STATE OF FLORIDA

STATE BOARD OF CONSERVATION

Ernest Mitts, Director

FLORIDA GEOLOGICAL SURVEY

Robert O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 18

GROUND-WATER RESOURCES OF MANATEE COUNTY, FLORIDA

By

Harry M. Peek

U. S. Geological Survey

Prepared by the

UNITED STATES GEOLOGICAL SURVEY

in cooperation with the

FLORIDA GEOLOGICAL SURVEY

BOARD OF COUNTY COMMISSIONERS OF MANATEE COUNTY

and the

MANATEE RIVER SOIL CONSERVATION DISTRICT

TALLAHASSEE, FLORIDA

1958

FLORIDA STATE BOARD
OF
CONSERVATION

LETTER OF TRANSMITTAL

Florida Geological Survey

Tallahassee

December 15, 1958

Mr. Ernest Mitts, *Director*
Florida State Board of Conservation
Tallahassee, Florida

Dear Mr. Mitts:

I am forwarding to you a report entitled, GROUND-WATER RESOURCES of MANATEE COUNTY, FLORIDA, which was prepared by Harry M. Peek, Geologist with the U. S. Geological Survey. This work was done in cooperation with the Florida Geological Survey, the Board of County Commissioners of Manatee County and the officials of the Manatee River Soil Conservation District. It is recommended that this report be published as Report of Investigation No. 18.

The rapid development and expansion of the coastal areas of Manatee County combined with increased irrigation of truck farms, cattle lands and citrus groves, have multiplied the problems of obtaining adequate supplies of water which meet the quality demands of the various competing interests. This study contributes the needed data for a wise development of the water resources of the area.

Respectfully submitted,

ROBERT O. VERNON, *Director*

Completed manuscript received

April 30, 1958

Published by the Florida Geological Survey

Rose Printing Company, Inc.

Tallahassee, Florida

January, 1959

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ABSTRACT

Manatee County comprises an area of about 800 square miles adjacent to the Gulf of Mexico in the southwestern part of peninsular Florida. Deposits of sand, limestone, and shells, mainly of Pleistocene age, but probably partly of Pliocene age, are exposed at the surface throughout most of the county. These range in thickness from a few feet to about 90 feet. They are underlain by interbedded marl, limestone, and sand of the Hawthorn formation of middle Miocene age. The Hawthorn formation is underlain, at depths ranging from about 175 to 350 feet below sea level, by a series of limestones of Tertiary age which have a total thickness of more than 4,000 feet. The upper part of the limestone section consists of the Avon Park limestone of late middle Eocene age, the Ocala group[1] of late Eocene age, the Suwannee limestone of Oligocene age, and the Tampa formation of early Miocene age.

Usable quantities of ground water are obtained in the county from all formations penetrated by wells. Small supplies for domestic use are obtained from the surficial deposits of sand and shells, which contain water under nonartesian conditions. Most domestic supplies, however, are obtained from the permeable beds in the upper part of the Hawthorn formation and from younger formations in which the water is under a slight artesian pressure.

The Suwannee limestone and Tampa formation are the principal sources of artesian water. All the large industrial, irrigation, and public supplies are obtained from them, but many domestic and small irrigation supplies are obtained from permeable beds in the Hawthorn formation, which serves as a confining bed for the water in the underlying limestones.

Records of the fluctuations of artesian head show that the withdrawal of large quantities of artesian water causes an extensive lowering of the piezometric surface. During periods of heaviest withdrawal, the piezometric surface declines at least four or five feet throughout the county and as much as 10 feet at some places. The magnitude of the seasonal fluctuations has increased and a progressive decline in the artesian head

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[1]The stratigraphic nomenclature used in this report conforms to the usage of the U. S. Geological Survey with the following exceptions: the Ocala limestone is herein referred to as the Ocala group, and the Tampa limestone is referred to as the Tampa formation. These exceptions are made in order to conform to the nomenclature used by the Florida Geological Survey.

has occurred in some parts of the county since about 1948, because of an increase in water use.

Determinations of the chloride content of the artesian water indicate salt-water contamination in a zone about 3 to 10 miles wide along the coast. The degree of contamination increases with depth and seaward. Throughout most of the zone, the water in the Tampa formation contains less than 250 parts per million (ppm) of chloride and is suitable for most purposes, but some wells in the vicinity of Palma Sola Bay yield water from the Tampa formation containing more than 400 ppm of chloride. The chloride content of the water in the Suwannee limestone is more than 2,000 ppm at some places but is generally less than 500 ppm. The water in the Eocene formations along the coast is probably too salty for most uses.

Periodic analysis of the water from many wells shows that the chloride content varies with the seasonal fluctuations of artesian pressure head. Some wells that show a progressive decline in artesian pressure head also show a progressive increase in chloride content of the water, indicating that significant declines in head result in upward movement of salty water from the deeper formations. This upward movement is probably retarded considerably by the beds of low permeability that separate the principal water-bearing zones.

INTRODUCTION

Ground water is the principal source of fresh water for public, domestic, agricultural, and industrial supplies in Florida. The increased use of ground water in the State, resulting from the growth of population and industry, has caused a large number of water-supply problems, particularly in coastal areas where population and industry are concentrated. Most of the water-supply problems in these areas can be classified as "salt-water" problems.

In much of the coastal area of southern Florida, a part or all of the formations capable of yielding large quantities of water contain naturally salty water. Thus, the problem in this area is one of finding supplies of fresh water that are adequate to meet the increased demand and are economically feasible to develop. The problem in other areas is to protect present supplies from contamination by salt-water encroachment from the sea or from underlying formations that contain naturally salty water. Encroachment of salt water from either source occurs as a result of excessive lowering of the fresh-water pressure head.

A large part of western Manatee County (fig. 1) is used for growing winter vegetables and citrus fruits, and large quantities of artesian water

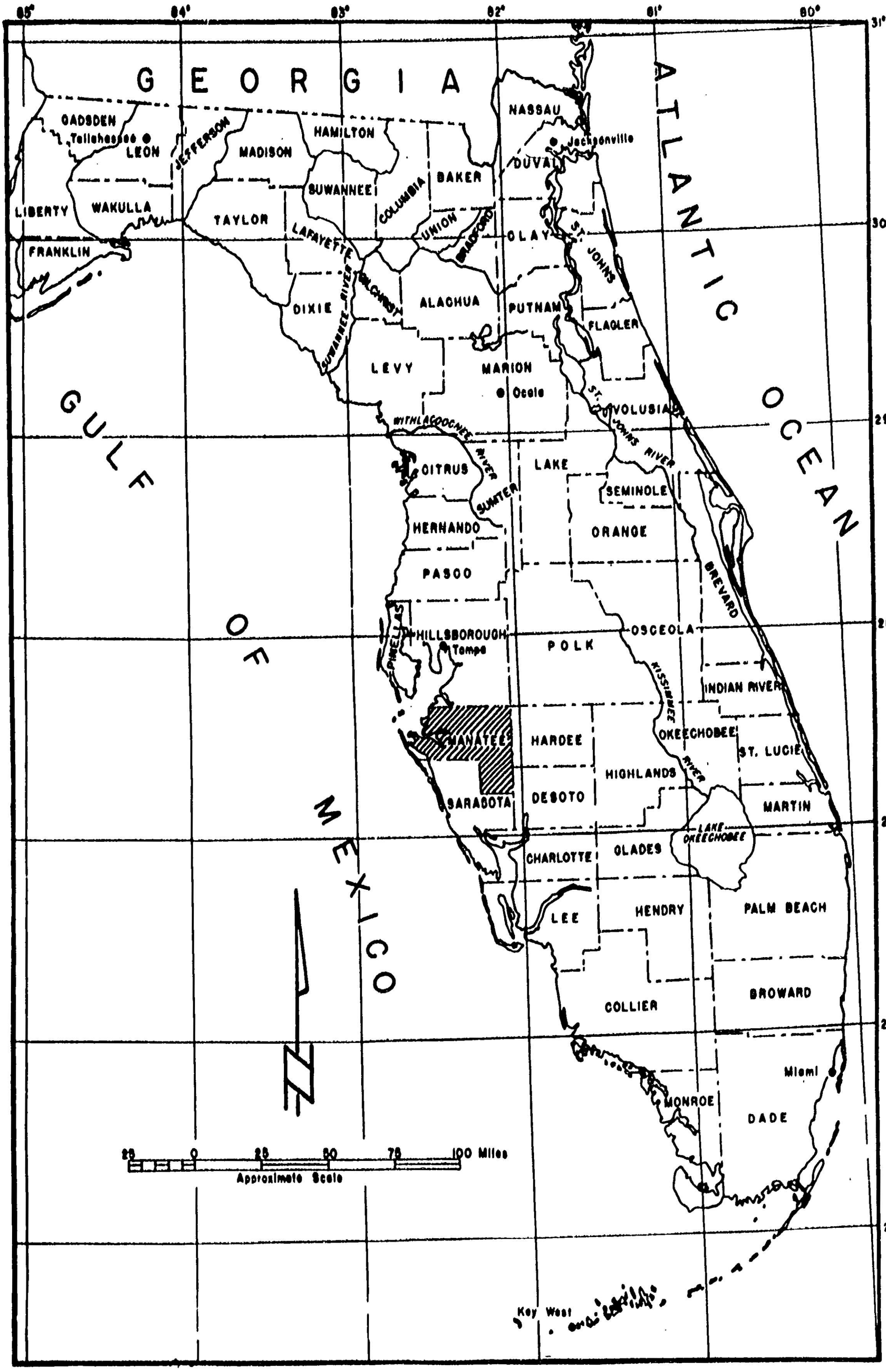


Figure 1. Map of the Florida Peninsula showing the location of Manatee County.

are used for irrigating these crops. The large withdrawals of artesian water for irrigation and for processing agricultural products result in a considerable seasonal decline of the artesian head, particularly in the western part of the county. This seasonal decline of artesian head has increased in proportion to the increase in withdrawal of artesian water.

The progressive increase in seasonal decline of the artesian head intensifies the danger of salt-water encroachment in the artesian aquifer. The presence of salty water in the artesian aquifer in parts of the coastal area of the county suggests that slight encroachment may already have occurred. Recognizing this possibility, and in response to the concern expressed by the farmers of the county, the Board of County Commissioners and the Supervisor of the Manatee River Soil Conservation District requested the U. S. Geological Survey and the Florida Geological Survey to make an investigation of the ground-water resources of the county. As a result of this request, an investigation was begun in December 1950 by the U. S. Geological Survey in cooperation with the above agencies.

PURPOSE AND SCOPE OF THE INVESTIGATION

The purpose of the investigation was to make a detailed study of the geology and ground-water resources of the county, principally to determine whether salt-water encroachment had occurred or was likely to occur. The investigation consisted of the following phases:

1. An inventory of more than 900 selected wells, to obtain information related to the occurrence and use of ground water in the county.
2. A collection of data on water levels for use in determining progressive trends and the magnitude of seasonal fluctuations, and in constructing maps showing the altitude to which water will rise in artesian wells.
3. Determinations of the chloride content of water from about 750 wells, to define the areas in which the ground water is relatively salty.
4. Periodic determinations of the chloride content of water from selected wells, to find the relation between salinity and artesian pressure.
5. A study of geologic conditions governing the occurrence and movement of ground water.
6. Exploration of selected wells with deep-well current meter, to determine the depth and thickness of the principal water-bearing zones.
7. Chemical analyses of water samples from selected wells.
8. Studies to determine the water-transmitting and water-storing properties of the water-bearing formations.

The field work of this investigation from December 1950 to January 1954 was done by R. B. Anders of the U. S. Geological Survey. An interim report covering this part of the investigation was published in March 1955 (Peek, H. M., and Anders, R. B., 1955). The field work from January 1954 until the investigation was completed in December 1955 was done by the author of the present report. The present report includes most of the data from the earlier field work and report.

ACKNOWLEDGMENTS

Acknowledgment is made to H. O. Kendrick, County Agent, and his staff and to E. L. Ayers, County Agent during the first part of the investigation, for the helpful assistance given throughout the investigation. I. H. Stewart of the Soil Conservation Service, U. S. Department of Agriculture, and Fonzie Outlaw and L. Rhinehart of his staff, contributed much valuable information and gave assistance in many ways toward completion of the field work.

Appreciation is expressed to the well drillers who furnished information and collected rock cuttings and water samples. These include: Charles and Lowell Pemelman, W. Reddick, T. M. Shacklee, and Dale Young, of Bradenton; C. D. Cannon, J. O. Mixon, and E. Moran, of Palmetto; E. E. Boyette, of Ruskin; J. P. Adams and R. Phillips, of Sarasota.

Special thanks are due the many well owners for their cooperation in contributing information and otherwise aiding the investigation.

PREVIOUS INVESTIGATIONS

No detailed investigations of the geology and ground-water resources of Manatee County had been made prior to the present study. However, several short studies were made, and the results have been published in the reports of the Florida Geological Survey and the U. S. Geological Survey. Some of the more informative reports are described below.

A report by Matson and Sanford (1913, p. 237, 254, 362-364; pl.5) includes a section on the geology and water supply of Manatee County and a table of selected well records. A report by Sellards and Gunter (1913, p. 266-269; fig. 16) also includes a brief summary of the geology and ground-water resources of the county and a map showing the area of artesian flow.

A report on a reconnaissance investigation of several counties in the State by Stringfield (1933, p. 3-5) contains a brief discussion of the geography, geology, and ground water of Manatee County. Another report by Stringfield (1936, p. 145, 164, 167, 170, 180, 182, 191, 192; pl. 10, 12, 16), which gives the results of a study of the artesian water of the Florida Peninsula, contains water-level measurements and other data on about 90 wells in Manatee County. The 1936 report also includes maps of the Florida Peninsula showing the area of artesian flow, the height above sea level to which water in the principal artesian aquifer will rise in wells, and the areas in which water having a chloride content of more than 100 ppm is present at moderate depths.

The formations that crop out are briefly described in a report on the geology of Florida by Cooke (1945, p. 138, 153, 157, 208, 223, 307). A report by MacNeil (1950, pl. 19) describes Pleistocene shorelines in Florida and Georgia and contains a map showing the general configuration of these shorelines in Manatee County.

Chemical analyses of water from several wells and springs in Manatee County are included in a report by Collins and Howard (1928, p. 220-221) and a report by Black and Brown (1951, p. 77).

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based on latitude and longitude. As shown in plate 1 and figure 2, the county has been divided into quadrangles by a grid of 1-minute parallels of latitude and 1-minute meridians of longitude. The wells have been assigned numbers according to their location within this grid. Each well number consists of three parts: The first part is the latitude, in minutes, of the south side of the 1-minute quadrangle, the second part is the longitude, in minutes, of the east side of the quadrangle, and the third part is the number of the well within the quadrangle. For example, the number 27-34-3 designates the third well listed in the quadrangle bounded by latitude 27′ on the south and longitude 34′ on the east. The degrees of latitude and longitude are not included as a part of the well number because they are the same for all wells in the county (fig. 1). Well locations are shown on plate 1 and figure 2. Complete well descriptions, locations, and other data are to be published as Florida Geological Survey Information Circular No. 19, and may be obtained for one dollar per copy.

GEOGRAPHY

Manatee County comprises an area of about 800 square miles adjacent to the Gulf of Mexico in the southwestern part of the Florida Peninsula (fig. 1). It is bounded on the north by Hillsborough County, on the east by Hardee and De Soto counties, on the south by Sarasota County, and on the west by Tampa Bay and the Gulf of Mexico.

CLIMATE

Manatee County has a subtropical climate and a mean temperature of about 72°F. According to the records of the U. S. Weather Bureau, the mean monthly temperatures at Bradenton range from 61.5°F in January to 81.2°F in August, as shown graphically in figure 3. For comparative purposes, the figure includes also the average maximum and minimum monthly temperatures during 1954.

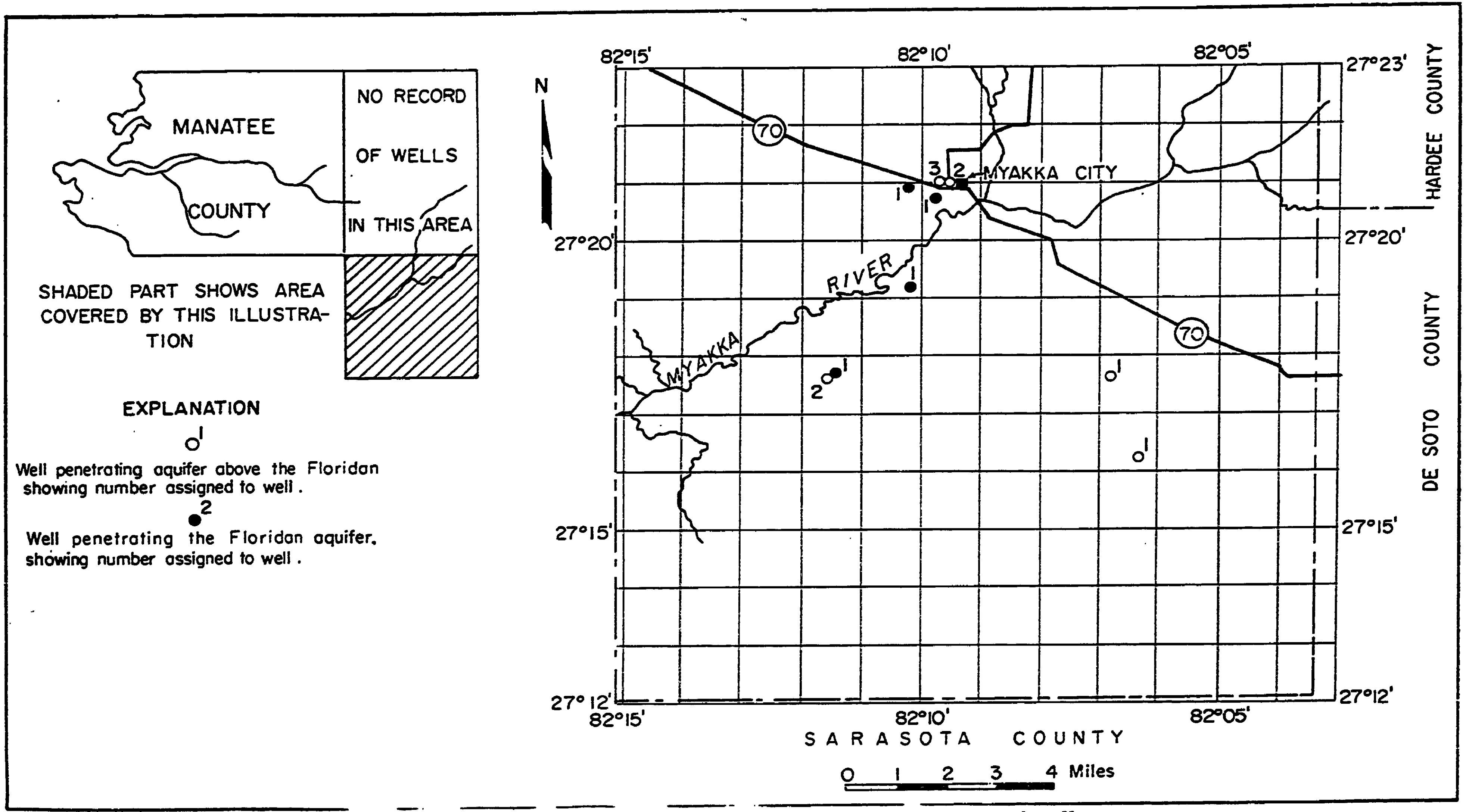


Figure 2. Map of eastern Manatee County showing locations of wells.

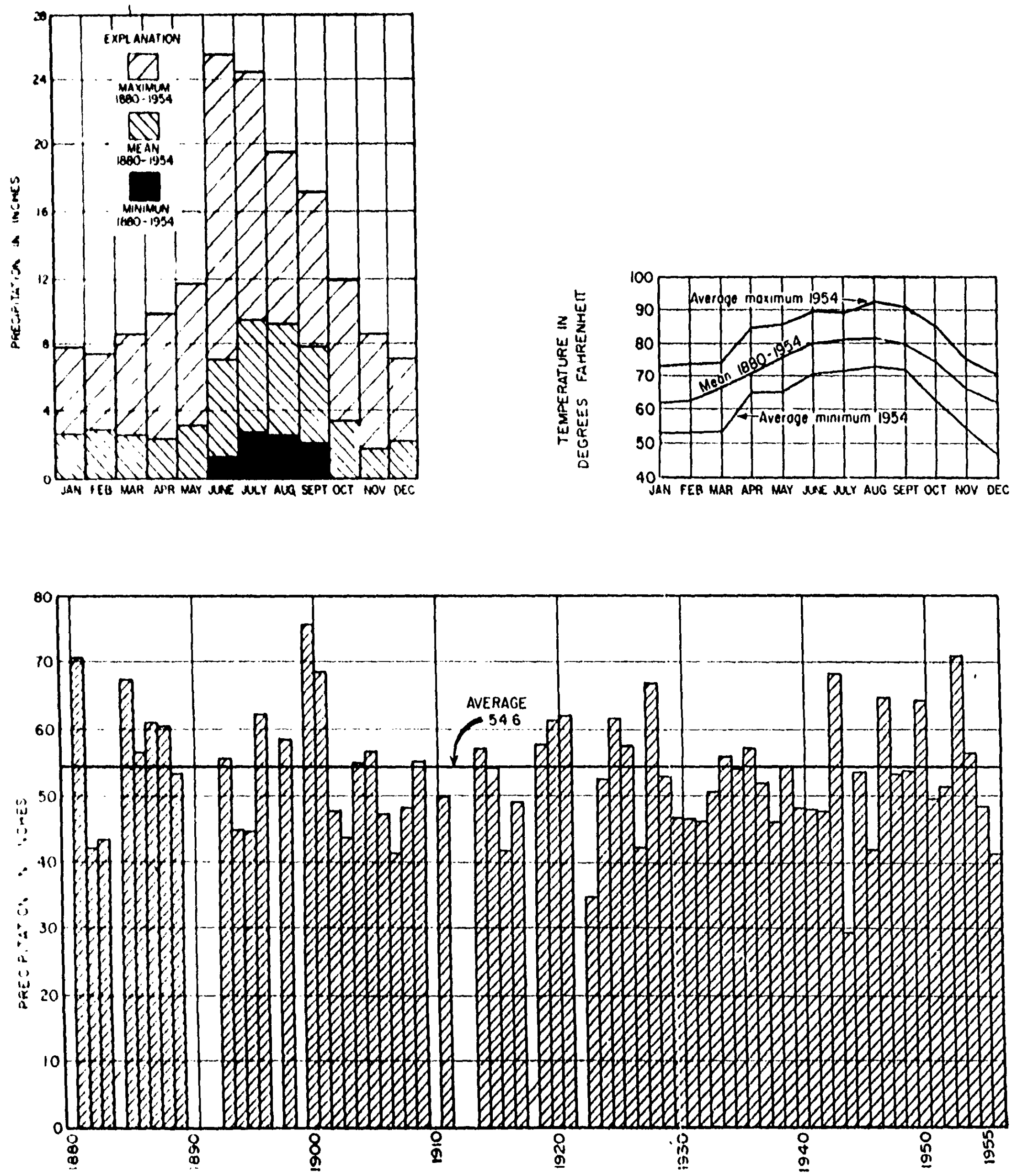


Figure 3. Precipitation and temperature at Bradenton.

The average annual rainfall at Bradenton from 1880 through 1955 was 54.6 inches (fig. 3) but it ranged from as much as 75.78 inches in 1900 to as little as 29.45 inches in 1944. The average monthly rainfall during the period of record ranged from 1.84 inches in November to 9.5 inches in July. About 60 percent of the yearly precipitation occurs between June 1 and September 30.

PHYSIOGRAPHY

Manatee County lies within the Terraced Coastal Lowlands as described by Vernon (1951, p. 16), a subdivision of the Coastal Plain Province. The topography is largely controlled by a series of marine terraces formed during Pleistocene time, when the sea several times stood above or below its present level.

The history of the Pleistocene epoch and the marine terrace deposits in Florida that are associated with the fluctuations of sea level are discussed in detail in reports by Cooke (1945, p. 11-13, 245-312), Vernon (1951, p. 15-42, 208-215), and Parker (1955, p. 89-124). The rise and fall of sea level are attributed to the advance and retreat of the great continental ice sheets; the sea level declined as the glaciers expanded and rose as they melted. When the sea was relatively stationary for long periods, shoreline features and marine plains were developed. The remnants of five marine terraces and four shorelines in Manatee County have been previously mapped (Cooke 1945, figs. 43-47; Parker 1955, pl. 10) as listed in the following table:

TABLE 1. Pleistocene Terraces and Shorelines in Manatee County

Terrace	Altitude of shoreline (feet above msl)
Sunderland	170[a]
Wicomico	100
Penholoway	70
Talbot	42
Pamlico	25

[a]The highest land surface in Manatee County, about 140 feet above sea level, represents a shallow sea bottom of Sunderland time.

Figure 4 shows the general configuration of the Pleistocene terraces in the county as determined from aerial photographs, topographic maps, and field observation. The highest and oldest surface represents an offshore portion of the Sunderland terrace (Cooke 1945, p. 278-279), which was formed when the sea was about 170 feet above the present level and covered practically all of southern Florida, including Manatee County. During Wicomico time, when the sea was at an altitude of about 100 feet, the only land area was in the northeastern part of the county. It consisted of the Sunderland terrace and associated islands.

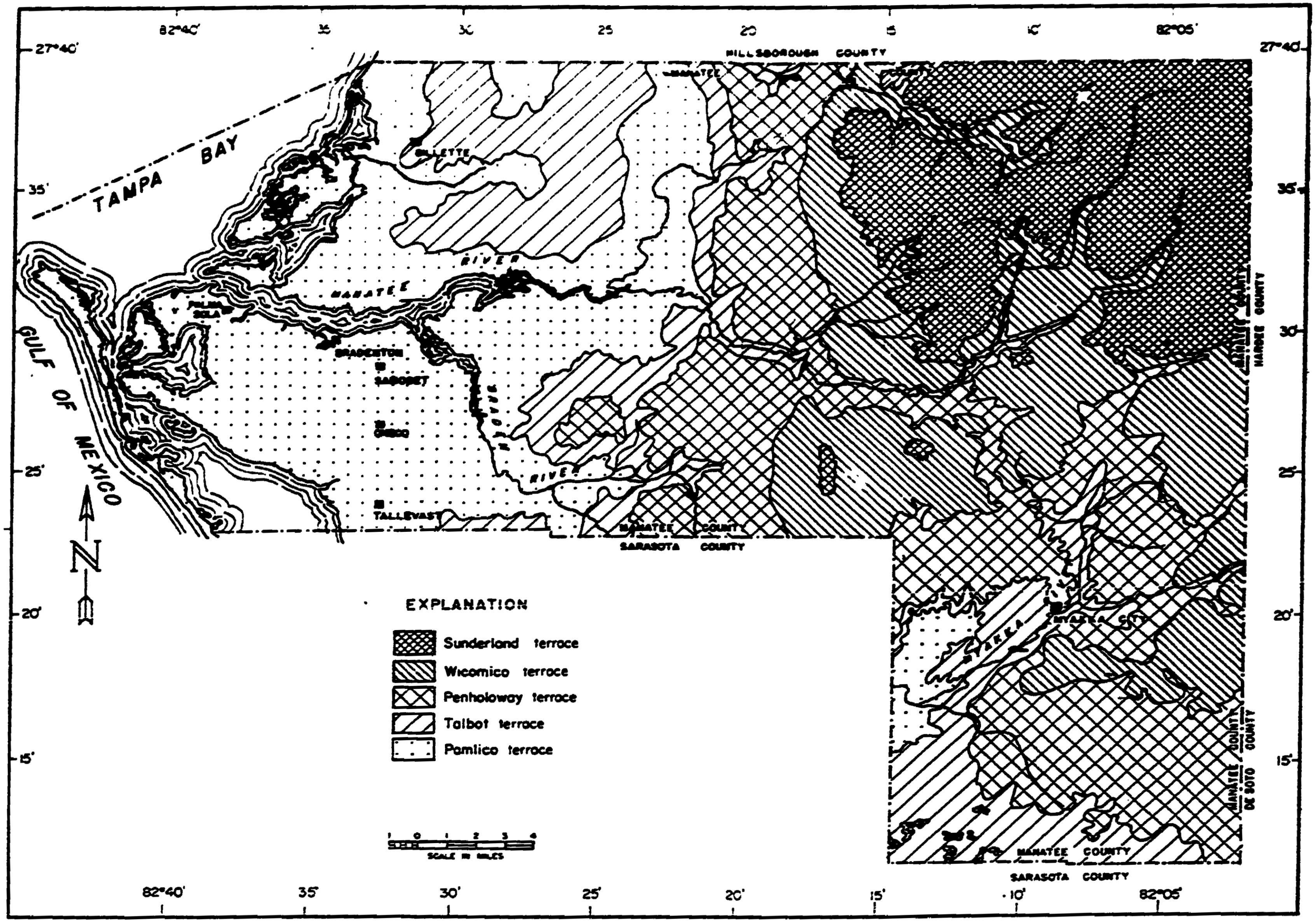


Figure 4. Map of Manatee County showing Pleistocene terraces.

The shoreline of the Wicomico sea is marked by an escarpment that is well preserved in many places. The base of the scarp is generally at an altitude of about 90 to 100 feet.

The Penholoway terrace was formed when the sea was about 70 feet above the present level and covered about two-thirds of the present land area of the county. The shoreline of the Penholoway sea is marked by a scarp that is well preserved in many places. The altitude of the scarp base is generally about 60 to 70 feet.

The Talbot terrace was formed when the sea was 42 feet above the present sea level and covered most of the western part of the county. The shoreline of the Talbot sea is poorly preserved in most places and is generally difficult to trace in the field. In the southeastern part of the county, however, the shoreline is fairly well defined by a low escarpment whose base is at an altitude of about 40 feet.

The Pamlico terrace is the youngest Pleistocene terrace that has been recognized in the county. It was formed when the sea was about 25 feet above the present level. A well-preserved scarp, whose base is at an altitude of 20 to 25 feet, and other shoreline features generally mark the shoreline of the Pamlico sea.

The Pamlico terrace forms a relatively flat coastal lowland that is generally less than 20 feet above sea level, although it contains a few low hills and ridges that rise to altitudes of 30 feet or more. The older terraces form an upland of rolling hills that extends inland from the Pamlico shoreline and gradually rises toward the northeast to an altitude of about 140 feet. The Talbot and Penholoway terraces have been modified to some extent by stream dissection but consist predominantly of low rolling hills having broad, relatively flat summits at altitudes of about 50 to 80 feet. The Wicomico and Sunderland surfaces have been more completely dissected by streams and the relief is more pronounced; however, in many places they are still relatively flat and drainage is poorly developed.

The surface drainage of the county is principally through the Manatee, Little Manatee, and Myakka rivers and their tributaries. Much of the coastal area is drained by small streams that empty directly into the Gulf of Mexico. A large part of the county, however, is poorly drained and contains many ponds and swamps. A network of canals has been dug throughout most of the county to supplement the natural drainage.

HISTORY

Manatee County was established in 1855 and originally included the area that is now Hardee, De Soto, and Sarasota counties. De Soto

County was separated from Manatee County in 1887, and Sarasota County was created from the southern part of Manatee County in 1921. The county received its name from the manatee, or sea cow, which inhabited the surrounding waters. The Spanish explorer, Hernando De Soto, landed on Terra Ceia Island in 1539. His army landed on the south side of the Manatee River at Shaws Point, which is now a national monument.

POPULATION

The population of the county in 1950 was 34,547, an increase of 32 percent from that of 1940 (fig. 5). About 90 percent of the total population is in the western one-third of the county. Bradenton, the county seat and largest city, had a population of about 13,000 in 1950. The growth of population in Bradenton and Palmetto from 1895 through 1950 is shown graphically in figure 5.

INDUSTRY

The principal sources of income are agriculture and associated industries, commercial fishing, and the tourist trade. The mild climate and the ready supply of water for irrigation have been the predominant factors in making the county one of the State's most productive agricultural areas. The agricultural use of land in the county in 1954, according to the U. S. Bureau of the Census, is given in table 2. In 1948 more than 3.5 million pounds of food fish were caught and marketed, in addition to shellfish, crabs, shrimp, and miscellaneous seafoods. The mild climate, beaches, waterways, and game fish annually attract thousands of tourists from all parts of the country. Mineral products from the county include limestone, dolomite, sand, and shells.

TABLE 2. Agricultural Use of Land in Manatee County in 1954

		Acres	
Approximate land area			448,640
Farmland			309,125
Cropland harvested		15,614	
Vegetables	4,558		
Groves	8,407		
Flowers and shrubs	2,082		
Other	567		
Cropland not used		7,330	
Total land pastured		266,803	
Cropland pastured	17,619		
Pastureland	109,567		
Woodland pastured	139,617		
Woodland not pastured		10,602	
Other land not pastured		8,776	

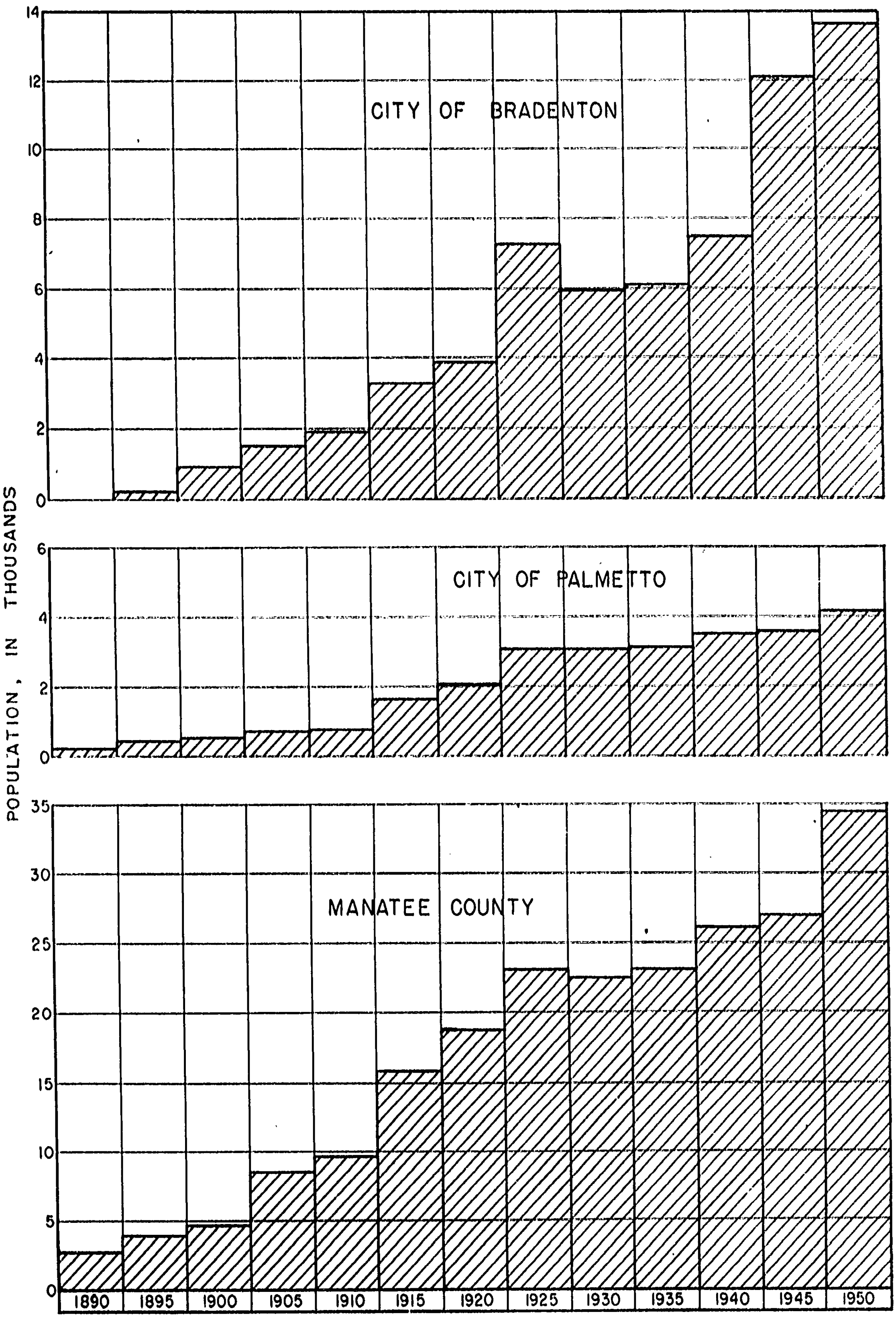


Figure 5. Population growth in Manatee County and the cities of Bradenton and Palmetto, 1890-1950.

TRANSPORTATION

U. S. Highways 19, 41, and 301, in addition to many State highways, provide easy access to all parts of the county and to adjacent counties. The Atlantic Coast Line Railroad and the Seaboard Air Line Railroad provide rail transportation, and scheduled air flights and bus service also are available.

GEOLOGY

The known geologic formations of Manatee County range in age from Recent to Cretaceous. They are listed and briefly described in table 3. The surface formations consist predominantly of undifferentiated deposits of Pleistocene and, probably, Pliocene age; however, beds of Miocene age are exposed at some places. The subsurface formations are described on the basis of studies of rock cuttings, electric logs, and drillers logs of wells in Manatee and adjacent counties. Detailed logs of selected wells are included in table 7.

PRE-TERTIARY ROCKS

Rocks older than middle Eocene in Manatee and adjacent counties are known only from a few deep oil-test wells. The data from these wells indicate that rocks of Cretaceous age occur at a depth of about 5,000 feet in Manatee County. Well 26-22-1, drilled in 1955 by the Magnolia Petroleum Corporation, entered the Upper Cretaceous at 5,120 feet below sea level and ended in Cretaceous rocks at more than 10,000 feet below sea level. The Cretaceous rocks consist of interbedded shale, limestone, and anhydrite and contain highly mineralized water. Water from near the bottom of well 26-22-1 contained more than 100,000 ppm of chloride, whereas sea water generally contains less than 20,000 ppm of chloride.

TERTIARY SYSTEM

The formations of Tertiary age in Manatee County and their approximate thicknesses are listed in table 3, but only those formations that are penetrated by water wells (fig. 6) are discussed in this report.

EOCENE SERIES

Avon Park Limestone: The upper part of the late middle Eocene in Florida was named the Avon Park limestone by the Applins (1944, p. 1680, 1686). It crops out in Citrus and Levy counties and is the oldest formation exposed at the surface in Florida. It is also the oldest formation penetrated by water wells in Manatee County.

