TEXAS WATER DEVELOPMENT BOARD

REPORT 72

GROUND-WATER RESOURCES OF LIBERTY COUNTY, TEXAS

By

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United States Geological Survey

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GROUND-WATER RESOURCES OF LIBERTY COUNTY, TEXAS

ABSTRACT

Liberty County is in the Coastal Plain of southeastern Texas adjacent to the Houston metropolitan area.

The aquifers in Liberty County contain large quantities of fresh water that extend to depths as great as 1,800 feet below sea level. The development of the county's ground-water resources resulted primarily from the increased use of ground water for rice irrigation. In 1965, an estimated 51.2 mgd (million gallons per day) of ground water was used in the county; 48.9 mgd (54,814 acre-feet), about 95 percent of the total, was used to irrigate about 18,400 acres of rice; and 1.6 mgd, about 3 percent of the total, was used for public supply. During the same year, an estimated 55,000 acre-feet of water was pumped from the Trinity River for the irrigation of an additional 18,400 acres of rice. Ground-water use can be increased to about 200 mgd if most of the development is restricted to the northern and central parts of the county. This estimate is based on a preliminary appraisal of the ground-water resources and is subject to revision as more data become available. However, this estimate is in agreement with data from the adjacent Houston district, where under similar ground-water conditions, about 400 mgd is being used.

The rocks that contain fresh water (less than 1,000 parts per million of dissolved solids) crop out across Liberty County and adjacent San Jacinto and Polk Counties in belts that are nearly parallel to the shoreline of the Gulf of Mexico. These rocks, which are composed primarily of sand, silt, and clay, with smaller amounts of gravel and calcareous material, dip gently toward the Gulf. According to their hydrologic properties, these rocks are divided into four units: the Jasper aquifer, the Burkeville aquiclude, the Evangeline aquifer, and the Chicot aquifer. The Evangeline and Chicot have supplied almost all of the ground water used in Liberty County. About 60 percent of the ground water used in 1965 was obtained from the Evangeline; about 40 percent from the Chicot; and less than 1 percent from the Jasper. The Evangeline and Chicot also have the greatest potential for future development.

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L I B E R T Y   C O U N T Y ,   T E X A S

INTRODUCTION

Location and Extent of the Area

Liberty County is in southeastern Texas in the West Gulf Coastal Plain (Fenneman, 1938), about 25 to 40 miles from the Gulf of Mexico. It is bordered on the west by Harris and Montgomery Counties, on the north by San Jacinto and Polk Counties, on the east by Hardin and Jefferson Counties, and on the south by Chambers County (Figure 1).

Liberty, the county seat, is 30 miles northeast of Houston and 40 miles west of Beaumont. The area of the county is 1,173 square miles.

Purpose and Scope of the Investigation

The investigation of the ground-water resources of Liberty County was a cooperative project of the Texas Water Development Board and the U.S. Geological Survey. Fieldwork was begun in March 1965 and continued until March 1966. The purpose of the investigation was to determine the occurrence, availability, dependability, quality, and quantity of the ground-water resources of the county suitable for public supply, irrigation, and industrial use. This report presents information and data that can be used in obtaining optimum benefits from available ground-water supplies. It also includes an analytical discussion of the hydrology as it relates to the occurrence and availability of ground water.

The investigation included: determination of the extent of the sands containing fresh water (less than 1,000 parts per million dissolved solids) and the sands containing slightly saline water (from 1,000 to 3,000 parts per million dissolved solids); a study of the chemical quality of the water; estimates of the quantities of water being withdrawn and a study of the effect of these withdrawals on water levels; determination of the hydraulic characteristics of the water-bearing sands; and estimates of the quantities of ground water available for development.

The investigation also included consideration of measures necessary for the protection of fresh ground water from contamination and a study of the problem of land-surface subsidence as a consequence of ground-water withdrawals. The establishment of a continuing observation program for collecting ground-water data is recommended.

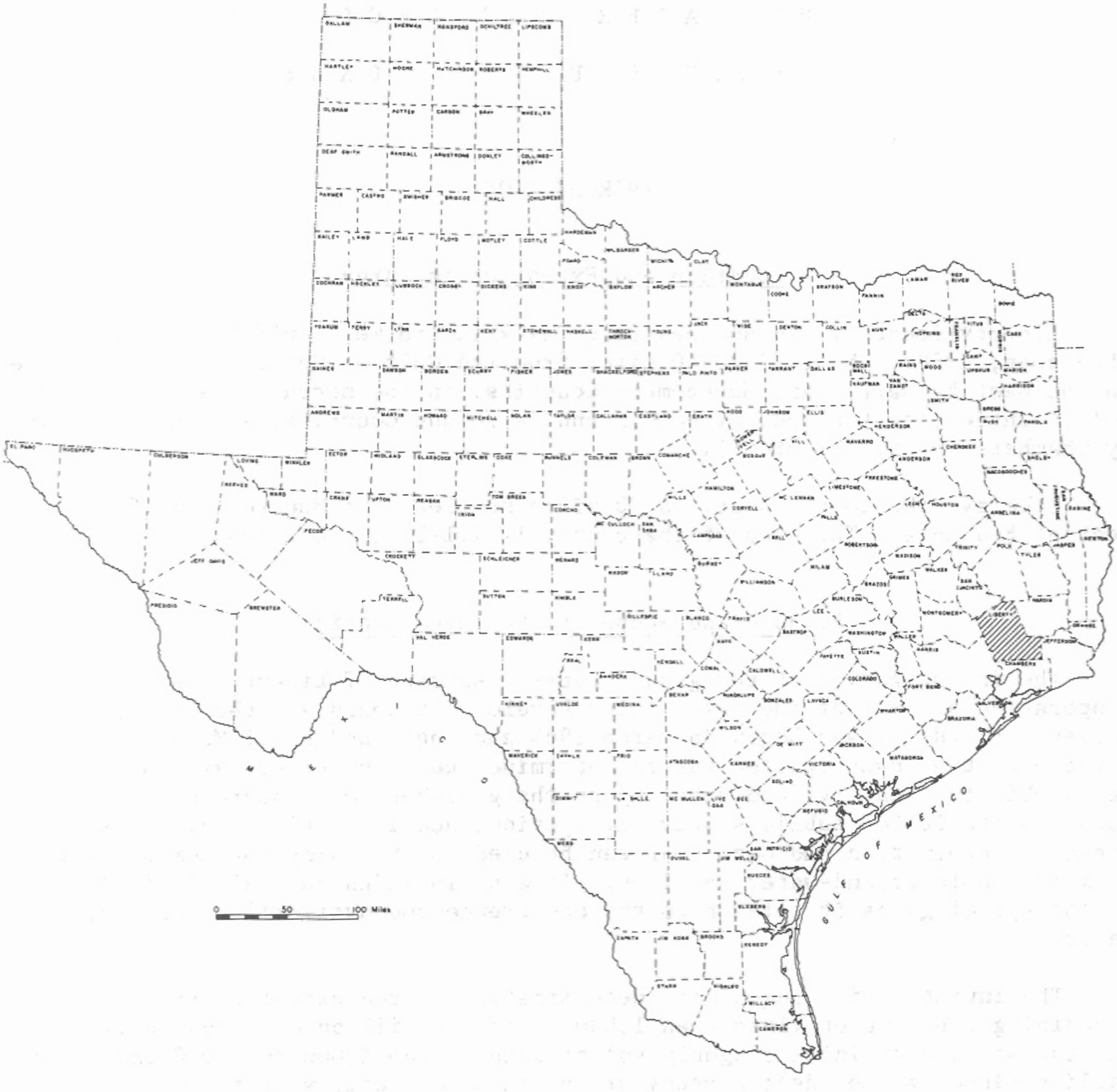

Figure 1
Location of Liberty County
U.S. Geological Survey in cooperation with the Texas Water Development Board

Methods of Investigation

The following items were included in the investigation of the ground-water resources of Liberty County:

1. An inventory was made of 3 springs and 343 water wells, including all public supply, irrigation, and industrial wells, and a representative number of domestic and livestock wells (Table 5). The locations of the springs and wells are shown on Figure 17.

2. The electric logs of 86 oil tests (Table 5) in Liberty County were used for correlation and evaluation of the water-bearing properties of the aquifers. The locations of the oil tests are shown on Figure 17. In addition, drillers' logs of water wells (Table 6) were used as an aid in determining the total thicknesses of sands containing fresh and slightly saline water.

3. An inventory was made of the withdrawals of ground water for public supply, irrigation, and industrial uses.

4. Pumping tests were run in 10 wells to determine the hydraulic characteristics of the water-bearing sands (Table 3).

5. Altitudes of water wells were determined from topographic maps.

6. Measurements of water levels were made in wells, and available records of past fluctuations of water levels were compiled (Tables 5 and 7, Figure 10).

7. Climatological records were collected and compiled (Figure 2), and records of streamflow were analyzed.

8. Analyses of 191 water samples collected from wells and springs during this and previous investigations were used to determine the chemical quality of the water (Table 8).

9. Maps, cross sections, and graphs were prepared to correlate and illustrate geologic and hydrologic data.

10. The hydrologic data were analyzed to determine the quantity and quality of ground water available for development.

11. Data were compiled on the subsidence of the land surface.

12. Problems related to the development and protection of the ground-water supplies in Liberty County were studied.

Related Investigations

Related water-resources investigations are mentioned in this report because the Trinity River supplies about half of the water for rice irrigation and most of the water used by industry in Liberty County. In 1965, an estimated 55,000 acre-feet of water was pumped from the Trinity River to irrigate rice, and about 6,500 acre-feet was used in the production of sulphur.

Stream-gaging stations are maintained at four localities in Liberty County: Trinity River at Romayor, Trinity River at Liberty, East Fork San Jacinto River near Cleveland, and Menard Creek near Rye (Figure 17); partial records are obtained for the Trinity River near Moss Hill, about 12 miles north of Liberty, and Tarkington Bayou near Dayton. The Trinity River drains an area of 17,186 square miles above the gaging station at Romayor. The average annual discharge of the Trinity at Romayor for a 41-year period was 5,166,000 acre-feet; the discharge for the water year 1964-65 was 5,308,000 acre-feet (U.S. Geological Survey, 1965, p. 186).

One water-quality station is maintained in Liberty County at the stream-gaging station on the Trinity River at Romayor (Figure 17), and partial water-quality records are obtained at the stations on Menard Creek near Rye and East Fork San Jacinto River near Cleveland. Water-quality records are available for short periods during the summers of 1946 to 1949, and daily from October 1949 to September 1965 at a location on the Trinity River about 4 miles north of the southern boundary of the county. The good chemical quality of the water at Romayor is indicated by the analyses of daily samples collected during the water year October 1963 to September 1964 (U.S. Geological Survey, 1964, p. 59-60). The time-weighted averages of some of the constituents, in ppm (parts per million), were as follows: sodium, 109; bicarbonate, 145; sulfate, 73; chloride, 131; dissolved solids, 448; and hardness, 137. Daily measurements of the temperature of the water ranged from 40°F in December 1963 to 93°F in July 1964.

Previous Investigations

Taylor (1907, p. 43-44) included nine wells in Liberty County in his report on the underground waters of the Coastal Plain of Texas. Deussen (1914, p. 290-300) included the records of 33 wells in Liberty County in his reconnaissance report on the geology and underground waters of the southeastern part of the Texas Coastal Plain.

Sundstrom, Hastings, and Broadhurst (1948, p. 197-200) published data on the public-supply wells at Cleveland, Daisetta, Dayton, and Liberty. The report on the ground-water resources of Liberty County by Alexander (1950), with a section on stream runoff by S. D. Breeding, included data on 248 wells and springs, drillers' logs, chemical analyses of 145 water samples, and an inventory of the use of ground water.

Liberty County is in the areas included in three reports on the availability of ground water in the Gulf Coast region of Texas--the first report by Wood, (1956), the second by Wood, Gabrysch, and Marvin (1963), and the third by Peckham, Souders, Dillard, and Baker (1963). Records of water levels in observation wells in Liberty County from 1943 through April 1958 were compiled by Rayner (1959, p. 12-22).

Economic Development

The economy of Liberty County is based on agriculture, lumbering, and the production of oil, natural gas, and sulphur. Ground water supplies all the water for municipal and domestic uses, most of the water for livestock use, about half of the water for rice irrigation, and some of the water for industrial use; the remainder of the water used for rice irrigation and industry is obtained from the Trinity River. The population of Liberty County in 1960 was 31,595; the populations of the cities and larger towns were: Liberty, 6,127; Cleveland, 6,050; Dayton, 3,367; Daisetta, 1,500; Hull, 1,500; Devers, 260; and Raywood, 200.

Rice is the principal crop; other crops include corn, grain sorghum, and vegetables. One-third of the total farm income is from beef cattle, dairying, and poultry production. The production of lumber has been an important industry for more than 60 years, especially in the northern part of the county. Oil was discovered in 1905, and by the end of 1960, the total production was 309,981,511 barrels.

Liberty County is served by the Southern Pacific, Missouri Pacific, and Santa Fe Railroads; and by a network of Federal and State highways.

Topography and Drainage

The topography of Liberty County consists of two flat to gently rolling upland surfaces that are separated by the broad valley of the Trinity River. The Trinity River traverses the county from north to south in a valley from 4 to 8 miles wide. The Trinity and its tributaries drain about half of the county. The northwestern part of the county is drained by the East Fork San Jacinto River and its tributary Luce Bayou; the easternmost part is drained by the tributaries of the West Fork of Pine Island Bayou, a tributary of the Neches River. The extreme southwestern and southeastern parts of the county are drained by small coastal streams.

The altitude of the flood plain of the Trinity River ranges from 5 feet above sea level at the southern boundary of the county to about 60 feet at the northern boundary. The altitude of the uplands ranges from 30 feet along the southern boundary of the county to 180 feet in the northwestern corner. The bluffs, which rise from 30 to 60 feet above the flood plain, are more prominent on the western side of the Trinity valley. The highest altitude in the county is 261 feet at Davis Hill, about 15 miles east of Cleveland.

Climate

The climate in Liberty County is warm and humid. The normal annual temperature is 69°F, and the normal annual precipitation ranges from 52 inches in the southeast to 48 inches in the northwest. The precipitation is fairly well distributed throughout the year (Figure 2).

Temperatures below freezing occur on the average of 22 days per year. The approximate dates of the first and last killing frosts are November 23 and March 7, respectively. The growing season is about 261 days.

The average monthly gross lake surface evaporation rates in Liberty County during the period 1940-57 ranged from 2.1 inches in February to 5.8 inches in August; the average annual rate during the same period was 45.8 inches (Lowry, 1960, table G-13).

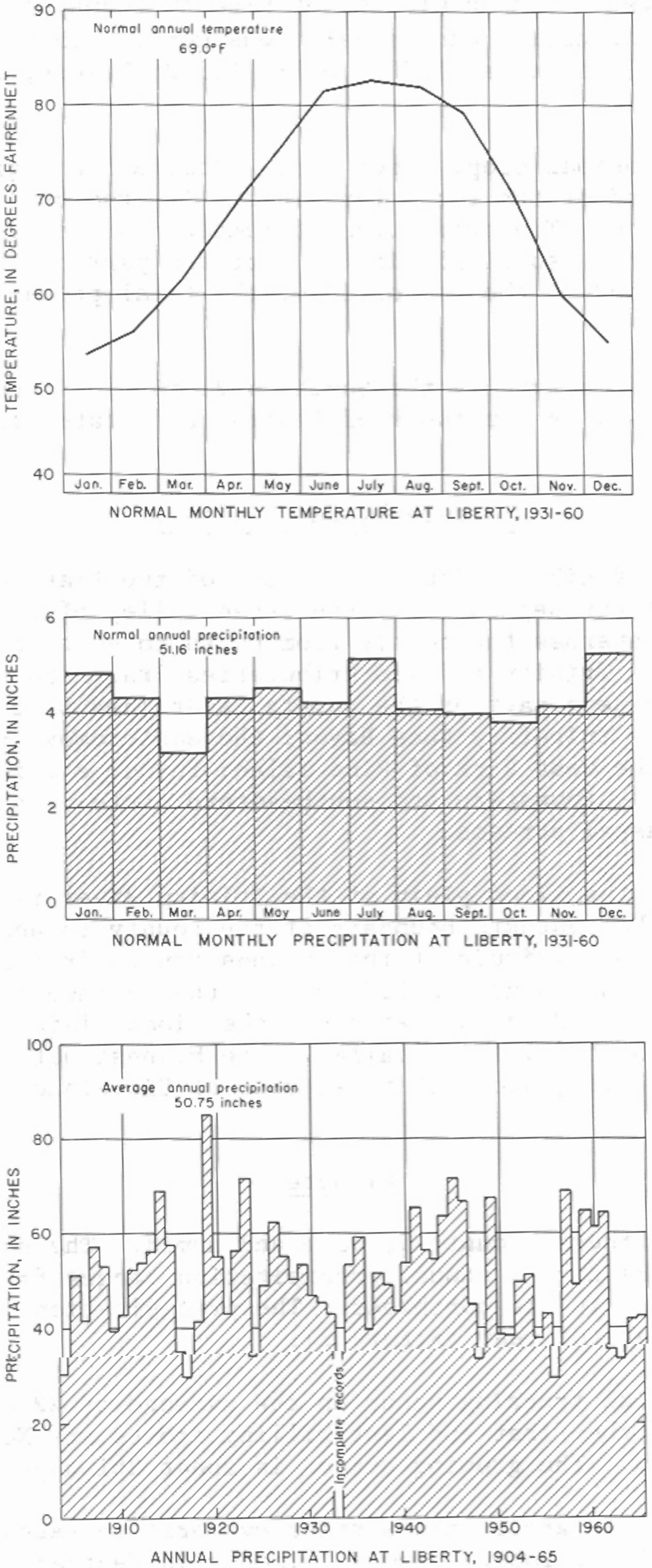

Figure 2

Annual Precipitation and Normal Monthly Precipitation and Temperature at Liberty

U.S. Geological Survey in cooperation with the Texas Water Development Board

Well-Numbering System

The well-numbering system used in this report, which is based on the divisions of latitude and longitude, was developed by the Texas Water Development Board for use throughout the State. Under this system, each 1-degree quadrangle is given a number consisting of two digits. These are the first two digits in the well number. Each 1-degree quadrangle is divided into 7-1/2 minute quadrangles which are given 2-digit numbers from 01 to 64. These are the third and fourth digits of the well number. Each 7-1/2 minute quadrangle is subdivided into 2-1/2 minute quadrangles which are given a single digit number from 1 to 9. This is the fifth digit of the well number. Finally, each well within a 2-1/2 minute quadrangle is given a 2-digit number in the order in which it is inventoried, starting with 01. These are the last two digits of the well number.

Only the last three digits of the well number are shown on the well location map (Figure 17); the second two digits are shown in the northwest corner of each 7-1/2 minute quadrangle; and the first two digits are shown by the large block numerals 60, 61, 64, and 65.

In addition to the 7-digit well number, a 2-letter prefix is used to identify the county. The prefixes for Liberty and adjacent counties are as follows: Liberty, SB; Chambers, DH; Harris, LJ; San Jacinto, WU; Polk, UT; Hardin, LH; and Jefferson, PT. The well and spring numbers used by Alexander (1950) and the corresponding numbers used in this report are listed in Table 1.

Acknowledgments

The authors gratefully acknowledge the cooperation of many landowners and city, county, and industrial officials in supplying information about their wells, allowing access to their wells for water-level measurements, and for their assistance in conducting pumping tests. Well drillers generously supplied drillers' logs, electric logs, and well completion data. Most of the data shown on the maps and cross sections in this report was obtained from the electrical logs of oil and gas tests.

HYDROLOGIC AND GEOLOGIC UNITS AND THEIR WATER-BEARING PROPERTIES

General Stratigraphy and Structure

The geologic units that contain fresh to slightly saline water in Liberty County are, from oldest to youngest: the Fleming Formation of Miocene age, the Goliad Sand of Pliocene age, the Willis Sand of Pliocene(?) age, the Lissie Formation and Beaumont Clay of Pleistocene age, and the alluvium of Recent age. The Fleming Formation, a name formerly abandoned by the U.S. Geological Survey, is reinstated in this report as a valid stratigraphic unit in east Texas and Louisiana. The upper part of the Willis Sand, the Lissie Formation, the Beaumont Clay, and the Recent alluvium crop out in Liberty County. The Fleming Formation and the lower part of the Willis Sand crop out in the area north of Liberty County. The Goliad Sand is overlapped by younger rocks in Liberty County.

