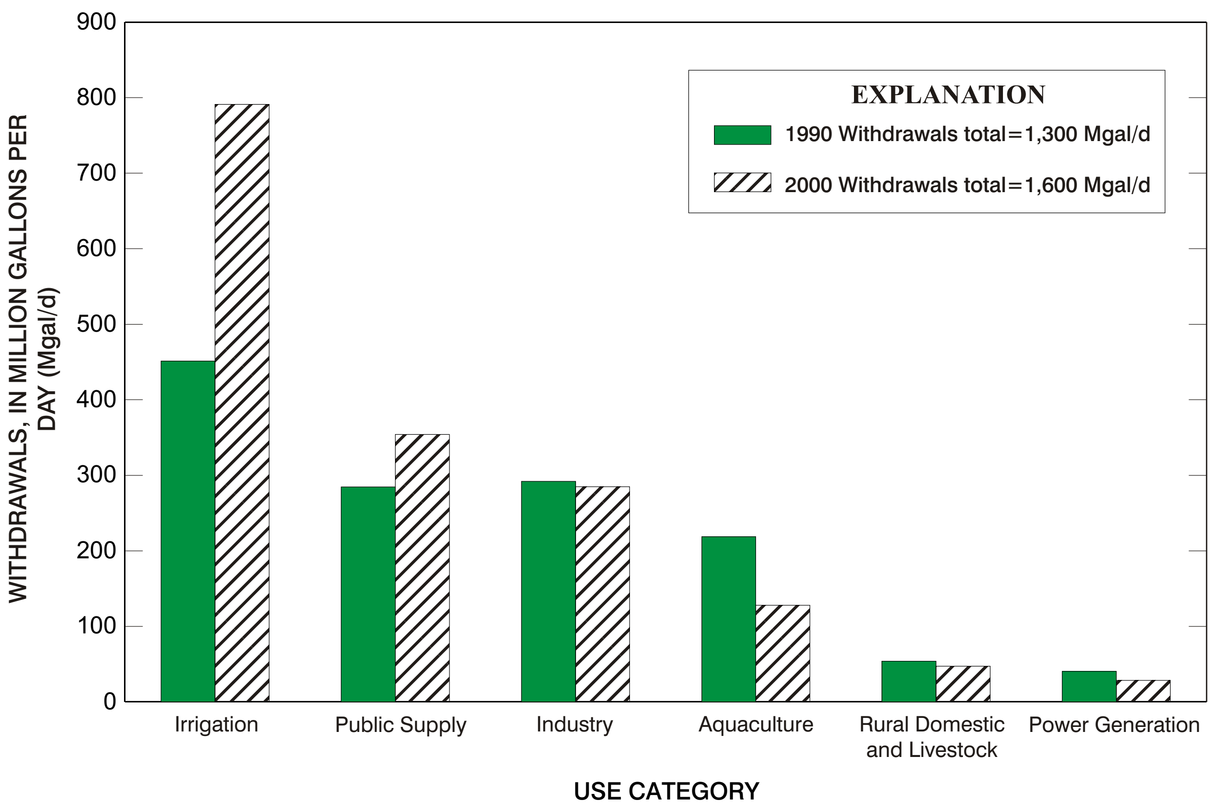


Figure 5. Ground-water withdrawals in Louisiana, by use, 1990 and 2000.

Chicot Aquifer System, Southwestern Louisiana

The Chicot aquifer system in southwestern Louisiana (fig. 2) is the most heavily pumped aquifer or aquifer system in the State (798 Mgal/d in 2000) (fig. 4). About 68 percent of the water withdrawn from the aquifer system in 2000 was for irrigation (fig. 6); other major uses included public supply (11 percent) and industry (9 percent). Withdrawals from wells screened in the aquifer system are shown in figure 7 for the period 1946-2000. Water-level data for the aquifer system have been documented since the early 1900's. The water-level surface throughout most of the aquifer system has been strongly influenced by withdrawals for rice irrigation since the early 1900's. In the Lake Charles area, withdrawals for industry and public supply also affect water levels.

Prior to ground-water development, the water-level surface in the Chicot aquifer system generally was highest in the northern outcrop area and decreased toward the coast and the Atchafalaya River Basin (Nyman and others, 1990, fig. 17). In central parts of the aquifer system (Acadia, Jefferson Davis, and Calcasieu Parishes) water levels were about 10 to 25 ft above sea level. Predevelopment ground-water flow was predominantly south toward the coast, but some of the flow was east toward the Atchafalaya River Basin and west toward the Sabine River.

By 1903, withdrawals from irrigation wells had caused a cone of depression to form in northern Vermilion and southern Acadia Parishes (Jones and others, 1956, p. 260). The dominant direction of movement in 1903 was still south toward the coast.

An extensive cone of depression in the aquifer system extended from the Lake Charles area in Calcasieu Parish into the Eunice area in St. Landry Parish by the early 1950's (Fader, 1954, pl. 2). Water in the aquifer system no longer discharged in coastal areas, and ground water in coastal areas began moving northward. Ground water no longer discharged into the Atchafalaya and Sabine Rivers, except locally, and the Atchafalaya River became a recharge area for the Chicot aquifer system (Nyman and others, 1990, p. 14).

By 2000, water levels in the Chicot aquifer system had declined to 50 ft or more below sea level in areas of Calcasieu, Jefferson Davis, and Acadia Parishes (Lovelace and others, 2001). This represents a decline of about 80 ft from prepumping levels, or approximately 0.8 ft/yr since the early 1900's.

Largest withdrawals from the Chicot aquifer system occur in areas underlying Calcasieu, Jefferson Davis, Acadia, Evangeline, and Vermilion Parishes. These parishes account for 81 percent of the water withdrawn from the aquifer system in 2000.

Data from the water-level network (table 1) were used to construct a map showing generalized water-level trends in the Chicot aquifer system for the period 1990-2000 (fig. 8). Data from the network indicate water levels in areas of largest withdrawals declined as much as 1.7 ft/yr during the period 1990-2000 (table 1). In the heavily pumped rice-growing area (approximately the area shown within the 0.5-ft/yr contour in fig. 8), the hydrograph for well Ev-229 (fig. 9) shows that water levels fluctuated seasonally more than 20 ft. Water levels declined about 1.1 ft/yr (1990-2000) at well Ev-229, in response to withdrawals for irrigation use. In the industrialized area of Calcasieu Parish, water levels fluctuated about 10 ft seasonally at well Cu-789 (fig. 9), due to seasonal withdrawals by industry and for irrigation. Water levels declined about 0.2 ft/yr (1991-1999) at well Cu-789. The hydrograph for well Be-443 (fig. 9) is representative of water levels in the outcrop area and shows seasonal water-level fluctuations, with a small decline, about 0.1 ft/yr (1990-2000).

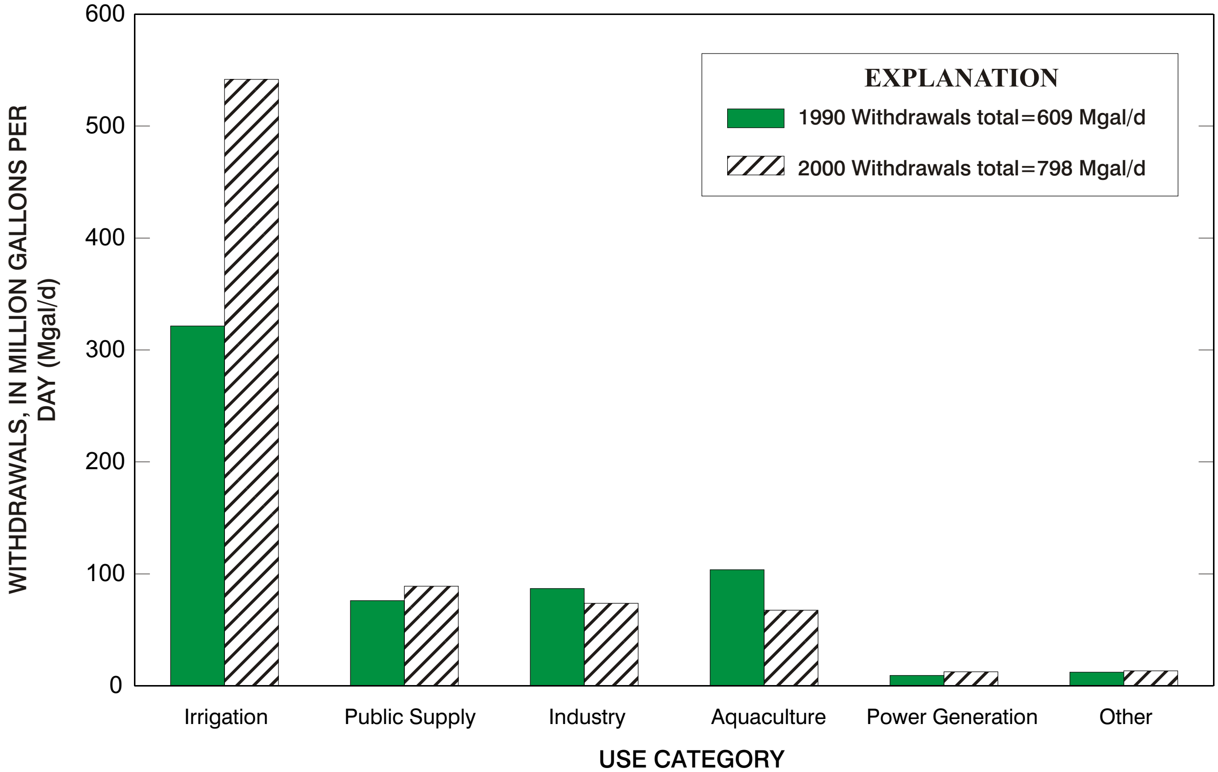


Figure 6. Withdrawals from the Chicot aquifer system, southwestern Louisiana, by use, 1990 and 2000.