Lithologically, the Avon Park, in the county, ranges from white or tan, fairly soft, coquinoid or granular limestone, to dark brown, hard, crystalline dolomite. Most of the formation is dolomitized to some

Table 3. Geologic Formations of Manatee County

System	Series	Formation	Characteristics	Thickness (feet)
Quaternary	Recent		Soil, muck, alluvium, sand.	0-20
	Pleistocene	Pamlico sand	Sand, shells, limestone.	0-20
		Older terrace deposits	Sand.	0-60
Tertiary	Pliocene	Caloosahatchee marl?	Marl, sand and gravel of quartz and phosphate, shells, bone fragments.	0-10
		Bone Valley formation	Sand and gravel of quartz and phosphate; clay, bone fragments.	0-30?
	Miocene	Hawthorn formation	Clay and marl, gray, greenish and bluish gray, sandy, phosphatic, calcareous, interbedded with sandy limestone, silt, sand, and shells. The sand, shell, and limestone beds are the source of small water supplies. The water in the Hawthorn formation is under artesian pressure and is generally less mineralized than the water in the Tampa and older formations.	150-300
		Tampa formation	Limestone, white, gray and tan, generally hard, dense, sandy, phosphatic in part, silicified in part, fossiliferous. Porosity due primarily to solution cavities. Yields large quantities of artesian water.	125-235
	Oligocene	Suwannee limestone	Limestone, creamy white and tan, soft to hard, granular, porous, crystalline, and dolomitic in part, very fossiliferous. Generally a more productive source of artesian water than the Tampa, but water is somewhat more mineralized in the western part of the county.	150-300
	Eocene	Ocala group	Limestone, white, cream, tan, chalky, soft, granular, porous, coquinoid in part, with some hard, dense layers and some thick beds of brown, crystalline dolomite. Probably a productive source of artesian water but penetrated by only a few wells. Water is relatively high in mineral content in the coastal area.	300-325
		Avon Park limestone	Limestone, cream, tan, and brown, soft to hard, granular and coquinoid in part, crystalline and dolomitic in part, very porous. Probably a very productive source of water, but tapped by very few wells. Water is probably high in mineral content in the coastal area.	700
		Lake City limestone	Limestone, cream and tan, chalky to granular, dolomitic and gypsiferous in part, and very fossiliferous in part.	500
		Oldsmar limestone	Limestone, tan and brown, granular, porous; interbedded with chert, anhydrite, and tan to brown, crystalline, porous, dolomite.	950
	Paleocene	Cedar Keys formation	Limestone, cream to tan, fairly hard, granular, gypsiferous, interbedded with tan to brown, crystalline dolomite, fossiliferous in part.	2,000
Cretaceous	Gulf		Limestone, shale, anhydrite	

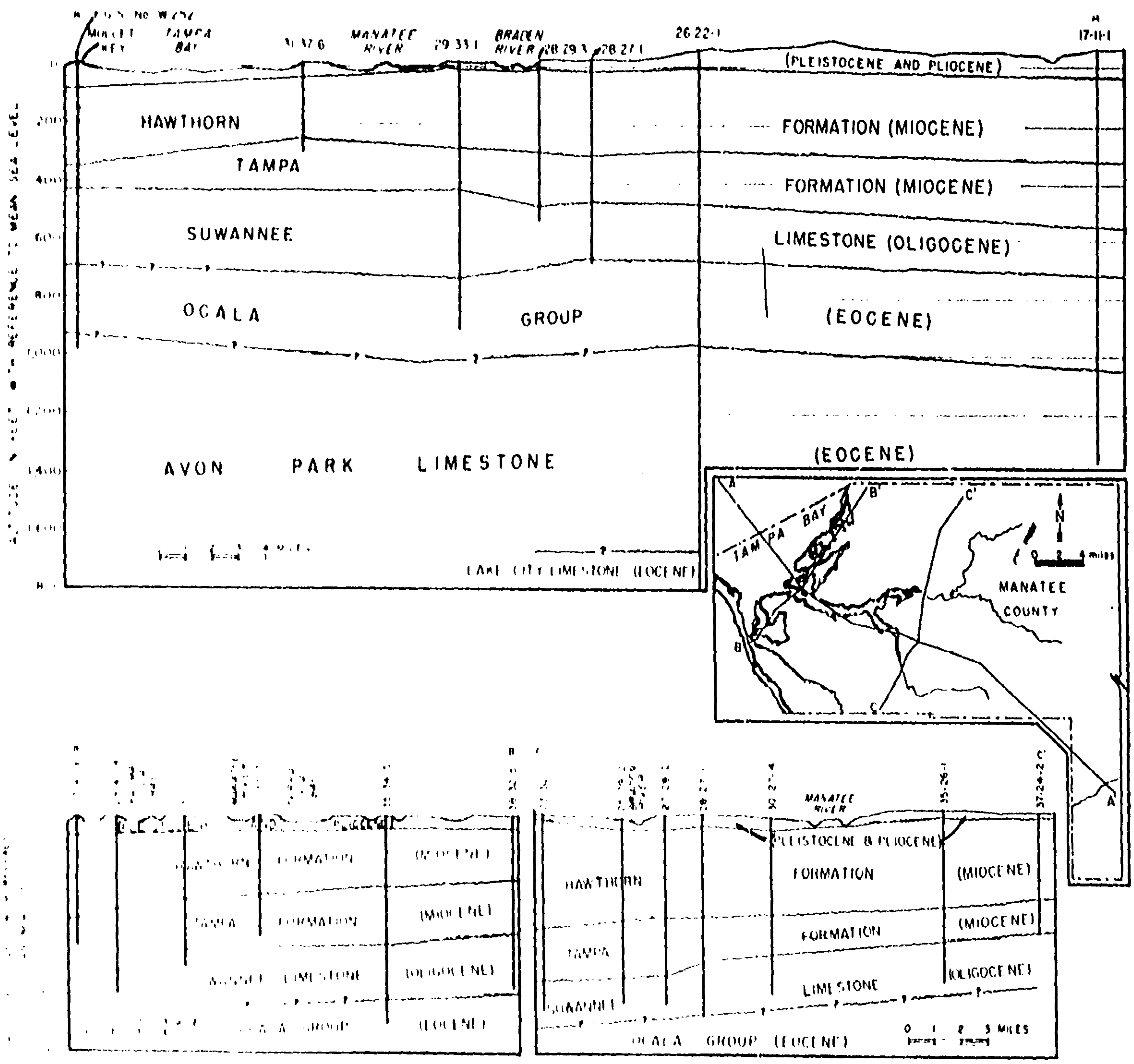


Figure 6. Cross sections showing the geologic formations penetrated by water wells in Manatee County.

degree and much of it is very fossiliferous, containing bryozoans, coral, echinoids, mollusks, and many foraminifers, including specimens of *Dictyoconus cookei, Lituonella floridana, Spirolina coryensis,* and *Valvulina intermedia.*

The Avon Park limestone is about 700 feet thick in Manatee County and is generally very permeable, owing to the extensive development of solution channels. Several wells obtain water from the Avon Park and it is probably a productive source of artesian water throughout the county. In the coastal area, however, the water probably is highly mineralized.

Ocala Group: Until recent years, all the limestones of late Eocene (Jackson) age in peninsular Florida were considered a single formation, the Ocala limestone. As shown in table 4, Cooke (1945, p. 53-62) and the Applins (1944, p. 1683) referred all the late Eocene limestone to the Ocala limestone; however, the Applins recognized an upper and a lower member on the basis of lithologic and faunal differences. After completion of his studies in Citrus and Levy counties, Vernon (1951, p. 111-171) separated the late Eocene limestones into two formations: the Ocala limestone, restricted to the upper part, and the Moodys Branch formation. Vernon also divided the Moodys Branch formation into two members: the Williston member (upper) and the Inglis member (lower).

Table 4. Stratigraphic Nomenclature of the Upper Eocene in Florida

<table>
<tr><th colspan="3">U.S. Geological Survey</th><th colspan="4">Florida Geological Survey</th></tr>
<tr><th>Cooke (1945)</th><th colspan="2">Applins (1944)</th><th colspan="2">Vernon (1951)</th><th colspan="2">Puri (1953)</th></tr>
<tr><td rowspan="3">Ocala limestone</td><td rowspan="3">Ocala limestone</td><td>Upper member</td><td colspan="2">Ocala limestone (restricted)</td><td rowspan="3">Ocala group</td><td>Crystal River formation</td></tr>
<tr><td rowspan="2">Lower member</td><td rowspan="2">Moodys Branch formation</td><td>Williston member</td><td>Williston formation</td></tr>
<tr><td>Inglis member</td><td>Inglis formation</td></tr>
</table>

Puri (1953, p. 130) changed the Ocala limestone (as restricted by Vernon) to the Crystal River formation and gave formational rank to the Williston and Inglis members of the Moodys Branch formation. The Crystal River, Williston, and Inglis formations are now referred to as the Ocala group by the Florida Geological Survey.

The Ocala group lies unconformably on the Avon Park limestone in Manatee County and is about 300 to 325 feet thick. The upper part consists predominantly of cream, tan and grayish-tan, soft, chalky, highly fossiliferous limestone. The lower part is similar but contains beds of brown and tan, hard, crystalline dolomite and dolomitic limestone. The Ocala group is penetrated by only a few wells in the county, although it may be a productive source of artesian water. In the coastal areas, however, the water in the Ocala group has a relatively high mineral content.

OLIGOCENE SERIES

Suwannee Limestone: As used in this report, the Suwannee limestone includes all deposits of Oligocene age in Manatee County. The Suwannee is differentiated from the underlying Eocene formations and overlying Miocene formations on the basis of lithology and fossils, and is separated from these formations by unconformities.

The upper part of the Suwannee is generally a creamy-white to tan soft to hard granular porous limestone, with some beds of crystalline and dolomitic limestone. It contains many echinoids, mollusks, and foraminifers. The lower part is generally tan to gray, and it is harder, more crystalline, more dolomitic, and less fossiliferous than the upper part. *Dictyoconus cookei* and *Coskinolina floridana* are found in the Suwannee in the western part of the county. They are generally restricted to the lower part of the Suwannee and may be diagnostic of the lower Suwannee in that area. However, these foraminifers were not found in the Suwannee in the eastern part of the county. Specimens of *Rotalia mexicana* are fairly abundant in the Suwannee limestone throughout the county.

The contours on the map in figure 7 represent the approximate altitude and the configuration of the top of the Suwannee limestone in Manatee County. The contours were drawn on the basis of well cuttings, drillers logs, and electric logs. The dashed lines in the eastern part of the county, where no control wells were available, were drawn on the basis of information from wells in adjacent counties. As shown on this map, the top of the formation ranges in depth from about 325 feet below sea level in the northeastern part of the county to more than 550 feet below sea level in the southern and southeastern parts of the county. The thickness of the formation ranges from about 150 feet in the northeastern part of the county to about 300 feet in the southwestern part.

The Suwannee is the most productive source of artesian water generally tapped by wells in the county. In the coastal area, the water in the Suwannee is somewhat more mineralized than the water in the overlying Tampa formation.

MIOCENE SERIES

In this report, the deposits of Miocene age in Manatee County are referred to the Tampa formation of early Miocene age (Cooke 1945, p. 107) and the Hawthorn formation of middle Miocene age. Both the Tampa and Hawthorn formations are of marine origin, but they represent different depositional environments and are probably separated by an unconformity.

Tampa Formation: The Tampa formation lies unconformably on the Suwannee limestone of Oligocene age and consists of white, gray and tan, hard, dense, sandy limestone which contains fine-grained phosphorite in some places. The limestone is crystalline and dolomitic, in part, and contains thin beds of chert. It is generally fossiliferous, containing echinoid plates and spines, ostracods, foraminifers, and many molds and casts of mollusks. Specimens of the foraminifers *Archaias floridanus* and *Sorites* sp. are fairly abundant throughout the formation.

The contours on the map in figure 8 represent the approximate altitude and configuration of the formation. They were drawn on the basis

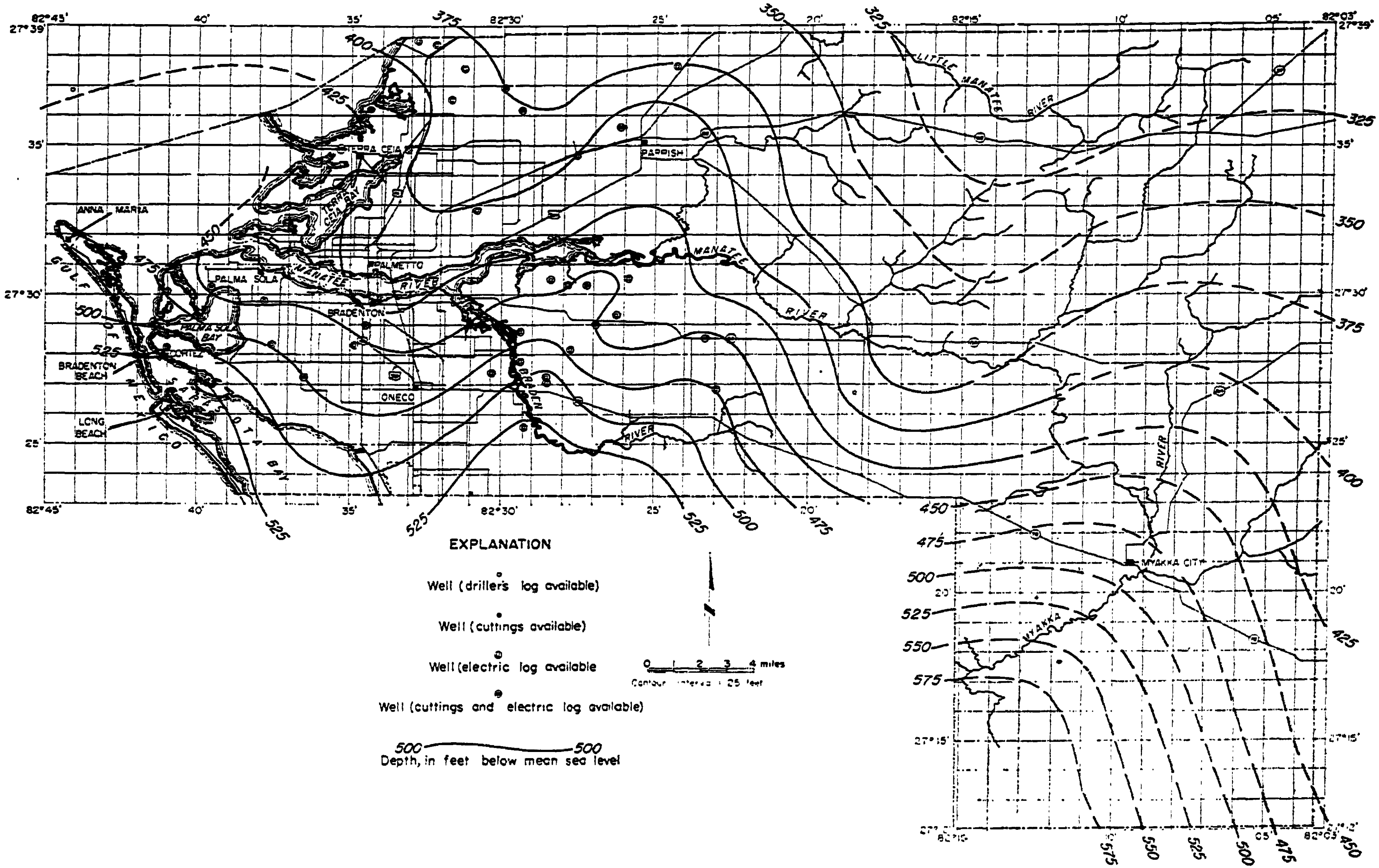


Figure 7. Structure-contour map of the top of the Suwannee limestone in Manatee County.

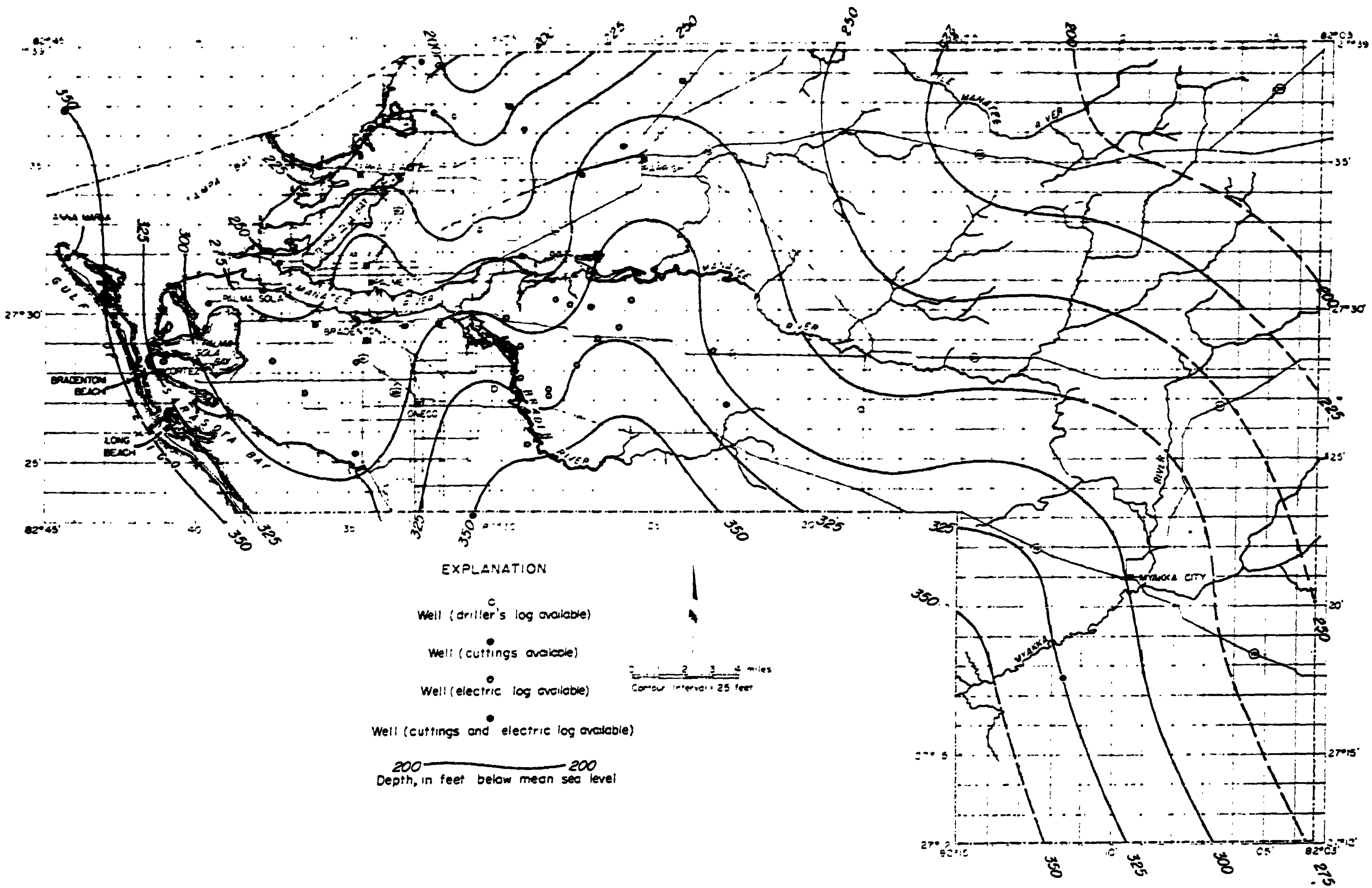


Figure 8. Structure-contour map of the top of the Tampa formation in Manatee County.

of information from electric logs, drillers logs, and the study of well cuttings. The dashed lines in the eastern part of the county, where control wells were not available, were drawn on the basis of information from wells in adjacent counties. As shown on the map (fig. 8) the top of the Tampa ranges in depth from about 200 feet below sea level in the northern and northeastern parts of the county to more than 350 feet below sea level in the southwestern part. The thickness of the formation ranges from about 125 feet in the northeastern part of the county to about 235 feet in the southeastern part. The average thickness is about 150 to 175 feet.

The Tampa formation generally has a relatively high permeability owing to numerous interconnecting solution cavities. It is a very productive source of artesian water in most parts of the county.

Hawthorn Formation: The Hawthorn formation, as used in this report, includes all deposits of Miocene age that are younger than the Tampa formation. The Hawthorn consists of gray, bluish-gray and greenish-gray, sandy, calcareous clay interbedded with white, gray, and tan sandy limestone and thin beds of sand and shells. The clay and limestone layers contain different amounts of chert, dolomite, sand, and phosphorite grains and pebbles. The limestone layers are fossiliferous, in part. The top of the Hawthorn is an irregular erosion surface that generally ranges from about 10 feet above sea level to about 50 feet below sea level in Manatee County. The Hawthorn is exposed along some streams and in shallow ditches in several places in the western part of the county. The thickness of the formation ranges from about 150 feet in the northeastern part of the county to more than 350 feet in the southern part, increasing in the direction of dip of the formation.

The beds of sand and limestone yield artesian water to many domestic and some irrigation wells. The water is generally less mineralized than that in the Floridan aquifer. Because of the low permeability and the thickness of the clay layers, the formation serves as a confining layer for the water in the underlying limestone formations of the Floridan aquifer.

PLIOCENE SERIES

Deposits of Pliocene age in Manatee County were referred by Cooke (1945, p. 208-223), to the Bone Valley formation and the Caloosahatchee marl. The Bone Valley formation consists of sand, gravel, clay, and phosphorite pebbles and is supposed to be present in much of the eastern part of the county. In well 17-11-1, sediments from the interval between five feet above sea level and about 40 feet below sea level consist of sand and gravel of quartz and phosphorite, with some clay and impure limestone near the base. These sediments, which are underlain by the Hawthorn formation, probably represent the Bone Valley formation. Material of similar lithology, in a ditch north of Ellenton, was referred to the Bone Valley formation by Cooke (1945, p. 208).

The marl, shell, and limestone beds overlying the Hawthorn formation in the western part of the county were included in the Caloosahatchee marl by Cooke (1945, p. 223). In some places the Hawthorn formation is overlain by a thin bed of sandy weathered material containing pebbles of quartz, phosphorite and bone fragments. In other places it is overlain by a thin bed of marl containing sand and gravel of quartz and phosphorite, marine shells, and bone fragments. These beds, which appear to be discontinuous and are generally less than 10 feet thick, may be of Pliocene age. The shell and limestone beds at or near the surface throughout much of the coastal area have been previously referred to the Caloosahatchee marl, but they appear to the author to be of Pleistocene age.

PLEISTOCENE SERIES

Pleistocene sediments older than the Pamlico sand consist predominantly of nonfossiliferous sand which ranges in thickness from a few feet to about 65 feet. In some places the sediments contain a layer of hardpan a few feet beneath the surface, which confines the water beneath it under slight artesian pressure. They are a source of water for small irrigation and domestic supplies in the eastern part of the county.

The Pamlico terrace is underlain by sand, sandy limestone, and shells. The beds of limestone and shells generally occur at altitudes less than 20 feet above sea level and pinch out seaward from the Pamlico shoreline. They were probably deposited during late Pleistocene time. The bed of shell contains a fauna very similar to that of present beach deposits; however, Cooke (1945, p. 222-223) reports that extinct species have been found in a bed of shells of apparently the same age in Hillsborough County. The Pleistocene sediments beneath the surface of the Pamlico terrace range in thickness from less than 1 foot to about 50 feet and are tapped by a few domestic wells.

GROUND WATER

PRINCIPLES OF OCCURRENCE

Practically all the usable water of the earth moves through the vast circulatory system known as the hydrologic cycle. In this cycle, water condenses from the moisture in the atmosphere and falls as rain or snow. Then it moves over and beneath the land surface to the oceans and is returned to the atmosphere. Actually, the cycle may be modified or completed at any time after the water condenses from the atmosphere, as evaporation may begin even before the water reaches the earth, and continues throughout the entire cycle whenever air undersaturated with moisture has access to the water. Also, great quantities of water are returned to the atmosphere by the transpiration of plants.

Subsurface water may be divided into two general classes—suspended (vadose) water and ground water. Suspended water is the water in the zone of aeration—the zone in which the interstices of the soil or rocks, whether, full or not, contain water, under less than atmospheric pressure. Ground water is the water in the zone in which all the interstices are filled with water under pressure greater than atmospheric. This saturated zone is the reservoir that yields water to all springs and wells.

The water in the zone of saturation may occur as (1) unconfined ground water (under nonartesian conditions) or as (2) confined ground water (under artesian conditions). Where the ground water is not confined, and its upper surface is under atmospheric pressure and is free to rise and fall, it is said to be under nonartesian conditions. Its upper surface is called the water table. Where the water is confined in a permeable bed that is overlain by a relatively impermeable bed, its upper surface is not free to rise and fall and it is said to be under artesian conditions. The term "artesian" is applied to ground water that is confined under sufficient pressure to rise above the top of the permeable bed that contains it, but not necessarily above the land surface.

An aquifer is a formation, group of formations, or part of a formation, in the zone of saturation that is permeable enough to transmit usable quantities of water. Recharge is the process of replenishment of the aquifer with water, and areas in which it occurs are known as recharge areas. Generally, nonartesian aquifers may receive recharge throughout their extent, whereas artesian aquifers receive recharge only where their confining beds are absent or somewhat permeable.

The piezometric surface of an aquifer is an imaginary surface to which water from an artesian aquifer will rise in tightly cased wells that penetrate the aquifer. Where the piezometric surface is above the land surface, artesian wells will flow under natural pressure.

GROUND WATER IN FLORIDA

Ground water occurs in Florida under both nonartesian and artesian conditions. Nonartesian conditions occur generally in the shallow deposits of sand, gravel, shells, and limestone which constitute many aquifers of relatively small areal extent. These deposits are the source of many domestic water supplies throughout the State and also of public and industrial supplies in areas where the deeper formations contain salty water. The water in the nonartesian aquifers is supplied chiefly by infiltration of local rainfall.

ARTESIAN WATER

Most of Florida is underlain by a thick section of permeable limestone formations of Eocene, Oligocene, and Miocene ages. These formations make up an extensive artesian aquifer from which most of the large ground-water supplies of the State are obtained. Stringfield (1936, p. 125-132, 146) described the aquifer and mapped the piezometric surface in 1933 and 1934. The name "Floridan aquifer" was introduced by Parker (1955, p. 188-189) to include "parts or all of the middle Eocene (Avon Park and Lake City limestones), upper Eocene (Ocala limestone), Oligocene (Suwannee limestone), and Miocene (Tampa limestone, and permeable parts of the Hawthorn formation that are in hydrologic contact with the rest of the aquifer)." The artesian water is confined by relatively impermeable layers in the limestone formations and by the overlying clay beds of Miocene age which are present in most of the State. The water in the artesian aquifer is replenished chiefly by rainfall in areas where the confining beds are absent or sufficiently permeable to permit the passage of substantial quantities of water from the surface into the limestone.

Piezometric Surface: The configuration of the piezometric surface in peninsular Florida is shown by contour lines in figure 9. These contour lines represent the height, in feet above sea level, to which water will rise in wells that penetrate the Floridan aquifer. The lines indicate the areas in which recharge occurs and the direction of movement of the water in the Floridan aquifer. In areas of recharge, the piezometric surface is relatively high. The water moves away from these areas in the direction of steepest gradient, at right angles to the contour lines, toward areas of discharge, where the piezometric surface is relatively low. The piezometric surface in central Florida forms an elongated dome which is centered in northern Polk County. This dome indicates that the lake region of Polk County is the center of a relatively large area of recharge which probably extends into adjacent counties (Stringfield, 1936, p. 148). The water enters the limestone formations in this area through the numerous sinkholes that penetrate the confining bed, or at places where the confining bed is absent.

The small ridge on the piezometric surface in Pasco County indicates that recharge occurs also in parts of Pasco, Hernando, and Hillsborough counties. The basin-shaped depression in the piezometric surface in the vicinity of Tampa Bay is the result of discharge of water from the artesian aquifer through springs and wells.

GROUND WATER IN MANATEE COUNTY

Ground water in usable quantities occurs in all formations penetrated by wells in Manatee County. The beds of shell and sand of Pliocene and

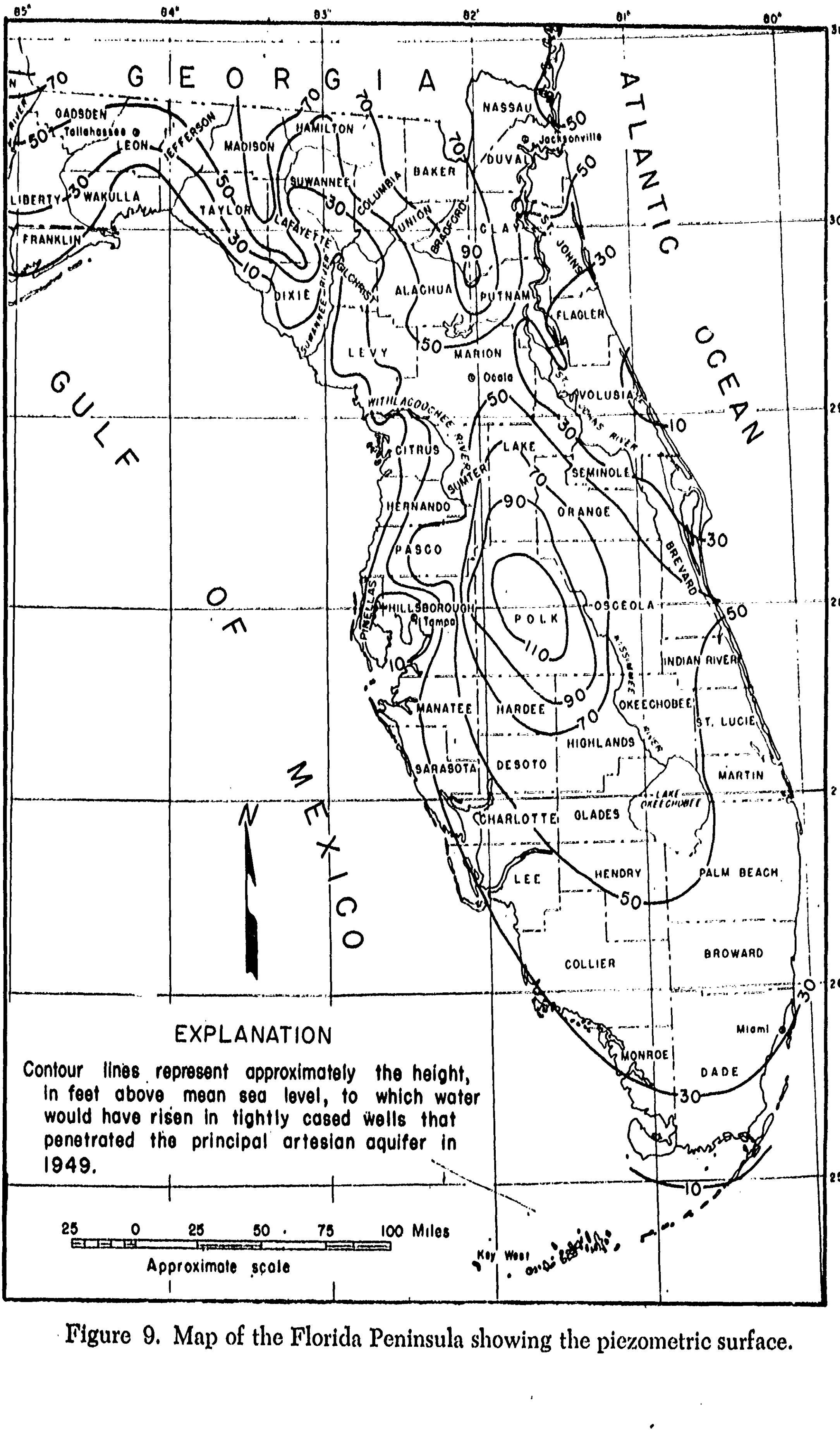


Figure 9. Map of the Florida Peninsula showing the piezometric surface.

Pleistocene age yield water to many domestic wells. The water in these deposits is replenished by local rainfall. In some places it is confined under slight artesian head by layers of hardpan, clay, or limestone. Reports by drillers indicate that most of the shallow wells in the county penetrate at least one thin bed of clay or limestone that confines the underlying water under artesian pressure, although the pressure is not generally sufficient to produce a flowing well.

ARTESIAN WATER

In Manatee County, as in most of the state, the Floridan aquifer is the principal artesian aquifer. Probably most of the water in the Floridan aquifer in Manatee County comes from rainfall that infiltrates into the aquifer in the recharge area of Polk County. From there it moves southwestward into Manatee County, as indicated by the configuration of the contours in figure 9. However, some recharge may occur in the northeastern part of Manatee County, where the piezometric surface is considerably lower than the water table and ground water from the nonartesian aquifer may percolate through the confining beds into the Floridan aquifer.

The Avon Park limestone and the Ocala group are penetrated by a few wells in the county and are probably capable of yielding large quantities of water, but they have not been used extensively because the Suwannee limestone and Tampa formation yield enough water to supply most wells. The water in the Suwannee limestone and the Tampa formation occurs in permeable zones that are generally separated by layers of low permeability which retard the vertical movement of water. These layers are discontinuous and are not completely impermeable, however; hence, water may move from one to another permeable zone.

The Hawthorn formation, consisting predominantly of clay and marl, serves as a confining bed for the water in the underlying limestone formations. Thin beds of sand, shells, and limestone within the formation, which are generally separated by relatively thick beds of clay, are the source of many domestic and small irrigation supplies. These permeable beds within the Hawthorn are generally separated from the Floridan aquifer by layers of clay or marl.

The piezometric surface of the Hawthorn formation has not been mapped; thus, the area of recharge is not known. Some recharge, at least to the upper part, probably occurs in eastern Manatee County. The lower part of the Hawthorn probably receives considerable recharge from upward leakage of water from the Floridan aquifer, as the artesian pressure in the Hawthorn is considerably less than that in the Floridan aquifer.

Current-meter Exploration: In order to determine the depth, thickness, and relative productivity of the permeable zones in the limestone formations, explorations were made in several selected wells with a deep-well current meter, a device for measuring the velocity of the flow of water through a well bore. The results of the current-meter traverses, and other data pertaining to these wells, are shown graphically in figures 10-16. The velocities are expressed in revolutions per minute (rpm) of the current meter. Actual flow rates, which are a function of velocity and cross-sectional area, cannot be computed accurately, as the diameter of the uncased part of the well bore is not uniform.

The results of a current-meter traverse in well 27-28-2 are shown graphically in figure 10, which includes also an electric log of the formations and a diagram showing the construction of the well. The well was

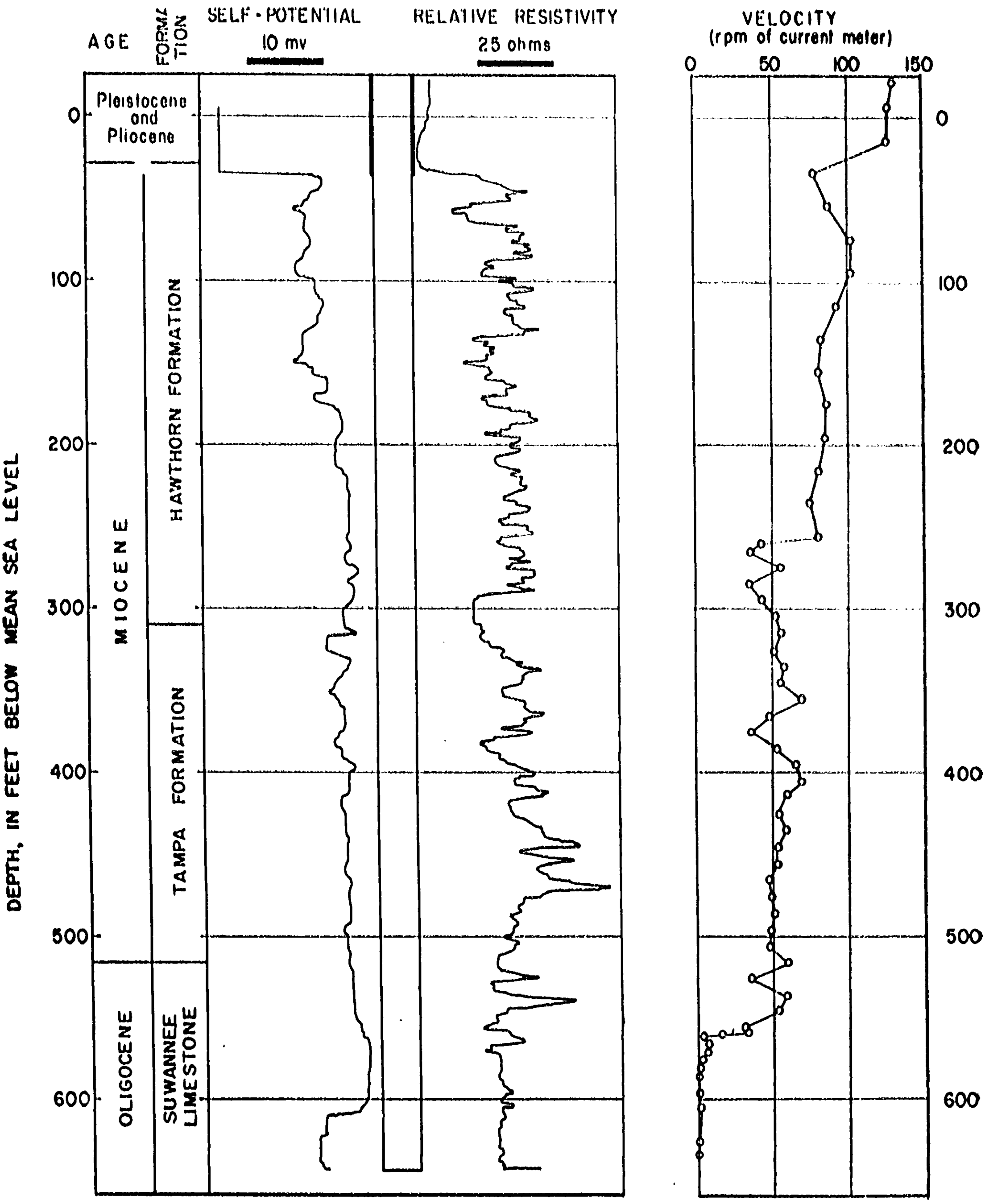


Figure 10. Graphs showing data from well 27-28-2, seven miles southeast of Bradenton.

flowing at the rate of about 450 gpm while the traverse was being made. The velocities show that little or no water entered the well below a depth of 615 feet. Some water entered the well between depths of 615 and 570 feet, but most of the total yield of the well was obtained from the interval between 560 and 540 feet. The permeable zones of the Tampa formation above 450 feet yielded some water. The large variations in velocity in the uncased part of the well probably represent differences in size of the well bore. The higher velocities in the cased part of the well indicate that the diameter of the uncased part is considerably larger than eight inches.