Table 1.--Well and spring numbers used by Alexander (1950) and corresponding numbers used in this report

Old number	New number	Old number	New number	Old number	New number	Old number	New number
1	SB-60-48-108	27	SB-61-41-403	53	SB-61-34-807	76	SB-61-49-801
2	60-48-104	28	61-49-101	54	61-33-901	77	61-49-803
3	60-48-109	29	61-41-501	55	61-42-101	78	61-57-201
4	60-56-201	30	61-41-405	56	61-34-402	79	61-57-102
7	60-48-102	31	61-41-401	57	61-33-902	80	61-57-104
8	60-48-103	32	61-41-502	58	61-34-403	81	61-57-101
9	60-48-802	33	61-41-901	59	61-33-603	82	61-57-207
10	60-48-501	34	61-41-902	60	61-33-604	84	61-57-406
11	60-48-105	35	61-49-102	61	61-33-601	85	60-64-601
12	60-48-106	36	61-41-402	62	61-33-602	86	61-57-403
13	60-48-107	37	61-41-406	63	61-33-903	87	61-57-404
14	60-48-402	38	61-41-503	64	61-33-909	88	61-57-405
15	60-48-401	39	61-49-301	65	61-33-801	89	61-57-701
16	60-48-801	42	61-41-301	66	61-33-803	90	61-57-410
18	60-48-404	44	61-42-402	67	61-33-904	91	61-57-507
19	60-48-502	45	61-34-601	68	61-33-908	92	60-64-908
20	61-33-706	46	61-34-604	69	61-34-902	93	60-64-907
21	61-33-703	47	61-34-502	70	61-34-606	96	60-64-605
22	61-33-707	48	61-34-503	71	61-34-603	97	60-64-604
23	61-33-705	49	61-34-408	72	61-34-605	98	60-64-603
24	61-33-704	50	61-34-401	73	61-34-607	101	61-57-402
25	61-33-702	51	61-34-501	74	61-34-903	103	60-64-904
26	61-41-102	52	61-34-801	75	61-57-501	105	61-57-412

(Continued on next page)

Table 1.--Well and spring numbers used by Alexander (1950) and corresponding numbers used in this report

Old number	New number	Old number	New number	Old number	New number	Old number	New number
106	SB-61-57-106	151	SB-61-51-401	176	SB-61-59-304	199	SB-61-58-509
107	64-01-103	152	61-51-707	177	61-59-307	203	61-59-509
108	64-01-102	154	61-51-715	178	61-58-515	204	61-59-504
109	64-01-101	155	61-50-604	179	61-58-504	205	61-59-703
110	64-01-202	156	61-51-402	180	61-58-503	212	61-59-807
111	64-01-201	157	61-50-603	181	61-58-517	216	64-02-601
113	64-01-203	158	61-50-801	182	61-58-505	218	64-03-101
114	64-01-204	159	61-50-602	183	61-58-514	220	64-03-402
115	61-57-802	161	61-50-901	185	61-58-516	221	64-03-401
119	61-57-606	162	61-50-902	187	61-58-506	222	64-03-103
120	61-57-605	163	61-50-605	188	61-58-511	226	61-60-503
121	64-02-701	166	61-51-906	189	61-58-512	227	64-04-101
124	61-57-903	167	61-59-305	190	61-58-507	229	61-60-802
125	61-57-902	168	61-59-203	191	61-58-607	232	61-60-502
127	61-58-703	169	61-51-909	192	61-58-608	234	61-60-903
128	61-58-401	170	61-59-308	193	61-58-518	237	61-60-902
133	61-58-702	171	61-59-306	195	61-58-508	245	64-04-702
136	64-02-202	172	61-59-302	196	61-58-510		
141	61-57-301	173	61-59-301	197	61-58-605		
149	61-51-104	174	61-59-309	198	61-58-606		

The geologic units in Liberty County and adjacent areas crop out in belts that are nearly parallel to the shoreline of the Gulf of Mexico. The younger formations crop out nearer to the Gulf and the older ones farther inland, as shown on the geologic map (Figure 3).

The geologic units dip toward the Gulf, and most of them thicken gulfward. The dip increases with depth and ranges from less than 15 feet per mile in the younger units to 60 feet per mile in the older units. The units are composed primarily of sand, silt, and clay, with smaller amounts of gravel and calcareous material.

Liberty County is included in the part of southeastern Texas that is underlain at great depth by a thick layer of salt (Murray, 1961, p. 251-260). In local areas, the salt pushed upward through many thousands of feet of sediments and formed salt domes. The upper parts of the salt domes are roughly circular in horizontal cross section, and in some areas, the top of the salt mass is only a few hundred feet below the land surface. The approximate altitudes of the top of the salt in the Liberty County salt domes (Murray, 1961, p. 271), in feet below sea level are as follows: South Liberty, 300; Hull, 400; North Dayton, 600; Davis Hill, 900; Moss Bluff, 1,000; Esperson, 5,900; and Hankamer, 7,300. The approximate locations of these salt domes are shown on Figure 4.

The intrusion of a salt mass results in a general deformation of the adjacent water-bearing rocks and substantially affects the availability and quality of ground water over and around the dome. Figure 4 shows the salt domes in Liberty County. Other effects in these areas are: the sands containing fresh water are thinner (Figure 14), and the altitudes of the base of fresh water (Figure 13) and the base of slightly saline water (Figure 15) are higher.

Faults are common in the subsurface in Liberty County, especially around the salt domes. However, they probably have little effect on the general movement of ground water in the county.

Hydrologic Units

An aquifer is a geologic formation, group of formations, or part of a formation that is water bearing. An aquiclude is an impermeable or relatively impermeable rock that may contain water but is incapable of transmitting an appreciable quantity. The hydrologic units in Liberty County are the Jasper aquifer, Burkeville aquiclude, Evangeline aquifer, and Chicot aquifer. This classification follows the one used by Wesselman (1967) in his report on the ground-water resources of Jasper and Newton Counties.

The approximate thickness, composition, and water-bearing properties of the hydrologic units are summarized in Table 2; the equivalent geologic units are also listed. The correlations between the hydrologic and geologic units are only approximate; furthermore, these correlations should be applied only to the report area. The three sections (Figures 18, 19, and 20) show the thickness of the hydrologic units, the lithology as indicated by electrical logs, the approximate base of fresh water, and the approximate base of slightly saline water.

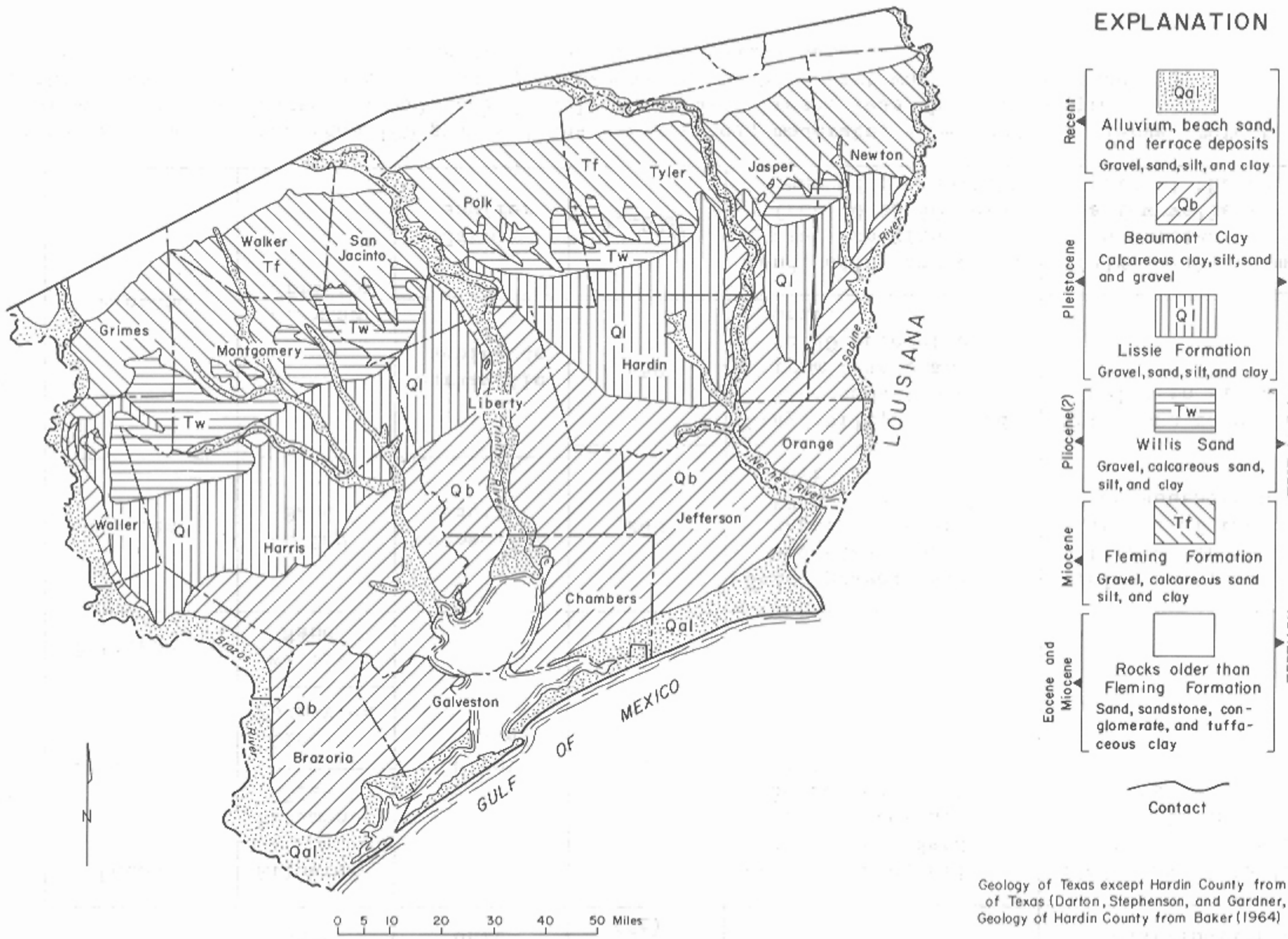

Figure 3

Geologic Map of Southeastern Texas

U.S. Geological Survey in cooperation with the Texas Water Development Board

Geology of Texas except Hardin County from Geologic Map of Texas (Darton, Stephenson, and Gardner, 1937)
Geology of Hardin County from Baker (1964)

Table 2.--Physical characteristics and water-bearing properties of the geologic and hydrologic units

System	Series	Geologic unit	Hydrologic unit	Maximum thickness (ft)	Composition	Water-bearing properties and distribution of supply
Quaternary	Recent	Alluvium	Chicot aquifer	480	Gravel, sand, silt, and clay. Sand constitutes about 50 percent of the unit.	Yields small to large[1] quantities of fresh[2] water to wells in the southern part of the county.
	Pleistocene	Beaumont Clay				
		Lissie Formation				
Tertiary(?)	Pliocene(?)	Willis Sand				
Tertiary	Pliocene	Goliad Sand	Evangeline aquifer	2,240	Sand, gravel, silt, and clay. Sand constitutes about 50 percent of the unit.	Yields small to large quantities of fresh water to wells in all of the county except the southernmost part.
	Miocene	Fleming Formation	Burkeville aquiclude	450	Clay, silt, and sand. Sand constitutes from less than 10 to 20 percent of unit.	Not known to yield water to wells in Liberty County.
			Jasper aquifer	2,400[3]	Sand, silt, and clay. Sand constitutes from 30 to 40 percent of the unit.[4]	Yields small to moderate[1] quantities of fresh water to a few wells in the northern part of the county.

[1] Yield of wells: small, less than 100 gpm (gallons per minute); moderate, 100-1,000 gpm; large, more than 1,000 gpm.
[2] Quality of water as ppm (parts per million) dissolved solids: fresh, less than 1,000 ppm.
[3] Maximum thickness in northern part of county; thickness in southern part was not determined.
[4] In the part of the aquifer that contains fresh to slightly saline water.

Jasper Aquifer

The Jasper aquifer, which includes the part of the Fleming Formation below the predominantly clay zone at the top (Table 2), crops out in a belt north of Liberty County (Figure 3). The aquifer consists of alternating beds of sand, silt, and clay. In the northern part of the county, the thickness of the aquifer is about 2,400 feet. The thickness was not determined in the southern part because only the uppermost part locally contains slightly saline water. Electrical logs indicate that sand generally constitutes from 30 to 40 percent of the aquifer in the part that contains fresh to slightly saline water. The logs also show that sand zones as much as 250 feet thick are common in the upper part of the aquifer.

The Jasper aquifer supplies small to moderate quantities of fresh water to a few wells in the northern part of Liberty County. In 1965, the Jasper supplied less than 1 percent of the ground water used in the county.

Burkeville Aquiclude

The Burkeville aquiclude, a predominantly clay zone of the Fleming Formation (Table 2), crops out in a belt north of Liberty County (Figure 3). The Burkeville consists of clay, silt, and sand. Sand constitutes less than 10 percent of the unit in the southern part of the county, and as much as 20 percent in the northern part. The thickness of the Burkeville ranges from 310 to 450 feet except in the salt-dome areas where it is considerably thinner or absent.

The Burkeville is essentially the "zone 2" in the Houston area as described by White, Rose, and Guyton (1944, p. 146-147), Land, Winslow, and White (1950, p. 36-40), and Wood and Gabrysch (1965, p. 4-10).

The Burkeville is not known to yield water to wells in Liberty County; however, the electrical logs (Figures 18 and 19) indicate that the sands in the Burkeville in the northern part of the county contain fresh to slightly saline water.

Evangeline Aquifer

The Evangeline aquifer, which is equivalent to the Goliad Sand and the upper part of the Fleming Formation (Table 2), is overlapped by younger sediments and does not crop out in Liberty County. This relationship is shown on section B-B' (Figure 19). The Evangeline, which is equivalent to part of the "heavily pumped layer" in the Houston area (Wood and Gabrysch, 1965, p. 7-10), consists of sand, gravel, silt, and clay. About 50 percent of the aquifer is sand. The thickness of the Evangeline ranges from 540 feet in the northern part of the county to about 2,240 feet in the southern part. The altitude of the base of the Evangeline aquifer is shown on Figure 4. The figure indicates that the dip of the base of the Evangeline is southeasterly at about 50 feet per mile, except in an area in the southwestern part of the county and in the salt-dome areas.

The Evangeline aquifer contains fresh water in the northern half of Liberty County and fresh to slightly saline water in the southern half. The irregular distribution of the fresh water and underlying slightly saline water is shown on sections B-B' and C-C' (Figures 19 and 20).

The Evangeline aquifer contains most of the fresh and slightly saline ground water in storage in Liberty County and supplied about 60 percent of the ground water used in 1965. The aquifer supplies small to large quantities of fresh water to wells in all of Liberty County except the southernmost part.

Chicot Aquifer

The Chicot aquifer, which includes the Willis Sand, Lissie Formation, Beaumont Clay, and Recent alluvium (Table 2), crops out in all parts of Liberty County (Figure 3). The Chicot consists of gravel, sand, silt, and clay. Sand constitutes about 50 percent of the aquifer. The thickness of the aquifer ranges from less than 100 feet in the northern part of the county to about 480 feet in the southern part. The dip of the base of the Chicot in much of the southern part of the county is southeasterly at about 18 feet per mile (Figure 5). The dip of the top of the aquifer, which is also the slope of the land surface, is also southeasterly at about 4 feet per mile.

Unlike the Jasper and Evangeline aquifers, which are separated by a thick zone of clay (the Burkeville aquiclude), no continuous clay unit separates the Chicot and Evangeline aquifers. In fact, the electrical logs of several wells, for example SB-61-43-102 (Figure 19) and SB-64-01-602 (Figure 20), show that sands in the two aquifers are probably in hydraulic continuity, so that water moves freely from one aquifer to the other in response to a change in head. In parts of Liberty County, the contact between the aquifers is difficult to determine. In Jasper and Newton Counties, Wesselman (1967) separated the Chicot and Evangeline on the basis of their differences in lithology and permeability. In Liberty County, the available data are insufficient to determine whether these criteria are applicable. In this report, the contact between the aquifers is placed arbitrarily at the base of a relatively thick, highly resistive sand bed, as determined from the electrical logs of wells.

The Chicot aquifer is sufficiently thick to be an important hydrologic unit only in the southern part of the county, where it supplies small to large quantities of fresh water to wells. The altitude of the base of the Chicot in this area is shown on Figure 5. In the northern part of the county, the principal hydraulic function of the Chicot is the transmission of water to the underlying Evangeline aquifer.

With the exception of the salt-dome areas, the Chicot contains only fresh water. In these relatively small areas, supplies of fresh water are either limited or not available. The Chicot contains a large quantity of fresh water in storage, and in 1965, the aquifer supplied about 40 percent of the ground water used in the county.

GROUND-WATER HYDROLOGY

The general principles of ground-water hydrology as they apply to Liberty County are discussed in this section of the report. For additional technical information on these and other hydrologic principles, the reader is referred to: Meinzer (1923a, 1923b), Meinzer and others (1942), Todd (1959), Tolman (1937), and Wisler and Brater (1959); and for non-technical discussions to: Leopold and Langbein (1960) and Baldwin and McGuinness (1963).

Source and Occurrence of Ground Water

The source of ground water in Liberty County is precipitation on the land surface of the county and adjoining areas to the north. Most of the precipitation runs off or is consumed by evapotranspiration; only a small part migrates downward until it reaches the zone of saturation. The upper surface of the zone of saturation is the water table, below which water is contained in the interstices or pore spaces between the rock particles of the aquifer.

Water-bearing rock units, or aquifers, are of two types--water table, or unconfined aquifers; and artesian, or confined aquifers. Unconfined, or water-table conditions, occur where the upper surface of the zone of saturation is under atmospheric pressure only, and the water is free to rise or fall in response to changes in the volume of water in storage. In and around Liberty County, water-table conditions occur at the outcrops of the aquifers and in the alluvial deposits along the major streams. A well penetrating an aquifer under water-table conditions becomes filled with water only to the level of the water table.

Confined, or artesian conditions, occur downdip from the outcrop, where an aquifer is overlain by less permeable sediments that confine the water under a pressure greater than atmospheric pressure. A well penetrating an aquifer under artesian pressure becomes filled with water to a level that is proportionate to the hydrostatic pressure. If the pressure head is high enough, water in the well may rise to an altitude greater than that of the land surface, causing the well to flow. Table 5 includes the records of 25 flowing wells in the Trinity River valley and one flowing well at Cleveland.

The level or surface to which water will rise in artesian wells is called the piezometric surface. Although the terms water table and piezometric surface are synonymous in the outcrop areas, the term piezometric surface, as used in this report, is applicable only in artesian areas.

Recharge, Movement, and Discharge of Ground Water

Recharge is the addition of water to an aquifer, either by natural or artificial processes. Natural recharge results from the infiltration of precipitation. The greater part of the natural recharge to the aquifers in Liberty County takes place in the northern part of the county and in the southern parts of adjacent San Jacinto and Polk Counties; the remainder takes place in the southern part of Liberty County. In some localities in the United States, artificial recharge results in significant increases in the quantities of ground water. Two methods used are the construction of flood control structures in highly permeable areas and the installation of injection wells. Usually, the process of artificial recharge includes only the relatively small quantities resulting from the infiltration of irrigation water, industrial waste water, and sewage. Recharge by improperly treated waste water and sewage is frequently a source of contamination of fresh ground water, especially at shallow depths.

Ground water moves slowly through the aquifers under the force of gravity from areas of recharge to areas of discharge. The initial direction of movement is downward from the surface of the outcrop to the zone of saturation; then the water moves in a more horizontal direction down the hydraulic gradient.

In an area where large quantities of water are withdrawn from an aquifer, water moves from all directions toward the center of heavy withdrawal. This is shown on the map of the altitude of water levels in wells tapping the Evangeline and Chicot aquifers in the spring of 1966 (Figure 6). The direction of movement of the water is at right angles to the contours in the direction of decreasing altitude, and the rate of movement is indicated by the spacing of the contours (or the hydraulic gradient, usually given in feet per mile).

When other factors are equal, the velocity is proportional to the hydraulic gradient--where the contours are 1 mile apart (10 feet per mile), the water will move with twice the velocity as in an area where they are 2 miles apart (5 feet per mile).