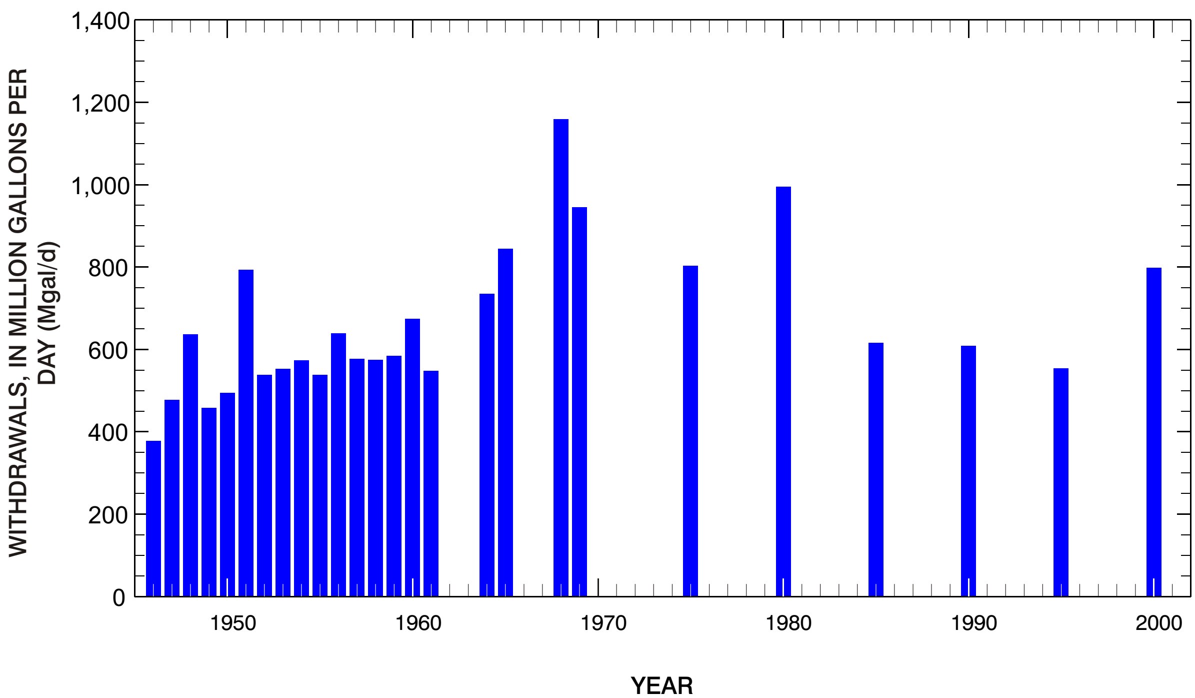


Figure 7. Withdrawals from the Chicot aquifer system, southwestern Louisiana, 1946-2000.

The hydrograph for well Cu-789 (fig. 9) represents the response of water levels to withdrawals by industry. Declines occurred during the period about 1965 to 1970 at well Cu-789. Water levels recovered 30 ft or more after 1982, in response to decreased withdrawals of ground water and increased use of surface water by industry in the Lake Charles area (Lovelace, 1999, p. 10).

Table 1.-- *Analysis of water-level trends in selected wells in the Chicot aquifer system, southwestern Louisiana*
[based on data from U.S. Geological Survey and Louisiana Department of Transportation and Development cooperative monitor-well network]

Number on map (fig. 8)	Well name	Number of observations [1]	Level of significance [2]	Slope, in feet per year [3]	Period of record analyzed [4]	
					Beginning	Ending
1	Ac-326	42	0.0001	1.7	7/10/1990	6/6/2000
2	Ac-335U	41	.0001	1.7	4/4/1990	3/17/2000
3	Al-241	41	.0246	.2	7/11/1990	6/19/2000
4	Be-430	41	.0915	+.1	7/11/1990	6/1/2000
5	Be-443	47	.0128	.1	10/24/1990	7/27/2000
6						
7	Cn-80L	10	.0087	1.2	9/6/1990	6/20/2000
8	Cn-81L	41	.0001	.7	7/11/1990	6/20/2000
9	Cu-789	18	.6239	.2	3/7/1991	1/27/1999
10	Cu-851	188	.4717	.1	3/5/1991	6/8/2000
11	Ev-229	626	.0001	1.1	6/5/1990	6/1/2000
12						
13	I-93	50	.0005	.2	7/13/1990	6/9/2000
14	JD-9	39	.0001	1.1	4/4/1990	3/15/2000
15	JD-485A	621	.0001	1.6	8/1/1990	7/27/2000
16	JD-773	39	.0001	1.1	7/10/1990	6/6/2000
17	Lf-662	39	.0037	.3	7/13/1990	6/8/2000
18						
19	SL-179	40	.626	.0	8/6/1990	6/5/2000
20	SMn-109	53	.0006	.4	7/13/1990	6/22/2000
21	SMn-134B	41	.0084	.3	7/13/1990	6/22/2000
22	Ve-637U	44	.0011	.2	7/10/1990	6/7/2000

[1] Total number of water-level measurements used to determine the slope in the trend line during the period analyzed.
[2] Probability that water-level change is due to chance rather than trend; values less than 0.05 generally are considered statistically significant.
[3] Computed slope in the trend line using method of ordinary least squares linear regression. The slope is equivalent to the water-level decline or rise (+) in feet per year during the period analyzed.
[4] Dates of first and last measurement of period analyzed.

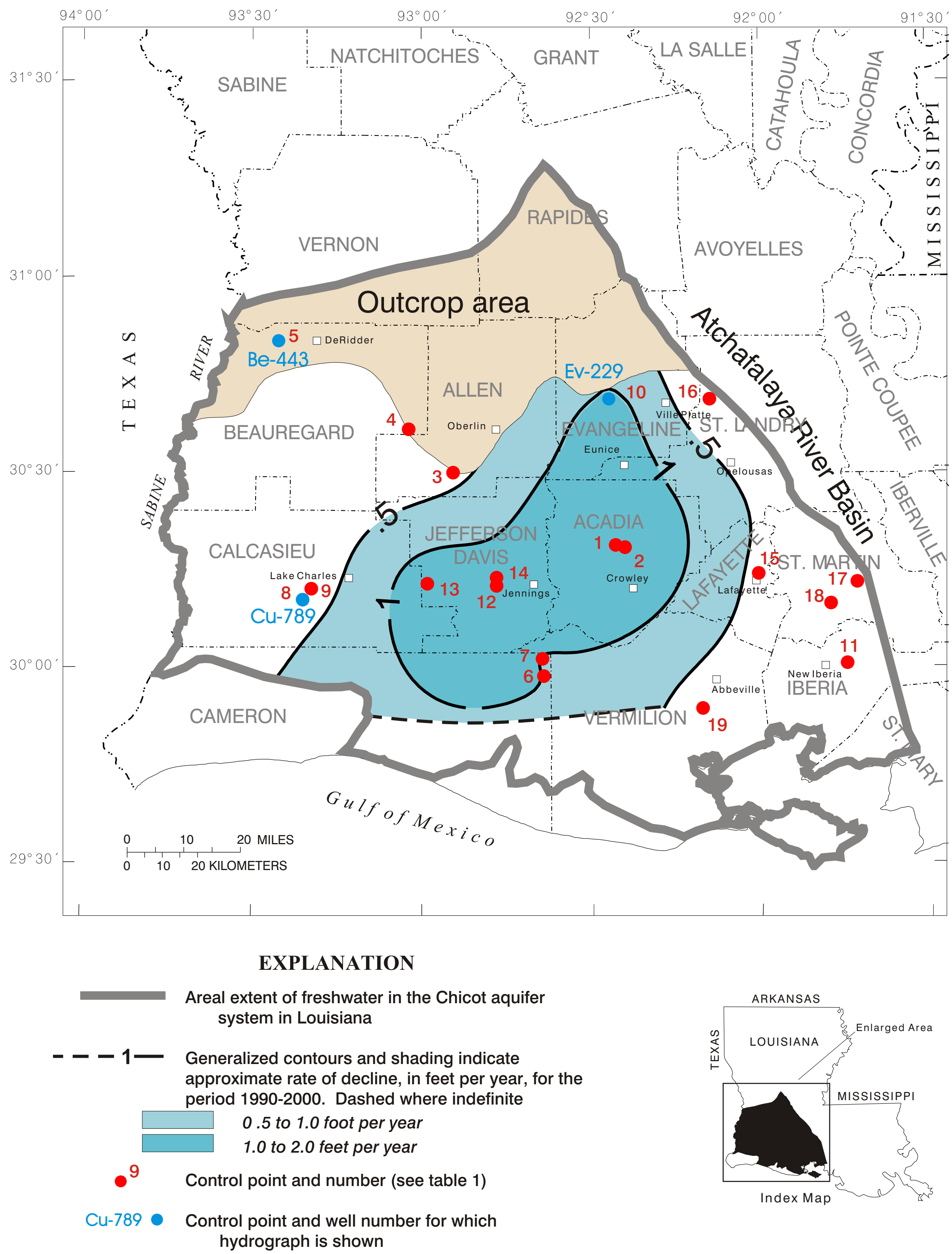


Figure 8. Rate of water-level decline in the Chicot aquifer system, southwestern Louisiana, 1990-2000.

