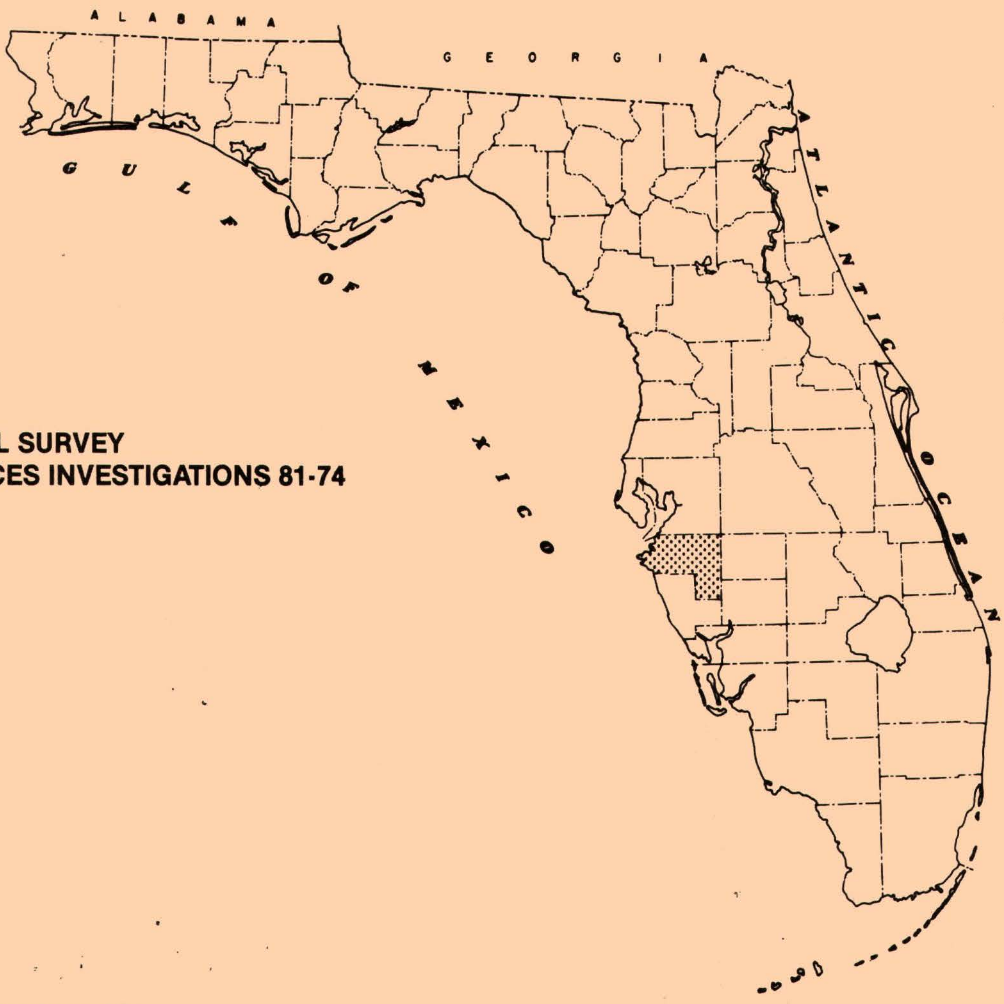
WATER RESOURCES OF MANATEE COUNTY, FLORIDA



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 81-74

Prepared in cooperation with

MANATEE COUNTY, FLORIDA

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16. Abstract (Limit: 200 words)

Rapid development of Manatee County in southwest Florida is creating water-resource problems. The report presents an evaluation of the water resources and potential effects of water-resource developments.

Most streams in the county have small drainage basins and low yields. Streamflow is variable with base flow occurring from November to May. The Manatee River and its largest tributary, the Braden River, are the principal sources of public supplies. Surface water is generally of good quality and less mineralized than ground water except in the tidally affected and coastal area.

The principal aquifers are the surficial, minor artesian, and the Floridan. The Floridan aquifer is the major source of irrigation water in the county. The minor artesian aquifer is a highly developed source of water for small rural supplies.

Withdrawals of 20 to 50 million gallons per day from the Floridan aquifer since the 1950's have caused declines in the potentiometric surface of about 20 to 50 feet.

The quality of ground water is good except in the coastal and southern parts of the county. Water in the Floridan aquifer is generally more mineralized than the other aquifers, generally increasing in mineral content with depth and from the northeast toward the southwest.

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By David P. Brown

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 81-74

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Tallahassee, Florida

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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Factors for converting inch-pound units to International System (SI) units and abbreviation of units

Multiply inch-pound unit	By	To obtain metric (SI) unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (L)
	0.003785	cubic meter (m^3)
square mile (mi^2)	2.590	square kilometer (km^2)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.6309	liter per second (L/s)
million gallons (Mgal)	3,785	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	(°F-32)/1.8	degree Celsius (°C)

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National Geodetic Vertical Datum of 1929 (NGVD of 1929).--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. In this report, NGVD of 1929 is referred to as sea level.

WATER RESOURCES OF MANATEE COUNTY, FLORIDA

By David P. Brown

ABSTRACT

Rapid development of Manatee County in southwest Florida and changes from an agricultural-retirement area to an urban-industrial area are creating water-resource problems. Evaluation of the water resources and potential effects of water-resource developments on the hydrologic environment can define and document water-quality and water-resource problems and water-management and regulatory needs.

Most streams in the county have small drainage basins, short channel lengths, and have low discharges. Streamflow is highly variable with base flow or zero flow occurring in the upper reaches of streams from November to May. The average discharge for 26 years of record of Manatee River near Bradenton is 109 cubic feet per second. Fifty percent of the time, flow near Bradenton may be expected to equal or exceed 24 cubic feet per second.

Surface water is generally less mineralized than ground water except in the tidally affected and coastal areas. Surface water generally is of good chemical quality and suitable for most purposes.

The Manatee River at Lake Manatee Reservoir and its principal tributary, the Braden River at Ward Lake, are sources for public water supplies. In 1977, average daily pumpage at Lake Manatee Reservoir and Ward Lake was 19.1 and 4.0 million gallons per day, respectively.

The principal aquifers in the county are the surficial aquifer, minor artesian aquifer, and the Floridan aquifer. The surficial aquifer is virtually undeveloped as a source of water; the minor artesian aquifer is a highly developed source of water for rural domestic and small public supplies. The Floridan aquifer is the major source of water in the county; the water is primarily used for irrigation. The Floridan aquifer system includes the upper confining beds, the Floridan aquifer, and the lower confining bed. Within the upper confining beds there are permeable zones that form the minor artesian aquifer.

Large withdrawals of water, 20 to 50 million gallons per day, from the Floridan aquifer since the 1950's have caused declines in the potentiometric surface of about 20 feet during periods of minimum pumpage and about 50 feet during periods of maximum pumpage. Seasonal fluctuations have increased from about 10 feet in 1954-55 to 30 feet in 1975.

The quality of ground water is good except in the western (coastal) and southern parts of the county where saltwater intrusion or incomplete flushing of residual seawater has occurred. Water in the Floridan aquifer is generally more mineralized than water from the surficial and minor artesian aquifers. The mineral content of water from the Floridan aquifer generally increases

with depth and from the northeast towards the west and south. Concentrations of chloride greater than 250 milligrams per liter occur in aquifers of the coastal part of the county. Concentrations of sulfate greater than 250 milligrams per liter occur in aquifers of the western and southern parts of the county.

INTRODUCTION

Manatee County, on the west-central coast of Florida, abuts Tampa Bay about 30 miles south of Tampa. Rapid development of the western part of the county and change from an agricultural-retirement area to an urban-industrial area are creating water-resource problems. A need exists for hydrologic information and evaluation of the effects of proposed water-resources developments on the county's hydrologic environment. Recognizing the need, the U.S. Geological Survey, in cooperation with Manatee County, undertook a study to evaluate the water resources of Manatee County. These activities will aid public officials in management of the county's water resources.

The purpose of this report is (1) to describe the geology, hydrology, and quality of water of Manatee County and (2) to evaluate the availability of surface and ground water for development. The report provides Manatee County, the Southwest Florida Water Management District, and the Florida Department of Natural Resources with a data base and an evaluation of the water resources of the area so that water-quality and water-resource problems and water-management and regulatory needs can be adequately defined and documented.

DESCRIPTION OF AREA

Manatee County is bounded by Hillsborough County to the north, DeSoto and Hardee Counties to the east, Sarasota County to the south, and Tampa Bay and the Gulf of Mexico to the west (fig. 1). The county contains about 739 mi^2 of land area and 46 mi^2 of inland surface water. The climate is subtropical, characterized by warm summers and mild winters. The mean annual temperature is about $72^{o}F$. Mean monthly temperatures range from about 60^{o} to $80^{o}F$.

Physiography

Manatee County lies within three physiographic units as described by White (1970). These units include the Gulf Coastal Lowlands, the DeSoto Plain, and the Polk Upland (fig. 1). Topography of these areas is largely controlled by a series of marine terraces that formed during Pleistocene time when the sea stood above its present level (Peek, 1958a). Altitudes of land surface range from sea level along the coast to about 170 feet above sea level in the northeast.

The Pamlico terrace, generally less than 20 feet above sea level, and the Talbot terrace, about 40 feet above sea level, form the relatively flat, poorly drained Gulf Coastal Lowlands. The Penholoway terrace, about 60 to 70 feet

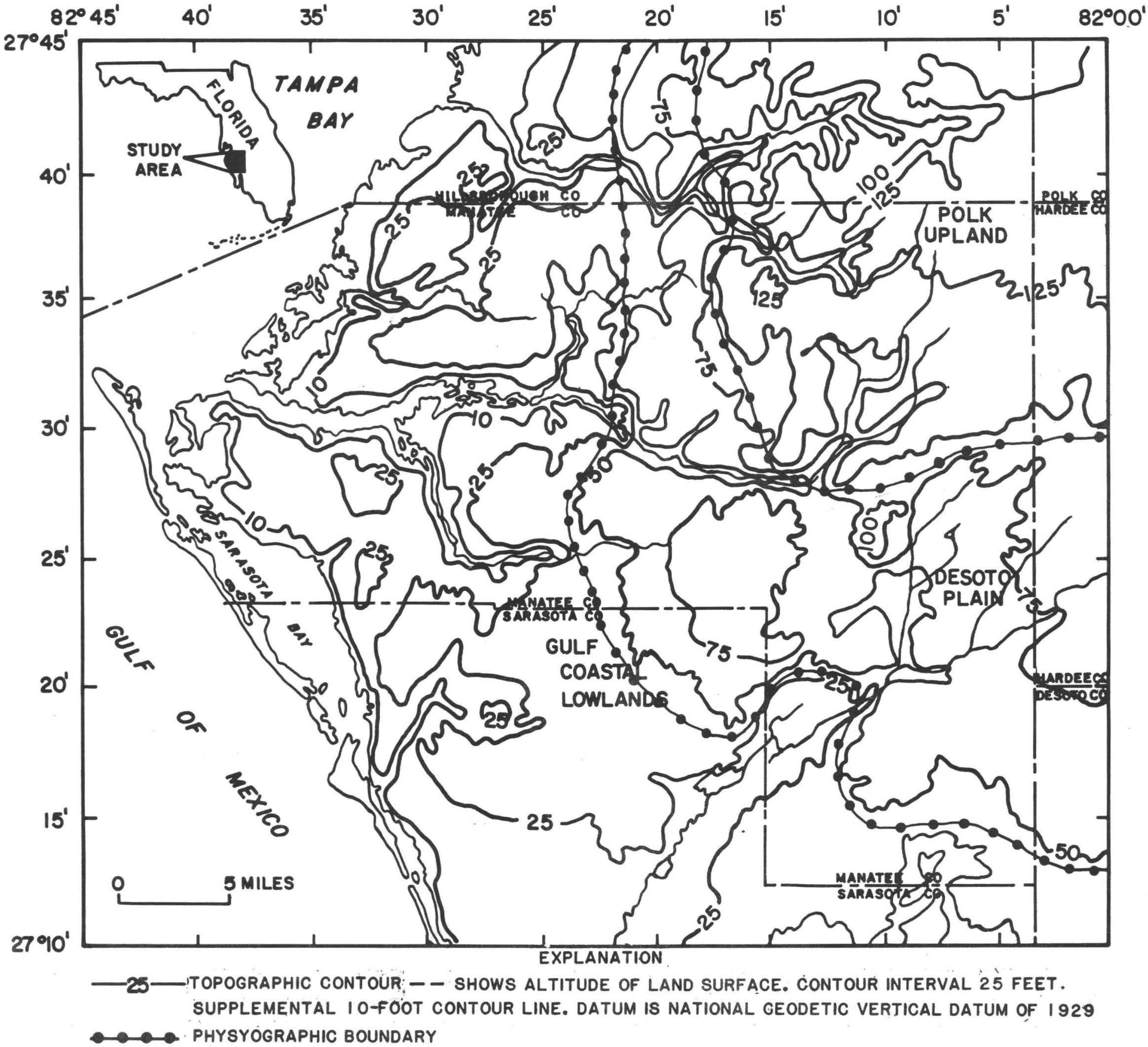


Figure 1.--Location, topography, and physiographic units, Manatee County, Florida.

Table 1.--Geologic formations and hydrogeologic units of Manatee County

[Modified from Peek, 1958, p. 15]

System	Series	Formation	Characteristics	Thickness (feet)	Hydrogeologic unit
Quaternary	Holocene	Surficial deposits	Soil, muck, alluvium, sand.	0- 20	Surficial aquifer
	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.	150-360	Upper confining beds and minor artesian aquifer

	Tampa Limestone	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 Limestone	Limestone, white, cream, tan, chalky, 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	Floridan aquifer
	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	Lower confining bed

above sea level, and the Wicomaco terrace, about 90 to 100 feet above sea level, comprise the DeSoto Plain. The highest and oldest surface is the Sunderland terrace that formed when the sea was about 170 feet above its present level. The Sunderland terrace forms the Polk Upland physiographic unit. The terraces have been modified by stream dissection, but there are large areas of relatively flat surfaces where drainage is poorly developed.

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 flow directly into the Gulf of Mexico. Large portions of the county, generally associated with the relatively flat terraces, are poorly drained and contain numerous small, shallow lakes and swamps. A network of canals has been dug throughout the county to augment natural drainage.

Hydrogeologic Framework

Knowledge of the hydrogeology of an area is essential in evaluating its water resources. Lithology and structure affect and control the occurrence, movement, and quality of ground water and surface water. A general description of the geologic framework is discussed below. Detailed discussions related to aquifers and confining-bed characteristics are contained in the ground-water section of this report.

Manatee County is underlain by a thick sequence of sedimentary rocks consisting of limestones and dolomites overlain by sands, clays, and marls interbedded with limestone. Table 1 shows the age, thickness, and lithology of the stratigraphic units penetrated by water wells. The units range in age from Eocene to Holocene and include, in ascending order, the following: the Lake City Limestone, Avon Park Limestone, Ocala Limestone, Suwannee Limestone, Tampa Limestone, Hawthorn Formation, and surficial deposits consisting of the Bone Valley Formation, Caloosahatchee (?) Marl, Pleistocene terrace deposits, and recent sediments. The surficial deposits and the upper part of the Hawthorn Formation are exposed in outcrops. Subsurface stratigraphic units are described on the basis of rock cuttings, geophysical logs, geologic logs, and drillers' logs.

The principal aquifers are (1) the surficial aquifer, (2) the minor artesian aquifer, and (3) the Floridan aquifer. The surficial aquifer consists of Pliocene and Pleistocene surficial deposits. Water in these deposits occurs in primary openings, such as spaces between grains. The minor artesian aquifer consists of Hawthorn Formation limestone and dolomite beds, marl, sand, and clay, while the Floridan aquifer consists of beds of limestone and dolomite. Water in these two aquifers occurs and moves principally in secondary openings, such as joints along bedding planes and pores that commonly have been enlarged from solution by water.

Land Use

In 1975, major land uses in Manatee County were: (1) rangeland, about 235,000 acres; (2) agricultural land, about 158,000 acres; and (3) urban land, about 38,000 acres (table 2). Principal types of agricultural land were cropland and pasture, 136,000 acres, and orchards and groves, 22,000 acres. Residential land, about 19,000 acres or 3.9 percent of the county, constituted half the urban and built-up land use.

Projected major land uses in the year 2000 remain rangeland, agricultural land, and urban or built-up land. Rangeland and agricultural land will comprise 234,000 acres and 146,000 acres, respectively, a slight decrease from that of 1975. Urban or built-up land will comprise 53,500 acres, an increase of about 30 percent from 1975.

Strip mines, quarries, and gravel pits represent the greatest projected change in acreage from 1975 to 2000. This reflects projected phosphate mining in eastern Manatee County. Mining is projected to utilize 2.5 percent of the land of the county by 1985 then decrease to about 1.8 percent by 2000. By 2035, most mining activity should be complete; representing less than 0.1 percent of land use in the county.

Table 2.--Generalized land use, 1975, and projected land use, 2000

[Modified from Texas Instruments Incorporated, 1978]

Land use	1975		2000		Percent change 1975-2000
	Acres	Percentage of study area	Acres	Percentage of study area	
Rangeland	235,329	47.40	234,130	47.16	-0.5
Agricultural land	158,783	32.00	146,331	29.48	-8.5
Cropland and pasture	136,427	27.48	127,330	25.65	-7.1
Orchards and groves	22,356	4.52	19,001	3.83	-18.0
Other	---	---	---	---	---
Urban or built up	38,152	7.67	53,555	10.78	28.8
Forest land	8,992	1.81	8,868	1.79	-1.1
Water	14,572	2.94	14,572	2.94	0
Wetlands	27,151	5.47	26,266	5.29	-3.3
Barren land					
Strip mines, quarries, and gravel pits	200	.04	8,702	1.75	4,275
Other	13,276	2.67	4,031	.81	-229.6
Total	496,455	100.0	496,455	100.0	

HYDROLOGIC SYSTEM

The source of freshwater in Manatee County is from rainfall in the county or in adjacent areas. Part of the rainfall collects in topographic depressions such as lakes, swamps, and marshes, or enters stream channels and flows out of the county. Some rainfall infiltrates into the soil and shallow aquifers, eventually returning to the surface as seepage and spring flow, or infiltrates into deep aquifers where it may remain in storage for thousands of years or until pumped. Most rainfall, however, returns to the atmosphere by evapotranspiration.

Rainfall and Evapotranspiration

The average annual rainfall in Manatee County is about 55 inches. Annual rainfall at Bradenton, near the coast, averaged 56.1 inches from 1956 to 1976; normal annual rainfall (1941-70) is 56.4 inches. From 1956 to 1976, average annual rainfall at Fort Green, in northeastern Manatee County, was 53.6 inches. From 1960 to 1976, rainfall was generally below normal; the cumulative departure from average annual rainfall (1956-76) was -44.6 inches at Bradenton and -33.8 inches at Fort Green.

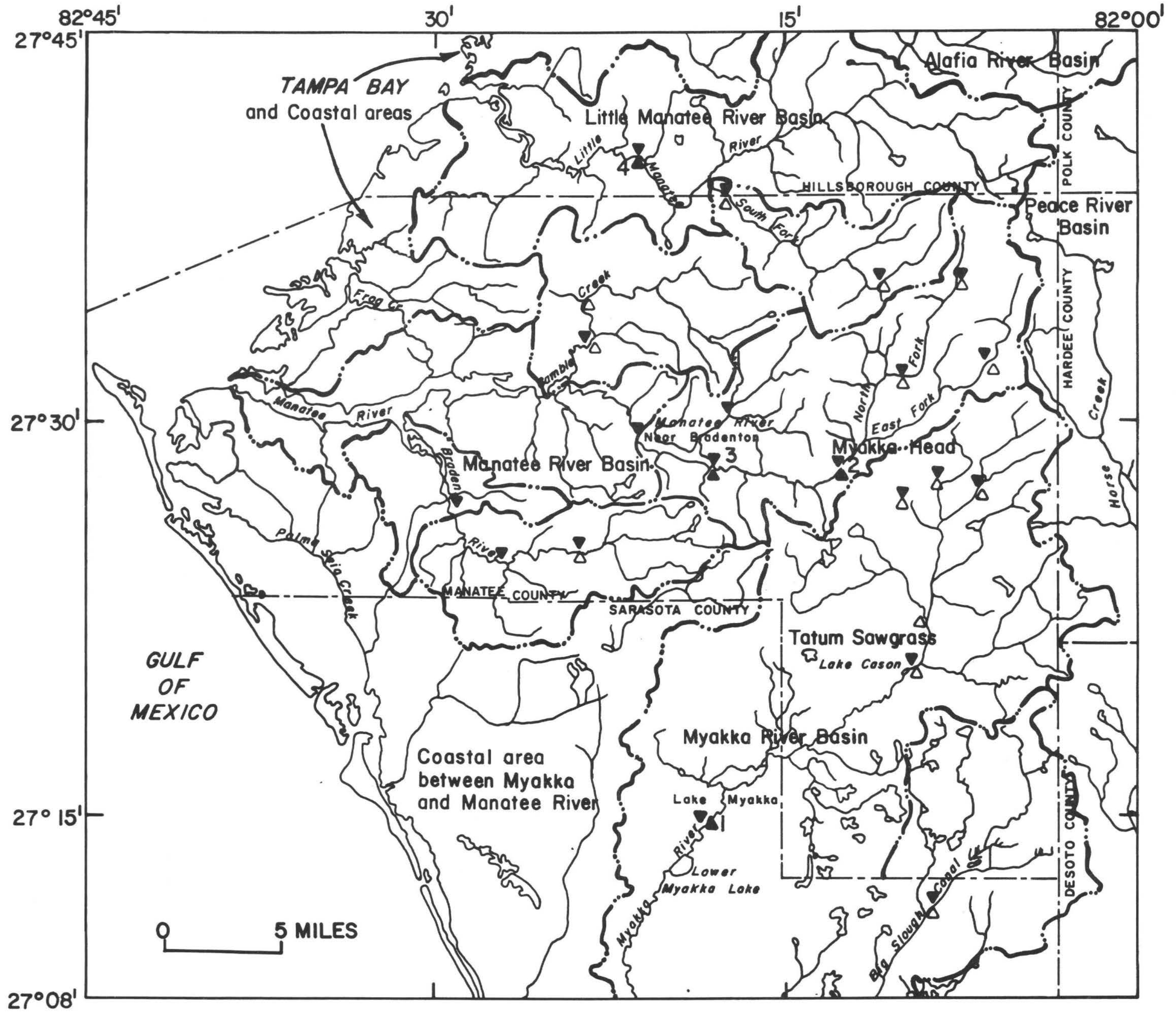
The rainy season extends from June through September when about 60 percent of the yearly rainfall occurs. Average rainfall during this period ranges from about 6 to 9 inches per month. The rains are generally associated with convective thunderstorms. From June to November, the county may be subjected to tropical storms and hurricanes; associated with these storms is heavy rainfall that may be as great as 15 inches or more.

The dry season is from October to May. From October to May, rainfall ranges from about 1.5 to 3 inches per month in Manatee County. Often from March to May, there is little or no measurable rainfall for 60 days or more.

Evapotranspiration in Manatee County is estimated to be about 39 inches per year (Cherry and others, 1970). About 60 percent occurs from May to October (Southwest Florida Water Management District, 1978). Average annual lake evaporation is estimated to be about 52 inches per year (Joyner and Sutcliffe, 1976).

Surface Water

The major drainage basins in Manatee County are the Myakka River, Manatee River, and Little Manatee River (table 3 and fig. 2). A small part of eastern Manatee County is in the Peace River basin. Small streams and canals occur along the coast between the Myakka and Manatee Rivers and along Tampa Bay north of the Manatee River. These streams and canals, such as Frog Creek and Palma Sola Creek, rise within several miles of the coast and flow into bays and estuaries. Each is tidal throughout much of its length.



EXPLANATION

- ▲ CONTINUOUS RECORD-GAGING STATION
- △ MEASUREMENT SITE WITHOUT A GAGE
- ▼ QUALITY-OF-WATER SITE
- —··— BASIN BOUNDARY

NUMBERS REFERENCE SITES LISTED IN TABLE 4

Figure 2.--Streams and surface-water data-collection network, Manatee County and adjacent areas.

Table 3.--Major drainage basins in Manatee County

Drainage basin	Drainage area	
	Total (mi^2)	Manatee County (mi^2)
Peace River	2,403	19
Myakka River	550	229
Coastal area between Myakka and Manatee Rivers	425	45
Manatee River	357	345
Little Manatee River	211	72
Tampa Bay and coastal areas	877	42

Myakka River Basin

Most of the Myakka River basin is in the Gulf Coastal Lowlands and the DeSoto Plain physiographic units. A small area in the headwaters is in the Polk Upland unit. The maximum elevation, 116 feet, is in the northeastern part of the basin where terraces have been eroded into rolling hills. The southwestern part of the basin is less than 20 feet above sea level and has little local relief.

The larger streams and canals that make up the drainage system are shown in figure 2. Large swampy areas border many channels. In the broad flatlands, most natural drainageways are shallow sloughs that range in width from a few feet to more than 1 mile. Only the Myakka River channel is well defined and naturally entrenched throughout. Many sloughs and swampy areas have been drained by ditches and canals. Agricultural areas in the upper Big Slough and recently developed residential areas have undergone extensive drainage changes.

Below an altitude of about 60 feet, hundreds of shallow depressions dot the landscape. Few depressions are perennial ponds or lakes, but all, unless drained by canals, hold water during wet weather.

The Myakka River rises in northeastern Manatee County and flows southward to the Gulf of Mexico. The river is 69 miles long and drains about 229 mi^2 in Manatee County. In the upper part, the channel has a fairly steep gradient (about 5 ft/mi); in the lower parts, the channel gradient is generally less than 1 ft/mi (fig. 3).

Lake Myakka and Lower Myakka Lake, located in Sarasota County, are the largest lakes in the basin and have a combined surface area of about 1,380 acres. The Tatum Sawgrass, a 4,300-acre marsh 4 miles northeast of Lake Myakka, ranges in altitude from about 15 to 20 feet and is several feet above the normal lake level of Lake Myakka. This marsh is flooded only following exceptionally heavy rainfall.

