Exhibit F –
Franklin Farm
Ground Water Study

LOUISIANA ECONOMIC DEVELOPMENT

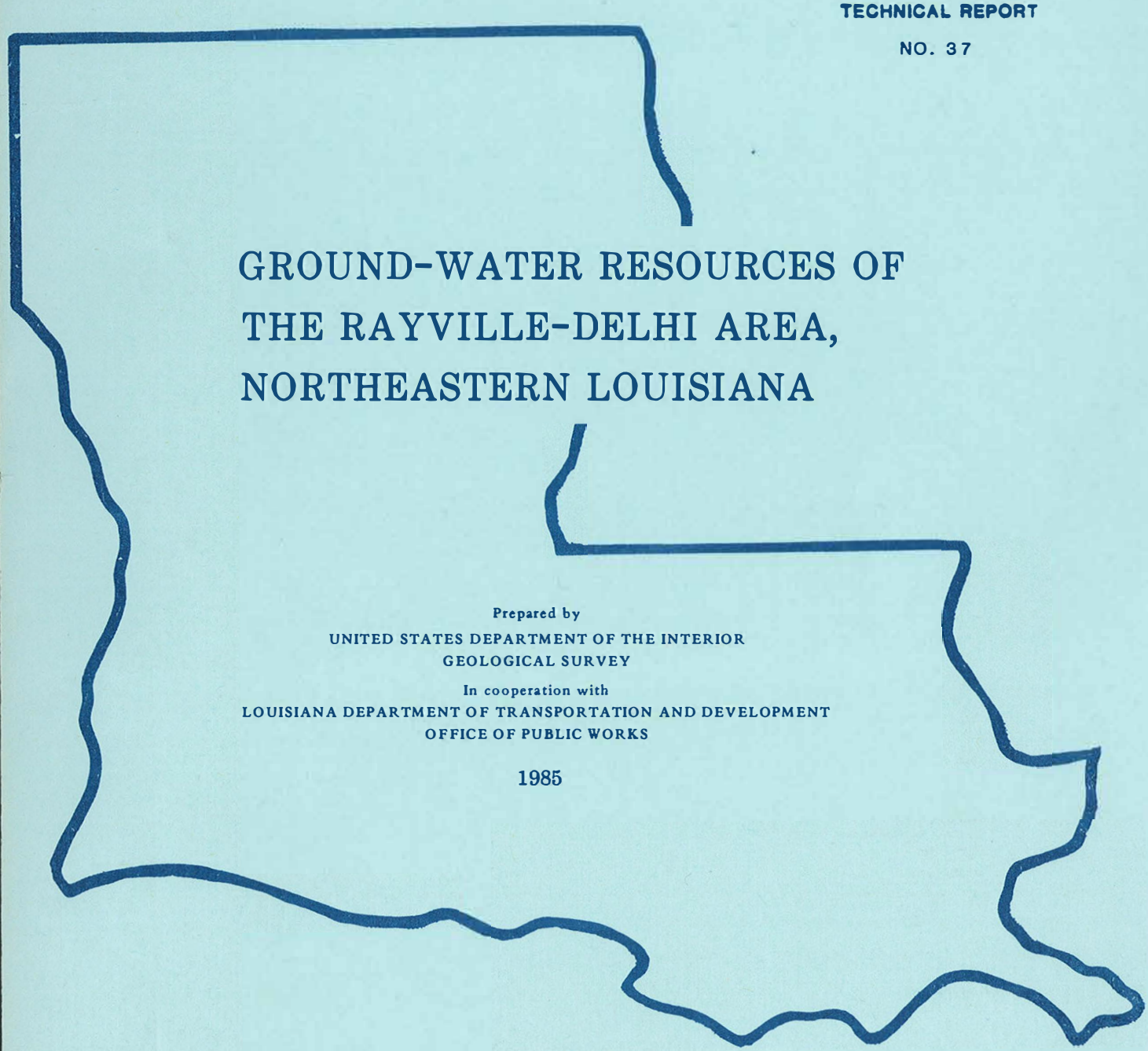
CERTIFIED SITE

Franklin Farm Ground Water Study

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS

WATER RESOURCES
TECHNICAL REPORT
NO. 37

GROUND-WATER RESOURCES OF THE RAYVILLE-DELHI AREA, NORTHEASTERN LOUISIANA



Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

In cooperation with
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS

1985

STATE OF LOUISIANA

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

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Water Resources

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GROUND-WATER RESOURCES OF THE RAYVILLE-DELHI AREA, NORTHEASTERN LOUISIANA

By

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U.S. Geological Survey

Published by

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Baton Rouge, Louisiana

1985

STATE OF LOUISIANA

EDWIN W. EDWARDS, Governor

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

ROBERT G. GRAVES, Secretary

OFFICE OF PUBLIC WORKS

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Cooperative projects with

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

DALLAS L. PECK, Director

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[Plates are at back]

ILLUSTRATIONS

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

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
inch (in.)	25.40	millimeters (mm)
gallon per minute (gal/min)	0.00378	cubic meter per minute (m^3/min)
million gallons per day (Mgal/d)	3,785	cubic meter per day (m^3/d)
micromhos per centimeter at 25° Celsius (µmhos/cm)	1	microsiemens per centimeter at 25° Celsius (µS/cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

To convert temperature in degrees Fahrenheit (°F) to degrees Celsius (°C), subtract 32 and divide by 1.8.

GROUND-WATER RESOURCES OF THE RAYVILLE-DELHI AREA, NORTHEASTERN LOUISIANA

By Kenneth J. Covay

ABSTRACT

Principal aquifers in the Rayville-Delhi area are in the Mississippi River valley alluvium of Pleistocene age and the Cockfield Formation of Eocene age. The Sparta Sand of Eocene age is of lesser importance and contains freshwater only in the extreme western part of the project area.

The Mississippi River alluvial aquifer contains freshwater throughout most of the area. The water is very hard and iron concentrations generally range from 300 to 3,000 micrograms per liter. However, large quantities of water are available; yields of several thousand gallons per minute are possible.

The Cockfield aquifer contains freshwater except in the extreme eastern part of the area where Cockfield sand units contain salty water. Except where water in the Cockfield is modified by infiltration from the overlying alluvial aquifer, the water generally is soft and iron concentrations generally range from 20 to 770 micrograms per liter. Hydraulic conductivities of the sand units generally range from 30 to 55 feet per day, and optimum well yields are a few hundred gallons per minute. The Cockfield aquifer is best suited for development of small to moderate supplies.

INTRODUCTION

Population density adjacent to Interstate Highway 20 and U.S. Highway 80 in northern Louisiana is increasing, which creates a demand for ground water, the principal source of local water supplies. The Rayville-Delhi study area (fig. 1) is principally in Richland Parish but also includes small parts of Morehouse, East Carroll, Franklin, and Madison Parishes. The 450 mi^2 area consists of Rs. 6 through 10 E. and Tps. 17 and 18 N. and the northern one-half of T. 16 N. (pl. 1). The major communities of Rayville and Delhi in northern Richland Parish (pl. 1) have increased in population and will likely continue to do so. Urban development also is occurring in other small towns and communities along the east-west corridor. Public water-supply systems have been established in numerous communities. Some systems serve less than 100 people, whereas, larger systems serve from 5,000 to 7,000 people. Because of increased demand for ground water for public supplies, industry, agriculture, and aquaculture, additional information is needed to describe the ground-water resources.