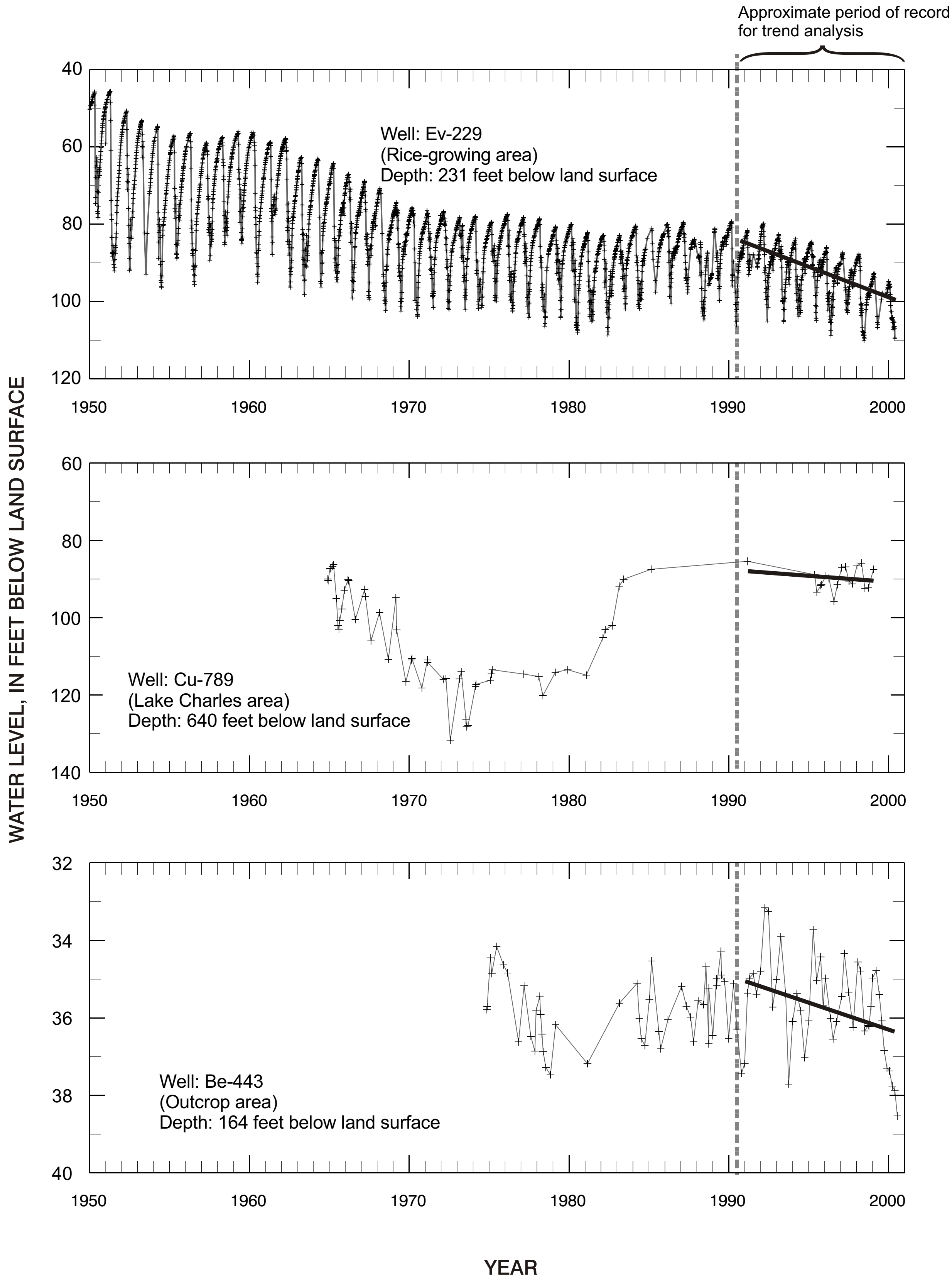


Figure 9. Water levels at selected wells in the Chicot aquifer system, southwestern Louisiana.

Sparta Aquifer, North-Central Louisiana

The Sparta aquifer in north-central Louisiana (fig. 2) is the fourth most heavily pumped aquifer in the State (about 68.2 Mgal/d in 2000; fig. 4). Major uses include public supply (55 percent) and industry (40 percent) (fig. 10). Small amounts of water are withdrawn for rural domestic use, aquaculture, livestock, and irrigation. Withdrawals from wells screened in the Sparta aquifer are shown for the period 1975-2000 (fig. 11).

About 1900, prior to ground-water development in the Sparta aquifer, water levels were 100 to 300 ft above sea level (Ryals, 1980). Water levels were generally highest in the western outcrop areas and decreased eastward toward the Mississippi River. Ground-water flow during predevelopment conditions was eastward toward the Mississippi River.

By 1965, withdrawals from wells had formed cones of depression at the cities of Minden, Jonesboro-Hodge, Monroe, Bastrop, and Farmerville (Ryals, 1980). Ground-water flow was still generally eastward, except locally around cones of depression.

As the water levels in the Sparta aquifer at Monroe and Bastrop continued to decline, a regional cone of depression formed that included pumping centers in both cities. By the early 1980's, the cone of depression in the aquifer extended from the Monroe-Bastrop area and northwest toward the Louisiana-Arkansas border (Ryals, 1980). Water in the aquifer no longer discharged eastward toward the Mississippi River; ground water flowed from eastern and southern areas toward pumping centers in central parts of the aquifer in Louisiana. Water levels in the aquifer had declined to more than 200 ft below sea level in the Monroe area of Ouachita Parish by 1997 (Joseph, 1997, pl. 1).

About 65 percent of total withdrawals from the Sparta aquifer in Louisiana is from Ouachita (23.2 Mgal/d), Bienville (12.3 Mgal/d), and Lincoln (8.9 Mgal/d) Parishes. Withdrawals by other parishes are less than 6 Mgal/d each.

Selected data from the water-level network (table 2) were used to construct a map showing generalized water-level trends in the Sparta aquifer for the period 1990-2000 (fig. 12). Data (table 2) indicate water levels have declined at all sites monitored in the Sparta aquifer during the period 1990-2000. Declines ranged from 0.1 to 5.2 ft/yr (1990-2000).

Generalized maps constructed from water-level network data (1990-2000) show that water levels declined greater than 1 ft/yr in most of the Sparta aquifer (fig. 12). Water-level data from well Wb-399 (fig. 13) are representative of many wells in or near the outcrop area. Although water levels fluctuate seasonally, only a very small (0.1 ft/yr) decline can be noted at this site. A hydrograph for well Cl-149 (fig. 13), located near the Arkansas-Louisiana border, represents long-term declining water-level trends that have occurred throughout most of the Sparta aquifer. Water levels in well Cl-149 declined about 2.0 ft/yr during the period 1990-2000 in response to withdrawals in Arkansas and Louisiana. The hydrograph for well Ou-444 (fig. 13) shows that water levels declined about 2.6 ft/yr (1990-2000) in response to withdrawals in the Monroe area, Louisiana.

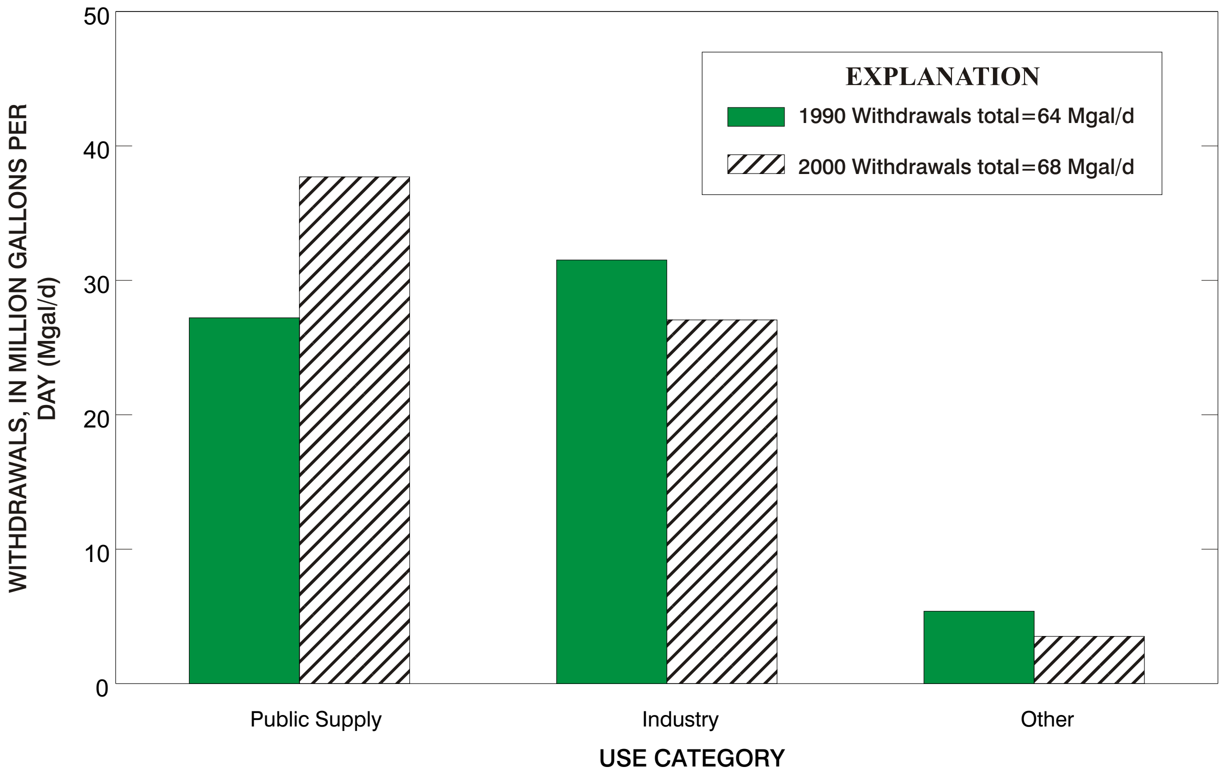


Figure 10. Withdrawals from the Sparta aquifer, north-central Louisiana, by use, 1990 and 2000.

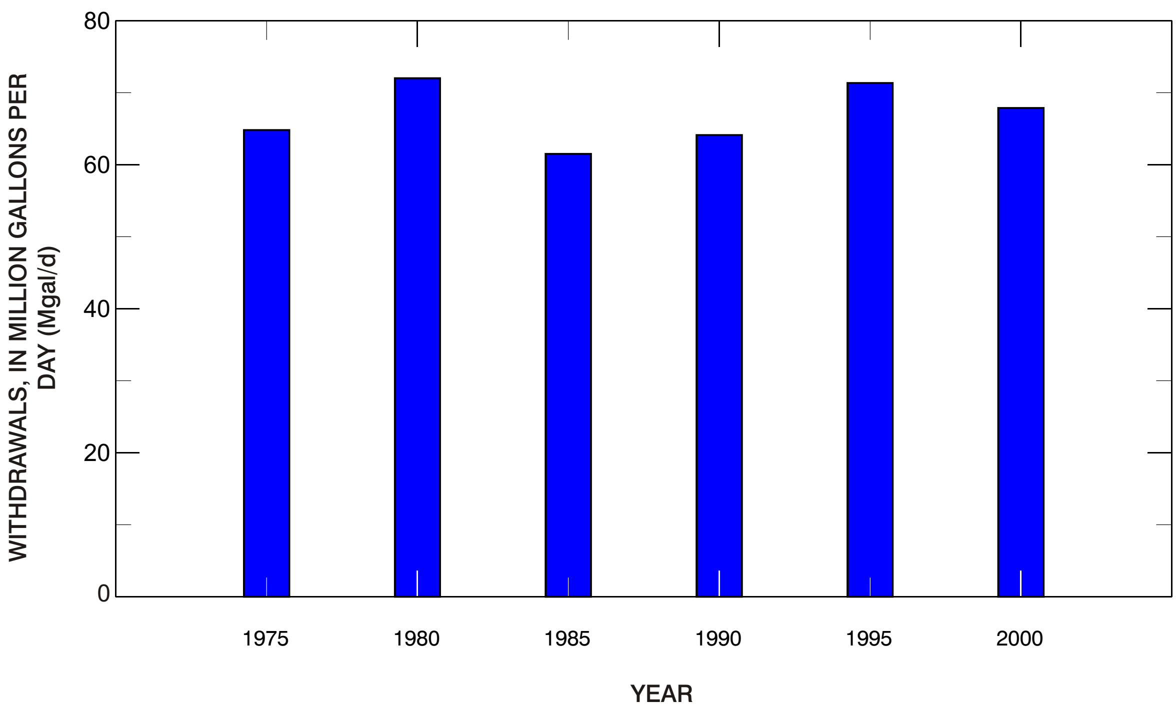


Figure 11. Withdrawals from the Sparta aquifer, north-central Louisiana, 1975-2000.