The velocities in well 28-29-3 (fig. 11) were determined when the well was flowing at the rate of about 60 gpm. They indicate that the Suwannee limestone yielded no water below a depth of 605 feet and that most of the water from this formation was obtained from the intervals

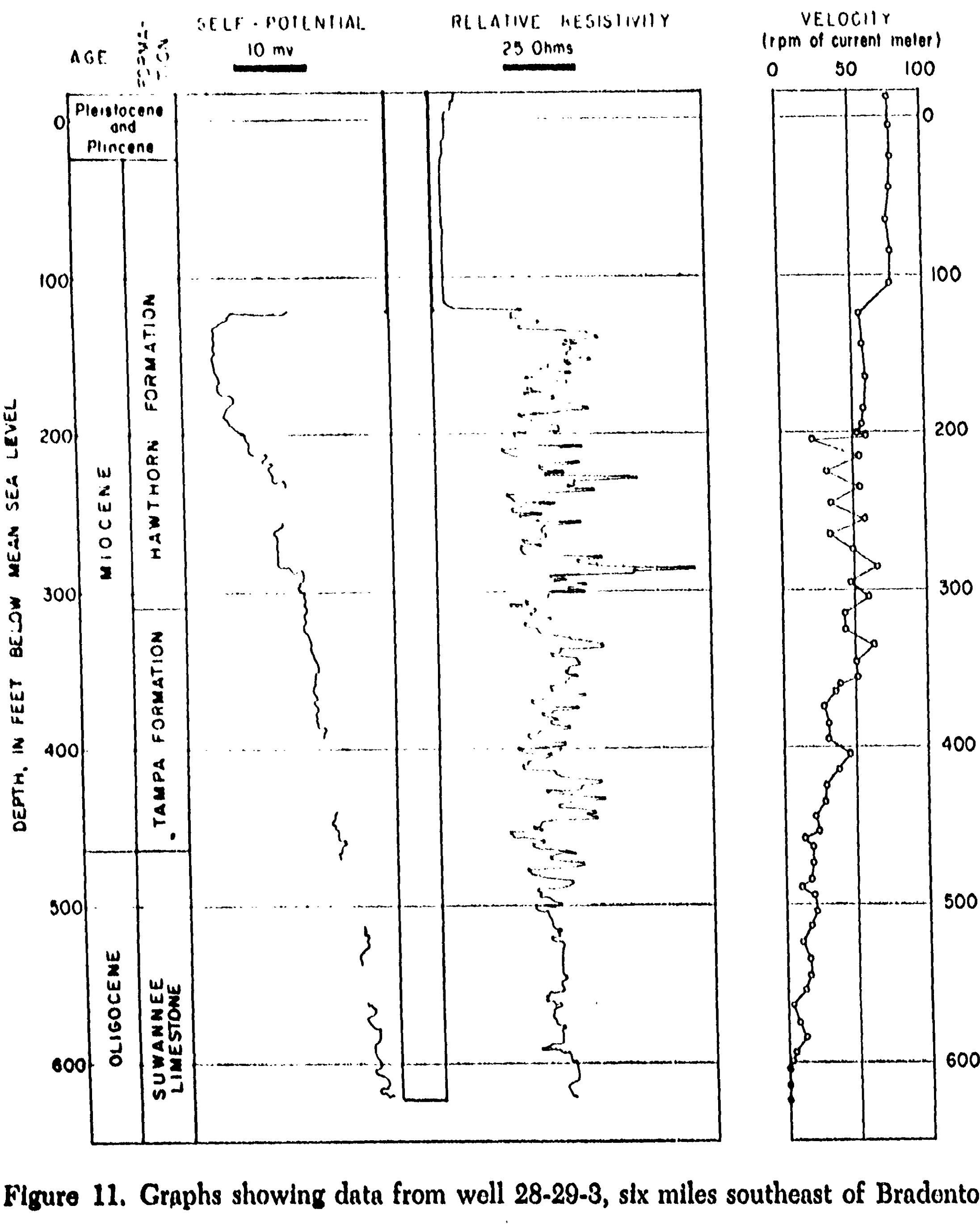


Figure 11. Graphs showing data from well 28-29-3, six miles southeast of Bradenton.

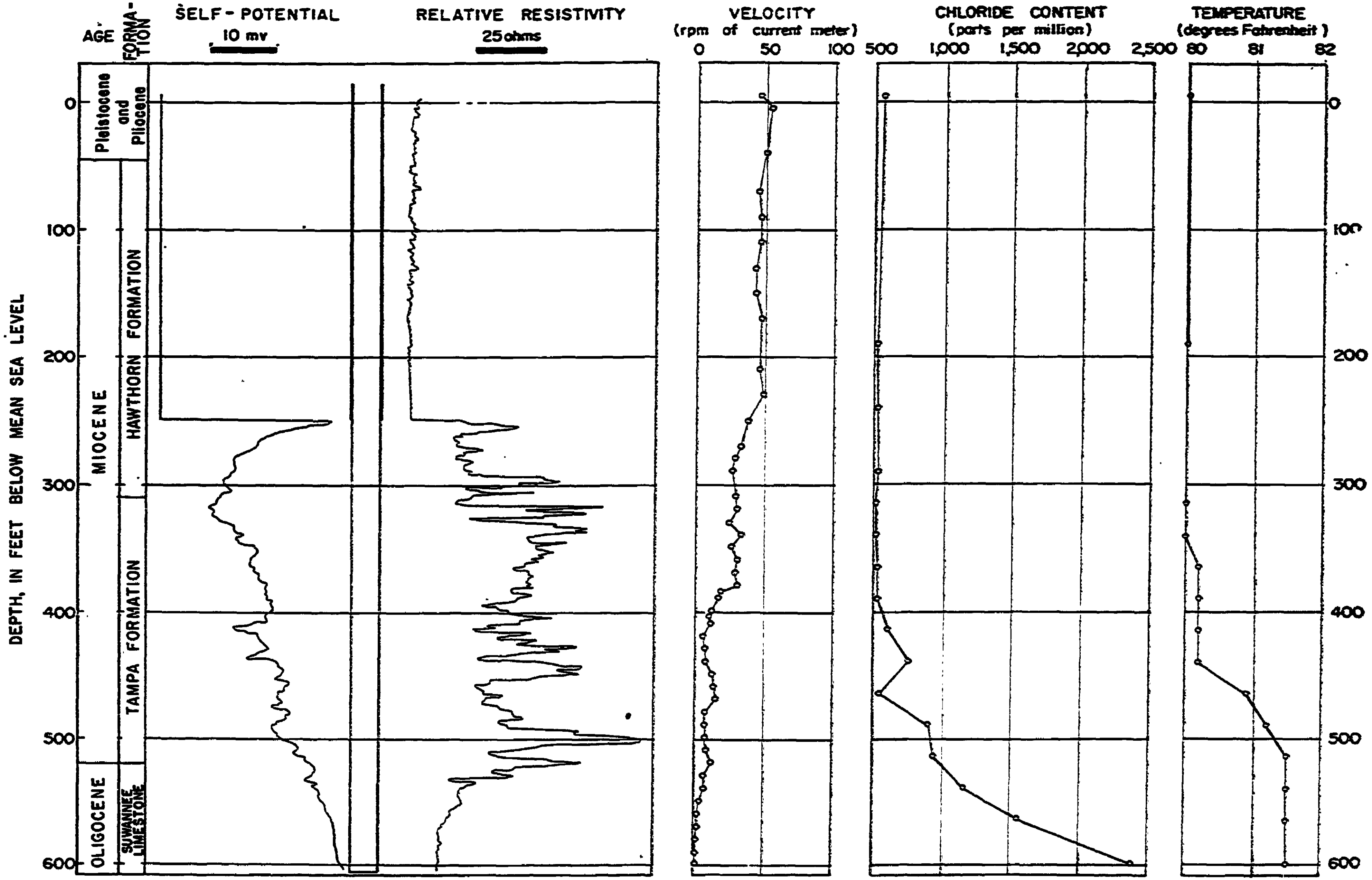


Figure 12. Graphs showing data from well 28-41-4, near Cortez.

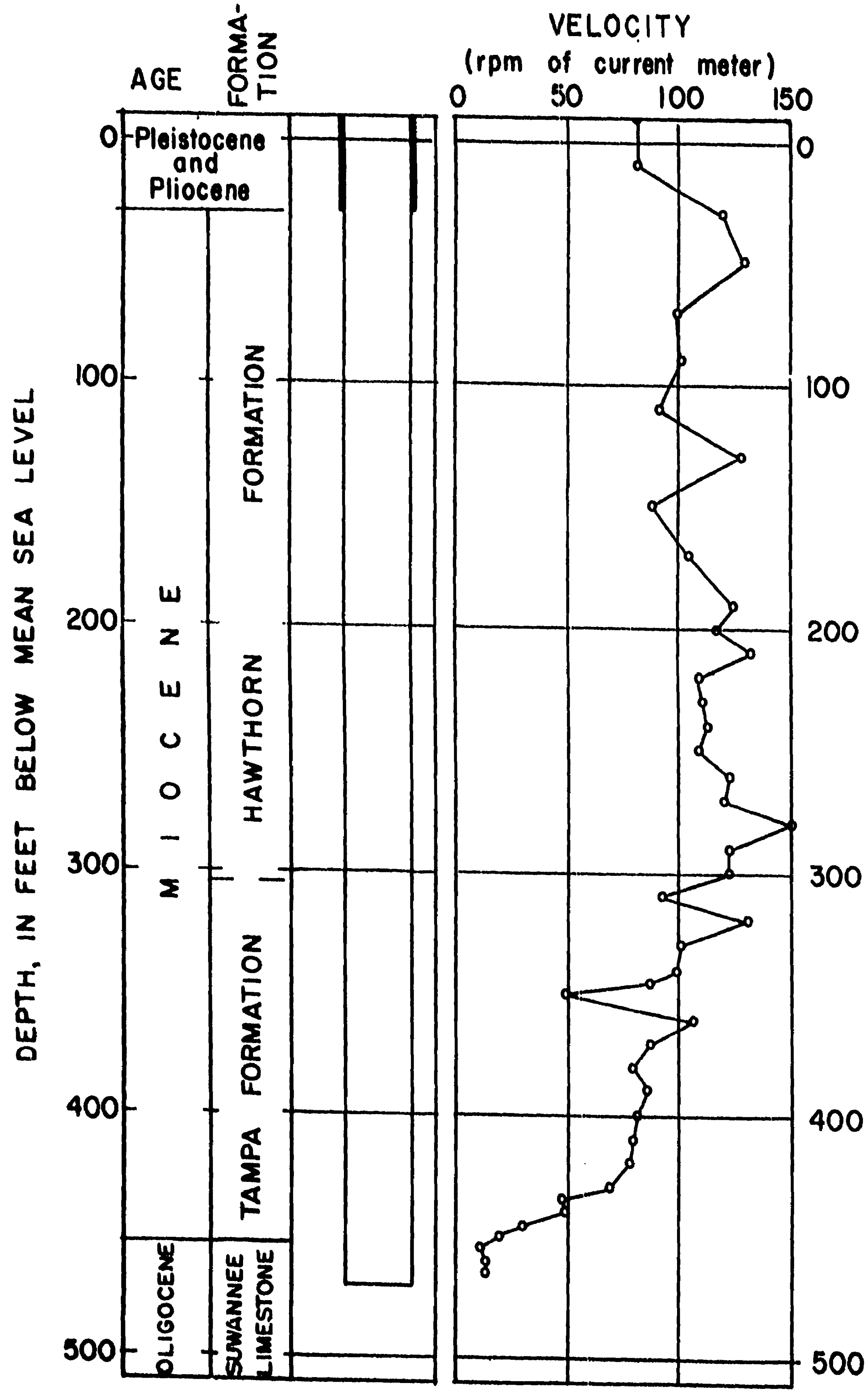


Figure 13. Graphs showing data from well 29-29-4, five miles east of Bradenton.

between depths of 605 and 585 feet and 525 and 505 feet. Most of the total yield of the well was obtained from the Tampa formation, between depths of 445 and 405 feet and 365 and 340 feet. The variations in velocity between depths of 335 and 200 feet are due to differences in size of the well bore, and they reflect the hard and soft layers in the Tampa and Hawthorn formations. The higher velocities in the 6-inch casing indicate that the diameter of the uncased part of the well is more than six inches.

The velocities in well 28-41-4 were determined when the well was flowing at the rate of about 60 gpm. They are shown in figure 12. Most of the water from the Suwannee limestone entered between 590 and 520 feet. Some water was obtained from the Tampa formation between depths of 480 and 470 feet, but most of the water from this formation entered the well between 420 and 365 feet. The productive zones

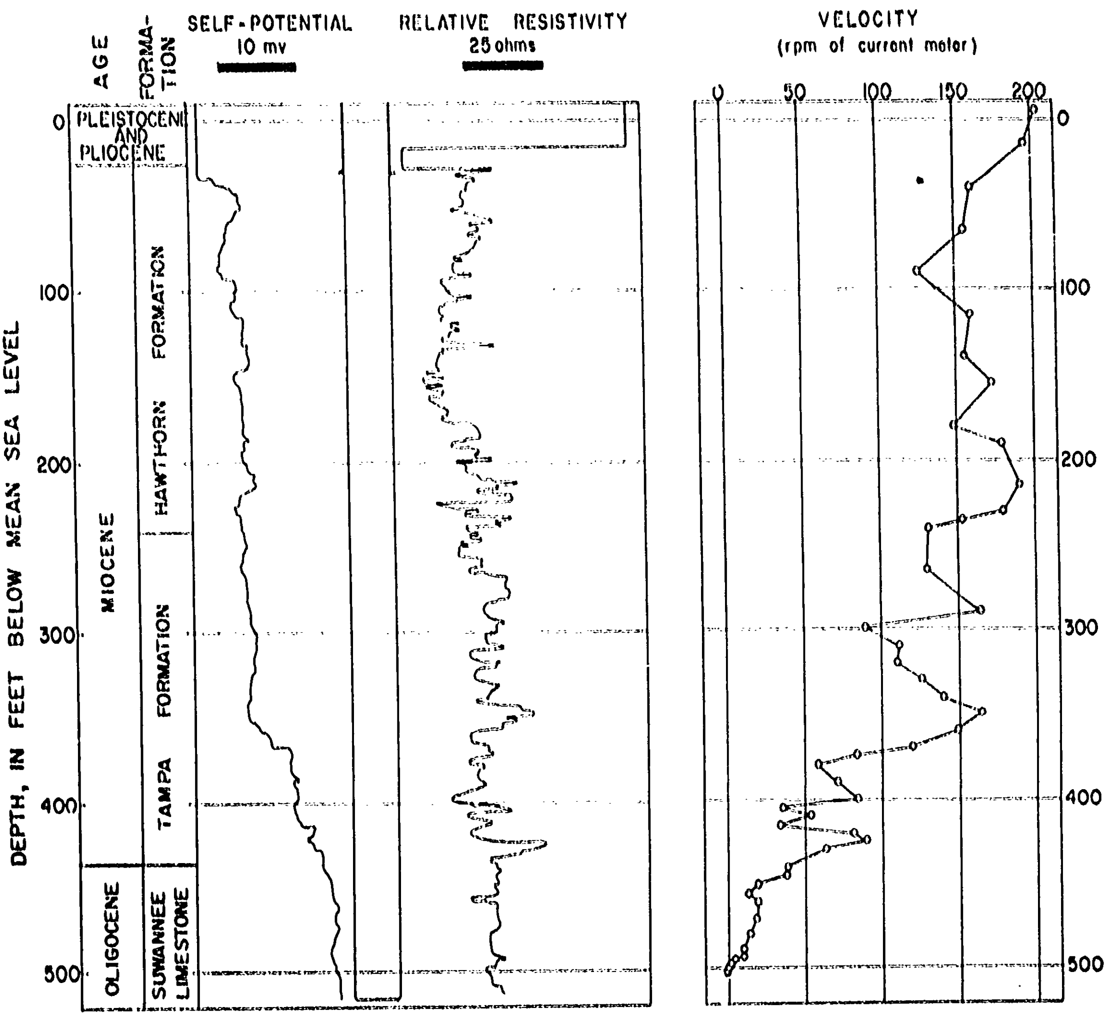


Figure 14. Graphs showing data from well 30-28-1, seven miles east of Bradenton.

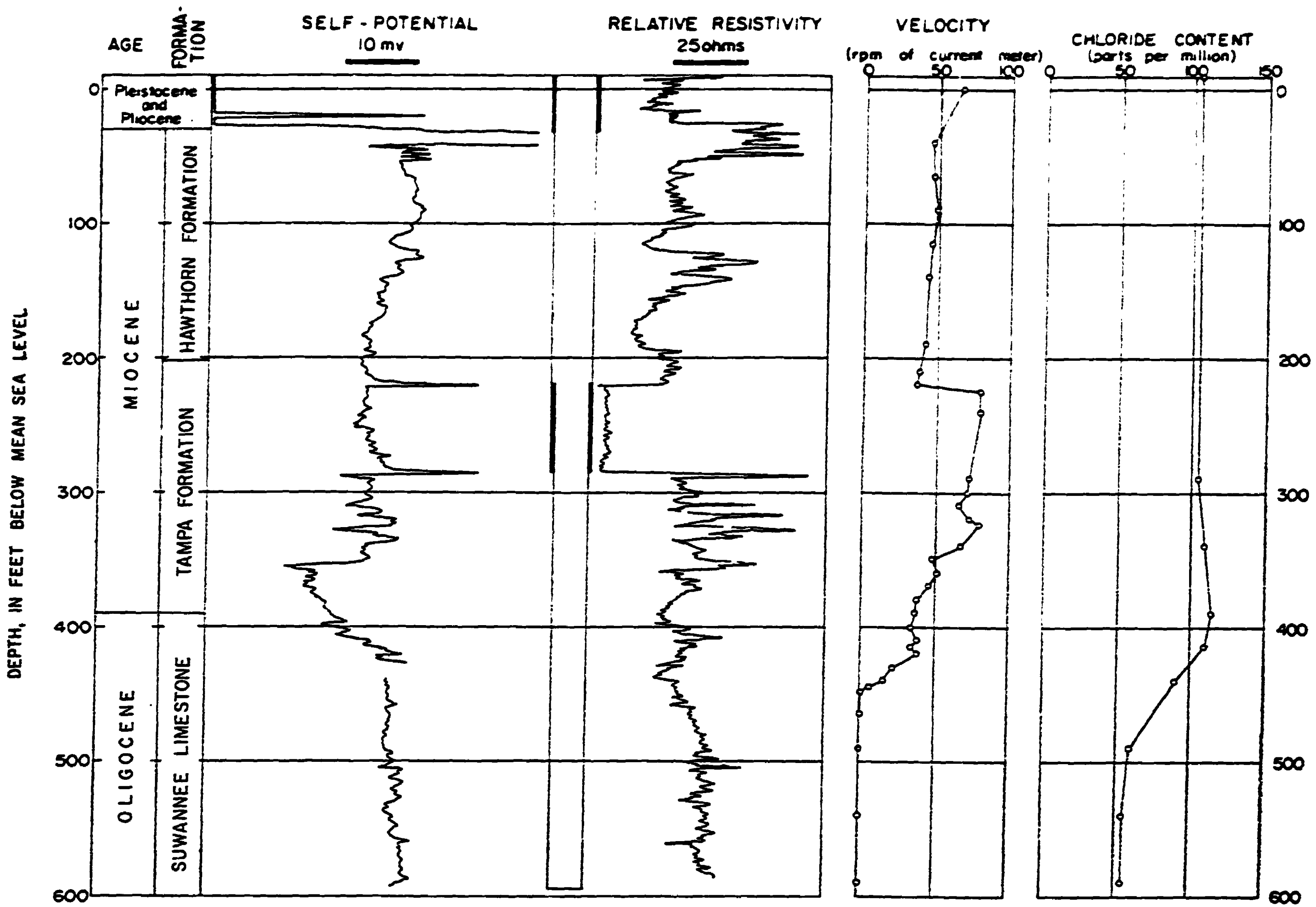


Figure 15. Graphs showing data from well 38-32-5, five miles northeast of Terra Ceia.

indicated by the velocities correlate generally with changes in chloride content and temperature, as shown in the figure.

Well 29-29-4 was flowing at an estimated rate of 110 gpm when the velocity measurements shown in figure 13 were made. The velocities indicate that most of the total yield was obtained from the Tampa formation, in the interval between depths of 450 and 360 feet. The large variations in velocity probably represent differences in the diameter of the well bore. The decrease in velocity above a depth of 50 feet may represent a loss of water to a permeable zone in the Hawthorn formation.

Well 30-28-1 was flowing an an estimated rate of 500 gpm when the velocity measurements shown in figure 14 were made. The velocities indicate that no water entered the well below a depth of 500 feet. Some water entered the well between depths of 500 and 470 feet and a large quantity entered between 465 and 430 feet. Most of the water came from the Tampa formation in the interval between 375 and 350 feet, but some may have entered the well from the upper part of the formation, between 240 and 230 feet. The large variations in velocity above a depth of 350 feet probably represent differences in the diameter of the well bore.

The velocities in well 38-32-5 were measured when the well was flowing at the rate of about 400 gpm. They are shown in figure 15. The velocities indicate that no water entered the well below a depth of 450 feet. A large part of the total yield was obtained from the upper part of the Suwannee limestone between depths of 450 and 420 feet. Some water probably entered the well from the Tampa formation between depths of 380 and 360 feet, but most of the water from this formation entered between 350 and 325 feet. The decrease in velocity above a depth of 225 feet represents a difference in the size of the well bore, as shown in the diagram.

Artesian Head: Water-level measurements were made in many wells during the investigation, to determine the altitude of the artesian pressure head in different parts of the county and in the different formations. These measurements, published separately as Florida Geological Survey Information Circular No. 19, show that the water in the Tampa formation and the water in the Suwannee limestone are under approximately the same artesian pressure head; however, small differences may occur locally during periods of heavy withdrawals. The head in the Hawthorn formation is generally several feet lower than the head in these underlying formations of the Floridan aquifer.

Because the head in the Floridan aquifer is higher than that in the Hawthorn formation, water from it moves up through partially cased wells and flows out into the permeable beds of the Hawthorn formation. This is illustrated by the graph in figure 16 which shows the results of a current-meter traverse in well 29-37-10. This well does not flow at the surface, and at the time the traverse was made the water level stood about eight feet below the top of the casing. Water entered the well from the Tampa formation and the top of the Suwannee limestone in the interval between depths of 450 and 325 feet, moved up the well and out into the Hawthorn formation above the top of the 6-inch casing, in the interval between depths of 70 to 60 feet.

Fluctuations of water level in artesian wells range from a fraction of a foot to several feet and are caused by one or several factors. The larger fluctuations are generally due to daily and seasonal variations in withdrawals of water from wells or to recharge from rainfall. Minor fluctuations are caused by such factors as ocean tides, atmospheric-pressure changes, winds, earthquakes, and passing trains. These factors and their effects on water levels are discussed in detail in a paper by Parker and Stringfield (1950).

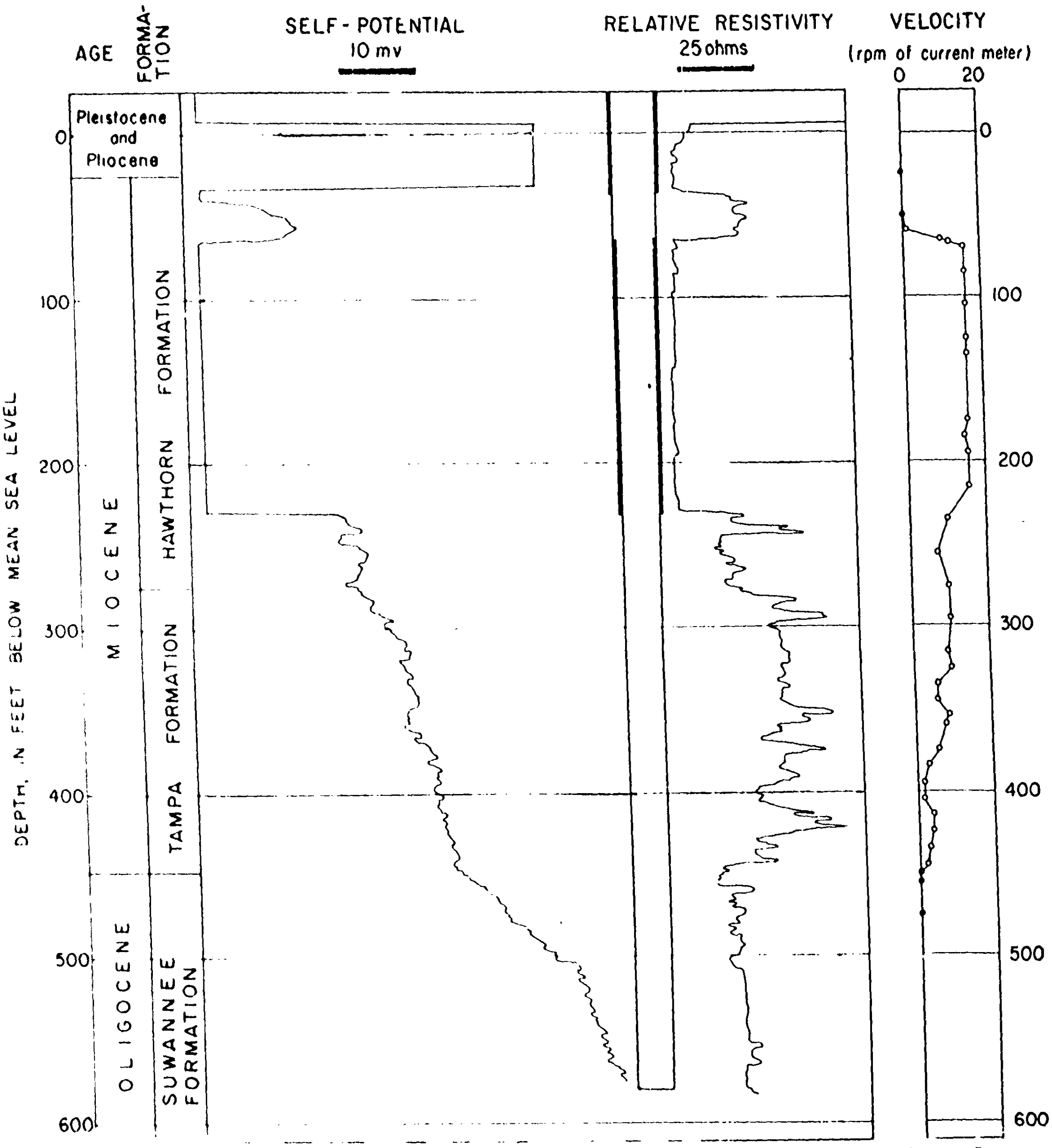


Figure 16. Graphs showing data from well 29-37-10, four miles west of Bradenton.

Records from continuous recording gages installed on four wells and water-level measurements made periodically in more than 30 wells provide information on the fluctuations and progressive trends of the artesian pressure head in Manatee County. These records show that the largest fluctuations were caused by the variations in daily and seasonal withdrawals of water from wells; however, observable fluctuations were caused by earthquakes, changes in barometric pressure, and ocean tides. Figures 17 and 18 show hydrographs prepared from records of the continuous recording gages, and figures 19-23 show hydrographs of 17 of the wells in which water levels were measured periodically. Water-level measurements in other wells are listed in table 6.

Measurements of water level in well 26-18-1 were begun in 1941. A continuous recording gage was installed in February 1945 and is still in operation. The hydrograph of this well (fig. 17) shows seasonal fluctuations and the general trend of artesian pressure head from June 1941 to December 1956. The seasonal use of artesian water in the area is indicated by a decline in head during the periods of least rainfall when large quantities of water were being used for irrigation. The higher head during periods of greater rainfall may be due partly to recharge, but it is due principally to a decrease in withdrawal. Seasonal fluctuations of several feet occurred during the period from 1941 to 1948, but there was apparently no progressive change in head. As shown by the hydrograph, the magnitude of the seasonal fluctuations has increased and the head has declined progressively since 1948, indicating a progressive increase in both seasonal and perennial use of water. The water level in this well reached a record low of 32.17 feet above sea level on April 28, 1956.

The hydrographs in figures 19-23 show the effects of seasonal use of water from 1951 through 1955. Most of them show a slight progressive decline in artesian pressure head during this period. The lowest water levels were recorded in April and May 1956.

Earthquake waves passing through the earth's crust cause a relatively rapid expansion and contraction of artesian aquifers and force the water levels in wells to rise and fall. The effects of earthquakes on the water level in well 26-18-1 are shown on the hydrographs in figure 24, which were traced from charts of the automatic recording gage. The destructive earthquake that occurred in the Dominican Republic on August 4, 1946, caused a maximum water-level fluctuation of 1.15 feet, and an after shock of this earthquake on August 8, 1946, caused a maximum fluctuation of 0.17 foot. A severe earthquake in northwestern Costa Rica on October 5, 1950, caused a maximum fluctuation of 1.55 feet.

The daily changes in atmospheric pressure cause minor fluctuations

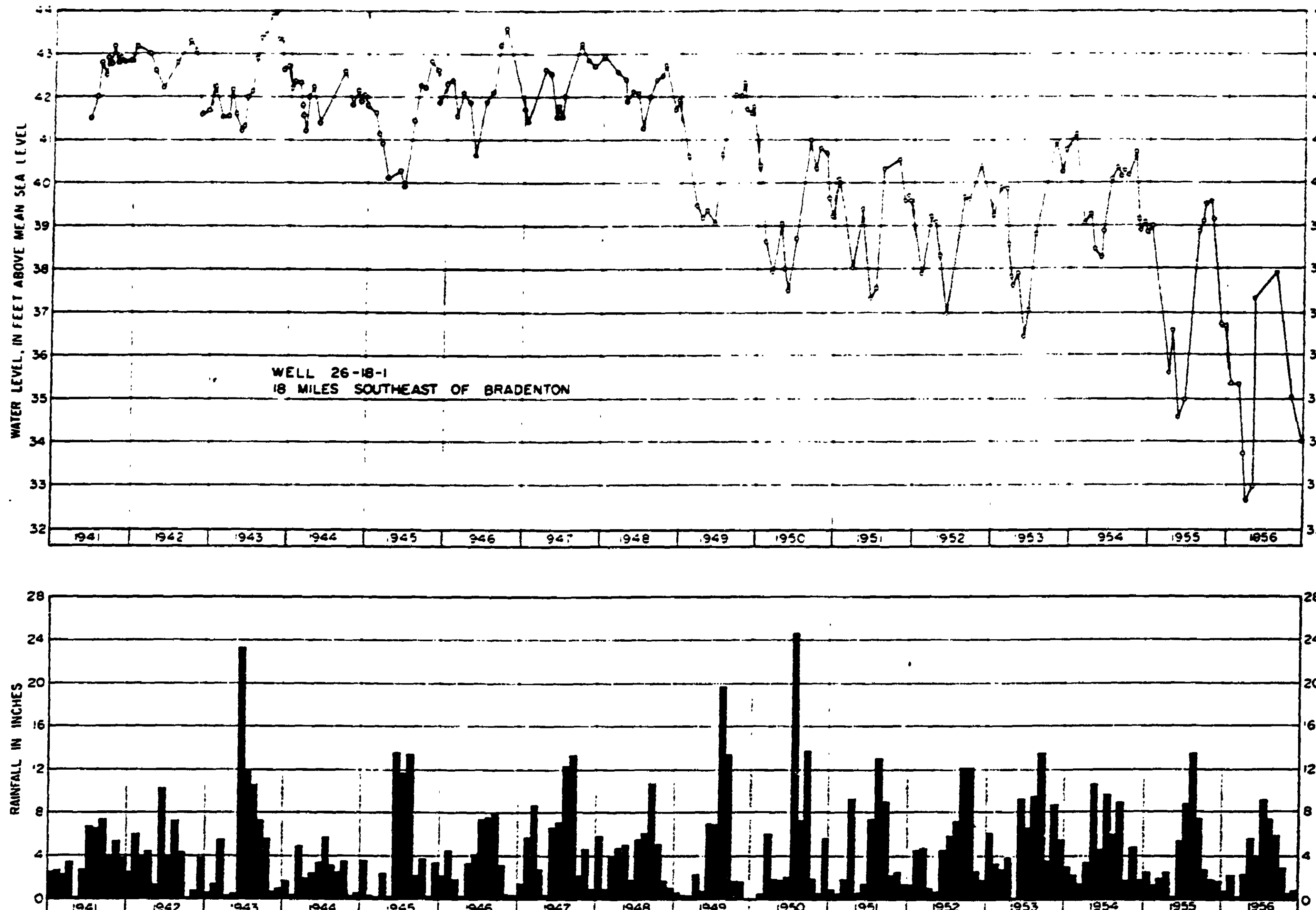


Figure 17. Hydrograph of well 26-18-1 and rainfall at Bradenton.

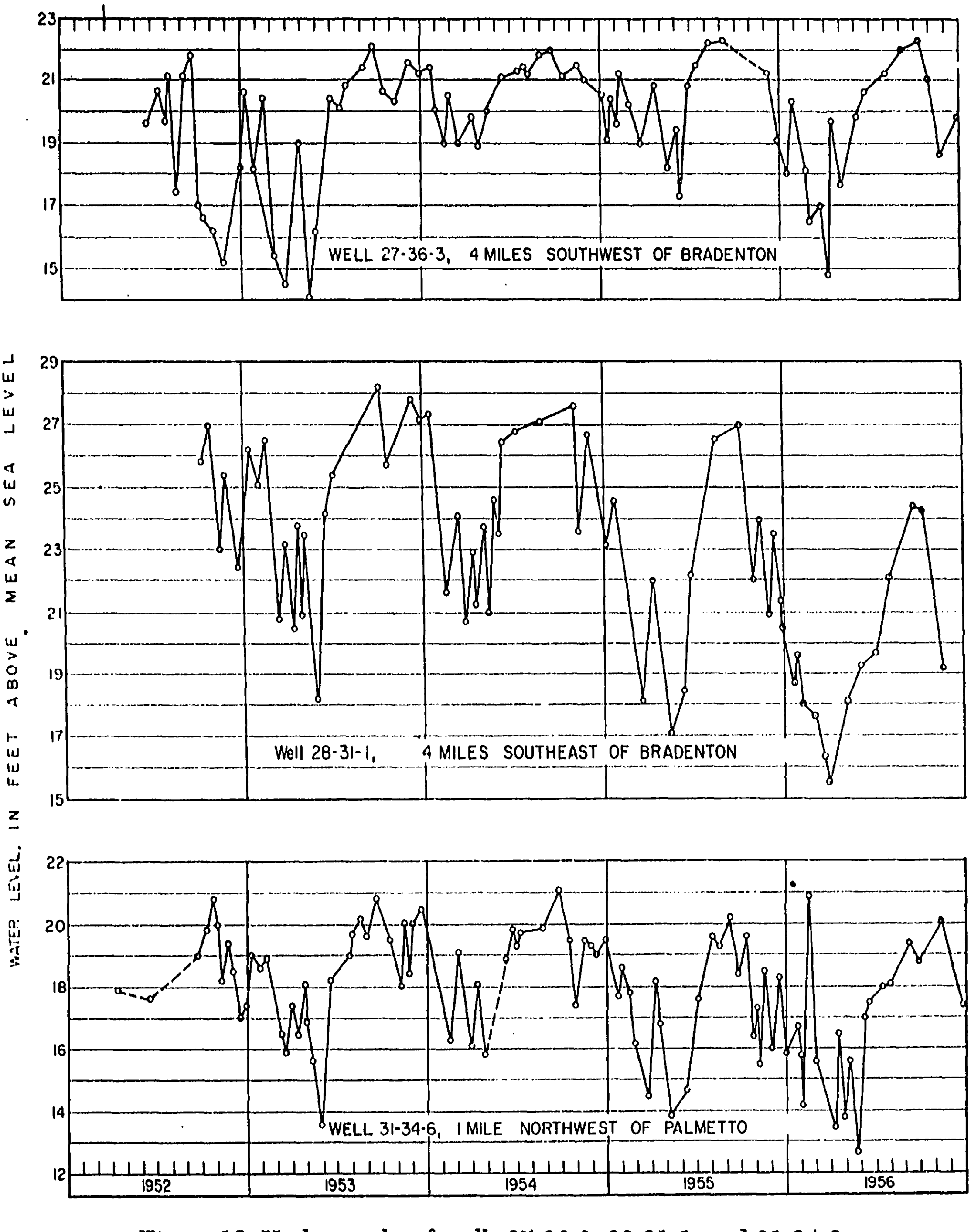


Figure 18. Hydrographs of wells 27-36-3, 28-31-1, and 31-34-6.

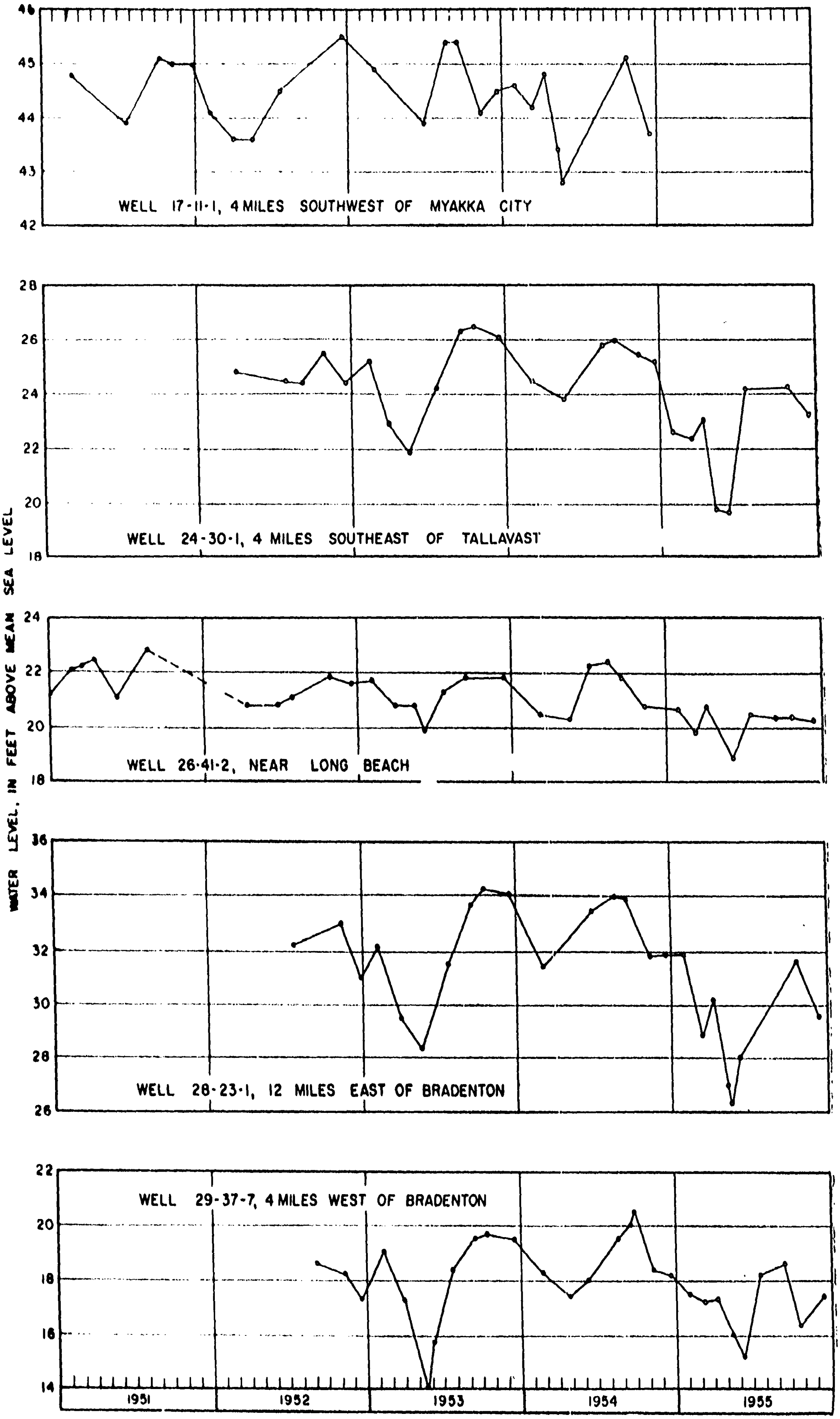


Figure 19. Hydrographs of wells 17-11-1, 24-30-1, 26-41-2, 28-23-1, and 29-37-7.