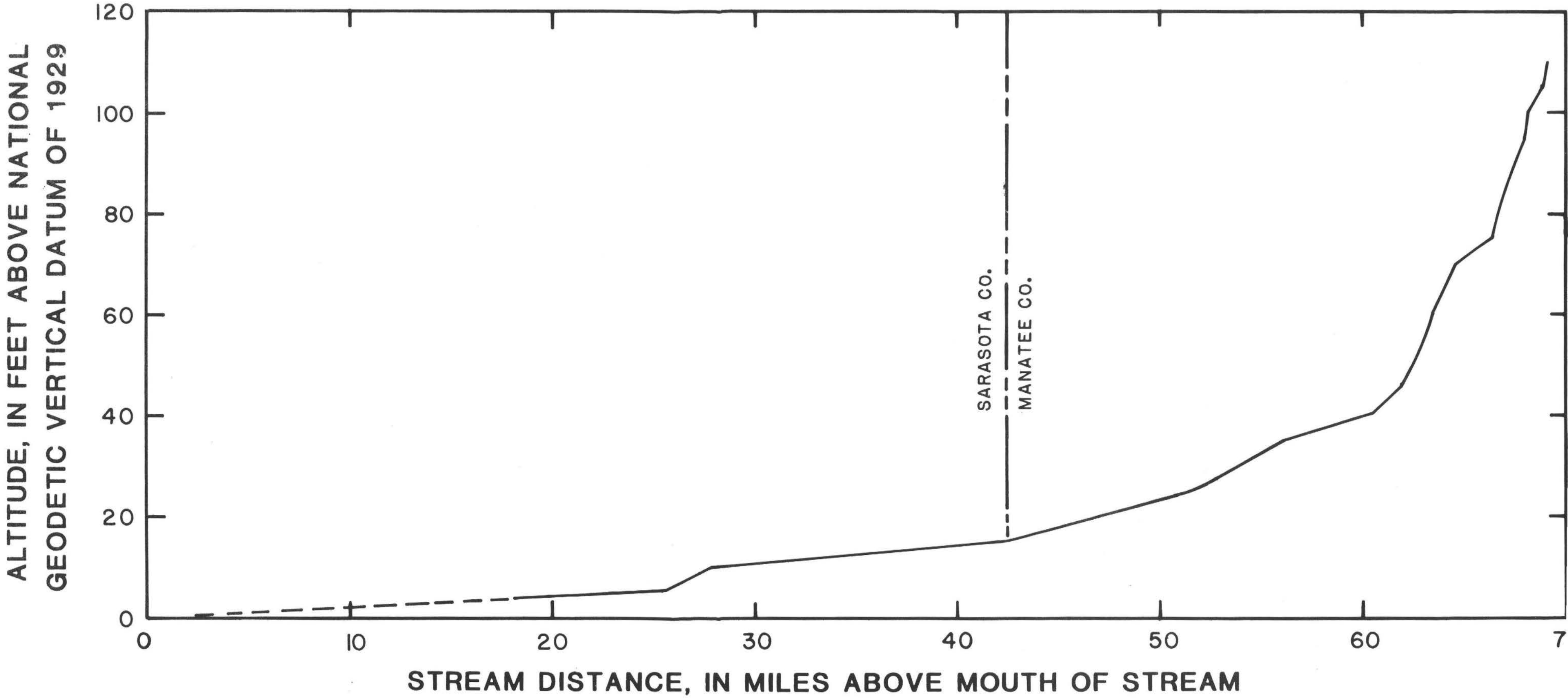


Figure 3.--Streambed profile of the Myakka River.

From 1937 to 1977, the discharge of the Myakka River near Sarasota has been gaged at a site between Lake Myakka and Lower Myakka Lake, about 36 miles upstream from its mouth. The average discharge at the site (229 mi^2 drainage area) is 253 ft^3/s or about 15 inches of runoff per year (table 4).

The flow-duration curve for the Myakka River near Sarasota is shown in figure 4. The curve shows the percent of time that specific discharges were equaled or exceeded during the period of record. For example, 50 percent of the time the discharge equaled or exceeded 500 ft^3/s. The steepness of the curve indicates a high variability in streamflow. The general flattening of the curve at its upper end indicates storage and gradual release of water from lakes and swamps during periods of heavy precipitation.

The magnitude and frequency of annual low and high flows for Myakka River near Sarasota are presented in table 5. A statistical analysis of the 41 years of continuous data indicate that there is no flow in the stream for extended periods of time; there is no flow for 15 consecutive days at intervals averaging 2 years, and for 90 days at intervals averaging 10 years.

Big Slough Canal and Mud Lake Slough drain about 48 mi^2 of southeastern Manatee County and eastern Sarasota County. The canals drain flat, swampy lowlands that are generally less than 50 feet above sea level. The sloughs have been deepened mainly to drain agricultural lands, and this deepening has probably increased low flows (Flippo and Joyner, 1968). The estimated 7-day 2-year annual low flow of Big Slough near Myakka City drainage area (36.5 mi^2) is about 0.1 ft^3/s and the 7-day 10-year annual low flow is zero (Flippo and Joyner, 1968).

Manatee River Basin

The Manatee River and its principal tributary, the Braden River, drain about 345 mi^2 in Manatee County, about 10 mi^2 in Sarasota County, and about 2 mi^2 in southwest Hillsborough County. Most of the basin is in the Gulf Coastal Lowlands. A small area in the headwaters is in the Polk Upland. The eastern part of the basin consists of relatively flat terraces that are poorly drained and contain numerous, small, shallow lakes, ponds, and swamps.

The Manatee River rises in northeastern Manatee County and flows westward to the Gulf of Mexico. The river is about 53 miles long. At its source, the channel is about 130 feet above sea level. In the upper part, the channel has a fairly steep gradient (5 ft/mi); in the lower part, it is affected by tides for about 20 miles upstream from the mouth (fig. 5).

Discharge of the Manatee River was gaged from 1939 to 1965 near Bradenton and from 1966 to 1977 near Myakka Head (table 4 and fig. 2). The average discharge (26 years) near Bradenton was 109 ft^3/s, or 17.0 inches of runoff per year. The average discharge (11 years) near Myakka Head was 63.6 ft^3/s, or 13.2 inches per year.

The flow-duration curves for the Manatee River near Bradenton and near Myakka Head are shown in figure 4. Ninety percent of the time, flow near Bradenton exceeded 9 ft^3/s, and 50 percent of the time, it exceeded about 100 ft^3/s. Flow near Myakka Head exceeded 6 ft^3/s 90 percent of the time and 70 ft^3/s 50 percent of the time.

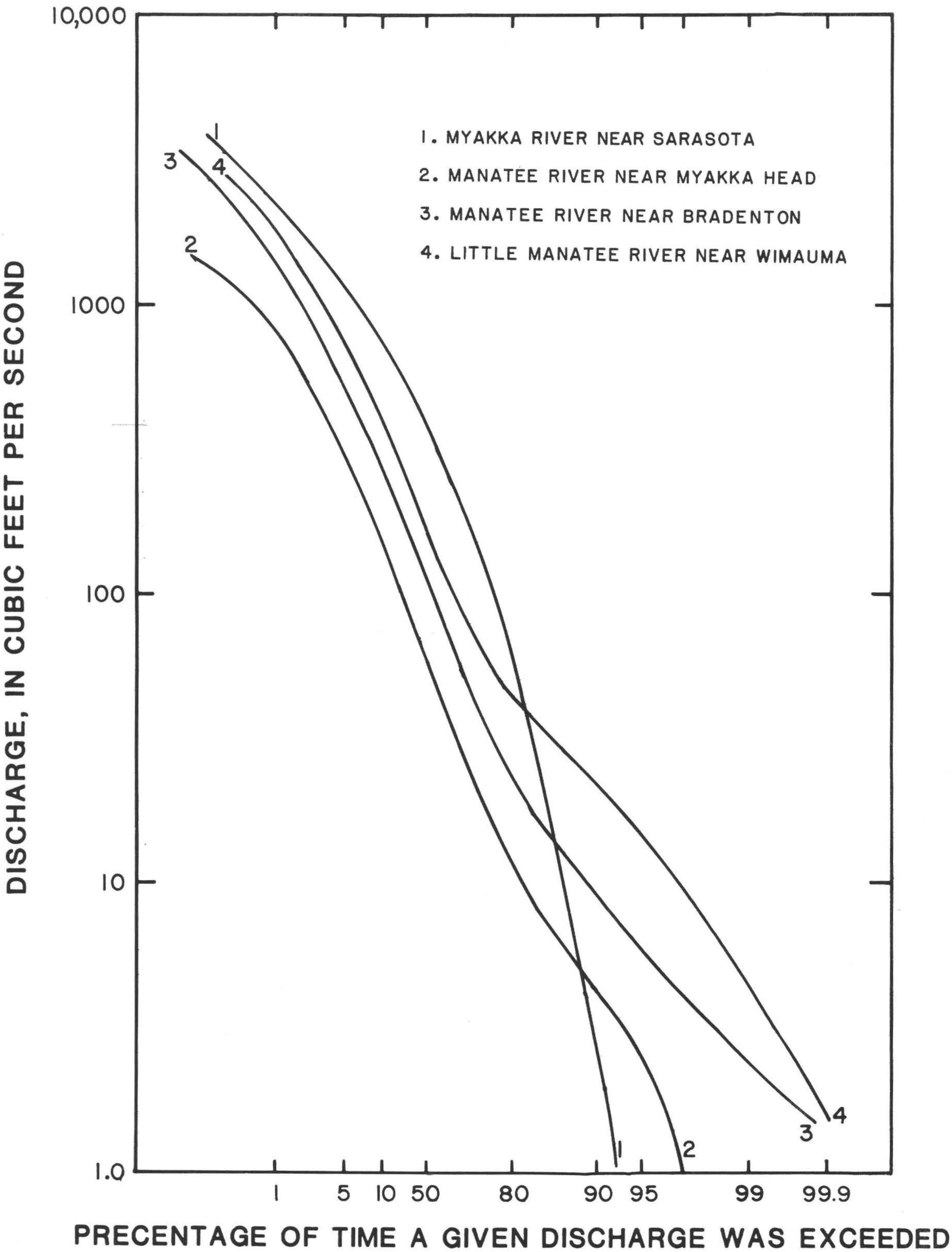


Figure 4.--Flow-duration curves for streams in and near Manatee County.

Table 4.--Summary of streamflow data from gaging stations in Manatee County and adjacent areas through September 1977

Map number	Station number	Station name	Years of record	Drainage area		Discharge			
						(ft^3/s)			(in/yr)
				(mi^2)	Percentage of total basin	Average	Maximum	Minimum	Average over gaged area
1	02298830	Myakka River near Sarasota	41	229	42	253	8,670	No flow	15.0
2	02299950	Manatee River near Myakka Head	11	65.3	18	63.6	3,130	No flow	13.2
3	02300000	Manatee River near Bradenton (discontinued)	26	87.1	24	109	3,440	1.7	17.0
4	02300500	Little Manatee River near Wimauma	38	149	71	172	14,000	1.2	15.5

Table 5.--Magnitude and frequency of annual low and high flows, Myakka River near Sarasota

Period (consecutive days)	Lowest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	20	50	100
7	0	0	0	0	0	0
15	0	0	0	0	0	0
30	.1	0	0	0	0	0
60	1.7	0	0	0	0	0
90	5.5	.1	0	0	0	0
120	11	1.1	.1	0	0	0
183	30	6.2	2.5	1.1	.4	.2
365	230	150	120	100	81	70

Period (consecutive days)	Highest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	25	50	100
7	1,800	2,900	3,800	5,100	6,300	7,600
15	1,400	2,100	2,600	3,400	4,100	4,800
30	990	1,500	1,900	2,500	2,900	3,400
60	720	1,200	1,500	2,000	2,500	3,000
90	570	930	1,200	1,700	2,000	2,500
120	460	760	990	1,400	1,600	1,200
183	320	520	670	890	1,100	1,300
365	240	350	420	520	590	660

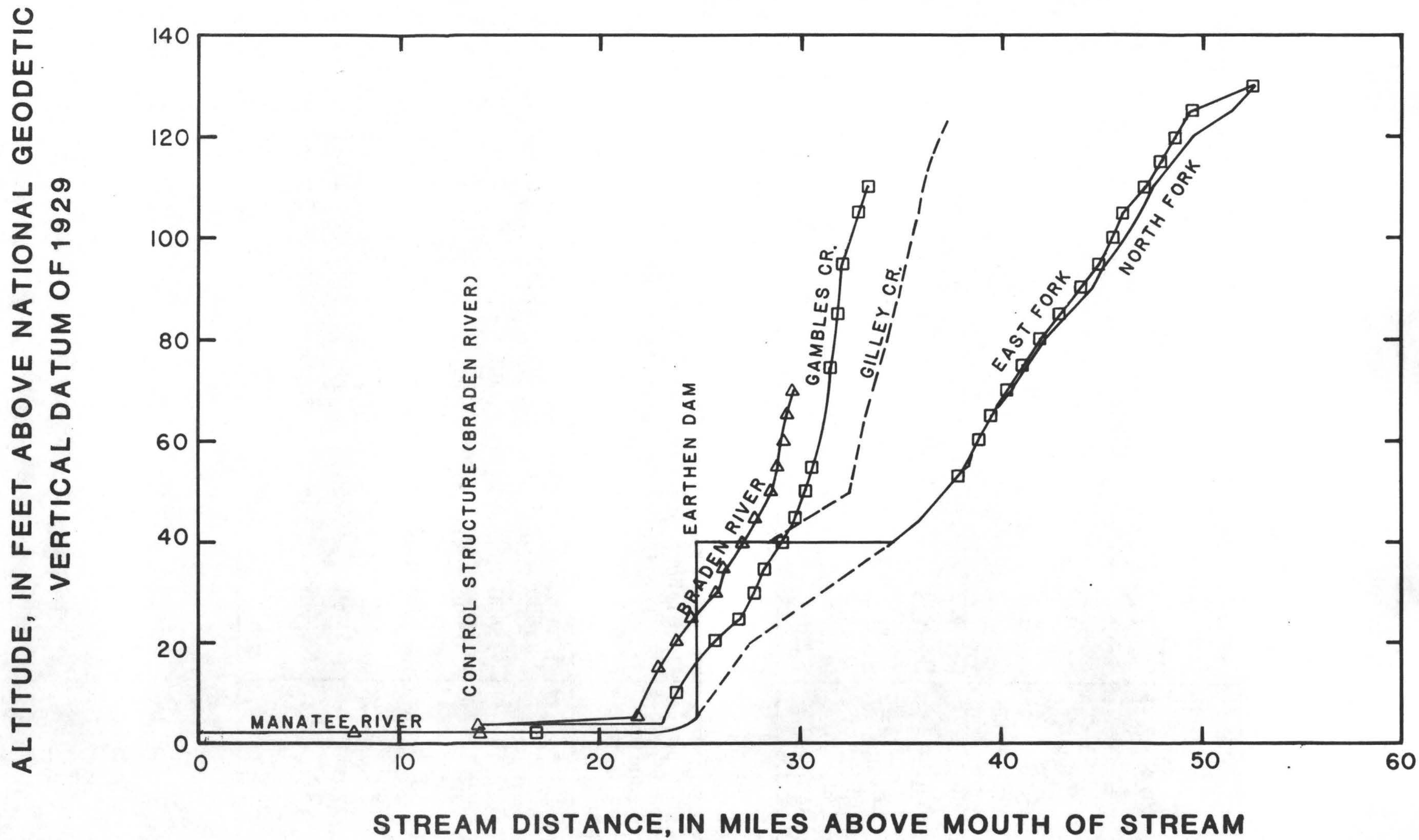


Figure 5.--Streambed profiles of streams in the Manatee River basin.

The flattening of the lower end of the flow-duration curve for Manatee River near Bradenton indicates that the stream has sustained flow. Base flow is sustained by drainage of ground water from the beds of fine sand and clay into which the stream is entrenched. The flattening of the flow-duration curve at high flows indicates detention and gradual release of water from storage in the small lakes and swamps following periods of intense rainfall.

The magnitude and frequency of annual low and high flows for Manatee River near Bradenton and near Myakka Head are presented in tables 6 and 7, respectively. The average annual 7-day 2-year low flow at Bradenton and at Myakka Head are 4.0 and 1.0 ft^3/s, respectively.

The Braden River, largest tributary to the Manatee River, rises in the south-central part of Manatee County (fig. 2). The river drains about 76 mi^2 in the county and about 10 mi^2 in northern Sarasota County. The river is about 23 miles long, and, at its source, the channel is about 70 feet above sea level (fig. 5).

Little Manatee River Basin

The Little Manatee River is about 39 miles long, heads in southeastern Hillsborough County, and flows westward into Tampa Bay. The stream drains about 140 mi^2 in southern Hillsborough County and about 72 mi^2 in northern Manatee County (fig. 2). At its source, the channel is about 100 feet above sea level and has a fairly steep gradient. In its lower reaches, the stage rises and falls with tides in Tampa Bay. During low flow, tidal effects are discernible for about 15 miles upstream from its mouth.

From 1939 to 1977, the average discharge of the Little Manatee River near Wimauma was 172 ft^3/s or 15.5 inches of runoff per year (table 4). Flow ranged from a minimum of 1.2 ft^3/s occurring on December 18-19, 1976, to a maximum of 14,000 ft^3/s occurring on September 11, 1960. The magnitude and frequency of annual low and high flows near Wimauma are presented in table 8.

The South Fork Little Manatee River, the largest tributary to the Little Manatee River, is about 14 miles long and heads in northeastern Manatee County (fig. 2). It drains about 40 mi^2 in Manatee County and about 1 mi^2 in Hillsborough County. Its average discharge at Duette during the period 1956 to 1958 was 46.4 ft^3/s (Menke and others, 1961).

Lakes and Springs

Manatee County contains numerous small lakes and ponds that have a total surface area of less than 700 acres. Most lakes are shallow and may go dry during moderate droughts. The Florida Gazetteer, Part 3 (Florida Board of Conservation, 1969), lists 18 natural freshwater lakes in Manatee County. Cason Lake, with a surface area of 50 acres at a stage of 17 feet above sea level, is the largest lake reported.

Table 6.--Magnitude and frequency of annual low and high flows, Manatee River near Bradenton

Period (consecutive days)	Lowest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	20	50	100
7	4.0	2.7	2.1	1.7	1.4	1.2
15	4.4	2.9	2.3	1.9	1.6	1.4
30	5.3	3.5	2.8	2.3	1.8	1.5
60	7.8	4.8	3.6	2.9	2.3	1.9
90	12	6.8	4.9	3.8	2.7	2.2
120	16	8.4	5.9	4.4	3.1	2.5
183	27	14	9.4	6.9	4.8	3.7
365	99	68	56	48	41	36

Period (consecutive days)	Highest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	25	50	100
7	1,250	1,500	1,900	2,600	3,100	3,800
15	620	940	1,200	1,500	1,800	2,100
30	430	660	830	1,070	1,260	1,450
60	320	500	650	860	1,030	1,220
90	260	400	520	680	810	960
120	210	330	420	560	660	780
183	150	230	290	380	440	520
365	99	140	180	220	250	290

Table 7.--Magnitude and frequency of annual low and high flows, Manatee River near Myakka Head

Period (consecutive days)	Lowest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	20	50	100
7	1.0	0.5	0.3	0.2	0.1	0.1
15	1.2	0.6	0.4	0.3	0.2	0.2
30	1.5	0.7	0.5	0.4	0.3	0.2
60	2.8	1.2	0.8	0.6	0.4	0.3
90	4.9	2.2	1.5	1.1	0.8	0.7
120	7.9	3.7	2.6	2.0	1.5	1.3
183	12	5.4	3.8	2.9	2.1	1.8
365	62	52	48	44	41	39

Period (consecutive days)	Highest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	25	50	100
7	720	860	940	1,030	1,080	1,100
15	440	560	630	720	780	840
30	290	390	450	520	580	630
60	220	280	310	350	370	380
90	170	210	240	270	290	320
120	130	170	190	210	230	240
183	95	110	120	140	140	150
365	64	77	84	93	98	100

Table 8.--Magnitude and frequency of annual low and high flows, Little Manatee River near Wimauma

Period (consecutive days)	Lowest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	20	50	100
7	8.4	4.5	3.1	2.2	1.4	1.1
14	9.4	5.4	3.9	3.0	2.1	1.7
30	12	7.2	5.6	4.6	3.6	3.1
60	17	10	8.0	6.5	5.1	4.4
90	25	15	11	8.7	6.7	5.6
120	34	19	14	11	8.5	7.1
183	49	26	19	15	12	9.7
365	160	100	80	64	50	42

Period (consecutive days)	Highest average flow, in cubic feet per second, for indicated recurrence intervals, in years					
	2	5	10	25	50	100
7	1,400	2,300	2,900	3,700	4,300	4,900
14	910	1,400	1,800	2,200	2,600	2,900
30	650	1,020	1,260	1,500	1,700	1,900
60	490	780	970	1,200	1,400	1,500
90	380	620	770	950	1,080	1,200
120	310	500	630	780	880	980
183	230	360	440	530	600	660
365	160	240	280	330	370	400

Several springs were reported by Ferguson and others (1947). In a revision of Ferguson's work by Rosenau and others (1977), no springs were reported in the county as the springs reported by Ferguson are now dry.

Ground Water

Ground water is water in the zone of saturation--the zone in which all interconnected voids, large and small, are filled with water under pressure greater than atmospheric pressure (Lohman and others, 1972). Ground water in Manatee County occurs under unconfined and confined conditions. The unconfined ground water is water in an aquifer that has a water table, the surface being at atmospheric pressure. The confined ground water is under pressure, and its upper limit is the bottom of a confining bed that has a distinctly lower hydraulic conductivity than the material in which the confined water occurs.

All stratigraphic units underlying Manatee County yield some water to wells, but the water-yielding properties differ considerably among units. Units have been classified hydrologically as aquifers or confining beds.

Surficial Aquifer

The surficial aquifer is composed primarily of deposits of sand, gravel, shells, and limestone whose composition may vary laterally and vertically. The deposits comprise the Holocene sediments, Pleistocene terrace deposits, the Caloosahatchee (?) Marl, and the Bone Valley Formation.

In the eastern and central part of Manatee County, the aquifer consists mostly of medium- to fine-grained, well-sorted, quartz sand and ranges in thickness from about 10 to 90 feet (fig. 6). Within this area, the sands contain a hardpan layer that consists of sand and carbonaceous and limonitic material that averages about 5 feet in thickness. The hardpan retards vertical flow of water. The sandy clays of the Bone Valley Formation and the Hawthorn Formation form the base of the surficial aquifer in eastern Manatee County.

In the western part of the county, the aquifer consists of sand, sandy limestone, and shell and ranges from about 1 to 20 feet in thickness. The sandy clays, clays, and marls form the base of the surficial aquifer.

Transmissivity and storage coefficient

Transmissivity and storage coefficients of the surficial aquifer were estimated by comparing the type of material comprising the aquifer with laboratory hydraulic conductivity and specific-yield values and aquifer tests run in similar materials in nearby areas.

The transmissivity of the surficial aquifer probably ranges from less than 100 ft^2/d to about 10,000 ft^2/d. Transmissivity of the thick sand and phosphorite deposits in the south-central part of the county probably ranges from 1,000

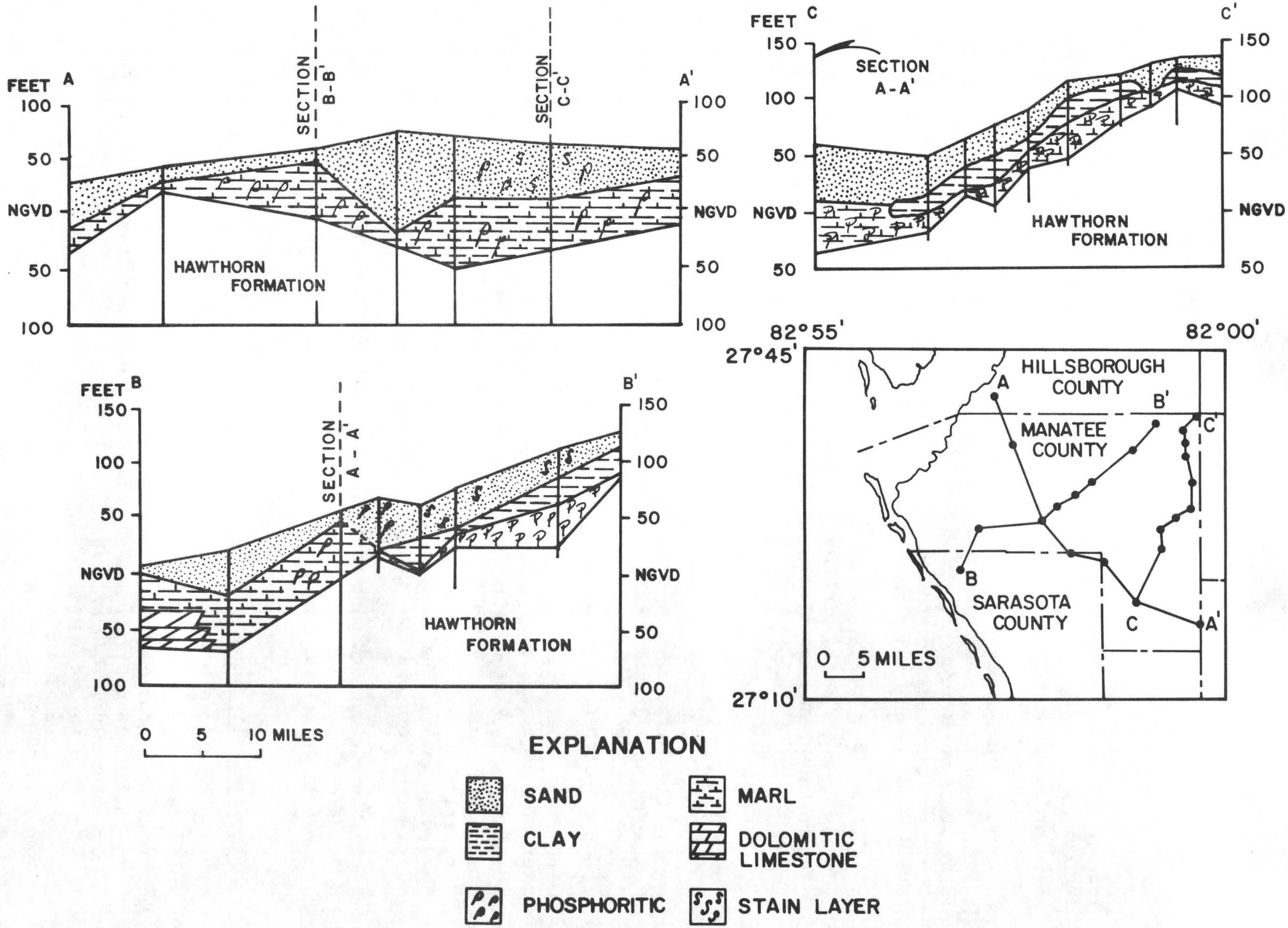


Figure 6.--Geologic sections showing surficial material overlying the Hawthorn Formation.

to about 2,000 ft^2/d. Similar transmissivity was reported by Wilson (1972) and Hutchinson and Wilson (1974) for surficial deposits in DeSoto and Hardee Counties. Transmissivity of a surficial aquifer in Charlotte County, south of Manatee County, that consists of sand and interbedded shell and limestone similar to deposits in western Manatee County was reported to be about 7,000 ft^2/d (Sutcliffe, 1975). The transmissivity of the surficial aquifer in adjacent counties, determined from aquifer tests, ranged from about 200 to 1,800 ft^2/d (R. M. Wolansky, written commun., 1977).