Table 2.-- *Analysis of water-level trends in selected wells in the Sparta aquifer, north-central Louisiana*
[based on data from U.S. Geological Survey and Louisiana Department of Transportation and Development cooperative monitor-well network]

Number on map (fig. 12)	Well name	Number of observations [1]	Level of significance [2]	Slope, in feet per year [3]	Period of record analyzed [4]	
					Beginning	Ending
1	Bi-144	43	0.0001	0.8	4/20/1990	4/3/2000
2	Bi-166	43	.0001	1.0	5/30/1990	4/6/2000
3	Cl-149	39	.0001	2.0	1/3/1990	10/4/1999
4	Ja-49	40	.0015	2.7	4/20/1990	4/3/2000
5	Ja-147	107	.0001	1.7	4/30/1990	4/5/2000
6	L-26	230	.0001	1.7	4/10/1990	4/6/2000
7	Mo-5	40	.0001	1.3	4/24/1990	4/4/2000
8	Ou-80	487	.0001	5.2	9/18/1990	4/7/2000
9	Ou-444	43	.0001	2.6	4/25/1990	4/7/2000
10	Un-26	40	.0001	2.0	7/27/1990	4/6/2000
11	W-28	36	.0001	2.6	7/22/1991	4/5/2000
12	W-172	42	.0001	1.1	7/20/1990	4/5/2000
13	Wb-399	41	.1274	.1	4/25/1990	4/21/2000

[1] Total number of water-level measurements used to determine the slope in the trend line during the period analyzed.
[2] Probability that water-level change is due to chance rather than trend; values less than 0.05 generally are considered statistically significant.
[3] Computed slope in the trend line using method of ordinary least squares linear regression. The slope is equivalent to the water-level decline in feet per year during the period analyzed.
[4] Dates of first and last measurement of period analyzed.

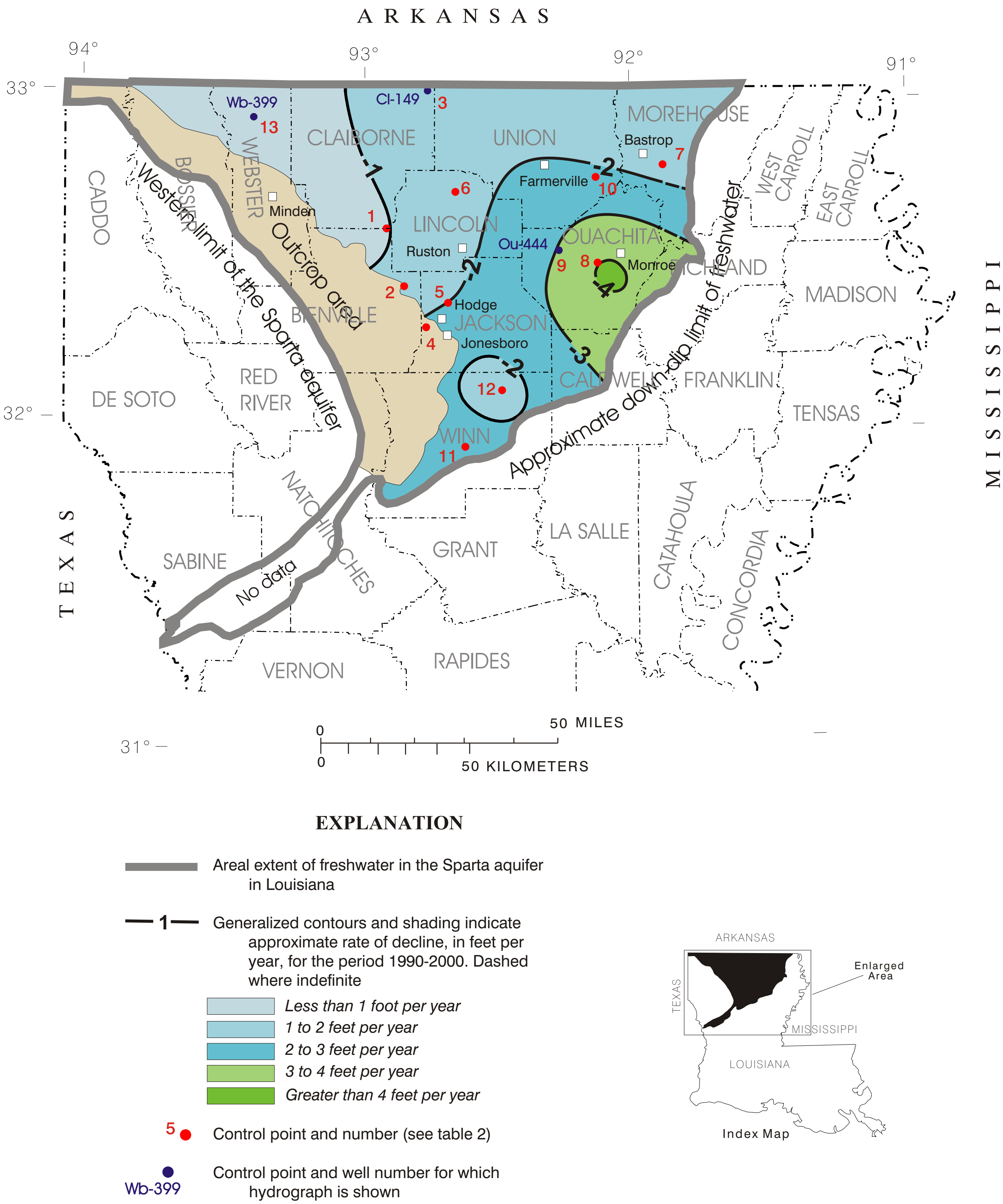


Figure 12. Rate of water-level decline in the Sparta aquifer, north-central Louisiana, 1990-2000.

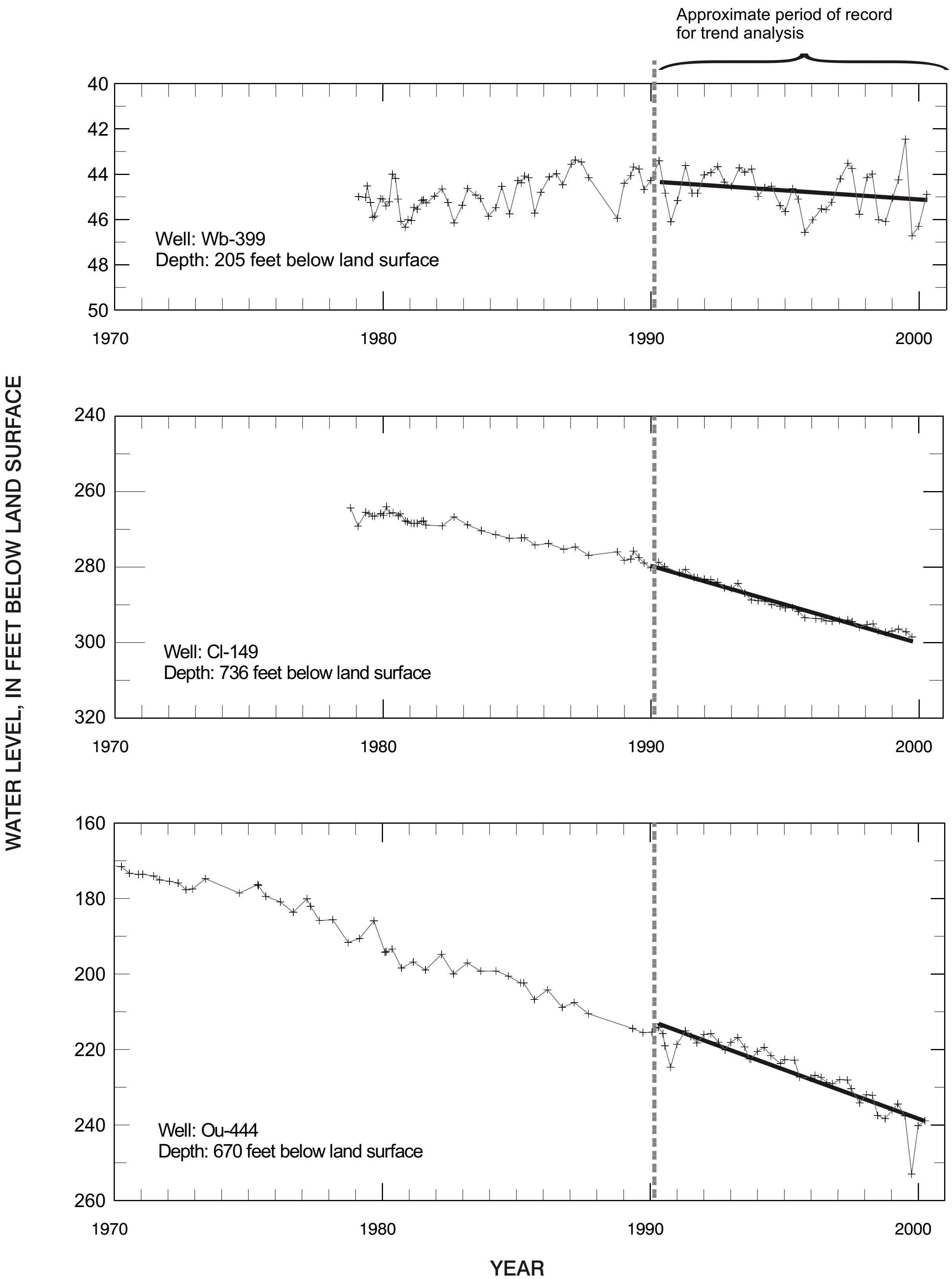


Figure 13. Water levels at selected wells in the Sparta aquifer, north-central Louisiana.

Southern Hills Aquifer System, Southeastern Louisiana

The Southern Hills aquifer system of southeastern Louisiana (fig. 2) is composed of numerous freshwater aquifers (fig. 3). This aquifer system is the third most heavily pumped aquifer or aquifer system in the State (291 Mgal/d in 2000, fig. 4). In 2000, about 50 percent of the water withdrawn from the aquifer system was for public supply and 39 percent was for industry (fig. 14). In East Baton Rouge Parish, about 135 Mgal/d was withdrawn in 2000, mostly for public supply and industry (fig. 15). Withdrawals in the Baton Rouge area affect water levels as far east as Tangipahoa Parish (Nyman and Fayard, 1978, p. 41, 47, 52, 57). Water-level data for the aquifer system have been documented since the early 1900's. The water-level surface throughout most of the aquifer system has been strongly influenced by withdrawals for public supply and industry.