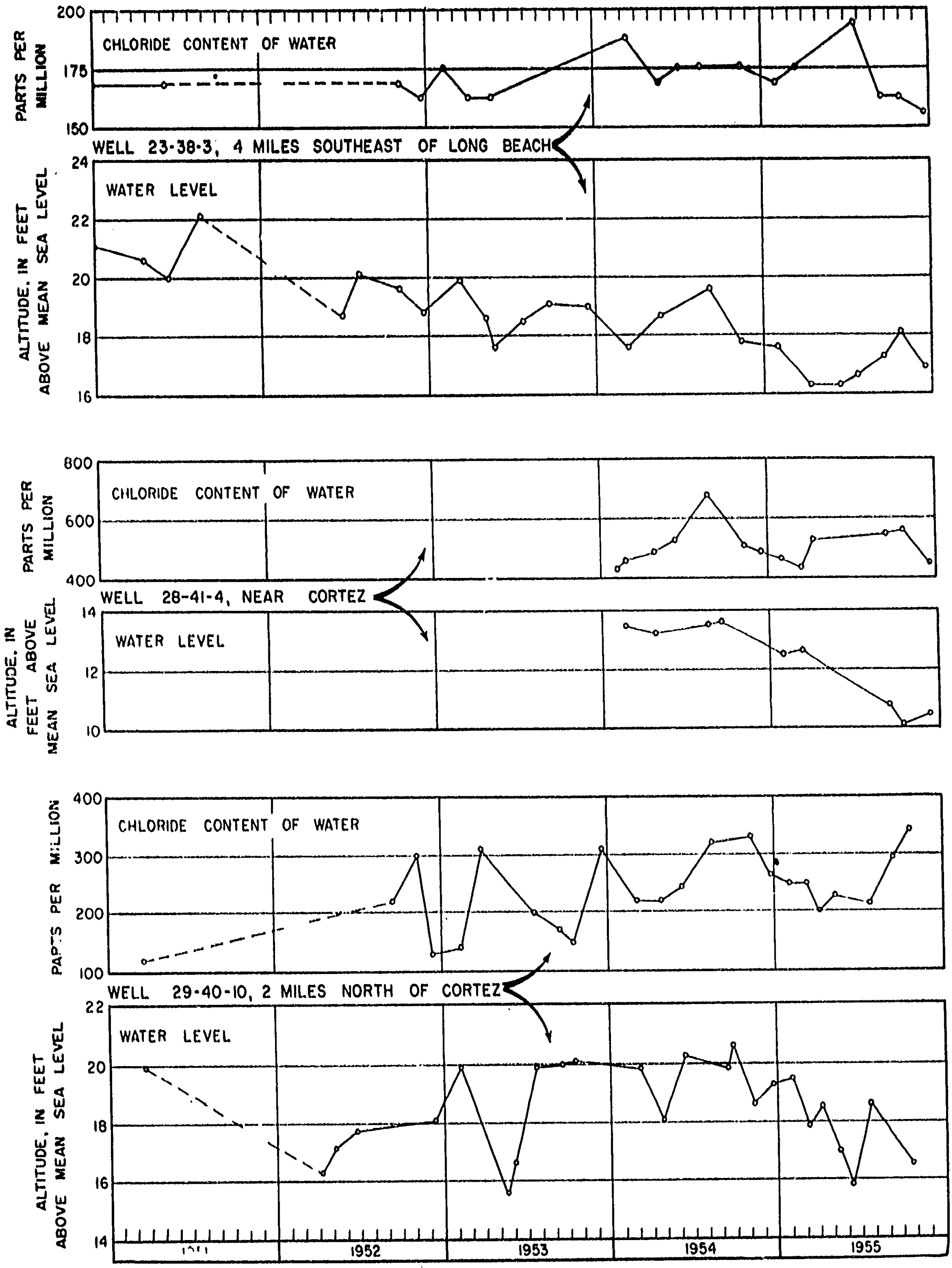


Figure 20. Graphs showing relation between water levels and chloride content of water in wells 23-38-3, 28-41-4, and 29-40-10.

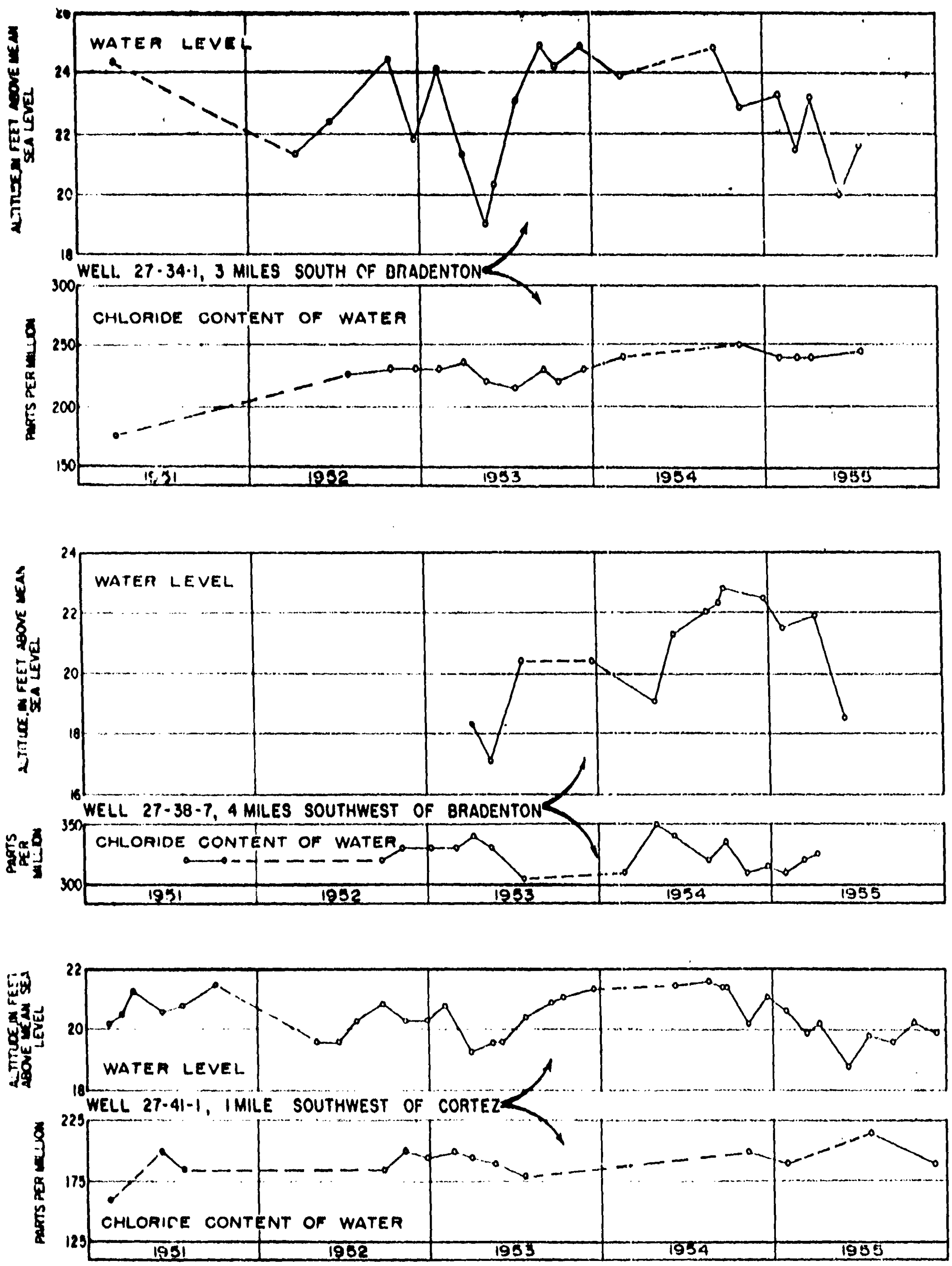


Figure 21. Graphs showing relation between water levels and chloride content of water in wells 27-34-1, 27-38-7, and 27-41-1.

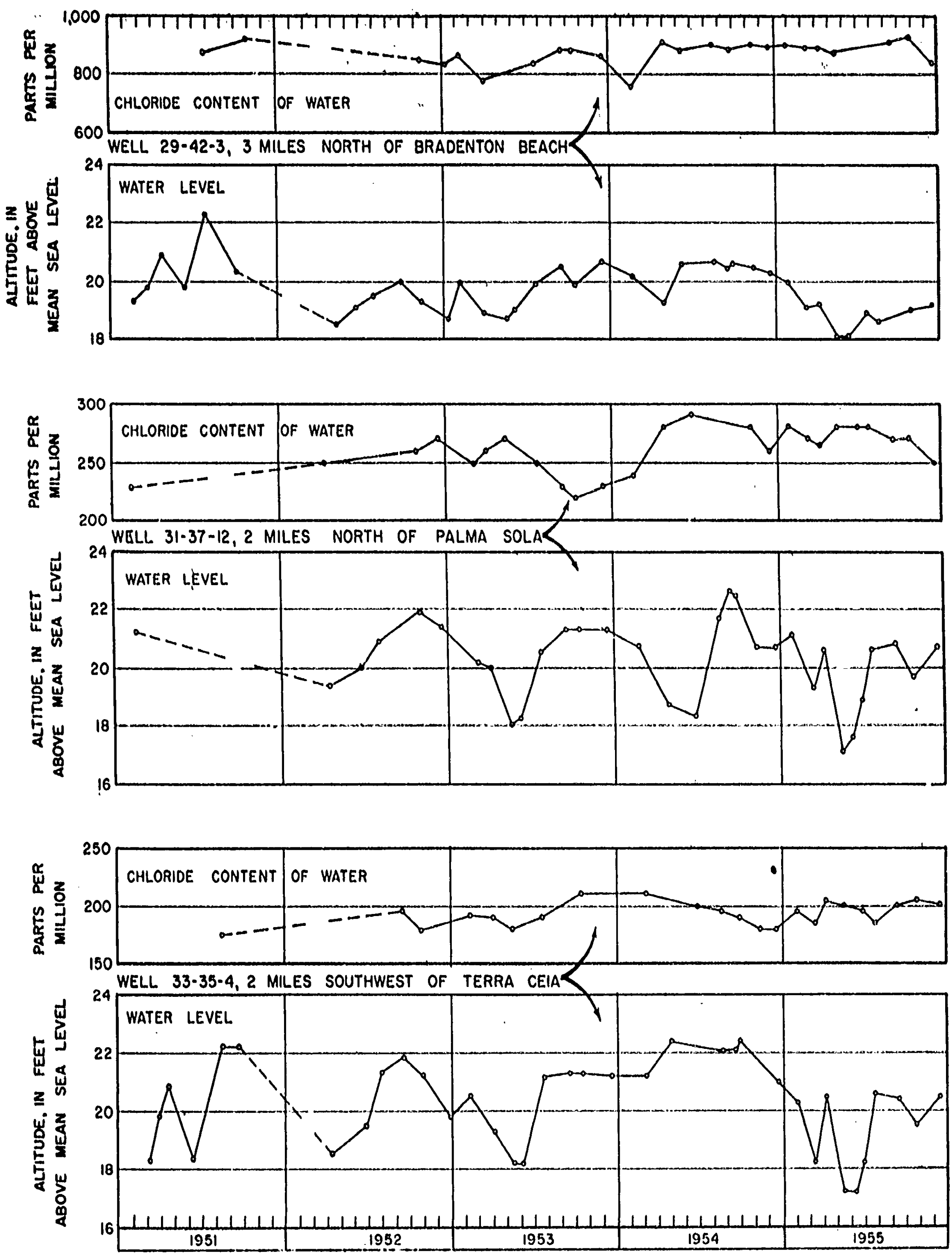


Figure 22. Graphs showing relation between water levels and chloride content of water in wells 29-42-3, 31-37-12, and 33-35-4.

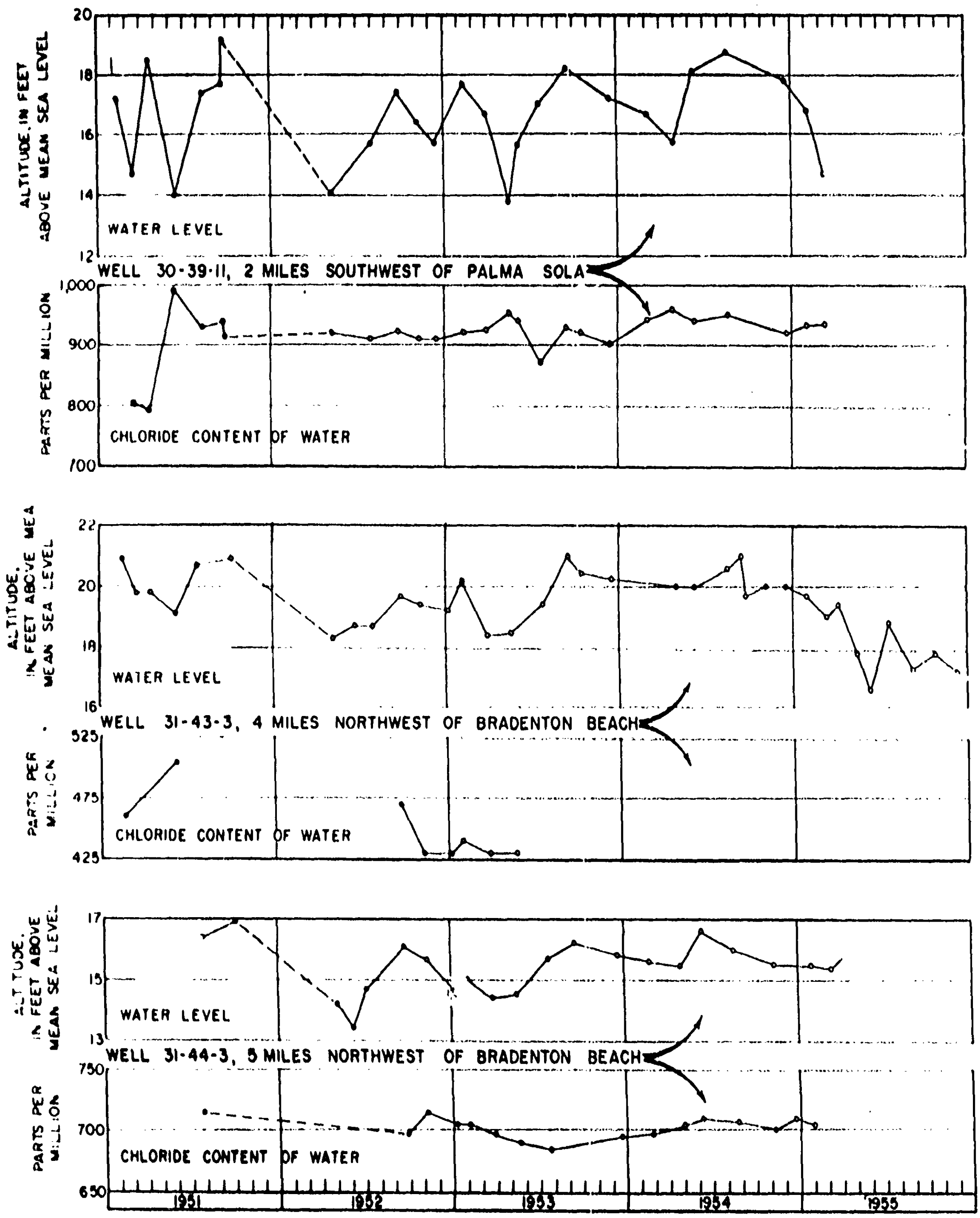


Figure 23. Graphs showing relation between water levels and chloride content of water in wells 30-39-11, 31-43-3, and 31-44-3.

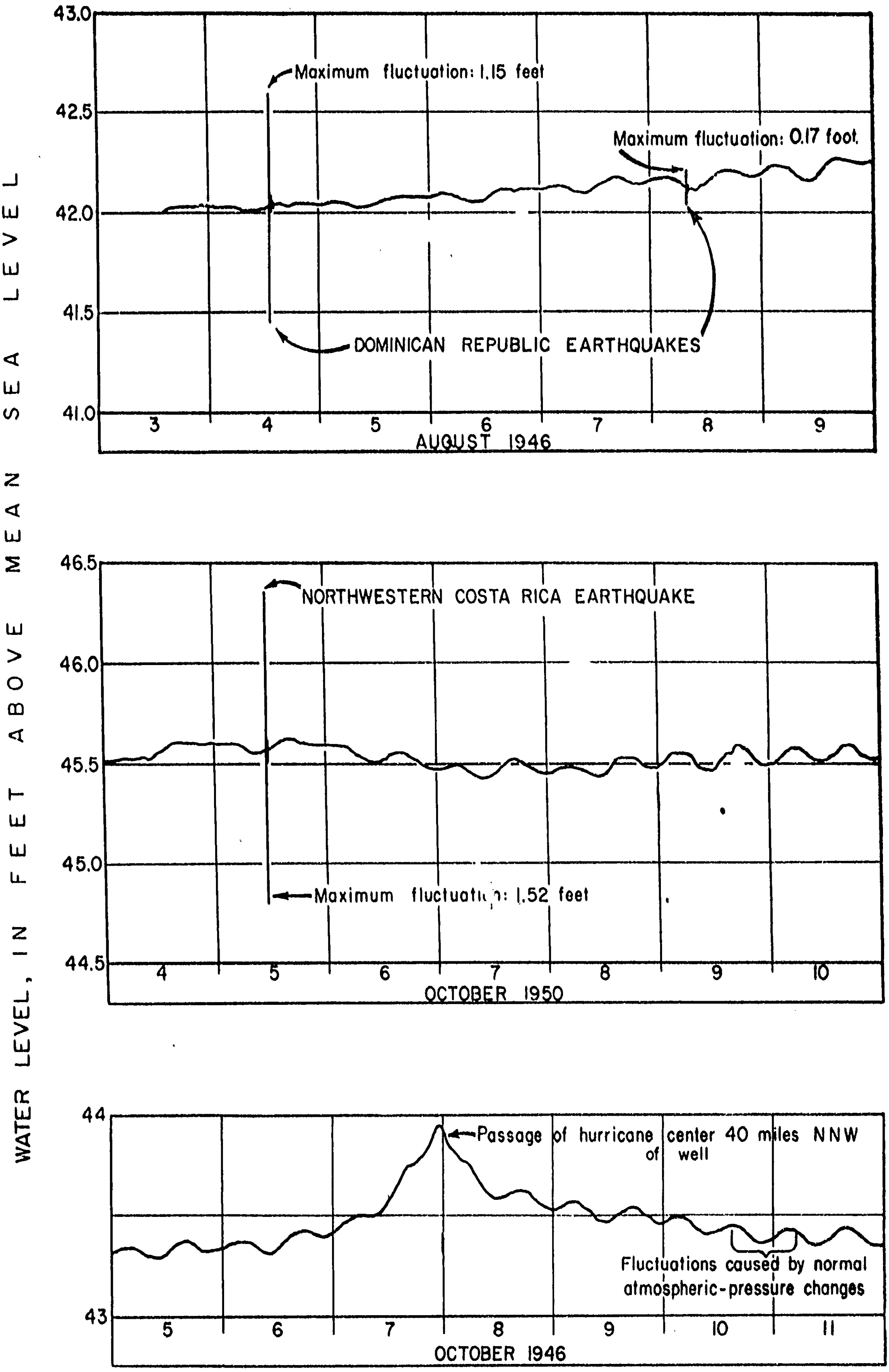


Figure 24. Effects of earthquakes and changes in barometric pressure on the water level in well 26-18-1, 12 miles northwest of Myakka City.

of water levels in most artesian wells. These fluctuations, however, are often masked by larger fluctuations resulting from local pumping, ocean tides, or other causes. The effects of atmospheric-pressure changes on the water level in well 26-18-1, which is not affected by pumping or ocean tides, are revealed by the hydrographs in figure 24. Periods of high barometric pressure occur about noon and midnight and are shown by low water levels at these times. The periods of low barometric pressure in the early morning and late afternoon are represented by high water levels on the hydrographs. The magnitude of the fluctuations in this well is generally less than 0.1 foot but may be considerably greater when barometric pressure changes are greater than normal. As shown in figure 24, the water level rose 0.45 foot on October 7, 1946, when the center of a hurricane passed about 40 miles west of the well at approximately 11:30 p.m. The lowest recorded barometric pressure at Sarasota was 29.26 inches, and at Cortez it was 28.95 inches, or about one inch lower than normal.

Piezometric Surface: The contours on the map in figure 25 show the configuration of the piezometric surface of the Floridan aquifer in Manatee County in September 1954. The piezometric surface was more than 65 feet above sea level in the northeast corner of the county and sloped westward to about 20 feet above sea level along the coast, indicating a general westward movement of water. East of the 30-foot contour, the piezometric surface has a fairly uniform gradient of about 1½ feet per mile. The uniformity of the gradient indicates that no large quantity of water was gained or lost by the aquifer in this area. West of the 30-foot contour, the gradient is less than one foot per mile. The configuration of the 20-foot and 22-foot contour lines indicates that appreciable discharge is occurring near Palma Sola and Palmetto. As the quantity of water being withdrawn from wells at the time the water-level measurements were made was small, the low-pressure trough around Palma Sola shown by the 20-foot and 22-foot contour lines, is probably due in part to a movement of water from the Floridan aquifer into the younger formations through unused irrigation wells.

Figure 26 shows the configuration of the piezometric surface in June 1955, during an extended period of dry weather when large quantities of water were being withdrawn from irrigation wells. The altitude of the piezometric surface ranged from about 60 feet in the northeast corner of the county to less than 13 feet in the vicinity of Palma Sola. A comparison of figures 25 and 26 shows that throughout the county the piezometric surface was about five feet lower in June than in September; at some places in the western part of the county it was about 10 feet lower. The configuration of the contour lines in the coastal area

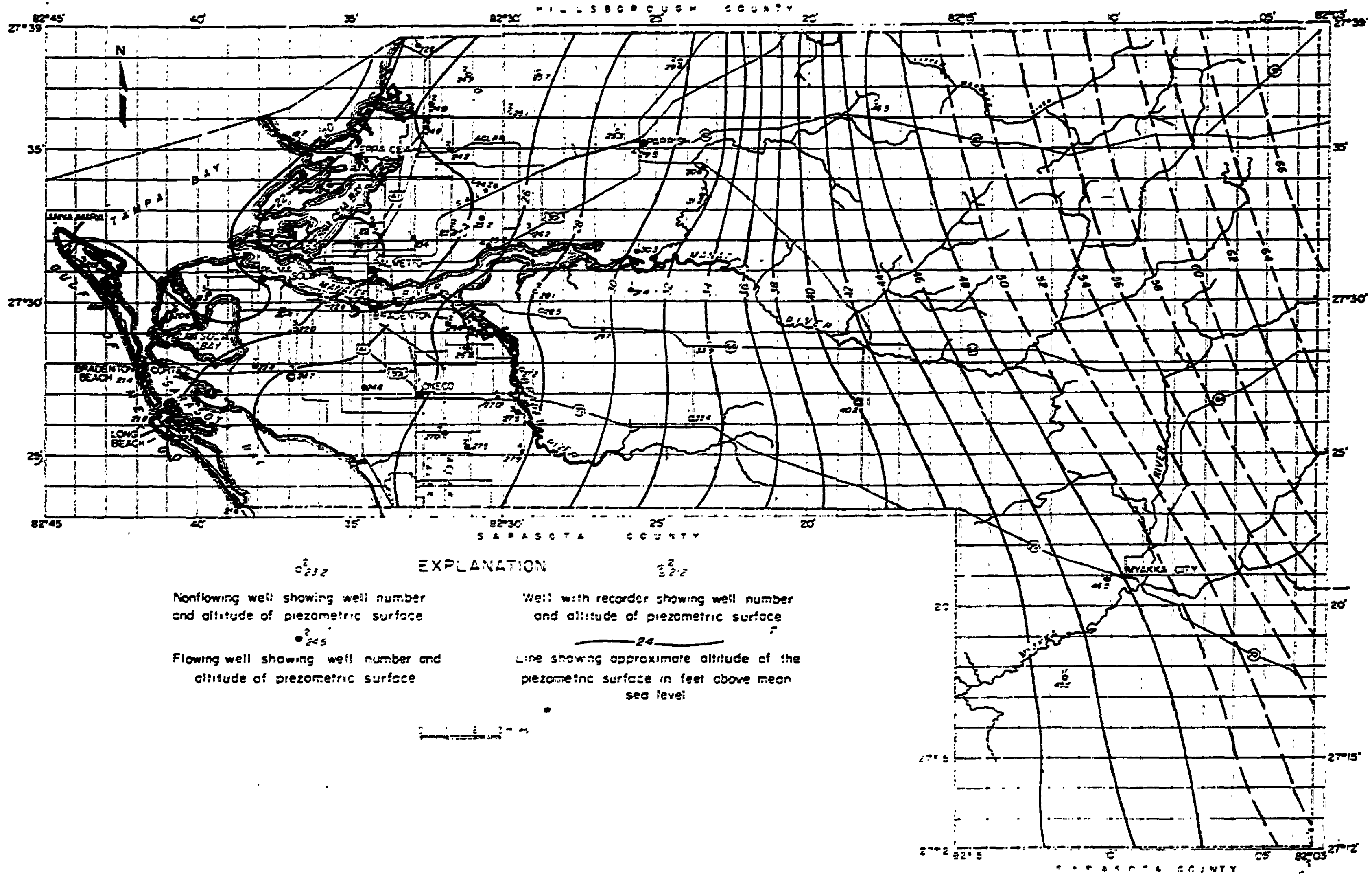


Figure 25. Map of Manatee County showing the piezometric surface in September 1954.

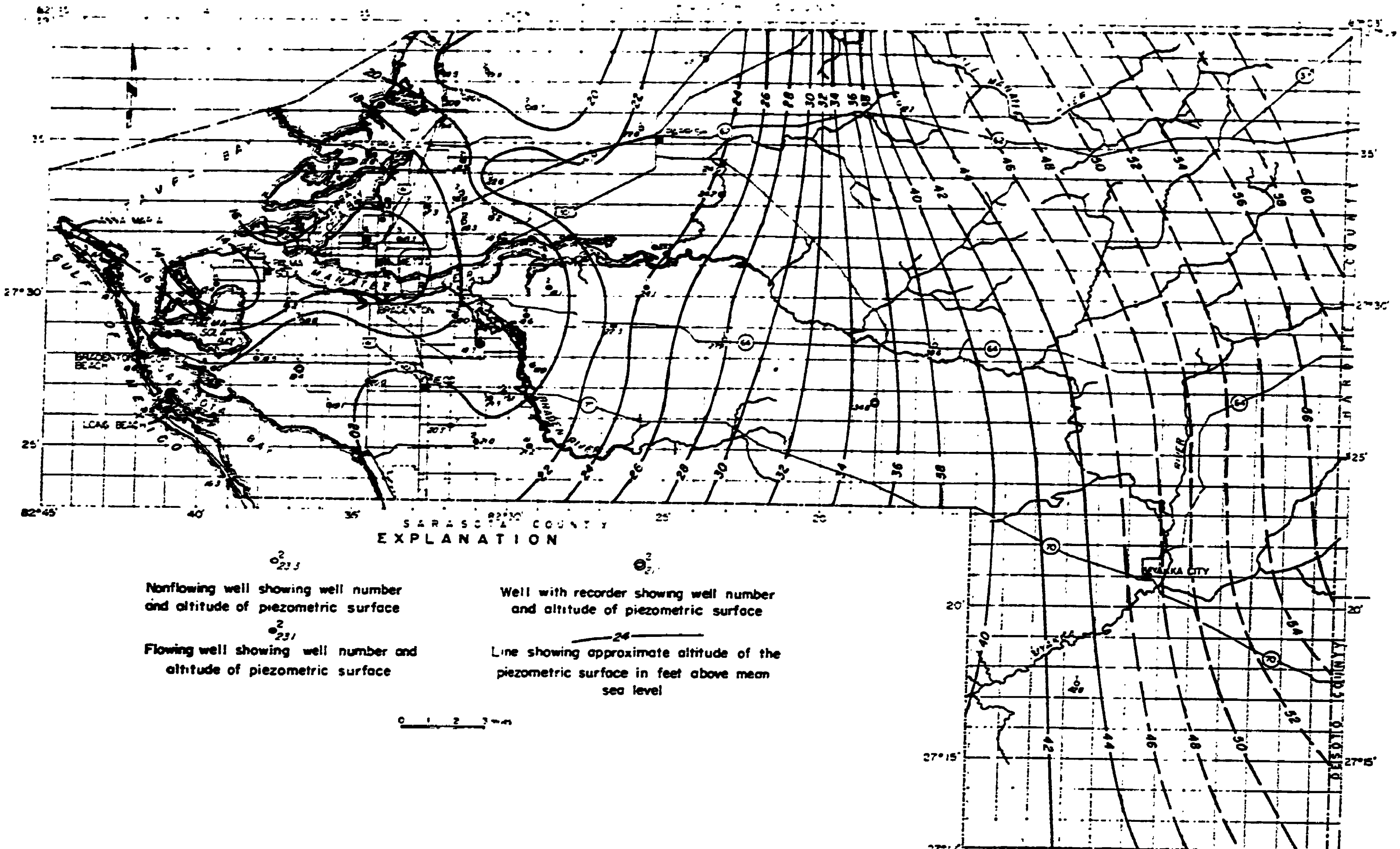


Figure 26. Map of Manatee County showing the piezometric surface in June 1955.

in figure 26 shows that the low-pressure trough in the Palmetto-Palma Sola area had expanded and deepened as a result of the increased withdrawals of water from irrigation, industrial, public supply, and domestic wells. The depression shown by the 20-foot contour line, in the northern part of the coastal area, was caused by the combined drawdowns of a large number of irrigation wells.

Depth to Water Level Below Land Surface: Figure 27 shows the areas of artesian flow and the approximate depth to water, below land surface, in wells that penetrate the Floridan aquifer. It is based on the piezometric surface in June 1955 (fig. 26).

The areas of artesian flow are along the coast and in the southeastern part of the county, and they extend several miles upstream along the valleys of the major streams. There are several isolated areas within the areas of artesian flow where the land surface is relatively high and wells will not flow.

In most of the county water levels are less than 25 feet below the land surface but in the northeastern part of the county they range in depth from 50 to more than 75 feet.

Temperature: The temperature of the earth's crust increases with depth at the rate of about 1°F for each 50 to 100 feet. The temperature of ground water generally increases with depth at approximately the same rate.

Measurements of the temperature of water from many wells were made during the investigation. The temperature of water in formations less than 100 feet deep is generally between 74° and 75°F, and that of water from the Hawthorn formation is between 75° and 77.5°F. The temperature of water from the Tampa formation generally ranges from 77.5° to 79°F, according to the depth of the principal producing zones and the proportion of the total yield of the well that is obtained from each zone. Water from wells that penetrate the Suwannee limestone and older formations ranges in temperature from about 79° to more than 84°F, according to the amounts of water obtained from the various producing zones in both the Tampa formation and the Suwannee limestone as well as in the older formations. Water samples taken with a deep-well sampler indicates that the temperature of the water in the Suwannee is 81° to 82°F (fig. 12).

The temperature of the water in the Hawthorn and older formations generally increases in the direction of dip, because of the increased depth of the various producing zones.

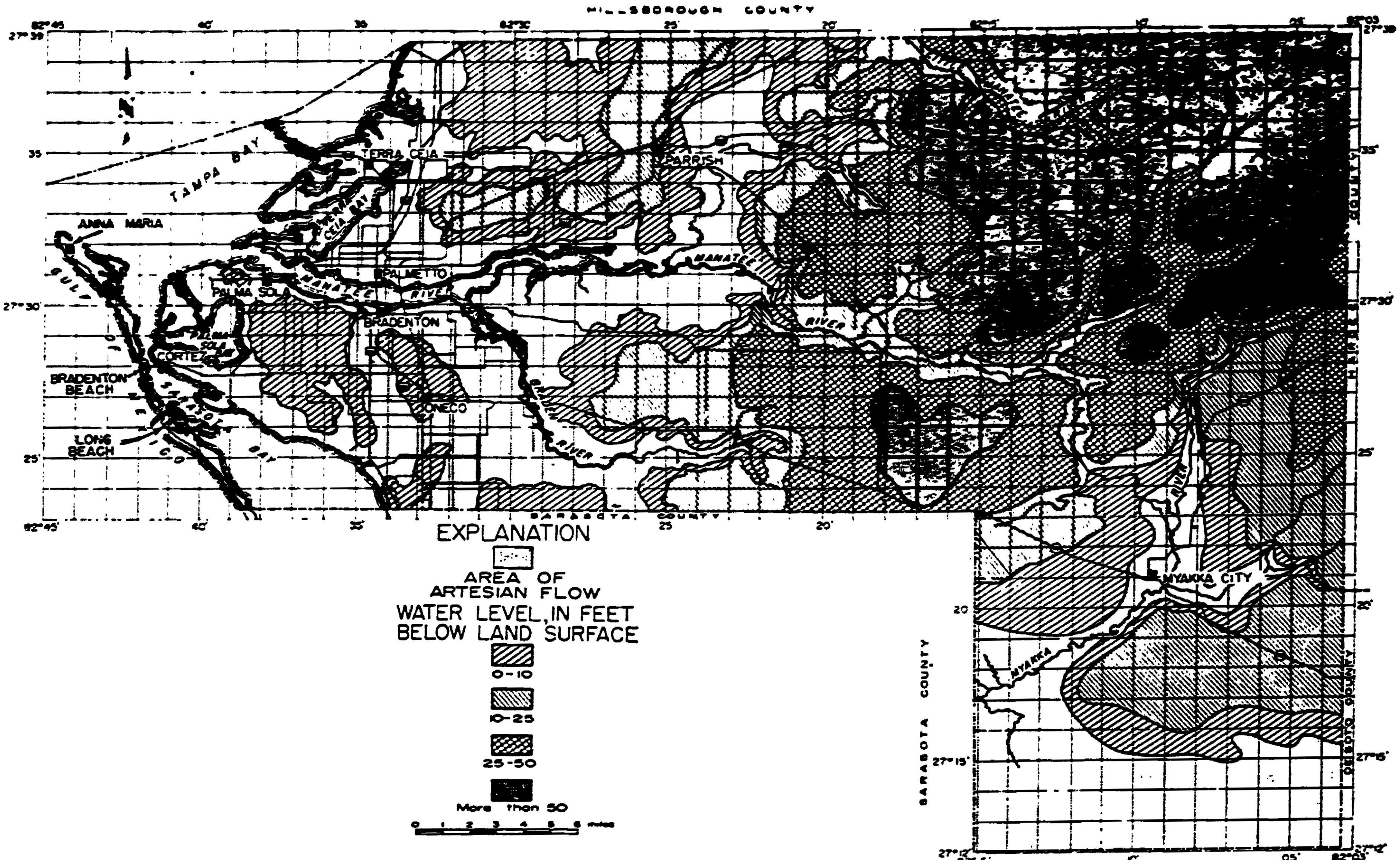


Figure 27. Map of Manatee County showing the area of artesian flow and the depth to water in June 1955.

USE OF WATER

Ground water is the source of practically all irrigation, industrial public, and domestic water supplies in Manatee County except the Bradenton municipal supply, which is obtained from the Braden River. The use of water from that municipal supply averages about 3 million gallons a day; however, numerous private wells throughout the city furnish water for lawn irrigation, air conditioning, and other uses.

The individual records of 865 wells are published as Florida Geological Survey Information Circular No. 19 and their locations are shown in plate 1 and figure 2. The wells that penetrate the Floridan aquifer are generally between 350 and 600 feet deep. They range from 3 to 12 inches in diameter, but most of them are 6 to 10 inches in diameter. They are cased to depths ranging from about 25 to more than 100 feet. In addition to the surface casing, some wells are lined with an inner casing to prevent the caving of sand from the Hawthorn and Tampa formations. The wells generally yield several hundred gallons per minute, but the yields differ according to the permeability of the aquifer, the diameter of the well bore, and the thickness of the aquifer that is penetrated by the well.

Shallow wells range from about 25 to more than 200 feet in depth and from 1¼ to 6 inches in diameter. Most domestic wells are two inches in diameter and yield about 30 to 75 gpm.

There is no practical method for determining accurately the average daily use of water in the county, because of the large variations in daily and seasonal withdrawals, and the fact that accurate records of withdrawal are available for only a few of the many wells. It is roughly estimated that the average daily use of water in Manatee County is in the range of 15 to 20 million gallons.

QUANTITATIVE STUDIES

The withdrawal of water from an aquifer creates a depression in the water table or piezometric surface around the point of withdrawal. This depression generally has the approximate form of an inverted cone and is referred to as the cone of depression. The amount by which the water surface is lowered at any given point within this cone is known as the drawdown. The size, shape, and rate of growth of the cone of depression depend on several factors: (1) the rate of pumping, (2) the water-transmitting and storage capacities of the aquifer, (3) the increase in recharge resulting from the lowering of the water surface, and (4) the decrease in natural discharge due to the lowering of that surface. The yield of the Floridan aquifer in Manatee County is limited by the extent to which the piezometric surface can be lowered without impairing the quality of the water or making the cost of obtaining it prohibitive.

The principal hydrologic properties of an aquifer are its capacities to transmit and to store water, for all aquifers serve as both conduits and reservoirs. An artesian aquifer functions primarily as a conduit, transmitting water from places of recharge to places of discharge; however, it is also capable of storing or releasing water, by expansion and compression.

A measure of the capacity of an aquifer to transmit water is the coefficient of transmissibility. In customary units, it is the quantity of water, in gallons per day (gpd) at the prevailing temperature of the water, that will flow through a vertical section of the aquifer one foot wide and extending the full saturated height, under a unit hydraulic gradient. The coefficient of storage is a measure of the capacity of an aquifer to store water, and is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in head normal to that surface.