The specific yield of an unconfined aquifer generally ranges between 0.1 and 0.3. The average specific yield of an unconfined aquifer for long periods of draining is about 0.2 (Lohman, 1972, p. 8). Specific yields determined in the surficial aquifer in Polk County ranged from 0.125 to 0.47 (Pride and others, 1966). Laboratory determinations of specific yield in Hillsborough County ranged from about 0.2 to 0.4 (Sinclair, 1974).

The storage coefficient of an unconfined aquifer is virtually equal to the specific yield, which is commonly determined by laboratory drainage tests. In Manatee County, the storage coefficient of the surficial aquifer is estimated to range from about 0.05 to 0.25 based on laboratory specific-yield tests of similar deposits in Polk County (Pride and others, 1966) and in Hillsborough County (Sinclair, 1974) and on an aquifer test in southeastern Hillsborough County (Hutchinson, 1977).

Ground-water movement, recharge, and discharge

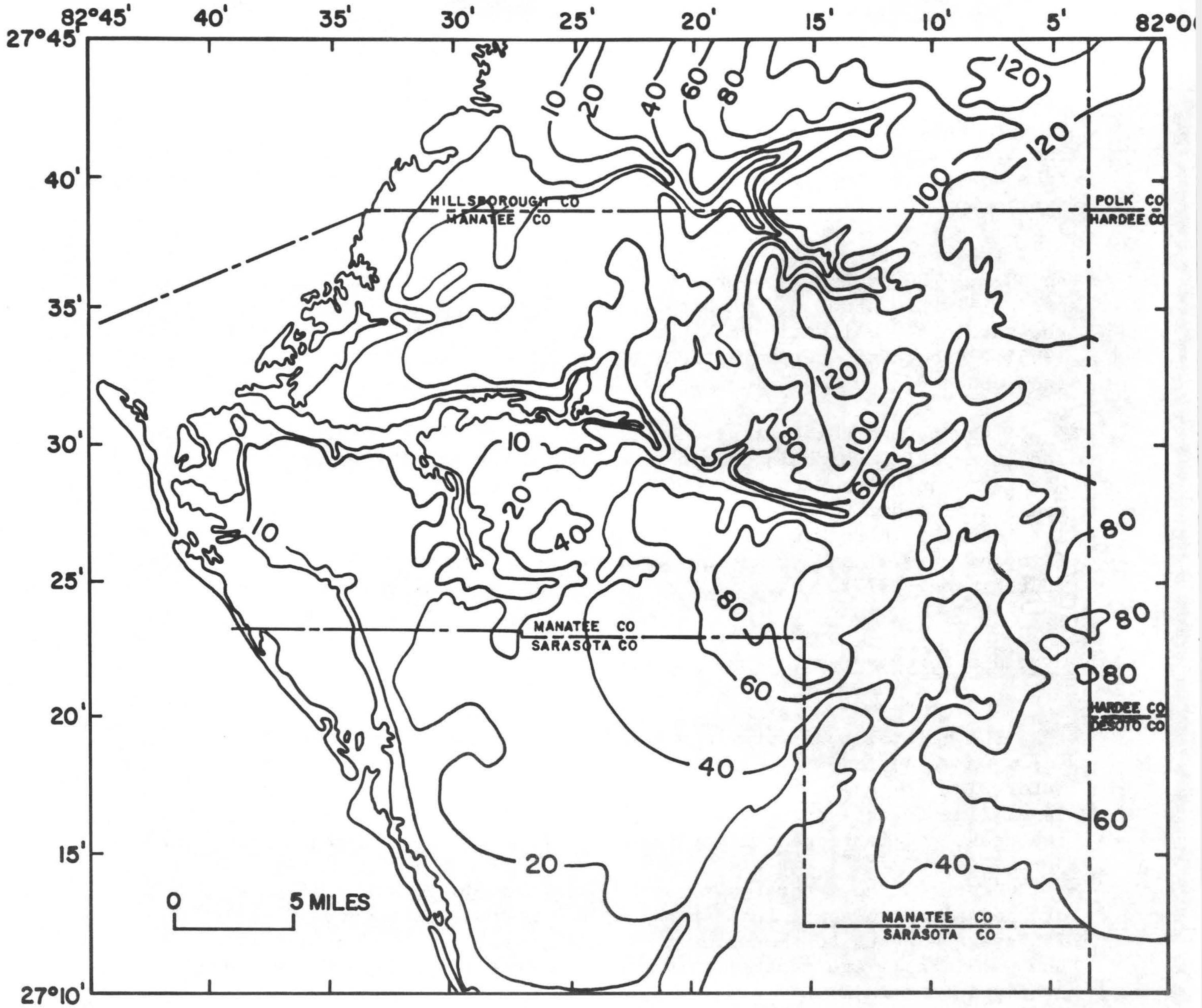
The general configuration of the water table in the surficial aquifer for a low-water period, May 1975, is shown in figure 7. The direction of ground-water flow is generally west and south. The configuration of the water surface is similar to that of the land surface. Water surface is at sea level along the coast and increases to altitudes of about 130 feet in the northeast.

Depth to the water table ranges from zero in coastal and flat, poorly drained areas to about 10 feet below land surface in topographically high areas. The average depth to the water table is about 5 feet. Seasonal fluctuations in the water table are generally less than 5 feet (fig. 8). Water levels are generally lowest in April or May and highest in September.

In some areas, the surficial aquifer is confined by layers of hardpan, clay, or limestone. Many shallow wells in the county penetrate one or more of these confining layers. Generally, the artesian pressure is insufficient to produce flowing wells (Peek, 1958b).

Infiltrating rainwater recharges the surficial aquifer. Of the 55 in/yr average rainfall, an estimated 39 inches is lost to evapotranspiration and about 15 inches runs off in streams. The remaining inch infiltrates the soil and recharges the surficial aquifer. This represents an estimated 17.4 Mgal of water per square mile that recharges the aquifer in an average year.

Recharge to the surficial aquifer also results from upward leakage of water from confined aquifers where the potentiometric surface is higher than the water table. Some recharge occurs as influent seepage from impounded



EXPLANATION

—40—

WATER-TABLE CONTOUR--SHOWS ALTITUDE OF WATER TABLE. CONTOUR INTERVAL 20 FEET. SUPPLEMENTAL 10-FOOT CONTOUR LINE. DATUM IS NGVD OF 1929

Figure 7.--Generalized water table, May 1975.

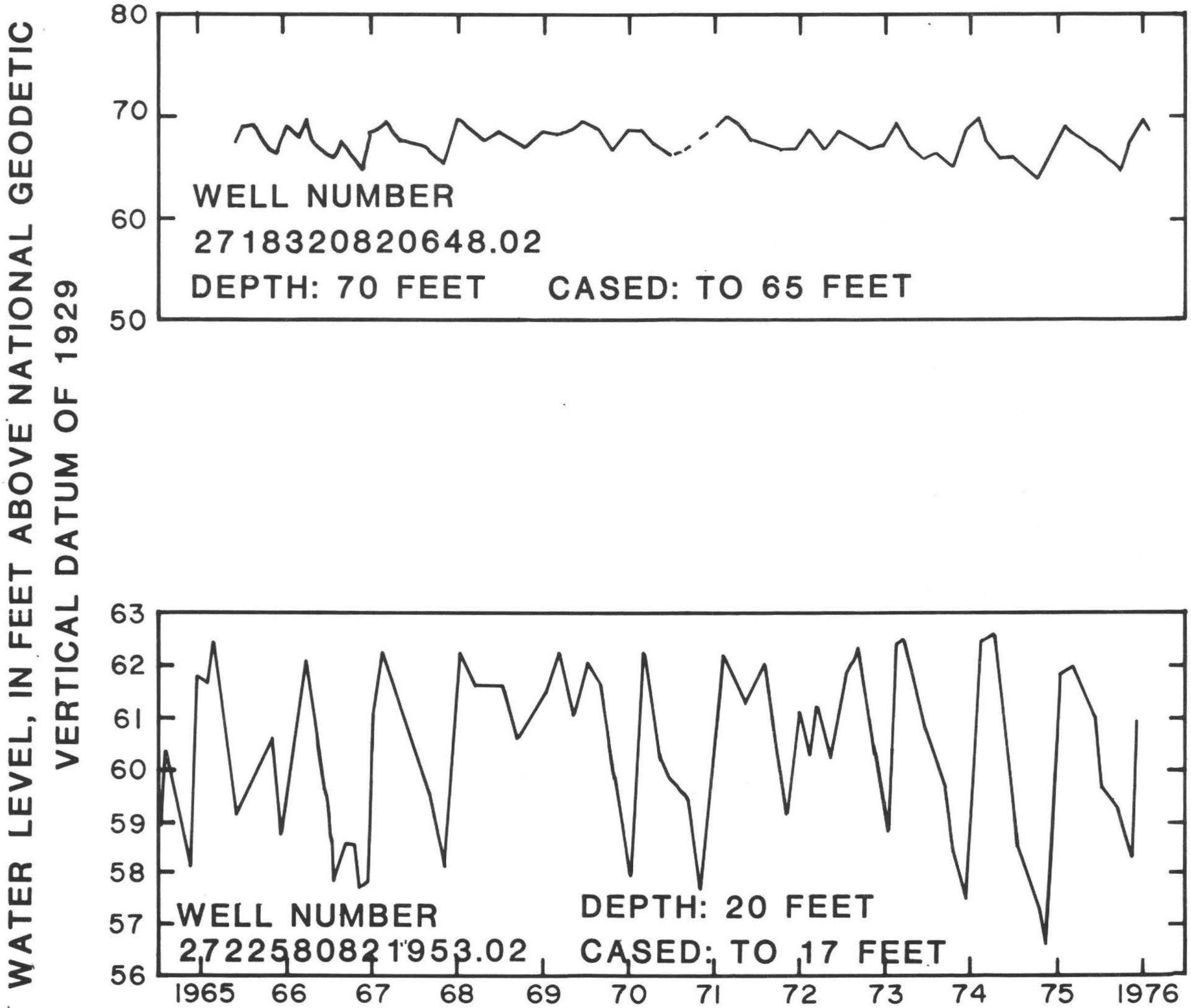


Figure 8.--Water levels in wells penetrating the surficial aquifer.

streams or streams at high stage. Also, artificial recharge occurs by infiltration of irrigation water, discharge from septic tanks, and infiltration of water from flowing or improperly constructed wells.

Discharge from the surficial aquifer is by evapotranspiration, seepage into surface-water bodies, downward leakage to underlying aquifers when the water table is higher than the potentiometric surface, and ground-water outflow to adjacent areas. Artificial discharge comes from pumpage, inflow into drainage ditches and canals, and by drainage by improperly constructed wells.

Upper Confining Bed and Minor Artesian Aquifer

The upper confining bed consists of sandy clay, clay, and marl and retards vertical movement of water between the surficial and the Floridan aquifers. The bed thickens from about 200 feet in the northern part of the county to about 375 feet in the southern part (figs. 9 and 10).

The minor artesian aquifer occurs within the upper confining bed. The aquifer consists of discontinuous beds of permeable sand, gravel, shell, and limestone within the upper part of the Hawthorn Formation. The top of the aquifer is between zero and 300 feet below sea level. The sand and shell beds, primarily quartz, phosphate minerals, and shell fragments, are generally less than 10 feet thick. Limestone beds are hard, sandy, fossiliferous, and dolomitic and range from about 10 to 50 feet in thickness.

The minor artesian aquifer in the Myakka River basin, which includes the southeastern part of Manatee County, was called Artesian Zone 2 by Joyner and Sutcliffe (1976). Wilson (1977a) described these beds in Hardee and DeSoto Counties as the upper unit of the Floridan aquifer.

Transmissivity, storage coefficient, and leakance

Estimated transmissivity derived from aquifer tests analyses of the minor artesian aquifer ranges from less than 1,000 to 11,500 ft^2/d (R. M. Wolansky, written commun., 1977). The transmissivity in the northeastern part of the county, however, is generally less than 1,000 ft^2/d. The storage coefficient of the minor artesian aquifer ranges from $4x10^{-5}$ to $3x10^{-4}$. Estimated leakance from the surficial aquifer to the minor artesian aquifer ranges from 10^{-5} to 10^{-3} (ft/d)/ft (R. M. Wolansky, written commun., 1977).

Ground-water movement, recharge, and discharge

Ground-water flow is generally westward. In May 1977, water levels ranged from about 10 feet above sea level in coastal areas to about 100 feet in the northeast (fig. 11). In September 1977, water levels ranged from about 20 to 100 feet above sea level (fig. 12). Seasonal water-level fluctuations range from less than 5 feet in the northeast and coastal areas to about 20 feet near the Verna well field in south-central Manatee County.

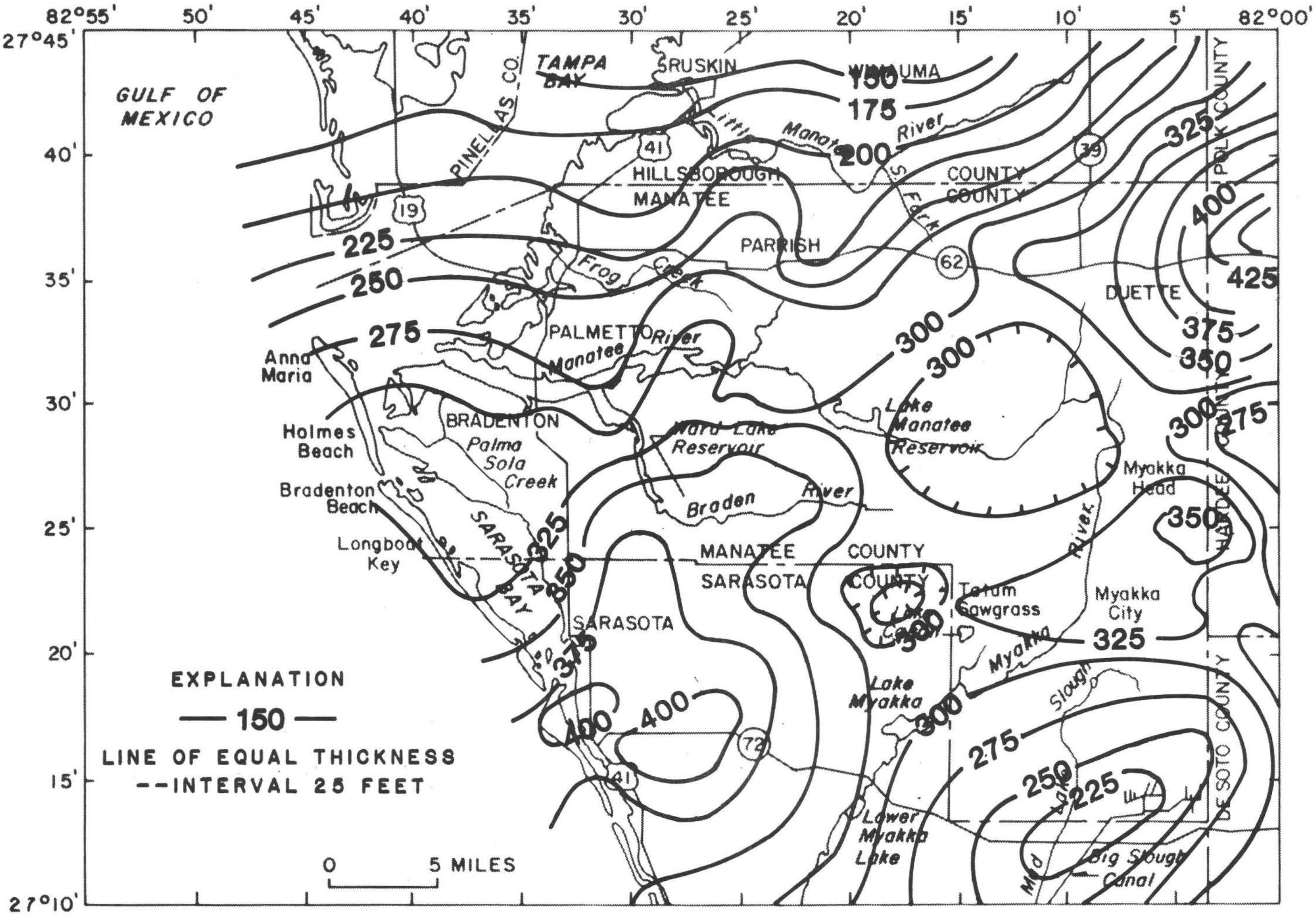


Figure 9.--Thickness of the upper confining bed of the Floridan aquifer system (modified from Wilson, 1977).

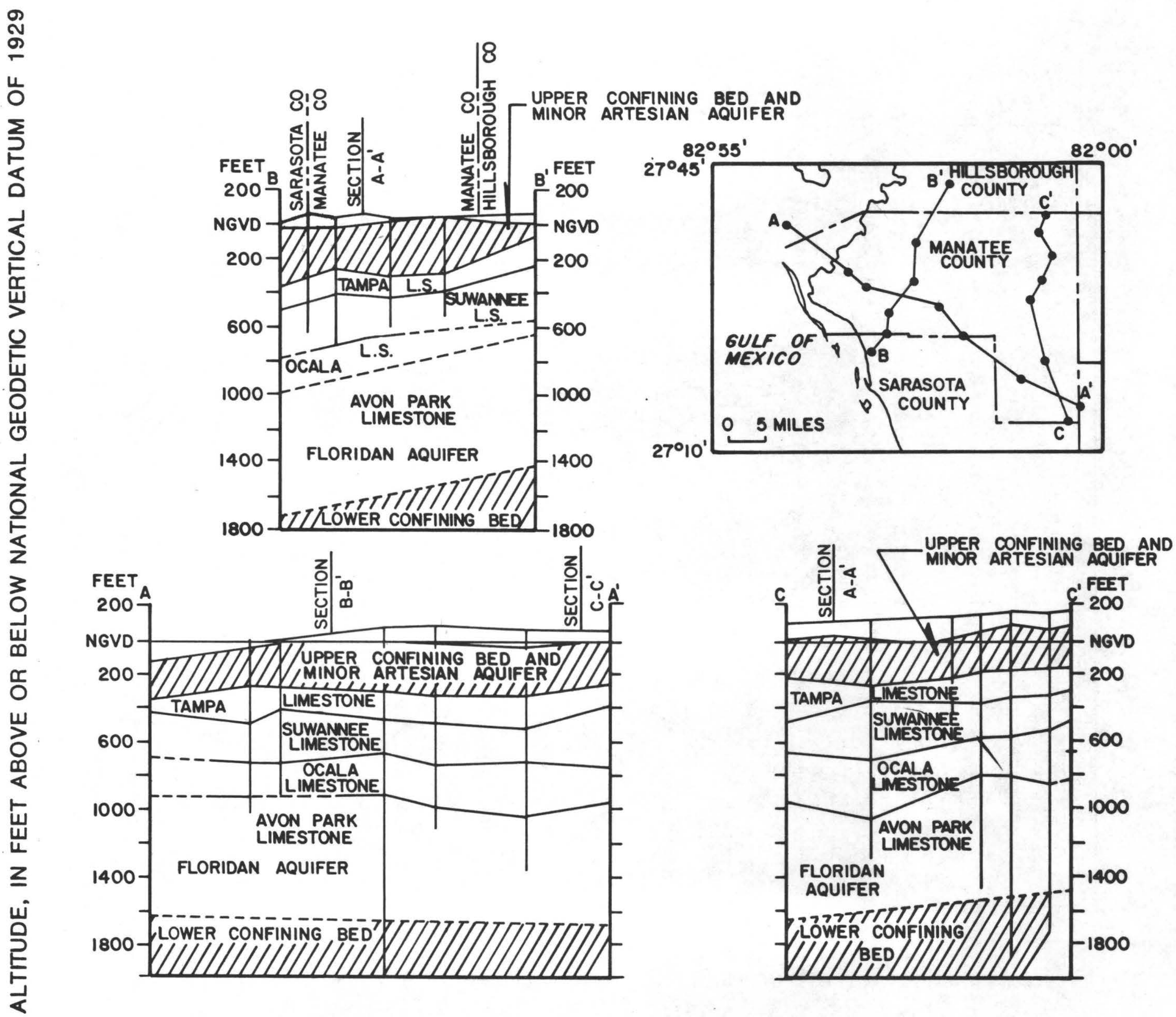
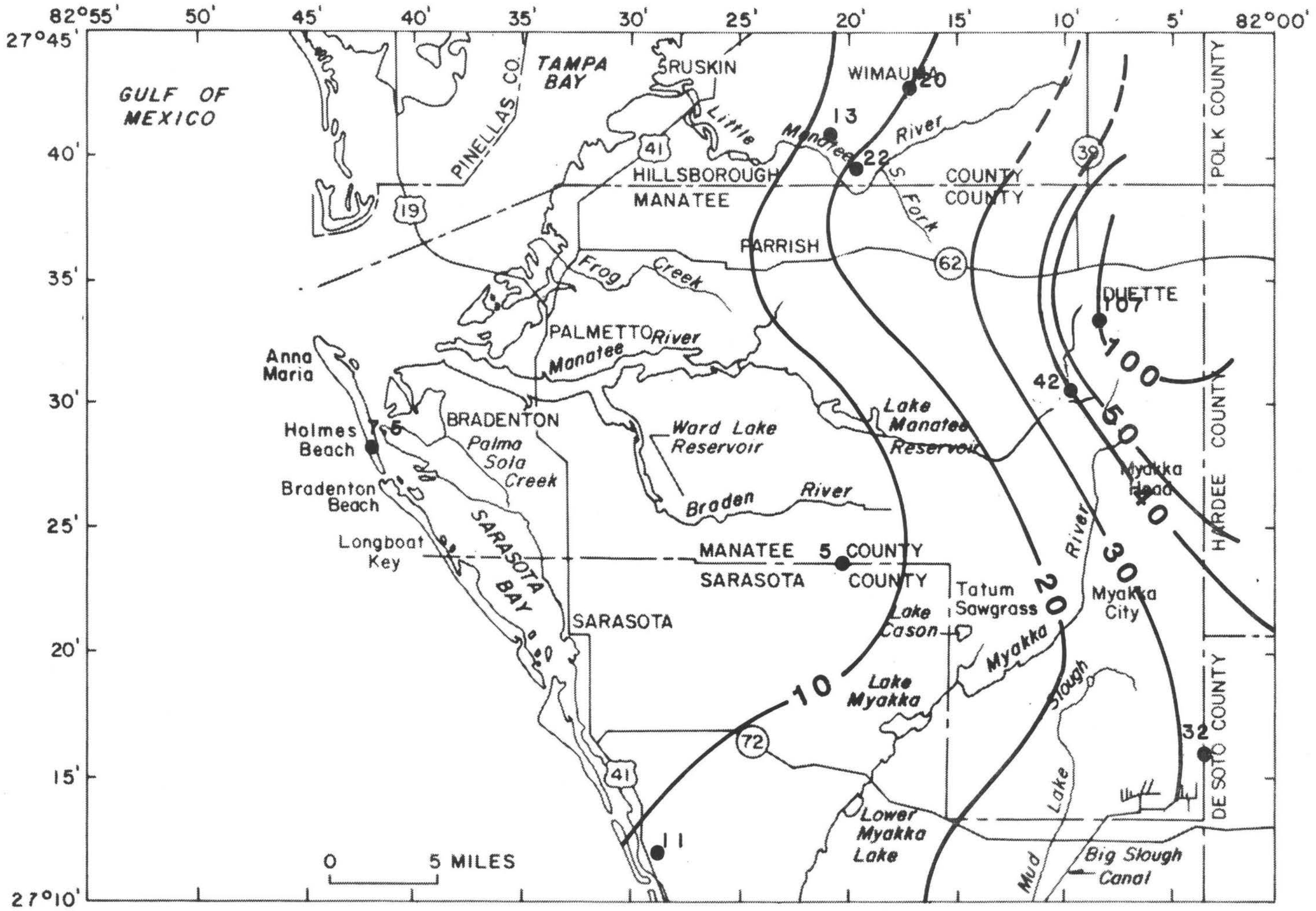


Figure 10.--Hydrogeologic sections.



EXPLANATION

—— 10 ——

POTENTIOMETRIC CONTOUR— SHOWS ALTITUDE AT WHICH WATER LEVEL WOULD HAVE STOOD IN TIGHTLY CASED WELLS. DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 10 AND 50 FEET. DATUM IS NGVD OF 1929

● 5

WELL WITH WATER—LEVEL ALTITUDE

Figure 11.--Potentiometric surface of the minor artesian aquifer, May 1977.