The heavy withdrawals in the area west of Dayton, at Liberty, and in the area east of Liberty have changed the natural direction and rate of movement of the ground water. Before development, ground water moved in a southeasterly direction across the county at a rate of about 60 feet per year. At present (1966), the water moves generally toward the south in the northern half of the county at rates of 120 to 180 feet per year (Figure 6). In the southern half of the county, water moves generally toward the west or northwest at an average rate of about 90 feet per year. The northward indentation of the contours in the north-central part of the county results in part from reductions of artesian pressure caused by the discharge of a number of flowing wells in that area during the past several decades, and in part from the discharge of spring water.

The deep aquifers, except where heavily pumped, are under greater artesian pressure than the overlying aquifers. In response to the difference in pressure, water is discharged slowly upward from the deep aquifers through the less permeable confining beds into the overlying aquifers (Winslow, Doyel, and Wood, 1957, p. 387). The slow underground movement results in fresh water from the recharge areas replacing the original, or connate water in the aquifers. This interformational leakage, or "flushing," is one of the principal factors involved in the occurrence of fresh water to altitudes of as much as 1,800 feet below sea level in Liberty County (Figure 13).

Ground water is discharged artificially by flowing or pumped wells; and naturally by springs and seeps where the water table intersects the land surface, and by evapotranspiration where the water table is just below the land surface. Most of the spring flow takes place in the southern parts of San Jacinto and Polk Counties and in the adjacent part of northern Liberty County. The natural recharge now being rejected by the aquifers, because the infiltration in the outcrop areas exceeds the present transmission capacities of the aquifers, will become additional supplies of recharge as the transmission capacities of the aquifers are increased by greater withdrawals in the deeper parts of the aquifers. It also represents additional supplies of ground water available in the outcrop areas.

Hydraulic Characteristics of the Aquifers

Hydraulic Principles and Definitions

When water is discharged from a well, the level of the water table or piezometric surface is lowered and a new hydraulic gradient is established that slopes in all directions toward the well. This depression of the water table or piezometric surface, which assumes the shape of an inverted cone centered at the well, is called the cone of depression. The difference between the discharging level and the static level (water level before pumping or before start of flow) is called the drawdown.

The amount of water and the rate at which water is transmitted by an aquifer depends upon the hydraulic gradient and the properties of the aquifer--the specific yield, porosity, permeability or transmissibility, and storage coefficient. The specific yield is the ratio (expressed as a percentage) of the volume of water a saturated rock will yield by gravity to its own volume.

Porosity is the ratio (in percent) of the aggregate volume of pore space in a rock to its own volume.

The permeability of an aquifer is the capacity for transmitting water under pressure and is measured by the coefficient of permeability--the rate of flow in gallons per day through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot (100 percent).

The coefficient of transmissibility is the rate of flow in gallons per day through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness of the aquifer under a hydraulic gradient of 100 percent.

The coefficient of storage is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. When artesian conditions prevail, the coefficient of storage is a measure of the ability of the aquifer to yield water from storage by the compression of the aquifer and the expansion of the water as the artesian pressure is lowered. The coefficients of storage in artesian aquifers are small compared to those in water-table aquifers; consequently, when an artesian well starts discharging, a cone of depression is developed through a wide area in a short time. When water-table conditions prevail, the coefficient of storage is a measure of the ability of the aquifer to yield water from storage by gravity drainage of the aquifer; consequently, the cone of depression extends through a relatively small area. Under water-table conditions, the volume of water attributable to expansion is such a negligible part of the total volume of water released from the aquifer that the coefficient of storage is considered the same as the specific yield.

Formulas based on the hydraulic characteristics of an aquifer indicate that within limits the discharge from a well varies directly with the drawdown--that is, doubling the drawdown will nearly double the amount of discharge. The discharge per unit of drawdown (gallons per minute per foot), or specific capacity, is of value in estimating the probable yield of a well and the required pump setting.

The yield of a well is usually measured in gallons per minute or gallons per hour. Yield depends on the ability of the aquifer to transmit water, the thickness of the water-bearing material, the construction of the well, the size and efficiency of the pump, and the allowable drawdown.

Aquifer Tests

Aquifer tests have been made in 15 wells in Liberty County to determine the ability of the aquifers to transmit water. The results of these tests are given in Table 3. Data from the aquifer tests were analyzed by using the Theis non-equilibrium method, as modified by Cooper and Jacob (1946, p. 526-534), and the Theis recovery method (Wenzel, 1942, p. 94-97). The coefficients of transmissibility determined from tests of nine wells tapping the Evangeline aquifer ranged from 2,200 to 95,000 gpd (gallons per day) per foot; results of tests of two wells tapping the Chicot aquifer were 21,000 and 47,000 gpd per foot; and results of tests of two wells that tapped both Evangeline and Chicot aquifers were 29,000 and 120,000 gpd per foot.

The coefficients of permeability in Table 3 were computed by dividing the coefficients of transmissibility by the estimated thicknesses of sands supplying water to the wells. The coefficients of permeability of the Evangeline aquifer at four wells were 55, 150, 310, and 330 gpd per square foot. The coefficient of permeability of the Evangeline and Chicot aquifers at one well was 190 gpd per square foot. The coefficient of storage obtained from a test of one well tapping the Evangeline aquifer was 0.00018.

The coefficients of transmissibility and storage may be used to predict future drawdown of water levels caused by pumping. Figure 7 shows the theoretical relation between drawdown or decline of water level and the distance from the center of pumping for different coefficients of transmissibility and storage. The calculations of drawdown are based on a withdrawal of 1 mgd (million gallons per day) for 1 year and coefficients of storage and transmissibility as shown. The figure shows that the amount of drawdown will increase with the decrease in the value of the coefficient of transmissibility. For example, if the coefficients of transmissibility and storage are 50,000 gpd per foot and 0.001, respectively, the drawdown or decline in the water level would be about 12 feet at a distance of 1 mile from a well or group of wells discharging 1 mgd for 1 year.

Figure 8 shows the relation of drawdown to time as a result of pumping from an artesian aquifer of infinite areal extent. It shows that the rate of drawdown decreases with time, and that the drawdown caused by pumping is proportional to the duration of pumping. For example, if the drawdown 100 feet from a well is 11 feet after 1 mgd has been pumped for 1 year, the drawdown would be about 15 feet after 1 mgd had been pumped for 100 years. The total drawdown at any one place within the cone of depression or influence of several wells would be the sum of the influences of the several wells. The equilibrium curve shows the time-drawdown relation when a line source of recharge is 25 miles from the point of discharge.

Pumping from wells drilled close together may create cones of depression that intersect, thereby causing additional lowering of the piezometric surface or water table. The intersection of cones of depression, or interference between wells, will result in lower pumping levels (and increased pumping costs)

Table 3.--Coefficients of permeability and transmissibility of the aquifers and specific capacities and yields of wells in Liberty County

Well number	Screened interval (feet)	Effective sand thickness (feet)	Aquifer	Date of test	Yield (gpm)	Draw-down (feet)	Specific capacity (gpm/ft)	Coefficient of transmissibility (gpd/ft)	Coefficient of permeability (gpd/ft^2)	Remarks
SB-60-48-102	619-833	85	Evangeline	Dec. 7, 1955	--	--	--	7,800	92	Interference test. Well SB-60-48-103 pumping. Coefficient of storage 0.00018.
60-48-103	614-833	85	do	do	340	--	--	6,200	73	Recovery test.
60-64-902	130-595	150	Evangeline and Chicot	Aug. 9, 1955	1,030	73	14	29,000	190	Do.
61-33-701	90-835	200	Evangeline	Aug. 2, 1955	2,500	86	29	67,000	330	Do.
61-41-701	234-627	--	do	do	1,950	50	39	72,000	--	Do.
61-49-805	117-624	--	do	Aug. 4, 1955	1,830	--	--	85,000	--	Do.
61-51-501	--	--	Chicot	July 23, 1965	320	31	10	21,000	--	Do.
61-51-701	215-678	--	Evangeline and Chicot	July 21, 1965	700	9.4	78	120,000	--	Do.
61-51-901	--	--	Chicot	Aug. 5, 1955	1,175	38	38	47,000	--	Do.
61-57-603	530-785	100	Evangeline	Dec. 13, 1955	835	54	15	31,000	310	Do.
61-59-501	--	--	do	Aug. 3, 1955	2,550	56	45	95,000	--	Do.
60-48-202	1,560-1,610	--	Jasper	Jan. 14, 1966	1,641	196	--	9,900	198	Drawdown.
61-57-806	423-624	--	Evangeline	Aug. 5, 1955	1,175	--	31	47,000	--	Do.
61-57-601	--	--	do	Dec. 13, 1955	228	83	2.9	2,200	55	Recovery test.
60-48-101	1,119-1,330	--	Jasper	Dec. 7, 1955	338	--	--	6,540	55	Do.

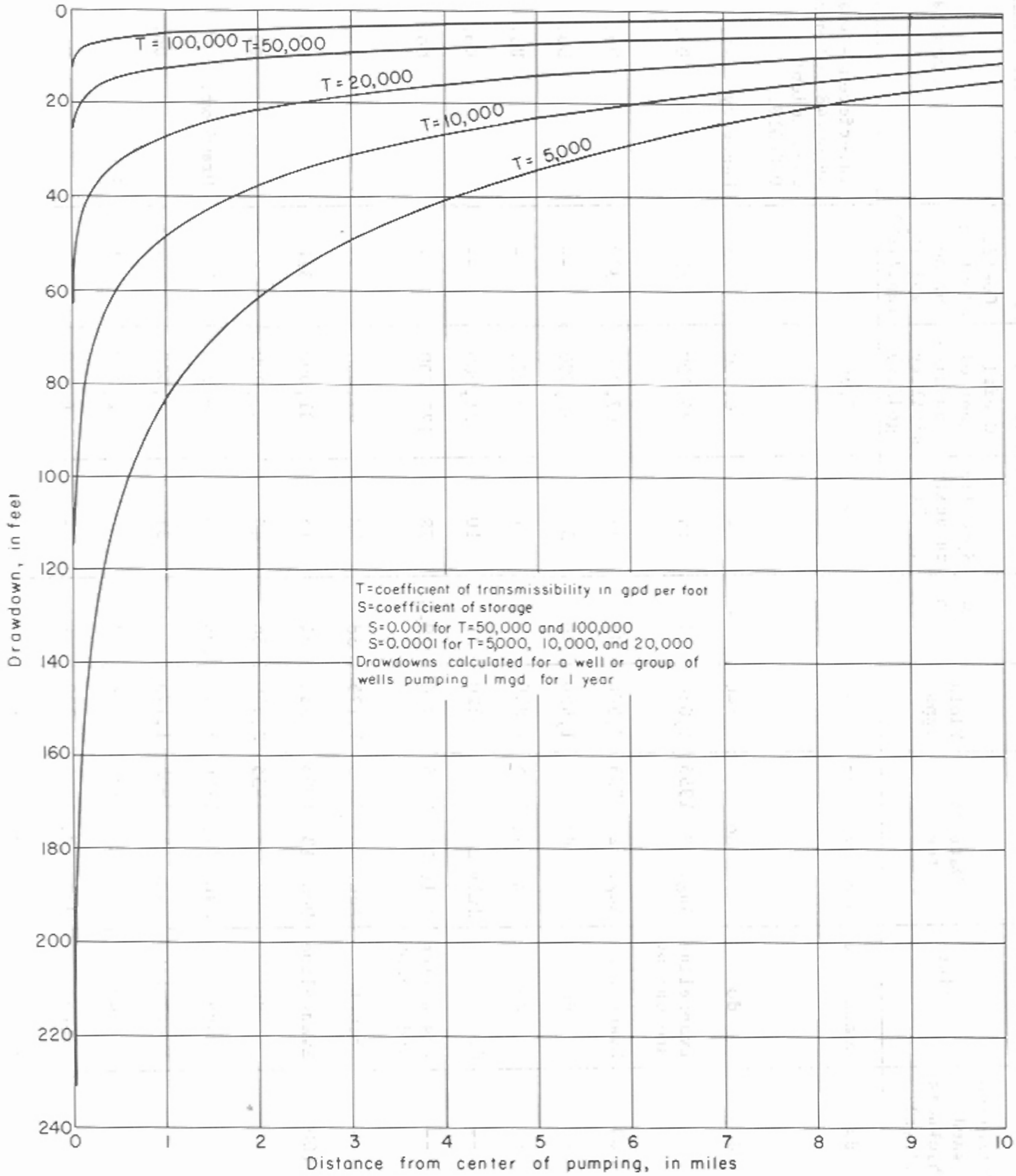

Figure 7

Relation of Drawdown to Transmissibility

U.S. Geological Survey in cooperation with the Texas Water Development Board

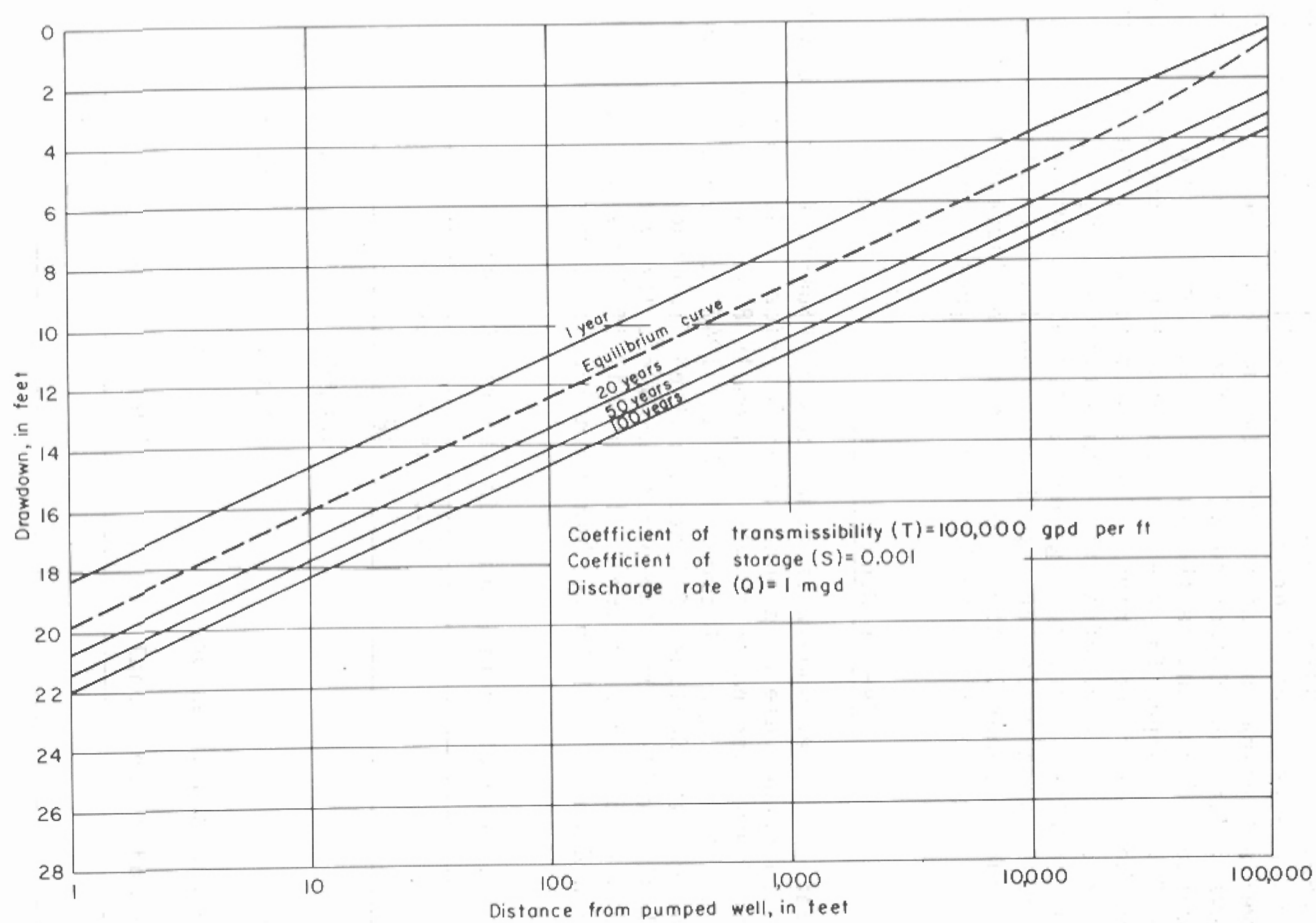

Figure 8

Relation of Drawdown to Time as a Result of Pumping Under Artesian Conditions

U. S. Geological Survey in cooperation with the Texas Water Development Board and may cause serious declines in yields of the wells. If the pumping level is lowered below the top of the well screen, that part of the aquifer will become dewatered, and the yield of the well will decrease in proportion to the reduction in thickness of the saturated part of the aquifer. The proper spacing of wells to minimize interference can be determined from the aquifer-test data.

The specific capacities (Table 3) were 2.9, 15, 29, 31, 39, and 45 gpm per foot (gallons per minute per foot of drawdown) in 6 wells tapping the Evangeline; 38 and 10 in two wells tapping the Chicot; and 14 and 78 gpm per foot in 2 wells tapping both the Evangeline and Chicot aquifers. Specific capacities are comparable if the duration of pumping is the same for each well tested. The wells mentioned in Table 3 were pumped for the same length of time, and the drawdowns were computed from the 1-hour recoveries. The 1-hour recovery, the rise of water level during the first hour after the termination of pumping, is about the same as the decline of water level during the first hour of pumping. The range of specific capacities among wells tapping the same aquifer results from a number of factors, but in general, those wells having the largest amount of screened, slotted, or perforated intervals have the largest specific capacity.

Use of Ground Water

The development of the ground-water resources of Liberty County resulted primarily from the increased use of ground water for rice irrigation. The rate of ground-water withdrawal increased slowly between 1908 and 1929, but did not exceed an average of about 5 mgd. Between 1930 and 1942, the rate of withdrawal was about 4 mgd; the decline of 1 mgd resulted from the decreased yields of uncontrolled flowing wells. For the period 1943-65, the withdrawals ranged from 5.2 mgd in 1946 to 52.5 mgd in 1963; the rate in 1965 was 51.2 mgd (Figure 9). The use of ground water in Liberty County in 1965 is given in Table 4.

Table 4.--Use of ground water in Liberty County, 1965

Use	Gallons per day (gpd)	Acre-feet
Irrigation	48,900,000	54,814
Public supply	1,600,000	1,794
Rural domestic and livestock	600,000	672
Industrial and recreational	100,000	112
Total	51,200,000	57,392

The sources of the ground water used in 1965 were: Jasper aquifer, less than 1 percent; Evangeline aquifer, about 60 percent; and Chicot aquifer, about 40 percent.