Pumping Test: A pumping test was made in August 1955 to determine the transmissibility and storage coefficients of the Floridan aquifer at one location in Manatee County. Well 34-30-1 was pumped at the rate of 1,000 gpm for a period of 123.5 hours, beginning at 11 a.m. on August 22 and ending at 2:30 p.m. on August 27. Water levels were measured periodically in wells 34-30-2, 34-30-3, and 34-30-4 (fig. 28) throughout the period of pumping, to determine the rates and magnitudes of drawdown at different distances from the pumped well. After

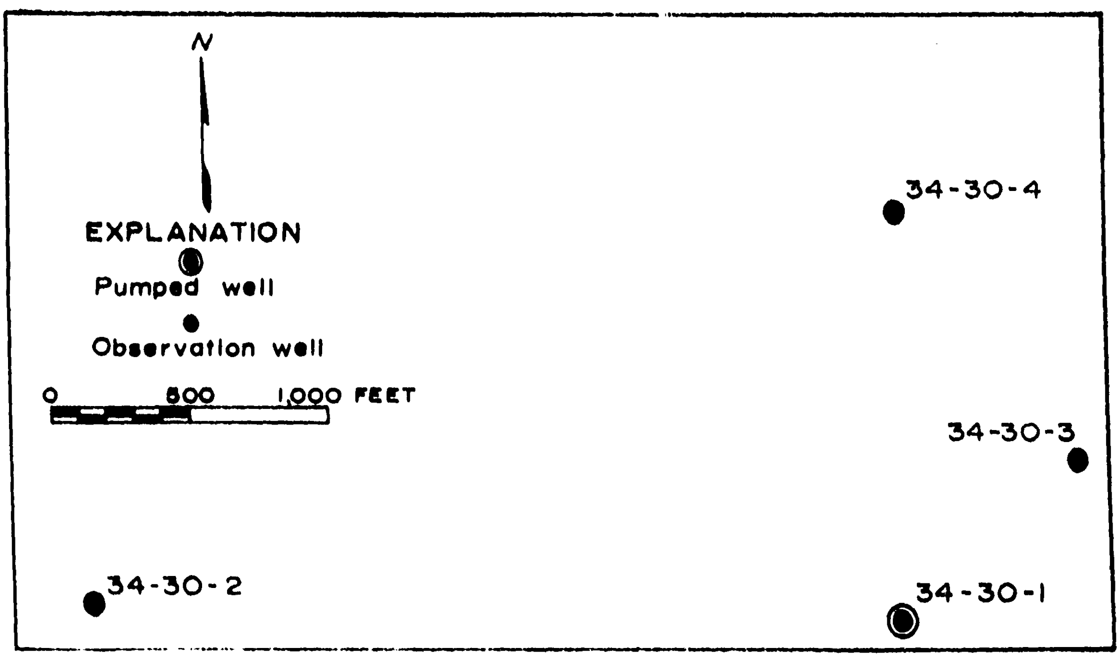


Figure 28. Sketch of pumping-test site, showing location of pumped well in relation to observation wells.

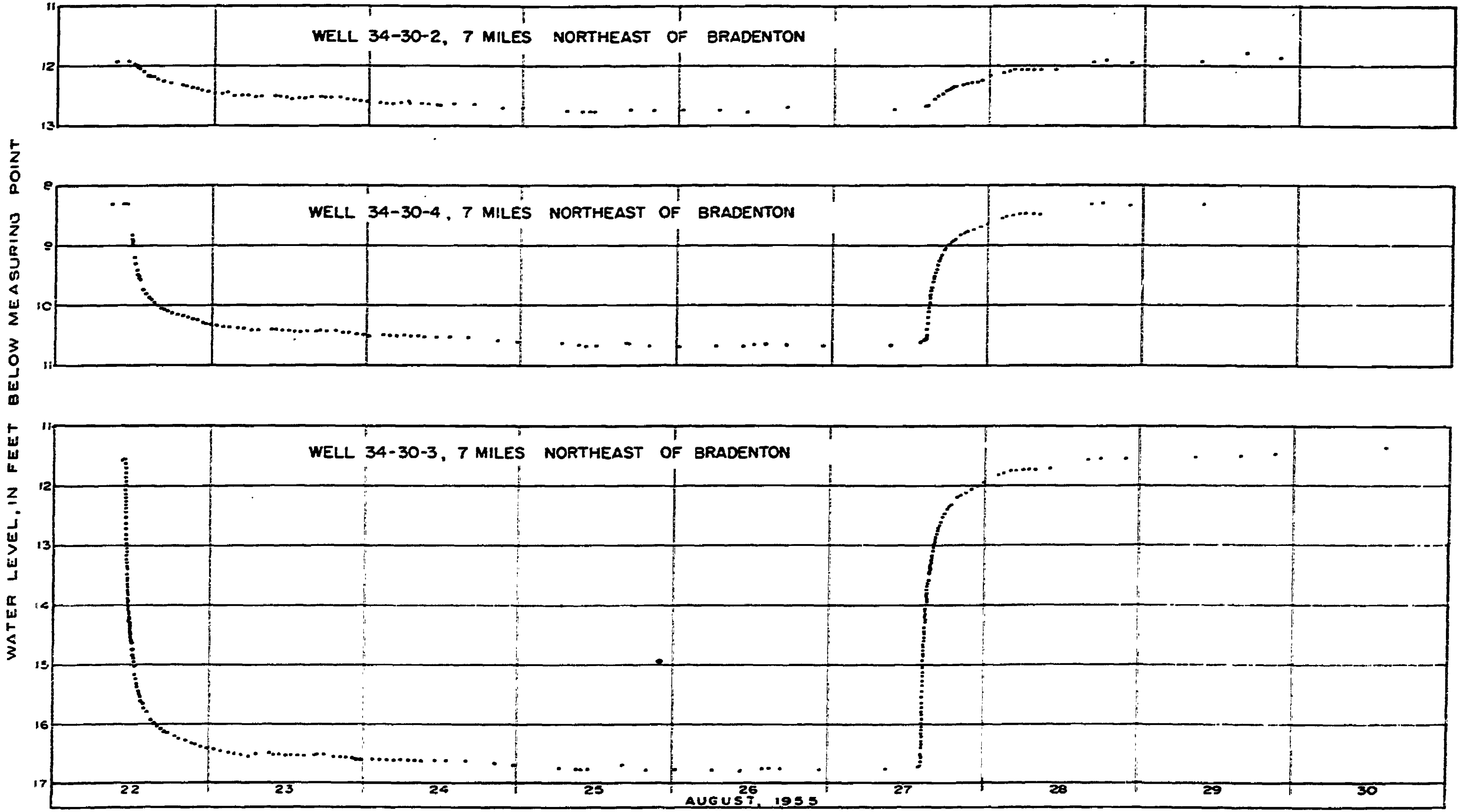


Figure 29. Graphs showing drawdown and recovery of water levels in observation wells during pumping test.

pumping stopped, measurement of water levels in the observation wells was continued for about 72 hours. Hydrographs prepared from these water-level measurements are shown in figure 29.

The Theis graphical method (Wenzel, 1942, p. 87-89) was used to compute the transmissibility and storage coefficients from the drawdowns in the observation wells. This method relates the drawdowns in the vicinity of a discharging well to the rate and duration of discharge and is based on several simplifying assumptions, including the following: (1) the aquifer is of infinite areal extent and is uniform in thickness, (2) the aquifer is homogeneous and transmits water with equal facility in all directions, (3) the discharge well penetrates the entire thickness of the aquifer, (4) there is no recharge to the aquifer in the area of influence of the discharging well, and (5) the aquifer is losing water through only the discharging well.

As shown in figures 30 and 31, the data for each of the observation wells plotted as a separate curve and the upper part of each curve fell below the type curve. These deviations indicate that the aquifer does not closely conform to one or more of the conditions assumed in the Theis equation. The downward deviation of the data curves from the type curve during the latter part of the test is an indication that the aquifer was receiving recharge – probably from the overlying Hawthorn formation. The data curves were analyzed by using a leaky-aquifer type curve (unpublished) developed by H. H. Cooper, Jr., of the U. S. Geological Survey, Tallahassee. The curve for well 34-30-3 best fitted the leaky-aquifer type curve. The results obtained by using data for well 34-30-3, therefore, are believed to be most representative of the Floridan aquifer in the area of the pumping test.

The coefficients of transmissibility and storage computed by matching the observed-data curves against the type curves are as follows:

Well	Coefficient of Transmissibility Drawdown	Coefficient of Transmissibility Recovery	Coefficient of Storage Drawdown	Coefficient of Storage Recovery
34-30-3	100,000	96,000	$1.1x10^{-4}$	$1.4x10^{-4}$
34-30-4	140,000	140,000	$4.3x10^{-4}$	$4.3x10^{-4}$
34-30-2	460,000	480,000	$1.0x10^{-3}$	$8.7x10^{-4}$

The data for well 34-30-3 were also analyzed by a method devised by Cooper and Jacob (1946, p. 526-534), which gave a transmissibility of 100,000 gpd per foot and a storage coefficient of $1.1x10^{-4}$ (fig. 32).

Theoretical Drawdowns: The results of the pumping test indicate that the transmissibility coefficient of the Floridan aquifer near the test site is about 100,000 gpd per foot and the storage coefficient is about 0.00014. The coefficients of transmissibility and storage may differ considerably from place to place, and because of this, it is not practicable to

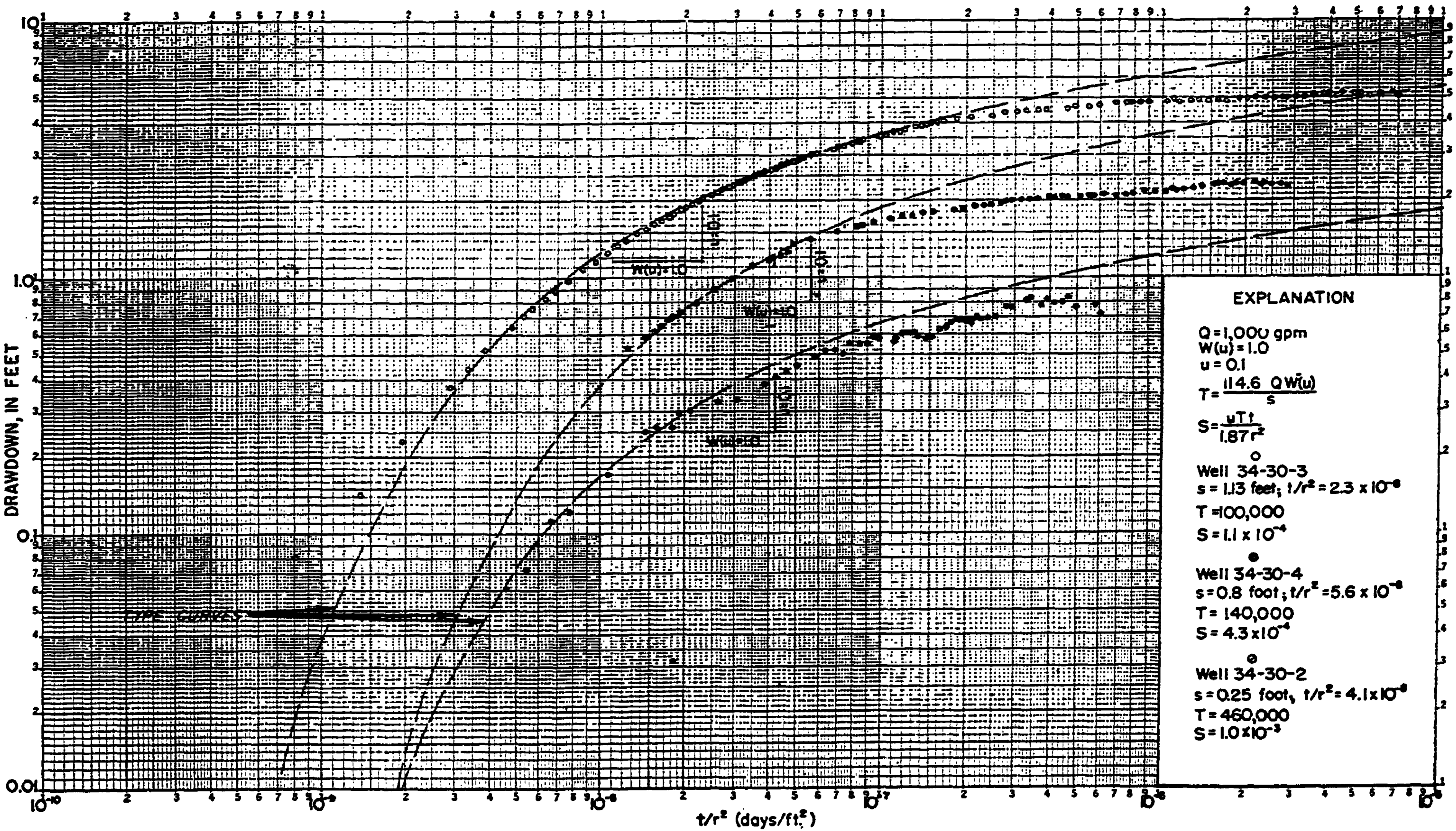


Figure 30. Logarithmic plot of drawdowns in observation wells versus t/r^2.

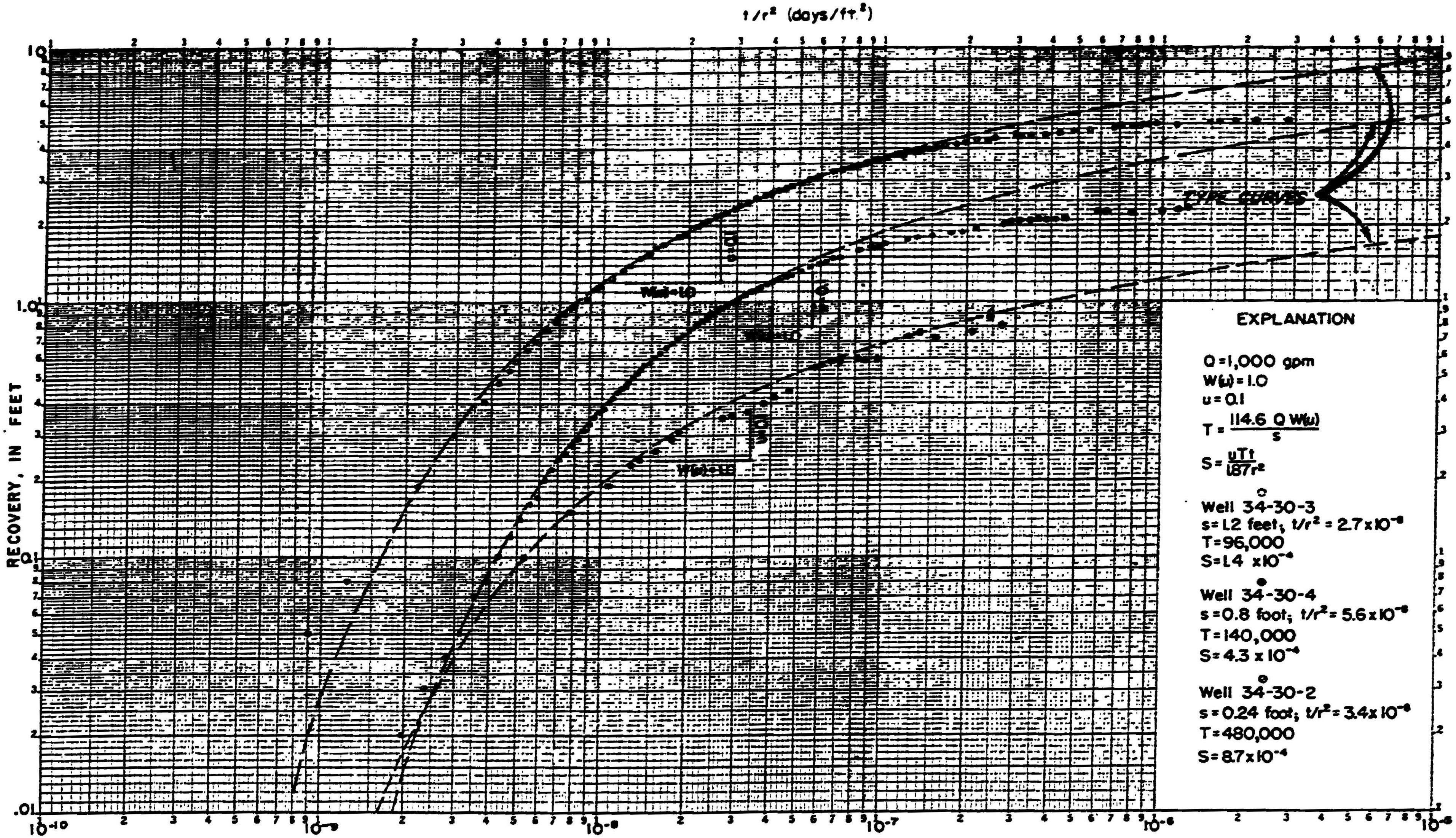


Figure 31. Logarithmic plot of recoveries in observation wells versus t/r^2.

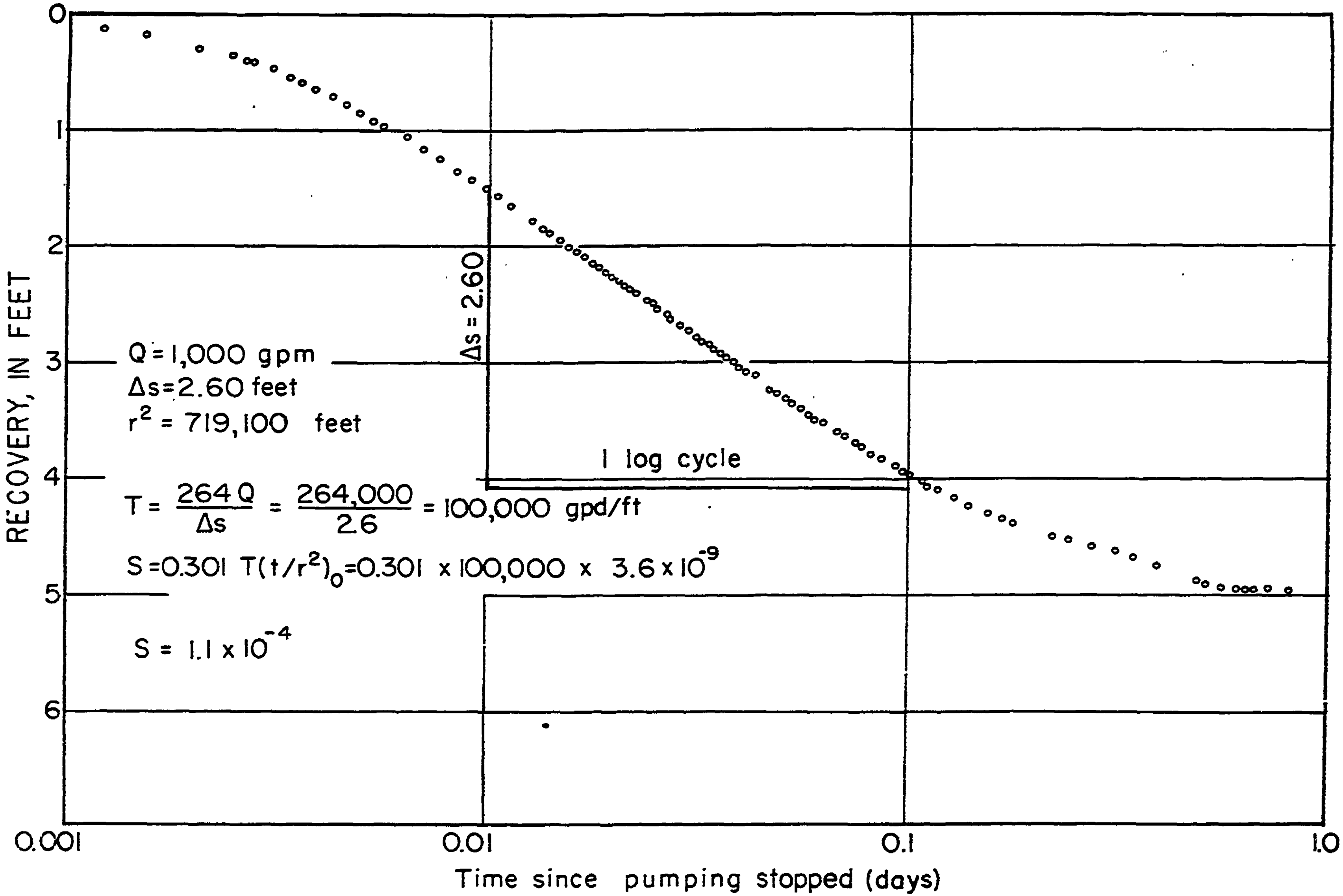


Figure 32. Semilog plot of recovery versus t for well 34-30-3, seven miles northeast of Bradenton.

predict drawdowns in one place on the basis of aquifer properties determined in some other place. However, in order to illustrate how water levels are affected in the vicinity of a pumping well, figure 33 was constructed. This figure shows theoretical drawdowns in the vicinity of a well pumping at the rate of 1,000 gpm from an aquifer having a transmissibility coefficient of 100,000 gpd per foot and a storage coefficient of 0.00014.

QUALITY OF WATER

The water that falls on the earth's surface as rain or snow is practically free of dissolved mineral matter except for small quantities of atmospheric gases, smoke and dust. Therefore, the mineral constituents and degree of mineralization of ground water depend generally upon the composition and solubility of the soil and rocks through which the water passes, and upon the time of contact. In some cases mineralization of ground water may result from the mixing of relatively fresh water with highly mineralized, residual sea water within the water-bearing formations.

Chemical analyses of the water from 137 selected wells in Manatee County (fig. 34) were made by the Quality of Water Branch of the U. S. Geological Survey (table 5). The wells range in depth from about 50 to more than 700 feet. In addition to these analyses, the chloride content of water from about 750 wells and the hardness of water from 287 wells were determined during the investigation and the results are published in Florida Geological Survey Information Circular No. 19.

Constituents and Properties: The principal mineral constituents and physical properties of water from wells in Manatee County are discussed below. The concentrations of mineral constituents are given in parts per million – 1 ppm is approximately equivalent to 8.34 pounds per million gallons of water. Specific conductance is expressed in micromhos at 25°C, and the hydrogen-ion content in standard pH units. The tolerable limits given for the ions, unless stated otherwise, are taken from standards prescribed by the U. S. Public Health Service (1946).

Calcium: Calcium (Ca) is dissolved from limestone, which is predominantly calcium carbonate, by water containing carbon dioxide. Calcium is a principal cause of hardness in water.

Water from wells that penetrate the Suwannee limestone or older formations was generally a composite of water from the Tampa formation and the Suwannee limestone and contained 50 to 320 ppm of calcium. The calcium content of water from the Tampa formation, ranged from 50 to 325 ppm. The Hawthorn and younger formations yielded water having a calcium content of 36 to 204 ppm.

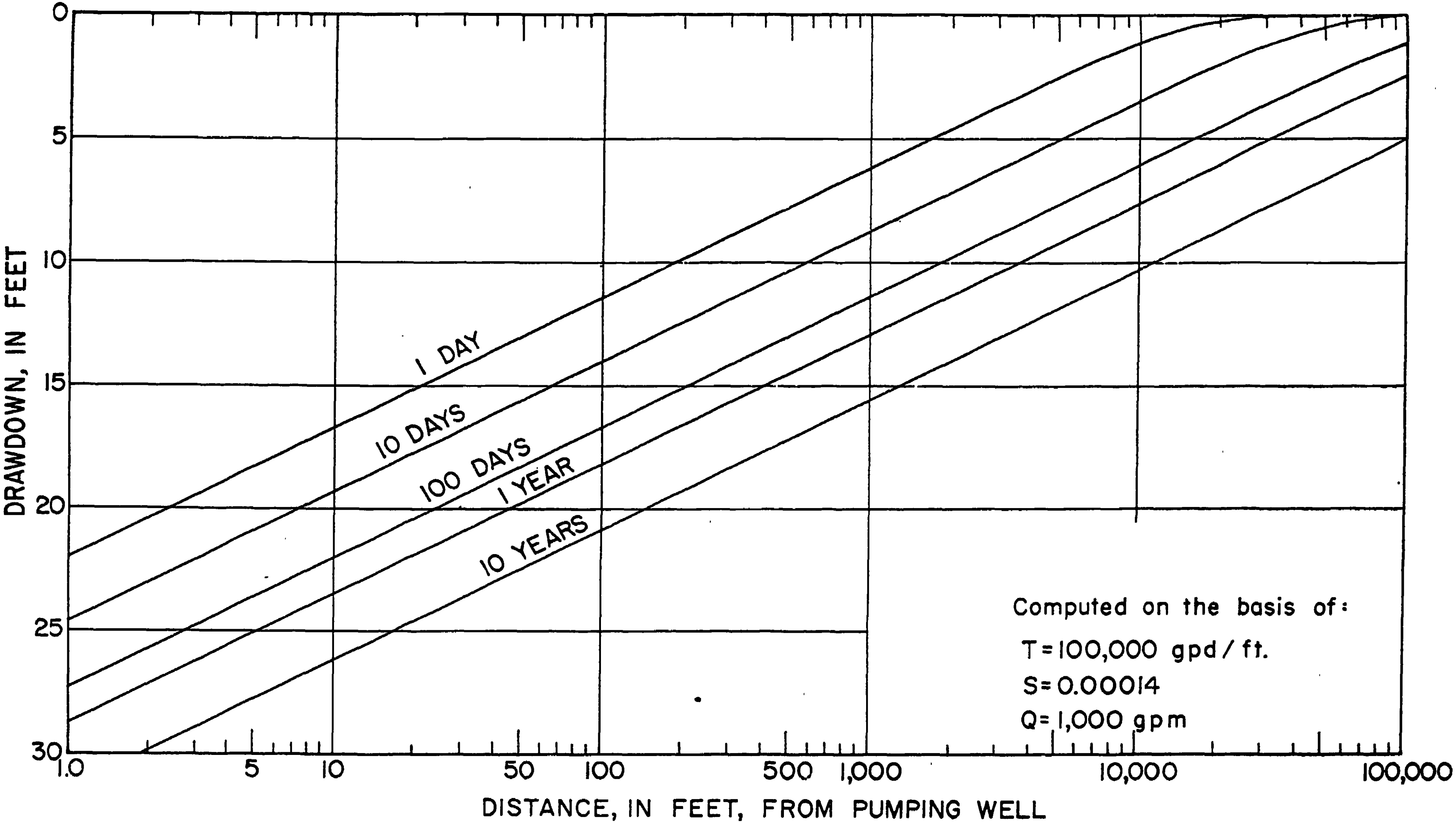


Figure 33. Graph showing theoretical drawdowns in the vicinity of a well being pumped at a rate of 1,000 gpm for selected periods of time.

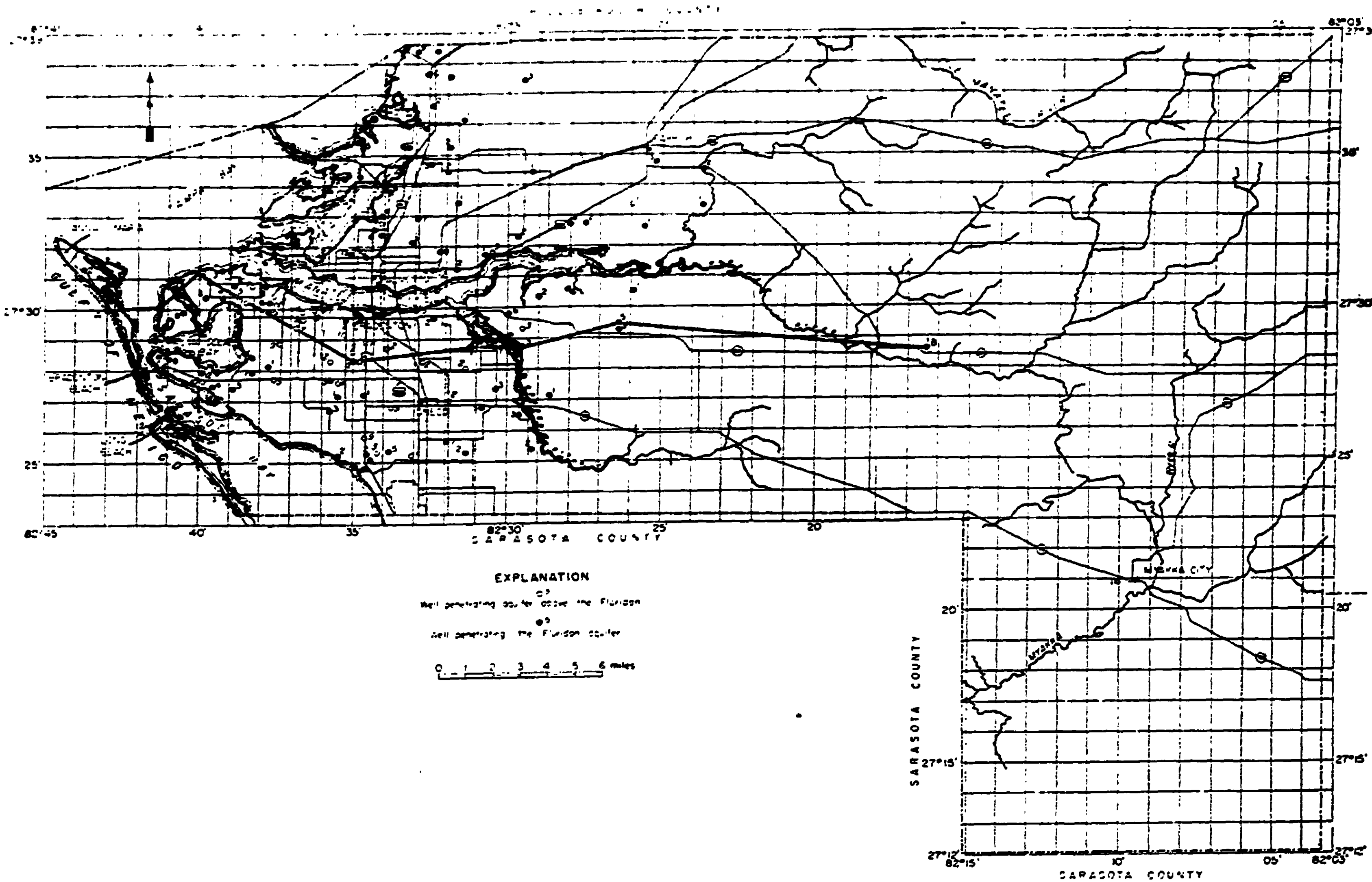


Figure 34. Map of Manatee County showing wells sampled for chemical analysis and location of line A-B in figure 44.

Magnesium: Magnesium (Mg) is dissolved principally from dolomite or dolomitic limestone, and, like calcium, it causes hardness. As magnesium is one of the principal mineral constituents of sea water, ground water that has been contaminated with sea water has a relatively high magnesium content.

The magnesium content of water from the Suwannee limestone and older formations ranged from 28 to 167 ppm. Water from the Tampa formation contained 13 to 113 ppm, and water from the Hawthorn and younger formations contained 5.8 to 99 ppm, but generally less than 50 ppm.

Sodium and Potassium: Sodium (Na) and potassium (K) are dissolved in small amounts from many types of rocks but they constitute only a small part of the total mineral content of fresh ground water. The sodium content of water that has been contaminated with sea water is generally high, as sea water is primarily a solution of sodium chloride.

Water from the Suwannee and older formations contained 0 to 628 ppm of sodium and potassium; water from the Tampa formation contained 0 to 246 ppm; water from the Hawthorn and younger formations contained 0 to 218 ppm.

Bicarbonate: Bicarbonate (HCO_3) in ground water is obtained from the solution of limestone and other carbonate rocks by water containing carbon dioxide.

Water from the Suwannee and older formations has a bicarbonate content of 102 to 264 ppm, and water from the Tampa formation had a bicarbonate content of 162 to 270 ppm. The bicarbonate content of water from the Hawthorn ranged from 48 to 557 ppm, but it was generally higher than that of water from the Floridan aquifer.

Sulfate: Sulfate (SO_4) in ground water may be due to the oxidation of sulfides or to the solution of sulfates of calcium, magnesium, sodium, or potassium that were deposited by the sea. Large quantities of sulfate salts in water may impart a bitter taste and have a laxative effect. Sulfates of calcium and magnesium cause boiler scale. The tolerable limit of sulfate in drinking water is considered to be about 250 ppm.

Water from the Floridan aquifer in Manatee County is generally high in sulfate. Wells penetrating the Suwannee and older formations yielded water having a sulfate content of 22 to 803 ppm (fig. 35). Water from the Tampa formation contained 22 to 750 ppm (fig. 36). Water from the Hawthorn and younger formations contained 5 to 550 ppm, but generally less than 200 ppm.

Chloride: Chloride (Cl) in small quantities may be dissolved from most rocks and soils and is found in large quantities in water that has

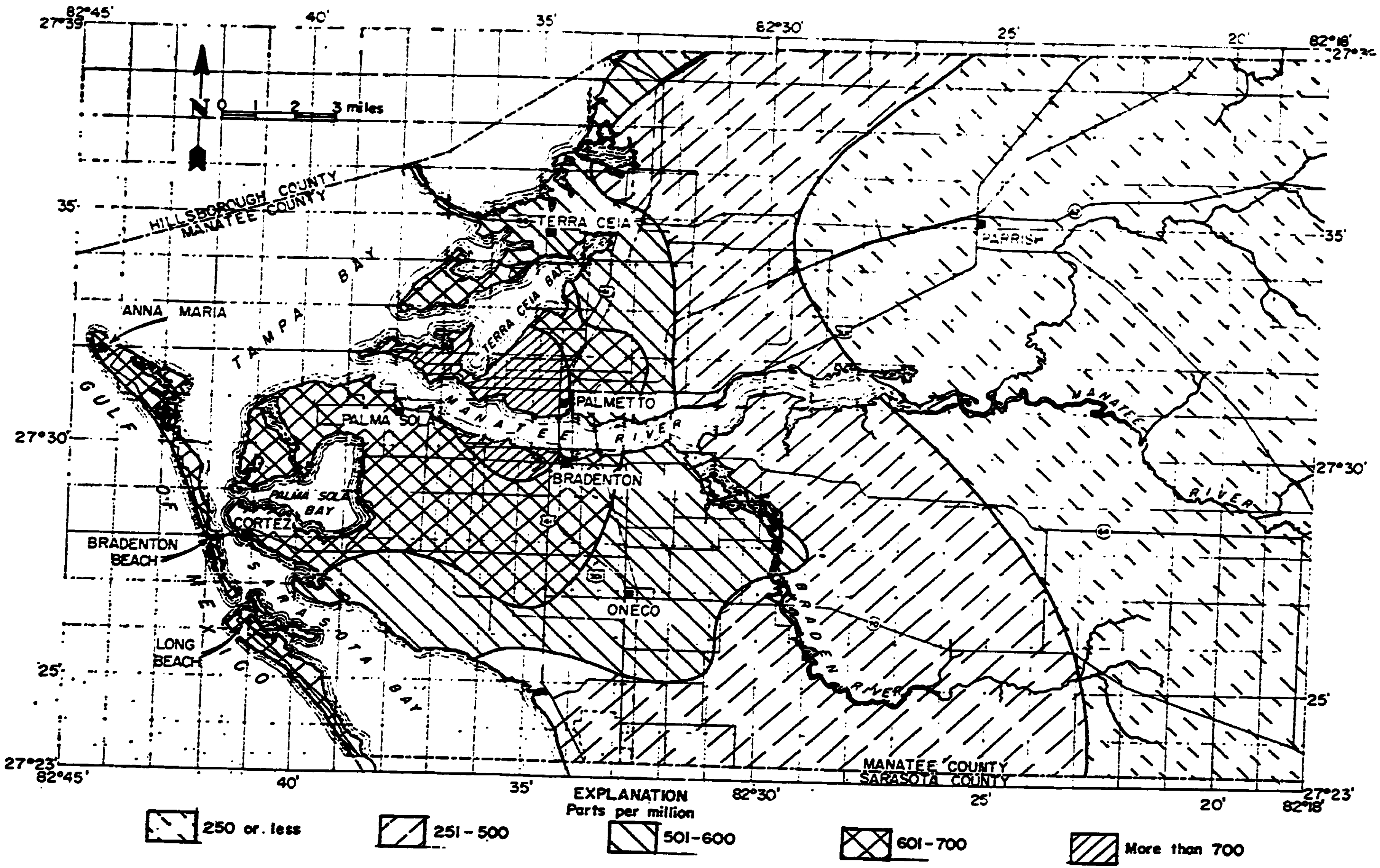


Figure 35. Map of western Manatee County showing sulfate content of water from wells that penetrate the Suwannee limestone and older formations.

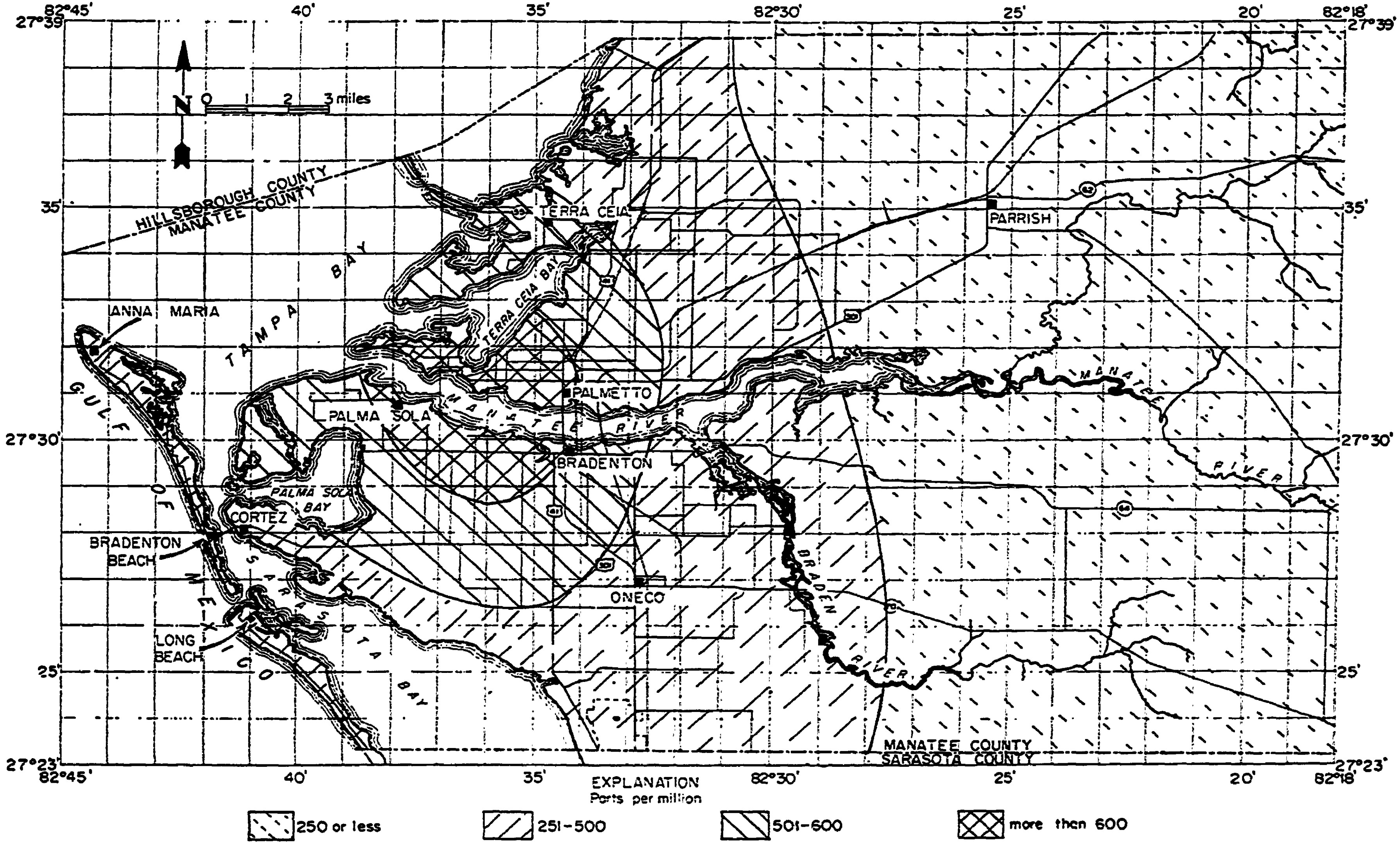


Figure 36. Map of western Manatee County showing sulfate content of water from the Tampa formation.

been contaminated by sea water. Chloride salts do not generally decrease the potability of water except when present in sufficient quantity to cause a salty taste. Water high in chloride content is very corrosive to metal surfaces and is harmful to most cultivated plants.