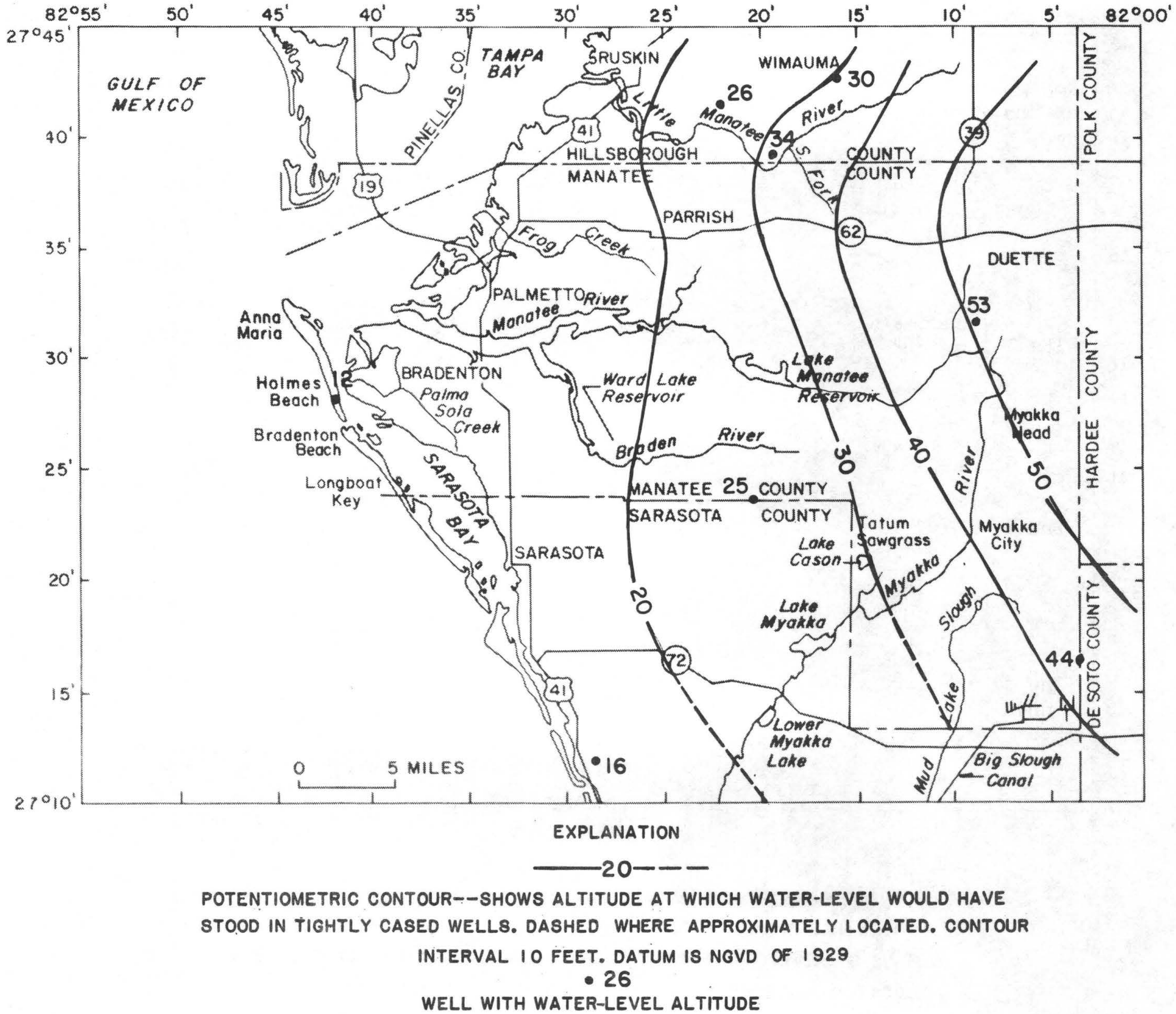


Figure 12.--Potentiometric surface of the minor artesian aquifer, September 1977.

Recharge to the minor artesian aquifer occurs both by downward leakage from the surficial aquifer, where the water table is higher than the potentiometric surface of the minor artesian aquifer, and by upward leakage from the Floridan aquifer, where the potentiometric surface of the Floridan aquifer is higher than the potentiometric surface of the minor artesian aquifer.

Discharge from the aquifer occurs by (1) downward leakage to the Floridan aquifer, where the potentiometric surface of the minor artesian aquifer is higher than the potentiometric surface of the Floridan aquifer; (2) by upward leakage to the surficial aquifer, where the potentiometric surface is higher than the water table; (3) ground-water outflow to the gulf or adjacent areas; (4) pumpage; and (5) flowing wells.

Floridan Aquifer

The Floridan aquifer, principal source of ground water in Manatee County, is composed of a thick, stratified sequence of limestone and dolomite (Miocene to Eocene in age). The aquifer includes the Tampa Limestone, Suwannee Limestone, Ocala Limestone, and the Avon Park Limestone (fig. 10). Permeable limestone beds of the Hawthorn Formation that are in hydrologic contact with the underlying Tampa Limestone are also included.

The altitude of the top of the Floridan aquifer ranges from about 200 feet below sea level in the northern part of the county to about 350 feet below sea level in the southern part (fig. 13). The aquifer thickens from about 1,000 feet in the western part of the county to 1,700 feet in the southern part (fig. 14).

The limestone and dolomite sequence generally functions as a single hydrologic unit; however, three distinct water-bearing zones are known to exist within the sequence. The highly permeable layers of the zones generally occur at or near formation contacts. The zones are separated by beds of low permeability that act as semiconfining beds retarding vertical movement of water.

The upper, middle, and lower zones of the Floridan aquifer correlate with zones 3, 4, and 5 as described by Joyner and Sutcliffe (1976). The upper zone includes permeable rock in the lower part of the Hawthorn Formation and the upper part of the Tampa Limestone. The zone consists of sand, sandy limestone, clay, and hard limestone layers that contain dark phosphatic pebbles. This zone underlies the entire county and is generally less productive in the northeast than in the western part of the county.

The middle zone consists of the lower part of the Tampa Limestone, all of the Suwannee Limestone, and the upper part of the Ocala Limestone. Depth to this zone ranges from about 300 feet in the northeastern part of the county to about 500 feet in the southern part. The more permeable layers of the zone occur at the formation contacts of the Tampa and Suwannee Limestones and the Suwannee and Ocala Limestones.

The Ocala Limestone, which is 300 to 400 feet thick and of low vertical permeability, generally acts as a semiconfining bed. It retards vertical movement of water between the lower zone and the middle zone.

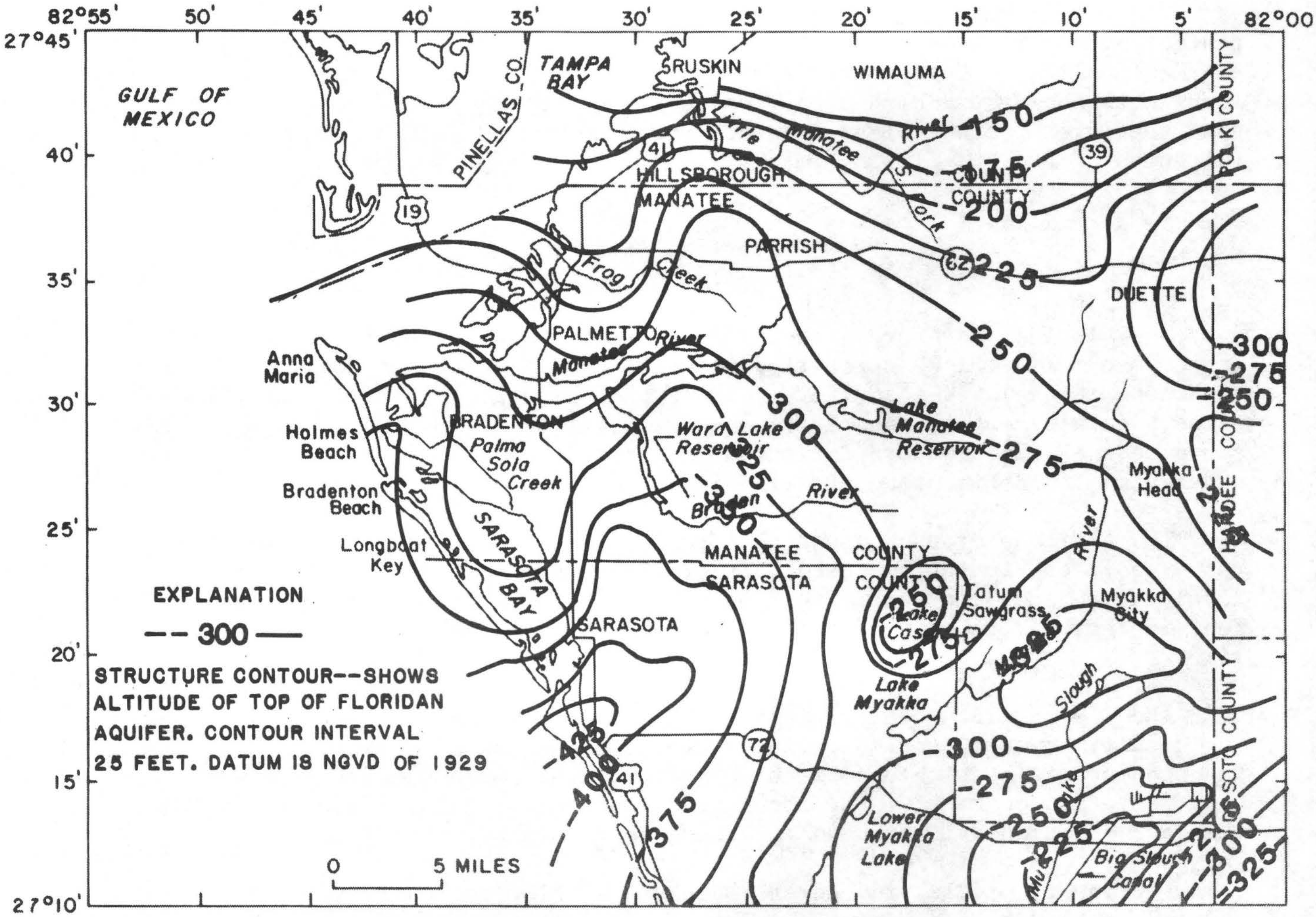


Figure 13.--Altitude of the top of the Floridan aquifer (modified from Buono and Rutledge, 1978).

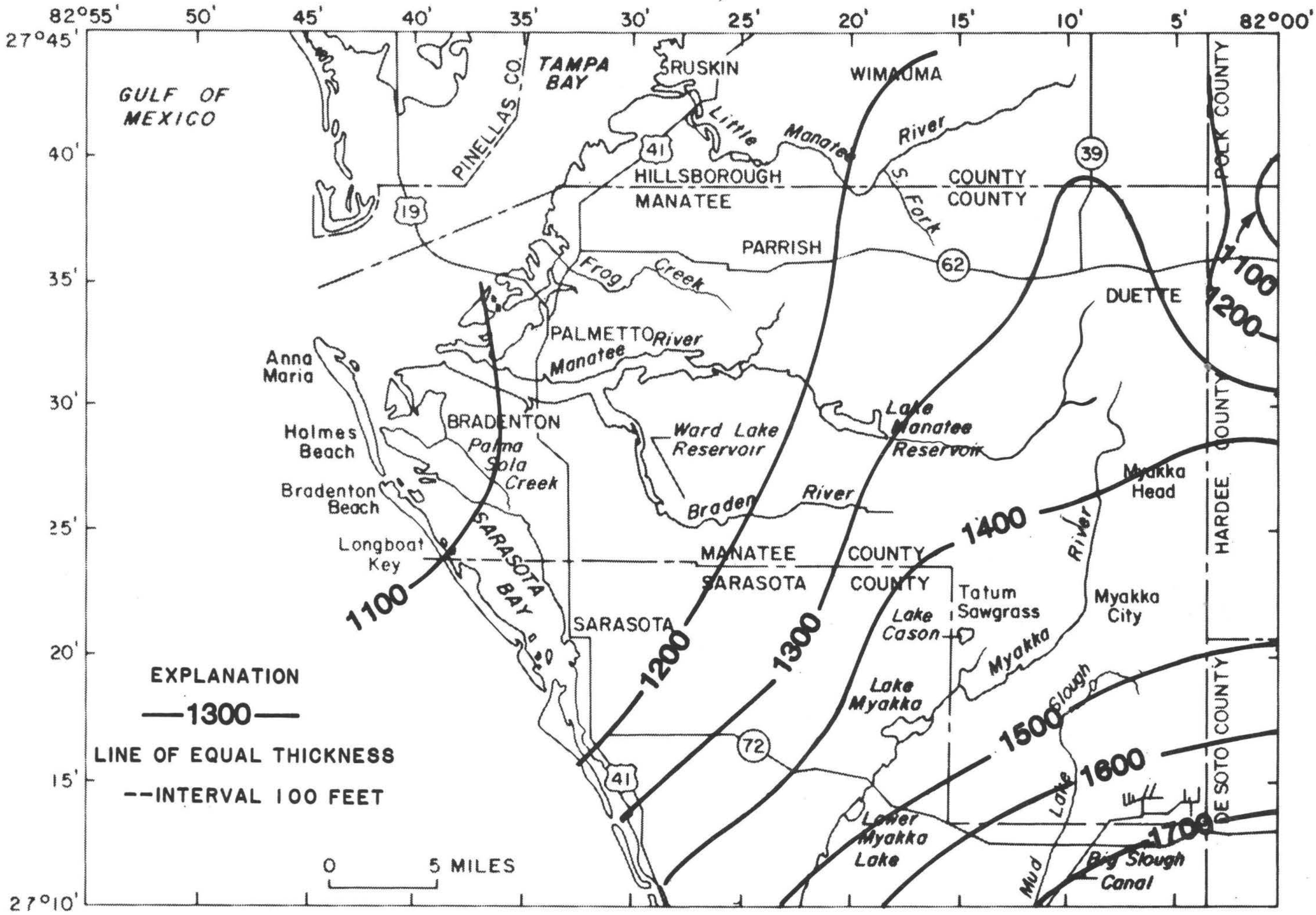


Figure 14.--Thickness of the Floridan aquifer (modified from Wilson, 1977).

The lower zone consists of permeable limestone and dolomitic rock in the Avon Park Limestone. It is the major water-bearing zone of the Floridan aquifer throughout southwest Florida. The lower zone underlies the county at depths ranging from about 900 feet below land surface in the north to about 1,200 feet below land surface in the south. This zone is separated from the overlying zones by the lower part of the Ocala Limestone.

Transmissivity, storage coefficient, and leakance

The transmissivity of the Floridan aquifer ranges from about 40,000 to 900,000 ft^2/d (R. M. Wolansky, written commun., 1977). Transmissivity of the dolomite unit of the Avon Park Limestone lower water-bearing zone ranges from about 20,000 to 700,000 ft^2/d. Most production wells, however, are also open to the lower part of the middle zone (Ocala Limestone). In eastern and southeastern Manatee County, the transmissivity of this zone ranges from 60,000 to 150,000 ft^2/d.

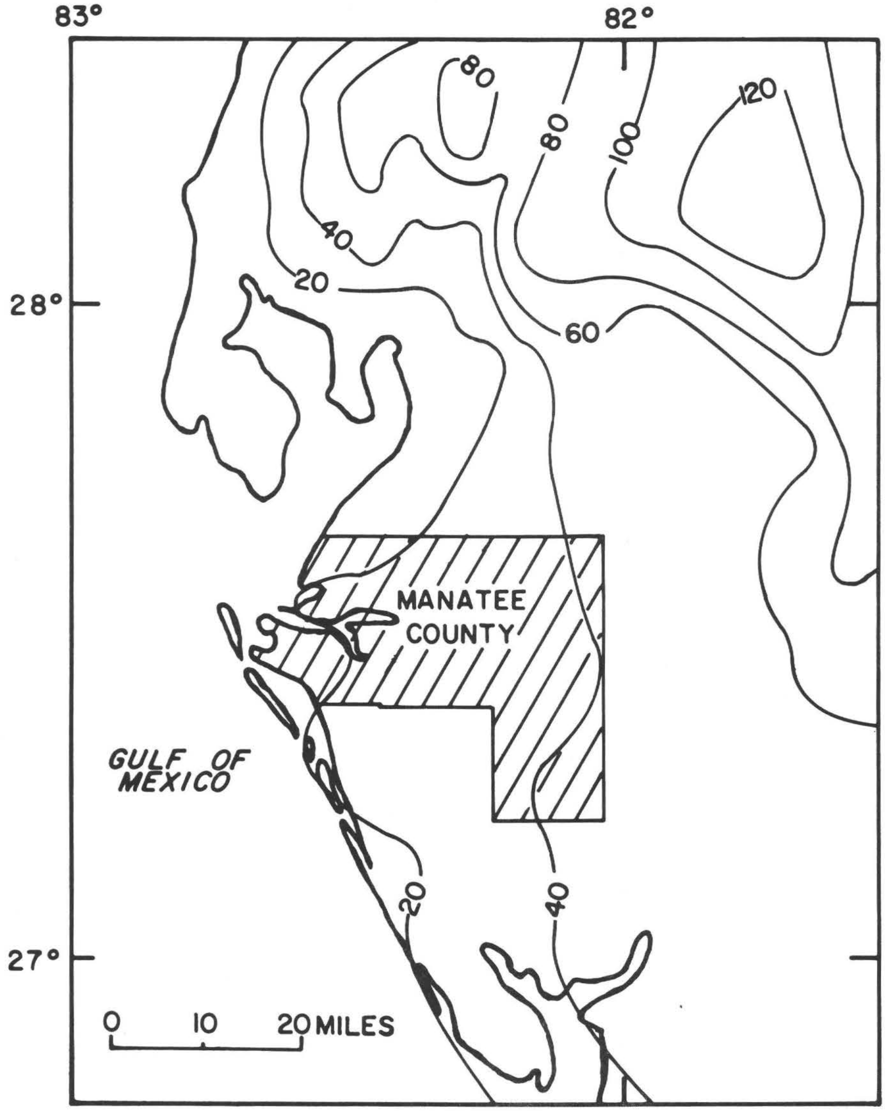
In western Manatee County, the transmissivity of the upper and middle zones is about 15,000 ft^2/d (Peek, 1958a). In northeastern Manatee County, William F. Guyton and Associates (1976d) reported an estimated transmissivity of about 3,300 ft^2/d for the Suwannee Limestone and also indicated that little water can be produced from the Tampa Limestone.

Storage coefficients of most confined aquifers range from about 10^{-5} to 10^{-3} and are about 10^{-6} per foot of thickness (Lohman, 1972). The storage coefficient of the Floridan aquifer ranges from 1.0 to 1.7×10^{-3} (R. M. Wolansky, written commun., 1977).

Leakance from the surficial aquifer to the Floridan aquifer where differences in head are favorable could not be determined accurately from aquifer tests. This was due to (1) extreme thickness of the upper confining beds (about 200 to 400 feet), (2) small drawdowns due to high transmissivity of the aquifer, (3) large fluctuations in background water levels due to seasonal irrigation, and (4) short duration of most aquifer tests (less than 30 days). Leakance to the Floridan aquifer is probably less than 10^{-4} (ft/d)/ft and is estimated to range from 10^{-6} to 10^{-5} (ft/d)/ft. Estimated leakances determined from aquifer tests range from 10^{-6} to 10^{-3} (ft/d)/ft. In northeastern Manatee County, William F. Guyton and Associates (1976d) estimated leakance to be about 1.34×10^{-6} to 1.34×10^{-5} (ft/d)/ft.

Ground-water movement, recharge, and discharge

The regional configuration of the potentiometric surface is shown in figure 15. The general configuration of the potentiometric surface as shown for September 1975 has changed little since 1961 (Healy, 1962) or as mapped by Stringfield in 1934 (Stringfield, 1936), but there has been a general downward trend in water levels since 1955. Ground-water flow is perpendicular to and toward potentiometric surfaces of lower altitude. Ground-water flow in the county is generally west and southwest from the regional high located about 30 miles northeast of the county.



EXPLANATION

——— 60 ———

POTENTIOMETRIC CONTOUR -- Shows altitude at which water level would have stood in tightly cased wells. Contour interval 20 feet. Datum is NGVD of 1929

Figure 15.--Potentiometric surface of the Floridan aquifer, west-central Florida, September 1975 (modified from Mills and others, 1976).

In May 1975, during a period of heavy pumpage on the order of 40 to 50 Mgal/d, the potentiometric surface ranged from about 10 feet below sea level in the central part of the county to about 30 feet above sea level in the southeastern part (fig. 16). The depression in the potentiometric surface in the central part of the county probably resulted from ground-water withdrawals for irrigation. At the coast, the potentiometric surface is relatively high because ground-water withdrawals there are small. In September 1975, during a period of relatively low pumpage on the order of 5 to 10 Mgal/d, the potentiometric surface ranged from about 20 feet above sea level near the coast to about 40 feet in the east (fig. 17). Figure 18 shows areas of artesian flow in May and September 1975.

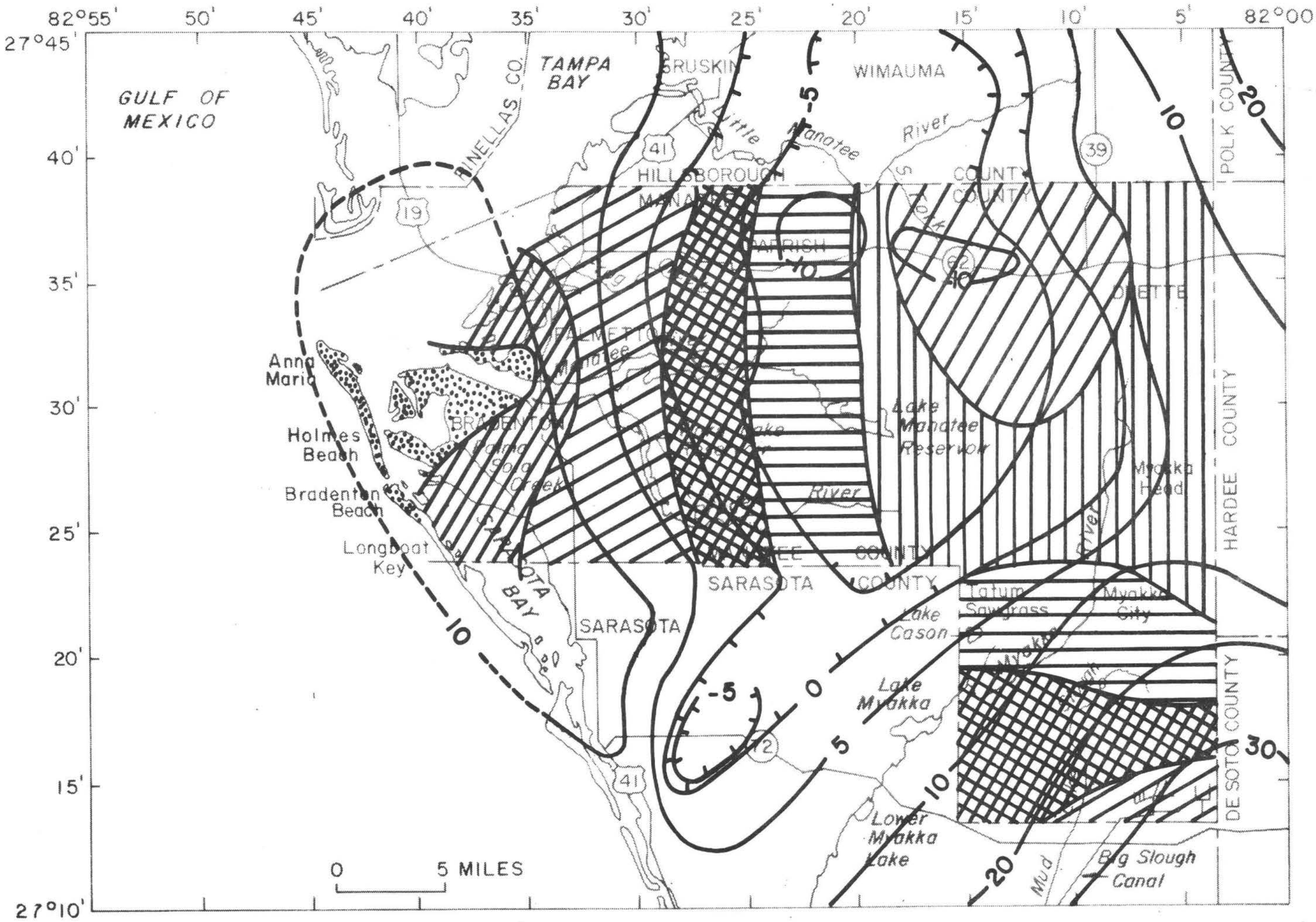
Seasonal fluctuations of the potentiometric surface are in response to changes in recharge and discharge. The potentiometric surface is generally lowest in April or early May, near or at the end of the dry season, when ground-water withdrawals are at a maximum. The potentiometric surface is generally highest in September near the end of the rainy season when ground-water withdrawals are minimal. The magnitude of seasonal fluctuations from May 1975 to September 1975 ranged from 5 feet near the coast to about 30 feet in the northeast (fig. 19).

From the early 1950's to the 1970's, the magnitude of seasonal fluctuations has increased. Peek (1958a) in 1954-55 reported seasonal fluctuations of about 5 feet and in some areas as much as 10 feet. Hydrographs of water levels in selected wells show fluctuations of 30 feet in the middle 1970's (fig. 20) compared to less than 20 feet in the early and middle 1950's (Peek 1958a). The increase in fluctuations is probably due to increased ground-water withdrawals and below-normal rainfall since 1960.

From September 1954 to September 1975, the potentiometric surface decline ranged from 5 feet near the coast to about 20 feet in the northeast (fig. 17). From June 1955 to May 1975, the decline ranged from less than 5 feet near the coast to about 50 feet in the northeast (fig. 16). The estimated decline of the potentiometric surface from May 1969 to May 1975 ranged from less than 5 feet near the coast to about 40 feet in the northeast (Mills and Laughlin, 1976).

Hydrographs of observation wells (fig. 20) indicate a general downward trend of seasonal peaks during 1965-75. Declines range from about 5 feet in northern Sarasota County (well I) to 15 feet in western Hardee County (well G). The potentiometric surface in Manatee County showed little or no decline from 1934 to 1954 (Stringfield, 1966; Peek, 1958a), but from 1954 to 1975, declines ranged from about 5 feet near the coast to 20 feet in the northeast. Most of the decline occurred from 1965 to 1975 and is probably due to increased ground-water withdrawals and below normal rainfall.

Recharge to the Floridan aquifer is generally from infiltration of precipitation through the semiconfining beds and from surface runoff into sinkholes in the central Florida highlands area, about 40 miles northeast and east of Manatee County (Stringfield, 1966). Thus, most of the water in the Floridan aquifer in Manatee County is from inflow from adjacent areas. In eastern Manatee County, some recharge occurs as downward leakage of water from the surficial and minor artesian aquifers where the potentiometric surface of the Floridan aquifer is lower than the water table and the potentiometric surface of the minor artesian aquifers. In May 1975, the computed downward leakage



EXPLANATION

——10——

POTENTIOMETRIC CONTOUR--SHOWS ALTITUDE AT WHICH WATER LEVEL WOULD HAVE STOOD IN TIGHTLY CASED WELLS. CONTOUR INTERVAL 5 AND 10 FEET. DATUM IS NGVD OF 1929

RANGE OF DECLINE IN THE POTENTIOMETRIC SURFACE, IN FEET

0-5 | **5-10** | **10-20** | **20-30**

30-40 | **40-50** | **> 50**

Figure 16.--Potentiometric surface of the Floridan aquifer, May 1975, and decline in the potentiometric surface, June 1955 to May 1975.