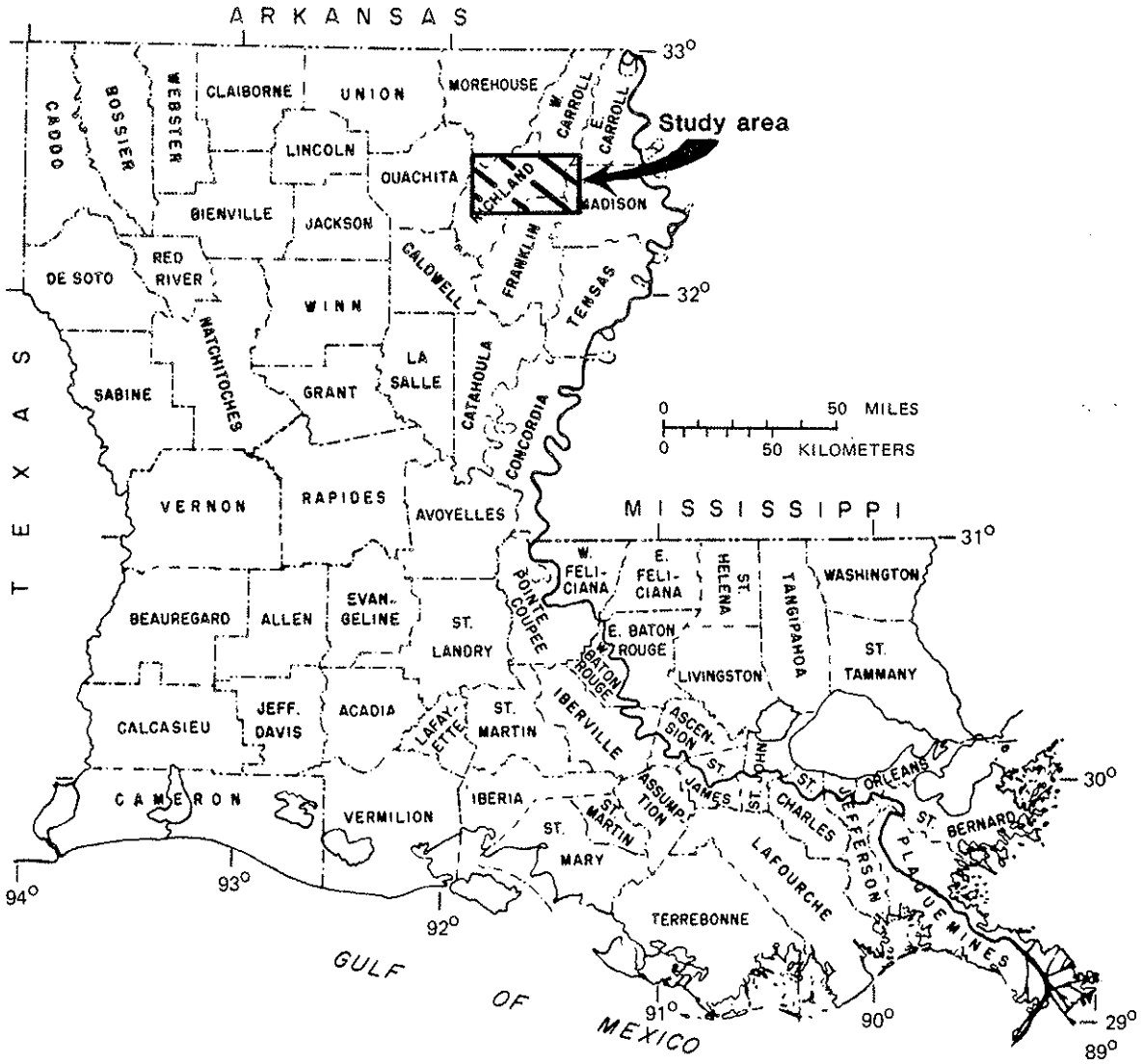

Figure 1.--Location of Rayville-Delhi study area, Louisiana.

The purposes of this report are to describe ground-water resources in the Rayville-Delhi area and to present data that should be useful to decision makers in developing additional water supplies in northern Richland Parish.

This report was based on an unpublished manuscript on the Rayville-Delhi area that was prepared by R. L. Hosman of the U.S. Geological Survey. This study was done by the U.S. Geological Survey, in cooperation with the Louisiana Department of Transportation and Development, Office of Public Works.

HYDROGEOLOGY OF THE PRINCIPAL AQUIFERS

Fresh ground water occurs in aquifers of three geologic units (table 1, figs. 2 and 3, and pl. 2). These units are--from youngest to oldest-- the Mississippi River valley alluvium of Pleistocene and Holocene age and the Cockfield Formation and Sparta Sand of Eocene age. The Mississippi River valley alluvium and the Sparta Sand underlie the entire area. The Cockfield Formation underlies nearly all of the area. Geologic units that consist chiefly of clay, the Cook Mountain and Cane River Formations, are confining beds (table 1) and retard water movement between aquifers. The alluvium is nearly flat lying, but the underlying Cockfield Formation and Sparta Sand generally dip about 30 to 35 ft/mi to the southeast (pl. 3). Freshwater occurs in the Mississippi River valley alluvium in most of the area and in the Cockfield Formation in about 80 percent of the area. The Sparta Sand contains freshwater only in the western part (pl. 2). In most of the alluvial aquifer and in all of the Cockfield and Sparta aquifers, the water is under artesian conditions.

Table 1.--Geohydrologic units in the Rayville-Delhi area, Louisiana

[Modified from Ryals, 1982]

System	Series	Group	Formation	Description	Aquifer	Hydrologic characteristics
Quaternary	Holocene and Pleistocene			Alluvial valley fill. Coarse, graveliferous at base grading upward to sand, silt, and clay. Thickness ranges from about 50 to 125 feet.	Mississippi River alluvial	Contains freshwater. Used locally for rural supplies and one public supply. Yields range from a few gallons per minute for small domestic supplies to several thousand gallons per minute for large irrigation wells. Hydraulic conductivity ranges from 130 to 270 feet per day.
Tertiary	Eocene	Claiborne	Cockfield Formation	Fine lignitic sand and carbonaceous clay. Thicker sands in lower part. Thickness ranges from about 20 to 600 feet.	Cockfield	Contains freshwater and saltwater. Used mostly for rural and small public supplies. Hydraulic conductivity ranges from less than 30 feet per day to about 55 feet per day.
			Cook Mountain Formation	Clay, partly sandy; glauconitic. Thickness ranges from about 100 to 150 feet.	Confining bed	Local sands yield small quantities of water for domestic supplies.
			Sparta Sand	Fine to medium sand with clay interbeds; lignitic. Thickness ranges from about 500 to 700 feet.	Sparta	Contains freshwater and saltwater. Principal aquifer of north-central Louisiana. Large withdrawals by domestic, municipal, and industrial wells. Only domestic wells in project area. Hydraulic conductivity ranges from 30 feet per day to more than 100 feet per day.
			Cane River Formation	Clay; glauconitic, lignitic. Thickness ranges from about 250 to 350 feet.	Confining bed	Does not yield water to wells.