The chloride content of water from wells in Manatee County is discussed in detail in this report under the heading "Salt-Water Contamination." The chloride content ranged from 12 to more than 1,500 ppm in water from wells that penetrate the Suwannee limestone and older formations (fig.37) and from 10 to 920 ppm in water from wells that penetrate only the Tampa formation (fig. 38). The chloride content of water in the Hawthorn and younger formations ranged from 8 to more than 400 ppm (fig. 39) except at the north end of Anna Maria Island, where it was as much as 44,000 ppm. The extreme saltiness of the water is apparently due to the solution of mineral salts that were deposited in the formation.

Iron: Iron (Fe) occurs in almost all rocks, but the quantity dissolved by ground water is generally very small in comparison with other constituents. Iron in water causes stains on plumbing fixtures and clothing, and in concentrations greater than 0.5 to 1.0 ppm it can be tasted. Iron can generally be removed from water by aeration and filtration.

Fluoride: Fluoride (F) is found in very minor amounts in most ground water. Water containing fluoride in excess of 1.5 ppm may cause mottling of the enamel of children's teeth during formation (Cox and Ast 1951, p. 641-648); however, in concentrations of 1.5 ppm or less, fluoride tends to reduce tooth decay in children and is added to many public supplies for this reason.

Dissolved Solids: The dissolved-solids concentration represents the approximate amount of mineral matter dissolved in the water. Water containing less than 500 ppm is generally of good chemical quality, according to U. S. Public Health Service standards, and water containing up to 1,000 ppm may be used for public supplies if a less mineralized water is not available.

The dissolved solids of water from wells penetrating both the Suwannee limestone and older formations range from 382 to 3,560 ppm. The concentration of dissolved solids in water from these wells is shown in figure 40. Figure 41 shows the concentration of dissolved solids in water from wells penetrating the Tampa formation, the range being from 376 to 1,700 ppm.

Water from the Hawthorn and younger formations had a dissolved-solids content ranging from 216 to 1,620 ppm, but most of the water had 350 to 600 ppm.

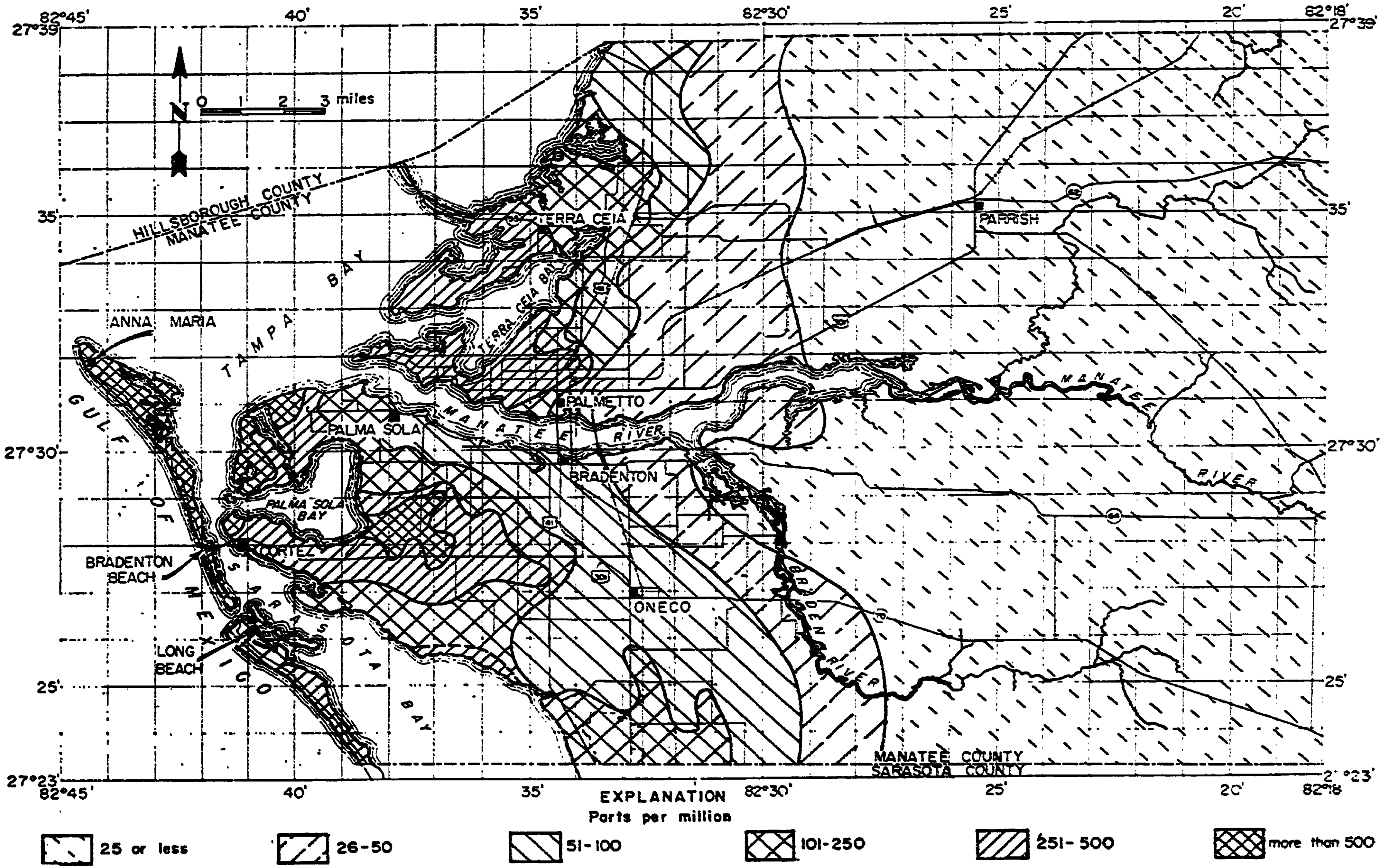


Figure 37. Map of western Manatee County showing chloride content of water from wells that penetrate the Suwannee limestone and older formations.

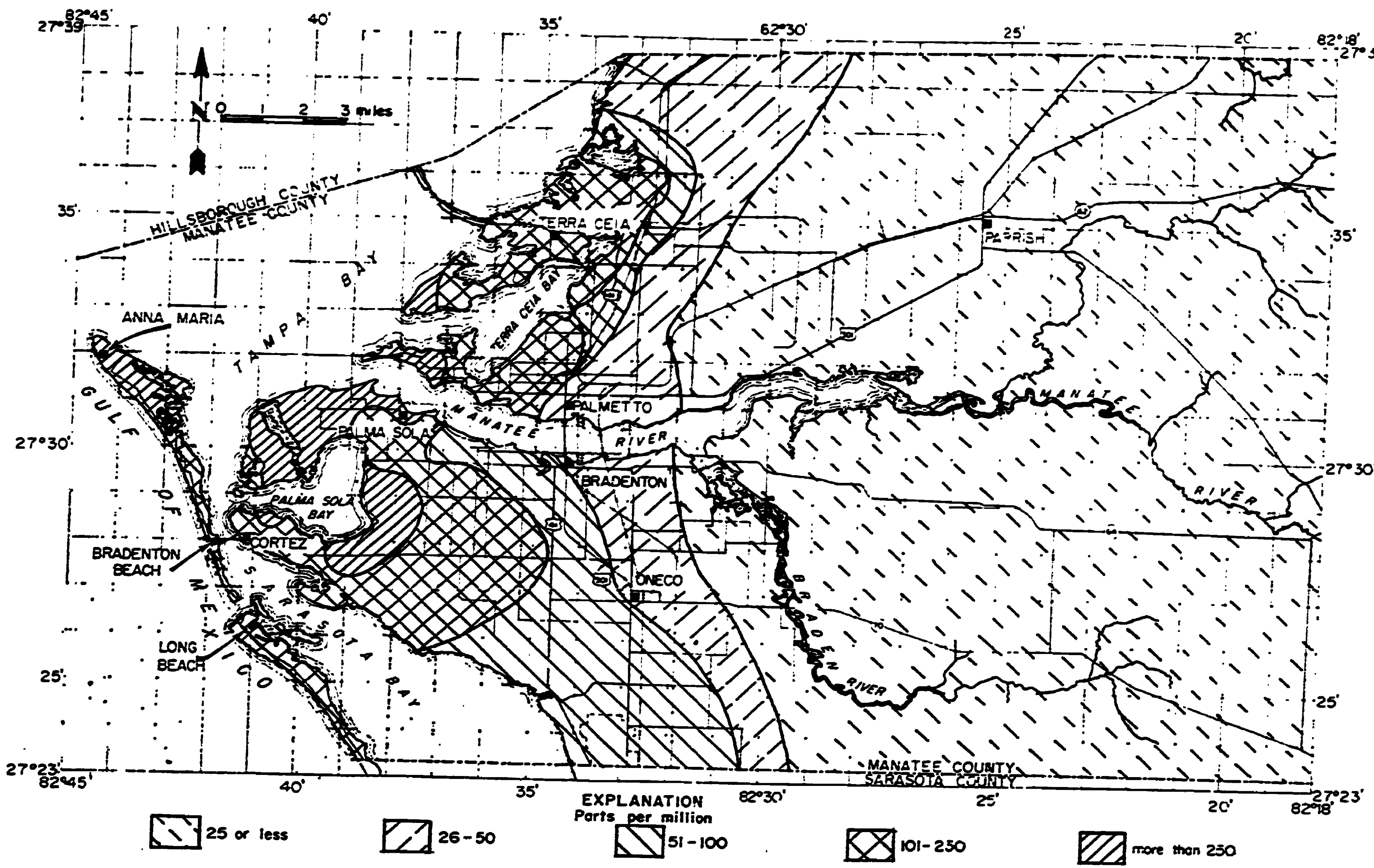


Figure 38. Map of western Manatee County showing chloride content of water from the Tampa formation.

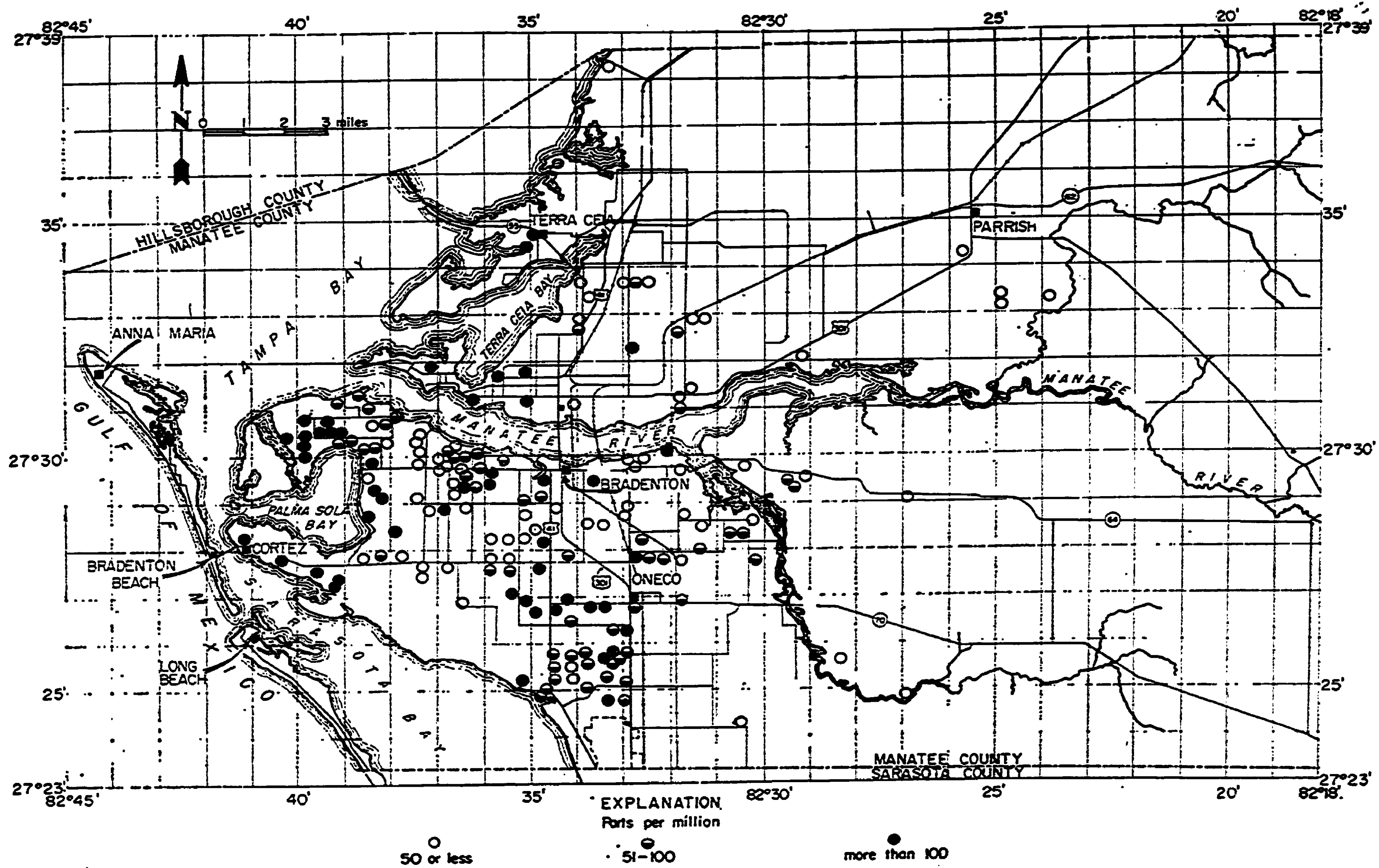


Figure 39. Map of western Manatee County showing chloride content of water from the Hawthorn and younger formations.

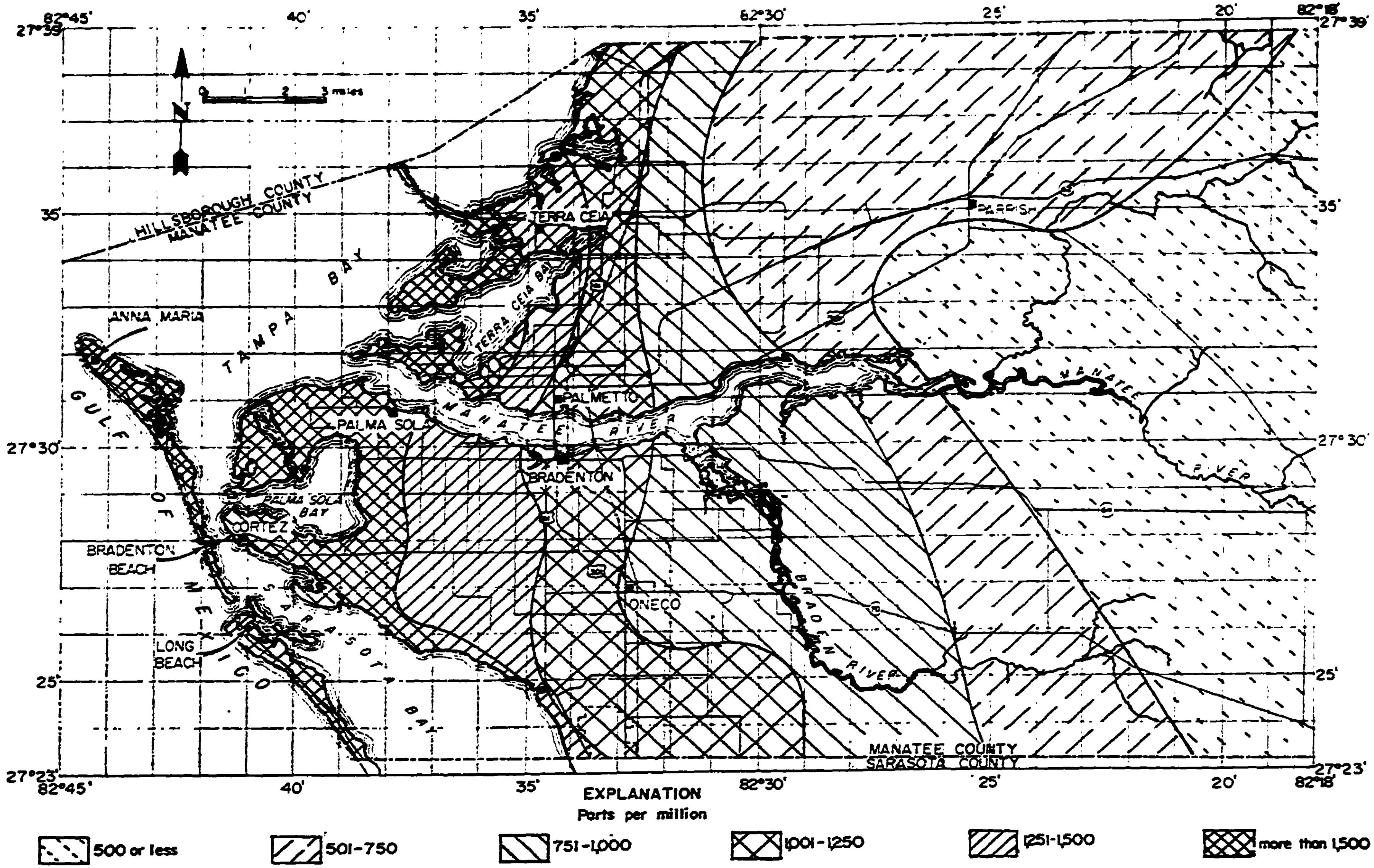


Figure 40. Map of western Manatee County showing concentration of dissolved solids in water from wells that penetrate the Suwannee limestone and older formations.

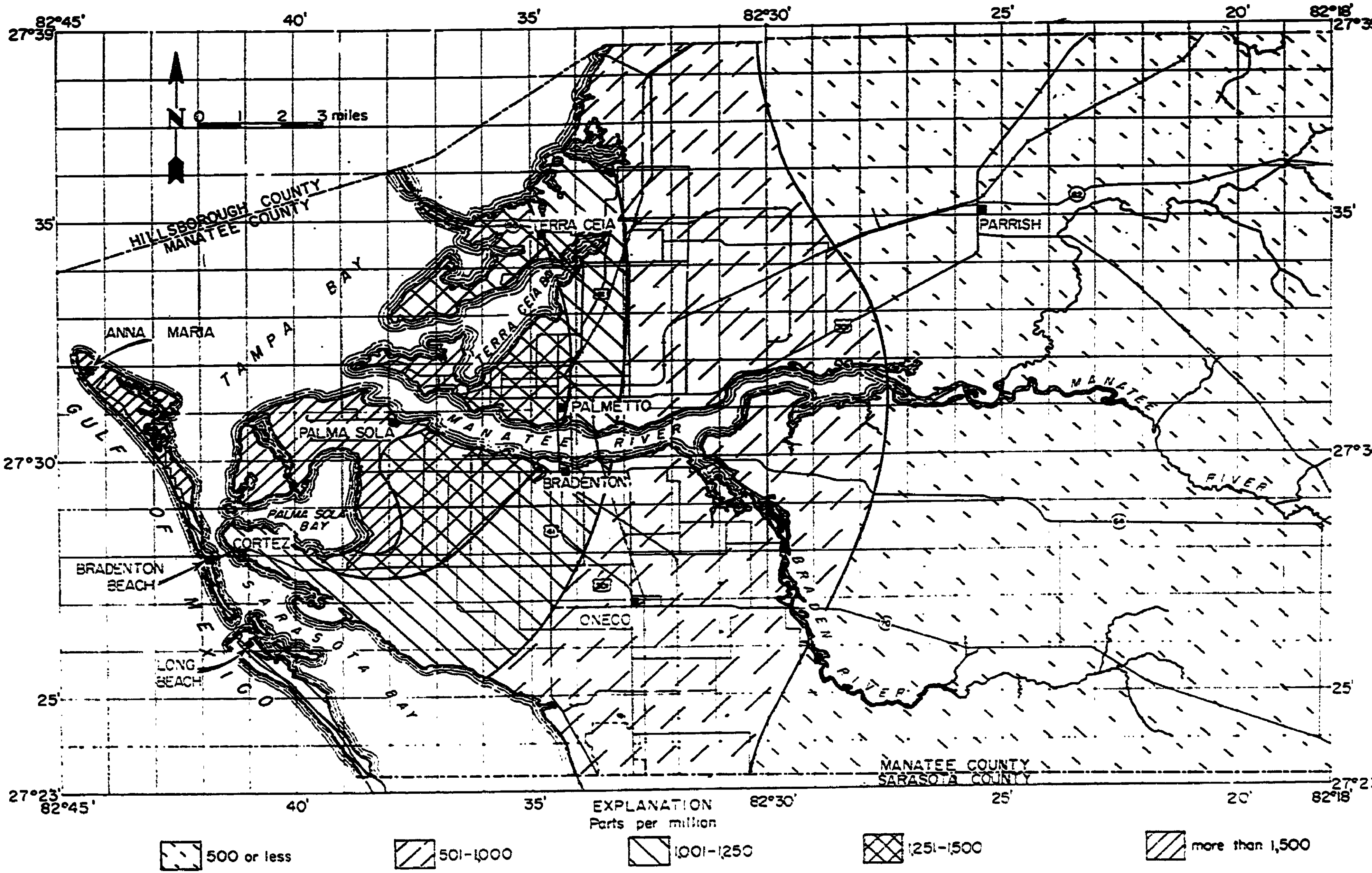


Figure 41. Map of western Manatee County showing concentration of dissolved solids in water from the Tampa formation.

Hardness: The hardness of a water is due almost entirely to the salts of calcium and magnesium. Hardness caused by calcium and magnesium equivalent to the carbonate and bicarbonate is referred to as carbonate hardness. Hardness caused by the chlorides, sulfates, and nitrates of calcium and magnesium is known as noncarbonate hardness. The most noticeable effects of hardness are the formation of soap curds and the lack of suds when soap is added to the water. Hard water also causes a scale in boilers or vessels in which the water is heated.

Water having a hardness of less than 50 ppm is generally satisfactory for most purposes. Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most purposes but does increase the use of soap and is generally objectionable to people who are accustomed to soft water. Water having a hardness of more than 150 ppm is rated as hard and is commonly softened for domestic and other uses.

Figure 42 shows the hardness of water from wells that penetrate the Suwannee and older limestones; it ranged from 240 to 1,680 ppm. Figure 43 shows the hardness of water from the Tampa formation; it ranged from 228 to 1,090 ppm. Wells that did not penetrate the Floridan aquifer yielded water ranging in hardness from 140 to 916 ppm, but the hardness was generally less than 500 ppm.

Specific Conductance: The specific conductance of water is a measure of its capacity to conduct an electric current and depends on the concentration and ionization of the minerals in solution. It is useful in determining the mineralization of a water. The specific conductance of water from the Floridan aquifer in the county ranged from 473 to 5,260 micromhos.

Hydrogen Sulfide: Hydrogen sulfide (H_2S) is a gas that gives water an objectionable odor and causes corrosion of plumbing. It can be removed by aeration. Water containing hydrogen sulfide is often referred to as "sulfur water." No determinations were made of the hydrogen sulfide content of water from wells in Manatee County; however, the gas is present in water from most wells that penetrate the Hawthorn and older formations.

Hydrogen-ion Concentration (pH): The pH value of a water indicates the instantaneous concentration of hydrogen ions. Water that has a pH of 7.0 is said to be neutral. Water having a pH of less than 7.0 is acidic and may be corrosive; water having a pH greater than 7.0 is alkaline and not generally corrosive. The pH of water from the Floridan aquifer in Manatee County ranged from 7.2 to 8.5, and the pH of water from the younger formations ranged from 7.3 to 8.2.

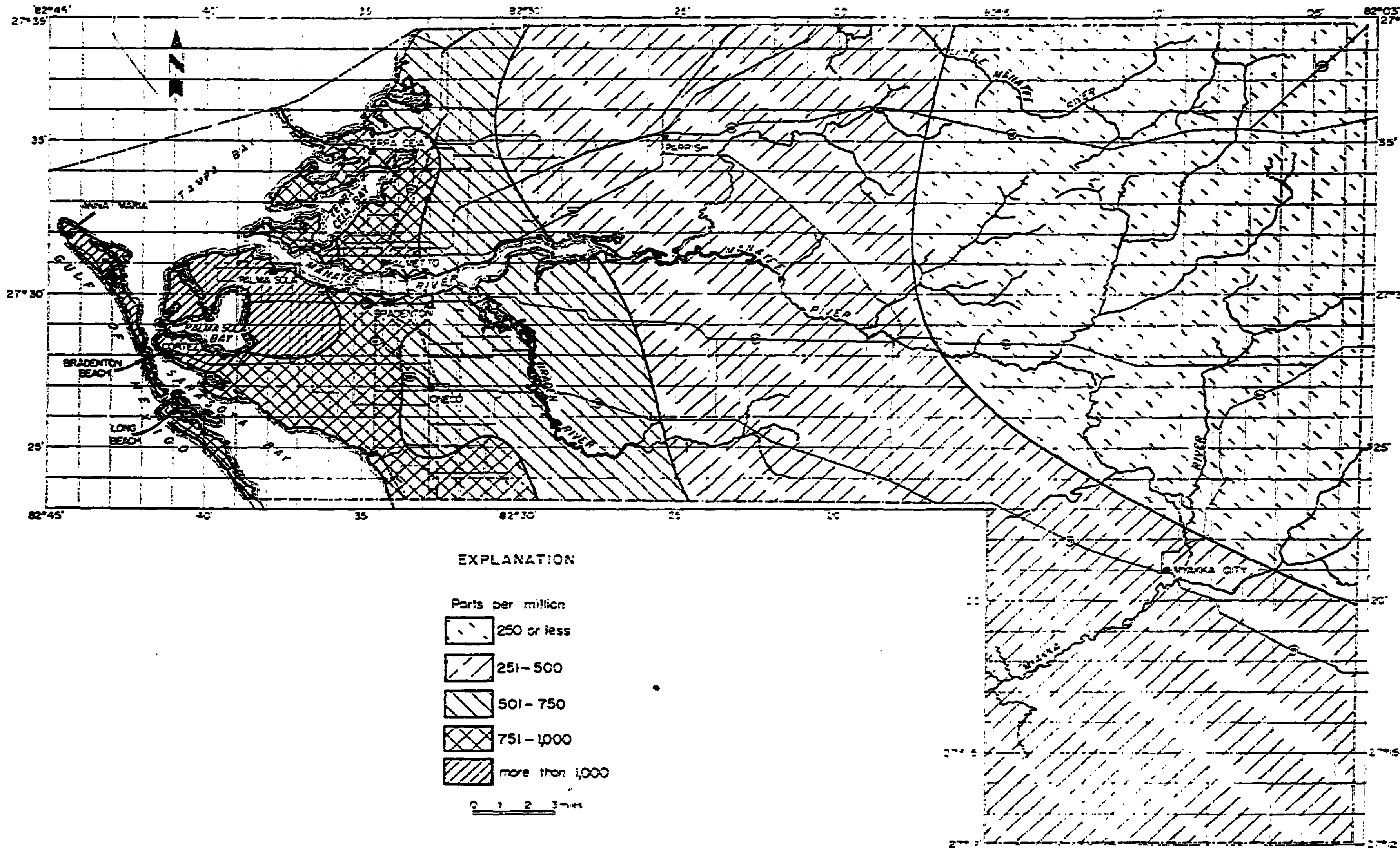


Figure 42. Map of Manatee County showing hardness of water from wells that penetrate the Suwannee and older limestones.

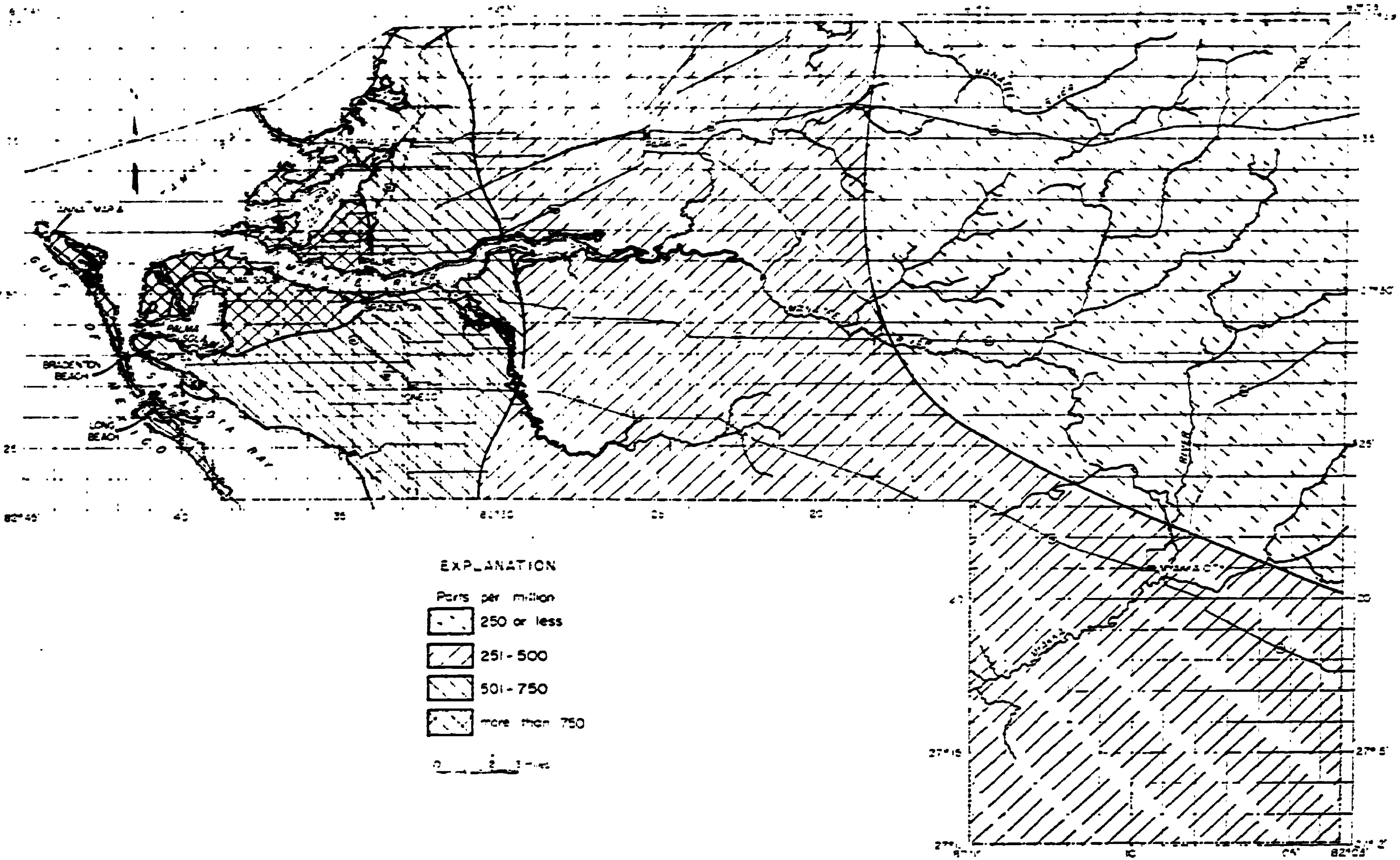


Figure 43. Map of Manatee County showing hardness of water from the Tampa formation.

SALT-WATER CONTAMINATION

In coastal areas where the water-bearing formations are hydraulically connected to the sea, the depth to salt water is directly related to the height that fresh water stands above sea level. The lowering of the water table or artesian pressure head in such areas may permit sea water to enter the water-bearing formation and contaminate the fresh water.

Salty water is present in the Floridan aquifer at relatively shallow depths throughout much of the coastal area of Florida. At some places, the lowering of the artesian pressure head by the withdrawal of large quantities of water from wells has caused the encroachment of sea water into the aquifer. In most of the coastal area, however, the head is sufficiently high to prevent encroachment of water directly from the sea; thus, the extensive occurrences of salty water are probably due to residuals of sea water that entered the aquifer prior to Recent time.

The Floridan aquifer was partly filled with sea water several times during the interglacial stages of the Pleistocene epoch, when the sea stood above the present level. Since the last recession of the sea, the circulation of fresh water through the aquifer has been gradually diluting and flushing out the salty water. In much of the coastal area, the flushing is incomplete and a part or all of the water-bearing formations still contain water which, although considerably less salty than sea water, is too salty for most uses. The dilution and flushing of the salty watef will continue as long as the artesian pressure head remains relatively high. Excessive lowering of the head will retard the flushing action and may cause an upward movement of the salty water from the lower zones of the aquifer, except where such movement is prevented by impermeable beds. If the head is lowered far enough, the seaward movement of water in the aquifer will be reversed, and thus will permit sea water to enter the aquifer.

The dissolved mineral matter in sea water consists predominantly of chloride salts. The chloride content of ground water, therefore, is generally a reliable index of contamination by sea water. Water samples from about 750 wells were analyzed to determine the chloride content of the water in the Floridan aquifer and in the Hawthorn and younger formations.

The analyses show that in most of the county the water in the Floridan aquifer has a chloride content of 25 ppm or less. In western Polk County the water in this aquifer has a chloride content of about 10 ppm, and in eastern Manatee County, about 15 ppm. It gradually increases westward, in the direction of ground-water movement. The principal constituents of water from selected wells that penetrate the Floridan aquifer (see line A-B in fig. 34) are shown graphically in figure 44, to illustrate the increase in mineral content of the water as it moves toward the coast.

As shown in figures 37 and 38, the water in the Floridan aquifer in much of the coastal area has a chloride content ranging from 26 to more than 500 ppm. The areas of highest chloride content are generally the areas of lowest artesian pressure head (fig. 25, 26); however, the mean artesian head along the coast is sufficiently high to prevent sea water from entering the aquifer at depths less than about 650 feet.

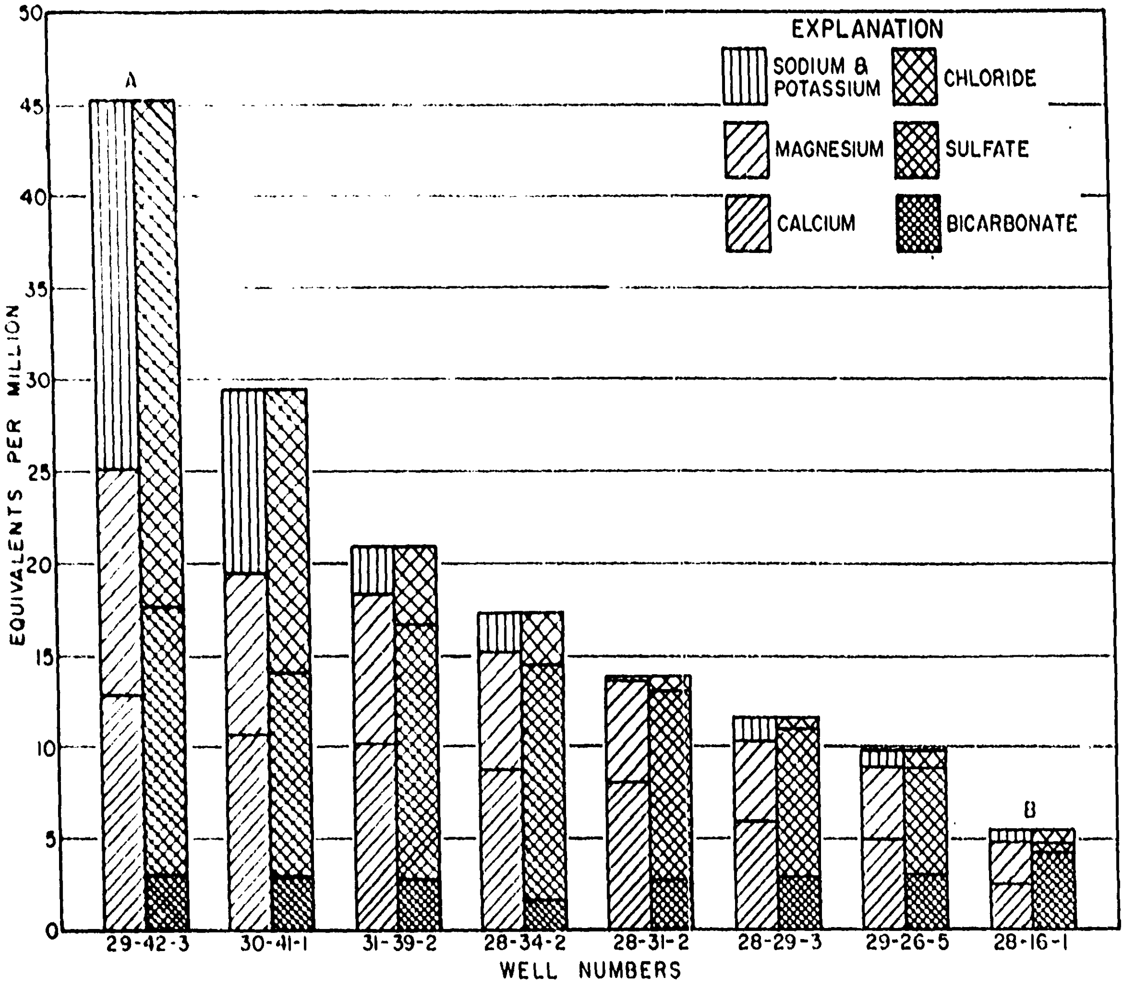


Figure 44. Graph showing the principal constituents of water from selected wells along line A-B in figure 34.