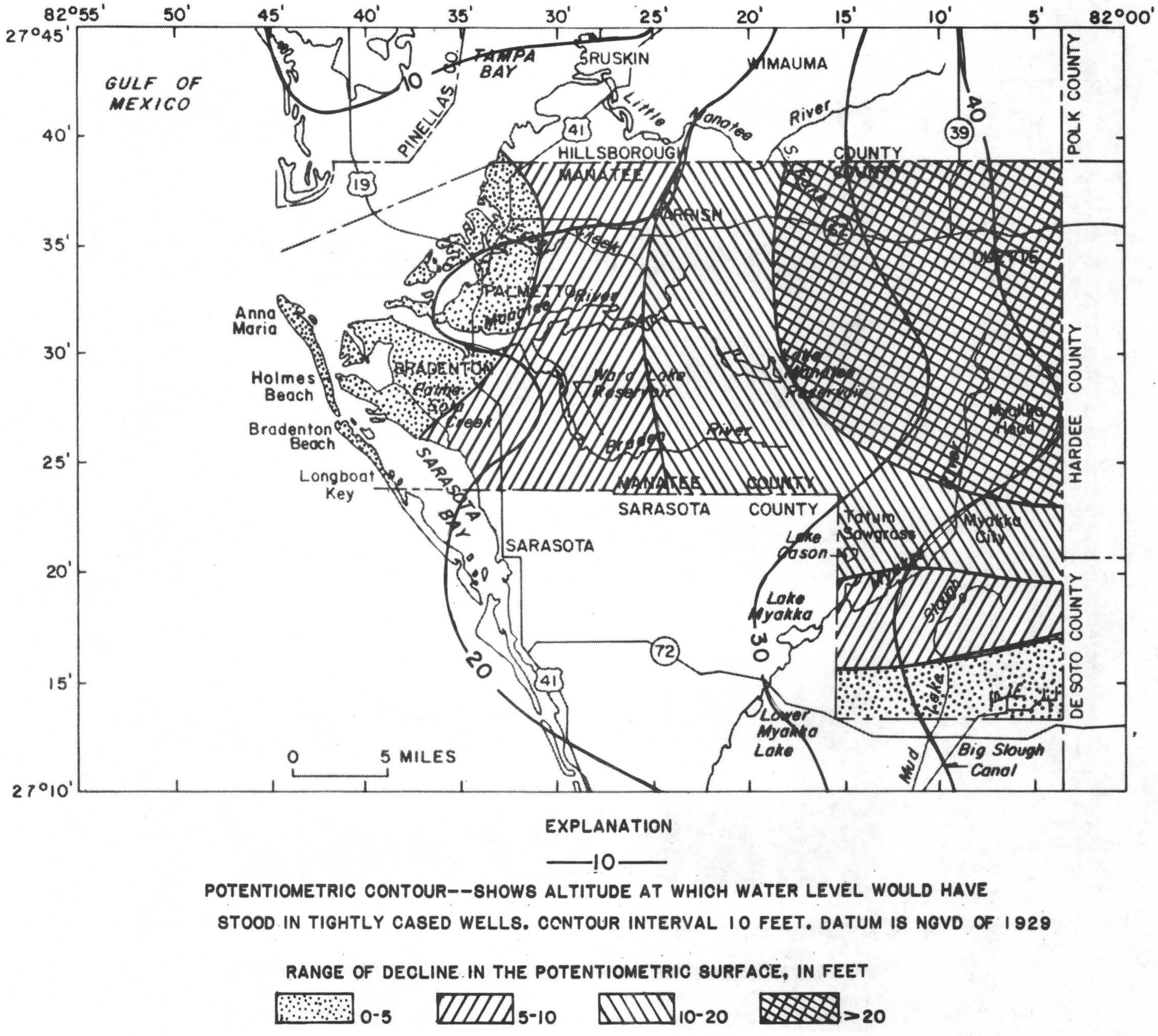


Figure 17.--Potentiometric surface of the Floridan aquifer, September 1975, and decline in the potentiometric surface, September 1954 to September 1975.

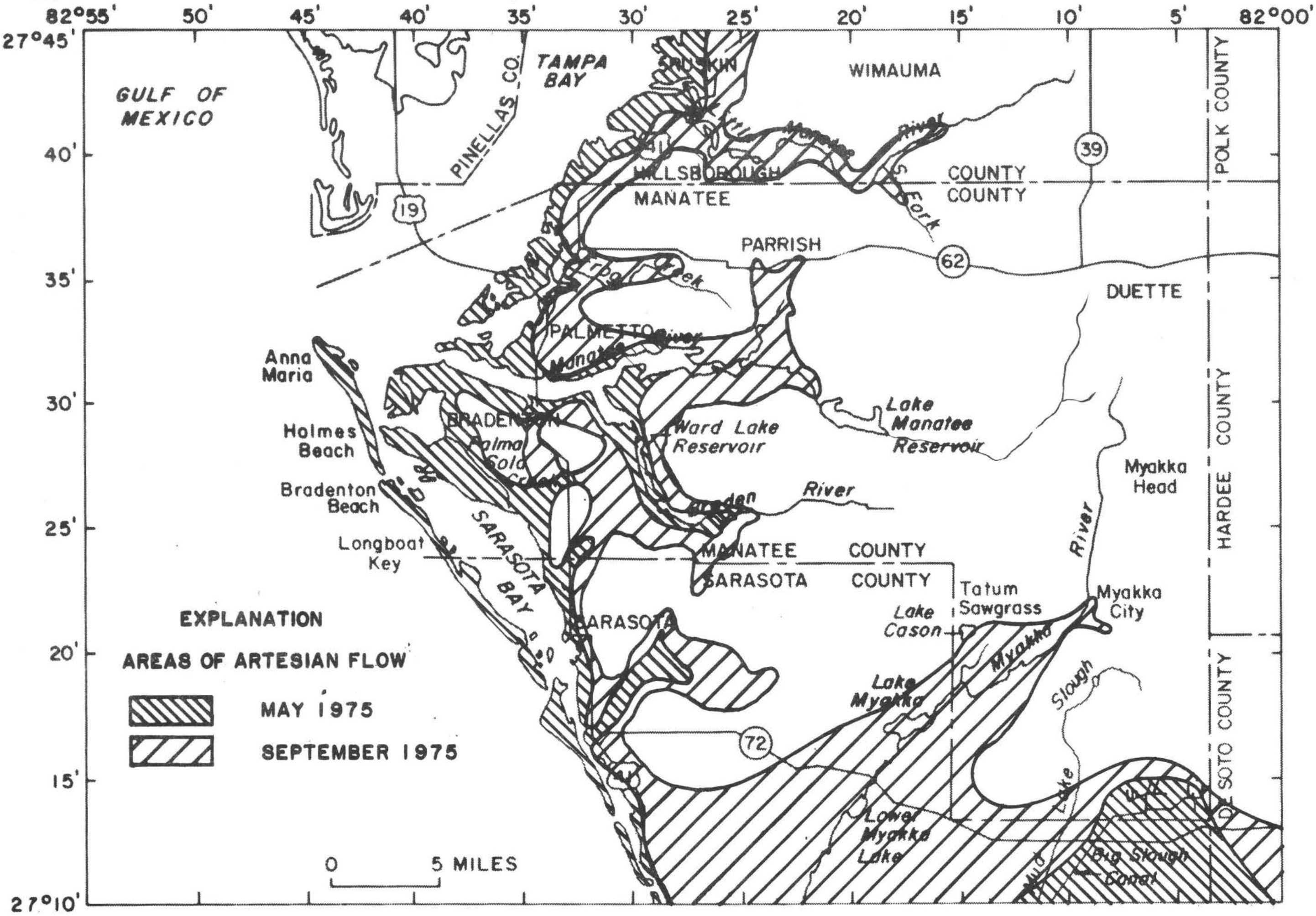


Figure 18.--Areas of artesian flow, May and September 1975.

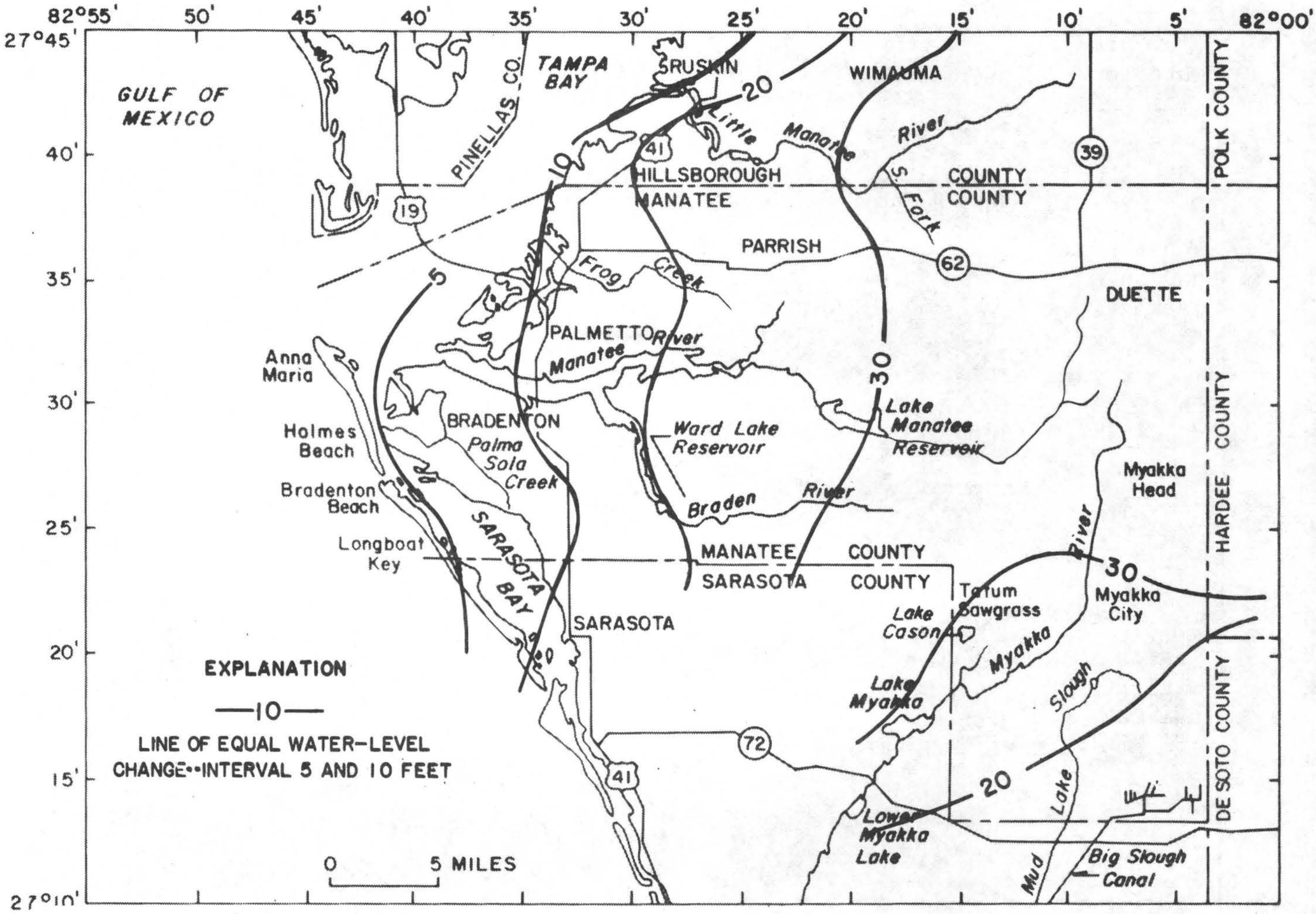


Figure 19.--Change in potentiometric surface, May 1975 to September 1975.

from the surficial aquifer to the Floridan aquifer over the 700-mi^2 area of downward leakage in Manatee County and parts of adjacent counties east of the coast was about 12 Mgal/d, based on an estimated leakance of 1.3×10^{-6} (ft/d)/ft and an average head difference of 60 feet. In September 1975, computed downward leakage was about 6 Mgal/d for an average head difference of 30 feet for the same area and leakance.

Discharge from the Floridan aquifer is primarily from pumpage, ground-water outflow to adjacent areas or the gulf, and upward leakage to the surficial and minor artesian aquifers. A small amount of discharge comes from uncapped, flowing, and improperly constructed wells, especially in coastal and inland areas where the potentiometric surface of the Floridan aquifer is above land surface. In May 1975, the computed upward leakage from the Floridan aquifer to the surficial aquifer over the 200-mi^2 area of artesian flow along the coast was about 0.1 Mgal/d, based on an estimated leakance of 1.3×10^{-6} (ft/d)/ft and an average head difference of 2 feet. In September 1975, computed upward leakage was about 0.5 Mgal/d for an average head difference of 9 feet for the same area and leakance.

Lower Confining Bed

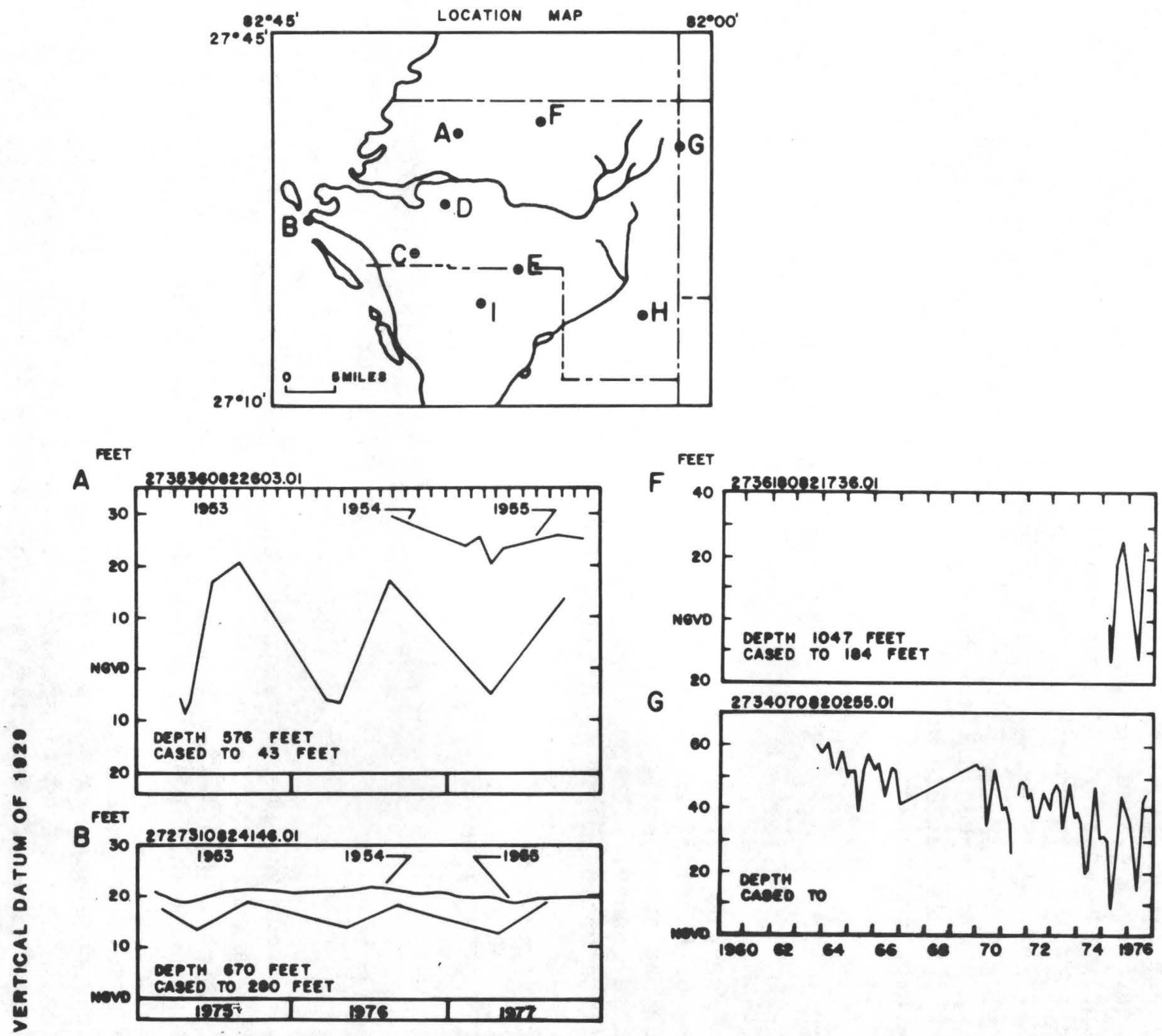
The Lake City Limestone, although a major source of ground water in some parts of Florida, is permeated with evaporites within the intergranular pore space and acts as the lower confining bed of the Floridan aquifer system in Manatee County. The upper part of the Lake City Limestone contains highly mineralized water and is described as having a very low permeability (William F. Guyton and Associates, 1976d). The unit retards vertical movement of mineralized water from deeper zones and forms the base of the Floridan aquifer. The top of the Lake City Limestone ranges from about 1,400 feet below sea level in the northwest to 1,900 feet in the southeast (fig. 21).

Quality of Water

Surface and ground water in Manatee County contain dissolved minerals in varying amounts that affect the quality of water. The mineral constituents and the degree of mineralization depend on composition and solubility of soil and rock through which water passes and upon duration of contact. Water with a low dissolved mineral concentration is generally more suitable for most purposes than water with a high mineral concentration. The source and significance of various constituents and properties of water are discussed in detail by Hem (1970). Those properties that have a practical bearing on water use are summarized in "Water Resources Data for Florida--Water Year 1976" (U.S. Geological Survey, 1977).

Surface Water

Surface water in Manatee County is generally less mineralized than ground water except in tidally affected and coastal areas. The quality of surface water is suitable for most purposes; however, the quality varies seasonally.


LOCATION MAP
82°45'
27°45'
82°00'
27°10'
0 5 MILES
A
B
C
D
E
F
G
H
I
VERTICAL DATUM OF 1929
FEET
27353608226O3.01
1953
1954
1955
30
20
10
NGVD
10
20
DEPTH 576 FEET
CASED TO 43 FEET
27273108241 46.01
DEPTH 670 FEET
CASED TO 280 FEET
1975
1976
1977
2736180821736.01
40
DEPTH 1047 FEET
CASED TO 184 FEET
2734070820255.01
60
40
DEPTH
CASED TO
1960
62
64
66
68
70
72
74
1976

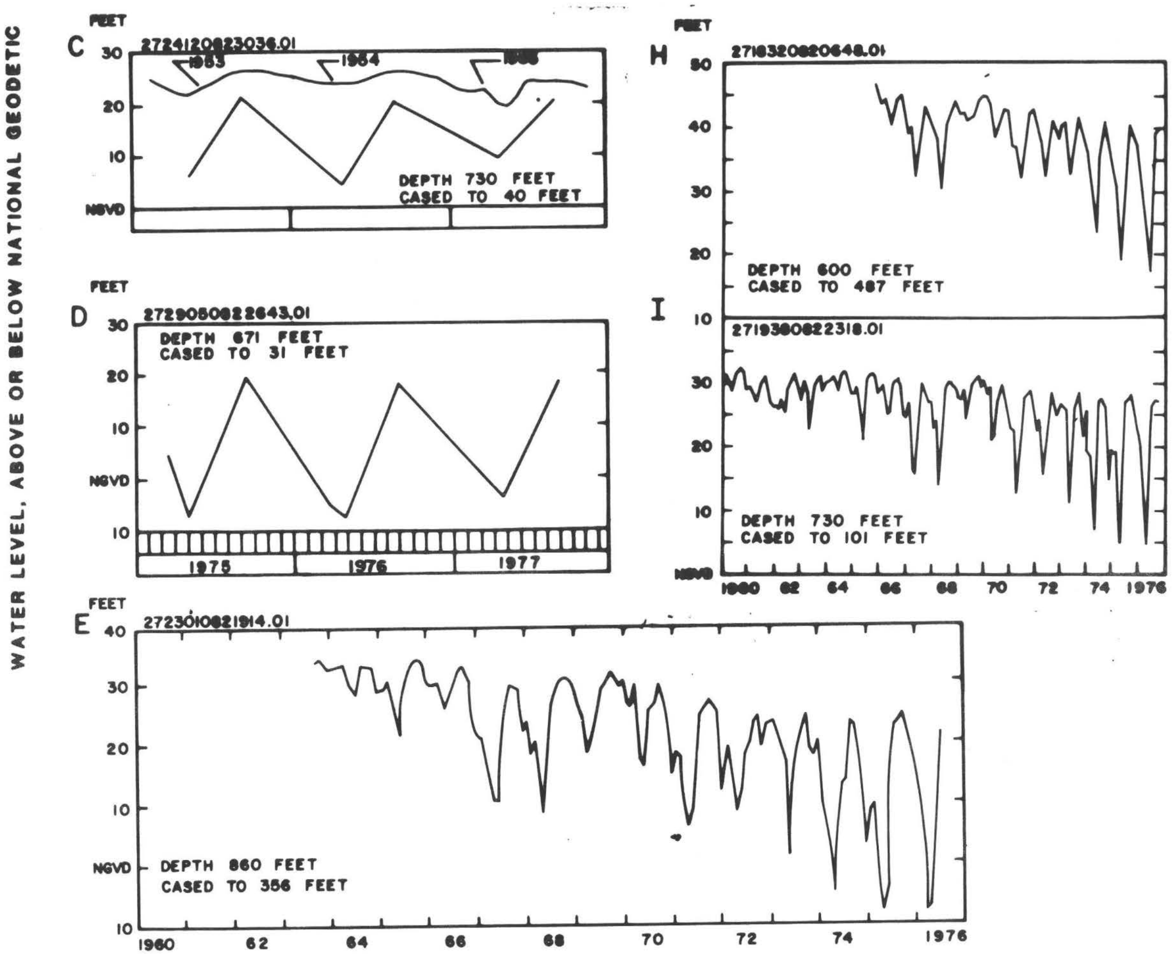


Figure 20.--Water levels in selected wells penetrating the Floridan aquifer.

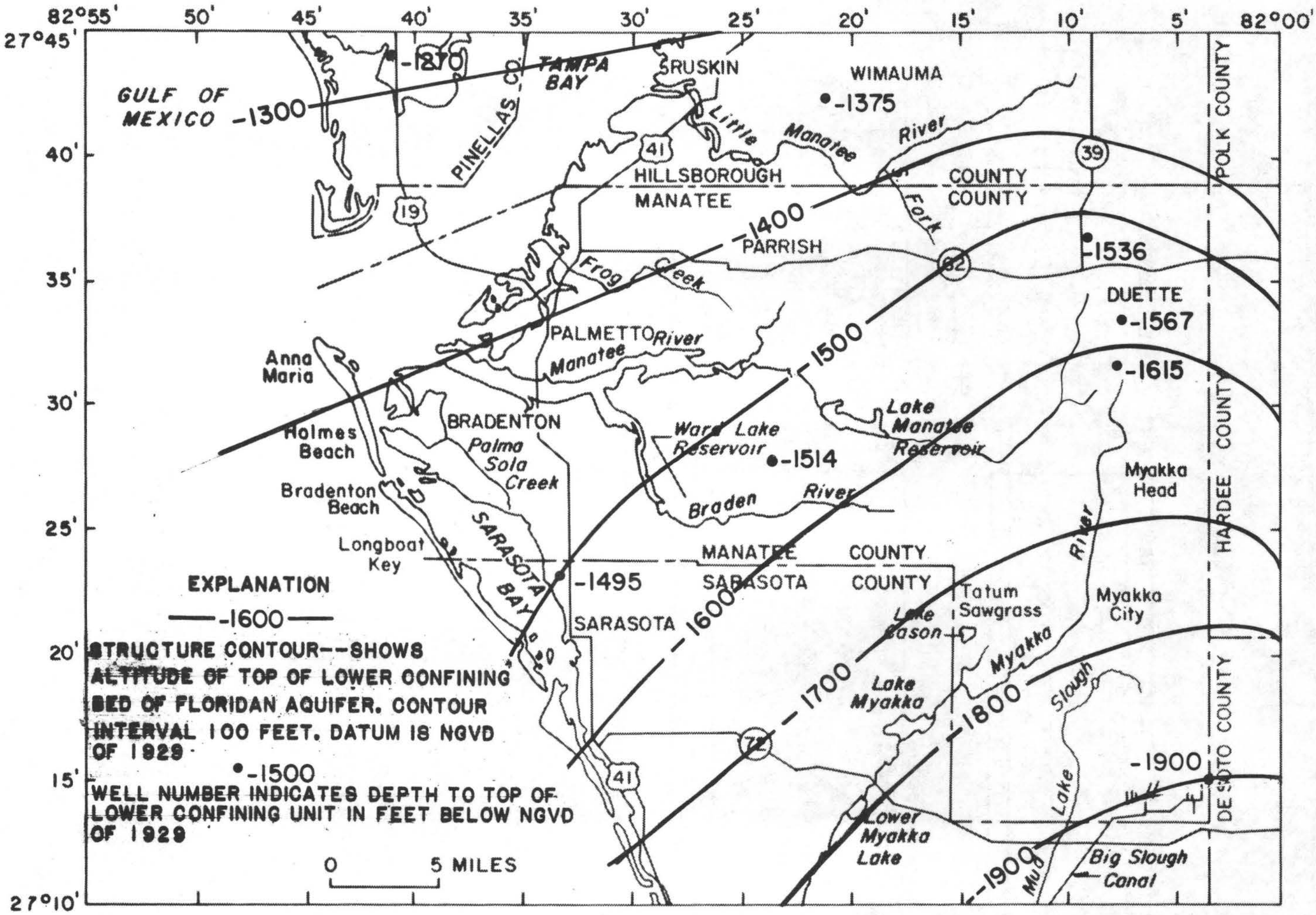


Figure 21.--Altitude of the top of the lower confining bed of the Floridan aquifer system.

Surface-water quality analyses discussed in this report were obtained from U.S. Geological Survey Annual Summary reports (1956-76). During the wet season (June through September), streamflow is composed mainly of runoff, and dissolved mineral concentrations and hardness are lowest. The color of the water, caused in part by decomposition and leaching of organic matter, becomes higher as streamflow increases and is highest in the wet season. During the dry season (October to May), flow of streams is maintained by ground-water discharge, and dissolved mineral concentrations and hardness increase and color decreases. Many streams also derive flow from runoff of irrigation water originating from wells that tap aquifers yielding water having high dissolved solids. Therefore, streams receiving irrigation wastewater tend to be moderately high in dissolved minerals.