The increased use of ground water for rice irrigation is indicated by the number of wells: six wells in 1908, 13 in 1945, and 85 in 1965. In 1965, 48.9 mgd (54,814 acre-feet), or about 95 percent of the ground water used in Liberty

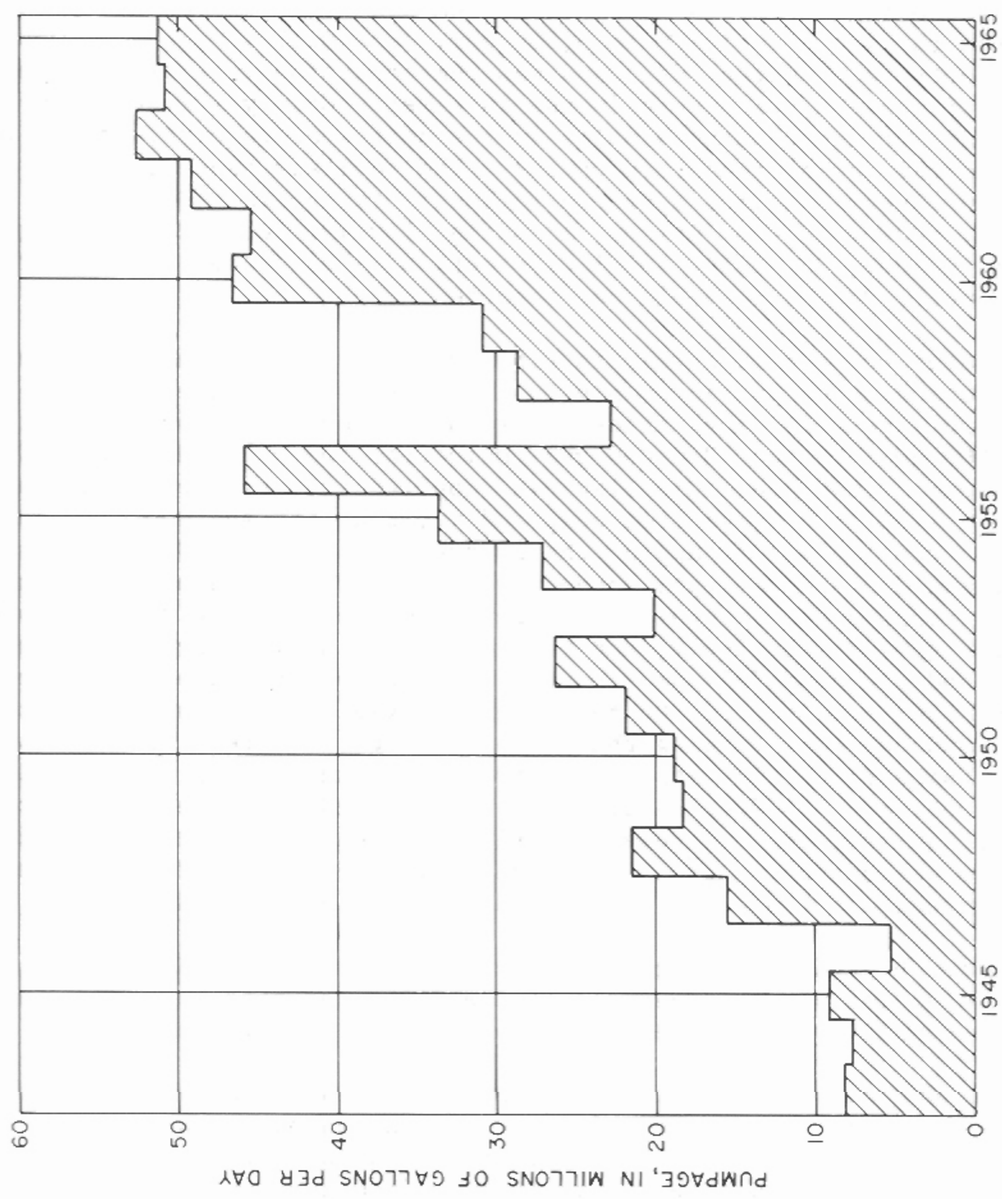

Figure 9

Estimated Pumpage of Ground Water, 1943-65

U S Geological Survey in cooperation with the Texas Water Development Board

County, was used to irrigate 18,400 acres of rice. The first inventory of water wells in Liberty County, which was made in 1908 (Deussen, 1914, p. 290-300), included 6 wells used for rice irrigation (5 wells ranging in depth from 380 to 415 feet in the southwestern part of the county and 1 well 365 feet deep near Liberty). The well near Liberty, completed in 1895, probably was the first well in the county used for rice irrigation. The next well inventory, which was made in 1945 (Alexander, 1950, p. 22-39), included 13 wells used for rice irrigation (12 wells in the southwestern part of the county and 1 in the northwestern part). The wells in the southwestern part of the county included 1 well 2,500 feet and flowing 30 gpm, and 11 wells from 558 to 1,005 feet deep and pumped at rates ranging from 1,170 to 3,500 gpm. The well in the northwestern part of the county was 226 feet deep and was pumped at the rate of 900 gpm. In 1965, 85 rice irrigation wells were in use in Liberty County (32 wells in the southwestern part of the county, 9 wells in the northwestern part, and 44 wells in the east-central and southeastern parts). The aquifers tapped, number of wells, range in depth, and yields are as follows: Evangeline, 36 wells, 100-1,180 feet, 600-3,450 gpm; Chicot, 13 wells, 100-496 feet, 250-2,400 gpm; Evangeline and Chicot, 35 wells, 404-1,017 feet, 671-3,500 gpm; and Jasper and Evangeline, 1 well, 980 feet, yield not reported.

All the water for public supply in Liberty County is obtained from wells. The total withdrawals for public supply in 1965 were at the rate of about 1,600,000 gpd for the following cities and towns: Cleveland, 550,000 gpd; Liberty, 540,000 gpd; Dayton, 350,000 gpd; Daisetta, 100,000 gpd; Hull, 50,000 gpd; and Raywood, 10,000 gpd. Cleveland is supplied from two wells tapping the Jasper aquifer, 1,337 and 1,641 feet deep and yielding 448 and 400 gpm, respectively; and from two wells tapping the Evangeline aquifer, 833 and 845 feet deep and yielding 353 and 387 gpm, respectively. Liberty obtains its supply from two wells tapping the Evangeline aquifer, 806 and 960 feet deep and yielding 726 and 750 gpm, respectively; and from one well tapping the Chicot aquifer, 351 feet deep and yielding 225 gpm. Dayton is supplied from two wells tapping the Evangeline aquifer, 490 and 806 feet deep and yielding 250 and 835 gpm, respectively; and one well tapping the Chicot aquifer, 376 feet deep and yielding 100 gpm. Daisetta obtains its supply from three wells tapping the Chicot aquifer, 365, 365, and 376 feet deep. Hull is supplied from one well tapping the Evangeline aquifer, 585 feet deep and yielding 401 gpm. Raywood obtains its supply from two wells tapping the Evangeline aquifer--one well 825 feet deep, yield not reported, and the other 845 feet deep and yielding 650 gpm.

An estimated 600,000 gpd of ground water was used for rural domestic and livestock purposes in 1965. Almost all of the water was obtained from small-capacity wells supplied from either the Evangeline or Chicot aquifers.

About 100,000 gpd of ground water was used for industrial and recreational purposes in 1965. Part of the water was used by the lumber, gravel, and petroleum industries, but most of it was used to maintain recreational lakes. The supplies were obtained in about equal quantities from the three aquifers.

Decline of Water Levels

The increased withdrawals of ground water (Figure 9) have resulted in progressive declines of water levels in wells. There has been some lowering of water levels throughout the county, but the declines have been greater in areas where the withdrawals have been greater, as shown by the hydrographs of water levels in wells in several parts of the county (Figure 10) and the records of water-level measurements in Table 7. Each hydrograph shows a decline caused by the larger withdrawals during the summer and a rise of water level the following spring. However, both the fall and spring measurements show progressive declines with the exception of part of the hydrograph of well SB-61-51-806. Water-level measurements reported in the 1908 well inventory (Deussen, 1914, p. 291-293) included wells in the area west of Dayton and at Liberty. On the basis of these data, the maximum declines of water level from 1908 to the spring of 1966 were about 80 feet at Liberty and about 100 feet in the area west of Dayton. The decline in the area west of Dayton was caused by the local withdrawals combined with withdrawals in adjacent Harris County. The decline at Liberty was caused by withdrawals for public supply and former withdrawals for industrial uses.

Subsidence of the Land Surface

The pressure in an artesian aquifer helps support the framework of the aquifer. When the artesian pressure is lowered, water is released from storage in the aquifer and the beds are compacted, most of the compaction taking place in the fine-grained sediments. The total amount of compaction and resulting subsidence depends on the amount of decline in artesian pressure and the thickness of the fine-grained sediments.

According to Winslow and Wood (1959, p. 1030-1034), the removal of ground water and the consequent lowering of artesian pressure has resulted in a subsidence of the land surface in about 7,200 square miles of the Gulf Coastal Plain, which includes all or parts of the following counties: Harris, Fort Bend, Waller, Brazoria, Galveston, Liberty, Chambers, Orange, and Jefferson. In the heavily pumped Houston area, the ratio of approximately 1 foot of subsidence to 100 feet of decline of artesian pressure head (or decline in water level) has remained fairly constant throughout the period of record. In the Houston area and adjacent heavily pumped areas, about 22 percent of the total ground water pumped resulted from the compaction of the clay beds.

The U.S. Coast and Geodetic Survey established in 1918 a line of bench marks that extended across the presently heavily pumped parts of Liberty County. A comparison of these measurements with the measurements of existing bench marks in 1964 shows the amounts of subsidence, as follows: 1.644 feet at Crosby in Harris County, about 14 miles southwest of Dayton; 0.568 foot, 2.85 miles southwest of Dayton; 0.810 and 0.863 foot at two bench marks in Dayton; 0.463 foot, at two bench marks in Liberty; and 0.154 foot, 2.05 miles east of Ames, about 5 miles east of Liberty. The estimated ratios of amounts of subsidence to declines of artesian pressure are as follows: At 2.85 miles southwest of Dayton, 0.7 foot per 100 feet; at Dayton, 0.9 foot per 100 feet; and at Liberty, 0.6 foot per 100 feet. Winslow and Wood (1959, p. 1033) reported subsidence of 1.0 foot per 100 feet of decline of artesian pressure at Crosby.

Construction of Wells

Generally, when a well is to be constructed for public supply, industrial, or irrigation uses in Liberty County, a test hole is drilled to the depth desired. Formation samples are collected during the drilling, and upon completion of the test hole, an electrical log is run so that the sands containing fresh water can be accurately selected. In some cases, tests are made to

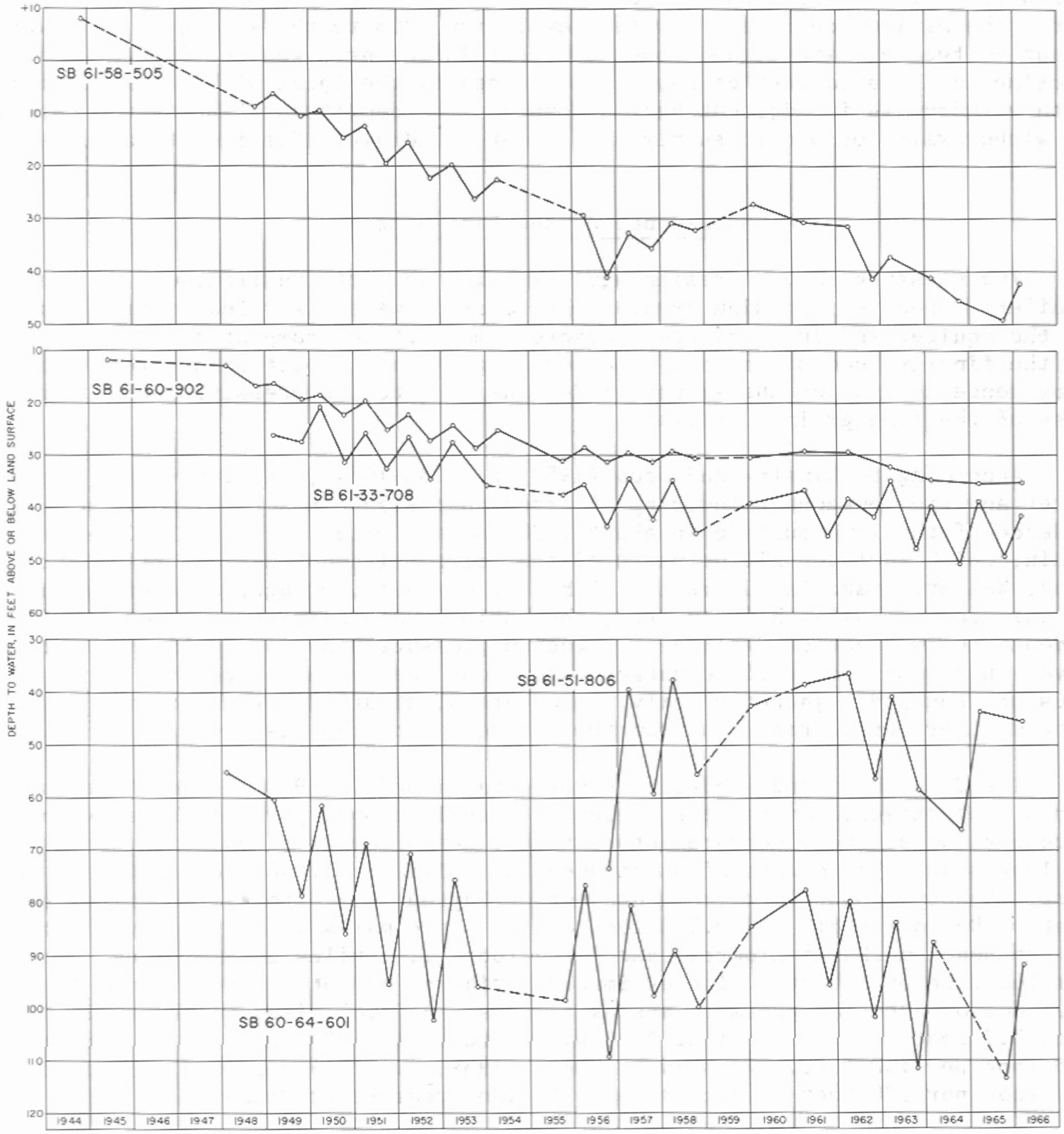

Figure 10

Hydrographs of Water Levels in Selected Wells

U. S. Geological Survey in cooperation with the Texas Water Development Board determine the quality of the water and the transmissibility of individual sands.

In wells to be used for irrigation, the pilot hole generally is reamed from top to bottom to diameters which normally range between 20 and 36 inches. Casing size generally ranges from 12 to 34 inches in diameter, and the screen size ranges from 12 to 24 inches in diameter. The screen used in irrigation wells in Liberty County is either slotted pipe or wire-wrapped perforated pipe. In many irrigation wells, the casing and screen are installed as a unit; in others, the screen is set in place after the surface casing is set. In large-capacity municipal or industrial wells, the pilot hole is reamed to between 16 and 30 inches in diameter, and surface casing is set and cemented. Then the section below the surface casing is underreamed and the screen is installed. In most of the municipal and industrial wells, the diameters of the surface casings are 12 inches or less, and the largest screen is 8 inches in diameter. Following placement of the screen, most of the large-capacity wells in Liberty County are "gravel packed" by pumping "gravel" into the annular space between the screen and the wall of the well. In these wells, the "gravel" actually ranges in size from medium to coarse sand. The gravel pack decreases the velocity of the incoming water by increasing the effective well diameter and minimizing the amount of sand moving from the aquifer into the well. In general, gravel packing increases maximum yield, minimizes drawdown, and decreases pump wear caused by pumping sand. The well is then developed by surging, swabbing, pumping, backwashing, or occasionally by the use of chemicals. Development is continued until the amount of sand produced is below allowable limits and the well meets performance specifications.

Some of the factors that should be given consideration in proper well construction are:

1. The well should be sufficiently straight to permit the operation of a deep-well pump without unnecessary wear.

2. The casing and screens should meet basic requirements for strength and should have maximum resistance to corrosion and to the abrasion caused by pumping sand.

3. The diameter of the surface casing should be large enough to accommodate a pump that is capable of producing the required amount of water, and the casing depth should be sufficient to allow the pump to be lowered as the pumping level declines during the expected life of the well.

4. The uppermost screen should be below the deepest pumping level that may be expected during the life of the well. This design is to prevent water from cascading into the well during pumping. Cascading water will trap air which will accumulate in pockets at the impellers of the pump and reduce the efficiency of the pump.

5. For a gravel-packed well, the size of the gravel and screen openings should be determined from a grain-size analysis of the sands to be screened. The gravel should be completely and uniformly packed around the screens and casing.

6. The well should be adequately developed to insure maximum production with minimum drawdown and sand production.

Most pumps on irrigation wells are driven by internal combustion engines, and the fuel is usually butane, natural gas, or diesel. Most public-supply and industrial wells are equipped with electric motors.

QUALITY OF GROUND WATER

The chemical constituents of the ground water in Liberty County originate principally from the soil and rocks through which the water has moved and thus reflect the differences in the mineral content of the geologic formations that have been in contact with the water. The quantities of some constituents, especially sodium and chloride, indicate the extent of removal of connate water by flushing. Generally, the chemical content of the water increases with depth. The temperature of ground water near the land surface is generally about the same as the mean air temperature of the region but increases with depth. The chemical analyses of water from 169 selected wells in the report area are given in Table 8, and the temperatures of the water samples are given in Table 5. General discussions of the quality of ground water are included in "A Primer on Water Quality" by Swenson and Baldwin (1965) and in the "Study and Interpretation of the Chemical Characteristics of Natural Water" by Hem (1959).

Relationship of Quality of Water to Use

The major factors that determine the suitability of a water supply are the limitations imposed by the contemplated use of the water. Among the various criteria established for water quality are: bacterial content; physical characteristics, such as temperature, odor, color, and turbidity; and chemical constituents. Usually, the bacterial content and the undesirable physical properties can be alleviated economically, but the removal of undesirable chemical constituents can be difficult and expensive.

The dissolved-solids content is an indication of the chemical quality of the water. A general classification of water based on dissolved-solids content, in ppm (parts per million), is as follows (Winslow and Kister, 1956, p. 5):

Description	Dissolved-solids content (ppm)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

The dissolved-solids and chloride contents of water samples from 160 wells are shown on Figure 11. The figure also shows the depths of the wells, the approximate locations of the salt domes, and the approximate depths to the top of the salt at each dome. The samples are classified as fresh water, with the exceptions of 12 samples that are in the lower range of slightly saline water.

The U.S. Public Health Service (1962) has established and periodically revises standards of drinking water to be used on common carriers engaged in interstate commerce. The standards are designed to protect the traveling public and may be used to evaluate domestic and public water supplies. According to the standards, chemical constituents should not be present in a public water supply in excess of the listed concentrations shown in the following table, except where other more suitable supplies are not available. Below is a partial list of the standards adopted by the U.S. Public Health Service (1962, p. 7-8) that includes those constituents in the analyses from the report area (Table 8):

Substance	Concentration (ppm)
Chloride (Cl)	250
Fluoride (F)	(*)
Iron (Fe)	0.3
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Dissolved solids	500

*According to the Public Health Service (1962, p. 8, 41), the optimum fluoride level for a given community depends on climatic conditions because the amount of water (and consequently the amount of fluoride) ingested is influenced primarily by air temperature. The optimum value of 0.7 ppm in Liberty County is based on the annual average of maximum daily air temperature of 80.3°F at Liberty. The presence of fluoride in average concentrations greater than twice this value, or 1.4 ppm, would constitute grounds for rejection of the supply.

Of the 39 samples analyzed for fluoride, 8 were greater than 0.7 ppm, and none exceeded 1.4 ppm. Water containing optimum fluoride content reduces tooth decay, especially when the water is used by children during the period of enamel calcification. In excessive concentration, fluoride may cause mottling of the teeth, depending on the age of the child, the amount of water consumed, and the susceptibility of the individual (Maier, 1950, p. 1120-1132).

Water having a chloride content of more than 250 ppm may have a salty taste. The chloride content of samples from 160 wells is shown on Figure 11. The figure shows that with a few exceptions the chloride content was less than 100 ppm in samples from the northern half of the county; in the southern half, most of the samples contained more than 100 ppm of chloride and ranged to 660 ppm.

Water containing iron in excess of 0.3 ppm may cause reddish-brown stains on laundry, utensils, and plumbing fixtures. Large amounts of iron give water an objectionable taste. Of the 69 samples analyzed for iron, 24 contained more than 0.3 ppm.

The drinking-water standards of the Public Health Service (1962, p. 7) suggest a limit of 45 ppm of nitrate. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants), and therefore, should not be used in infant feeding (Maxcy, 1950, p. 271). Of the 100 samples analyzed for nitrate, 4 contained more than 45 ppm. The depth of the wells that yielded water with an excessive amount of nitrate ranged from 18 to 62 feet. It is evident that these wells were polluted by sewage or by other organic material from surface water entering the wells, because no deep wells in the county are known to yield water with an excessive amount of nitrate.

Water containing sulfate in excess of 250 ppm may produce a laxative effect. The sulfate content in 136 samples ranged from 0.0 to 58 ppm; consequently, sulfate is not a problem in Liberty County.

Calcium and magnesium are the principal constituents in water that cause hardness. Hard water forms scale in boilers, water heaters, and pipes, and increases the consumption of soap. The commonly accepted classification of water hardness, expressed in ppm calcium carbonate, is as follows: less than 60 ppm, soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; and more than 181 ppm, very hard. The water samples in Table 8 have a wide range in hardness and are about equally divided among the four groups.

The quality-of-water requirements for industrial uses range widely, as almost every industrial requirement has different standards. In general, water used for industry may be placed in three categories--process water, cooling water, and boiler water. Process water is the term used for the water incorporated into or in contact with the manufactured products. The quality requirements for this use may include physical and biological factors in addition to chemical factors. Water for cooling and boiler uses should be non-corrosive and relatively free of scale-forming constituents. In boiler water the presence of silica is undesirable because it forms a hard scale or encrustation, the scale-forming tendency increasing with the pressure in the boiler (Moore, 1940, p. 263). Suggested water-quality tolerances for a number of industries have been summarized by Hem (1959, p. 250-254) and Moore (1940).