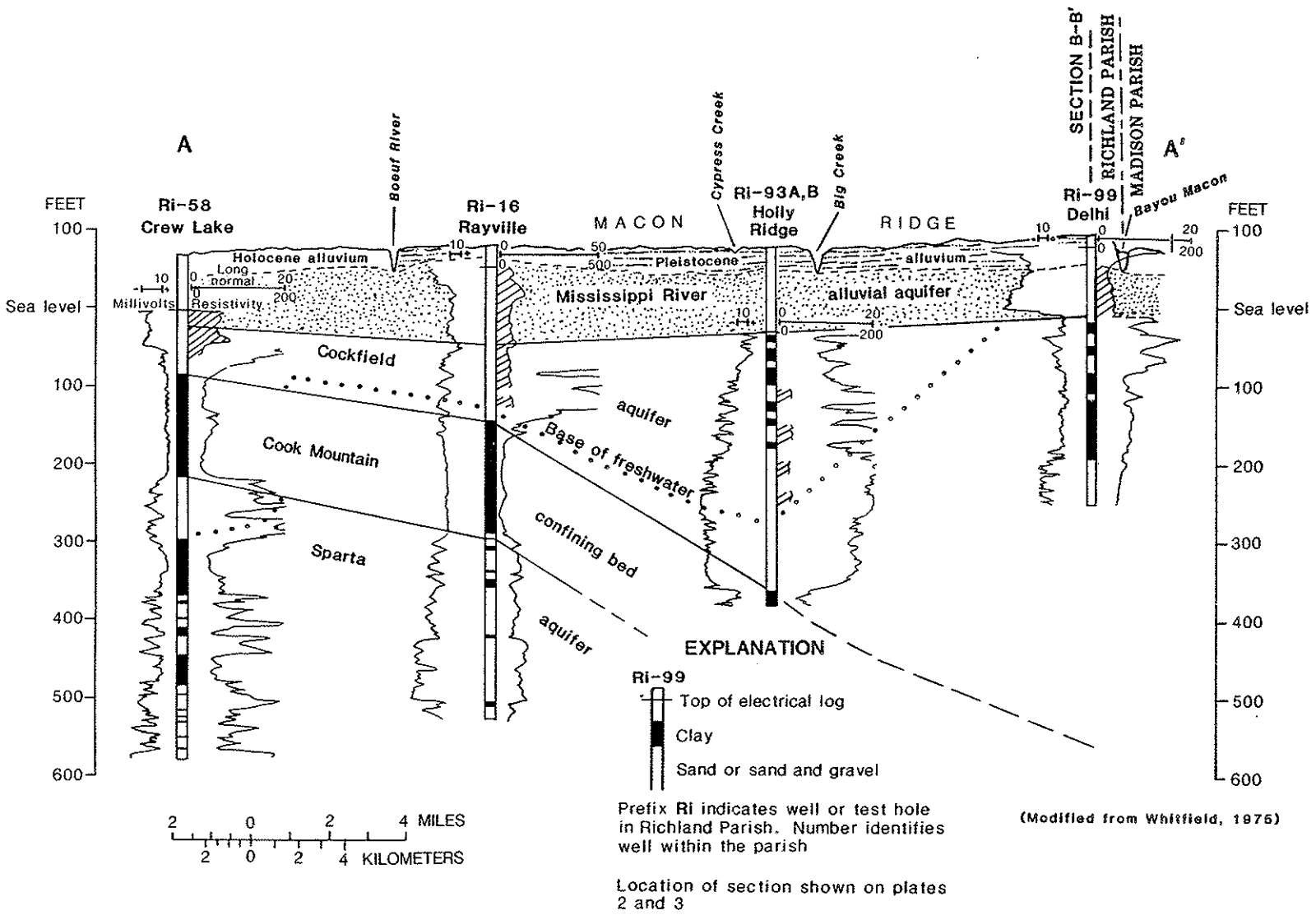

Figure 2.--East-west geohydrologic section across the Rayville-Delhi area, northeastern Louisiana.

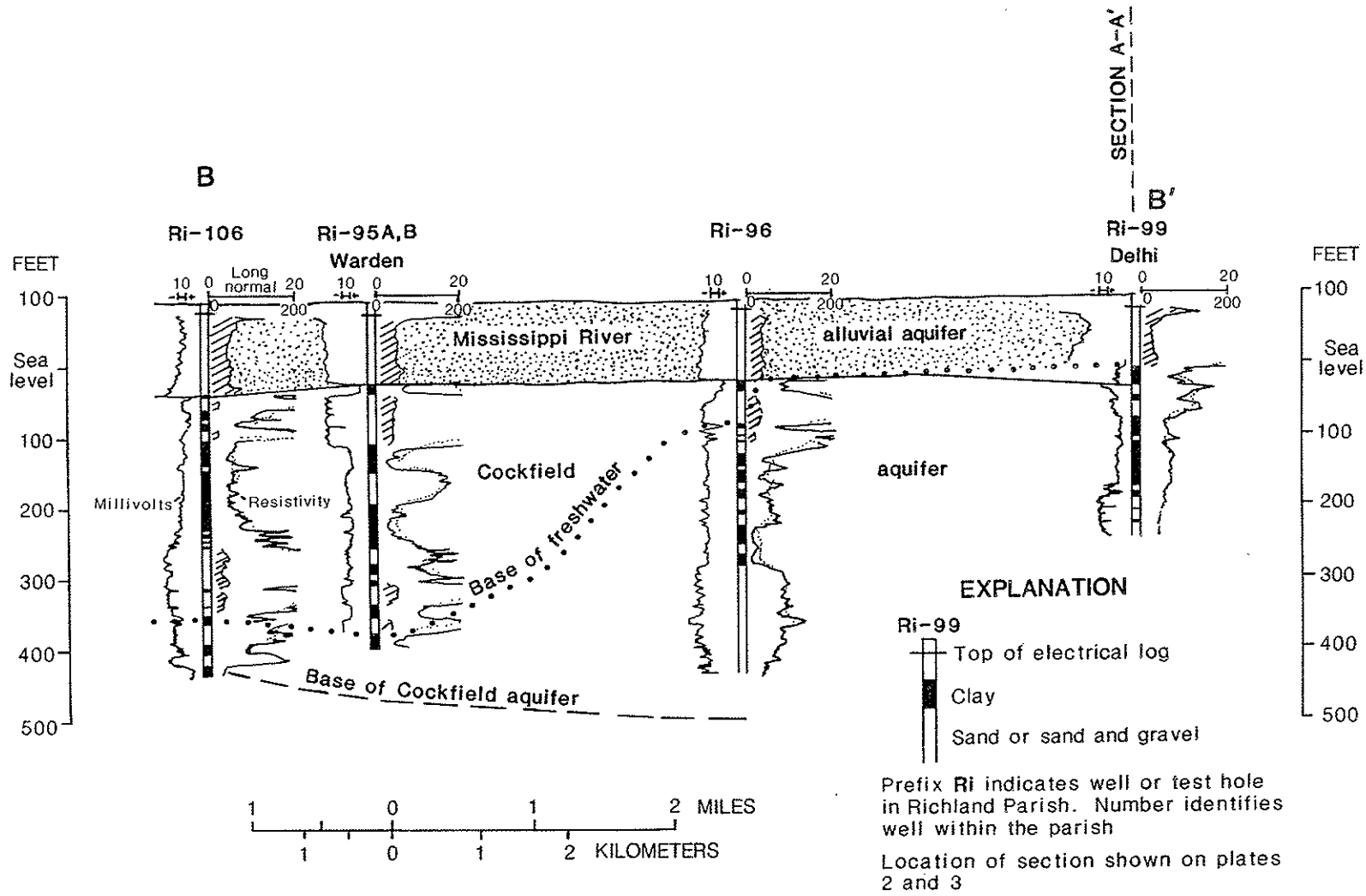

Figure 3.--North-south geohydrologic section across the Rayville-Delhi area, northeastern Louisiana.

Mississippi River Alluvial Aquifer

The Mississippi River valley alluvium was deposited on an erosional surface cut into deposits of Tertiary age. The alluvium consists of poorly sorted sand and gravel grading upward to medium and fine sand. Clay and silt of Holocene age overlie and act as a confining layer for the coarse material which forms the Mississippi River alluvial aquifer. The aquifer thickness ranges from less than 50 ft to more than 125 ft in the area, generally increasing to the southeast. The base of the alluvium ranges from about 25 to 50 ft below sea level. Water levels range from about 10 to 30 ft below land surface. Water generally moves in a southwesterly direction in the Rayville area and toward Bayou Macon in the Delhi area. Details of the geohydrology and water quality of the Mississippi River alluvial aquifer have been presented by Whitfield (1975).

The hydraulic conductivity of the Mississippi River alluvial aquifer ranges from 130 to 270 ft/d. Transmissivity ranges from 6,500 to 40,000 ft^2/d based on aquifer tests made in Morehouse Parish (Sanford, 1973), East and West Carroll Parishes (Poole, 1961), and Madison Parish (Turcan and Meyer, 1962).

Yields of several thousand gallons of water per minute are possible from properly constructed wells where aquifer thickness and hydraulic conductivity are adequate. Total withdrawal in the Rayville-Delhi area in 1980 was about 59 Mgal/d.

Rainfall is the primary source of recharge to the Mississippi River alluvial aquifer in Louisiana. Most rainfall occurs from December through May and least in September and October. The average annual rainfall is about 52 in. Recharge depends on the thickness and permeability of the silt and clay that overlie the alluvial aquifer. The overlying deposits are relatively permeable because of their organic content and lack of compaction.