The ranges in concentration for selected water-quality parameters for Myakka River near Sarasota, Manatee River near Myakka Head, Manatee River near Bradenton, and Little Manatee River near Wimauma are presented in table 9. The concentrations for chloride, sulfate, dissolved solids, and hardness are within the limits established by the U.S. Environmental Protection Agency (1976) for public water supplies. However, color exceeded 75 platinum-cobalt units, the recommended upper limit for drinking water. Figure 22 shows the seasonal variations of discharge, color, iron, pH, and specific conductance for the Manatee River near Bradenton from October 1964 to September 1965.

During low flow, calcium and magnesium bicarbonate are the dominant chemical constituents present in surface waters in upland areas, whereas, calcium, magnesium and sulfate, and sodium chloride dominate in coastal and low-lying areas (Kaufman, 1972). Calcium and magnesium bicarbonate water is generally associated with Tertiary carbonate terrane in central Florida or may be derived from agricultural runoff or discharge from the Floridan or minor artesian aquifers. Calcium and magnesium sulfate water may be derived from agricultural runoff or may result from discharge from gypsiferous aquifers. Sodium chloride is associated with saline water in the low-lying coastal areas of tidal and estuarine environments. It may also be derived from excess irrigation runoff or discharge from wells penetrating saline water in aquifers.

Ground Water

The chemical quality of ground water is primarily affected by the quality of water recharged to the aquifer, types of rocks in which water is in contact, and length of time water has been circulating within the aquifers. In Manatee County, the chemical quality is also affected by intrusion of seawater or the mixing of relatively fresh water with highly mineralized water, believed to be residual seawater within the water-bearing formations (Peek, 1958a).

Wells that penetrate deep water-bearing zones are commonly constructed with tens to hundreds of feet of open hole and are open to one or more water-bearing zones. Water in each zone has distinctive water-quality characteristics. Thus, the quality of water pumped depends on which zones are tapped and the proportion of water derived from each.

Table 9.--Range in concentration for selected water-quality parameters for streams in Manatee County and adjacent areas

Sampling site	Period of record	Chloride, Cl (mg/L)	Sulfate, SO_4 (mg/L)	Dissolved solids (mg/L)	Hardness as $CaCO_4$ (mg/L)	Specific conductance (umho/cm at 25°C)	Color (Pt-Co units)	Temperature (°C)
Myakka River near Sarasota	1962-66 1967-76	3.0-24 5.5-90	0-8.6 0.8-71	18-67 59-235	10-38 15-120	41-182 42-418	60-210 60-320	9-27 13-33
Manatee River near Myakka Head	1967-76	3.5-16	0.8-20	34-146	10-61	17-212	5-320	11-31
Manatee River near Bradenton	1962-66	2.0-13	0-12	22-80	6-140	19-263	5-220	9-32
Little Manatee River near Wimauma	1956-76	3.2-22	0.8-140	21-323	2-230	37-668	5-250	13-31
Available standard for potable water U.S. Environmental Protection Agency (1976)	---	250	250	500	---	---	75	---

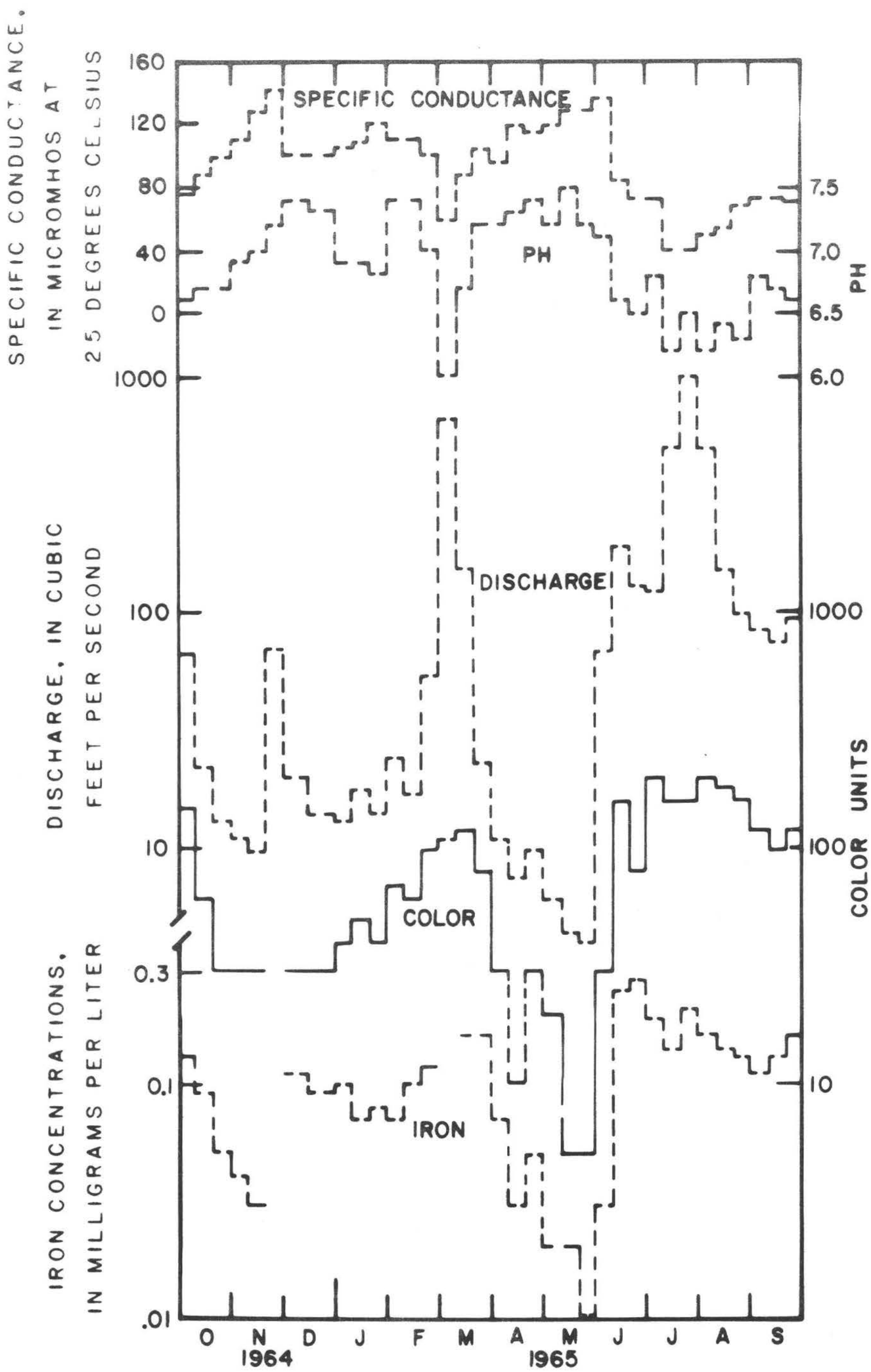


Figure 22.--Seasonal variations of discharge, color, iron, pH, and specific conductance, Manatee River near Bradenton, October 1964 to September 1965 (modified from Kaufman, 1969).

Surficial aquifer

The dissolved mineral content of water from the surficial aquifer varies greatly. Water is generally of potable quality except near the coast and tidally affected streams where saltwater intrusion has taken place.

In northeastern Manatee County, the surficial aquifer is composed of relatively insoluble, quartz sand resulting in water that is low in mineral content and hardness (table 10 and fig. 23). Dissolved solids concentrations are usually less than 300 mg/L. Concentrations of chloride and sulfate are also low, usually less than 10 mg/L and 5 mg/L, respectively. Most water that is soft and low in mineral content has a relatively low pH.

Near the coast and tidally affected streams, water in the surficial aquifer has concentrations of dissolved solids and chlorides of more than 200 and 50 mg/L, respectively. Concentrations of sulfate vary considerably, but are usually less than 20 mg/L. In many places along the coast, water in the surficial aquifer is highly mineralized, approaching that of seawater. In some low-lying and coastal areas, the surficial aquifer is highly mineralized because of infiltration or intrusion by seawater, leakage from improperly constructed wells, uncapped flowing wells, and irrigation water from wells that contain moderate to highly mineralized water (Joyner and Sutcliffe, 1976).

Minor artesian aquifer

The quality of water in the minor artesian aquifer is generally good except near the coast where saltwater intrusion has taken place or residual seawater has not been completely flushed from the aquifer. In northern and eastern Manatee County, concentrations of dissolved solids range from less than 200 to about 400 mg/L (fig. 24 and table 11). Concentrations of sulfate and chloride are less than 20 and 50 mg/L, respectively.

In the central and northeastern parts of the county, the potentiometric surface of the minor artesian aquifer is lower than water levels of the surficial aquifer. Downward leakage of water from the surficial aquifer occurs, and the quality of water is similar to that of the surficial aquifer.

Near the coastal and southeastern parts of the county, the mineral content of water increases. Concentrations of dissolved solids range from about 500 to 1,000 mg/L. Concentrations of sulfate range from less than 100 to about 500 mg/L. Concentrations of chloride are generally less than 250 mg/L except along the coast.

Near the coast, the potentiometric surface of the Floridan aquifer is higher than the potentiometric surface of the minor artesian aquifer, and upward leakage of moderate to highly mineralized water from the Floridan aquifer occurs. In some areas, water in the minor artesian aquifer is more mineralized than water from the Floridan aquifer. This is probably due to either (1) incomplete flushing of the system since the last recession of the sea during Pleistocene time, or (2) solution of mineral salts within the aquifer (Peek, 1958a).

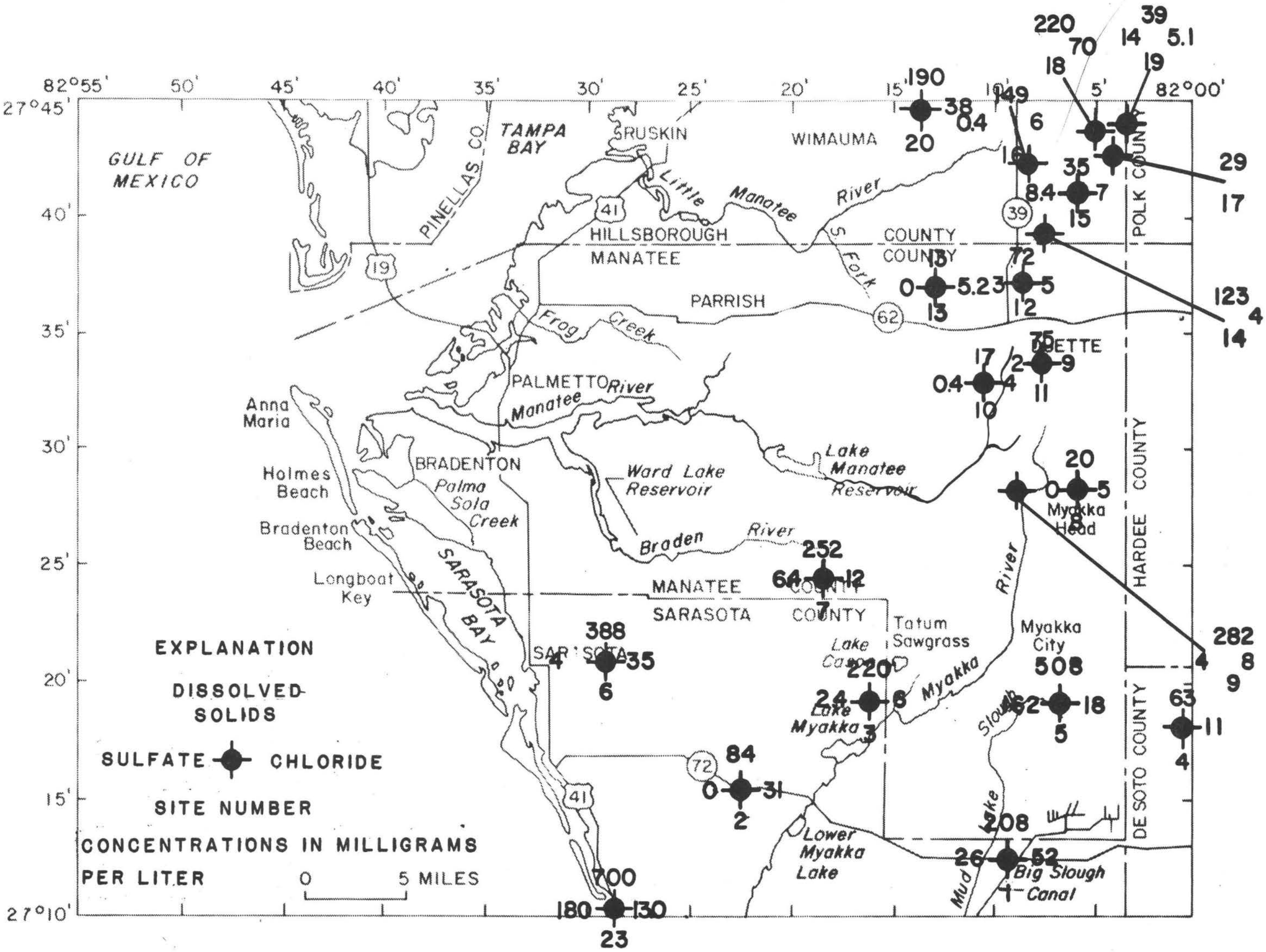


Figure 23.--Quality of water from the surficial aquifer.

Table 10.--Quality of water from the surficial aquifer

[Concentrations are in milligrams per liter, except as indicated]

Site number (fig. 23)	Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate
1	271134N0820922.2[a]	11/28/66	20-25	1.2	--	6.3	12	63	1.5	116	26
2	271456N0822309.2[a]	11/29/66	21-25	.7	--	11	4.4	14	20	64	0.0
3	271821N0821551.1[a]	5/18/65	17-22	15	.32	47	21	5.6	2.3	221	2.4
4	271730N0820020.1[b]	10/14/75	10-26	5.0	1.6	8	3.4	--	--	24	<1
5	271832N0820648.2[a]	2/24/66	65-70	14	.05	83	29	16	3.4	180	162
6	272048N0822858.02[a]	8/26/66	35-38	19	.05	64	31	32	2.4	380	4.0
7	272356N0821813.01[a] (test well)	3/15/65	70-76	16	--	45	20	12	2.2	248	6.4
8	2727340820524.01[a]	4/23/64	15	2.8	--	.8	.2	2.6	0	3	0
9	2727350820834.01	8/30/65	116-120	26	--	50	25	14	2.1	308	4.0
10	2732030821032.01	4/02/66	20-35	--	--	2.4	--	--	--	-	.4
11	Swift south shallow well[c]	6/09/75	10-36	4.3	.31	3.2	1.0	6.1	.19	-	2
12	Swift north shallow well	6/09/75	10-36	6.2	.74	19	5.3	4.1	.62	76	3
13	2736240821241.01[a]	4/02/66	22-30	3.0	--	.7	.6	2.8	0	2	0
14	2735170820728.01[a]	3/31/66	10-22	--	--	3.9	--	--	--	-	--
15	2740330820536.01[a]	3/31/66	11	2.4	--	3.2	1.3	2.7	3.1	3	8.4
16	2742130820848.01[a]	3/31/66	25-41	11	--	6.6	2.3	4.3	.3	30	.4
17	2742280820348.01[a]	3/14/66	30	--	--	3.7	--	--	--	-	--
18	2743170820402.01[a]	3/14/66	30	--	--	2.0	--	--	--	-	--
19	2743360820336.01	3/11/75	SA[d]	2.5	--	6	1.5	3.5	.8	11	14
20	2744400821252.01[a]	3/12/70	19	--	--	--	--	--	--	-	--
21	2706030822502.01	7/13/65	46	22	160	96	7.4	23	1.5	312	15
22	2707570822701.01	4/13/78	29	--	--	400	91	--	--	230	1,100
23	2709040822817.01	4/26/78	42	--	--	150	26	--	--	360	180
24	2708410822659.01	1/26/71	20	--	--	--	--	--	--	-	60

Footnotes are at end of table.

Table 10.--Quality of water from the surficial aquifer--Continued

Site number (fig. 23)	Chloride	Fluoride	Nitrate	Phosphate	Dissolved solids		Hardness		Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
					Calculated	Residue at 180°C	Calcium-magnesium	Noncarbonate				
1	52	1.9	0.2	0.06	221	208	65	0	410	7.9	5	--
2	31	.1	.4	.02	96	84	46	0	238	7.1	10	--
3	8.0	.9	0	.70	212	220	204	23	370	8.0	5	--
4	11	.3	--	1.45	-	63	34	--	--	5.7	50	--
5	18	1.2	0	.00	416	508	335	188	693	7.8	50	--
6	35	.5	.4	0	375	388	288	0	672	8.2	15	--
7	12	.7	.1	--	236	252	196	0	400	7.9	10	--
8	.5	0	0	--	13	20	3	0	22	5.8	5	--
9	8.0	.7	0	.12	282	--	228	0	475	8.1	5	--
10	4.5	--	--	.2	-	17	4	--	33	-	--	--
11	9	.2	--	--	-	24	12	--	75	-	5	--
12	5	.7	--	--	-	72	70	--	134	6.4	5	--
13	5.2	.1	--	0	13	--	4	3	32	5.2	--	--
14	36	.3	10	.04	123	--	32	28	242	-	0	--
15	7.0	.2	6.4	.07	-	35	14	11	62	5.2	0	--
16	6.0	.7	--	2.6	49	--	26	2	75	6.6	--	--
17	--	.1	--	.9	-	29	--	--	55	-	--	--
18	7.0	.2	--	.03	-	220	--	--	381	-	--	--
19	5.1	.1	--	--	39	--	21	--	64	6.4	--	--
20	38	--	--	--	-	190	--	--	341	-	--	--
21	36	.4	0	0	355	--	270	14	609	7.7	5	--
22	54	.3	--	--	-	-1,330	1,400	1,200	2,150	-	--	--
23	130	.5	--	--	-	700	480	190	1,165	-	--	--
24	80	--	--	--	-	410	300	--	700	-	--	23

[a]Analysis by U.S. Geological Survey.

[b]Analysis by Geraghty and Miller, Inc. (1975).

[c]Analysis by Swift Chemical.

[d]Surficial aquifer.

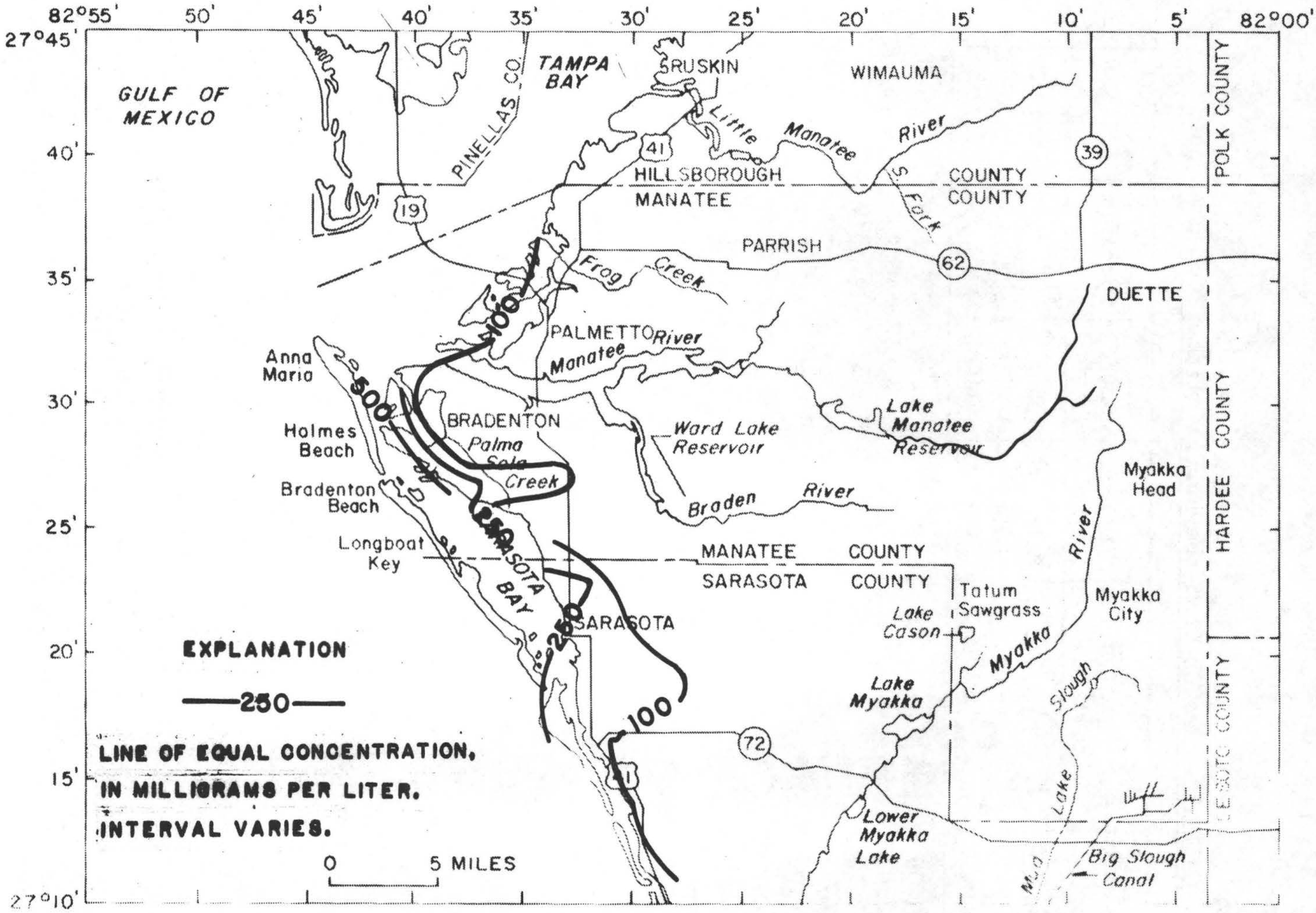


Figure 24a.--Concentrations of chloride in water from the minor artesian aquifer.

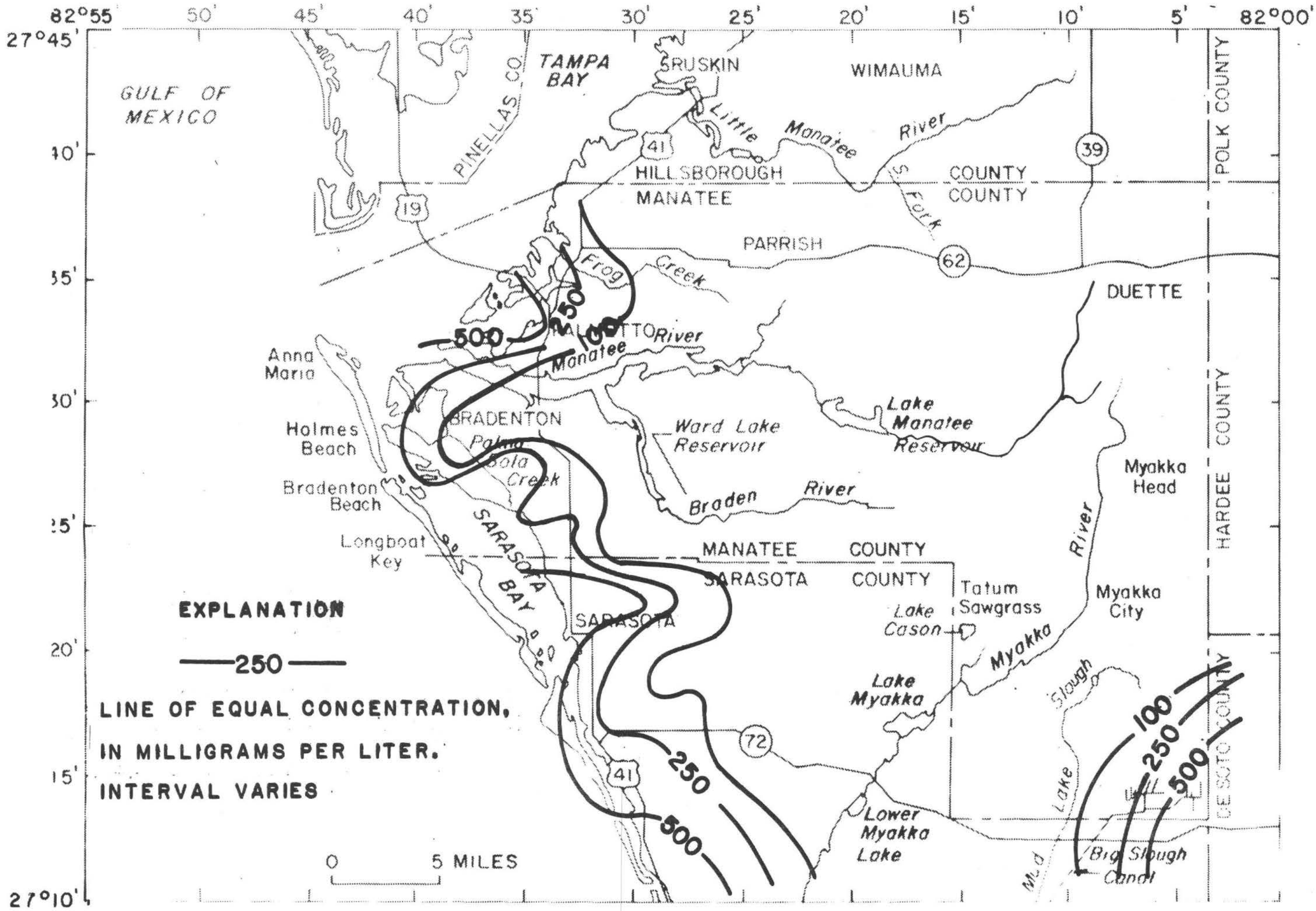


Figure 24b.--Concentrations of sulfate in water from the minor artesian aquifer.