Several factors other than the chemical quality are involved in determining the suitability of water for irrigation. The type of soil, adequacy of drainage, crops grown, climatic conditions, and quantity of water used--all have important bearing on the continued productivity of irrigated land.

The tabulation of the chemical analyses of water samples from 169 wells in Liberty County (Table 8) includes the basic data commonly used in the determination of the suitability of water for irrigation. However, the other factors should be considered because they may modify the effects of the chemical content of the water. The following discussion of the suitability of water for rice irrigation, which is from Irelan's (1956, p. 330-331) report on the quality of water in southwestern Louisiana (where climate and other conditions are similar to Liberty County), describes briefly the relationship among the several factors, especially the relationship of salt tolerance to the stage of growth of the rice.

> The suitability of water for rice irrigation depends not only on the concentration of its chemical constituents but also upon the stage of growth of the rice, the nature of the soil (porosity, permeability, drainage, and other factors), and the concentrations of harmful salts present in the soil prior to the application of the irrigation water.

Published standards of water quality for irrigation use were developed for arid regions where rainfall is not sufficient to prevent salt accumulation in the soil. Salt accumulation in the soil probably occurs very infrequently in southwestern Louisiana as the high rainfall normally leaches excessive salts from the soil during periods when the land is not in cultivation. It is now recognized generally that quality-of-water requirements are much less rigid in regions of high rainfall (Straebner, 1940, p. 3).

It is well known to the rice farmers in Louisiana that the concentration of salts in the irrigation water has an important effect upon the growth of rice. Salt-water damage to rice crops ranges from slight reductions in quality and yield to complete loss, depending upon the salinity of the applied water, the age of the rice when irrigated with salty water, and the length of its application.

Data given in various publications on salt tolerance of rice differ widely. It generally seems to agree, however, that water containing less than 600 ppm of sodium chloride (35 grains of sodium chloride, salt, per gallon or 350 ppm of chloride) is not harmful to rice at any stage of growth.

The following is a digest of instructions issued by the Acadia-Vermilion Rice Irrigation Co., Inc., in 1937 in regard to salinity of irrigation water.

"Water with more than 40 grains of salt per gallon should not be used to wet young rice for the first time.

"The soil should not be allowed to dry after the first wetting.

"No more than the following maximum salinities should be permitted. Salinity can be increased during stages as shown."

Permissible salinity of water for irrigation of rice in grains (salt) per gallon of water. (Multiply by 10 to give limits as parts per million of chloride.)

Plant growth		Salinity	
		Variety of rice	
Stage	Age (days)	Blue Rose	Prolific
Stooling..............	25-30	75-100	75-100
Jointing..............	30-80	150-200	140-175
Booting...............	80-90	200-250	175-200
Heading...............	100-110	250-275	200-225

Ground water has been used successfully to irrigate rice in Liberty County since 1895. However, it cannot be assumed that all the ground water is suitable for rice irrigation in all parts of the county because a few irrigation wells are reported to have been abandoned due to the high salinity of the water.

A classification for judging the quality of a water for irrigation was proposed in 1954 by the U.S. Salinity Laboratory Staff (1954, p. 69-82). This classification, which is now commonly used, is based on the salinity hazard as measured by the electrical conductivity of the water and the sodium hazard as measured by the SAR (sodium-adsorption ratio). Sodium can be a significant factor in evaluating the quality of irrigation water because water with a high SAR will cause the soil structure to break down by deflocculating the colloidal soil particles. Consequently, the soil can become plastic, thereby causing poor aeration and low water availability. This possibility is especially true of fine-textured soils. Wilcox (1955, p. 15) stated that the system of classification of irrigation waters proposed by the Laboratory Staff "...is not directly applicable to supplemental waters used in areas of relatively high rainfall." Wilcox (1955, p. 16) indicated that generally water may be used safely for supplemental irrigation if its conductivity is less than 2,250 micromhos per centimeter at 26°C and its SAR is less than 14.

Another factor in assessing the quality of water for irrigation is the RSC (residual sodium carbonate) in the water. Excessive RSC will cause the water to be alkaline, and the organic material in the soil will tend to dissolve. The soil may become a grayish black and the land areas affected are referred to as "black alkali." Wilcox (1955, p. 11) states that laboratory and field studies have resulted in the conclusion that water containing more than 2.5 epm (equivalents per million) RSC is not suitable for irrigation. Water containing from 1.25 to 2.5 epm is marginal, and water containing less than 1.25 epm RSC probably is safe. However, the successful use of marginal water for irrigation might be made possible by proper irrigation practices and use of soil amendments. Furthermore, the degree of leaching will modify the permissible limit to some extent (Wilcox, Blair, and Bower, 1954, p. 265).

Boron is essential to proper plant nutrition, but an excessive boron content will make water unsuitable for irrigation. Wilcox (1955, p. 11) indicated that a boron concentration of as much as 1.0 ppm is permissible for irrigating sensitive crops. The small boron content of 30 water samples, which ranged from 0.02 to 0.39 ppm, indicates that boron is not a problem in Liberty County.

Chemical Quality of Ground Water in the Hydrologic Units

Jasper Aquifer

The samples from wells tapping the Jasper aquifer are fresh water of the sodium bicarbonate type. The water is soft, low in chloride and sulfate, and suitable for public supply. The SAR values of the water samples ranged from 12 to 23, and the RSC values ranged from 3.87 to 5.57 epm.

Evangeline Aquifer

The samples from wells completed in the Evangeline aquifer in the northern half of Liberty County are fresh water of the calcium bicarbonate type. The water is low in chloride and sulfate, ranges from soft to very hard, and is suitable for public supply and irrigation uses. The SAR values ranged from 0.2 to 2.3, and the RSC values ranged from 0.00 to 1.34 epm.

The samples from wells completed in the Evangeline aquifer in the southern half of Liberty County are fresh water and may be classified in three groups: the calcium bicarbonate type, mixtures of the sodium chloride and calcium bicarbonate types, and mixtures of the sodium chloride and sodium bicarbonate types. The water samples range from soft to very hard; the sulfate contents are small; but the chloride contents range from 26 to 588 ppm. The SAR values range from 1.7 to 13, and the RSC values range from 0.00 to 3.28 epm. The samples indicate that most of the water is suitable for public supply and irrigation uses.

Chicot Aquifer

The samples from wells completed in the Chicot aquifer range from fresh to slightly saline water and may be classified in three groups: the calcium bicarbonate type, mixtures of the sodium chloride and calcium bicarbonate types, and mixtures of the sodium chloride and sodium bicarbonate types. The water samples range from soft to very hard, the sulfate contents are small, but the chloride contents range from 8 to 660 ppm. The SAR values range from 0.1 to 16, and the RSC values range from 0.00 to 5.08 epm. The samples indicate that most of the water is suitable for public supply and irrigation uses.

Protection of Ground Water

A potential source of ground-water contamination in Liberty County exists in the movement of brines from the underlying salt water-bearing formations through improperly cased oil wells or improperly plugged oil tests. In recent years, the Texas Water Development Board has made recommendations to the oil operators of the depths to which water-bearing formations should be protected; the Oil and Gas Division of the Railroad Commission of Texas regulates oil and gas production operations and requires protection of the water-bearing formations.

Figure 12 shows the approximate depth of the fresh to slightly saline water sands in some of the oil fields in Liberty County and the amount of cemented casing required according to published rules of the Railroad Commission. The figure indicates that at least in some of the fields the fresh to slightly saline water sands are not adequately protected. No cases have been determined def - nitely where salt-water contamination has resulted from inadequately cased oil wells in Liberty County. However, such contamination is suspected in the older salt-dome oil fields, which were extensively developed before casing regulations went into effect.

Figure 11 indicates no extensive contamination of the ground-water supplies in areas adjacent to the salt domes. However, the reported high chloride content of water from wells in the areas over the shallow salt domes indicates local contamination of the ground-water supplies. The earliest oil discoveries in Liberty County were reservoirs related to shallow salt domes--North Dayton in 1905, Hull in 1918, and South Liberty in 1925--and many wells were drilled before the procedure of cementing casing was invented. Consequently, leaks of

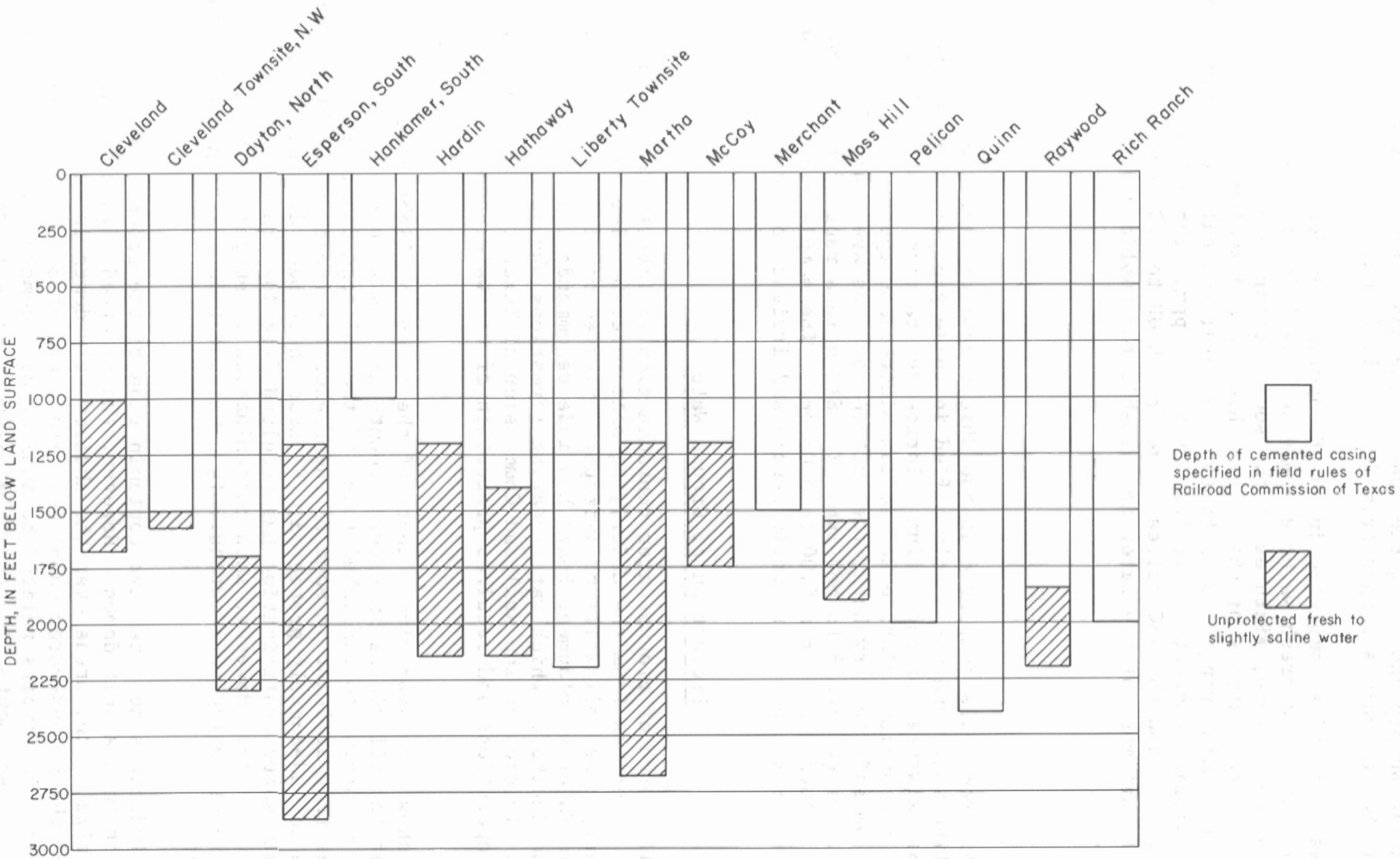

Figure 12

Comparison Between Depth to Base of Fresh to Slightly Saline Water and Depth of Surface Casing Required in Oil Fields

U.S. Geological Survey in cooperation with the Texas Water Development Board

saline water through corroded well casings were probably the cause of much of the present contamination. Natural contamination caused by the solution of the salt plug is believed to be a factor of minor importance. Jones (1956, p. 97) wrote:

> The salt mass of a piercement-type dome generally is tightly sealed from ground water in the beds penetrated. Fault gouge and crushed and altered rock blanket the plug. Steeply upturned pinched-off beds abut it. Therefore, the principal hydrologic effect of salt domes is a function of the thinning of overlying beds and the faulting and folding they produce, rather than an effect on the quality of the water in the adjacent beds.

Another potential source of contamination is the infiltration of oil-field brine from disposal pits on the outcrop of the Chicot aquifer. The Texas Water Commission and Texas Water Pollution Control Board (1963) published a statistical analysis of data on oil-field brine production and disposal in Texas for the year 1961. The data are from an inventory conducted by the Texas Railroad Commission.

In 1961, 18,541,000 barrels (23,900 acre-feet, or 778.7 million gallons) of brine was produced from the oil reservoirs in Liberty County. Of this amount, disposal of 15,682,000 barrels (2,021.3 acre-feet, or 658.6 million gallons--84.6 percent of the total) was by means of injection wells; disposal of 2,108,000 barrels (271.6 acre-feet, or 88.5 million gallons--11.4 percent of the total) was by means of pits; disposal of 722,000 barrels (93.0 acre-feet, or 30.3 million gallons--3.9 percent of the total) was in surface watercourses; and disposal of 29,000 barrels (43.9 acre-feet, or 13.5 million gallons--0.15 percent of the total) was by miscellaneous or unknown methods. It is unlikely that any contamination of the water supplies results from the disposal of brine in properly constructed injection wells. However, it is probable that at least part of the brine disposed of by other methods has contaminated water in the shallow sands in local areas in Liberty County. Because of the slow rate at which ground water moves in Liberty County, contamination may not be detected for many years. Also, it cannot be remedied immediately by stopping the contamination at the source, because purification by leaching and dilution will require a longer time than the period of contamination.

AVAILABILITY OF GROUND WATER

The availability of water for future development from the aquifers in Liberty County is dependent upon a number of factors; the most important are: the ability of the aquifers to transmit water, the amount of water in storage, the rate of recharge to the aquifers, the chemical quality of the water, and economic factors including the cost of wells.

Fresh water occurs to altitudes ranging from as much as 1,800 feet below sea level in the northwestern and south-central parts of Liberty County to less than 100 feet below sea level at two salt domes in the southern part (Figure 13). The total thickness of sands containing fresh water ranges from 0 feet at the Moss Bluff salt dome in the south-central part of the county to more than 500 feet in an area that extends northeastward through Liberty County (Figure 14). The potential for development of the fresh-water resources of Liberty County is greater in the areas where the total thickness of these sands is greater.

Large quantities of fresh water are available to wells in the area where the thickness is more than 300 feet.

Because of the large quantity of fresh water available in Liberty County, only a small quantity of slightly saline water is being used. The county contains a relatively large quantity of slightly saline water which, without treatment, may be suitable for some purposes. Figure 15 shows that the approximate altitude of the base of slightly saline water in Liberty County ranges from less than 500 feet below sea level to more than 3,200 feet below sea level. The altitude is higher in the salt-dome areas than in adjacent areas, and generally, the pattern of this map resembles Figure 13. As shown on Figure 16, the total thickness of sands containing slightly saline water in Liberty County has a general range from less than 100 feet to more than 300 feet. There has been relatively little development of the slightly saline water in Liberty County; consequently, no hydrologic data are available for this resource. However, it is estimated that large quantities of slightly saline water are available to wells in the southern part of the county in areas where the sand thickness is more than 300 feet.

The Evangeline and Chicot aquifers have supplied almost all of the ground water used in Liberty County. In 1965, the two aquifers supplied an estimated 51 mgd of the total 51.2 mgd used. The Evangeline and Chicot also have the greatest potential for future development--an increase to about 200 mgd, if most of the future development is restricted to the northern and central parts of the county. This estimate was made from data obtained during the present investigation and from a comparison with pumpage in the Houston district, where the hydraulic characteristics of the aquifers are very similar to those in Liberty County and where large quantities of water have been pumped for many years. Present data are adequate only for a preliminary estimate of the potential development of the aquifers in Liberty County; more data on aquifer performance are needed to obtain more accurate estimates of availability.

One of the principal factors in determining the quantity of water available is the ability of an aquifer to transmit water to wells. In order to estimate the quantity of water available from the Evangeline and Chicot aquifers, a set of theoretical computations was made. It was assumed that a line of wells was installed across the county through Dayton, Liberty, and Daisetta. This line would be 28 miles long, parallel to the outcrop, and would transect the centers of lowest artesian pressure (Figure 6). It was assumed that the wells were pumped in such a way that the water level along the line of wells was lowered to 500 feet below the land surface; that during the pumping period, no water moved into the aquifer except the recharge along the centerline of the outcrop area (line of recharge would be 28 miles long and 18 miles updip from and parallel to the line of wells); that recharge would be adequate to maintain the water level along the line of recharge at the same altitude as at the beginning of pumping; and that all sands between the line of recharge and the line of discharge transmit water from the outcrop to the line of discharge. On the basis of the hydraulic gradient that would be established (28 feet per mile) and the composite transmissibility of the aquifer (250,000 gpd per foot), about 200 mgd (224,000 acre-feet per year) of fresh water would be transmitted from the line of recharge to the line of discharge.

The water being pumped in Liberty County comes from four sources: recharge on the outcrop, interformational leakage, storage in the aquifers, and compaction of clays. If the withdrawals were increased to 200 mgd, most of the additional water would come from the supply of recharge now being rejected at the outcrop--the increases from the other sources would be relatively small. Prior to development, the hydraulic gradient was 2.5 feet per mile and recharge to the aquifers about 18 mgd. Present development has increased the hydraulic gradient from the northwesterly direction to about 7 feet per mile, and consequently, the present recharge rate is at least 50 mgd. The natural discharge now being rejected at the outcrop in the northern part of Liberty County and the southern parts of adjacent San Jacinto and Polk Counties is a potential supply of recharge to the aquifers in Liberty County. The quantity available in this area is not known, but preliminary estimates of rejected recharge in areas east of Liberty County that are comparable in size and where conditions are very similar indicate that rejected recharge will be adequate to increase the withdrawal of ground water in Liberty County to about 200 mgd. Water from recharge and from interformational leakage are renewable sources, but the water released from storage in the aquifers and from the compaction of clays is not renewable. The small quantity of water available from the compaction of clays is indicated by the relatively small amount of subsidence of the land surface in the southern part of the county.

An immediate estimate of the availability of ground water in Liberty County can be determined by comparing the area with a similar area in which large-scale development has already taken place and for which much more data are available. In the adjacent Houston district, observations of the performance of the aquifers in response to large-scale withdrawals have been made since 1929. Pumpage in the Houston district is from the same aquifers as in Liberty County, and the hydraulic characteristics of the aquifers in the two areas are very similar. Large-scale withdrawals in the Houston district have caused large declines in water levels, especially in areas of concentrated pumpage. Pumpage in the Houston district was reported to have been about 377 mgd in 1964 and 387 mgd in 1965 (Personal communication, R. K. Gabrysch, 1966). In response to this increase in pumping, water levels have continued to decline with the greatest decline occurring in the area of greatest withdrawal. In the area of heaviest pumping, water levels have declined more than 350 feet since development began. The fresh and slightly saline water-bearing beds underlying Liberty County may not be as prolific as those underlying the Houston district, but it seems reasonable that about 200 mgd could be pumped perennially from properly spaced wells in Liberty County without excessive water-level declines.

Very little data are available from which an estimate can be made of the potential of the Jasper aquifer. Two wells yield only moderate supplies of fresh water, and it is very probable that the yields of future wells tapping the Jasper in the county would be of the same magnitude. The only fresh water in the Jasper in Liberty County occurs in the uppermost part of the aquifer along the northern boundary of the county (Figures 18 and 19). Because of the limited areal extent of the occurrence of fresh water and the availability of large quantities of fresh water in the overlying Evangeline and Chicot aquifers, no significant development of the Jasper is anticipated in Liberty County.

RECOMMENDATIONS FOR FUTURE STUDIES

Large quantities of fresh water are available in the aquifers in most of Liberty County. However, proper planning and proper development will be necessary to obtain the maximum economic benefits from this natural resource.