Water from the Mississippi River alluvial aquifer generally is a calcium-bicarbonate type. Locally, sodium may be the codominant cation and chloride may be the codominant anion, especially where salty water is found in the alluvium (pl. 2). The water is considered to be hard or very hard[1]. Concentrations of dissolved solids range from 198 to 1,910 mg/L, and the mean concentration is 580 mg/L. Concentrations of chloride and iron may exceed recommended limits of the U.S. Environmental Protection Agency (1976a) for drinking water. Treatment of water to reduce the concentrations of iron and hardness generally is necessary for domestic, public supply, and specific industrial uses. Chemical analyses of water from wells screened in the alluvial aquifer are summarized in table 2 and presented in tables 3 and 4.

---

[1] The U.S. Environmental Protection Agency (1976a, p. 75) classifies hardness as follows: Water having a hardness of 0-75 mg/L is considered soft, 75-150 mg/L is moderately hard, 150-300 mg/L is hard, and more than 300 mg/L is very hard.

Table 2.--Summary of selected physical and dissolved-chemical constituents of water from the Mississippi River alluvial aquifer, northeastern Louisiana

[µS/cm, microsiemens per centimeter; mg/L, milligram per liter; µg/L, microgram per liter; $CaCO_3$, calcium carbonate; N, nitrogen; NO_3, nitrate]

Constituent	Number of samples analyzed	Range	Recommended limits[a]
pH (units)	13	7.1 - 8.2	6.5-8.5
Color (platinum-cobalt units)	9	0 - 10	75
Temperature	8	18.5- 20.5°C 65.0- 69.0°F	----------
Specific conductance (µS/cm at 25°C)	32	485 -4070	----------
Calcium (mg/L)	15	43 - 140	----------
Magnesium (mg/L)	15	.4- 100	----------
Potassium (mg/L)	9	1.1- 19	----------
Sodium (mg/L)	9	34 - 530	----------
Bicarbonate (mg/L)	13	150 - 432	----------
Chloride (mg/L)	169	21 -1400	250 mg/L
Fluoride (mg/L)	10	0 - .5	[b]1.8 mg/L
Sulfate (mg/L)	39	2.2- 43	250 mg/L
Nitrate as N (mg/L)	9	.2- 3.4	10 mg/L
Nitrate as NO_3 (mg/L)	10	0 - 15	----------
Dissolved solids (mg/L)	10	198 -1910	500 mg/L
Hardness (mg/L as $CaCO_3$)	140	190 -1100	----------
Iron (µg/L)	6	300 -3000	300 µg/L
Manganese (µg/L)	3	150 - 610	50 µg/L

[a] U.S. Environmental Protection Agency, 1976a.
[b] U.S. Environmental Protection Agency, 1976b.

The aquifer contains saltwater in two small areas, one southwest of Delhi and one in northern Franklin Parish (pl. 2). The anomalous zone southwest of Delhi probably is the result of contamination from saltwater disposal pits. Upward movement of saltwater from the Cockfield Formation probably is the source of the saltwater anomaly in Franklin Parish.

Cockfield Aquifer

The Cockfield Formation underlies the Mississippi River alluvial aquifer and overlies the Cook Mountain confining bed (table 1 and figs. 2 and 3). The formation, which also is the Cockfield aquifer, is composed of very fine to medium sand, silty sand and clay, clay, and lignite. Thickness of the interconnected sand beds ranges from a few feet to more than 100 ft. Some sand beds are traceable for only short distances. The

Table 3.--Complete chemical analyses of water

Well no.	Location Sec.	T. (N.)	R. (E.)	Depth of well, total (feet)	Date of sample	Temperature (°C)	pH (standard units)	Specific conductance (µS/cm)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Carbon dioxide, dissolved (mg/L as CO2)	Alkalinity, field (mg/L as CaCO3)
						Richland Parish								
						Mississippi River Alluvial Aquifer								
Ri-1	4	17	7	86	5-29-45	19.5	8.0	----	58	23	----	---	3.4	202
Ri-3	18	17	10	95	5-25-45	19.5	7.3	1120	100	38	10	77	34	349
				95	3-22-55	18.5	7.3	1430	110	45	3.2	110	34	354
Ri-6	4	17	7	60	5-29-45	20.0	---	----	43	16	----	---	----	139
Ri-14	4	17	7	80	11-12-52	----	7.1	----	140	100	----	---	----	---
				80	1-21-58	20.5	7.9	626	62	22	2.2	38	5.4	---
				80	7-24-68	----	7.4	631	63	23	.6	34	18	234
Ri-18	18	17	10	94	1- 7-60	20.0	7.4	1110	96	36	19	86	26	336
Ri-48	9	17	7	115	6-28-61	----	7.5	----	140	110	----	---	12	195
Ri-92	16	17	7	153	12- 5-69	20.0	7.7	498	48	16	1.1	40	9.3	---
Ri-114	24	17	9	66	6-22-72	----	7.6	3630	130	53	6.0	530	16	---
				66	4-26-83	----	---	----	63	23	----	---	----	---
				66	8-31-83	----	---	----	55	24	----	---	----	---
Ri-124	25	17	9	84	4-26-83	----	---	----	170	62	----	---	----	---
				84	8-31-83	----	---	----	140	58	----	---	----	---
Ri-228A	4	17	7	110	6- 9-81	20.0	7.3	485	58	18	2.1	15	20	202
Ri-260	26	17	9	70	4-26-83	----	---	----	140	55	----	---	----	---
				70	8-31-83	----	---	----	110	54	----	---	----	---
Ri-22	15	17	9	371	4- 7-61	----	7.6	2290	4.0	1.0	7.8	500	21	440
Ri-53	7	18	8	293	9- 8-69	----	7.6	440	42	13	2.3	35	11	---
Ri-56	4	17	6	190	2-14-67	20.0	7.5	438	27	9.1	1.8	62	13	---
Ri-57	33	18	6	183	11-29-66	20.0	7.7	429	60	11	1.8	48	8.4	218
Ri-59	20	18	6	182	8-18-67	19.5	6.9	621	58	17	1.9	58	77	---
Ri-88	34	18	7	239	8-27-69	20.5	8.0	466	44	13	1.5	47	4.8	---
Ri-89	26	18	7	300	9- 9-69	----	---	390	38	12	1.4	32	----	---
Ri-91	16	17	7	180	12- 5-69	----	---	497	31	6.5	1.3	74	----	---
Ri-93A	10	17	8	239	6-12-70	----	---	1170	4.2	.9	4.5	280	----	---
Ri-93B	10	17	8	411	6- 6-70	----	---	2120	1.2	1.2	4.0	470	----	---
Ri-94	15	18	8	345	6-19-70	----	---	699	64	19	2.9	68	----	---
Ri-95A	13	18	9	200	6-26-70	----	---	1140	62	21	4.0	160	----	---
Ri-95B	13	18	9	420	6-26-70	----	---	1030	2.3	.5	3.0	260	----	---
Ri-96	36	18	9	170	7- 2-70	----	---	805	20	21	4.5	96	----	---
Ri-97	7	17	9	239	7-16-70	----	---	846	13	4.5	2.9	180	----	---
Ri-104	33	17	7	189	9-16-70	20.5	8.1	567	50	11	2.4	60	3.9	---
Ri-105	8	18	8	335	8-25-70	----	8.3	857	33	16	5.1	140	3.4	---
Ri-106	12	18	9	420	11- 2-71	22.0	8.0	958	.6	.1	1.2	240	7.5	---
Ri-108	26	18	9	440	3-17-72	----	8.2	1340	1.8	.4	2.5	320	4.5	371
Ri-126	13	18	9	426	5-31-73	----	8.0	793	1.0	.3	---	200	7.1	364
				426	7-19-83	22.0	7.7	903	1.0	.4	1.4	230	15	385
Ri-127	13	18	9	416	1- 8-73	----	7.5	----	1.2	.3	---	190	22	364
Ri-211	8	18	9	419	3-25-80	21.0	7.4	993	20	6.8	6.0	250	29	381
Ri-228B	4	17	7	185	6- 4-81	20.0	7.4	552	28	7.8	1.8	78	17	223
						Richland Parish								
						Sparta Aquifer								
Ri-16	4	17	7	562	7-26-51	----	8.2	----	4.0	1.0	---	---	5.4	438