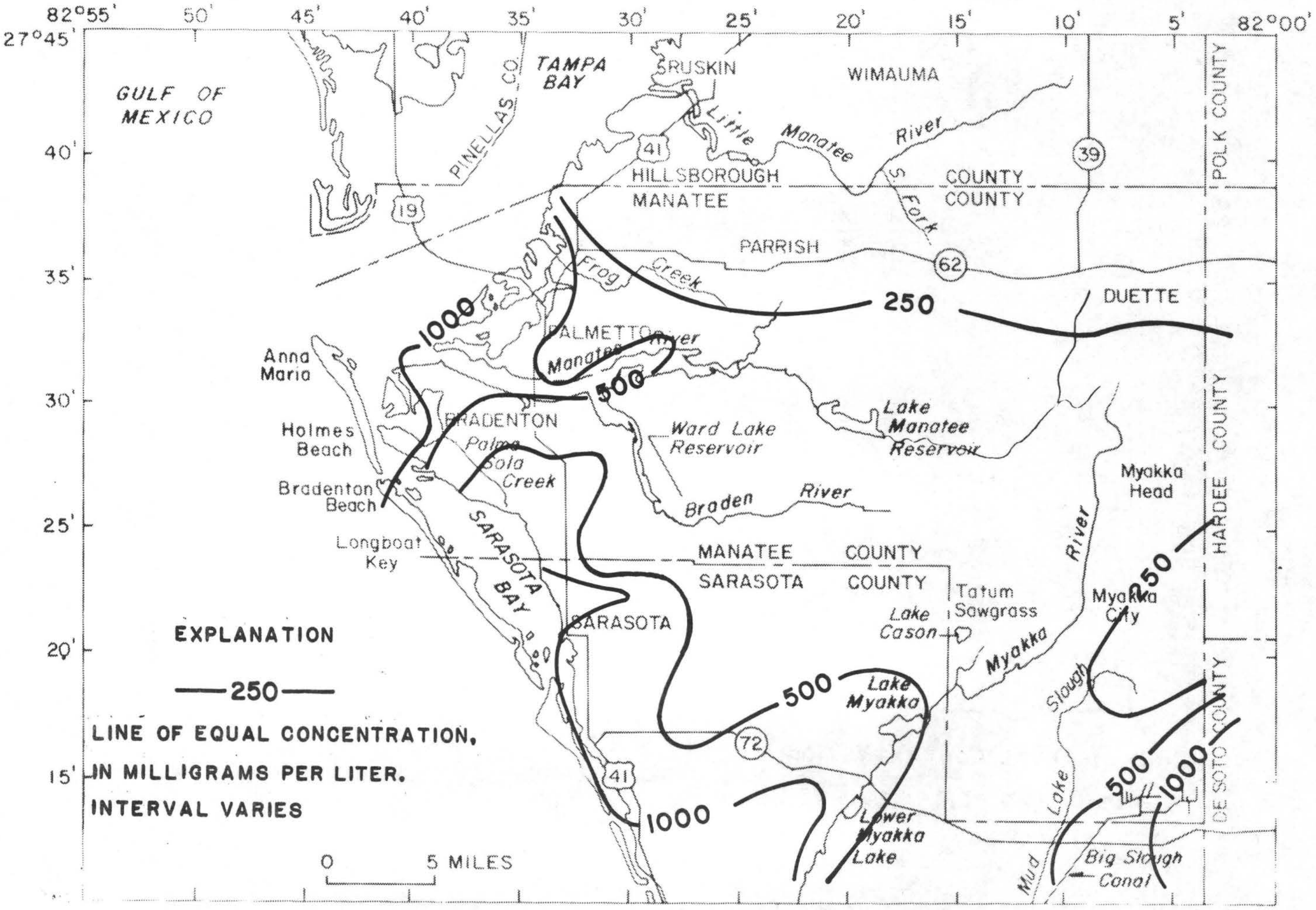


Figure 24c.--Concentrations of dissolved solids in water from the minor artesian aquifer.

Table 11.--Quality of water from the minor artesian aquifer

[Concentrations are in milligrams per liter, except as indicated]

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2709070822616.01	4/20/71	63-89	--	--	-	-	--	-	--	140	80
2710420822953.01	7/07/66	110	--	--	-	-	--	-	--	325	158
2712300820530.01[a]	11/07/74	60-300	24	0.4	184	60	--	-	186	530	58
2713080823057.01	9/12/63	148	--	--	-	-	--	-	--	483	186
2713130820817.01	12/13/63	43-256	33	--	70	39	20	1.8	246	134	28
2714570820322.02[b]	2/21/75	300	4.6	.89	256	10	--	-	26	651	34
2715320823017.01	2/11/65	60-263	--	.03	-	-	--	-	--	406	50
2715340822401.01	2/15/68	82-290	--	--	-	-	--	-	--	88	86
2715520823004.01	11/12/64	100	--	--	-	-	--	-	--	68	100
2716080822802.01	4/21/66	58-102	--	--	-	-	--	-	--	346	68
2716080823108.01	11/12/64	61-150	--	--	-	-	--	-	--	158	185
2716370823338.01	3/24/64	180	--	--	-	-	--	-	--	510	240
2716480822637.01	12/18/66	134-180	--	.1	-	-	--	-	--	7.6	74
2717280822742.01	11/08/72	107-152	--	<.01	-	-	--	-	--	120	100
2717360823319.01	10/10/63	71-150	--	--	-	-	--	-	--	289	125
2717520821606.01	4/11/62	150	--	--	-	-	--	-	--	193	38
2717530822723.01	11/08/72	76-106	--	.01	-	-	--	-	--	80	80
2717570822413.01	8/--/66	67-120	--	--	-	-	--	-	--	418	78
2718300822814.01	11/13/64	82-100	--	--	-	-	--	-	--	38	122
2719380821748.01	7/11/63	120	--	--	-	-	--	-	--	58	72
2719420822842.01	9/21/64	53-91	--	--	-	-	--	-	--	145	87
2720100822705.01	2/15/73	245	--	<.01	-	-	--	-	--	150	60
2721030823235.01	10/10/62	60-230	--	--	-	-	--	-	--	536	269
2721060823105.01	4/21/64	94-170	--	--	-	-	--	-	--	54	116
2721260822929.01	5/16/62	55-150	--	--	-	-	--	-	--	560	85

Footnotes are at end of table.

Table 11.--Quality of water from the minor artesian aquifer--Continued

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal- cium	Magne- sium	Sodium	Potas- sium	Bicar- bonate	Sul- fate	Chlor- ide
2721260823230.02	10/21/62	145	--	--	-	-	--	-	--	53	122
2721420823718.01	9/30/66	168-213	--	--	-	-	--	-	--	160	460
2722030823221.01	1/27/72	51-199	--	.6	-	-	--	-	--	825	1,200
2722550823039.01	11/12/64	47-173	--	--	-	-	--	-	.2	10	--
2725050823314.01	10/28/71	33-87	--	.2	-	-	--	-	225	84	--
2725450824104.01	6/07/67	45-228	--	--	-	-	--	-	--	--	--
2727330820532.01	6/03/64	80-280	51	--	44	25	17	2.1	270	16	11
	3/31/66		52	--	42	25	19	2.1	268	15	9.0
2727410824146.02	6/10/76	350	25	1.1	230	110	160	9.6	179	670	410
2727460824009.01	7/21/64	147-163	--	--	-	-	--	-	--	194	570
2727510823703.01	3/12/68	290-350	--	--	-	-	--	-	--	450	360
2730020820816.01[c]	74	130-200	32	7.8	68	36	28	8.0	182	76	17
2731180823842.01	2/18/55	23-100	--	--	104	56	--	-	220	240	96
	9/27/65		31	--	96	50	44	4.2	226	294	100
2732150821027.01	4/02/66	65-105	27	.01	49	24	10	.3	288	0.0	4.0
2732540820728.01[d]	6/09/75	120-249	56	.13	50	15	--	-	--	34	12
2735030823657.01	9/19/75	330	--	--	150	79	--	-	300	240	--
2736490821237.01	4/01/66	80-350	41	--	32	16	5.1	1.7	184	.4	3.0
2737220823158.01	5/10/66	35-98	1.2	--	86	26	35	6.0	241	106	70
	4/28/67		28	--	74	27	38	6.9	244	69	75
	9/08/67		27	--	78	25	39	6.8	248	90	72
2737230823211.01	5/10/66	170-284	--	--	-	-	--	-	--	202	44

Table 11.--Quality of water from the minor artesian aquifer--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids		Hardness		Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
				Calculated	Residue at 180°C	Calcium-magnesium	Noncarbonate				
2709070822616.01	-	--	--	--	480	225	-	750	-	--	26.0
2710420822953.01	-	--	--	--	--	--	-	--	-	--	28.9
2712300820530.01[a]	1.9	0.28	0.84	--	998	706	520	1,000	7.4	--	24.2
2713080823057.01	-	--	--	--	1,000	741	-	1,580	-	--	--
2713130820817.01	2.1	0.0	.06	449	482	336	134	690	8.0	5	24.4
2714570820322.02[b]	.91	.72	--	--	1,179	683	655	1,300	7.9	--	26.5
2715320823017.01	-	-	--	--	680	560	-	1,150	-	--	25
2715340822401.01	-	-	--	--	580	354	-	910	-	--	--
2715520823004.01	-	-	--	--	520	320	-	810	-	--	24.4
2716080822802.01	-	-	--	--	800	608	-	1,230	-	--	26.1
2716080823108.01	-	-	--	--	800	480	-	1,230	-	--	23.9
2716370823338.01	-	-	--	--	1,130	525	-	1,800	-	--	--
2716480822637.01	-	-	--	--	440	--	-	682	-	--	--
2717280822742.01	-	-	--	--	480	400	-	740	-	--	--
2717360823319.01	-	-	--	--	700	530	-	1,100	-	--	--
2717520821606.01	-	-	--	--	500	418	-	678	-	--	23.9
2717530822723.01	-	-	--	--	420	400	-	650	-	--	--
2717570822413.01	-	-	--	--	860	626	-	1,310	-	--	26.1
2718300822814.01	-	-	--	--	560	264	-	779	-	--	24.4
2719380821748.01	-	-	--	--	440	306	-	730	-	--	--
2719420822842.01	-	-	--	--	550	386	-	845	-	--	24.4
2720100822705.01	-	-	--	--	500	300	-	675	-	--	--
2721030823235.01	-	-	--	--	1,300	--	-	1,980	-	--	--
2721060823105.01	-	-	--	--	550	--	-	860	-	--	24.4
2721260822929.01	-	-	--	--	1,000	840	-	1,550	-	--	25.0

Table 11.--Quality of water from the minor artesian aquifer--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness: Calcium-magnesium	Hardness: Noncarbonate	Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
2721260823230.02	-	-	--	--	--	92	-	--	-	--	--
2721420823718.01	-	-	--	--	1,320	--	-	2,070	-	--	--
2722030823221.01	-	-	--	--	4,150	1,950	-	6,500	-	--	--
2722550823039.01	-	-	--	--	350	294	-	553	-	--	--
2725050823314.01	-	-	--	--	800	530	-	1,250	-	--	23.5
2725450824104.01	-	-	--	--	520	--	-	800	-	--	26.1
2727330820532.01	2.9	0.00	0.0	302	298	213	0	435	8.0	5	--
	.3	.00	.1	296	--	208	0	435	8.0	0	--
2727410824146.02	1.7	-	--	1,720	1,870	1,100	900	2,700	7.4	0	26.5
2727460824009.01	1.6	-	--	--	1,450	--	-	2,300	-	--	23.8
2727510823703.01	-	-	--	--	1,400	--	-	2,150	-	--	26
2730020820816.01[c]	1.6	.01	4.0	398	399	318	116	420	8.5	--	--
2731180823842.01	-	-	--	--	750	490	310	1,040	7.4	--	23.8
	.5	0.0	--	731	--	445	260	1,100	7.5	15	23.3
2732150821027.01	.2	.20	<.01	257	--	220	0	420	8.0	10	--
2732540820728.01[d]	-	.49	--	--	290	186	2.0	390	7.7	5	--
2735030823657.01	-	-	--	--	--	700	-	1,650	-	--	25.6
2736490821237.01	.2	-	.35	--	170	--	-	267	7.5	--	24.4
2737220823158.01	.6	0.00	.26	451	564	320	130	780	7.8	5	27.7
	.7	.20	--	441	450	300	98	800	7.9	5	--
	1.1	.10	.02	463	486	300	96	725	7.7	10	--
2737230823211.01	-	-	--	--	500	370	-	810	-	--	26.7

[a]Phillips no. 62.

[b]Phillips 300 feet.

[c]Beker H-1.

[d]Swift H-035.

Fluoride concentrations in water from wells penetrating the Hawthorn Formation range from less than 0.5 to about 3.0 mg/L. The source of the fluoride is apparently associated with the phosphate minerals within the formation (Toler, 1967).

Floridan aquifer

Water in the Floridan aquifer is generally more mineralized than water from the surficial and minor artesian aquifers. Mineral content of the water within the aquifer varies vertically and areally. Mineral content of the water generally increases with depth of the aquifer penetrated. Water from wells open to the upper water-bearing zone is generally less mineralized than water from wells open to the middle water-bearing zone. Water from wells open to the lower water-bearing zone or to the full thickness of the aquifer has the highest mineralization.

Dissolved Solids.--Concentrations of dissolved solids in water from the Floridan aquifer range from about 300 to more than 2,500 mg/L in the three major water-bearing zones. Concentrations generally increase with depth and laterally from the northeastern part of the county towards the west and south. Dissolved solids in water from wells penetrating the upper zone exceed 500 mg/L in the western and southern parts of the county (fig. 25 and table 12).

Water from wells penetrating the middle zone has dissolved solids concentrations ranging from about 300 to 1,800 mg/L (fig. 25 and table 13). In northeastern Manatee County, dissolved solids are less than 500 mg/L, and in the western and southeastern parts of the county, dissolved solids concentrations range from about 600 to 1,500 mg/L. Dissolved solids concentrations in a small area west of Myakka City near the Verna well field exceed 1,000 mg/L.

Concentrations of dissolved solids in water from wells penetrating the lower zone range from about 300 to 2,500 mg/L (table 14 and fig. 25). In the northeastern part of the county, dissolved solids concentrations are generally less than 400 mg/L, and in the western and coastal parts, dissolved solids exceed 1,000 and 2,000 mg/L, respectively. Concentrations exceeding 1,000 mg/L of dissolved solids occur east of Parrish and northwest of Myakka City (fig. 25).

Chloride.--Concentrations of chloride in water from the Floridan aquifer are less than 250 mg/L except near the coast where the aquifer contains connate water (fig. 26 and table 15). In eastern and southeastern Manatee County, concentrations of chloride are generally less than 50 mg/L and change little with depth.

Concentrations of chloride in the western and coastal areas open to the upper zone range from less than 50 to more than 700 mg/L, generally increasing seaward and with depth (fig. 26). Concentrations of chloride in water from wells open to the middle zone usually exceed 250 mg/L in the coastal areas (fig. 26). In water from wells open to the upper part of the lower zone, concentrations exceed 500 mg/L in coastal areas (fig. 26).

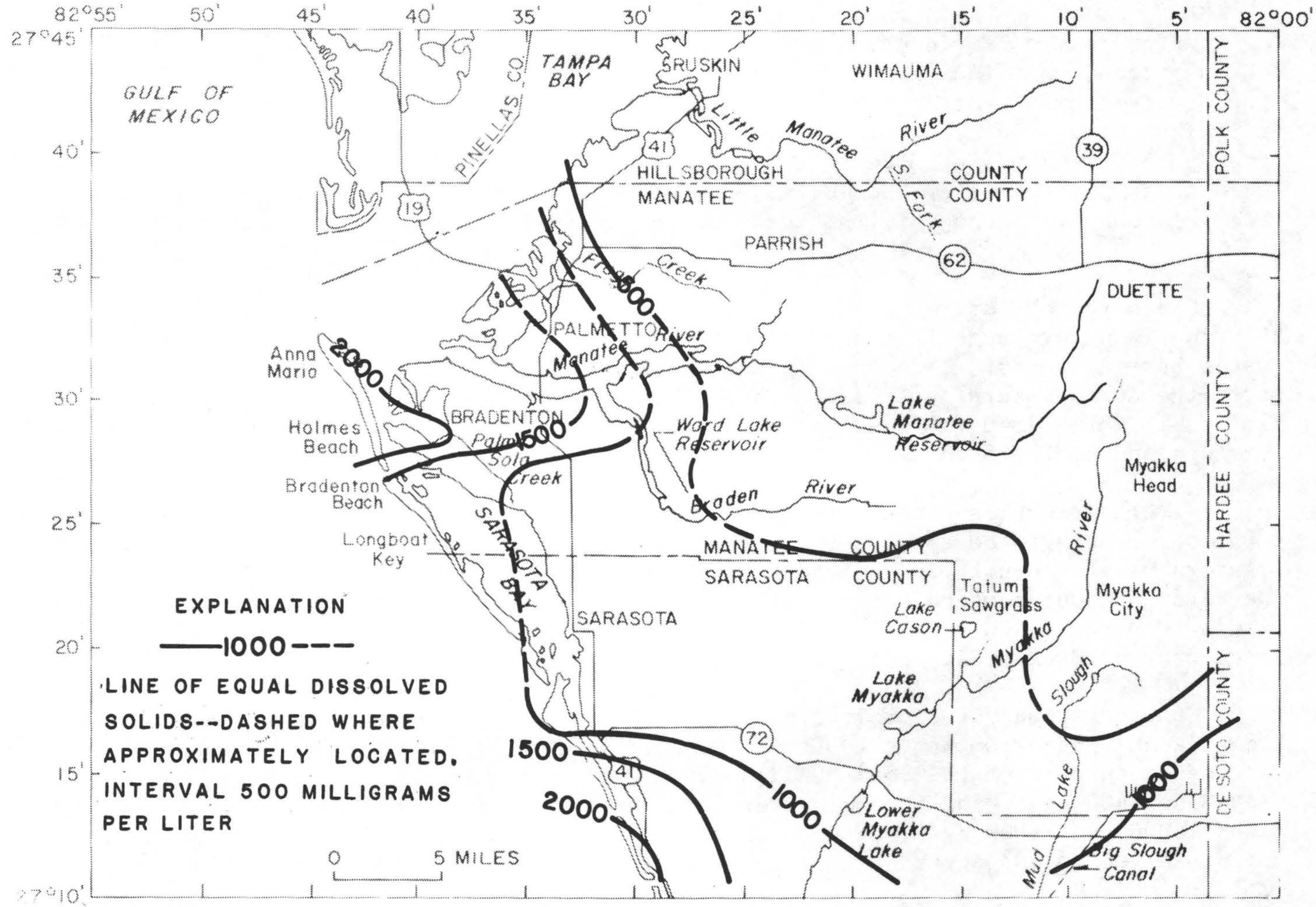


Figure 25a.--Concentrations of dissolved solids in water from the Tampa (upper zone) Limestone.

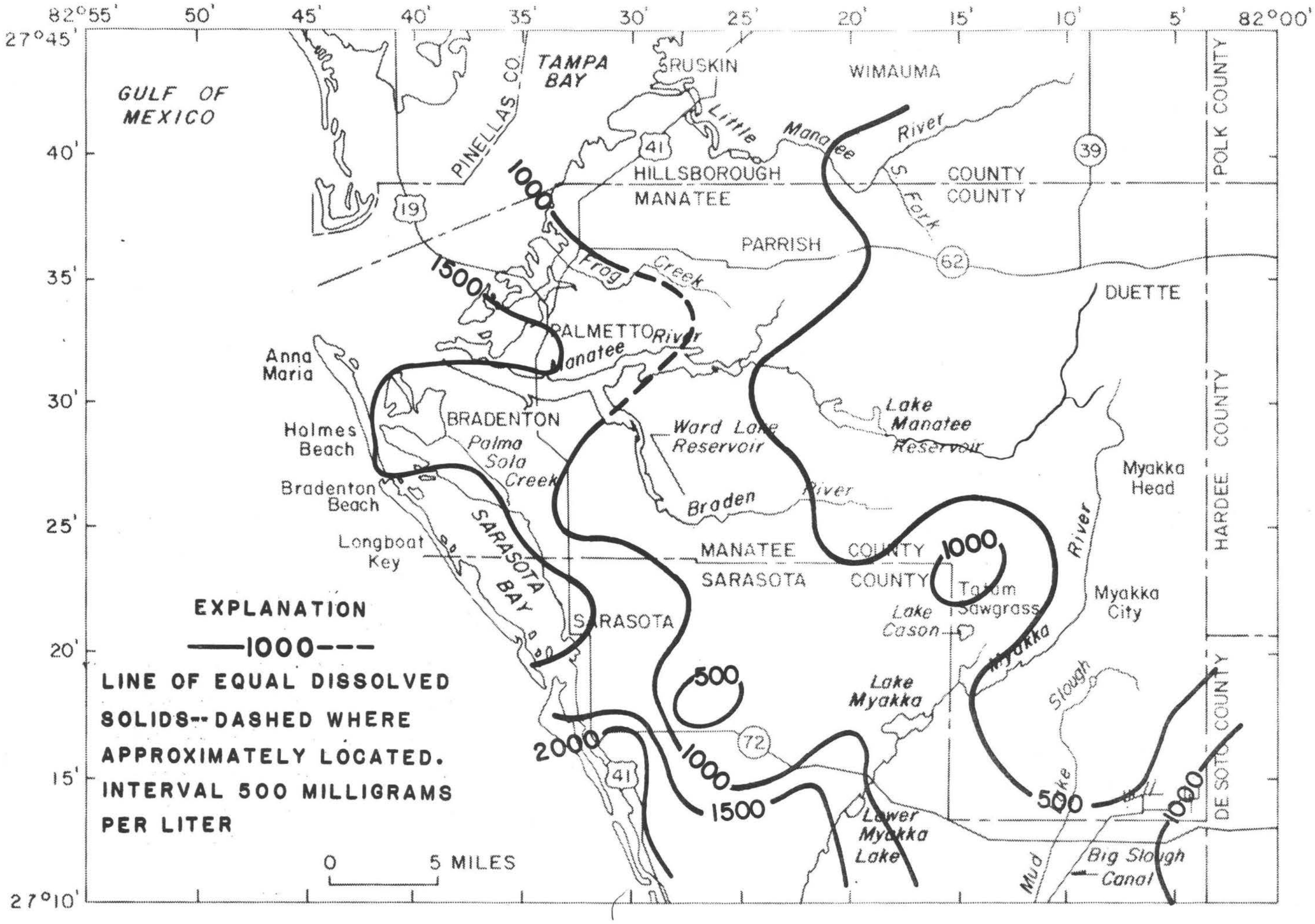


Figure 25b.--Concentrations of dissolved solids in water from the Suwannee-Ocala (middle zone) Limestones.

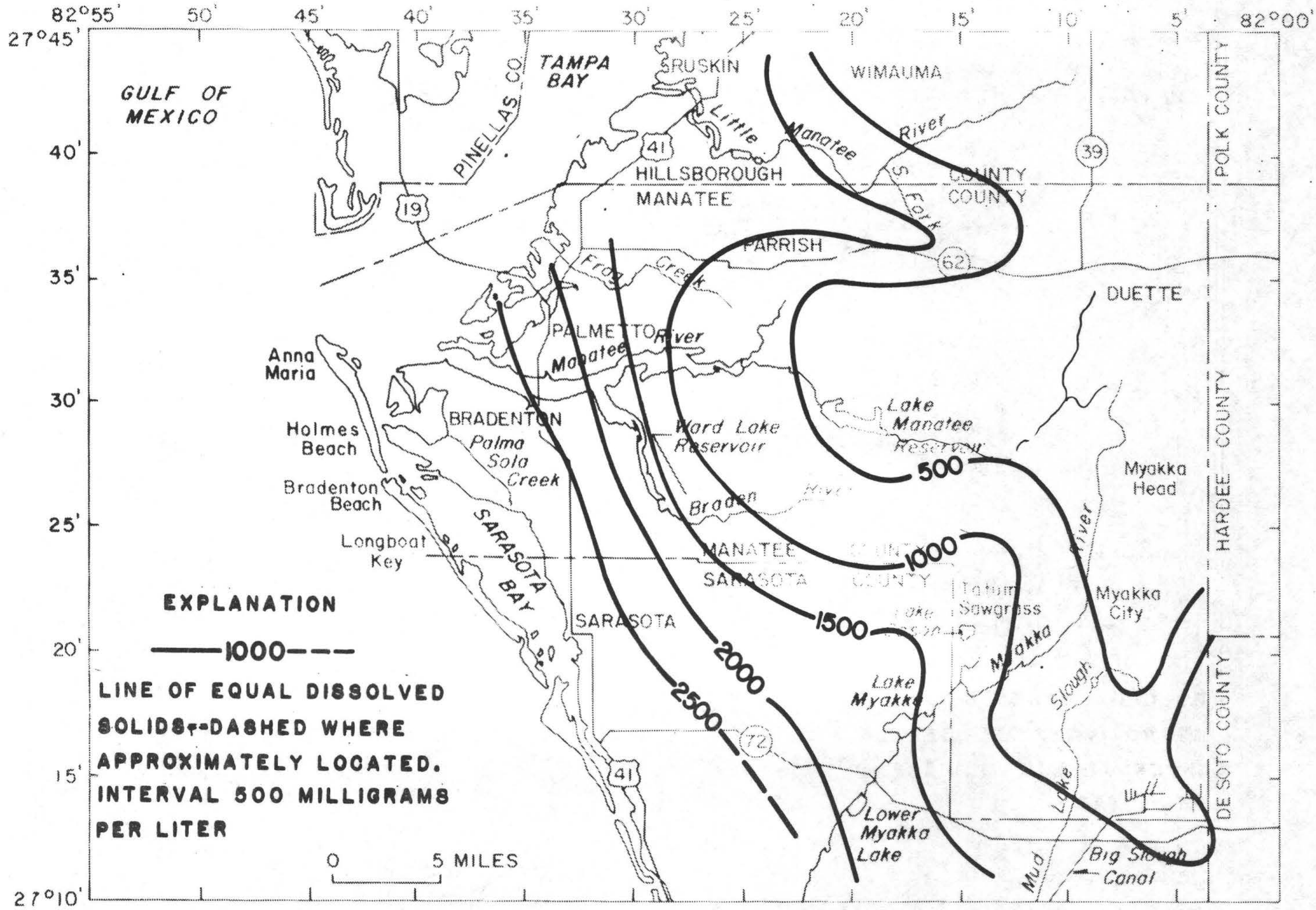


Figure 25c.--Concentrations of dissolved solids in water from the Avon Park (lower zone) Limestone.