The information in this report indicates the scope of the basic data needed for an accurate evaluation of the county's ground-water resources: (1) a more accurate estimate of the recharge being rejected by the aquifers, (2) detailed records of withdrawals and declines of water levels, and (3) an extensive testing of the hydrologic properties of the aquifers.

It is essential that the collection of basic data be continued. The better method of acquiring additional data is to obtain it as new developments are made and the information is still readily available. An inventory of large-capacity wells as they are drilled is an essential part of a pumpage inventory, and the well data required for the proper evaluation of an aquifer test usually are more readily available for a new well than an old one.

The greater part of the ground water available for future development will be supplied by recharge that is now being rejected in the outcrop areas. An accurate evaluation of this potential source will require measurement of spring discharge at numerous locations, accurate estimates of evapotranspiration losses between places of discharge and gaging sites, and the correlation of these data with climatological records. These measurements should be continued for a period of at least several years to determine the relationship of variations of climate to the quantities of natural discharge.

Pumping costs can be kept at a minimum if the larger developments are restricted to the more favorable areas and if the wells are properly designed and adequately spaced to minimize interference. The quantities of water withdrawn should be adjusted to local differences in aquifer conditions. Water levels will decline as withdrawals are increased, and it is possible to increase withdrawals in local areas to the extent that pumping costs become prohibitive. However, future rates of water-level decline can be anticipated and preventive measures can be made in time if adequate records of water-level measurements and quantities of water withdrawn are maintained.

The present program of measuring water levels in observation wells should be expanded to include all of the county. Inventories of the quantities of water pumped should be made at regular intervals, preferably once each year, for the entire county.

An enlarged network of bench marks that are measured periodically will be required to more completely determine the subsidence of the land surface. The amounts of subsidence to date have been small and apparently have extended over a large area. Consequently, no damage from subsidence has been reported. Subsidence will continue as the artesian pressure declines, but possible future damage can be kept at a minimum if pumpage is evenly distributed throughout the area.

Salt-water intrusion, which is occurring at several localities along the coast, is a normal result of the development of coastal artesian aquifers. The problem has become increasingly more serious in recent years as the demands for ground-water supplies have increased. The piezometric map (Figure 6) indicates that water is moving slowly updip in the southern part of the county. This movement will ultimately result in the intrusion of salt water from the downdip parts of the aquifers. However, most of the withdrawals that caused the reversal of the natural downdip movement of water have occurred during the past two decades, and it may be several decades before intrusion becomes a hazard in Liberty County. Periodic sampling of key wells in the southern part of the county should be included in the continuing program because only a slight increase in salinity would be sufficient evidence that the quality of the water in a local area could not be maintained under heavy pumping. This probably will be the situation in the southwestern corner of the county, which is adjacent to a heavily pumped part of the Houston District.

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Table 5.--Records of wells and springs in Liberty County

All wells are drilled unless otherwise noted in remarks column.

Water level : Reported water levels are given in feet; measured water levels are given in feet and tenths.

Method of lift and type of power: A, airlift; B, bucket and rope; C, cylinder; Cf, centrifugal; E, electric; G, gasoline, butane or diesel engine; H, hand; J, jet; N, none; Ng, natural gas; T, turbine; W, windmill. Number indicates horsepower.

Use of water : D, domestic; Ind, industrial; Irr, irrigation; N, none; P, public supply; S, livestock.

Water-bearing unit : J, Jasper aquifer; Ev, Evangeline aquifer; Ch, Chicot aquifer.

	Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
									Below land surface datum (ft)	Date of measurement			
	SB-60-40-901	Roy Morton & Sons	--	--	215	13	Ev	161	38.0	Apr. 9, 1952	N	N	Unused irrigation well.
	903	do	- Peveto	1947	220	13	Ev	159	36.1	Mar. 15, 1949	N	N	Abandoned. Unused irrigation well.[3]
*	48-101	City of Cleveland well 3	Layne-Texas Co.	1951	1,337	14,12,6	J	160	22	June 1951	T,E,20	P	Cased to bottom. Screen from 1,119-1,139, 1,170-1,185, 1,205-1,210, 1,280-1,300, and 1,310-1,330 ft. Gravel-walled 1,106 to 1,1337 ft. Temp. 86°F.
*	102	City of Cleveland well 1	do	1938	845	13,7	Ev	157	14.7	Jan. 26, 1945	T,E,15	P	Screen from 619-640, 753-774, and 795-833 ft. Reported flowed 400 gpm in 1938.
*	103	City of Cleveland well 2	do	1938	833	13,7	Ev	157	16.9	Jan. 26, 1945	T,E,20	P	Originally drilled to 929 ft; plugged back to 833 ft. Screen from 614-637, 753-771, 793-833 ft. Reported flowed in 1938. Drawdown 78 ft pumping 353 gpm in 1938. Temp. 78°F.
*	104	G.C. & S.F. RR. Co.	--	1937	1,152	13,4	J	157	+	Oct. 1937	T,E,5, Flows	Ind	Screen from 1,181-1,208, 1,250-1,280, 1,286-1,338, 1,424-1,446, 1,466-1,478 ft. Reported flowed 30 gpm in 1937. Supplies boiler water for Santa Fe and Southern Pacific RR.[1]
*	105	Grimes Veneer & Panel Co.	--	1937	90	6	Ev	157	24	Jan. 1945	N	N	Formerly supplied water for sawmill boiler. Open hole at bottom, no screen. Abandoned in 1966.
*	106	E. L. Bruce Co. of Texas	--	1938	300	4	Ev	157	30	do	N	N	Formerly supplied water for sawmill boilers. Screen from 277 ft to bottom. Abandoned in 1966.
*	107	Corrigan Lumber Co.	--	1935	200	6	Ev	157	28.4 26.9	Jan. 26, 1945 Feb. 19, 1948	N	N	Formerly supplied water for sawmill boilers. Abandoned, 1966.[3]
*	108	G. C. & S. F. RR. Co.	R. C. Davant	1916	1,298	8,4	Ev,J	157	44	1916	N	N	Originally drilled to 1,360 ft; plugged back to 1,298 ft. Screen from 690-710, 763-785, 912-952, and 1,180-1,298 ft. Reported flowed 300 gpm, Dec. 1916. Replaced in 1937. Flowed from 1-in. line in 1945. Abandoned.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-60-48-109	Gulf States Utilities Co.	A. J. Lesterjette	1905	386	4,3	Ev	160	32	1930	N	N	Screen from 364 to 386 ft. Reported sealed in 1938. Formerly used for municipal water supply.
* 202	City of Cleveland well 4	Stamm-Scheele	1965	1,641	12,6	J	157	+ 17	1966	Flows, T,E,40	P	Screen from 1,560 to 1,610 ft. Temp. 89°F.
* 301	Vernon Elledge well 3	Katy Drilling Co.	1957	980	20,12	J(?),Ev	153	37.7 40.4	Jan. 4, 1960 Mar. 26, 1965	T,Ng	Irr	Casing: 250 ft of 20-in. Gravel-walled.
* 302	Vernon Elledge well 2	Texas Water Wells, Inc.	1954	452	14	Ev	153	39.0 41.2	Jan. 4, 1960 Mar. 26, 1965	T,Ng	Irr	Gravel-walled. Temp. 70°F.
* 401	Clarkson & Mechim	Ford & Thompson	1920	327	8	Ev	110	+	Apr. 6, 1945	N	N	Screen from 287 to 327 ft. Formerly supplied gravel pit. Reported flowed 10 gpm, Apr. 6, 1945. Destroyed, 1965. Temp. 70°F.
* 402	Grogan Manufacturing Co.	--	1910	187	4	Ev	115	+ 7	Feb. 1945	N	N	Reported flowed 10 gpm, Apr. 1945. Formerly supplied sawmill boilers. Destroyed, 1965. Temp. 69°F.
* 404	W. E. Henry	E. L. Chambers	1944	18	1	Ev	130	10	Apr. 1945	N	N	Driven well. Formerly used as domestic well. Destroyed, Dec. 1965.
* 405	do	W. E. Henry	1963	25	2	Ev	129	10	Dec. 1965	J,E	D,S	Bored well. Screen from 20 ft to bottom.
501	C. W. Dove	Pitre Water Well Drilling Co.	1936	304	4	Ev	132	6.2 8.8 9.7	June 8, 1945 Apr. 9, 1952 Mar. 26, 1965	N	N	Formerly used for highway construction.[3]
502	Shell Oil Co.	L. Patterson	1944	179	4	Ev	--	20	Oct. 1944	N	N	Screen from 129 to 152 ft. Formerly supplied water for drilling rig. Abandoned, 1965.
503	Dunman well 1	Smith & McDonald	1936	6,185	--	--	149	--	--	--	--	Oil test.[2]
504	Grogan well 1	Shell Oil Co.	1945	12,200	--	--	140	--	--	--	--	Do.
701	Zoe B. McDonald well 1	Humble Oil & Refining Co.	1946	10,503	--	--	110	--	--	--	--	Do.
* 702	Williams Lumber Co.	Gay Drilling Co.	1961	1,394	--	J	125	+	Jan. 1966	Flows,A	Ind	Screen from 135 ft to bottom. Temp. 85°F.
703	do	do	1960	314	4	Ev	125	--	--	A	D	Screen from 294 ft to bottom.
* 801	Gulf Oil Corp.	--	1940	100	4	Ev	128	20	1940	N	N	Screen from 94 ft to bottom. Formerly supplied water for boilers. Abandoned, 1965.
802	Black Gold Petroleum Co.	Layne-Texas Co.	1934	95	6	Ev	135	--	--	N	N	Screen from 75 to 84 ft. Formerly supplied water for drillers rig. Abandoned, 1965.[1]

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-60-48-803	-- Kirby well 10	Gulf Production Co.	1935	5,840	--	--	131	--	--	--	--	Oil test.[2]
804	-- Kirby well C-13	Gulf Oil Co.	1936	5,870	--	--	130	--	--	--	--	Do.
805	Blanding well 1	Chapman Minerals Co.	1938	6,118	--	--	135	--	--	--	--	Do.
56-201	Jordan Campbell	Humble Oil & Refining Co.	1928	2,000	--	--	118	--	--	--	--	Oil test.[1]
202	Baldwin Estate well 1	Sohio Petroleum Co.	1952	7,660	--	--	106	--	--	--	--	Oil test.[2]
901	E. J. Stoesser well 3	Layne-Texas Co.	1953	1,015	20	Ev	86	94.4 63.0	Oct. 15, 1956 Apr. 3, 1961	N	N	Unused irrigation well. Observation well.[3]
* 902	do	do	1965	1,040	20,12	Ev	85	109	Mar. 1965	T,Ng	Irr	Casing: 20-in. to 303 ft, 12-in. from 303 to 740 ft. Screened opposite sands 300 to 1,040 ft. Originally drilled to 1,104 ft; plugged back to 1,040 ft. Measured discharge 1,200 gpm, Aug. 5, 1965. Temp. 76°F.
64-301	E. J. Stoesser	do	1949	1,006	20,12	Ev	82	46.9 62.4 78.3	Mar. 17, 1949 Apr. 2, 1956 Mar. 23, 1965	T,E,200	Irr	Irrigated 1,035 acres in 1958, and 1,258 acres in 1959. Observation well.[3]
302	Roy Seaberg	--	--	--	--	Ev	82	63.7 65.4 77.8	Apr. 12, 1954 Apr. 3, 1962 Mar. 23, 1965	N	N	Abandoned oil test supply well. Salt reported at 1,100 ft. Observation well.[3]
501	I. T. May	Layne-Texas Co.	1947	850	14	Ev	78	--	--	N	N	Unused irrigation well. Abandoned 1965.
* 502	Roy Seaberg	do	1949	980	--	Ev	76	73.9 83.7	Jan. 25, 1960 Mar. 1, 1966	T,Ng	Irr	Reported measured pumping 1,400 gpm July 25, 1965. Temp. 75°F.
* 601	E. J. Stoesser well 1	do	1944	808	24,12	Ev,Ch	83	55.1 76.8 87.4	Feb. 19, 1948 Apr. 2, 1956 Feb. 27, 1964	T,Ng	Irr	Cased to 437 ft, slotted. Pump set at 165 ft. Gravel-walled below 135 ft. Observation well. Temp. 72°F.[1] [3]
* 602	do	do	1955	1,017	20	Ev,Ch	83	113.2 82.4 120.1	Oct. 10, 1956 Apr. 3, 1961 Oct. 21, 1965	T,Ng	Irr	Reported drawdown 62 ft after pumping 3,405 gpm. Observation well. Temp. 76°F.[3]
* 603	Magnolia Pipeline Co.	--	1927	540	4	Ev,Ch	77	53.0 66.2 83.0	Feb. 19, 1948 Apr. 17, 1951 Jan. 7, 1960	N	N	Formerly supplied pipe line pump station. 200 ft of casing, finished open hole. Formerly observation well. Destroyed, 1962.[3]
* 604	H. T. Glatter	J. N. Nadrntil	1927	20	4	Ch	79	12	Apr. 1945	N	N	No screen. Destroyed, 1965.
605	Myrtle Ridge School	F. Gay	1928	165	4,2	Ch	82	37.1	Apr. 18, 1945	N	N	Screen from 155 ft to bottom. Destroyed, 1948.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-60-64-606	Simmons well 1	W. H. Hunt Trust Estate	1947	9,974	--	--	70	--	--	--	--	Oil test.[2]
* 901	M. F. Zalesky	Texas Water Wells, Inc.	1959	912	18,14	Ev	70	118 79.6 101.4 89.7	1959 Jan. 27, 1960 Mar. 23, 1965 Mar. 1, 1966	T,Ng	Irr	Measured discharge 730 gpm, Aug. 5, 1965. Irrigated 240 acres in 1958; 420 acres in 1959. Gravel-walled. Temp. 74°F.
* 902	L. M. Zalesky well 1	do	1950	595	20,13	Ev,Ch	69	113.3	Aug. 9, 1955	T,G	Irr	Casing: 20-in. to 340 ft, 13-in. from 340 ft to bottom. Slotted pipe 130 ft. Measured discharge 1,030 gpm. Temp. 72°F.
903	M. F. Zalesky	do	1953	802	20,14,8	Ev,Ch	69	63.5 61.4 57.5	Jan. 27, 1960 Mar. 23, 1965 Mar. 1, 1966	T,G	Irr	
904	C. Newman	C. A. Brown	--	400	10,7	Ev,Ch	69	17	1908	N	N	Formerly used for rice irrigation. Reported discharge 800 gpm in 1908. Old well. Destroyed.
905	Henry Zarsky	--	1959	420	10	Ch	69	--	--	T,G	Irr	
906	Charlie Uyoral	Katy Drilling Co.	1962	388	12	Ch	67	--	--	T,G	Irr	Slotted pipe from 180 ft to bottom. Reported discharge 1,000 gpm.
* 907	Mrs. Henry Bode	Rudolph Ckracha	1942	276	3,2	Ch	69	46.0	Apr. 18, 1945	N	N	Formerly used for domestic and livestock well. Abandoned, 1955.
908	Patrick-Tynell	Pitre Water Well Drilling Co.	1941	256	4	Ch	71	46	June 1941	N	N	Screen from 243 to 253 ft. Formerly supplied water for oil test. Destroyed, 1941.
909	Mrs. Henry Bode	Henry Bode	1955	18	3	Ch	70	8	1965	J,E	D,S	Bored well. Open end.
* 61-33-601	C. Die	J. W. Smith	1911	140	4	Ev	126	49.5 56.3 59.3	Apr. 4, 1945 Apr. 3, 1956 Dec. 9, 1965	J,E	D,S	Screen from 130 ft to bottom. Observation well.[3]
* 602	S. J. Keith	--	1940	86	2	Ev	82	7.0	Apr. 4, 1945	B,H	D,S	
* 603	A. M. Smith	--	1924	23	1	Ev	76	14	Apr.	N	N	Driven well. Destroyed, 1965.
* 604	C. Die	Jim Gibson	1911	56	8	Ev	125	47.8 48.1	Apr. 4, 1945 Apr. 16, 1951	J,E	D	Concrete casing.[3]
605	C. M. Lusk	Noack Drilling Co.	1963	262	4	Ev	70	14	Mar. 1963	T,E,5	Irr	Slotted pipe from 143 to 155 ft. Irrigated Coastal Bermuda grass.[1]
* 701	Roy Elledge	Texas Water Wells, Inc.	1955	835	20,12	Ev	157	36.1 37.6 39.7	Apr. 3, 1956 Apr. 4, 1962 Mar. 26, 1965	T,G	Irr	Measured discharge 2,500 gpm. Casing: 20-in. to 250 ft, 12-in. from 250 to 580 ft. Pump set at 190 ft. Observation well. Temp 74°F.[3]

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-61-33-702	I. H. Ellington	Otto Adams	1940	110	3	Ev	155	22	Apr. 1945	J,E	D,S	Screen from 78 ft to bottom.
* 703	B. E. Quinn Estate	--	--	1,200	8	J	156	45	Dec. 1936	N	N	Drilled to 1,800 ft as an oil test; plugged back to 1,200 ft, and completed as a water well. Abandoned, 1939. Old well.
* 704	J. W. Whatley	Jim Gibson	1943	52	8	Ev	155	31.9 34.0	Apr. 5, 1945 Oct. 12, 1955	N	N	Casing: 8-in. concrete. Destroyed, 1965.[3]
* 705	Mrs. W. P. Johnston	Pitre Water Well Drilling Co.	1945	440	4	Ev	156	61.0 71.9	Apr. 17, 1945 Dec. 10, 1965	J,G,1	D,S	Screen from 415 to 430 ft.[1]
* 706	Roy Morton	Layne-Texas Co.	1943	226	18,12	Ev	161	32 31.0 30.9	June 1943 Apr. 10, 1957 Mar. 26, 1965	T,G	Irr	Reported drawdown 69 ft, at 900 gpm. Casing slotted from 57-70, 87-123, and 172-225 ft. Gravel-walled. Observation well.[1] [3]
* 707	M. A. Ellis	--	1912	36	30	Ev	160	28	Mar. 1945	N	N	Dug well. Destroyed, 1965.
708	Roy Morton	Layne-Texas Co.	1947	693	18,10	Ev	161	26.0 35.5 39.0	Mar. 15, 1949 Apr. 3, 1956 Mar. 26, 1965	T,G	Irr	Casing slotted from 500-600 ft, and 635-700 ft. Reported discharge 1,600 gpm. Observation well.[3]
709	B. B. Quinn well A-1	Quintana Petroleum Co.	1950	4,220	--	--	156	--	--	--	--	Oil test.[2]
* 801	J. W. Phillips	Seismograph Crew	1940	85	3	Ev	135	37	June 1940	C,G,1	D,S	Screen from 80 ft to bottom.
802	Lewis Wells, Jr.	A. & L. Pump & Well Service	1963	48	4	Ev	130	38	Mar. 1963	J,E,1/3	D	Screen from 42 ft to bottom.[1]
* 803	J. C. Carter	Jim Gibson	1943	45	8	Ev	125	32.7	Apr. 5, 1945	N	N	Concrete casing. Destroyed, 1965.
* 901	Texas Construction & Materials Co.	--	1937	135	4	Ev	58	+ 18.0	Jan. 9, 1945	Flows,N	N	Reported flowed 20 gpm, Aug. 31, 1965. Formerly industrial well.
* 902	Dolen School	Seismograph Crew	1940	100	4	Ev	70	--	--	J,E	D	Reported flowed 4 gpm in 1944. Supplied water for 4 houses in 1965. Reported not flowing in 1965. Temp. 70°F.
* 903	Pearl Kirkham	-- Reuter	1943	22	2	Ev	71	9	Apr. 1945	N	N	Screen from 18 ft to bottom. Destroyed, 1965.
* 904	Irving Ellington	--	1940	30	2	Ev	60	20	do	N	N	Reported gravel from 8 ft to bottom. Casing slotted. Destroyed, 1965.
* 905	A. A. Richards	J. E. Gay	1946	236	--	Ev	65	+	July 26, 1965	Flows	D,S	Screen from 216 ft to bottom. Supplies water for minnow pond. Flowed 2 gpm in 1965. Temp. 69°F.
906	L. J. Smith	--	1957	257	2	Ev	65	+	Sept. 1965	Flows	D,S	Screen from 247 ft to bottom.
907	G. H. Plander	--	--	296	--	Ev	61	+	Sept. 13, 1965	Flows	D,S	