from wells in the Rayville-Delhi area, Louisiana

Bicarbonate, fet-fld (mg/L as HCO3)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Sulfate, dissolved (mg/L as SO4)	Silica, dissolved (mg/L as SIO2)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as NO3)	Hardness (mg/L as CaCO3)	Dissolved solids, sum of constituents (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)
				Richland Parish							
				Mississippi River Alluvial Aquifer							
210	37	----	14	----	1.80	8.0	240	278	100	----	---
420	150	0.20	13	37	1.90	8.4	410	643	420	----	---
430	250	.00	7.6	32	.45	2.0	460	773	10	----	310
150	24	----	7.0	----	3.40	15	170	198	100	----	---
----	50	----	32	22	----	----	760	----	50	----	---
270	56	.00	24	33	1.10	4.9	250	375	20	----	200
280	50	.10	22	29	.20	.89	250	363	---	0	---
410	150	.50	23	35	1.60	7.1	390	654	140	----	40
240	23	.25	----	33	----	----	800	----	100	----	---
290	21	.20	3.4	32	----	.00	190	308	---	1300	---
400	1000	.20	.4	----	----	----	550	1960	---	460	---
----	170	----	14	----	----	----	250	----	---	----	---
----	140	----	----	----	----	----	240	----	---	----	---
----	310	----	24	----	----	----	680	----	---	----	---
----	280	----	----	----	----	----	590	----	---	----	---
----	33	.20	2.2	33	----	----	220	285	---	1900	---
----	350	----	27	----	----	----	580	----	---	----	---
----	300	----	----	----	----	----	500	----	---	----	---
540	480	.80	.4	12	.07	.31	14	1270	150	----	0
290	7.0	.20	1.6	20	----	.10	160	263	---	760	---
260	18	.20	6.2	23	----	.10	100	276	---	390	---
270	14	.20	.6	28	.00	.00	200	295	---	770	---
390	20	.20	.8	27	----	.10	210	374	---	630	---
300	7.6	.30	.6	21	----	.00	160	283	---	420	---
240	9.1	.10	.2	27	----	.10	140	238	---	20	---
280	29	.20	.0	25	----	.00	100	303	---	530	---
430	160	.30	.2	9.3	----	----	14	711	---	----	---
470	420	.40	1.0	15	----	----	8	1190	---	----	---
410	19	.20	2.2	24	----	----	240	431	---	1100	---
580	90	.20	.2	25	----	----	240	646	---	----	---
470	110	.40	18	15	----	----	8	638	---	----	---
280	70	.20	.2	21	----	----	140	404	---	----	---
410	73	.50	.0	23	----	----	51	499	---	180	---
310	30	.20	10	22	----	----	170	339	---	190	---
430	69	.20	10	24	----	----	150	516	---	340	---
470	91	.20	3.0	15	.02	.10	2	583	---	220	---
450	230	.20	.4	13	----	----	6	791	---	300	---
440	58	.10	1.0	19	----	----	4	----	---	50	---
---	69	.20	.9	13	----	----	4	547	---	30	---
440	38	.10	1.0	17	----	----	4	----	---	100	---
460	130	.20	23	20	----	----	78	685	---	360	---
---	29	.40	.4	24	----	----	100	304	---	310	---
				Richland Parish							
				Sparta Aquifer							
534	750	----	1.0	13	----	----	14	----	300	----	---

Table 4.--Partial chemical analyses of water from wells in the Rayville-Delhi area, Louisiana

Well No.	Location			Depth of well, total (feet)	Date of sample	Specific conductance (µS/cm)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Hardness (mg/L as CaCO3)
	Sec.	T. (N.)	R. (E.)						
Richland Parish									
Mississippi River Alluvial Aquifer									
Ri-1	4	17	7	86	4- 1-41	----	38	13	220
Ri-3	18	17	10	95	2-11-42	----	180	16	460
Ri-17	18	17	10	94	7-30-70	----	170	----	420
Ri-21	12	17	8	85	2-26-70	----	39	----	390
Ri-85	24	17	9	67	9-19-69	----	1400	----	700
				67	6- 3-70	----	1400	----	----
Ri-86	24	17	9	90	4- 1-69	----	1100	----	560
Ri-87	36	17	9	98	4- 1-69	----	150	----	40
Ri-109	24	17	10	90	4- 1-69	----	150	----	400
				90	9-19-69	----	150	----	410
				90	3-26-70	----	150	----	410
				90	9-14-71	----	150	----	380
Ri-110	24	17	9	67	4- 1-69	----	190	----	420
				67	9-19-69	----	180	----	460
				67	3-26-70	----	170	----	450
				67	1-28-71	----	170	----	420
				67	6-25-71	----	180	----	460
				67	9-14-71	----	180	----	440
				67	5-25-72	----	190	----	----
				67	9- 7-72	----	180	----	420
				67	5-21-75	----	150	----	----
				67	8- 6-75	----	160	----	420
				67	8-24-76	----	170	----	500
				67	5-19-77	----	160	----	450
				67	12- 7-77	----	150	13	640
				67	5-26-78	1160	150	----	420
				67	4-11-79	----	150	----	440
				67	8-21-79	----	------	----	450
				67	3- 5-80	----	150	43	440
				67	4- 8-81	1170	160	20	440

Table 4.--Partial chemical analyses of water from wells in the Rayville-Delhi area, Louisiana--Continued

Well No.	Location Sec.	T. (N.)	R. (E.)	Depth of well, total (feet)	Date of sample	Specific conductance (µS/cm)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Hardness (mg/L as CaCO3)
Richland Parish									
Mississippi River Alluvial Aquifer									
Ri-111	23	17	9	67	4- 1-69	----	250	----	370
				67	9-19-69	----	250	----	390
				67	3-26-70	----	210	----	360
				67	6-30-70	----	200	----	----
				67	11-30-70	----	200	----	370
				67	1-28-71	----	190	----	380
				67	6-25-71	----	220	----	430
				67	9-14-71	----	220	----	420
				67	1-28-72	----	250	----	450
				67	5-25-72	----	300	----	----
				67	9- 7-72	----	300	----	440
				67	12- 5-72	----	290	----	----
				67	3-20-73	----	260	----	410
				67	5-31-73	----	270	----	420
				67	10-29-73	----	270	----	430
				67	5-21-75	----	260	----	----
				67	8- 6-75	----	270	----	390
				67	2-20-76	----	220	----	380
				67	8-24-76	----	210	----	380
				67	1- 4-77	----	220	----	380
				67	5-19-77	----	230	----	400
				67	12- 7-77	----	200	35	450
				67	5-26-78	1500	240	----	410
				67	12- 1-78	1410	190	----	400
				67	4- 9-79	----	180	----	390
				67	8-20-79	----	160	----	400
				67	3- 5-80	----	170	32	410
				67	9- 9-80	----	160	----	410
				67	4- 8-81	1300	160	36	400
				67	9-22-81	1360	170	37	400
				67	4-26-82	1360	190	38	400
				67	9-22-82	----	160	----	----
				67	4-26-83	----	160	29	420
				67	8-31-83	----	150	----	380
Ri-112	24	17	9	67	4- 1-69	----	230	----	490
				67	9-19-69	----	230	----	500
				67	3-26-70	----	270	----	550
				67	6- 3-70	----	240	----	----

Table 4.--Partial chemical analyses of water from wells in the Rayville-Delhi area, Louisiana--Continued