Two wells on Mullet Key, about five miles north of Anna Maria Island, yield water from the Floridan aquifer having a chloride content of about 900 ppm. A well on the Sunshine Skyway, about three miles south of the Pinellas County peninsula, yields water from the Floridan aquifer having a chloride content of 1,350 ppm. The relatively low chloride content of water from these wells indicates that most of the salt water has been flushed from the upper part of the Floridan aquifer in an area extending a considerable distance offshore.

As shown in figure 38, the water from the Tampa formation contains less than 250 ppm of chloride throughout most of the coastal area. This indicates that most of the salty water has been flushed out by the circulation of fresh water, although a few wells at the northern end of Anna Maria Island yield water from the Tampa formation containing as much as 460 ppm of chloride. The flushing of the salty water from the Suwannee limestone and older formations is less complete than it is from the Tampa formation (fig. 37, 38). The water from wells that penetrate the Suwannee limestone and older formations is principally a composite of water from the Tampa formation and Suwannee limestone, and it contains less than 500 ppm of chloride in most of the coastal area. However, several deep wells in the vicinity of Palma Sola Bay yield water having a chloride content ranging from about 1,000 ppm to more than 1,500 ppm. The chloride content of the water in the Suwannee limestone and older formations is probably much higher than indicated by the analyses of the composite samples.

Water samples were collected at various depths in selected wells to determine the chloride content of water from the different producing zones. As indicated by graphs in figures 12, 15, 45, and 46, the saltier water enters the wells from the deep producing zones and is diluted by fresher water from other producing zones as it moves up the well bore. For example, the analyses of samples collected in well 28-41-4 (fig. 12) show that the chloride content of water from the Suwannee limestone at the bottom of the well was about 2,400 ppm, whereas at a depth of 500 feet, where additional water entered the well, the average chloride content was about 900 ppm. At a depth of about 380 feet, where a considerable quantity of water entered the well from the Tampa formation, the average chloride content was about 550 ppm.

Periodic analyses of water samples show that the chloride content of the water changes with changes in artesian pressure head. Generally, a decrease in head is accompanied by an increase in chloride content, and vice versa (fig. 20, 22). This relationship indicates that the lowering of the head causes an upward movement of the salty water from the deep formations. The relationship may also reflect variations in the proportion of the total yield of the well that is obtained from each producing zone. During periods of heavy withdrawal, the head in the Tampa formation in localized areas is slightly less than the head in the deeper formations. During such times, the proportionate yield from the deeper formations is increased, and the chloride content of the water is higher.

Although the periodic determinations of chloride content indicate that the lowering of the artesian pressure head causes an upward movement of salty water from the deeper formations, they do not show any lateral expansion of the contaminated area. However, a continued decline of the piezometric surface in the coastal area will eventually result in lateral encroachment from the ocean. Lateral encroachment can be prevented

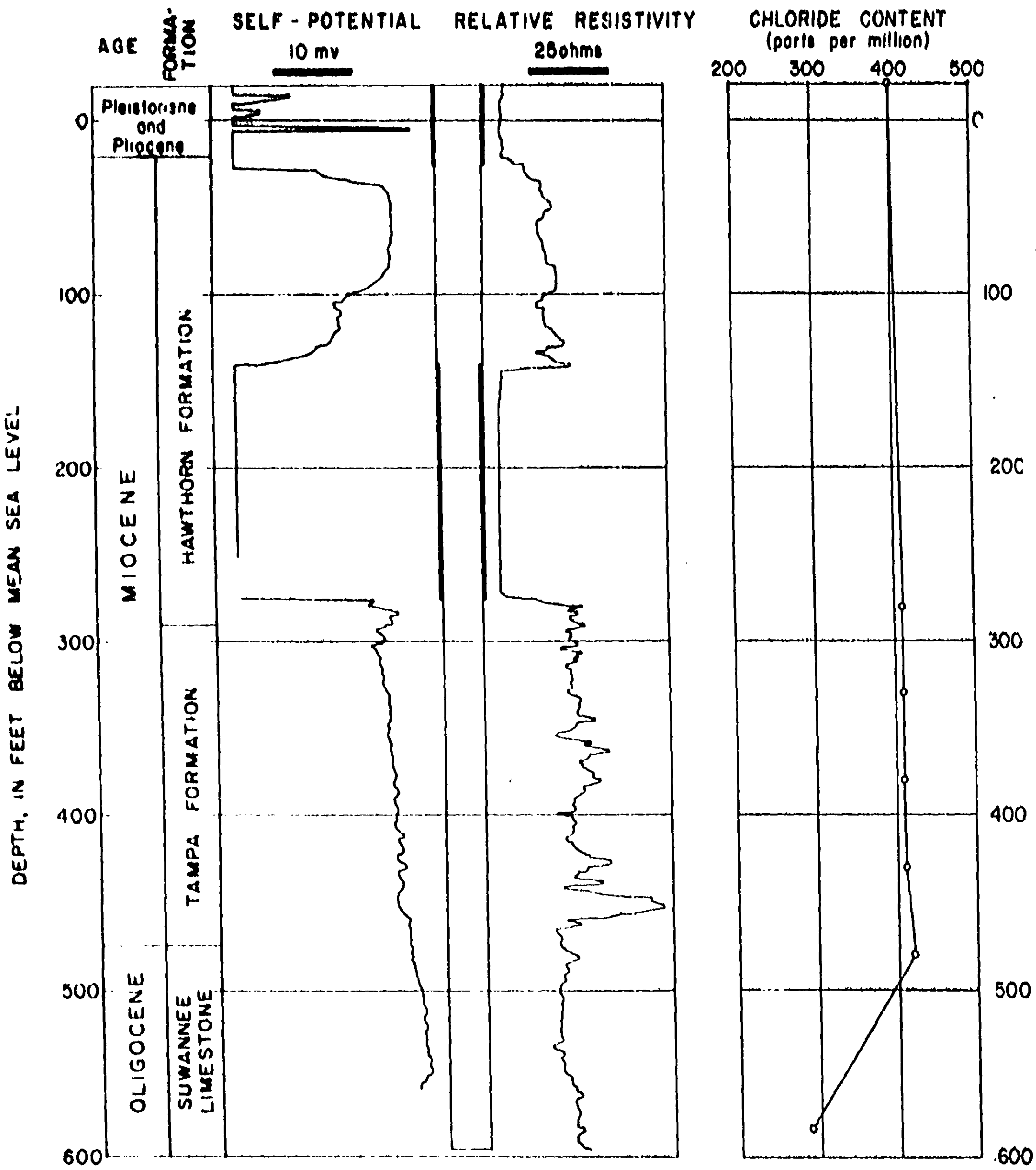


Figure 45. Graph showing data from well 27-36-1, four miles southwest of Bradenton.

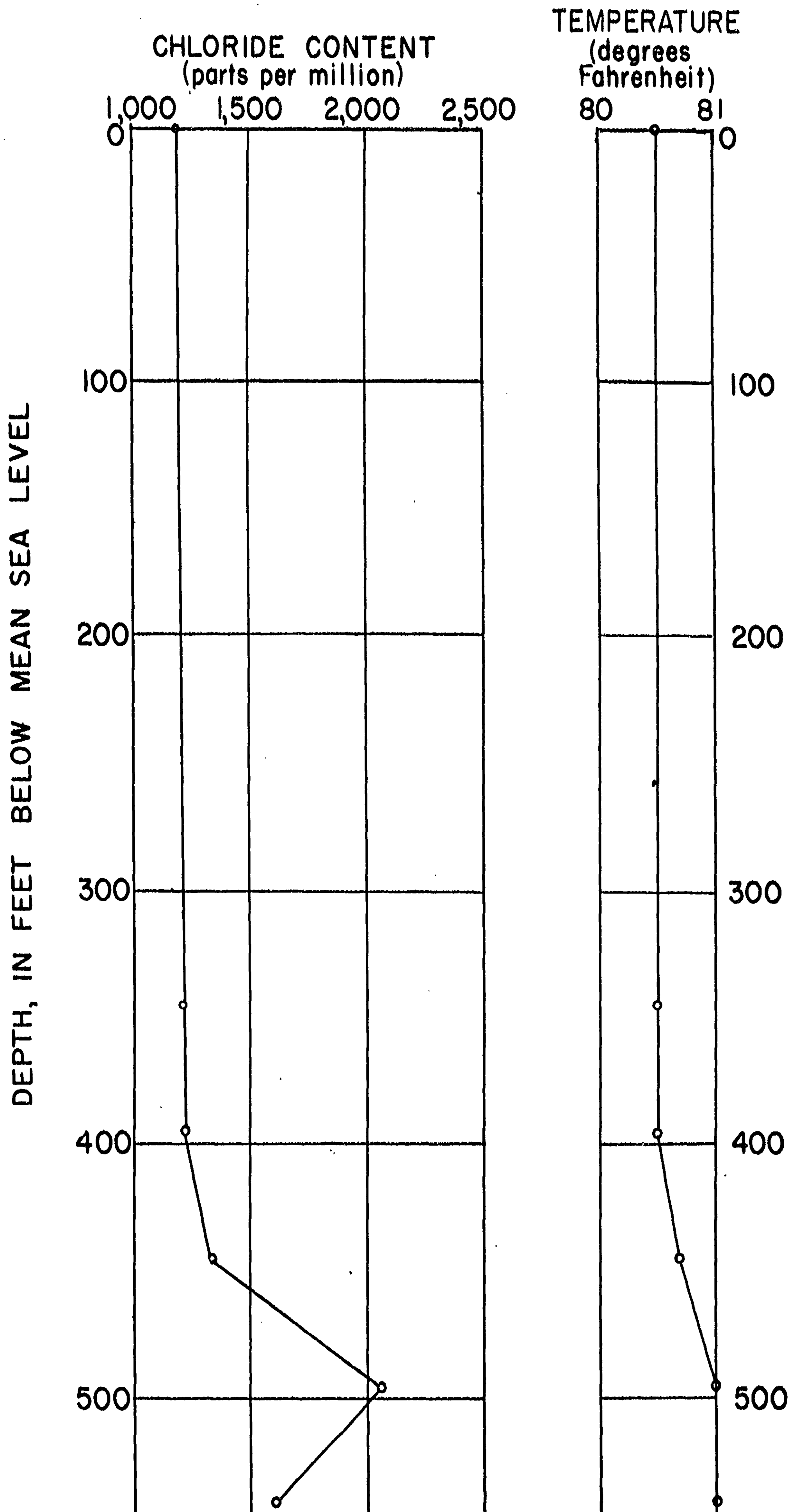


Figure 46. Graph showing chloride content and temperature of water from well 29-40-3, two miles north of Cortez.

and upward encroachment retarded by avoiding excessive drawdown, through the use of proper well spacing and controlled discharge rates in the coastal area.

SUMMARY AND CONCLUSIONS

The investigation of the ground-water resources of Manatee County consisted primarily of collecting and evaluating data from more than 900 private and public wells. The principal results are summarized below:

The county is underlain below depths ranging from about 175 to 375 feet, by a thick section of limestone consisting of formations of Eocene, Oligocene, and Miocene ages. The limestone formations penetrated by water wells are the Avon Park limestone and the Ocala group of Eocene age, the Suwannee limestone of Oligocene age, and the Tampa formation of early Miocene age. These formations are overlain by the Hawthorn formation of middle Miocene age, which consists of interbedded marl, limestone, and sand. The Hawthorn is overlain by deposits of sand, clay, shells, and limestone of Pliocene and Pleistocene age, which range in thickness from a few feet to about 90 feet.

Water in usable quantities generally occurs in all formations penetrated by wells. The sand, limestone, and shell beds of Pliocene and Pleistocene age yield water to many domestic wells. The water in these deposits is replenished by local rainfall. The Suwannee limestone and Tampa formation, which form a part of the Floridan aquifer, are the principal sources of ground water in the county. The water in these formations occurs in permeable zones separated by relatively impermeable layers which retard the vertical movement of the water. The water is replenished by rainfall in northern Polk County and, possibly, in northeastern Manatee County. The Hawthorn formation serves as a confining layer for the water in the Floridan aquifer. Beds of sand, shells, and limestone within the Hawthorn are the source of many small irrigation and domestic water supplies.

The artesian pressure head of the water in the Hawthorn formation is generally several feet lower than that of water in the Floridan aquifer. Because of this difference in head, water from the Suwannee limestone and Tampa formation leaks upward into the permeable beds in the Hawthorn formation through wells that are open to all these formations. The depression in the piezometric surface in the vicinity of Palma Sola (fig. 25) is probably due in part to such leakage through unused irrigation wells.

Water-level records show that significant changes in artesian pressure head result from daily and seasonal variations in withdrawal of water from wells. During periods of heaviest withdrawal, the piezometric surface is lowered four or five feet throughout the county and as much as 10 feet at some places. The increase in both seasonal and perennial use of water since 1948 has resulted in a progressive decline of artesian head in parts of the county and a progressive increase in the magnitude of seasonal fluctuations.

Because of the decline in head, pumping is necessary in many areas where sufficient quantities of water were formerly obtained by natural flow. In other areas, the depth of the water below the land surface has exceeded the lift capacity of centrifugal pumps, and turbine pumps must now be used.

The chloride content of the artesian water in most of the county is about 15 to 25 ppm, but in a zone about 3 to 10 miles wide along the coast it ranges from 26 to more than 1,500 ppm. This indicates that the ground water is contaminated by salt water. The salty water is probably a diluted residue of sea water which entered the aquifer during Pleistocene times and which has not been completely flushed from the aquifer. The mean artesian head along the coast is sufficiently high to prevent the encroachment of salt water directly from the sea.

A few wells yield water containing more than 400 ppm of chloride from the Tampa formation, but the water in the Tampa generally contains less than 250 ppm of chloride, indicating that most of the salt water has been flushed out. The flushing is less complete from the Suwannee limestone, in which the water at some places contains more than 2,000 ppm of chloride. Throughout most of the coastal area, however, the chloride content of water in the Suwannee is less than 500 ppm. The water in the Eocene formations along the coast is probably too salty for most uses.

Periodic determinations of chloride content show that the chlorinity of the water changes with significant changes in artesian pressure head. Some wells that show a progressive decline in head show also a progressive increase in chloride content, indicating that the lowering of head causes an upward migration of salty water from the deeper formations.

Little or no expansion of the contaminated area has occurred during the period of investigation; however, if the piezometric surface continues to decline in the coastal area, lateral encroachment from the ocean will eventually result. Lateral encroachment can be prevented and vertical encroachment retarded by avoiding excessive drawdowns, through the use of proper well spacing and controlled discharge rates in and adjacent to the contaminated area.

Water-level measurements and periodic determinations of the chloride content of water from selected wells should be continued, so that any changes in the head and chlorinity of the artesian water can be detected and controlled.

REFERENCES

Anders, R. B. (see Peek, H. M.)

Applin, Esther R. (see Applin, Paul L.)

Applin, Paul L.

1944 (and Applin, Esther R.) *Regional subsurface stratigraphy and structure of Florida and southern Georgia:* Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12.

Ast, D. B. (see Cox, C. R.)

Black, A. P.

1951 (and Brown, Eugene) *Chemical character of Florida's waters – 1951:* Florida State Board of Cons., Division Water Survey and Research, Paper 6.

Brown, Eugene (see Black, A. P.)

Collins, W. D.

1928 (and Howard, C. S.) *Chemical character of waters of Florida:* U. S. Geol. Survey Water-Supply Paper 596-G.

Cooke, C. W.

1945 *Geology of Florida:* Florida Geol. Survey Bull. 29.

Cooper, H. H., Jr.

1946 (and Jacob, C. E.) *A generalized graphical method of evaluating formation constants and summarizing well-field history:* Am. Geophys. Union Trans., vol. 27.

Cox, C. R.

1951 (and Ast, D. B.) *Water fluoridation – a sound public health practice:* Am. Water Works Assoc. Jour., vol. 43, no. 8.

Ferguson, G. E. (see Parker, G. G.)

Gunter, Herman (see Sellards, E. H.)

Howard, C. S. (see Collins, W. D.)

Jacob, C. E. (see Cooper, H. H., Jr.)

Love, S. K. (see Parker, G. G.)

MacNeil, F. S.

1950 *Pleistocene shorelines in Florida and Georgia:* U. S. Geol. Survey Prof. Paper 221-F.

Matson, G. C.

1913 (and Sanford, Samuel) *Geology and ground waters of Florida:* U. S. Geol. Survey Water-Supply Paper 319.

Parker, G. G.

1950 (and Stringfield, V. T.) *Effects of earthquakes, trains, tides, winds, and atmospheric pressure changes on water in the geologic formations of Southern Florida:* Econ. Geology, vol. 45, no. 51.

1955 (and Ferguson, G. E., Love, S. K., and others) *Water resources of southeastern Florida:* U. S. Geol. Survey Water-Supply Paper 1255.

Peek, H. M.

1955 (and Anders, R. B.) *Interim report on the ground-water resources of Manatee County, Florida:* Florida Geol. Survey Inf. Circ. 6.

Puri, Harbans

1953 *Zonation of the Ocala group in peninsular Florida (abstract):* Jour. Sedimentary Petrology, vol. 23.

Sanford, Samuel (see Matson, G.C.)

Sellards, E. H.
1913 (and Gunter, Herman) *The artesian water supply of eastern and southern Florida:* Florida Geol. Survey 5th Ann. Rept.

Stringfield, V. T. (also see Parker, G. G., 1950)
1933 *Ground-water investigations in Florida:* Florida Geol. Survey Bull. 11.
1936 *Artesian water in the Florida peninsula:* U. S. Geol. Survey Water-Supply Paper 773-C.

U. S. Public Health Service
1946 *Public Health Reports:* vol. 61, no. 11, p. 371-384.

Vernon, R. O.
1951 *Geology of Citrus and Levy counties, Florida:* Florida Geol. Survey Bull. 33.

Wenzel, L. K.
1942 *Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods:* U. S. Geol. Survey Water-Supply Paper 887.

Table 5. Chemical Analyses of Water from Wells in Manatee County
(Analyses, in parts per million, by U.S. Geological Survey)

Well No.	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	Temperature (°F)	pH
									Total	Noncarbonate			
20–10–1	3– 9–55	72	38	1.6	208	135	20	430	336	166	635	79	7.7
23–38–1	3– 7–55	212	113	146	164	750	280	1,700	994	860	2,180	80.5	7.4
23–38–3	3– 7–55	162	93	96	162	615	158	1,270	786	654	1,610	79.2	7.4
*24–26–1	4– 1–55	36	17	55	248	15	44	342	160	160	529	....	7.5
25–29–2	3–23–55	140	69	29	165	472	49	966	633	498	1,220	79.5	7.4
25–31–2	3– 9–55	166	84	12	170	508	83	1,120	760	621	1,430	79.5	7.5
25–31–7	3– 9–55	146	73	.0	167	412	66	940	664	527	1,240	78.5	7.5
*25–32–1	4– 1–55	94	51	50	236	268	57	716	444	251	967	....	7.5
25–33–5	2–24–55	151	71	55	166	495	97	988	668	532	1,320	80	7.7
25–34–1	1–26–54	126	52	....	172	385	65	860	528	....	1,140	78	7.5
25–34–2	1–29–54	149	58	....	162	468	80	974	614	....	1,250	78.5	7.4
*25–34–3	2–16–55	109	20	26	309	108	32	476	354	101	728	....	7.3
*25–34–9	2–16–55	120	18	30	412	25	54	534	374	37	778	....	7.4
25–35–2	2–16–55	186	91	195	160	495	283	1,530	838	707	1,980	81	7.4
25–40–3	3– 7–55	140	78	82	172	480	147	1,130	670	529	1,440	79.2	7.3
26–29–3	3–23–55	139	67	37	175	475	46	944	622	479	1,180	82	7.4
26–30–3	3– 9–55	154	78	12	170	498	51	960	704	565	1,250	80	7.4
*26–31–2	4– 1–55	70	34	49	250	106	74	606	314	109	817	....	8.1
*26–33–5	4– 1–55	145	45	160	527	124	236	1,110	547	115	1,650	....	7.3
26–35–3	1–20–54	170	103	....	186	472	145	1,100	690	....	1,540	80	7.3
26–41–2	3– 7–55	122	80	78	178	500	97	1,010	634	488	1,330	78	7.4
27–28–1	3–23–55	130	60	49	178	475	27	862	571	425	1,110	81	7.4
27–29–1	3–23–55	141	65	35	171	502	24	928	620	480	1,115	79	7.4
27–30–3	3–23–55	144	68	32	166	515	26	936	630	494	1,150	79.8	7.3
*27–31–2	4– 1–55	73	35	51	362	55	58	504	326	30	802	74	7.4
27–34–1	2–16–55	192	88	114	162	625	217	1,410	841	709	1,800	79	7.4
*27–35–1	2–21–55	188	77	65	194	535	149	1,170	786	627	1,580	75.5	7.5
*27–35–2	2–21–55	154	23	26	338	126	90	664	478	201	1,000	....	7.5
27–35–3	2–18–55	252	115	171	156	660	467	1,970	1,100	972	2,660	81	7.5

Table 5 (continued)

Well No.	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	Temperature (°F)	pH
									Total	Noncarbonate			
*27-37-5	2-17-55	97	19	20	345	15	46	426	320	138	681	75	7.5
27-38-3	3- 3-55	208	100	101	162	575	296	1,550	930	798	2,100	79.9	8.2
27-38-7	1-20-54	219	88	....	166	595	300	1,580	912	....	2,120	79	7.4
27-39-4	3- 3-55	120	82	64	195	355	174	1,030	636	476	1,390	78	7.4
27-39-12	1-20-54	229	94	....	168	682	240	1,650	958	....	2,030	80	7.4
27-41-3	1-20-54	134	71	....	200	392	112	1,020	628	....	1,330	79	7.4
28-16-1	3- 9-55	50	28	15	264	22	24	382	240	24	473	79	7.5
28-29-3	3-23-55	118	54	29	178	388	21	760	516	370	991	78	7.5
*28-30-7	4- 1-55	113	9.2	26	316	72	30	448	320	61	678	75	7.5
28-31-2	1-28-54	164	69	....	168	545	28	1,020	696	....	1,250	85	7.3
*28-32-2	4- 1-55	71	27	43	326	19	67	482	288	22	748	....	7.5
*28-33-2	4- 1-55	36	20	13	196	14	18	216	172	12	376	....	7.4
*28-34-1	3-17-55	229	42	78	250	490	141	1,220	744	539	1,600	....	7.4
28-34-2	3-25-55	177	78	47	102	622	94	1,280	762	679	1,570	78	7.9
*28-34-5	3-25-55	107	10	40	317	62	50	486	308	48	724	74	7.3
*28-34-7	3-25-55	77	28	29	301	72	34	420	307	61	639	....	7.3
*28-35-12	4- 1-55	101	5.8	14	314	21	20	344	276	19	553	....	7.5
28-37-1	1-20-54	235	97	....	216	500	578	1,910	990	....	2,880	78	7.3
*28-37-9	3- 3-55	123	13	25	412	15	44	444	360	23	721	....	7.8
[1] 28-38-6	5-21-53	326	135	412	160	803	925	2,900	1,370	1,240	4,110	....	7.5
28-40-8	1-20-54	158	96	....	204	415	232	1,230	740	....	1,700	79	7.3
28-41-5	3- 7-55	320	167	414	178	675	1,090	3,220	1,480	1,340	4,580	80.3	7.2
28-41-6	3- 7-55	134	83	70	204	435	148	1,100	676	509	1,400	76	7.5
28-41-7	3- 7-55	110	66	85	224	365	118	1,090	546	363	1,180	77.8	7.9
29-26-3	3- 4-55	52	34	23	209	99	32	376	270	109	604	77.5	7.6
29-26-5	3- 4-55	99	49	16	190	280	25	604	448	293	833	80	7.8
*29-29-3	4- 1-55	38	28	40	232	38	47	354	210	20	561	....	7.6
29-29-6	3- 4-55	136	63	15	174	440	22	804	598	456	1,050	79.7	7.6
29-32-2	1-27-54	168	59	....	176	512	27	1,000	664	....	1,210	79	7.5

Table 5 (continued)

Well No.	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	Temperature (°F)	pH
									Total	Noncarbonate			
*29-32-5	3-25-55	40	9.8	31	48	102	44	280	140	101	431	....	8.1
*29-35-1	2-21-55	110	21	29	362	54	50	508	361	65	787	75	7.3
29-35-2	1-28-54	191	88	....	164	668	52	1,250	840	....	1,500	78	7.3
29-35-7	2-24-55	222	101	21	161	755	69	1,380	970	838	1,610	79.3	7.6
*29-36-7	3- 3-55	108	17	.0	372	8	18	400	340	34	606	76	7.3
*29-36-9	2-23-55	132	22	39	426	6	106	620	420	71	1,010	....	7.4
*29-36-14	2-14-55	86	9.8	31	292	12	50	392	255	16	615	76	7.9
*29-36-18	2-14-55	82	26	32	323	35	56	446	312	48	700	76	7.9
29-37-9	2-14-55	204	99	61	169	665	155	1,350	916	778	1,740	79.5	7.3
29-40-8	1-29-54	147	89	....	210	255	598	1,580	678	....	2,550	79	7.4
29-42-3	3- 7-55	260	149	394	184	700	878	2,630	1,260	1,110	3,820	79.8	7.4
30-25-1	3- 4-55	94	46	6.4	187	245	21	578	424	271	780	81.5	7.6
30-27-6	3- 4-55	124	65	10	180	400	25	776	577	430	994	82	7.5
30-28-2	2-14-55	126	61	.0	172	368	26	802	566	425	1,040	81.5	7.5
30-30-1	1-28-54	128	50	....	174	390	23	....	524	....	995	77	7.5
*30-37-2	2-14-55	113	9.2	17	351	12	41	410	320	33	637	76.5	7.3
30-37-6	3- 3-55	214	102	43	154	690	144	1,450	954	828	1,750	78	7.3
*30-37-7	3- 3-55	118	26	8.3	270	116	55	516	402	181	781	76.5	7.7
30-37-8	1-28-54	197	106	....	180	645	295	1,660	930	....	2,180	79	7.4
*30-38-1	3- 3-55	77	31	45	241	100	82	550	320	123	768	....	7.9
*30-38-5	3- 3-55	106	51	20	202	259	58	706	474	309	957	77.3	7.4
30-38-7	3- 3-55	160	63	33	210	355	134	1,080	658	486	1,380	75	7.6
30-38-9	1-21-54	172	104	....	182	542	208	1,410	780	....	1,810	....	7.3
*30-39-4	3- 3-55	108	34	46	248	175	89	662	410	207	911	76.2	7.4
[2]*30-39-5	7-18-51	204	99	218	186	542	472	1,660	916	769	2,530	....	8.2
30-41-1	2-16-55	214	107	229	182	540	540	1,910	974	825	2,830	79.5	7.3
31-24-1	3- 4-55	74	36	15	196	170	20	438	332	172	650	79	7.5
31-30-1	1-27-54	134	52	....	176	432	24	862	546	....	1,040	77	7.5
*31-30-3	3-25-55	74	61	75	390	165	76	696	436	117	1,090	....	7.3

Table 5 (continued)

Well No.	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	Temperature (°F)	pH
									Total	Noncarbonate			
31-31-2	1-27-54	137	53	....	170	448	23	860	556	....	1,050	77	7.4
*31-32-2	3-25-55	178	80	58	365	490	64	1,130	773	474	1,510	....	7.2
*31-32-3	3-25-55	58	78	49	259	278	50	712	465	253	1,030	....	7.4
31-32-4	3-25-55	163	67	28	165	542	31	1,010	682	497	1,260	79.8	7.2
31-32-8	2- 8-55	150	66	42	176	535	26	914	646	502	1,160	78	7.7
*31-34-1	3-25-55	57	34	20	331	19	24	352	282	11	580	....	7.3
31-34-10	1-21-54	193	117	....	162	608	92	1,260	802	....	1,510	....	7.5
31-34-13	2- 4-55	236	98	133	172	790	225	1,670	992	851	2,120	80	7.5
31-37-3	1-29-54	227	97	....	172	722	282	1,770	966	....	2,240	78	7.3
31-37-6	1-21-54	187	113	....	188	580	232	1,510	858	....	1,950	77	7.4
31-37-10	2- 7-55	232	99	167	162	725	328	1,820	986	854	2,390	80	7.5
*31-38-4	2-18-55	104	56	35	220	240	96	750	490	310	1,040	75	7.4
31-39-2	2-18-55	286	152	628	188	675	1,310	3,560	1,340	1,186	5,260	81.5	7.5
*31-39-3	2-18-55	118	46	25	232	199	100	680	484	294	963	75.5	7.3
[3]*31-43-2	11-20-50	1,260	1,590	13,100	201	1,710	25,500	43,500	9,800	9,690	53,600	....	7.6
31-43-2	1-20-54	216	93	....	194	490	440	1,570	924	....	2,320	78	7.4
32-25-1	2-15-55	78	39	11	188	178	28	454	355	201	671	81.4	7.4
32-27-2	2-15-55	82	48	3.2	188	215	22	492	402	248	725	79	7.7
32-27-3	2-15-55	94	48	1.4	200	232	21	550	432	268	784	80	8.5
32-29-2	1-27-54	103	47	....	178	342	23	752	450	....	904	77	7.5
32-32-1	2- 7-55	153	76	54	124	630	38	1,100	694	592	1,300	79	7.9
32-32-7	2- 8-55	172	69	51	160	570	70	1,090	712	582	1,350	79	7.4
32-33-2	2- 7-55	281	109	105	156	750	332	1,870	1,150	1,020	2,400	84	7.5
32-33-4	2- 4-55	169	73	33	156	575	48	1,140	722	594	1,340	80	7.9
*32-33-6	3-25-55	179	74	47	193	580	65	1,140	751	593	1,430	....	7.3
32-34-6	2- 4-55	173	81	66	120	660	87	1,270	764	666	1,500	80	8.0
33-23-1	2- 8-55	75	32	6.4	180	153	18	444	318	171	636	82	7.8
*33-25-1	3-25-55	44	23	11	262	5	6	254	204	204	418	....	7.3
33-31-1	2- 4-55	136	60	23	192	420	30	856	586	428	1,100	81	7.9

Table 5 (continued)

Well No.	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	Temperature (°F)	pH
33-33-8	2- 4-55	195	78	105	168	580	208	1,390	807	670	1,810	80	7.4
33-35-4	1-21-54	176	107	....	172	530	202	1,280	770	....	1,770	77	7.3
34-23-2	2- 8-55	79	35	17	208	176	18	510	341	170	692	80	8.0
34-25-3	3- 2-55	80	41	0.9	192	178	19	454	368	210	687	79	7.7
34-29-1	2-15-55	88	45	5	188	220	23	570	404	250	813	80.1	7.3
34-31-2	2- 4-55	133	55	44	172	460	24	792	558	417	1,040	77	7.6
34-32-3	2- 4-55	114	65	69	120	505	56	952	552	454	1,150	79	8.1
34-33-7	2- 4-55	195	82	167	180	595	297	1,530	824	676	2,070	81	7.3
34-34-2	1-21-54	179	75	....	168	535	175	1,280	760	....	1,670	78	7.3
34-35-2	2- 8-55	199	88	143	160	590	301	1,560	858	728	2,110	79	7.6
35-31-2	2- 8-55	136	57	37	172	425	50	852	574	433	1,120	78	7.6
35-32-11	2- 7-55	148	62	66	172	445	117	1,040	624	484	1,360	79	7.6
35-33-6	1-28-54	153	64	....	174	428	118	1,040	648	....	1,400	77	7.5
35-34-5	2- 8-55	171	72	111	178	510	204	1,330	722	576	1,740	79	7.6
36-31-1	2- 7-55	116	52	39	178	355	52	748	504	358	1,020	79	7.6
36-32-2	3- 9-55	106	58	34	188	310	72	788	503	349	1,070	78	7.5
37-29-3	1-27-54	69	13	....	270	40	28	388	228	....	556	76	7.7
37-31-3	2- 4-55	123	50	31	176	360	44	738	512	368	1,010	80	7.5
37-32-10	1-22-54	122	47	....	190	320	35	736	500	....	976	77	7.6
38-32-5	2- 4-55	159	69	62	180	505	100	1,030	680	532	1,340	81	7.7
38-32-9	2- 4-55	129	57	48	188	420	50	820	556	402	1,070	78	7.7
38-33-5	1-22-54	111	50	....	193	335	31	754	482	....	950	76	7.7

* Analysis of water from the Hawthorn or a younger formation.

[1] Contains silica (SiO_2), 21 ppm; iron (Fe) in solution, 0.00 ppm; total iron, 0.59 ppm; fluoride (F), 1.9 ppm; nitrate (NO_3), 0.4 ppm; color, 5.

[2] Contains silica (SiO_2), 29 ppm; iron (Fe) in solution, 0.00 ppm; total iron, 0.07 ppm; fluoride (F), 0.9 ppm; nitrate (NO_3), 2.9 ppm; color, 12.

[3] Contains silica (SiO_2), 8.6 ppm; iron (Fe), in solution, 0.16 ppm; total iron, 5.0 ppm; fluoride (F), 0.2 ppm; nitrate (NO_3), 22 ppm; color, 40.

Table 6. Water-Level Measurements
(All measurements in feet with reference to measuring point)

Well No.	Date	Water level	Date	Water level	Date	Water level	Date	Water level
23-38-1	5-16-53	11.0	10-13-53	11.2	7- 1-54	12.9	3- 7-55	8.5
	6- 3-53	9.5	12-11-53	11.0	8-16-54	13.2	7-21-55	11.6
	7-23-53	10.2	3- 4-54	11.2	9-16-54	12.2	10-27-55	12.1
	9-16-53	11.5	5-17-54	12.5	1-31-55	8.5	12-15-55	10.5
	9-16-53	11.3	....	....	....	....	....	....
23-38-2	3-16-54	14.0	8-21-51	15.2	7-29-52	13.4	2- 4-53	11.5
	4-16-51	12.6	4-11-52	12.0	10-29-52	15.0	3-31-53	11.9
	6- 6-51	12.6	5-25-52	10.8	12-15-52	11.8	4-30-53	11.0
25-31-7	10-27-52	5.2	7-22-53	3.46	12-22-54	4.2	6- 6-55	- 1.75
	12-15-52	2.95	9-16-53	5.2	1-31-55	2.2	7-21-55	3.2
	2-11-52	4.10	10-15-53	5.3	3- 9-55	- 0.35	9-15-55	4.2
	3-31-53	0.47	12-18-53	4.8	4- 6-55	1.4	10-27-55	1.1
	5-16-53	- 0.9	9-16-54	4.9	5- 9-55	- 2.2	12-13-55	1.4
	6- 2-53	- 0.8	....	....	....	....	....	....
25-40-3	3-16-51	14.0	7-29-52	14.2	6- 3-53	13.9	3- 4-54	14.0
	4-16-51	15.5	10-29-52	14.7	7-23-53	14.3	5-17-54	14.0
	6- 6-51	15.1	12-15-52	15.3	9-16-53	14.5	7- 1-54	15.2
	5-21-51	16.1	2- 4-53	14.8	10-13-53	15.2	8-16-54	16.1
	4-11-52	14.0	3-31-53	14.2	12-11-53	15.0	9-16-54	15.0
	6-25-52	13.8	5-16-53	13.6	....	....	....	....
26-30-5	3- 1-54	9.0	11- 8-54	8.0	4- 6-55	8.3	9-15-55	10.1
	6-30-54	10.2	12-22-54	10.0	5-10-55	2.35	10-27-55	6.7
	9-17-54	11.1	1-31-55	6.5	6- 6-55	3.2	12-13-55	7.2
27-39-9	11-13-52	1.85	3-30-53	3.65	7-22-53	3.55	12-18-53	5.3
	2-12-53	6.5	5-15-53	1.55	10-13-53	3.2	....	....