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-61-33-908	J. H. Haltom	Jim Gibson	1940	62	2	Ev	130	52	Apr. 1945	N	N	Screen from 58 ft to bottom. Destroyed, 1965.
* 909	Liberty County	--	--	Spring	--	Ev	85	+	Apr. 4, 1945	N	N	Flowed 5 gpm in 1945; no flow in 1965. Destroyed.
911	P. C. Kirkham	Gay Drilling Co.	1947	202	4	Ev	72	--	--	J,E,1/2	D,S	Screen from 192 ft to bottom. Reported flowed until 1950.
* 912	J. H. Haltom	do	1959	283	2	Ev	128	--	--	J,E	D,S	Screen from 273 ft to bottom.
* 34-106	Bob LaSalle	--	1948	800	--	J	87	+	1948 Aug. 31, 1965	Flows	P	Flowed 2.5 gpm on Aug. 31, 1965. Reported 6 pound pressure when drilled.
* 107	C. & S. Farms	--	--	Spring	--	Ev	65	+	Aug. 1965	Flows	N	Estimated flow 60 gpm, Aug. 1965.
108	do	--	--	Spring	--	Ev	65	+	do	Flows	N	Estimated flow 200 gpm, Aug. 1965.
201	-- Roberts well 1	John A. Mayo, Inc.	1938	5,350	--	--	85	--	--	--	--	Oil test.[2]
* 401	G.C. & S.F. RR.	Homer Wright	1943	645	8,6	Ev	85	37.0	Jan. 5, 1944	Cf,E,2	P,Ind	Measured discharge 205 gpm. Screen from 536 to 600 ft. Flowed in 1945. Supplies water for railroad station and 6 houses. Temp. 75°F.[1]
* 402	Frost Lumber Co.	W. J. Giles	1907	608	8,6	Ev	76	+ 55	1908	Flows,N	D,S	Formerly supplied water for sawmill boilers. Measured flow 165 gpm in 1945, 50 gpm in 1959. Screen from 485 ft to bottom. Temp. 75°F.
* 403	W. D. Dunnan	--	1939	233	4	Ev	65	2.6 15	Jan. 10, 1945 Aug. 1965	Cf,E,1/4	D,S	
* 404	Horseshoe Lake Estate	-- Miller	1963	382	4	Ev	55	+	Aug. 1965	Flows,N	D	Screen from 340 ft to bottom. Temp. 73°F.
406	W. D. Dunnan	Gay & Son	1949	398	3	Ev	75	+	Sept. 9, 1965	Flows,N	S	Screen from 368 ft to bottom. Gravel-walled.
* 408	G.C. & S.F. RR.	Giles-Williams	1910	650	6	Ev	85	32.0	July 22, 1932	N	N	Destroyed, June 1943. Originally drilled to 300 ft in 1902; deepened to 650 ft in 1910. Formerly used to supply water for boilers. Reported discharge 200 gpm in June 1932.
* 501	Texas Construction Material Co.	-- Jackson	1917	808	8	Ev	75	+	Dec. 9, 1965	Flows	D	Reported flowed 170 gpm, 15 ft above land surface datum in 1944; flowing 25 gpm in Dec. 1965. Formerly used for washing gravel and steam locomotives. Temp. 76°F.
* 502	Miller-Vidor Lumber Co.	R. B. Melat	1907	585	10,4	Ev	75	+ 40	1908	N	N	Reported flowed 300 gpm in 1908; 200 gpm in 1959; no flow in 1965. Screen from 532 ft to 574 ft. Temp. 75°F.

See footnotes at end of table.

Table 5.--Records of wells and spring in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-61-34-503	T. B. Allen & Co.	R. B. Melat	1907	659	3	Ev	82	+ 30	1908	Flows	N	Formerly supplied water for sawmill. Estimated flow 25 gpm, 1945, 15 gpm in 1965. Temp. 75°F.1/
* 506	Bill Daniels	Emanuel Miller	1955	715	6	Ev	60	+	Aug. 1965	Flows	S	Measured flow 60 gpm, Aug. 1965. Screen from 645 ft to bottom. Supplies water for fish pond.
508	J. L. Biggs	Pitre Water Well Drilling Co.	1942	181	4	Ev	58	+	1965	Flows, J,E,1/2	D,S	Reported flows from December thru June; pump used from July through November. Screen from 160 ft to bottom.
* 509	Bill Daniels	Emanuel Miller	1957	500	4	Ev	60	+	Aug. 1965	Flows	D,Irr	Estimated flow 120 gpm.
* 511	Jack Biggs	-- Miller	1956	650	--	Ev	58	+	do	Flows	S	Estimated flow 60 gpm. Casing slotted from 630 ft to bottom.
* 601	P. A. Racki Lumber Co.	--	1906	580	10,4	Ev	82	+	Dec. 1965	Flows	N	Drilled as oil test; plugged back to 580 ft, and completed as water well. Estimated flow 50 gpm in 1965. Formerly supplied water for sawmill. Temp. 78°F.
602	A. Garner well 1	Texam Oil Co.	1954	7,216	--	--	76	--	--	--	--	Oil test.2/
* 603	John Griffin	Chas. Carlson	--	165	4	Ev	123	41.5 44.1	Jan. 11, 1945 Apr. 4, 1957	N	N	Destroyed, 1958.3/
604	Racki Lumber Co.	do	1935	86	6,3	Ev	80	40	1935	N	N	Screen from 76 to 86 ft. Destroyed, 1965.
* 605	Hollis Griffin	--	1940	90	2	Ev	125	40	1940	J,E,1/2	D	
606	Boyd Sewell	Pitre Water Well Drilling Co.	1940	135	2	Ev	122	60	Dec. 1940	N	N	Screen from 116 to 126 ft. Destroyed, 1965.
* 607	A. A. Uprung	Chas. Carlson	1929	87	4,2	Ev	115	47	Jan. 1945	C,E,1	D	Cased to bottom. Screen from 81 ft to bottom.
608	-- Clever	Gay & Son Drilling Co.	1965	136	2	Ev	122	67	Sept. 1965	J,E,1/3	D	
609	Boyd Sewell	Gay Drilling Co.	1954	765	2	Ev	122	4.0	Dec. 8, 1965	J,E,3/4	D,S	
* 801	Texas Construction Material Co.	-- Jackson	1937	808	6,4	Ev	57	+	Jan. 1945	Flows	N	Screen from 706 to 728 ft, and 773 ft to bottom. Measured flow 173 gpm 1945. Formerly supplied water to wash gravel. Temp. 78°F.1/
804	C. F. Lauder	George Gay	1956	480	4	Ev	62	+	July 20, 1965	Flows, C,E, 1-1/2	P	No screen; open hole. Supplies water for small subdivision.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-61-34-805	C. F. Lauder	George Gay	1965	480	--	Ev	57	+	July 20, 1965	Flows, C,E, 3-1/2	P	Reported flow 250 gpm, 1965. Temp. 72°F.
* 807	Texas Construction Material Co.	-- Jackson	1937	310	6	Ev	57	+ 21.5	Jan. 5, 1945	Flows	N	Screen from 270 ft to bottom. Measured flow 25 gpm in 1945. Formerly used to wash gravel. Temp. 71°F.
* 902	Concord School	Pitre Water Well Drilling Co.	1943	104	4	Ev	76	21	Jan. 1943	N	N	Screen from 87 to 97 ft. Destroyed, 1965.
* 903	Liberty County School	--	--	Spring	--	Ev	60	+	1945	Flows	P	Estimated flow 2 to 3 gpm, July 1965. Temp. 68°F.
* 41-101	Vernon Elledge	Texas Water Wells, Inc.	1953	502	14	Ev	153	45.0 45.2 42.4	Jan. 4, 1960 Mar. 26, 1965 Mar. 3, 1966	T,Ng	Irr	Gravel-walled. Temp. 70°F.
* 102	Ida Smith	--	--	45	12	Ev	143	32.2	Apr. 17, 1945	N	N	Bored well. Casing 12-in. wood. Destroyed, 1965. Old well.
103	Ballard well 1	Brazos Oil Co.	1953	10,256	--	--	140	--	--	--	--	Oil test.[2]
202	John DiStefano	George Gay & Son	1964	814	2	Ev	73	+	Dec. 1965	Flows, C,E,1/3	S	Reported flows from December to June. Supplies water to fill fish tank.
203	do	do	1963	199	--	Ev	75	26	Mar. 1963	J,E,1/2	D	Screen from 179 ft to bottom.
204	J. E. Bishop well 1	Humble Oil & Refining Co.	1959	9,495	--	--	141	--	--	--	--	Oil test.[2]
* 301	Wirt Davis	J. W. Gibson	1943	40	8	Ev	133	32.1	Jan. 9, 1945	B,H	D	Bored well. Casing 8-in. concrete.
* 401	Tarkington School	F. E. Gay	1933	325	4,2	Ev	130	50	1945	N	N	Screen from 305 ft to bottom. Abandoned, 1965.
* 402	R. E. Wortham	-- Adams	1936	100	2	Ev	134	15	Jan. 1945	N	N	Bored well. Screen from 90 ft to bottom. Destroyed, 1965.
403	Dovall Ranch	Pitre Water Well Drilling Co.	1936	284	4	Ev	130	18	Apr. 1936	N	N	Formerly supplied water for highway construction. Destroyed, 1947.[1]
404	-- Champion well 1	Porter & Phillips Co.	1953	10,502	--	--	132	--	--	--	--	Oil test.[2]
* 405	W. C. Crawley	--	1939	35	8	Ev	132	24.0	Jan. 25, 1945	N	N	Bored well. Casing 30 ft of concrete. Destroyed, 1965.
* 406	R. E. Wortham	Lee Angel	1936	39	8	Ev	136	9.9	Jan. 26, 1945	N	N	Bored well. Casing 8-in. concrete. Destroyed, 1948.
407	Tarkington School	Noack Drilling Co.	1964	347	4	Ev	131	50	1964	T,E	P	Screen from 337 to 342 ft. Supplies water for school, and 2 houses.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-41-408	R. E. Wortham	Noack Drilling Co.	1962	75	4	Ev	135	--	--	J,E	Ind,D	Supplies water for garage and auto agency. Screen from 65 ft to bottom.
* 501	W. C. Leasure	Pitre Water Well Drilling Co.	1943	368	4	Ev	131	49.9	Jan. 25, 1945	J,E,1/2	D,S	Screen from 322 to 343 ft.1/
* 502	L. O. Ward	A. E. Fawcett, Sr.	1944	247	3	Ev	130	45.0	do	N	N	Screen from 241 to 247 ft. Formerly supplied water for dairy. Destroyed, 1965.
* 503	H. E. Kirk	-- Bland	1944	95	4,3	Ev	132	41.5	Apr. 17, 1945	N	N	Screen from 85 ft to bottom. Abandoned, 1962.
504	L. O. Ward	Noack Drilling Co.	1964	110	4	Ev	130	47.2	Dec. 10, 1965	T,E,1/2	D,S	Screen from 100 ft to bottom.
* 701	M. H. Scott	Katy Drilling Co.	1955	625	20,12	Ev	128	60.8 49.2 54.6	Oct. 6, 1950 Apr. 4, 1962 Mar. 26, 1965	T,E,125	Irr	Casing: 20-in. to 300 ft, 12-in. from 300 to 625 ft. Slotted last 250 ft. Measured discharge 1,950 gpm. Observation well. Temp. 73°F.3/
702	E. J. Scheelky Estate well 2	Nafco Oil & Gas Co.	1960	6,494	--	--	132	--	--	--	--	Oil test.2/
801	Floyd Reidland and P. E. Guthrie	Layne-Texas Co.	1946	677	20,12	Ev	128	41	Nov. 1946	T,G	Irr	Slotted from 91-116, 166-205, 207-261, 303-345, 409-430, and 478-661 ft. Gravel-walled.
* 901	E. J. Groce	A. E. Fawcett, Sr.	1944	222	4,3	Ev	109	45	Jan. 1945	N	N	Destroyed, 1965. Screen from 210 ft to 220 ft.
* 902	S. F. Stevens, Jr.	C. D. Jones	1942	60	2	Ev	109	--	--	N	N	Driven well. Screen from 57 ft to bottom. Destroyed, 1965.
903	F. J. Groce	Noack Drilling Co.	1963	485	4	Ev	110	50	1965	T,E,3/4	D,S	Screen from 473 ft to bottom.
* 42-101	Bert Davis	A. E. Fawcett	1933	480	6	Ev	61	+	Jan. 1945	Flows	S	Measured flow 28 gpm, Jan. 1945. Flowing from pipe 12 ft above land surface datum. Formerly supplied water for sawmill boilers. Temp. 72°F.
* 301	-- Henley	-- Miller	1963	1,000	4	Ev	50	+	Sept. 9, 1965	Flows	D	Estimated flow 120 gpm, Sept. 1965. Screen from 970 ft to bottom.
302	do	do	1964	1,000	3	Ev	53	+	do	Flows	D	Measured flow 40 gpm, Sept. 1965. Slotted pipe from 970 ft to bottom.
402	A. G. Lesterjette	--	1907	662	--	Ev	50	+	1908	N	N	Reported salt and sulfur water, 640 to 642 ft. Strong flow. Old test, plugged in 1909.1/
404	Waters & Davis well 1	Humble Oil & Refining Co.	1956	8,618	--	--	75	--	--	--	--	Oil test.2/

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-61-42-501	Sam Houston Lake Estates	-- Miller	1963	379	--	Ev	54	+	Aug. 5, 1965	Flows, J,E,1/3	D	
* 503	do	C. Lewis	1963	600	--	Ev	48	+	do	Flows	S	Measured flow 1/2 gpm, Aug. 5, 1965. Temp. 73°F.
505	Wirt Davis Estate well 4	The Texas Co.	1955	9,106	--	--	51	--	--	--	--	Oil test.[2/]
506	Wirt Davis Estate well 7	do	1961	5,500	--	--	51	--	--	--	--	Do.
901	-- Neal well 1	Stanolind Oil Co.	1953	8,850	--	--	47	--	--	--	--	Do.
43-102	-- Kirby well A-1	Atlantic Refining Co.	1950	7,971	--	--	106	--	--	--	--	Do.
401	Nona Mills well 2	do	1952	8,503	--	--	106	--	--	--	--	Do.
* 701	A. L. Erickson	J. W. Greak	1952	150	10	Ev	99	67.6	July 23, 1965	T,G	Irr	Reported irrigated 200 acres in 1958 and 1959. Gravel-walled. Temp. 70°F.
* 702	B. J. Jones	Katy Drilling Co.	1953	639	20,12	Ev	97	48.6 44.7	Aug. 8, 1955 Jan. 8, 1960	T,E,150	Irr	Casing: 20-in. to 298 ft, 12-in. from 298 to 341 ft. Casing slotted to 400 ft.
703	A. L. Erickson	do	1963	312	12	Ev	99	67.7	July 23, 1965	T,G	Irr	Cased to bottom. Slotted 259 ft. Gravel-walled. Temp. 70°F.
* 801	do	J. W. Greak	1953	100	10	Ev	93	50.8	do	T,G	Irr	Temp. 69°F.
802	Allen Chambers	Katy Drilling Co.	1952	652	20,12	Ev	95	44.0	Aug. 8, 1959	T,G	Irr	Casing: 20-in. to 200 ft, 12-in. from 200 to 452 ft. Screen 551 ft. Irrigated 240 acres in 1958, 330 acres in 1959.
901	Wesley Fregia	J. W. Greak	1954	158	12	Ev	84	26.6 27.3	Jan. 8, 1960 Apr. 1, 1965	T,G	Irr	Reported irrigated 65 acres in 1958 and 105 acres in 1959.
49-101	Harvard Ranch	Pitre Water Well Drilling Co.	1936	204	4	Ev	118	39.4 46.0 53.8	Jan. 25, 1945 Apr. 16, 1951 Oct. 12, 1955	N	N	Formerly supplied water for highway construction and livestock. Observation well from 1945 to 1955. Destroyed, 1956.[3/]
* 102	Edna Young	A. E. Fawcett, Sr.	1944	103	4	Ev	117	14	Mar. 1944	J,E,3/4	D,S	Screen from 96 ft to bottom.
* 301	Joe Simmonds	--	1900	24	48	Ev	116	7.5 10	June 8, 1945 Dec. 1965	J,E	D,S	Dug well. 48-in. wooden curb. Tile casing at bottom.
* 801	A. C. Holbrook	A. E. Fawcett, Sr.	1943	750	20,12	Ev	95	50	June 1945	T,G	Irr	Reported irrigated 350 acres of rice in 1944. Discharge 1,000 gpm in June 1945.
* 802	W. A. Conner	Layne-Texas Co.	1951	760	14	Ev	97	80.5 82.4 79.5	Jan. 7, 1960 Mar. 23, 1965 Mar. 1, 1966	T,G	Irr	Measured discharge 700 gpm on Aug. 4, 1965. Reported irrigated 700 acres in 1958; and 700 acres in 1959. Temp. 73°F.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date com-plet-ed	Depth of well (ft)	Diam-eter of well (in.)	Water-bearing unit	Altitude of land surface	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-49-803	W. A. Conner	Layne-Texas Co.	1944	742	20,12	Ev	97	48.3 64.0 64.2	Apr. 19, 1945 Apr. 3, 1956 Mar. 23, 1965	N	N	Casing slotted from 150 ft to bottom. Observation well. Unused irrigation well.3/
* 804	do	Katy Drilling Co.	1954	760	18,12	Ev	97	--	--	T,G	Irr	Measured discharge 1,000 gpm on Aug. 4, 1965. Temp. 74°F.
* 805	do	do	1952	624	24,12	Ev	97	--	--	T,G	Irr	Casing: 24-in. to 240 ft, 12-in. from 240 ft to 501 ft. Slotted from 117 ft to bottom. Originally drilled to 741 ft; plugged back to 624 ft. Estimated discharge 120 gpm on Aug. 4, 1965. Reported casing collapsed at 300 ft. Temp. 71°F.3/
* 806	A. C. Holbrock	do	1963	885	20,12	Ev	91	--	--	T,G	Irr	Casing slotted 596 ft. Gravel-walled. Temp. 73°F.
50-302	Knights Forest Subdivision	--	1965	940	--	Ev	38	+	1965	Flows	P	Measured flow 13 gpm on Aug. 16, 1965. Temp. 76°F.
602	Humble Oil & Refining Co.	Pitre Water Well Drilling Co.	1938	218	6,4	Ev	42	15	Nov. 1938	N	N	Casing pulled. Screen from 185 to 212 ft. Formerly supplied water for oil test. Abandoned in 1939.
603	do	do	1938	200	4	Ev	42	15	July 1938	N	N	Screen from 178 to 199 ft. Formerly supplied water for oil test. Abandoned in 1966.
604	do	do	1938	230	4	Ev	42	12	Dec. 1938	N	N	Screen from 183 to 211 ft. Formerly supplied water for oil test. Abandoned in 1939.1/
605	do	do	1938	223	4	Ev	32	14	Oct. 1938	N	N	Screen from 183 to 211 ft. Formerly supplied water for oil test. Abandoned in 1939.
606	M. F. Tulles well 1	L. W. Wickes	1938	7,628	--	--	40	--	--	--	--	Oil test.2/
701	L. Hagy well 1	Shell Oil Co.	1947	9,002	--	--	54	--	--	--	--	Do.
801	James R. Mowery	Pitre Water Well Drilling Co.	1941	197	4	Ch	31	25.5	Jan. 10, 1966	N	N	Cased to bottom. Drilled to 254 ft plugged back to 197 ft. Formerly supplied water for oil test. Not used.1/
901	Humble Oil & Refining Co.	do	1940	230	4	Ch	50	16	May 1940	N	N	Screen from 186 to 214 ft. Formerly supplied water for oil test. Destroyed, 1966.
902	do	do	1940	244	4	Ch	52	15 21.0	May 1940 Jan. 10, 1966	N	N	Screen from 199 to 228 ft. Formerly sup-water for oil test. Not used.
903	Hutcheson well 1	Scurlock Oil Co.	1960	9,260	--	--	47	--	--	--	--	Oil test.2/