Well No.	Location Sec.	T. (N.)	R. (E.)	Depth of well, total (feet)	Date of sample	Specific conductance (µS/cm)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Hardness (mg/L as CaCO3)
Richland Parish									
Mississippi River Alluvial Aquifer									
Ri-112	24	17	9	67	11-30-70	----	320	----	580
				67	1-28-71	----	360	----	660
				67	6-25-71	----	480	----	770
				67	9-14-71	----	540	----	850
				67	1-28-72	----	640	----	970
				67	5-25-72	----	700	----	----
				67	9- 7-72	----	800	----	1100
				67	12- 5-72	----	840	----	----
				67	10-29-73	----	890	----	1100
				67	9-20-74	----	980	----	1000
				67	5-21-75	----	800	----	----
				67	8- 6-75	----	860	----	650
				67	2-20-76	----	280	----	550
				67	8-24-76	----	850	----	750
				67	1- 4-77	----	840	----	740
				67	5-19-77	----	860	----	700
				67	5-26-78	3050	800	----	650
				67	12- 1-78	2860	680	----	600
				67	4- 9-79	----	620	----	550
				67	8-20-79	----	610	----	530
				67	3- 5-80	----	530	15	440
				67	9- 9-80	----	540	----	410
				67	4- 8-81	2270	520	8.8	400
				67	9-22-81	2140	470	10	350
				67	4-26-82	1810	420	9.8	300
				67	9-22-82	----	390	----	----
Ri-113	24	17	9	67	9-19-69	----	190	----	470
				67	3-26-70	----	190	----	480
				67	6- 3-70	----	210	----	----
				67	11-30-70	----	210	----	490
				67	1-28-71	----	210	----	490
				67	6-25-71	----	210	----	500
				67	9-14-71	----	210	----	500
				67	1-28-72	----	220	----	510
				67	5-25-72	----	230	----	----
				67	9- 7-72	----	230	----	470
				67	12- 5-72	----	240	----	----
				67	10-29-73	----	340	----	650

Table 4.--Partial chemical analyses of water from wells in the Rayville-Delhi area, Louisiana--Continued

Well No.	Location Sec.	T. (N.)	R. (E.)	Depth of well, total (feet)	Date of sample	Specific conductance (µS/cm)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Hardness (mg/L as CaCO3)
Richland Parish									
Mississippi River Alluvial Aquifer									
Ri-113	24	17	9	67	5-21-75	----	260	----	----
				67	8- 6-75	----	270	----	520
				67	2-20-76	----	280	----	550
				67	8-24-76	----	300	----	580
				67	1- 4-77	----	340	----	580
				67	5-19-77	----	350	----	630
				67	12- 7-77	----	380	14	490
				67	5-26-78	1950	420	----	680
Ri-114	24	17	9	66	6-22-72	3630	1000	.4	550
				66	9- 7-72	----	870	----	540
				66	12- 5-72	----	980	----	----
				66	10-29-73	----	1100	----	620
				66	9-20-74	----	880	----	880
				66	5-21-75	----	730	----	----
				66	8- 6-75	----	790	----	970
				66	2-20-76	----	630	----	820
				66	8-24-76	----	840	----	800
				66	1- 4-77	----	940	----	540
				66	5-19-77	----	1100	----	540
				66	12- 7-77	----	1000	9.2	430
				66	5-26-78	3940	1100	----	610
				66	12- 1-78	4070	1100	----	520
				66	4- 9-79	----	960	----	460
				66	8-20-79	----	730	----	390
				66	3- 5-80	----	780	11	360
				66	9- 9-80	----	770	----	450
				66	4- 8-81	2720	730	12	350
				66	9-22-81	2150	540	10	340
				66	4-26-82	1590	360	16	290
				66	9-22-82	----	250	----	----
				66	4-26-83	----	170	14	250
				66	8-31-83	----	140	----	240
Ri-124	25	17	9	84	9-20-74	----	150	----	490
				84	5-21-75	----	170	----	----
				84	8- 7-75	----	180	----	500
				84	2-20-76	----	160	----	480
				84	8-24-76	----	150	----	480

Table 4.--Partial chemical analyses of water from wells in the Rayville-Delhi area, Louisiana--Continued

Well No.	Location			Depth of well, total (feet)	Date of sample	Specific conductance (µS/cm)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Hardness (mg/L as CaCO3)
	Sec.	T. (N.)	R. (E.)						
Richland Parish									
Mississippi River Alluvial Aquifer									
Ri-124	25	17	9	84	1- 4-77	----	150	----	480
				84	5-19-77	----	160	----	500
				84	12- 7-77	----	140	25	460
				84	5-26-78	1220	160	----	480
				84	12- 1-78	1230	150	----	470
				84	4- 9-79	----	150	----	490
				84	8-20-79	----	180	----	520
				84	3- 5-80	----	180	23	530
				84	9- 9-80	----	200	----	550
				84	4- 8-81	1570	270	24	630
				84	9-22-81	1440	210	23	560
				84	4-26-82	1300	190	22	510
				84	9-22-82	----	220	----	----
				84	8-31-83	----	280	----	590
Ri-260	26	17	9	70	4-26-82	1700	340	----	540
				70	9-22-82	----	360	----	----
				70	4-26-83	----	350	27	580
				70	8-31-83	----	300	----	500
Richland Parish									
Cockfield Aquifer									
Ri-51	31	17	10	645	10-26-63	----	10000	----	580
Ri-53	7	18	8	293	10- 8-64	----	16	----	140
				293	9- 8-69	440	7.0	1.6	160
Ri-54	5	17	7	189	1-21-65	----	44	----	150
Ri-98	13	17	9	160	7-24-70	----	100	----	40
				160	7-30-70	----	100	----	46
Ri-107	3	17	7	210	1-28-72	----	48	----	220

Table 4.--Partial chemical analyses of water from wells in the Rayville-Delhi area, Louisiana--Continued

Well No.	Location Sec.	T. (N.)	R. (E.)	Depth of well, total (feet)	Date of sample	Specific conductance (µS/cm)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO4)	Hardness (mg/L as CaCO3)
					Richland Parish				
					Sparta Aquifer				
Ri-16	4	17	7	562	6-11-51	----	1300	----	14
				562	8-14-51	----	630	----	----
					Morehouse Parish				
					Sparta Aquifer				
Mo-163	20	18	6	624	12- 6-63	----	370	----	8
				624	8- 1-67	1950	400	----	6

thickness of the Cockfield in the project area ranges from about 20 ft to about 500-600 ft and increases from west to east. The entire thickness of the unit occurs south and southeast of Delhi. West of Delhi, the Cockfield has been truncated and overlapped by Quaternary deposits (pl. 3). The base of the aquifer ranges from about 100 to about 750 ft below sea level (pl. 3). Water levels are generally within 25 ft of the land surface (12 to 28 ft below land surface, on the basis of available records).

The abundance of clays and silts interlayered with the sand units influences the hydraulic characteristics of the aquifer. Sand percentages range from 20 to 70 percent. Hydraulic conductivity of the sand ranges from 30 to 55 ft/d. Because total sand thickness may be relatively low, transmissivity ranges from about 800 to 12,000 ft^2/d. Determination of these values was based on examination of aquifer tests of the Cockfield in Morehouse, East Carroll, and West Carroll Parishes.

The Cockfield is the most extensively used aquifer in the Rayville-Delhi area for nonagricultural purposes. Total withdrawals are small, about 1.5 Mgal/d in 1980. Large wells screened in the Cockfield aquifer can yield several hundred gallons of water per minute, but most wells are for domestic use and yield about 20 gal/min or less.

Recharge to the Cockfield aquifer in the project area primarily is from water infiltrating downward from the Mississippi River alluvial aquifer where sand units of the Cockfield are in contact with the alluvial aquifer. The water moves downgradient (generally to the east and southeast) in each sand unit and subsequently moves upward through overlying confining layers and is discharged to the alluvial aquifer.