Prior to ground-water development (and in 2000), the water-level surface in the Southern Hills aquifer system generally was highest in the outcrop areas that include parts of southeastern Louisiana and southwestern Mississippi. Some of the precipitation in outcrop areas entered into the aquifer system as recharge and moved downdip toward the coastal areas of southeastern Louisiana; however, the Baton Rouge fault zone in southeastern Louisiana impeded farther southward movement of freshwater. Also, in southern areas, water slowly moved upward through clays and sands and historically discharged at land surface. In areas near the fault, water levels were as much as 100 ft above sea level in deep aquifers.

In 1892, the first recorded public supply well had been completed in the Baton Rouge area, and withdrawals for industry began in 1914 (Meyer and Turcan, 1955, p. 51). In 1953, withdrawals in the Baton Rouge area for public supply and industrial uses were estimated to be about 65 Mgal/d (Meyer and Turcan, 1955, p. 53). In the Baton Rouge area, the ground water that historically discharged as upward seepage and discharge at land surface was by the 1950's being intercepted as flow to wells and withdrawn chiefly for public supply and industry.

By 1960, about 210 Mgal/d was withdrawn in southeastern Louisiana, including about 100 Mgal/d in East Baton Rouge Parish (Snider and Forbes, 1961, table 1). Extensive cones of depression at major pumping centers (Baton Rouge area and the New Orleans area) had developed by the 1960's (Rollo, 1969). By the 1970's, water levels throughout much of southeastern Louisiana were declining in response to large withdrawals in the Baton Rouge area and smaller withdrawals in southeastern Louisiana (Dial, 1968). Saltwater encroachment also had been documented in major aquifers in the Baton Rouge area (Rollo, 1969; Whiteman, 1979). By 2000, water levels in the heavily pumped "2,000-foot sand" in southeastern Louisiana had declined to 200 ft and more below sea level in East Baton Rouge Parish.

Within the Southern Hills aquifer system of southeastern Louisiana, the largest withdrawals (135 Mgal/d in 2000) are in East Baton Rouge Parish, which uses about 46 percent of the water withdrawn from the aquifer system. About 70 percent of the ground-water withdrawn in the Baton Rouge area is from deep aquifers.

Selected data from the water-level network (table 3) were used to construct a map showing generalized water-level trends in the Southern Hills aquifer system (fig. 16). Selected water-level data (table 3) were limited to wells screened in deep aquifers located north of the Baton Rouge fault zone (fig. 16). Water-level trends within individual sands and aquifers contained in the Southern Hills aquifer system vary vertically. The generalized water-level trend map is representative of the most regionally

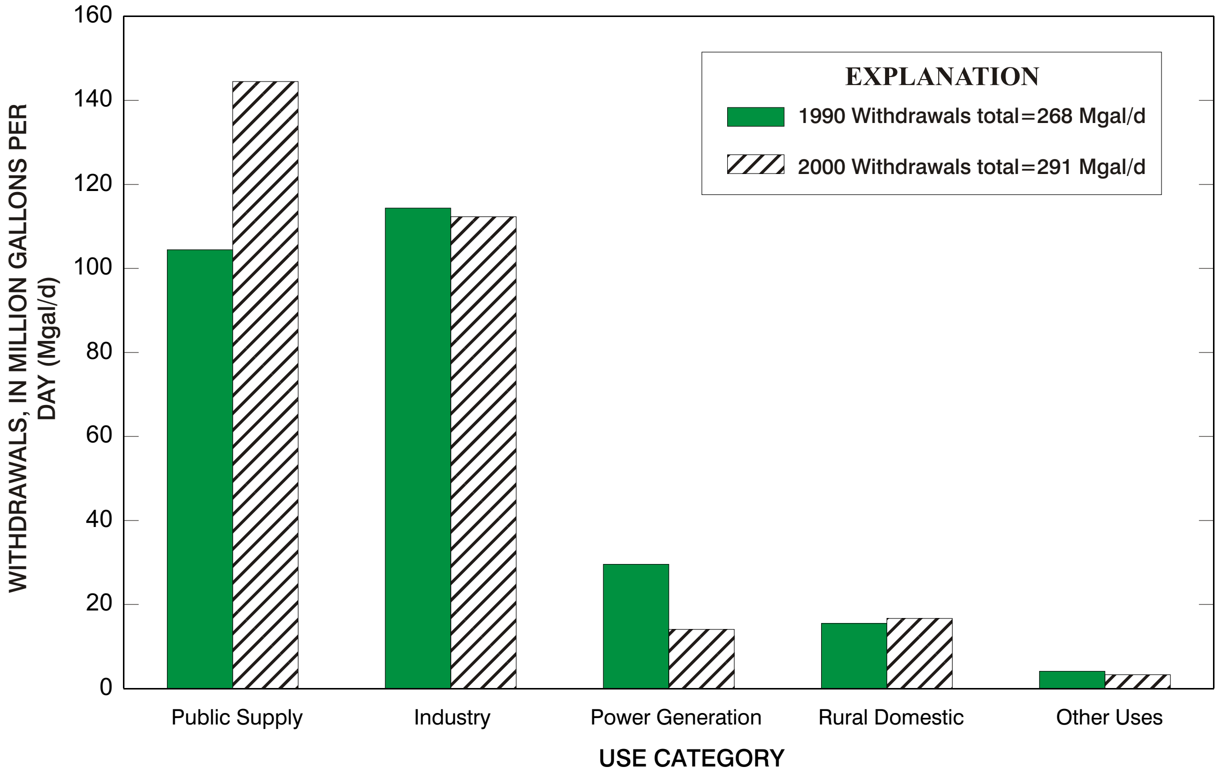


Figure 14. Withdrawals from the Southern Hills aquifer system, southeastern Louisiana, by use, 1990 and 2000.

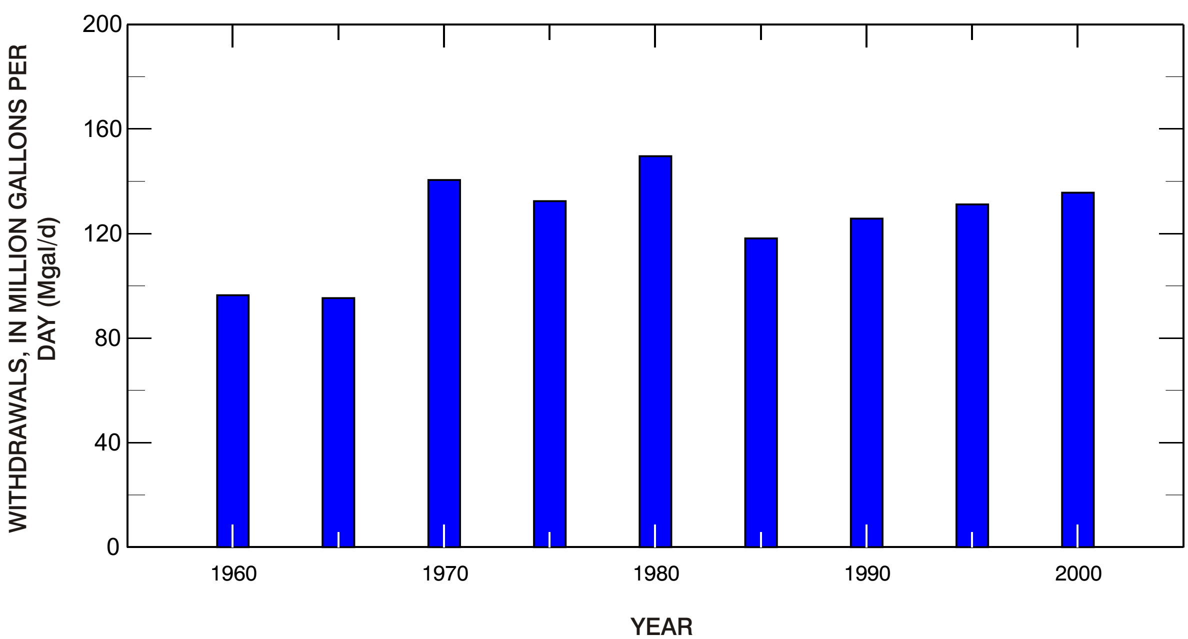


Figure 15. Withdrawals from the Southern Hills aquifer system in East Baton Rouge Parish, Louisiana, 1960-2000.

extensive and most heavily pumped aquifers within the system. These aquifers include the "1,500-foot sand," Kentwood, and most underlying deeper aquifers in southeastern Louisiana (fig. 3). The map provides a generalized representation of regional water-level declines in deep aquifers in southeastern Louisiana; however, additional water-level data are needed to determine local conditions. The map does not account for localized extremes at pumping centers. The map may not be representative of water-level changes in shallow, less heavily pumped aquifers.

Data from the water-level monitoring network indicate water levels in aquifers having the largest withdrawals (deep aquifers) declined about 0.2 to 3.5 ft/yr during the period 1990-2000 (table 3). In the heavily pumped Baton Rouge area, the hydrograph for well EB-90 shows that water levels can fluctuate as much as 75 ft over a few years (1997-2000) (fig. 17). Water levels declined about 2.0 ft/yr at well EB-90 (1990-2000), in response to withdrawals for industry and public supply. The hydrograph for well Ta-268 (fig. 16) represents the response of water levels to withdrawals for public supply in the Hammond area and large withdrawals from correlative aquifers in the Baton Rouge area (figs. 16 and 17). Water levels declined about 1.4 ft at this site during the period 1990-2000. The hydrograph of well Wa-13 is representative of water levels in outcrop areas (shallow aquifers) and shows seasonal water-level fluctuations (figs. 16 and 17). A small increase in water levels has occurred at this site during the period (1990-2000).