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-51-101	Mrs. Ralph Hill	J. W. Greak	1954	1,150	12	Ch	95	47.1 50.6 48.0	Jan. 8, 1960 Mar. 26, 1965 Mar. 1, 1966	N	N	Gravel-walled. Unused irrigation well.
* 102	Frank Duke	Texas Water Wells, Inc.	1955	660	--	Ev	87	44.6 46.9 46.4	Jan. 8, 1960 Mar. 26, 1965 Mar. 1, 1966	T,E,150	Irr	Irrigated 500 acres in 1958; 490 acres in 1959. Temp. 73°F.
103	Mrs. Ralph Hill	J. W. Greak	1956	100	8	Ch	93	45.6 49.2 46.9	Jan. 8, 1960 Mar. 26, 1965 Mar. 1, 1966	N	N	Unused irrigation well.
104	S. A. Odem	Pitre Water Well Drilling Co.	1945	192	4	Ch	86	40	May 1940	J,E,1/4	D	Screen from 163 to 173 ft.
* 107	Ethel Cleveland	West Water Well Service	1965	90	--	Ch	92	48	Apr. 1965	J,E,1/3	D	Slotted from 80 to 86 ft. Reported high iron content.[1]
110	B. F. Pickle	Pitre Water Well Drilling Co.	1963	65	2	Ch	95	14	Oct. 1963	J,E,1/2	D	Screen from 56 to 62 ft.
* 201	H. E. LaCour	Katy Drilling Co.	1952	643	20,12	Ev	88	41.2 42.1	Apr. 1, 1965 Mar. 3, 1966	T,G	Irr	Casing: 20-in. to 217 ft, 12-in. from 217 ft to bottom. Slotted 443 ft. Gravel-walled. Temp. 74°F.
* 202	A. L. Erickson	J. W. Greak	1953	100	12	Ch	86	--	--	T,G	Irr	Reported irrigated 160 acres in 1958 and 1959. Gravel-walled. Temp. 69°F.
401	L. Daffern	Pitre Water Well Drilling Co.	1945	125	4	Ch	83	40	Apr. 1945	J,E,1/2	D	Screen from 108 to 120 ft.
402	Humble Oil & Refining Co.	do	1940	228	4	Ch	67	15	July 1940	N	N	Screen from 199 to 228 ft. Originally drilled to 257 ft; plugged back to 228 ft. Supplied water for oil test. Abandoned in 1940.
403	G. W. Tanner well 1	W. W. Harvey, et al.	1960	8,595	--	--	81	--	--	--	--	Oil test.[2]
* 501	Harvey Mecom, Jr.	J. W. Greak	1958	160	12	Ch	75	24.2	Mar. 25, 1965	T,G	Irr	Measured discharge 320 gpm. Reported irrigated 121 acres of rice in 1958 and 1959; and 134 acres in 1962.
* 502	Harry W. Archer	do	--	106	--	Ch	73	--	--	T,G	Irr	Casing slotted from 56 ft to bottom. Temp. 69°F.
503	George McRight	West Water Well Service	1965	95	2	Ch	82	27	Mar. 1965	T,G	D	Casing slotted from 84 to 90 ft.
* 601	R. N. Yarbrough	Katy Drilling Co.	1951	550	24,12, 10	Ev,Ch	76	29.8	Jan. 12, 1960	T,G	Irr	Casing: 200 ft of 24-in.; 314 ft of 12-in.; and 36 ft of 10-in. Screened 350 ft. Measured discharge 770 gpm, July 19, 1965. Gravel-walled. Temp. 69°F.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-51-603	Jim Best	J. W. Greak	1954	150	8	Ch	76	19.5 17.4	Mar. 24, 1965 Mar. 3, 1966	T,G	Irr	
* 701	F. L. Carothers	Katy Drilling Co.	1953	678	20,12	Ev,Ch	76	53.5	Jan. 11, 1960	T,E,100	Irr	Casing: 20-in. to 300 ft, 12-in. from 300 to 378 ft. Slotted pipe 463 ft. Gravel-walled. Temp. 72°F.
702	F. M. Graves	do	1959	746	20,12	Ev	76	52.5	do	T,G	Irr	Casing: 20-in. to 303 ft, 12-in. from 303 to 443 ft. Screened 421 ft. Originally drilled to 781 ft; plugged back to 746 ft. Irrigated 700 acres from 3 wells in 1958 and 1959.
703	Mrs. Mike Splane & Mrs. Hardie Jane Van Deventer	do	1951	350	16,10	Ch	72	54.1	Jan. 14, 1960	N	N	Casing: 16-in. to 200 ft, 10-in. from 200 to 150 ft. Screen 252 ft. Unused irrigation well.
* 705	F. L. Carothers	J. W. Greak	1962	150	--	Ch	71	--	--	Cf,G	Irr	Reported discharge 300 gpm. Screen from 50 ft to bottom. Temp. 70°F.
707	S. E. Viles	Pitre Water Well Drilling Co.	1937	228	4	Ch	78	34.9 48.1	June 7, 1945 Apr. 13, 1954	N	N	Observation well from 1945 to 1954. Formerly supplied water for sawmill boilers. Destroyed.3/
709	W. A. Lacy	do	1963	94	2	Ch	81	42	Sept. 1963	J,E,1/2	D	Screen from 82 to 88 ft.1/
711	Clyde Griffin	J. W. Greak	1964	92	4	Ch	77	35	Feb. 1964	-,E,1/2	D	Casing slotted from 84 ft to bottom.
713	S. E. Carothers	Pitre Water Well Drilling Co.	1962	78	2	Ch	76	15	Oct. 1962	J,E,1/3	D	Screen from 69 to 75 ft.
714	Franklin Parker	West Water Well Service	1965	90	2	Ch	81	37	May 1965	J,E	D	Casing slotted from 84 ft to bottom.
715	Travis Durham	Pitre Water Well Drilling Co.	1944	110	4	Ch	75	26	Mar. 1944	J,E,1/2	D,S	Screen from 71 to 82 ft.
* 801	J. Perkins	Layne-Texas Co.	1955	817	12	Ev	71	44.5	Mar. 25, 1965	T,E,125	Irr	Measured discharge 1,450 gpm, July 1965. Temp. 74°F.
802	James Gentz	Katy Drilling Co.	1955	300	18,12	Ch	68	31.8	Jan. 13, 1960	T,G	Irr	Casing: 18-in. to 296 ft, 12-in. from 296 ft to bottom. Screened 140 ft.
* 804	Morgan Tippett	do	1965	625	--	Ev	64	--	--	N	N	Temp. 73°F.
805	Petroleum Dehydrating Co.	Pitre Water Well Drilling Co.	1957	602	4,2	Ev	65	83	Mar. 1957	N	N	Unused industrial well.
* 806	Morgan Tippett	Katy Drilling Co.	1954	624	20,12	Ch,Ev	68	80.4	Aug. 5, 1955	T,G	Irr	Casing: 20-in. to 245 ft, 12-in. from 245 ft to bottom. Measured discharge 1,175 gpm in 1955. Slotted pipe 423 ft. Temp. 74°F.3/

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-51-901	Morgan Tippett	J. W. Greak	1952	150	8	Ch	68	9.2 14.2 10.8	Jan. 12, 1960 Mar. 24, 1965 Mar. 1, 1966	N	N	Abandoned irrigation well.
902	Keith Flournoy	do	1952	130	--	Ch	67	5.3 12.0 7.2	Jan. 28, 1960 Mar. 24, 1965 Mar. 1, 1966	N	N	Unused irrigation well. Gravel-walled.
903	Hull Grade School	Pitre Water Well Drilling Co.	1948	589	--	Ev	67	21.4	July 28, 1948	N	N	Abandoned public supply.
904	Mobil Petroleum Co. well 3	Layne-Texas Co.	1956	455	14,8	Ev,Ch	66	70	Jan. 1966	T,E	Ind	Cased to 257 ft.
905	Mobil Petroleum Co. well 1	Pitre Water Well Drilling Co.	1955	746	10,8	Ev,Ch	67	70	do	T,E,60	D	Cased to 248 ft. Reported pumps 700 gpm.
* 906	Daisetta Water Corp.	do	1940	365	6	Ch	67	27	May 1940	T,E,5	P	Screen from 337 to 350 ft. Temp. 74°F.
907	Daisetta Water Corp. well 3	--	--	365	8	Ch	67	--	--	T,E,15	P	
908	Daisetta Water Corp. well 2	Pitre Water Well Drilling Co.	1950	376	6	Ch	67	50.2 52.3	Jan. 13, 1960 Feb. 1, 1966	T,E,5	P	Cased to 353 ft. Screen from 353 ft to bottom.
909	Hancomer Lumber Co.	do	1943	181	4	Ch	67	7	Nov. 1 1943	N	N	Originally drilled to 222 ft; plugged back to 181 ft. Screen from 161 to 181 ft. Formerly supplied water for sawmill. Abandoned. Reported salty.
911	Mobil Oil Co.	Layne-Texas Co.	1956	748	14,8	Ev,Ch	65	63	1956	T,E,60	Ind	Cased to 566 ft. Gravel-walled.
* 913	Hull Fresh Water Supply District well 1	do	1963	580	10,6	Ev	66	68	Nov. 1965	T,E,40	P	Originally drilled to 760 ft; plugged back to 580 ft. Screen from 405-420, 460-475, 510-520, 550-570 ft. Drawdown 71 ft pumping 401 gpm in 4 hour test.
914	Mrs. J. M. Phillips	Pitre Water Well Drilling Co.	1963	74	2	Ch	70	25	June 1963	J,E,1/4	D	Screen from 57 to 63 ft.[1]
* 57-101	D. A. Reidland well 2	Layne-Texas Co.	1944	1,000	20,8	Ev,Ch	92	38.6 69.5 78.8 71.2	Apr. 19, 1945 Apr. 2, 1956 Mar. 23, 1965 Mar. 1, 1966	N	N	Casing slotted below 120 ft. Observation well. Abandoned about 1960. Temp. 76°F.[3]
* 102	D. A. Reidland well 1	do	1943	740	16,10	Ev,Ch	92	37.4	Apr. 19, 1945	T,G,120	Irr	Casing slotted below 118 ft. Temp. 77°F.
104	D. A. Reidland	do	1943	550	--	Ev,Ch	92	--	--	--	--	Test well. Reported salt water.
* 105	do	do	1960	880	34,20,12	Ev	142	142	1960	T,G	Irr	Cased to bottom. Slotted from 280 ft to bottom. Temp. 76°F.
106	Taylor-Dayton Co. well 1	--	--	1,200	--	--	100	--	--	--	--	Oil test. Old well.

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-57-107	J. D. Williams well 2	The Texas Co.	1950	6,947	--	--	85	--	--	--	--	Oil test.[2]
201	D. A. Reidland	Layne-Texas Co.	1943	569	18,14	Ev	96	60	Sept. 1943	N	N	Cased to 569 ft. Slotted from 215-236, 264-278, 303-322, 365-382, 389-452, and 482-569 ft. Abandoned about 1950. Drilled to 812 ft; plugged back to 569 ft.[1]
* 202	do	do	1956	816	24	Ev	98	83.2 101.6 90.4	Jan. 18, 1960 Mar. 23, 1965 Mar. 1, 1966	T,G	Irr	Temp. 73°F.
203	do	do	1947	829	18	Ev	97	116.5 94.4	Mar. 23, 1965 Mar. 1, 1966	N	N	Abandoned irrigation well.
* 204	do	do	1948	827	18	Ev	94	87.0	Jan. 18, 1960	T,G	Irr	Gravel-walled. Temp. 76°F.
205	Mrs. Sophie Graves	Katy Drilling Co.	1951	845	24,12,10	Ev,Ch	92	73.6 72.9 69.3	Jan. 18, 1960 Mar. 23, 1965 Mar. 1, 1966	N	N	Cased to bottom. Casing slotted 700 ft. Screened from 145 ft to bottom. Unused irrigation well.
* 206	do	do	1957	887	20,12	Ev,Ch	92	88.0 98.3	Jan. 7, 1960 Mar. 1, 1966	T,G	Irr	Casing: 20-in. to 308 ft, 12-in. from 308 to bottom. Casing slotted 674 ft. Gravel-walled.
207	Ralph Graves	Layne-Texas Co.	1943	558	18,10	Ev,Ch	90	75.4 62.3 62.8	Jan. 18, 1960 Mar. 23, 1965 Mar. 1, 1966	N	N	Casing slotted from 140-189, 199-214, 239-289, 299-444, 449-479, and 484-549 ft. Gravel-walled. Unused irrigation well.
208	Mrs. Sophie Graves	do	1946	798	--	Ev	90	76.3 74.3	Mar. 23, 1965 Mar. 1, 1966	N	N	Unused irrigation well.
301	Russ Mitchell well 4	Pitre Water Well Drilling Co.	1936	413	3	Ev,Ch	83	61.7 83.4 95.4	Mar. 14, 1949 Apr. 8, 1958 Mar. 23, 1965	N	N	Formerly supplied water for highway construction. Observation well. Abandoned.[3]
303	Essye May Flowers well 1	Stanolind Oil Co.	1939	9,113	--	--	78	--	--	--	--	Oil test.[2]
* 401	A. J. & F. B. Ash	Layne-Texas Co.	1957	545	--	Ev,Ch	88	89.6 112.1 100.3	Jan. 19, 1960 Mar. 23, 1965 Mar. 1, 1966	T,E,125	Irr	Reported discharge 2,000 gpm. Drawdown 57 ft. Temp. 74°F.
* 402	Roy Seaburg	do	1945	1,030	16,12	Ev,Ch	88	47	Mar. 1945	T,G	Irr	Temp. 80°F.
* 403	F. M. Graves	A. E. Fawcett	1944	1,005	20,12	Ev,Ch	85	60	Mar. 1944	T,G,160	Irr	Screened opposite sand below 240 ft. Temp. 77°F.
* 405	Leo Moreau	do	1944	870	20,12	Ev,Ch	78	52.8	Apr. 18, 1945	T,G	Irr	Reported discharge 310 gpm. Casing slotted opposite sands below 240 ft. Temp. 73°F.[3]

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*SB-61-57-406	Romain Roach	Layne-Texas Co.	1943	834	20,16	Ev,Ch	88	94.2	Jan. 18, 1960	T,G	Irr	Measured discharge 790 gpm, July 30, 1965. Temp. 78°F.
408	F. M. Graves	Katy Drilling Co.	1963	873	20,12	Ev	84	--	--	T,G	Irr	Casing: 20-in. to 330 ft, 12-in. from 330 to 529 ft. Slotted from 344 ft to bottom.
* 409	W. F. Graves Estate	do	1964	884	20,12	Ev	84	127	Feb. 1964	T,G	Irr	Casing: 20-in. to 326 ft, 12-in. from 326 to 558 ft. Slotted screen 557 ft. Measured discharge 780 gpm, July 30, 1965. Temp. 76°F.
410	Peterson & Sterling	Layne-Texas Co.	1920	592	--	Ev	83	--	--	N	N	Screen from 349-389, 406-484, and 520 ft to bottom. Abandoned irrigation well.
412	Sun Oil Co.	--	1905	1,763	--	--	88	--	--	--	--	Oil test.1/
413	Quinette Oil Co. well 2	Production Maintenance Co.	1949	4,731	--	--	100	--	--	--	--	Oil test.2/
501	C. B. Peterson	--	--	3,407	--	--	84	--	--	--	--	Oil test.1/
502	W. T. Jamison	Layne-Texas Co.	1948	825	18,12	Ev	86	64	1948	N	N	Casing: 18-in. to 300 ft, 12-in. from 300 to 540 ft. Drawdown 57 ft pumping at 1,940 gpm. Unused irrigation well.
503	do	do	1953	837	18,16,12	Ev	86	84.2	Jan. 25, 1960	T,G	Irr	Casing: 18-in. to 100 ft, 16-in. from 100 to 200 ft, and 12-in. from 200 ft to bottom. Reported drawdown 99 ft pumping 2,487 gpm in 1953.
* 506	W. M. Moreau	Katy Drilling Co.	1962	940	20,12	Ev	78	105.0 103.9	Mar. 23, 1965 Mar. 1, 1966	T,G	Irr	Casing slotted 502 ft.
507	C. B. Peterson	--	--	1,910	--	--	83	--	--	--	--	Oil test.
* 601	City of Dayton well 4	Big State Water Wells Inc.	1950	490	13,6	Ev	82	93.9	Feb. 19, 1960	T,E,20	P	Screen from 450 ft to bottom. Drawdown 88 ft pumping 250 gpm in Dec. 1955. Temp. 73°F.
* 602	City of Dayton well 3	-- White	1946	376	--	Ch	82	--	--	T,E,15	P	Screen opposite sand from 315 ft to bottom. Temp. 72°F.
* 603	City of Dayton well 5	Layne-Texas Co.	1954	806	16,8	Ev	82	92.6	Feb. 19, 1960	T,E	P	Screen from 530-540, 589-605, 614-624, 634-644, 654-684, 709-719, and 750-785 ft. Gravel-walled. Temp. 75°F.
* 605	City of Dayton well 2	J. A. Walling	1929	399	8,6	Ch	81	45	Nov. 1929	N	N	Destroyed. Formerly used as public supply well. Temp. 79°F.
606	City of Dayton well 1	do	1929	395	8,6	Ch	81	45	do	N	N	Destroyed. Formerly used as public supply well.
607	-- Charza well 1	Stanolind Oil Co.	1939	8,163	--	--	77	--	--	--	--	Oil test.2/

See footnotes at end of table.

Table 5.--Records of wells and springs in Liberty County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
SB-61-57-608	C. F. Seaburg well 4	Stanolind Oil Co.	1940	8,379	--	--	77	--	--	--	--	Oil test.[2/]
609	Sidney Pickett well 1	do	1958	9,544	--	--	75	--	--	--	--	Do.
* 701	A. C. Holbrook	A. E. Fawcett	1944	780	20,12	Ev,Ch	73	95.7	Jan. 18, 1960	T,G	Irr	Casing slotted opposite sands below 240 ft. Temp. 74°F.
* 703	J. M. Frost, Jr.	Katy Drilling Co.	1955	837	20,12	Ev,Ch	67	93.2 101.2	Jan. 18, 1960 Mar. 1, 1966	T,G	Irr	Casing: 20-in. to 318 ft, 12-in. from 318 ft to 519 ft. Casing slotted 597 ft. Estimated discharge 980 gpm, Aug. 1965. Temp. 73°F.
802	C. S. Brown	C. S. Brown	1902	400	--	Ch	72	16	1908	N	N	Abandoned irrigation well.
901	Fred Ash	Texas Water Wells, Inc.	1950	478	--	Ev,Ch	73	--	--	T,E,40	Irr	Gravel-walled.
* 902	Humble Pipe Line Co.	--	--	400	6	Ch	67	49.5 80.7	Jan. 27, 1945 Apr. 8, 1958	N	N	Observation well. Formerly supplied boilers at pump station.
* 903	Peoples Lumber Co.	Frank Gay	1942	685	4	Ev	77	62.4 69.4	Mar. 14, 1949 Apr. 13, 1951	N	N	Observation well. Formerly supplied saw-mill boilers. Screened from 665 to 685 ft. Destroyed about 1953.[3/]
58-301	Central Chemical Corp.	Pitre Water Well Drilling Co.	1962	265	2	Ch	35	38	Oct. 1962	T,E,5	Ind	Screen from 241 to 263 ft.
302	-- Brauer well 1	General Crude Oil Co.	1956	10,004	--	--	72	--	--	--	--	Oil test.[2/]
401	Ed Pruitt	J. A. Conklin	1904	1,014	8	Ev,Ch	15	50	1904	N	N	Drilled as oil test. Reported strong flow in 1908. Unable to locate. Probably destoyed, 1965.
* 501	City of Liberty	Katy Drilling Co.	1959	960	14	Ev	32	--	--	T,E,75	P	Gravel-walled. Reported discharge 750 gpm in 1960. Temp. 76°F.
* 502	City of Liberty well 1	Layne-Texas Co.	1948	806	16,8	Ev	32	13.6 32.5 54.7	Mar. 16, 1949 Feb. 15, 1960 Mar. 28, 1963	T,E,50	P	Gravel-walled. Casing: 16-in to 379 ft, 8-in. from 379 to 477 ft. Screened opposite sands 503 to 798 ft. Pumping level 90 ft pumping 726 gpm, Feb. 1948. Observation well.[3/]
* 503	City of Liberty well 3	A. E. Fawcett	1939	351	8	Ch	32	6	July 1943	T,E,20	P	Temp. 72°F.
* 504	City of Liberty well 2	do	1939	565	13,7	Ev	32	17.2 51.0 46.4	Mar. 16, 1949 Apr. 9, 1958 Mar. 24, 1965	N	N	Abandoned public supply well. Observation well. Screen from 445-455 and 523-562 ft. Casing 13-in. cemented to 443 ft. Drawdown 48-1/2 ft pumping 321 gpm, Jan. 1939. Temp. 75°F.[1/] [3/]

See footnotes at end of table.