Water from the Cockfield aquifer generally is a mixed calcium-sodium-bicarbonate type. Locally, magnesium can be a codominant cation and chloride can be a codominant anion. The water ranges from soft to very hard; the zones of hard water probably are caused by infiltration of very hard water from the overlying alluvial aquifer. Dissolved-solids concentrations range from 238 to 1,270 mg/L, and the mean concentration is 521 mg/L. Locally, color and concentrations of chloride and iron can be high and may exceed the U.S. Environmental Protection Agency (1976a) limits for drinking water. Therefore, treatment may be necessary for the water to be satisfactory for some uses. In other places, the water is suitable for use without treatment. Chemical analyses of water from wells in the Cockfield aquifer are summarized in table 5 and presented in tables 3 and 4.

The lower part of the Cockfield aquifer contains salty water in much of the Rayville-Delhi area. In the eastern part of the area, all water in the aquifer is salty.

Table 5.--Summary of selected physical and dissolved-chemical constituents of water from the Cockfield aquifer, northeastern Louisiana

[µS/cm, microsiemens per centimeter; mg/L, milligram per liter; µg/L, microgram per liter; $CaCO_3$, calcium carbonate; N, nitrogen; NO_3, nitrate]

Constituent	Number of samples analyzed	Range	Recommended limits[a]
pH (units)	15	6.9 - 8.3	6.5-8.5
Color (platinum-cobalt units)	21	0 - 90	75
Temperature	9	19.5- 22.0°C 67.0- 72.0°F	----------
Specific conductance (µS/cm at 25°C)	23	390 -2290	----------
Calcium (mg/L)	23	1.0- 64	----------
Magnesium (mg/L)	23	.1- 21	----------
Potassium (mg/L)	22	1.1- 6.0	----------
Sodium (mg/L)	22	32 - 470	----------
Bicarbonate (mg/L)	21	240 - 577	----------
Chloride (mg/L)	30	7.0- 480	250 mg/L
Fluoride (mg/L)	24	.1- .5	[b]1.8 mg/L
Sulfate (mg/L)	24	0 - 23	250 mg/L
Nitrate as N (mg/L)	3	0 - .07	10 mg/L
Nitrate as NO_3 (mg/L)	9	0 - .31	----------
Dissolved solids (mg/L)	21	238 -1270	500 mg/L
Hardness (mg/L as $CaCO_3$)	29	2 - 580	----------
Iron (µg/L)	17	20 - 770	300 µg/L
Manganese (µg/L)	21	10 - 920	50 µg/L

[a] U.S. Environmental Protection Agency, 1976a.
[b] U.S. Environmental Protection Agency, 1976b.

Sparta Aquifer

The deepest occurrence of freshwater in the Rayville-Delhi area is in the Sparta Sand, which comprises the Sparta aquifer. However, freshwater occurs in the Sparta only in the western part of the area. To the east and southeast, water in the Sparta becomes increasingly salty. The Sparta aquifer underlies the Cook Mountain confining bed (table 1 and figs. 2 and 3) and consists of interbedded sand, silt, and clay. Individual sand units are laterally discontinuous and occur at varying depth intervals throughout the entire unit. However, the sand units are interconnected and generally are considered to form a single aquifer. Thickness of the individual sand units ranges from a few feet to several tens of feet. The maximum thickness of the Sparta section in the project area is about 700 ft. The base of the Sparta ranges from 800 to about 1,200 ft below sea level.

Physical characteristics of the aquifer, such as the discontinuous sand beds and the size and sorting of the sand, influence the hydraulic characteristics. Hydraulic conductivity of the Sparta aquifer ranges from 30 to about 100 ft/d and averages about 40 ft/d in the project area. Transmissivity averages about 13,400 ft^2/d.

Very few wells tap the Sparta aquifer in the Rayville-Delhi area; however, the aquifer is heavily developed to the north in Morehouse Parish and to the west in Ouachita Parish. Large wells in the adjacent parishes yield from several hundred to nearly 2,000 gal/min. A few domestic wells in the project area yield about 5 to 15 gal/min. Withdrawals at centers of concentrated pumping in Bastrop and Monroe to the edge of the study area have created large cones of depression in the potentiometric surface. As a result, water levels have been lowered about 100 ft in the western part of the Rayville-Delhi area. Originally, water moved from the outcrop area to the discharge area in Ouachita, Morehouse, and Richland Parishes. Now water in the Sparta aquifer in Richland Parish moves toward these centers of pumping.

Freshwater in the Sparta is a soft, sodium-bicarbonate type. Where salty, the water is a sodium-chloride type. In some places, the water may be used without treatment. Sanford (1973) indicated that high fluoride, dissolved solids, hydrogen sulfide, and color in some areas in Morehouse Parish would inhibit development of water from the Sparta Sand as a public-supply source. Only two chemical analyses are available of water from the Sparta aquifer in the project area and one of these is in the saltwater zone (well Ri-16 is not in use). Based on analyses from Ouachita Parish, (Rogers and others, 1972), water quality varies areally and with depth.

The proximity of salty water in the Sparta in Richland Parish restricts development of large yield wells in the freshwater-bearing area. Large pumping rates would induce flow of salty water toward a well. Movement in response to smaller yields would be much slower and result in a much longer period of use before deterioration of water quality might force abandonment.

PRESENT AND POTENTIAL DEVELOPMENT

Seven public-supply systems serve the Rayville-Delhi area. The Mississippi River alluvial aquifer is the source of water for one of these systems and Cockfield aquifer is the source for the remaining six. Data for the seven systems and corresponding public-supply wells are presented in tables 6 and 7. Selected test-hole data are presented in table 8.

Supplies could be developed from the Mississippi River alluvial aquifer in most of the Rayville-Delhi area. Existing public-supply wells yield as much as 2,000 gal/min, and wells of similar capacity can be developed in much of the area. As further indication of the yield potential, existing irrigation wells yield as much as 7,000 gal/min. Future development of supplies from the alluvial aquifer for some uses may be retarded because water from the aquifer is very hard and has high concentrations of iron and dissolved solids. Treatment would be required for the water to be satisfactory for some uses.

Table 6.--Public water-supply systems in the Rayville-Delhi area, Louisiana

[Aquifer: CCKF, Cockfield; MRVA, Mississippi River alluvial. Mgal/d, million gallons per day]

Name of user	Population served	Well No.	Aquifer	Average daily pumping rate, 1980 (Mgal/d)
Bayou Macon Water Supply--	800	(1)	CCKF	----
Town of Delhi----------	4000	Ri-126 Ri-127	CCKF	0.37 .42
East Richland Water Works-	900	(1)	CCKF	----
Town of Rayville----------	5000	Ri-15 Ri-48 Ri-183	MRVA	.58
River Road Water System---	1500	Ri-250 Ri-322	CCKF	.20
Village of Start----------	800	Ri-90 Ri-246	CCKF	.04 .07
Walnut Bayou Water System-	300	Ri-226 Ri-227	CCKF	.03

[1] Purchase water from town of Delhi.

Table 7.--Description of selected public-supply wells in the Rayville-Delhi area, Louisiana

[Principal aquifer: CCKF, Cockfield; MRVA, Mississippi River alluvial]

Well No.	Owner	Location			Date completed	Depth of well (feet)	Principal aquifer	Depth to first opening (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)
		Sec.	T. (N.)	R. (E.)							
					RICHLAND PARISH						
Ri-15	Town of Rayville---	4	17	7	6- -53	80	112MRVA	40	17.50	6- -53	600
Ri-48	-----do----------	9	17	7	6- -61	115	112MRVA	75	30.00	6- -61	2000
Ri-90	Village of Start---	4	17	6	1969	188	124CCKF	142	12.36	8- 5-69	206
Ri-126	Town of Delhi------	13	18	9	5- 1-73	426	124CCKF	351	26.70	5-30-73	600
Ri-127	-----do----------	13	18	9	2-28-73	416	124CCKF	341	18.10	3- 8-73	602
Ri-183	Town of Rayville---	4	17	7	1973	112	112MRVA	80	18.00	9-15-73	1200
Ri-226	Walnut Bayou Water System.	1	18	9	1-10-80	450	124CCKF	402	28.00	1-10-80	500
Ri-227	-----do----------	1	18	9	3-10-80	434	124CCKF	394	26.00	3-10-80	500
Ri-246	Village of Start---	4	17	6	12-10-80	190	124CCKF	150	16.00	12-10-80	220
Ri-250	River Road Water System.	26	18	7	7-10-81	283	124CCKF	241	23.00	7-28-81	300
Ri-322	-----do----------	8	18	9	3- 2-83	390	124CCKF	330	24.00	3- 2-83	250