Table 6 (continued)

Well No.	Date	Water level	Date	Water level	Date	Water level	Date	Water level
27-41-2	2-18-51	7.0	7-30-52	7.0	7-23-53	7.9	12-23-54	8.0
	3-16-51	7.5	9-27-52	8.1	9-17-53	8.5	1-31-55	7.8
	4-17-51	7.8	11- 8-52	8.2	10-13-53	7.8	3- 7-55	7.4
	6- 8-51	8.0	12-29-52	8.3	12-17-53	7.4	4- 4-55	7.6
	7-22-51	8.9	2- 3-53	8.1	6- 7-54	9.0	6- 7-55	6.5
	10- 2-51	8.2	3-20-53	7.0	8-18-54	9.0	7-22-55	7.2
	5- 4-52	7.3	5-15-53	7.1	9-15-54	8.8	9-13-55	7.5
	6-21-52	7.1	6- 3-53	8.3	11- 9-54	7.5	12-13-55	7.6
28-37-6	12-11-52	- 3.65	4- 7-53	- 4.83	6- 3-53	- 4.68	9-15-53	- 1.58
	2-12-53	- 2.57	5-15-53	- 5.68	7-22-53	- 2.25	12- 9-53	- 1.22
29-26-1	2-22-51	- 1.72	9-19-51	1.87	2- 4-53	0.44	10-15-53	2.65
	3-16-51	- 1.80	7-24-52	.90	4- 1-53	- 4.20	12-15-53	2.50
	4-11-51	0.67	10-11-52	1.88	5-16-53	- 5.49	3- 1-54	- 0.1
	6- 6-51	- 3.37	11- 7-52	.74	7-22-53	1.09	9-21-54	2.9
	8-22-51	2.69	12-29-52	- 1.84	9-17-53	2.75	6- 7-55	- 4.5
29-34-1	6-27-51	- 0.27	12-29-52	- .58	7-23-53	1.02	9-16-54	2.40
	7-29-52	1.23	2-11-53	1.20	9-17-53	2.49	9-28-54	2.75
	11- 8-52	- .70	5-30-53	- 2.63	12-15-53	1.73		
29-36-3	11-13-52	- 4.5	7-22-53	- 3.67	8-18-54	- 3.0	6- 6-55	- 5.70
	12-22-52	- 5.6	9-15-53	- 3.01	9-16-54	- 2.5	7-21-55	- 3.17
	2-11-53	- 3.9	10-13-53	- 2.95	11- 9-54	- 4.0	9-15-55	- 3.04
	3-31-53	- 6.9	12-15-53	- 3.07	12-23-54	- 3.4	10-27-55	- 3.98
	5-15-53	- 7.6	3- 2-54	- 8.2	1-31-55	- 3.8	12-13-55	- 4.05
	6- 2-53	- 6.3	4-27-54	- 5.1	4- 4-55	- 4.2		
30-39-19	6- 7-54	- 5.7	11- 9-54	- 8.5	2- 2-55	- 5.3	4- 4-55	- 6.5
	8-18-54	- 5.1	12-23-54	- 5.7	3- 7-55	- 9.3	5-13-55	- 9.5
	9-15-54	- 5.1						

Table 6 (continued)

Well No.	Date	Water level	Date	Water level	Date	Water level	Date	Water level
31–38–4	3–16–51	5.8	10– 2–51	5.6	3–30–53	5.6	8–18–54	7.5
	6– 8–51	5.1	9–27–52	8.3	5–15–53	3.2		
	8– 9–51	7.1	12–11–52	5.6	9–15–53	8.5		
	9–19–51	8.3	2–11–53	8.3	12–16–53	8.8		
32–29–3	6–22–52	2.05	5–16–53	– 3.90	10–15–53	5.0	6–28–54	5.0
	7–29–52	3.20	7–21–53	3.57	12–10–53	5.05	8–23–54	5.2
	2–11–53	3.6	9–17–53	5.09	2–25–54	0.9	9–17–54	4.6
	4– 1–53	1.77						
32–30–1	9–20–54	– 10.05	2– 2–55	– 13.5	10–26–55	– 14.45		
	12–22–54	– 11.9	5– 9–55	– 18.9	12–15–55	– 13.37		
35–26–1	9–20–54	– 11.5	4– 6–55	– 15.3	5–31–55	– 17.95	12–15–55	
	3– 9–55	– 16.8	5– 9–55	– 20.6	10–26–55	– 14.80		
35–33–6	2– 7–51	8.4	12–28–51	10.4	10–30–52	9.8	7–21–53	9.8
	4–16–51	10.8	4–10–52	7.0	12–29–52	7.5	9–14–53	10.7
	6– 6–51	5.5	5– 4–52	4.34	2–10–53	10.5	10–14–53	10.1
	8–23–51	11.9	7–29–52	12.0	4– 1–53	8.0	12–17–53	9.6
	9–26–51	11.5	9–15–52	11.2	5–15–53	4.9	2– 2–55	8.4
	10– 2–51	11.3	10–11–52	10.2	6– 2–53	6.1		
36–29–2	12– 7–52	– 7.5	3–10–55	– 10.60	10–26–55	– 8.07		
	9–22–54	– 2.7	5–31–55	– 8.10	12–15–55	– 5.99		
36–32–2	3–20–51	13.1	7–29–52	13.0	5–15–53	6.7	9–14–54	13.6
	4–16–51	14.2	9–15–52	14.3	6– 2–53	8.0	9–28–54	15.5
	6– 6–51	11.5	10–11–52	14.1	7–21–53	11.4	3– 9–55	9.0
	8–15–51	14.1	10–30–52	12.1	9–14–53	14.1	5–31–55	11.6
	5– 4–52	7.6	2–10–53	3.2	10–15–53	13.6		
	6–26–52	11.3	4– 2–53	9.0	12–17–53	13.6		

Table 6 (continued)

Well No.	Date	Water level	Date	Water level	Date	Water level	Date	Water level
37-24-2	4-20-52	- 1.83	4- 1-53	- 4.10	6-28-54	0.5	4-19-55	- 2.40
	6-22-52	- 2.26	5-16-53	- 6.44	8-23-54	.7	5- 9-55	- 8.00
	7-24-52	1.00	7-22-53	- 0.38	9-30-54	1.35	5-31-55	- 5.60
	9-16-52	- 0.75	8-19-53	0.2	11-11-54	- 1.75	10-26-55	- 2.57
	10-11-52	.25	9-17-53	1.05	12-21-54	- .9	12-15-55	- 3.64
	12-11-52	- 1.79	12-15-53	1.20	2- 1-55	- 2.9	...	...
	2-11-53	- .64	2-25-54	- 2.9	3- 9-55	- 5.15	...	...
38-32-9	3-20-51	13.2	10-11-52	14.1	3- 2-54	14.7	2- 1-55	12.9
	4-16-51	14.7	2-10-53	12.2	6-29-54	16.2	3- 9-55	11.7
	6- 8-51	12.1	4- 2-53	8.2	8-17-54	14.7	4- 4-55	13.9
	8-18-51	13.5	5-15-53	9.5	9-14-54	12.6	5-13-55	9.9
	9-25-51	7.9	6- 1-53	9.4	9-28-54	15.4	5-31-55	13.0
	5- 4-52	8.0	7-21-53	15.3	11- 5-54	13.5	9-15-55	12.2
	7-29-52	11.5	9-14-53	14.9	12-22-54	14.0	12-14-55	12.5
	9-15-52	9.5	12-17-53	11.2	...	...	...	...

TABLE 7. Logs of Selected Wells in Manatee County
Well 17-11-1
(Florida Geological Survey No. W-2595)

Lithology	Depth Below Land Surface (feet)
Pleistocene and Pliocene:	
Sand, clear, fine, quartz	0-3
Sand, dark brown, fine, with some coarse grains; contains carbonaceous and limonitic material ("hardpan")	3-10
Sand, tan, fine	10-15
Sand, brown, very fine; a few heavy mineral grains and some limonite	15-20
Sand, tan, less stained than above, fine to medium	20-25
Sand, darker tan than above, medium, with some fine and a few large frosted pebbles; some sand is frosted and some is polished	25-40
Sand, dark gray-brown, fine to medium; dark mineral grains, some larger polished quartz grains	40-50
Sand, dark tan, fine to medium, with some rounded, frosted, and polished pebbles; a few phosphate minerals; fragments of brown sandstone	50-60
Sand, lighter tan than above, fine to medium, with frosted and polished pebbles of quartz; many dark gray pebbles of phosphate minerals	60-65
Sand, as above, but lighter in color and finer	65-70
Sand, as above, but dark gray-tan in color	70-75
Sand, as above, with some calcareous cement	75-80
Sand, gray, medium to coarse; much black phosphate minerals, fine to pebble size; calcareous clay	80-90
Sand and gravel of quartz and phosphate minerals; gray fairly hard, sandy, silty limestone; shark tooth	90-95
Hawthorn formation:	
Sand and gravel of quartz and phosphate minerals; gray-green, silty, calcareous, slightly sandy clay, with fine black and gray phosphate minerals	95-105
As above, with fragments of gray-tan to dark gray limestone	105-125
Clay, greenish-gray and green, calcareous, sandy, phosphatic	125-129
Sand and gravel of quartz and phosphate minerals; dark gray, hard, sandy limestone	129-135
Limestone, light to dark gray, hard, sandy; phosphate and quartz pebbles; mollusk fragments	135-144
Clay, light gray, chalky, sandy; limestone as above; quartz and phosphate pebbles	144-155
Clay, gray, silty, sandy, calcareous; fine-grained phosphate minerals; impure limestone	155-170
Limestone, gray to tan, hard, sandy, porous in part, crystalline in part, fossiliferous; chert	170-180
Limestone, gray-white, fairly hard, crystalline in part, fossiliferous, slightly sandy	180-196
Limestone, as above; gray, calcareous, chalky, sandy clay; chert; sand; phosphate minerals	196-213
Clay, as above; gray and tan, hard, dense limestone	213-218
Clay, as above; gray-white, hard, sandy limestone, crystalline in part; chert; phosphate minerals	218-230
Clay, dark gray-green, calcareous, silty, sandy; phosphate minerals; limestone, as above	230-235
Clay, gray-white, chalky, sandy, with phosphate grains and pebbles; white to tan, hard, sandy limestone; some chert	235-260

Clay, gray, calcareous, sandy, with phosphate; tan and gray, hard, sandy limestone; phosphate minerals and chert	260-291
Limestone, white to tan, soft, fairly pure, fine, granular, fossiliferous; chert and phosphate pebbles	291-300
Clay, white, chalky; tan, fairly soft, fossiliferous limestone, crystalline in part; some chert	300-306
Clay, dark green, silty, sandy, calcareous; white, gray, and tan, hard, dense limestone, crystalline in part; chert	306-317
Clay, reddish-tan, calcareous; tan and gray, hard, dense limestone, some white, sandy; much dark brown chert	317-323
Clay, white, chalky; tan, hard, finely crystalline dolomitic, fossiliferous limestone; chert; fine sand; phosphate minerals	323-340
Clay, as above, with brown and gray chert	340-345
Clay, gray and white, chalky, phosphatic; tan, finely crystalline, hard limestone; some chert	345-360
Clay, gray, sandy, chalky, phosphatic; white to tan, soft, sandy limestone, porous in part, hard, dense, silicified, dolomitic in part, fossiliferous in part	360-365
Clay, as above; white and gray, hard limestone, very sandy in part	365-377
Clay and limestone, as above; many shell fragments, ostracods, and Foraminifera	377-383
Tampa formation:	
Limestone, white and gray, fragmental, fossiliferous	383-390
Limestone, white to tan, soft, sandy in part, porous; fine sand; shell fragments, Foraminifera	390-396
Limestone, gray, white and tan, hard, sandy, fossiliferous; contains crystalline calcite, phosphate minerals, sand and chalcedony	396-400
Limestone, gray, white to tan, hard, very sandy, dolomitic in part, porous in part; some chert; fossiliferous, mollusks, echinoid spines, *Sorites* sp., and other Foraminifera	400-443
Limestone, creamy white, soft, chalky, containing many Bryozoa, also gray and tan, hard, sandy, fossiliferous	443-456
Limestone, white, soft, chalky, sandy, fossiliferous; phosphate grains	456-464
Limestone, as above, with some dark gray, hard, sandy	464-471
Limestone, light to dark gray, tan, hard, dense, very sandy, crystalline and dolomitic in part; fossiliferous; some phosphate and chert	471-497
Limestone, white, fairly soft, chalky, very sandy, fossiliferous; some black phosphate grains; molds and casts of mollusks	497-512
Clay, gray, green, waxy; fine sand; phosphate minerals; limestone, gray, hard, dense, with fragments and pebbles of sandy limestone	512-517
Limestone, white and tan, chalky, sandy, granular in part; chert and chalcedony; mollusk molds and casts, and ostracods	517-539
Clay, gray to tan, waxy, shaly, slightly sandy, calcareous; much very fine phosphate, also some white, chalky, very sandy; a few limestone fragments	539-544
Limestone, white, soft, chalky, very sandy; phosphate minerals; also some tan, hard, dense limestone	544-578
Limestone, as above; some chert	578-582
Limestone, as above, fossiliferous	582-586
Limestone, as above, also tan and brown, hard, dense, less sandy, fossiliferous; very little phosphate	586-596
Limestone, gray, tan, and brown, hard, dense, sandy in part, porous in part, fossiliferous; contains crystalline calcite	596-608
Limestone, as above, but more granular; *Archaias floridanus* present	608-612
No sample	612-624

Suwannee limestone:	
Limestone, creamy white and tan, fairly hard, granular, porous in part; poorly preserved fossils, *Rotalia mexicana,* and other Foraminifera	624-631
Limestone, white to tan, soft, pure, granular, porous, fossiliferous; abundant echinoid spines and plates, *Rotalia mexicana,* and other Foraminifera	631-720
Limestone, as above, but darker tan and more crystalline; fewer Foraminifera	720-767
Limestone, as above, but less granular	767-773
Ocala group:	
Limestone, gray-tan, "dirty" appearing, fairly soft, somewhat granular, fossiliferous	773-783
Limestone, gray, tan, fairly hard to soft, granular to fragmental, crystalline in part, fossiliferous; many Foraminifera, including *Gypsina globula*	783-805
Limestone, as above, with *Lepidocyclina floridensis, L. ocalana, Heterostegina ocalana, Operculinoides* sp.	805-831
Limestone, gray to tan; foraminiferal coquina with a fine granular chalky matrix, *Nummulites* sp., *Gypsina globula, Lepidocyclina ocalana, Operculinoides floridensis, Heterostegina ocalana*	831-930
Limestone, as above; gray-tan, sticky, calcareous clay	930-937
Limestone, as above, and brown, hard, crystalline dolomite	937-955
Limestone, dark brown, saccharoidal, dolomitic; some fragments are white, fairly soft	955-974
Limestone, as above, but porous	974-981
Limestone, as above, but lighter in color	981-987
Limestone, as above, but gray-tan in color	987-1,051
Limestone, dark brown, saccharoidal, dolomitic; some fragments are white and gray	1,051-1,063
Limestone, as above, also tan, fairly hard, dense, some granular, porous in part, fossiliferous; contains mollusks, echinoids, ostracods, Foraminifera, *Gypsina globula, Nummulites* sp., and others	1,063-1,089
Limestone, gray and tan, hard, dense, dolomitic in part, crystalline in part, has chalky matrix; mollusks, echinoids, Foraminifera	1,089-1,097
Avon Park limestone:	
Limestone, tan, fairly soft, granular, chalky, crystalline calcite, echinoids, ostracods, *Dictyoconus cookei,* and other Foraminifera	1,097-1,112
Limestone, as above, also porous, foraminiferal; abundant *Dictyoconus cookei,* ostracods, echinoids	1,112-1,136
Limestone, creamy white and tan, soft, granular with a chalky matrix, foraminiferal, crystalline in part; *Dictyoconus cookei, Lituonella floridanus, Valvulina* sp., and other Foraminifera	1,136-1,151
Limestone, white and tan, soft, chalky, granular, porous, foraminiferal; *Dictyoconus cookei, Spirolina coryensis, Valvulina* sp., and others	1,151-1,246
Limestone, as above, but with fewer fossils; also brown hard crystalline dolomite	1,246-1,253
Limestone, creamy white to gray-white and tan, hard, dense to granular, chalky, fossiliferous; some brown crystalline dolomite; *Dictyoconus cookei,* and others	1,253-1,275
Limestone, as above, fossils fewer and poorly preserved	1,275-1,301
Limestone, as above, but more fossiliferous	1,301-1,330
Limestone, dark tan and gray, hard, dense, nodular, porous in part, fossiliferous; *Dictyoconus cookei,* and others	1,330-1,376
Limestone, as above; dolomite, dark brown, crystalline, porous	1,376-1,418

Well 23-30-1
(Florida Geological Survey No. W-257)

Lithology	Depth Below Land Surface (feet)
No sample	0-25
Hawthorn formation:	
Clay, dark gray-green, shaly, slightly sandy, phosphatic, calcareous; small amount of white soft limestone, and a few shell fragments	25-35
Limestone, white, soft and chalky to hard; fine black phosphate minerals; some fine sand	35-40
Clay, dark gray-green, silty, slightly sandy, calcareous; some phosphate minerals	40-50
Clay, gray-white, chalky, with fine phosphate minerals; white hard dolomitic limestone; some chert and fine sand	50-60
No sample	60-90
Clay, gray-white, chalky, with fine phosphate minerals; limestone, white, hard, dolomitic; some chert and fine sand	90-120
Clay, gray, very sandy, calcareous, silty; much fine dark phosphate minerals and some white limestone	120-175
Clay, white, chalky, sandy; phosphate minerals; some limestone and chert; fragments of mollusks and echinoids	175-200
No samples	200-230
Clay, dark gray, calcareous, silty; fine to coarse sand; gray, tan, and black phosphate minerals	230-240
Clay, gray, silty, sandy, calcareous; phosphate minerals and some white soft limestone; some chert	240-250
Clay, gray-white, chalky, slightly sandy; some fine phosphate minerals; some gray-green waxy clay; some soft white limestone	250-280
Clay, as above; white, soft, sandy limestone, containing some chert and mollusk fragments	280-290
Clay, as above, with some limestone, chert, and sand	290-390
Tampa formation:	
Clay, as above; limestone, white, soft, finely crystalline, dolomitic; chert; oolitic chalcedony	390-400
Limestone, creamy white, very sandy, fairly soft; fragments of mollusks, Bryozoa and echinoids; ostracods and Foraminifera	400-420
Limestone, as above; *Sorites* sp.	420-440
Limestone, tan and brown, less sandy than above; abundant fossils	440-470
Limestone, creamy white to tan, hard, porous in part, sandy in part, fossiliferous, crystalline in part; *Archaias floridanus*, and *Sorites* sp.	470-500
Limestone, as above; also tan, hard, somewhat granular, porous, fossiliferous	500-550
Limestone, gray-white to tan, fairly hard, porous, somewhat granular, sandy, fossiliferous, *Archaias floridanus*, and other Foraminifera.	550-560
Suwannee limestone:	
Limestone, gray to tan, granular, porous, crystalline in part, fossiliferous	560-580
Limestone, creamy white to tan, pure, soft, granular, very porous, finely crystalline, fossiliferous; abundant miliolids and other Foraminifera	580-590
Limestone, as above, well preserved; *Rotalia mexicana*	590-600
Limestone, white, soft, granular, porous, very fossiliferous	600-630
Limestone, cream to tan, soft, granular to dense, porous, fossiliferous	630-640
No sample	640-650
Limestone, tan, hard, dense, fossiliferous	650-675

Well 26-22-1
(Florida Geological Survey No. W-3612)

Lithology	Depth Below Land Surface (feet)
Pleistocene and Pliocene:	
Sand, clay, impure limestone, quartz, and phosphate gravel	0-10
Clay, greenish-gray, calcareous, silty, sandy; quartz and phosphate gravel; gray, hard, sandy, impure limestone fragments; mollusk fragments	10-60
Hawthorn formation:	
Limestone, gray-white, chalky, dolomitic, sandy in part; phosphate grains and pebbles; gray, calcareous, sandy clay	60-120
Limestone, as above, with some chert	120-140
Limestone, gray-white, soft, chalky, sandy, to gray, hard, dense; clay, greenish-gray, sandy, calcareous, phosphatic	140-150
Clay, gray to greenish-gray, chalky, sandy, phosphatic; white and gray, soft, chalky to hard, dense limestone	150-160
Clay, gray-white, chalky, sandy, phosphatic; sand; gray chert and some impure limestone	160-210
Clay, as above; limestone, gray-white, hard, sandy; chert; phosphate grains and pebbles; mollusk fragments	210-220
Clay, as above; tan to dark gray, crystalline, sandy, phosphatic limestone	220-240
As above, with much sand and phosphate minerals	240-290
As above, with some chert	290-300
Limestone, white to gray, hard, sandy in part, fossiliferous; green waxy, silty, sandy, calcareous, phosphatic clay	300-330
Clay, gray, chalky, sandy, phosphatic; gray and tan, hard, very sandy limestone, crystalline and dolomitic in part	330-360
Tampa formation:	
Limestone, tan, fairly hard, sandy, porous, crystalline in part, fossiliferous; small amount of phosphate minerals; mollusk casts and molds, echinoid spines and Foraminifera, *Archaias floridanus,* and *Sorites* sp.	360-380
Limestone, as above, with some chert	380-390
Limestone, as above, but less porous	390-400
Limestone, light to dark tan and gray, hard, dense, sandy, crystalline in part, fossiliferous	400-450
Limestone, gray-white, hard, dense, porous in part, slightly sandy, fossiliferous; *Archaias floridanus*	450-460
Limestone, gray and tan, hard, dense, porous (contains solution cavities), partly granular, sandy, fossiliferous; abundant miliolids, *Archaias floridanus*	460-480
Limestone, white to tan, fairly hard, sandy in part, porous; some fragments are creamy white, soft, granular, porous, and fossiliferous; *Archaias floridanus,* and *Sorites* sp.	480-530
Suwannee limestone:	
Limestone, creamy white, soft, granular, fossiliferous, crystalline in part; *Rotalia mexicana,* and other Foraminifera	530-550
No sample	550-556
Limestone, creamy white to tan, soft, granular, porous, fossiliferous, crystalline in part; mollusk fragments, echinoid spines and plates, Foraminifera, *Rotalia mexicana*	556-610
Limestone, gray-tan, harder and more crystalline than above, granular in part, porous, fossiliferous, mollusks, echinoids, *Rotalia mexicana,* and other Foraminifera	610-630

Limestone, as above, but more granular and softer	630-660
Limestone, tan and brown, hard, crystalline and dolomitic, fossiliferous; mollusks, echinoids, *Rotalia mexicana*, and other Foraminifera	660-700
Limestone, tan, fairly hard, granular to chalky, crystalline in part, fossiliferous, *Rotalia mexicana*, and other Foraminifera	700-720
Ocala group:	
Limestone, tan, soft, fragmental, silty, chalky, crystalline in part, foraminiferal, *Gypsina globula*, *Nummulites* sp., *Lepidocyclina ocalana*, *L. floridensis*, and others	720-840
Limestone, coquina of foraminifers and other fossils in a chalky matrix; *Camerina*, *Gypsina globula*, *Lepidocyclina ocalana*, *Operculinoides floridensis*, *Heterostegina ocalana*, and others	840-960
Limestone, brown, hard, dolomitic and crystalline, chalky matrix, not very fossiliferous; a few *Lepidocyclina* noted	960-990
Limestone, as above, more fossiliferous; *Nummulites* sp., *Lepidocyclina ocalana*, *Operculinoides* sp., and others	990-1,000
Limestone, white to brown, chalky, soft, crystalline, coquinoid; Foraminifera and other fossils	1,000-1,020
Avon Park limestone:	
Limestone, tan to brown, fairly soft, granular, crystalline in part, dolomitic, chalky matrix, fossiliferous, echinoids, *Dictyoconus cookei*, *Spirolina coryensis*	1,020-1,060
Limestone, as above but softer and more chalky	1,060-1,080
Limestone, cream and tan, soft, coquinoid, some crystalline and dolomitic	1,080-1,110
Limestone, light to dark brown, hard, dolomitic, crystalline, limonitic in part; contains solution cavities; some lignite	1,110-1,130
Limestone, as above, with fragments that are white, soft, fossiliferous, and porous	1,130-1,140
Limestone, as above; *Coskinolina floridana*, *Dictyoconus cookei*, *Spirolina coryensis*, *Valvulina* sp., and other Foraminifera	1,140-1,160
Limestone, dark brown, hard, crystalline, dolomitic, porous	1,160-1,170
Limestone, dark gray and brown, hard, dense, finely crystalline, dolomitic, porous in part, lignitic	1,170-1,190
No sample	1,190-1,320
Limestone, dark brown, as above, to tan, very porous; no fossils noted	1,320-1,370
Limestone, as above, with some carbonaceous material	1,370-1,400
Limestone, as above; fossils rare, poorly preserved	1,400-1,420
Limestone, tan, fairly soft, somewhat granular, porous, carbonaceous; few poorly preserved fossils	1,420-1,510
Limestone, tan and brown, hard, crystalline in part, porous in part, limonitic in part, carbonaceous	1,510-1,540

Well 29-33-1
(Florida Geological Survey No. W-75)

Lithology	Depth Below Land Surface (feet)
Pleistocene and Pliocene:	
No sample	0-20
Sand, brown stained, fine to coarse, quartz; large rounded and frosted quartz pebbles; some impure limestone fragments; carbonaceous material	20-21
Sand, white, quartz, fine; pebbles as above; brown shaly clay; bone fragments	21-24
Limestone, white, hard, dolomitic, somewhat chalky; fine sand and phosphate minerals	24-30
Limestone, white, hard, dolomitic, porous in part, phosphatic; chert; mollusk casts and molds	30-38
Hawthorn formation:	
Limestone, white, chalky, sandy in part; phosphate, fine sand to pebble size	38-74
Clay, gray, calcareous, sandy; phosphate grains and pebbles; limestone, gray, fairly hard, impure, sandy; chert	74-78
Clay and limestone as above; phosphate gravel; much chert	78-80
Clay, gray, chalky, sandy, phosphatic; limestone, white, sandy, chalky, phosphatic; chert	80-96
Clay, light to dark gray, calcareous, sticky, sandy; impure limestone; phosphate minerals and chert	96-110
Clay, dark blue-gray, calcareous, sticky, phosphatic	110-126
No sample	126-132
Clay, gray, calcareous, sticky, phosphatic; limestone and chert	132-154
Clay, gray, calcareous, silty, sandy, phosphatic; some gray, sandy limestone; a few mollusks	154-185
Clay, white, chalky, sandy; phosphate grains and pebbles; white, hard, sandy, phosphatic limestone; a few mollusk molds and casts	185-220
Limestone, gray, hard, silicified, sandy in part, phosphatic	220-235
Clay, gray-white, calcareous, sandy, phosphatic; white fairly hard limestone; sandy chert and chalcedony	235-250
Clay, as above; white, fairly hard, dense limestone; shell fragments	250-270
Clay, gray, calcareous, sandy; white and gray, hard, phosphatic, sandy limestone; fine sand and pebbles; chalcedony	270-280
Hawthorn and Tampa formations undifferentiated:	
Clay, as above; gray and tan, fairly hard, sandy, fossiliferous limestone; chalcedony; *Archaias, Sorites,* and other Foraminifera	280-300
Tampa formation:	
Limestone, gray and tan, hard, dense, porous in part, sandy in part, fossiliferous, phosphatic; *Archaias floridanus* and *Sorites* sp.	300-340
Limestone, tan, slightly sandy, fairly hard, porous, fossiliferous; mollusks and Foraminifera, *Archaias floridanus* and *Sorites* sp.	340-370
Limestone, tan, fairly hard, sandy, porous, crystalline in part; chert; mollusks, ostracods, *Archaias floridanus, Sorites,* sp., and other Foraminifera	370-397
Limestone, gray and tan, hard, slightly sandy, dense, porous in part, dolomitic in part, fossiliferous; some chert	397-440
Suwannee limestone:	
Limestone, creamy white and tan, soft, granular, porous, foraminiferal	440-450

Limestone, creamy white, soft, chalky, granular, porous, fossiliferous	450-535
Limestone, white and tan, soft, granular, fossiliferous; mollusks, abundant echinoid spines and plates, *Rotalia mexicana*, and other Foraminifera	535-555
Limestone, gray and tan, soft, granular, porous; echinoid fragments abundant, few Foraminifera	555-575
Limestone, as above, with abundant well-preserved *Rotalia mexicana*, and other Foraminifera	575-600
Limestone, creamy white, soft, granular, porous, somewhat chalky, foraminiferal	600-650
Limestone, tan, soft, granular, fossiliferous, *Rotalia mexicana*	650-667
Limestone, dark tan, granular, crystalline in part, fossiliferous; *Dictyoconus cookei*, *Rotalia mexicana*, and other Foraminifera	667-685
Dolomite, tan to dark brown, hard, finely crystalline, porous in part; some limestone as above	685-700
Limestone, gray and tan, hard, dense, finely crystalline, dolomitic	700-710
Dolomite, dark brown, hard, crystalline; tan, granular, porous, chalky limestone; abundant miliolids	710-745
Ocala Group:	
Limestone, creamy white and tan, fragmental, granular, somewhat chalky, very fossiliferous; mollusks, echinoids, Bryozoa, *Gypsina globula*, and other Foraminifera	745-800
Limestone, white and tan, soft, granular; in part a foraminiferal coquina, *Nummulites* sp., *Lepidocyclina* sp., *Heterostegina ocalana*, and others	800-922

Well 30-27-4
(Florida Geological Survey No. W-2317)

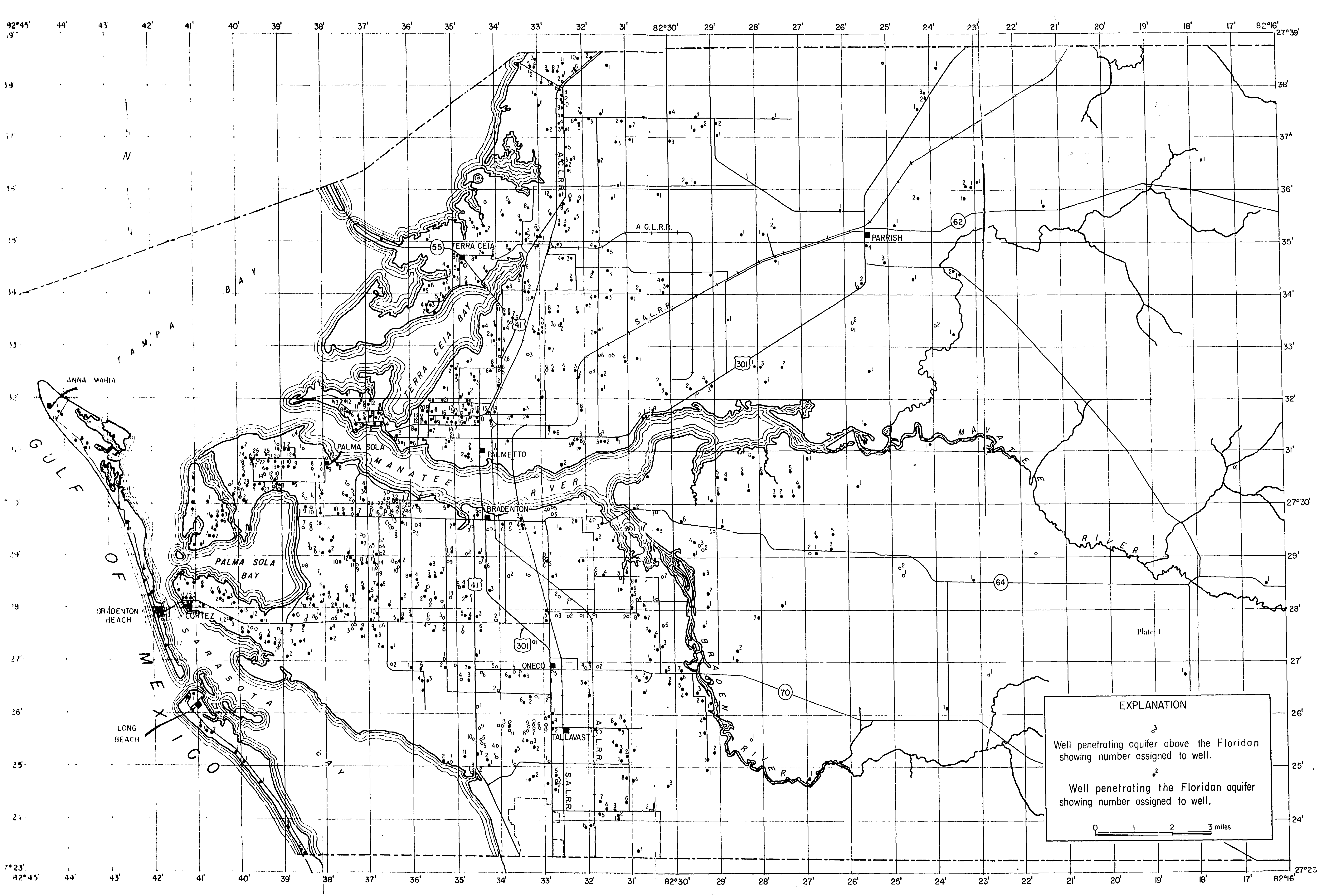
Lithology	Depth Below Land Surface (feet)
No sample	0-75
Hawthorn formation:	
Clay, gray-white, calcareous, chalky, sandy; fine phosphate grains; limestone, gray, tan, sandy in part, crystalline in part, porous in part, phosphatic; few fossil fragments	75-105
Clay, as above; sand, fine to medium; shells	105-115
Clay, gray, chalky, sandy, and green shale; light gray, hard, sandy limestone, porous in part; chert; phosphate minerals; fragments of mollusk shells and casts	115-135
Clay, gray-white, gray and tan, sandy, calcareous, phosphatic; gray, hard, sandy limestone	135-145
Silt, greenish-gray, calcareous, very sandy; fine sand; fine black phosphate minerals; some gray-white limestone	145-155
Clay, gray-tan, silty, very sandy, calcareous; fine phosphate; limestone, gray, hard, with few mollusk molds and casts	155-175
Clay, dark gray-green, very silty and sandy, some dark gray-brown, waxy; small amount of limestone	175-195
As above, with some chert	195-225
Clay, gray-white, chalky to greenish-gray, waxy, sandy; limestone, gray, impure, sandy; mollusk molds and casts; phosphate minerals; some chert	225-265
Clay, white, chalky, sandy; phosphate minerals; limestone fragments; chert	265-285
Limestone, light to dark gray, hard, sandy, dolomitic in part; chert; a few mollusk fragments	285-295
Limestone, as above; clay, gray, chalky, sandy, phosphatic	295-315
Clay, as above; some dolomite; limestone and shell fragments	315-325
Hawthorn and Tampa formations undifferentiated:	
Clay, as above; white and gray sandy limestone, dolomitic in part; mollusk and echinoid fragments	325-335
Tampa formation:	
Limestone, white and gray, hard, sandy, porous, fossiliferous, dolomitic in part; mollusks, echinoids, *Archaias floridanus, Sorites* sp., and other Foraminifera	335-345
Limestone, tan, gray and brown, fairly hard, porous, sandy in part, dolomitic and crystalline in part, fossiliferous; mollusks, *Archaias floridanus, Sorites* sp., and other Foraminifera	345-385
Limestone, light to dark gray and tan, hard, sandy, fossiliferous, dolomitic and crystalline in part; *Archaias floridanus* and *Sorites* sp.	385-435
Limestone, white and tan, hard, sandy, fossiliferous, porous in part	435-465
Suwannee limestone:	
Limestone, light gray and tan, fairly soft, granular, porous, fossiliferous, *Rotalia mexicana* and other Foraminifera	465-485
Limestone, tan, soft, granular, porous, fossiliferous, crystalline; calcite; mollusks, echinoids, *Rotalia mexicana,* and other Foraminifera	485-545
Limestone, tan to gray-tan, soft, granular, porous; abundant mollusks, echinoids, *Rotalia mexicana,* and other Foraminifera	545-605
Limestone, gray, tan and brown, granular, fossiliferous, as above, with specimens of *Dictyoconus cookei*	605-625

Well 35-26-1
(Florida Geological Survey No. W-2715)

Lithology	Depth Below Land Surface (feet)
Pleistocene and Pliocene:	
Sand	0-15
Clay, yellow to brown, calcareous, fine to coarse sand and phosphate grains	15-21
Hawthorn formation:	
Clay, gray, calcareous; phosphate minerals, sand and pebbles	21-61
Sand, quartz and phosphate, fine; some clay, as above	61-62
Clay, gray-green, slightly calcareous, silty, slightly sandy, very fine, phosphatic	62-85
Clay, gray, calcareous, sandy; phosphate minerals and sand, fine	85-100
Clay, as above; white and gray, hard, impure limestone, porous in part	100-140
Clay, light gray to dark greenish-gray, silty, phosphatic; very little sand	140-160
Clay, light to dark gray, calcareous, sandy, phosphatic; fragments of gray limestone	160-185
Clay, gray-white, chalky, silty, slightly sandy, phosphatic	185-200
Clay, as above; gray and tan, hard, dense, sandy limestone	200-215
Clay and limestone, as above; many phosphate pebbles; gray chert; mollusks and ostracods	215-250
Clay, as above; some limestone, as above; much quartz and phosphate sand	250-330
Limestone, gray and brown, hard, crystalline, some white, soft, sandy, fossiliferous; fragments of *Archaias floridanus*	330-347
Tampa formation:	
Limestone, dark brown, hard, sandy, crystalline and dolomitic, porous in part; chert; *Archaias floridanus*	347-385
Limestone, tan, gray and brown, hard, crystalline, sandy, dolomitic, porous; chert	385-400
Limestone, gray and tan, soft, chalky to fairly hard, granular in part, porous, fossiliferous; miliolids, *Archaias floridanus*, and other Foraminifera	400-450
Suwannee limestone:	
Limestone, creamy white to tan, soft, granular, porous, some crystalline, and fossiliferous; mollusks, echinoids, *Rotalia mexicana*, and other Foraminifera	450-570
Limestone, cream to tan, granular, crystalline in part, to gray hard, dense; chert; *Coskinolina floridana*, *Dictyoconus cookei*, *Rotalia mexicana*, and other Foraminifera	570-590

Well 36-29-1
(Florida Geological Survey No. W-2393)

Lithology	Depth Below Land Surface (feet)
No sample	0-75
Hawthorn formation:	
Clay, gray, sandy, calcareous; with phosphate grains and pebbles and a few fragments gray impure limestone	75-85
Clay, as above; gray-white, sandy, phosphatic limestone	85-100
Clay, as above; light to dark gray limestone, very sandy in part; fine to coarse phosphate sand; few shell fragments	100-125
Clay, greenish-gray, calcareous, sandy; gray and black phosphate grains and pebbles; gray, hard, impure, sandy limestone; a few poorly preserved Foraminifera	125-150
Clay, gray, sandy, calcareous, with fine to coarse phosphate sand; gray and tan, fairly hard, impure, sandy limestone; few shell fragments and poorly preserved Foraminifera	150-175
Clay, as above, with a few limestone fragments	175-200
Limestone, gray-white, fairly soft, chalky, sandy, with phosphate; few mollusk fragments; gray, calcareous, sandy clay, large phosphate pebbles	200-225
Limestone, gray-white to tan, fairly hard, sandy in part, dolomitic; gray, calcareous clay; fine phosphate sand and pebbles	225-250
Tampa formation:	
Limestone, gray-white to tan, fairly hard, dense, sandy, dolomitic, fossiliferous; a few mollusk mold and cast fragments; dark gray chert; fine sand	250-275
Limestone, white, gray, and tan, hard, dense, sandy, phosphatic; solution cavities; mollusks, ostracods, and Foraminifera, *Archaias floridanus,* and *Sorites* sp. present	275-300
Limestone, white to gray, fairly hard, dense, sandy, dolomitic and crystalline in part; phosphate minerals and chert; mollusks, ostracods, and Foraminifera, *Archaias floridanus, Sorites* sp.	300-325
Limestone, gray and tan, hard, dense, sandy; solution cavities; few phosphate grains; fossiliferous, as above	325-350
Limestone, as above	350-400
Limestone, tan, hard, dense to soft, granular, porous, sandy in part; mollusks, echinoid spines, Foraminifera	400-410
Suwannee limestone:	
Limestone, white to tan, fairly hard, very porous; contains many solution cavities; small amount of chert; mollusks, echinoid spines, Foraminifera	410-425
Limestone, as above; *Rotalia mexicana* present	425-440
Limestone, creamy white to tan, soft, granular, porous; crystalline calcite in solution cavities; mollusk casts of crystalline calcite; echinoid spines, Foraminifera, *Rotalia mexicana* abundant	440-463
Limestone, as above	463-475
Limestone, as above, dolomitic	475-490
Limestone, as above	490-530
Limestone, tan, gray and brown, fairly hard, granular and porous in part, dolomitic and crystalline in part; some pyrite; mollusks, echinoid spines, Foraminifera, *Dictyoconus cookei* present	530-575
Limestone, tan, soft to hard, granular, crystalline in part, dolomitic; brown, hard, crystalline dolomite; mollusks, echinoids, Foraminifera, *Coskinolina floridana,* and *Dictyoconus cookei*	575-600


EXPLANATION
Well penetrating aquifer above the Floridan showing number assigned to well.
Well penetrating the Floridan aquifer showing number assigned to well.
0 1 2 3 miles
Plate 1
TAMPA BAY
GULF OF MEXICO
ANNA MARIA
BRADENTON BEACH
CORTEZ
LONG BEACH
PALMA SOLA
PALMA SOLA BAY
SARASOTA BAY
TERRA CEIA
TERRA CEIA BAY
MANATEE RIVER
PALMETTO
BRADENTON
ONECO
TALLAVAST
PARRISH
BRADEN RIVER
A.C.L.R.R.
S.A.L.R.R.
A.C.L.R.R.
S.A.L.R.R.
55
41
301
62
64
70
82°45'
82°30'
82°16'
27°39'
27°30'
27°23'