Table 3.--*Analysis of water-level trends in selected wells in the Southern Hills aquifer system, southeastern Louisiana*
[based on data from U.S. Geological Survey and Louisiana Department of Transportation and Development cooperative monitor-well network]

Number on map (fig. 16)	Well name	Number of observations [1]	Level of significance [2]	Slope, in feet per year [3]	Period of record analyzed [4]	
					Beginning	Ending
			Shallow aquifers			
1	EB-128	22	0.0001	3.3	11/2/1990	7/17/2000
2	EB-146	41	.0001	2.0	11/2/1990	7/17/2000
3	EB-155	678	.0001	2.4	1/08/1990	12/6/1999
4	EB-327	31	.0001	1.8	9/4/1992	7/17/2000
5	EB-367	453	.0035	+1.0	8/5/1990	8/2/2000
6	EB-782A	45	.0001	1.2	11/1/1990	7/21/2000
7	EB-789A	43	.0718	.6	11/1/1990	7/21/2000
8	EB-805	46	.0001	1.8	9/24/1990	7/21/2000
9	EB-824	41	.0001	1.8	9/25/1990	7/21/2000
10	EB-825	38	.0004	.7	9/25/1990	7/21/2000
11	EB-827	41	.0073	.7	9/28/1990	7/17/2000
12	EB-839	25	.0162	+3.1	11/19/1994	7/26/2000
13	EB-870	46	.0001	2.5	9/25/1990	7/17/2000
14	EB-896	39	.0001	+1.1	10/31/1990	7/17/2000
15	EB-933	39	.0001	1.5	10/31/1990	7/17/2000
16	EB-934	39	.0001	1.1	10/31/1990	7/17/2000

Table 3.--*Analysis of water-level trends in selected wells in the Southern Hills aquifer system, southeastern Louisiana—Continued*

Number on map (fig. 16)	Well name	Number of observations [1]	Level of significance [2]	Slope, in feet per year [3]	Period of record analyzed [4]	
					Beginning	Ending
			Shallow aquifers—continued			
17	EB-945	93	0.0001	2.8	2/15/1990	12/6/1999
18	EB-946	94	.0242	.9	2/15/1990	12/6/1999
19	EB-1019	34	.0001	1.2	10/31/1990	7/20/2000
20	EF-61	39	.1510	.2	10/10/1990	7/24/2000
21	Li-113	39	.0001	.5	10/17/1990	7/7/2000
22	PC-155	41	.0003	.4	7/30/1990	7/14/2000
23	ST-532	22	.2787	.1	3/22/1995	7/11/2000
24	ST-776	24	.0047	.5	10/16/1990	7/11/2000
25	Ta-454	40	.4852	.1	10/17/1990	7/10/2000
26	WA-13	39	.5437	+.1	10/15/1990	7/10/2000
27	WBR-5	40	.0108	.9	11/2/1990	7/25/2000
28	WBR-102A	41	.0026	.7	8/29/1990	7/25/2000
29	WBR-146	42	.6822	.2	11/2/1990	7/25/2000
30	WBR-148	49	.0008	.7	9/24/1990	7/25/2000
31	WBR-160	40	.0001	5.0	11/2/1990	7/25/2000
32	WBR-161	40	.0001	1.6	11/2/1990	7/25/2000
33	WF-158	39	.0128	+.2	11/1/1990	7/24/2000
			Deep aquifers			
34	EB-90	42	.0243	2.0	11/2/1990	7/20/2000
35	EB-297	40	.0033	3.4	11/1/1990	7/25/2000
36	EB-304	40	.0001	2.2	10/31/1990	7/17/2000
37	EB-322	41	.0001	2.0	11/1/1990	7/17/2000
38	EB-392	28	.0001	2.8	9/22/1993	7/18/2000
39	EB-468	40	.0001	1.9	11/1/1990	7/17/2000
40	EB-581	40	.0001	1.6	10/31/1990	7/17/2000
41	EB-685	40	.0506	1.0	10/31/1990	7/17/2000
42	EB-804A	48	.0004	1.0	9/24/1990	7/21/2000
43	EB-806B	40	.0001	3.5	7/10/1990	5/15/2000
44	EB-944	93	.0001	1.7	2/15/1990	12/6/1999
45	EB-1000	47	.0001	1.6	8/29/1990	7/25/2000

Table 3.--*Analysis of water-level trends in selected wells in the Southern Hills aquifer system, southeastern Louisiana—Continued*

Number on map (fig. 16)	Well name	Number of observations [1]	Level of significance [2]	Slope, in feet per year [3]	Period of record analyzed [4]	
					Beginning	Ending
			Deep aquifers—continued			
46	EB-1028	47	0.0015	3.0	3/29/1991	7/21/2000
47	Li- 52	38	.0001	1.1	10/18/1990	7/7/2000
48	Li-185	39	.0001	1.9	10/17/1990	7/7/2000
49	Or-179	40	.0001	1.0	7/24/1990	7/11/2000
50	PC-39	42	.4657	.2	7/30/1990	7/14/2000
51	PC-70	41	.0001	1.1	7/30/1990	7/14/2000
52	PC-143	41	.0001	.7	7/30/1990	7/14/2000
53	PC-144	41	.0001	.4	7/30/1990	7/14/2000
54	SH-9	39	.0001	.3	10/17/1990	7/10/2000
55	ST-563	39	.0057	2.4	10/16/1990	7/10/2000
56	ST-576	39	.0001	1.2	10/16/1990	7/11/2000
57	Ta-260	38	.0001	1.0	10/17/1990	7/10/2000
58	Ta-268	39	.0001	1.4	10/17/1990	7/7/2000
59	Ta-273	38	.0001	1.2	10/17/1990	7/13/2000
60	Ta-278	39	.0001	.9	10/17/1990	7/7/2000
61	Ta-343	39	.0001	1.2	10/18/1990	7/10/2000
62	Ta-440	40	.0001	.6	10/17/1990	7/10/2000
63	WBR-100A	41	.0001	2.0	9/24/1990	7/25/2000
64	WBR-100B	48	.0001	3.5	9/24/1990	7/25/2000
65	WBR-102B	41	.0036	1.7	8/28/1990	7/25/2000
66	WBR-106	40	.1079	1.5	11/2/1990	7/25/2000
67	WF-22D	41	.0001	.6	8/6/1990	7/24/2000
68	WF-40	33	.1409	.2	8/6/1990	7/24/2000
69	WF-222	40	.0001	1.4	8/6/1990	7/24/2000
70	WF-254	39	.0011	.4	10/26/1990	7/24/2000
71	WF-274	39	.0001	1.5	11/1/1990	7/24/2000

[1] Total number of water-level measurements used to determine the slope in the trend line during the period analyzed.
[2] Probability that water-level change is due to chance rather than trend; values less than 0.05 generally are considered statistically significant.
[3] Computed slope in the trend line using method of ordinary least squares linear regression. The slope is equivalent to the water-level decline or rise (+) in feet per year during the period analyzed.
[4] Dates of first and last measurement of period analyzed.

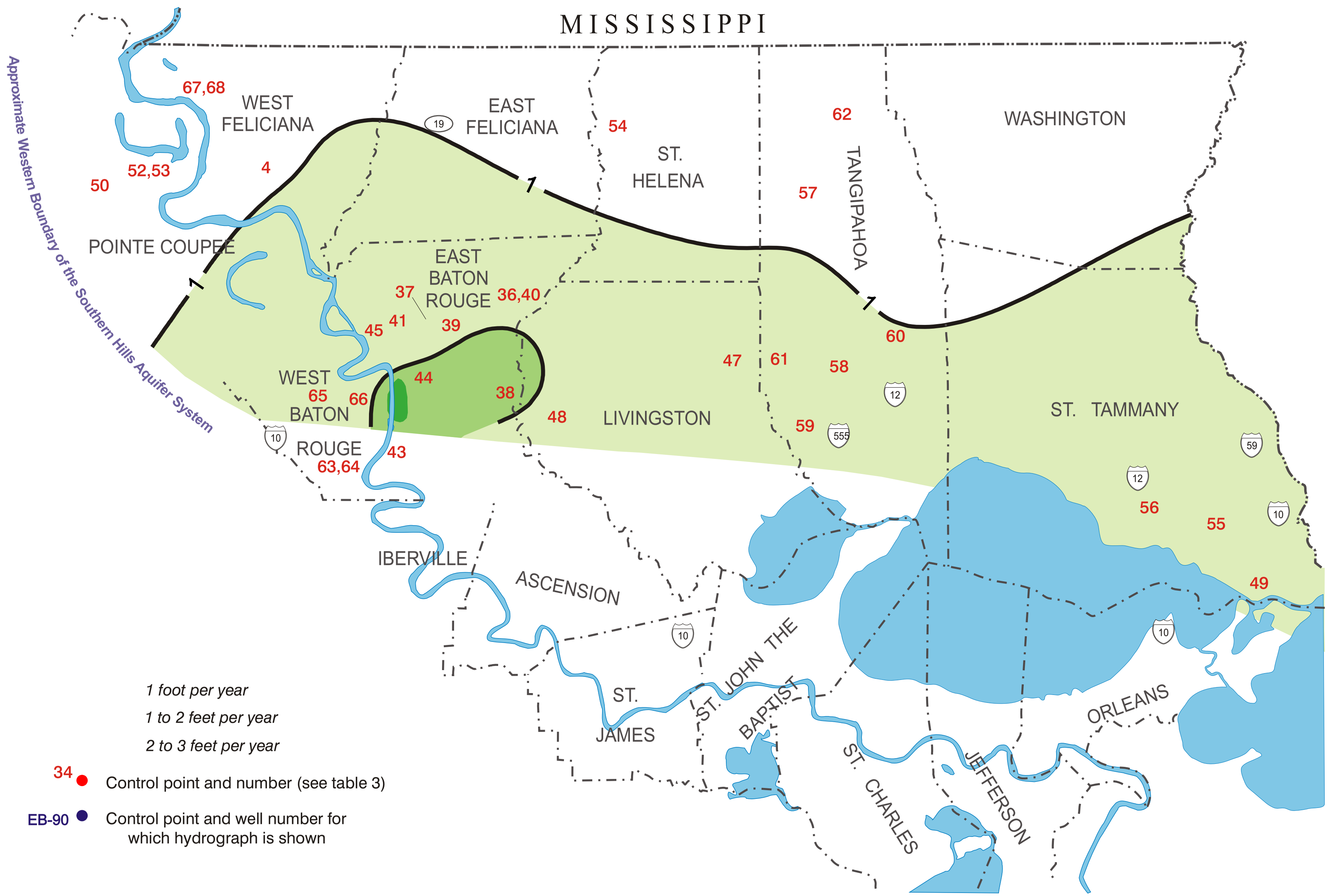


Figure 16. Rate of water-level decline in deep aquifers in the Southern Hills aquifer system, southeastern Louisiana, 1990-2000.