The potential for development in the Cockfield aquifer is variable because of areal variations in aquifer thickness and variations in water quality. Within the -300-foot contour line that defines the base of freshwater (pl. 2) north of Holly Ridge and Delhi, the greatest thickness of aquifer is available for development; however, thick sand units do not occur in all of this area. Other areas may have good potential because, even though less total thickness of formation is available, thick individual sand units may occur. One of these areas is in the vicinity of well Ri-88, less than 2 mi northeast of Rayville (pl. 1). In the western part of the study area, the aquifer thickness is from less than 100 ft to about 250 ft. All sand units contain freshwater and individual units can exceed 100 ft in thickness. In the eastern part of the area near Delhi, the Cockfield aquifer does not contain significant amounts of freshwater. Here, the aquifer contains only salty water except for thin sand beds in the upper part of the formation; therefore, the potential is small. Freshwater, however, is found to the north and west of Delhi in the upper part of the Cockfield. The thickness of the freshwater zone increases in these directions to about 100 ft.

Properly constructed and developed wells could yield 100-300 gal/min where sand beds are greater than 30 ft thick. Where sand beds are more than 100 ft thick, yields up to 500 gal/min may be obtainable.

Where the Cockfield aquifer is in contact with the overlying alluvial aquifer, water in the Cockfield generally is hard and high in iron concentrations. In the western part of the Rayville-Delhi area, hardness ranges from moderately hard to hard, and iron concentrations may exceed

Table 8.--Selected data from test holes in the Rayville-Delhi area, Louisiana

[Owner: LOPW, Louisiana Office of Public Works; USGS, U.S. Geological Survey. Principal aquifer: CCKF, Cockfield; MRVA, Mississippi River alluvial; SPRT, Sparta. Data available: C, chemical analysis; D, driller's or geologist's log; E, electrical log; MA, mechanical analysis of sand samples; PT, pumping test; S, sand samples]

Well No.	Owner	Location			Date completed	Depth drilled (feet)	Depth of well (feet)	Principal aquifer	Depth to first opening (feet)	Depth to base of freshwater (feet)	Water level (feet)	Date water level measured	Data available
		Sec.	T. (N.)	R. (E.)									
Richland Parish													
Ri-56	LOPW	4	17	6	2-14-67	824	190	124CCKF	180	345	18.27	2-14-67	C, D, E, MA, PT, S.
Ri-57	LOPW	33	18	6	11-28-66	640	183	124CCKF	168	188	16.42	11-29-66	C, D, E, MA, PT, S.
Ri-58	LOPW	6	17	6	7-25-67	813	---	-------	---	360	-----	--------	D, E, S.
Ri-59	LOPW	20	18	6	8-18-67	822	182	124CCKF	167	192	15.75	8-18-67	C, D, E, MA, PT, S.
Ri-88	USGS	34	18	7	8-27-69	349	239	124CCKF	228	276	20.13	8-27-69	C, D, E, MA, PT, S.
Ri-89	USGS	26	18	7	9- 9-69	365	300	124CCKF	290	338	21.23	9-10-69	C, D, E, MA, S.
Ri-91	USGS	16	17	7	12- 5-69	347	180	124CCKF	170	209	13.54	12-13-69	C, D, E, MA, S.
Ri-92	USGS	16	17	7	12- 5-69	163	153	112MRVA	143	209	13.54	12-13-69	C, D, PT, S.
Ri-93A	USGS	10	17	8	6-12-70	444	239	124CCKF	229	320	16.32	6-15-70	C, D, E, MA, S.
Ri-93B	USGS	10	17	8	6- -70	444	411	124CCKF	401	320	18.73	6- 6-70	C, D, E, MA, S.
Ri-94	USGS	15	18	8	6-19-70	438	345	124CCKF	335	372	14.07	6-24-70	C, D, E, MA, S.
Ri-95A	USGS	13	18	9	6-26-70	482	200	124CCKF	190	469	25.41	7- 1-70	C, D, E, MA, S.
Ri-95B	USGS	13	18	9	6-26-70	482	420	124CCKF	410	469	25.85	6-29-70	C, D, E, MA, S.
Ri-96	USGS	36	18	9	7- 2-70	526	170	124CCKF	160	172	17.31	7- 6-70	C, D, E, MA, S.
Ri-97	USGS	7	17	9	7-16-70	437	239	124CCKF	229	266	17.02	7-20-70	C, D, E, MA, S.
Ri-98	USGS	13	17	9	7- -70	460	160	124CCKF	150	160	17.00	7- -70	D, E, MA, S.
Ri-99	USGS	18	17	10	7- -70	339	---	-------	---	102	-----	--------	D, E, S.
Ri-100	USGS	3	17	9	1970	508	---	-------	---	152	-----	--------	D, E, S.
Ri-101	USGS	15	17	9	1970	281	---	-------	---	147	-----	--------	D, E, S.
Ri-102	LOPW	17	16	7	8-26-70	297	150	112MRVA	140	186	21.51	8-26-70	C, D, E, MA, PT, S.
Ri-104	LOPW	33	17	7	9-16-70	288	189	124CCKF	179	247	17.88	9-16-70	C, D, E, MA, PT, S.
Ri-106	LOPW	12	18	9	11- -71	523	420	124CCKF	400	432	25.23	11- 2-71	C, D, E, MA, PT, S.
Ri-108	LOPW	26	18	9	3-16-72	522	440	124CCKF	420	450	23.08	3-17-72	C, D, E, MA, PT, S.
Ri-210	LOPW	1	18	8	2-27-80	402	---	-------	---	241	-----	--------	D, E, S.
Ri-211	LOPW	8	18	9	3-25-80	424	419	124CCKF	399	416	19.60	3-25-80	C, D, E, MA, PT, S.
Ri-228A	LOPW	4	17	7	6- 9-81	260	110	112MRVA	90	212	17.10	6- 9-81	C, D, E, MA, PT, S.
Ri-228B	LOPW	4	17	7	6- 4-81	260	185	124CCKF	165	212	17.01	6- 4-81	C, D, E, MA, PT, S.
Madison Parish													
Ma-52	LOPW	29	18	10	10- 1-71	424	---	112MRVA	---	135	-----	--------	D, E, S.

recommended limits for drinking water. In the eastern part of the Rayville-Delhi area, water in the upper part of the aquifer is very hard and relatively high in iron. Water in the lower part of the Cockfield aquifer is very soft and low in iron. A comparison of analyses of water from test wells Ri-95A (200-ft deep) and Ri-95B (420-ft deep) (table 3) indicates the influence of the alluvial aquifer on the water quality in the Cockfield aquifer. Water from the shallower well had a hardness of 240 mg/L, whereas, water from the deeper well had a hardness of only 8 mg/L.

SUMMARY

The Rayville-Delhi area has abundant supplies of fresh ground water available for development in the Mississippi River alluvial and Cockfield aquifers. Wells screened in the alluvial aquifer can yield several thousand gallons per minute. The water is very hard and high in iron concentration and would require treatment for most uses. Wells screened in the Cockfield aquifer can yield several hundred gallons per minute in areas where thick sand beds occur, as in the area northeast of Rayville and northwest of Delhi. Water in the Cockfield aquifer varies in quality, depending upon the degree of influence of water from the overlying alluvial aquifer. In areas where water moves from the alluvial aquifer to the Cockfield, water in the upper part of the Cockfield generally is hard and contains high iron concentrations. Where the alluvial aquifer has little or no influence on water quality in the Cockfield, the water in the Cockfield generally is soft and has low concentrations of iron and dissolved solids. The Sparta sand contains fresh water only along the western edge of the area and is of minor importance as a source of water.

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