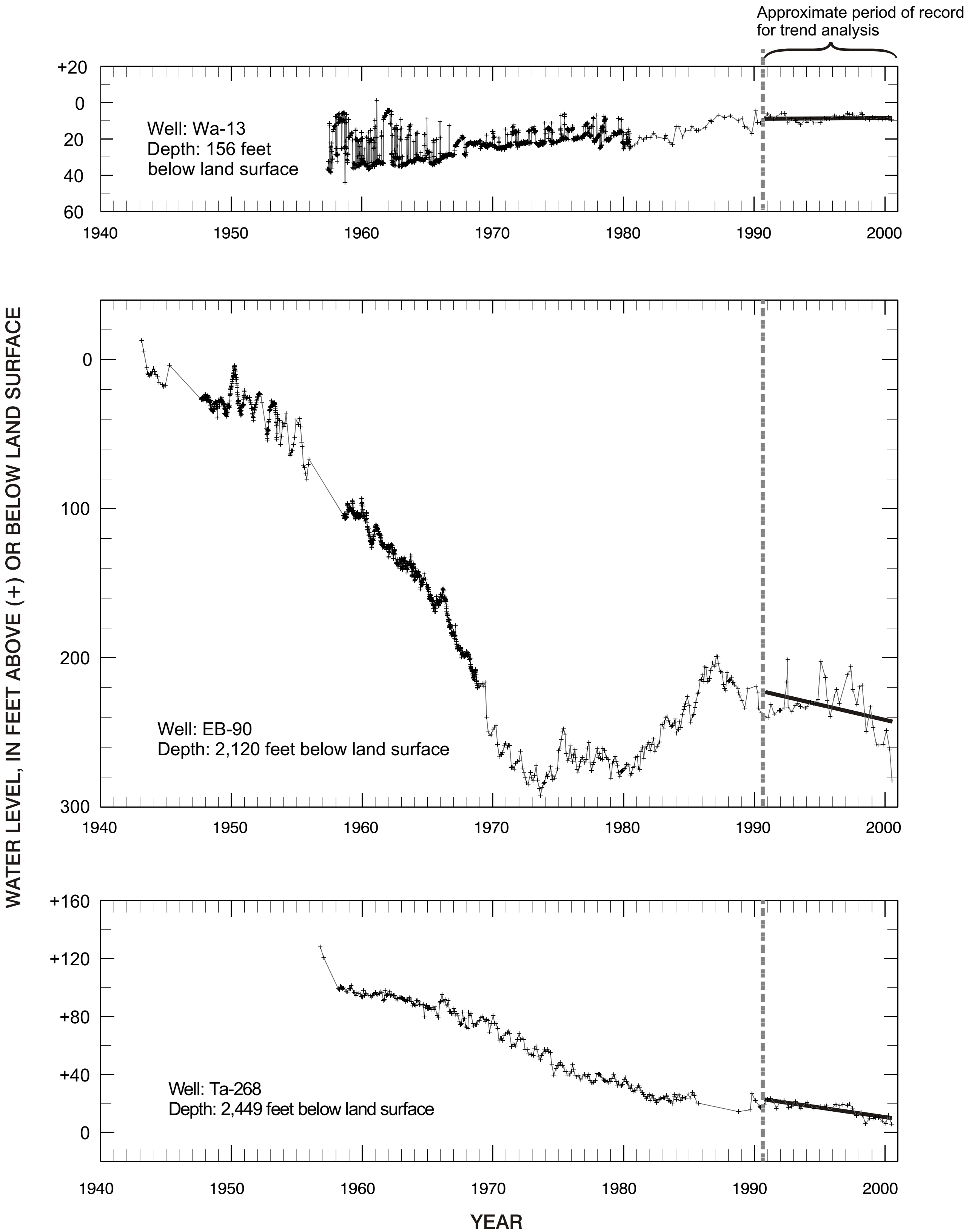


Figure 17. Water levels at selected wells in the Southern Hills aquifer system, southeastern Louisiana.

STREAM WITHDRAWALS AND DISCHARGE TRENDS

Louisiana has abundant surface-water resources, including streams, lakes, and reservoirs. Water is withdrawn from many of these water bodies for power generation, public supply, industrial, and agricultural uses (fig. 18). About 64 percent of the surface water withdrawn was for power generation. In 2000, about 84 percent (8,700 Mgal/d) of the water withdrawn in the State was surface water (fig. 1). Approximately 79 percent of the surface-water withdrawn in 2000 was from the Mississippi River (B.P. Sargent, U.S. Geological Survey, written commun., 2001). Nearly all of the surface water withdrawn was utilized within the State; less than 0.1 percent was exported. Surface-water withdrawals increased about 9 percent during the period 1990-2000. Total withdrawals from surface water are shown for the period 1960-2000 (fig. 19).

Records of streamflow provide information on the availability of streamflow and its variability in time and space. These records are the basic data used for developing reliable surface-water supplies, and are used for the planning, design, and management of surface-water related projects. A gaging station is a stream site installation instrumented and operated so that records of stage, discharge, velocity, temperature, water-quality, or other hydrologic data can be obtained. In Louisiana, the 2000 network of 59 stations to monitor continuous discharge are maintained by the USGS in cooperation with the U.S. Army Corps of Engineers, Louisiana Department of Environmental Quality, and DOTD. The streams that are monitored by these 59 stations represent most of Louisiana’s streamflow.

To determine whether streamflow has decreased, trend analyses were conducted on data from the statewide network of continuous discharge stations for the period 1990-2000. Forty-two continuous discharge stations contained data for the period 1990-2000. Trend analyses identified 11 of the 42 stations on nine streams that had decreasing mean annual discharge during the period 1990-2000 (fig. 20). Water-use data in USGS files were checked to determine amounts and uses of withdrawals from these streams (table 4).

Table 4.--*Surface-water sites in Louisiana with declines in mean annual discharge during the period 1990-2000*

[ft^3/s, cubic foot per second; $(ft^3/s)/yr$, cubic foot per second per year; Mgal/d, million gallons per day]

Number on map (fig. 20)	Site number	Site name	Withdrawals (use and total)	Discharge, mean annual, 2001, in ft^3/s	Decline in discharge, in $(ft^3/s)/yr$[1]	Level of significance[2]
1	7375500	Tangipahoa River at Robert	None	1,102	88	0.005
2	7376000	Tickfaw River at Holden	None	379	39	.008
3	2492000	Bogue Chitto near Bush	None	2,084	157	.020
4	7385700	Bayou Teche at Keystone Lock near St. Martinville	Aquaculture, irrigation, public supply, industry (19.2 Mgal/d)	503	23	.020
5	7366200	Little Corney Bayou near Lillie	None	346	21	.0290
6	7377782	White Bayou southeast of Zachary	None	94.4	7	.0290
7	7373000	Big Creek at Pollock	Public supply (2.5 Mgal/d)	55.1	4	.0430
8	7377500	Comite River near Olive Branch	None	289	22	.0430
9	7378000	Comite River near Comite	None	608	51	.0430
10	7378500	Amite River near Denham Springs	None	2,530	190	.0430
11	7377000	Amite River near Darlington	None	848	88	.0480

[1]Computed decline in discharge using method of ordinary least squares linear regression. The decline in discharge is equal to the slope in the trend line for the period 1990-2000.

[2]Probability that decline in discharge is due to chance rather than trend; values less than 0.05 generally are considered statistically significant.

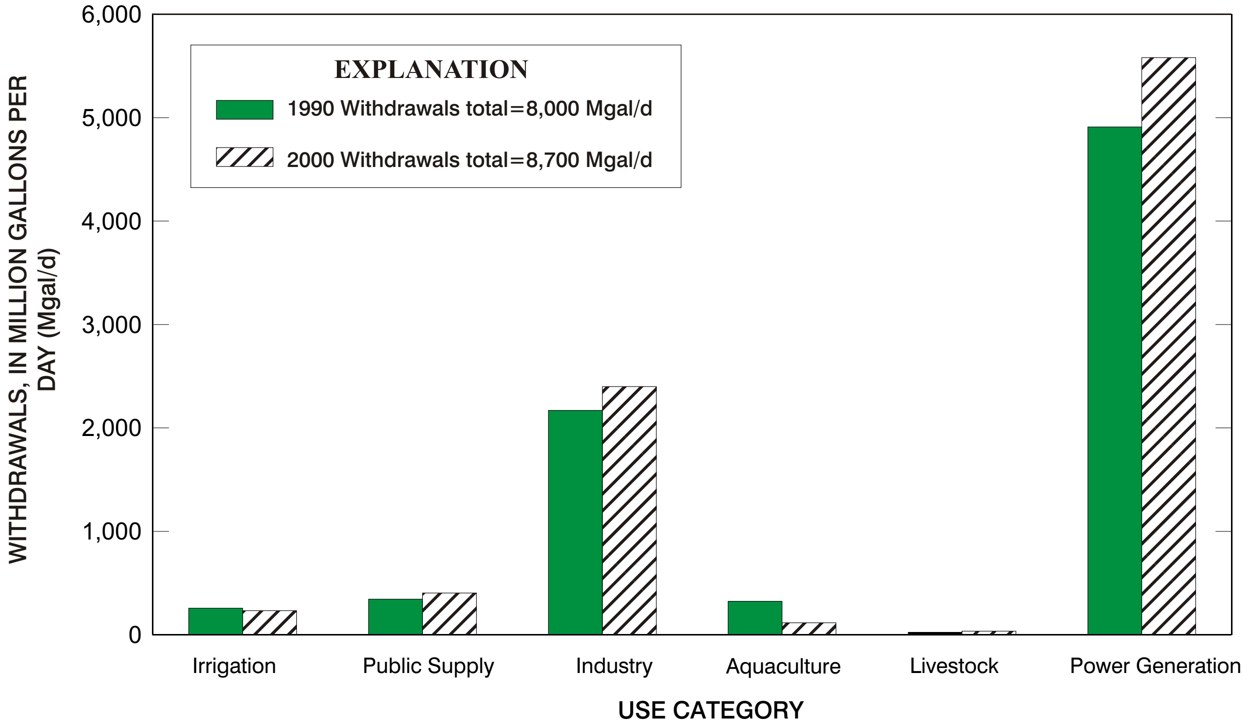


Figure 18. Surface-water withdrawals in Louisiana, by use, 1990 and 2000.

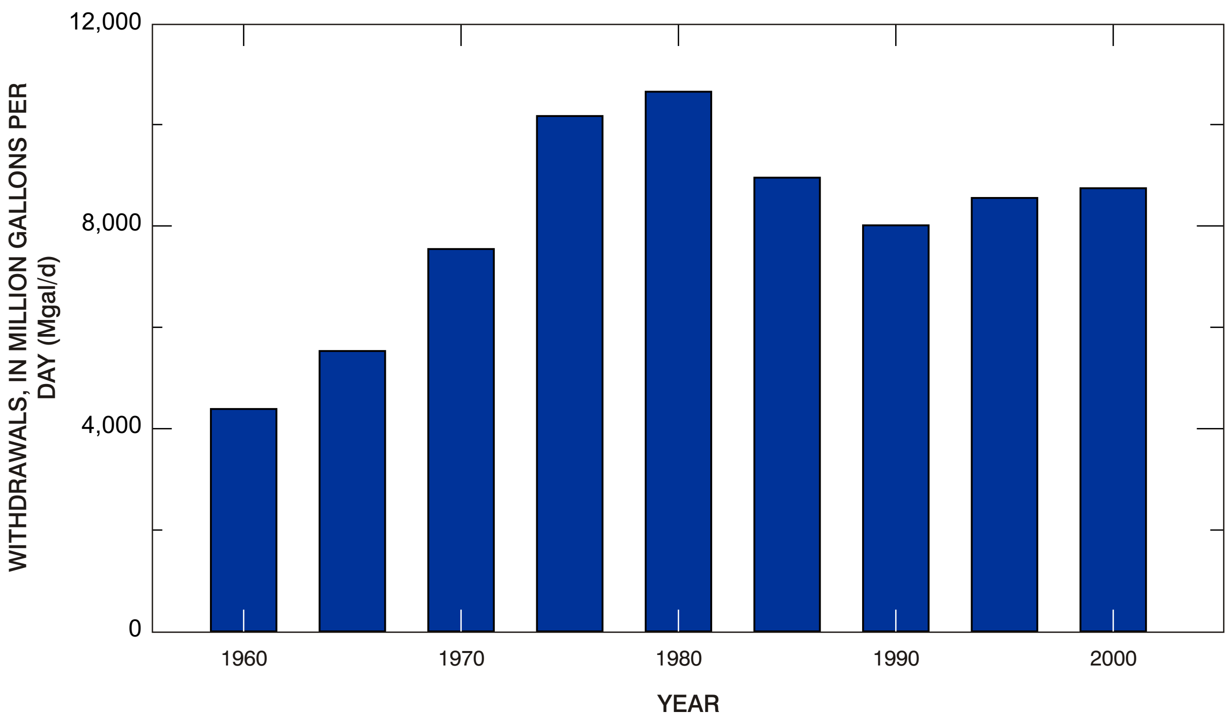
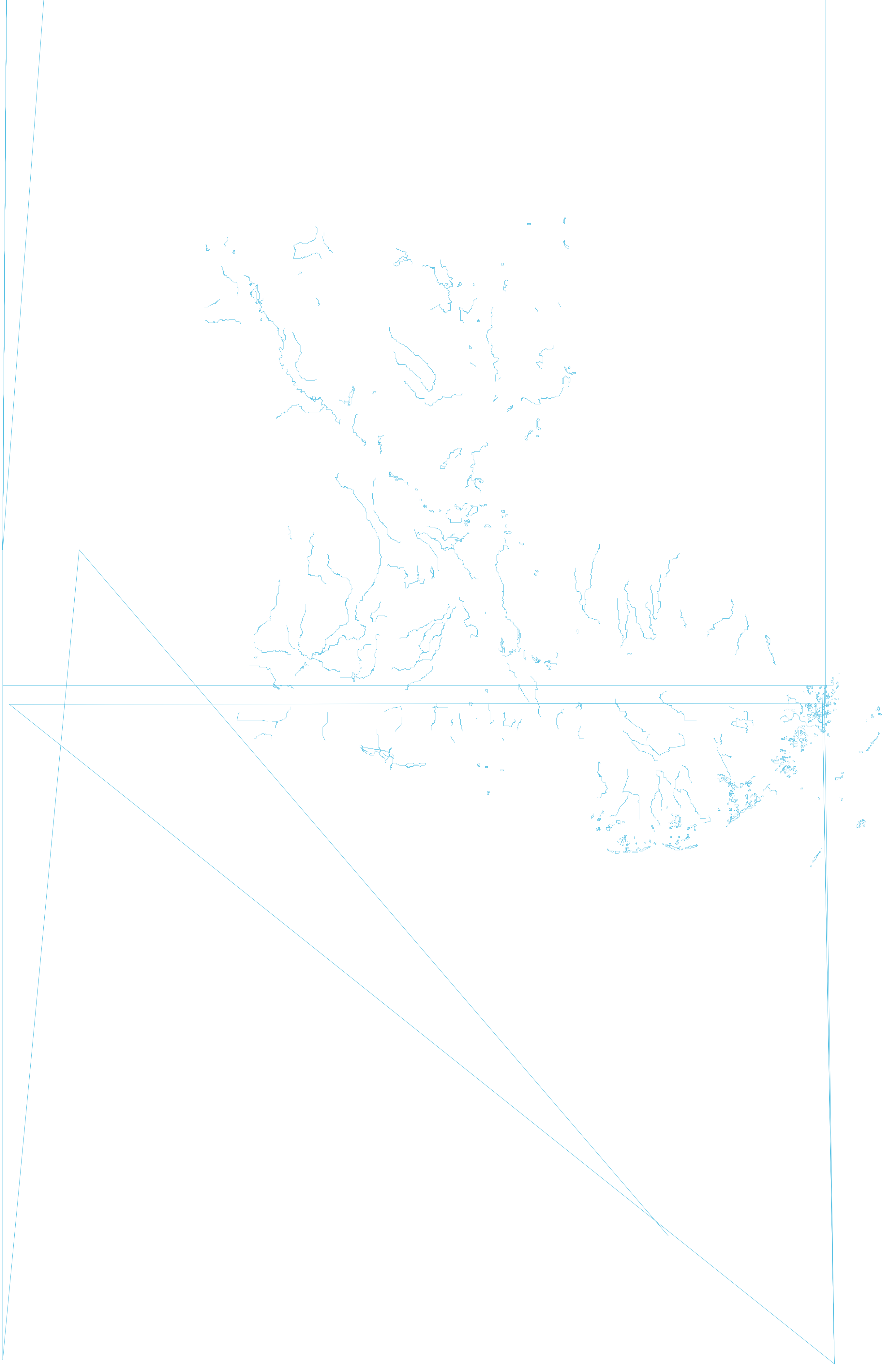


Figure 19. Surface-water withdrawals in Louisiana, 1960-2000.



SUMMARY

Although Louisiana has abundant supplies of fresh ground and surface water, there have been recent concerns about the increasing withdrawals of water for various purposes and the effects of these withdrawals on water resources. In 2000, approximately 10,400 Mgal/d (million gallons per day) of water was withdrawn from ground- and surface-water sources in Louisiana, an increase of 10 percent from 1990.

In 2000, about 16 percent (1,600 Mgal/d) of the water withdrawn in Louisiana was ground water. Approximately 93 percent of the ground water withdrawn was from four aquifers or aquifer systems: the Chicot aquifer system (49 percent), the Mississippi River alluvial aquifer (22 percent), the Sparta aquifer (4 percent), and the Southern Hills aquifer system (18 percent). In the Chicot aquifer system, the Sparta aquifer, and the Southern Hills aquifer system, statistically significant changes (declines) of 1 ft/yr (foot per year) or greater occurred during 1990-2000.

The Chicot aquifer system in southwestern Louisiana is the most heavily pumped aquifer or aquifer system in the State (798 Mgal/d in 2000). About 68 percent of the water withdrawn from the aquifer system in 2000 was for irrigation. In the Lake Charles area, withdrawals for industry and public supply also affect water levels.

Prior to ground-water development, water levels were about 10-25 feet above sea level in central parts of the Chicot aquifer system. The dominant direction of movement was south toward the coast. Ground water in coastal areas began moving northward by the early 1950’s. By 2000, water levels in areas of Calcasieu, Jefferson Davis, and Acadia Parishes had declined to 50 feet or more below sea level, a decline of about 80 feet from prepumping levels, or approximately 0.8 ft/yr since the early 1900’s. Water levels in areas of largest withdrawals declined as much as 1.7 ft/yr during the period 1990-2000.

The Sparta aquifer in north-central Louisiana is the fourth most heavily pumped aquifer in the State; about 68.2 Mgal/d was withdrawn in 2000. About 1900, prior to ground-water development in the aquifer, water levels were 100 to 300 feet above sea level. Ground-water flow was eastward toward the Mississippi River. By the early 1980's, an extensive cone of depression had developed in the aquifer, and water in the aquifer flowed from eastern and southern areas toward pumping centers in central parts of the aquifer. Water levels in the aquifer declined to more than 200 feet below sea level in the Monroe area of Ouachita Parish by 1997. During 1990-2000, water-level declines ranged from 0.1 to 5.2 ft/yr at all sites monitored in the aquifer. The declining water-level trend in the aquifer can be attributed to withdrawals for public supply and industry.

The Southern Hills aquifer system of southeastern Louisiana is composed of numerous freshwater aquifers. This aquifer system is the third most heavily pumped aquifer or aquifer system in the State (291 Mgal/d in 2000). In 2000, about 50 percent of the water withdrawn from the aquifer system was for public supply and 39 percent was for industry

Prior to ground-water development and at present, the water-level surface in the Southern Hills aquifer system generally was highest in the outcrop areas that include parts of southeastern Louisiana and southwestern Mississippi. Some of the precipitation in outcrop areas entered into the aquifer system and moved downdip toward the coastal areas of southeastern Louisiana. Also, in southern areas, water slowly moved upward through clays and sands and historically discharged at land surface. In areas near the Baton Rouge fault, water levels were as much as 100 feet above sea level in deeper aquifers.

In 1953, withdrawals in the Baton Rouge area for public supply and industry were estimated to be about 65 Mgal/d. By 1960, about 210 Mgal/d was withdrawn in southeastern Louisiana, including about 100 Mgal/d in East Baton Rouge Parish. Within the Southern Hills aquifer system, the largest withdrawals (135 Mgal/d in 2000) are in East Baton Rouge Parish, which uses about 46 percent of the water withdrawn from the aquifer system.

By the 1970's, water levels throughout much of southeastern Louisiana were declining. Saltwater encroachment also had been documented in major aquifers in the Baton Rouge area. By 2000, water levels in some heavily pumped aquifers in areas of East Baton Rouge Parish had declined to 200 feet and more below sea level. Water levels in aquifers having the largest withdrawals (deep aquifers) declined about 0.2 to 3.5 ft/yr during the period 1990-2000.

In 2000, about 84 percent (8,700 Mgal/d) of the water withdrawn in Louisiana was surface water. Stream discharge data were analyzed for 59 continuous discharge stations. The streams monitored by these stations represent most of Louisiana's streamflow. This analysis identified 11 stations on nine streams that had decreasing mean annual discharge during the period 1990-2000.

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