Table 12.--Quality of water from the Tampa Limestone (upper water-bearing zone)

[Concentrations are in milligrams per liter, except as indicated]

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2707140821552.01	3/30/66	282-350	25	60	141	87	71	4.4	176	506	142
2710370822748.01	1/26/68	28-424	-	-	-	-	-	-	-	1,750	300
2711180822853.01	8/25/66	154-255	26	20	450	158	59	6.2	168	1,540	110
2715230823213.01	7/16/62	138-412	-	-	-	-	-	-	-	1,140	175
2716110822348.01	1/23/68	122-349	-	-	-	-	-	-	-	29	146
2716190822402.01	12/07/67	104-446	-	-	-	-	-	-	-	440	60
2716540823311.01	5/25/71	415	-	20	-	-	-	-	-	500	75
2717040823319.01	4/04/73	406	-	0	-	-	-	-	-	357	63
2718320820648.01	6/24/65	416-485	25	0	82	42	19	3.4	228	191	20
2720190823226.01	3/15/72	346	750	-	-	-	-	-	-	330	170
2722480821846.01 (P-5)	4/28/75	383	-	-	130	60	-	-	119	370	18
2723070821645.01	6/23/70	404	26	-	139	68	14	2.7	194	450	18
	4/30/75	-	-	-	140	62	-	-	190	420	16
2723240823831.01	6/10/76	417	27	140	210	96	140	9.0	163	660	320
2723560821813.01	4/09/65	309-350	28	20	40	30	23	4.4	298	2.4	13
2724170823909.01	11/03/72	433	-	100	-	-	-	-	-	260	220
2725580823606.01	10/11/72	399	-	10	-	-	-	-	-	120	60
2727350820834.01	9/22/65	227-400	-	-	31	26	-	-	-	0	28
2727400823730.01	6/11/76	134-410	35	10	160	53	120	4.2	281	220	290
2727500823803.01	6/11/76	360	25	300	290	120	310	5.8	161	730	770
2731310824303.01	6/10/76	402	28	90	220	100	220	9.6	191	450	630
2733330823329.01	3/09/71	403	-	-	-	-	-	-	-	600	190

Table 12.--Quality of water from the Tampa Limestone (upper water-bearing zone)--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids		Hardness		Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
				Calculated	Residue at 180°C	Calcium-magnesium	Noncarbonate				
2707140821552.01	1.8	0	0.02	1,065	1,190	710	566	1,610	7.7	5	--
2710370822748.01	-	-	--	--	1,810	--	--	2,800	-	--	26.7
2711180822853.01	1.4	0	.04	2,430	2,860	1,788	1,650	2,835	7.5	0	--
2715230823213.01	-	-	--	--	1,550	--	--	2,380	-	--	25.0
2716110822348.01	-	-	--	--	500	264	--	789	-	--	--
2716190822402.01	-	-	--	--	780	--	--	1,210	-	--	27.8
2716540823311.01	-	-	--	--	530	630	--	840	-	--	--
2717040823319.01	-	-	--	--	--	498	--	--	-	--	--
2718320820648.01	1.5	0	.07	496	574	376	189	740	7.5	5	--
2720190823226.01	-	-	--	--	930	800	--	1,420	-	--	--
2722480821846.01 (P-5)	1.7	-	--	700	--	610	440	1,100	7.5	--	27.0
2723070821645.01	1.3	0.0	0.0	926	835	650	491	1,110	8.0	0	27.0
	1.4	-	--	840	--	630	480	1,120	7.5	--	26.5
2723240823831.01	1.6	-	--	1,560	1,650	940	810	2,380	7.4	0	26.5
2723560821813.01	2.7	.2	.2	291	318	222	0	462	7.8	10	--
2724170823909.01	-	-	--	--	680	830	--	1,050	-	--	26.0
2725580823606.01	-	-	--	--	430	400	--	650	-	--	--
2727350820834.01	2.5	-	.06	--	305	188	--	488	-	--	--
2727400823730.01	1.0	-	--	1,030	1,060	620	390	1,780	7.7	10	25.6
2727500823803.01	1.8	-	--	2,350	2,390	1,200	1,100	3,980	7.3	0	26.0
2731310824303.01	1.7	-	--	1,170	1,870	980	820	3,120	7.3	0	26.0
2733330823329.01	-	-	--	--	--	--	--	--	-	--	--

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)

[Concentrations are in milligrams per liter, except as indicated]

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2709430822814.01	12/15/71	43-513	--	0.4	-	--	-	-	-	875	278
2710370822748.01	1/26/68	28-424	--	--	-	--	-	-	-	1,750	300
2711350822802.01	7/14/65	53-720	--	--	-	--	-	-	-	1,660	70
2712130820559.01	9/27/63	58-845	--	--	-	--	-	-	-	52	45
2712260821053.01	2/15/68	70-593	--	--	-	--	-	-	-	200	53
2713330822332.01	5/24/62	53-730	--	--	-	--	-	-	-	1,380	15
2714200822257.01	5/19/66	58-880	--	--	-	--	-	-	-	624	42
2714240821858.01	9/27/62	600	--	--	-	--	-	-	-	592	40
2714500822332.01	5/24/62	660	--	--	-	--	-	-	-	1,070	35
2714570820322.03	2/21/75	623	--	350	257	3.9	-	8.2	29	574	36
2715230823213.01	7/16/62	138-418	--	--	-	--	-	-	-	1,140	175
2716080823233.01	10/10/62	77-515	--	--	-	--	-	-	-	1,100	364
2716110822348.01	1/23/68	122-349	--	--	-	--	-	-	-	29	146
2716130823002.01	9/24/64	43-601	--	--	-	--	-	-	-	1,540	502
2716190822402.01	12/07/67	104-446	--	--	-	--	-	-	-	440	60
2717030822737.01	9/24/71	885	--	--	-	--	-	-	-	85	104
2718080823414.01	5/02/72	732	--	210	-	--	-	-	-	250	180
2718120821112.01	5/25/75	800	31	100	69	25	15	1.8	276	55	11
2718370822814.01	9/08/72	625	--	40	-	--	-	-	-	250	60
2719220822418.01	1/28/72	691	--	1,000	-	--	-	-	-	410	60
2720230823548.01	1/21/72	546	--	500	-	--	-	-	-	490	120
2720320822503.01	3/15/72	1,038	--	600	-	--	-	-	-	550	28
2721220821632.01	1/17/72	925	--	200	-	--	-	-	-	250	26
2722030821654.01	11/28/72	1,011	--	50	-	--	-	-	-	500	26
2723010821459.01	5/25/70	700	21	80	220	82	13	2.9	157	750	18

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2723100822004.01	11/09/72	893	--	0	-	--	-	-	-	18	40
2724050823120.01	6/17/76	700	22	100	140	69	40	4.0	172	490	74
2724340823241.01	6/17/76	827	22	80	150	69	41	3.7	163	490	81
2725570823023.01	12/26/72	780	--	0	-	--	-	-	-	240	60
2726410822958.01	6/17/76	650	--	60	150	68	20	2.9	171	--	37
2727000823153.01	10/10/72	504	--	40	-	--	-	-	-	225	60
2727070823828.01	6/11/76	600	24	60	250	110	160	4.6	163	650	380
2727310824146.01	6/10/76	670	26	20	210	96	65	4.5	174	660	190
2727350820834.01	10/22/65	514-560	11	--	38	11	11	2.5	64	90	15
2727380823831.01	6/29/72	506	--	30	-	--	-	-	-	250	400
2727580824153.01	3/22/72	586	--	1,350	-	--	-	-	-	600	340
2728180824051.01	6/11/76	600	36	70	110	77	53	8.5	223	310	150
2729020823428.01	6/10/76	131-475	10	260	170	74	34	2.8	57	630	81
2729040822707.01	5/27/76	500	25	260	89	38	18	2.9	186	260	24
2729150823631.01	6/10/76	800	23	270	260	100	150	4.3	162	760	360
2729310823319.01	6/03/76	100	--	--	-	--	-	-	-	--	-
		200	--	--	-	--	-	-	-	--	-
		300	--	--	-	--	-	-	-	--	-
		470	22	20	280	100	63	3.4	149	820	230
		600	22	40	230	90	31	3.3	154	760	88
		700	--	--	-	--	-	-	-	--	-
		930	22	40	210	91	26	3.0	161	710	61
2729460823804.01	6/10/76	600	30	190	210	87	72	6.0	171	630	190
2729490824040.01	4/26/76	600	--	--	-	--	-	-	-	--	420
	6/10/76	600	31	10	77	33	39	4.0	215	110	81

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2730070822231.01	5/27/76	600	23	280	71	30	13	2.8	180	130	17
2730080820817.01	12/02/74	510-650	12	1,400	23	13	17	19	62	86	12
2730090822506.01	5/27/76	653	23	170	88	34	18	2.9	195	220	21
2730420822728.01	5/27/76	550	22	20	120	47	15	2.8	179	320	20
2731040822407.01	5/27/76	600	25	50	71	29	15	2.6	188	150	17
2731290823544.01	8/10/71	561	--	--	-	--	-	-	-	525	540
2731340823446.01	6/09/76	547	21	80	250	100	170	4.4	152	740	390
2731590823731.01	6/09/76	525	25	50	190	99	100	5.5	188	640	230
2732540820724.01	6/09/75	444-748	10	1,000	56	10	11	-	-	50	9.2
2733430823343.01	6/09/76	600	23	180	190	79	100	3.8	166	550	230
2733470823541.01	6/09/76	450	29	20	170	83	88	5.8	178	520	210
2734530823337	6/09/76	500	26	20	180	80	110	5.5	170	500	240
2735170822152.01	5/19/76	700	23	120	110	41	12	2.2	180	260	17
2735500822519.01	5/19/76	600	23	240	86	35	13	2.2	184	200	17
2736290823224.01	6/09/76	600	24	20	140	61	58	3.5	174	400	130
2737090822930.01	6/19/76	600	23	100	95	43	19	2.4	181	250	30
2737310822703.01	5/19/76	800	24	50	87	35	14	2.4	182	200	18
2737420823225.01	6/09/76	404	26	90	110	47	23	3.0	185	310	36
2737530822106.01	5/11/76	700	--	--	-	--	-	-	-	310	19
2737530822806.01	5/19/76	600	25	70	87	36	15	2.5	185	230	19
2738210823233.01	5/19/76	600	26	30	130	56	35	3.3	171	370	88
2738240822032.01	5/23/74	800	--	--	40	22	18	1.6	-	3	15
2738450823140.01	5/10/76	600	--	--	-	--	-	-	-	360	60
2739170821840.01	8/08/72	510	--	--	-	--	-	-	-	130	13
2740010822954.01	5/09/77	575	--	--	-	--	-	-	-	260	22

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2740170822721.01	5/23/74	600	--	--	89	11	19	1.1	-	37	27
2740300822852.01	5/09/77	600	--	--	-	--	-	-	-	230	26
2740420822759.01	5/10/76	700	--	--	-	--	-	-	-	270	19
2741090822825.01	5/29/75	70-550	--	--	-	--	-	-	-	--	29
2741180822351.01	5/22/74	145-575	--	--	89	34	13	1.9	-	190	19
2741540822911.01	5/10/76	38-545	--	--	-	--	-	-	-	260	20
2742520822324.01	5/12/76	192-700	--	--	-	--	-	-	-	270	19
2742560822016.01	1/22/75	129-664	--	--	82	1.5	6	-	166	166	18
2744060822407.01	5/22/74	450	--	--	95	36	15	1.7	-	190	20
	5/09/77		--	--	-	--	-	-	-	200	21
2744140822649.01	5/21/74	600	--	--	240	110	90	3.1	-	700	290
2744550822536.01	9/07/76	500	--	--	-	--	-	-	-	--	290

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids		Hardness		Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
				Calculated	Residue at 180°C	Calcium-magnesium	Noncarbonate				
2709430822814.01	-	-	-	2,350	--	2,200	-	3,400	-	--	27.0
2710370822748.01	-	-	-	1,810	--	--	-	2,800	-	--	26.6
2711350822802.01	-	-	-	1,880	--	1,870	-	2,700	-	--	--
2712130820559.01	-	-	-	980	--	730	-	1,300	-	--	25
2712260821053.01	-	-	-	640	--	--	-	830	-	--	--
2713330822332.01	-	-	-	1,700	--	--	-	2,400	-	--	25.6
2714200822257.01	-	-	-	1,050	--	800	-	1,470	-	--	--
2714240821858.01	-	-	-	980	--	810	-	1,350	-	--	27.2
2714500822332.01	-	-	-	1,420	--	--	-	2,060	-	--	26.1
2714570820322.03	0.8	1.1	22	--	1,076	659	-	1,025	7.8	--	27
2715230823213.01	-	-	-	--	1,550	--	-	2,380	-	--	25
2716080823233.01	-	-	-	1,900	--	--	-	2,750	-	--	25.6
2716110822348.01	-	-	-	--	500	264	-	789	-	--	--
2716130823002.01	-	-	-	2,500	--	1,920	-	3,650	-	--	27.7
2716190822402.01	-	-	-	780	--	--	-	1,210	-	--	27.7
2717030822737.01	-	-	-	--	420	120	-	510	-	--	--
2718080823414.01	-	-	-	--	1,300	1,200	-	1,800	-	--	27.0
2718120821112.01	.7	-	-	349	388	280	54	578	7.5	0	25.0
2718370822814.01	-	-	-	--	750	540	-	950	-	--	26.0
2719220822418.01	-	-	-	--	800	640	-	1,050	-	--	--
2720230823548.01	-	-	-	--	830	720	-	1,100	-	--	26.5
2720320822503.01	-	-	-	--	860	680	-	1,130	-	--	--
2721220821632.01	-	-	-	--	940	630	-	1,250	-	--	27.5
2722030821654.01	-	-	-	--	900	950	-	1,200	-	--	--
2723010821459.01	1.1	-	-	1,210	1,320	910	790	1,580	7.5	0	31.0

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Fluor-ide	Ni-trate	Phos-phate	Dissolved solids: Calcu-lated	Dissolved solids: Residue at 180°C	Hardness: Calcium-magne-sium	Hardness: Non-carbo-nate	Specific conduc-tance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Tem-pera-ture (°C)
2723100822004.01	-	-	-	--	395	250	-	480	-	--	--
2724050823120.01	1.2	-	-	947	1,040	660	520	1,440	7.4	0	--
2724340823241.01	1.3	-	-	960	992	680	550	1,450	7.4	0	27.0
2725570823023.01	-	-	-	--	740	580	-	970	-	--	26.5
2726410822958.01	1.2	-	-	--	940	680	540	1,275	7.5	0	--
2727000823153.01	-	-	-	--	680	700	-	875	-	--	--
2727070823828.01	1.9	-	-	1,680	1,770	1,100	960	2,620	7.6	0	25.0
2727310824146.01	1.9	-	-	1,360	1,460	940	800	2,050	7.4	0	27.0
2727350820834.01	.6	0.4	0.30	212	232	144	92	382	7.9	5	--
2727380823831.01	-	-	-	--	1,300	850	-	1,700	-	--	26.0
2727580824153.01	-	-	-	--	1,550	1,200	-	2,200	-	--	26.0
2728180824051.01	3.2	-	-	870	934	610	420	1,420	7.4	0	26.0
2729020823428.01	1.4	-	-	1,040	1,160	740	700	1,520	7.3	0	26.0
2729040822707.01	1.1	-	-	566	618	400	240	861	7.4	0	26.0
2729150823631.01	2.0	-	-	1,760	1,830	1,100	950	2,680	7.3	0	26.5
2729310823319.01	-	-	-	--	--	--	-	2,230	7.6	--	--
	-	-	-	--	--	--	-	2,240	7.6	--	--
	-	-	-	--	--	--	-	2,260	7.6	--	--
	1.8	-	-	1,620	1,870	1,100	1,000	2,230	7.3	0	--
	1.6	-	-	1,320	1,470	960	840	1,800	7.7	0	--
	-	-	-	--	--	--	-	1,700	7.8	--	--
	1.6	-	-	1,220	1,400	920	790	1,730	7.6	0	--
2729460823804.01	2.3	-	-	1,330	1,450	900	760	1,980	7.3	0	26.0
2729490824040.01	-	-	-	--	--	--	-	2,280	-	--	--
	2.2	-	-	491	528	340	160	870	7.5	0	25.5

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids		Hardness		Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
				Calculated	Residue at 180°C	Calcium-magnesium	Noncarbonate				
2730070822231.01	1.1	-	-	387	446	310	160	640	7.7	0	26.0
2730080820817.01	.84	0.01	0.43	222	225	111	49	320	8.9	--	--
2730090822506.01	1.0	-	-	519	578	380	220	827	7.3	0	--
2730420822728.01	1.1	-	-	654	744	510	370	957	7.3	0	27.0
2731040822407.01	1.1	-	-	414	498	310	160	687	7.6	0	26.0
2731290823544.01	-	-	-	--	1,250	990	--	1,600	-	--	26.0
2731340823446.01	1.5	-	-	1,770	1,840	1,100	930	2,740	7.6	0	24.0
2731590823731.01	1.7	-	-	1,400	1,520	900	750	2,150	7.6	0	25.0
2732540820724.01	.54	.97	-	--	556	185	43	328	7.8	20	--
2733430823343.01	1.3	-	-	1,270	1,350	810	680	2,040	7.4	0	26.0
2733470823541.01	1.4	-	-	1,210	1,340	780	640	1,920	7.5	0	25.0
2734530823337	1.3	-	-	1,240	1,370	790	650	2,050	7.4	0	26.5
2735170822152.01	1.3	-	-	564	634	450	310	808	7.5	0	--
2735500822519.01	1.2	-	-	477	566	370	220	715	7.4	0	--
2736290823224.01	1.0	-	-	914	1,020	610	470	1,440	7.2	0	26.5
2737090822930.01	1.1	-	-	560	654	420	270	830	7.3	0	--
2737310822703.01	1.1	-	-	480	544	370	220	733	7.4	0	--
2737420823225.01	1.0	-	-	657	738	480	330	1,000	7.3	0	--
2737530822106.01	-	-	-	--	660	--	--	860	-	--	29
2737530822806.01	1.1	-	-	515	582	370	220	750	7.4	0	--
2738210823233.01	1.1	-	-	806	894	570	430	1,300	7.2	0	--
2738240822032.01	-	-	-	--	335	190	--	409	-	--	24.5
2738450823140.01	-	-	-	--	808	--	--	1,100	-	--	26.0
2739170821840.01	-	-	-	--	490	500	--	600	-	--	--
2740010822954.01	-	-	-	--	651	--	--	832	-	--	25.5

Table 13.--Quality of water from the Suwannee and Ocala Limestones (middle water-bearing zone)--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness: Calcium-magnesium	Hardness: Noncarbonate	Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
2740170822721.01	-	-	-	--	450	270	--	557	-	--	--
2740300822852.01	-	-	-	--	582	--	--	767	-	--	--
2740420822759.01	-	-	-	--	608	--	--	840	-	--	25.5
2741090822825.01	-	-	-	--	700	--	--	940	-	--	26.0
2741180822351.01	-	-	-	--	580	360	--	726	-	--	25.5
2741540822911.01	-	-	-	--	602	--	--	810	-	--	25.5
2742520822324.01	-	-	-	--	596	--	--	800	-	--	25.5
2742560822016.01	-	0.48	-	--	504	211	44	697	7.7	10	--
2744060822407.01	-	-	-	--	570	390	--	759	-	--	24.5
	-	-	-	--	569	--	--	744	-	--	25.5
2744140822649.01	-	-	-	--	1,560	1,100	--	2,180	-	--	--
2744550822536.01	-	-	-	--	1,450	--	--	2,000	-	--	25.5

Table 14.--Quality of water from the Avon Park Limestone (lower water-bearing zone)

[Concentrations are in milligrams per liter, except as indicated]

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal- cium	Magne- sium	Sodium	Potas- sium	Bicar- bonate	Sul- fate	Chlor- ide
2712220820423.01	5/16/72	188-1,507	--	20	--	--	--	--	-	310	80
2714570820322.05	2/18/75	1,400	8.2	550	216	16	42	--	26	608	24
2716070822328.01	3/12/75	1,157	--	-	540	150	--	--	154	1,600	85
2717030820318.01	3/30/75	300-1,400	23	610	292	62	15	--	147	794	29
2717470821124.01	4/02/75	1,400?	--	-	--	--	--	--	-	--	12
2718020820627.01	5/25/76	1,535	42	210	63	27	27	2.1	276	77	17
2720530823202.01	11/29/73	1,270	16	-	1,300	970	10,000	300	188	2,900	19,000
	12/06/73	1,495	15	-	1,300	940	9,000	310	190	3,100	19,000
	12/09/73	1,160	24	170	400	300	600	18	144	1,400	1,400
	1/02/74	1,645	23	-	690	300	1,900	40	150	1,600	3,700
2724130821257.01	5/24/76	1,100	21	430	150	66	13	2.8	162	530	17
2724230820519.01	5/24/76	1,320	43	520	54	24	13	2.1	265	20	11
2726120821424.01	5/25/76	1,120	22	80	90	37	12	2.4	180	250	15
2726350822510.01	5/27/76	1,250	23	40	140	64	14	2.9	170	470	50
2728150821051.01	5/24/76	1,200	28	160	41	20	13	1.9	184	47	11
2729130823304.01	6/16/76	1,060	22	100	370	130	220	4.0	160	890	670
	3/26/62		--	-	--	--	--	--	-	726	200
2730000820651.01	8/27/76	1,244	18	20	52	19	8.7	1.5	155	72	12
2730000820829.01	10/16/74	1,260	19	50	68	23	10	1.6	190	82	10
2730240822123.01	5/24/76	1,100	22	50	82	32	12	2.4	182	200	16
2731350823547.01	6/21/76	2,660	24	80	300	130	350	9.0	156	860	760
2731500820614.01	5/19/76	1,150	22	510	43	19	9.0	.7	188	22	13
2735360821505.01	5/19/76	1,710	22	50	150	48	11	2.1	169	430	15
2735470822934.01	3/10/77	1,100	--	50	190	78	90	3.8	160	510	220
2736240821640.01	5/19/76	1,100	21	60	230	63	11	2.2	161	650	16

Table 14.--Quality of water from the Avon Park Limestone (lower water-bearing zone)--Continued

Well number	Date of collection	Sampling depth (feet)	Silica	Iron	Cal-cium	Magne-sium	Sodium	Potas-sium	Bicar-bonate	Sul-fate	Chlor-ide
2736290820907.01	6/19/75	430-1,464	17	140	91	1.9	0.12	--	-	73	15
2736550824509.01	9/19/75	68-991	--	-	190	59	350	--	-	270	900
2739120820546.01 (GD-4)	10/17/74	910	14	<100	50	13	--	1.2	172	49	9
2741030822836.01	5/29/75	945	--	-	--	--	--	--	-	--	180
2742430822115.03	11/17/66	641-935	22	-	110	41	12	1.7	174	280	17
2742590824102.02	2/03/76	920-1,141	10	-	490	1,100	11,000	410	190	3,000	22,000
2743130821511.01	10/31/74	710-1,489	--	-	--	--	--	--	-	--	12
	8/07/58		47	10	38	17	6.6	1.2	-	4	5
2743220822026.01	5/12/76	240-900	--	-	--	--	--	--	-	140	13
	5/29/74		20	10	70	24	8.8	1.4	168	130	11

Table 14.--Quality of water from the Avon Park Limestone (lower water-bearing zone)--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids: Calculated	Dissolved solids: Residue at 180°C	Hardness: Calcium-magnesium	Hardness: Noncarbonate	Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
2712220820423.01	-	--	--	--	850	1,100	--	1,150	-	--	--
2714570820322.05	0.9	0.72	21	--	1,164	604	578	1,225	8.1	--	--
2716070822328.01	2.0	--	--	--	2,100	2,000	1,900	2,800	7.6	--	--
2717030820318.01	-	.44	4.6	--	1,406	--	--	--	-	--	31.1
2717470821124.01	-	--	--	--	--	--	--	1,040	-	--	--
2718020820627.01	1.4	--	--	398	436	270	48	650	7.6	0	25.5
2720530823202.01	1.8	--	--	34,600	34,200	7,300	7,100	42,000	7.6	--	--
	1.9	--	--	34,400	34,500	7,200	7,000	43,000	7.7	--	--
	.2	--	--	4,210	4,450	2,200	2,100	5,940	7.6	6	--
	1.5	--	--	8,390	8,720	3,100	3,000	11,200	7.8	--	31.5
2724130821257.01	.9	--	--	904	1,010	670	540	1,250	7.4	0	30.0
2724230820519.01	1.5	--	--	303	316	240	20	500	7.7	0	27.5
2726120821424.01	.8	--	--	547	608	410	260	813	7.8	0	29.0
2726350822510.01	1.1	--	--	874	966	640	500	1,190	7.6	0	30.5
2728150821051.01	.9	--	--	265	292	200	46	430	7.8	0	--
2729130823304.01	1.7	--	--	2,410	2,460	1,500	1,400	3,780	7.3	0	--
	-	--	--	1,450	--	1,060	--	1,944	-	--	27.8
2730000820651.01	.7	--	--	269	286	220	91	--	-	0	30.0
2730000820829.01	.7	.12	1.2	330	368	265	75	430	8.5	5	--
2730240822123.01	1.1	--	--	480	518	360	210	750	7.4	0	30.0
2731350823547.01	1.5	--	--	2,530	2,640	1,300	1,200	4,300	-	0	26.5
2731500820614.01	1.2	--	--	223	232	190	32	380	7.4	0	--
2735360821505.01	1.2	--	--	774	824	580	450	1,320	7.5	0	--
2735470822934.01	1.0	--	--	1,210	1,270	810	680	1,670	7.7	0	28.5
2736240821640.01	1.8	--	--	1,090	1,140	850	720	1,320	7.5	0	--

Table 14.--Quality of water from the Avon Park Limestone (lower water-bearing zone)--Continued

Well number	Fluoride	Nitrate	Phosphate	Dissolved solids		Hardness		Specific conductance (umho/cm at 25°C)	pH (units)	Color (Pt-Co units)	Temperature (°C)
				Calculated	Residue at 180°C	Calcium-magnesium	Noncarbonate				
2736290820907.01	-	1.1	--	--	287	236	98	383	7.7	5	27.8
2736550824509.01	-	--	--	--	--	720	--	3,170	-	--	27.1
2739120820546.01 (GD-4)	-	--	--	--	369	180	39	410	7.2	--	25.6
2741030822836.01	-	--	--	--	1,250	--	--	1,700	-	--	27
2742430822115.03	.5	--	--	575	593	450	310	827	7.6	0	--
2742590824102.02	1.1	--	--	38,200	38,200	5,800	5,600	62,000	-	5	28.4
2743130821511.01	.5	--	--	--	340	--	--	451	-	--	--
	.7	0	--	--	229	165	--	313	-	--	--
2733220822026.01	-	--	--	--	382	--	--	560	-	--	25.0
	.5	--	--	349	371	270	140	551	7.5	--	25.0

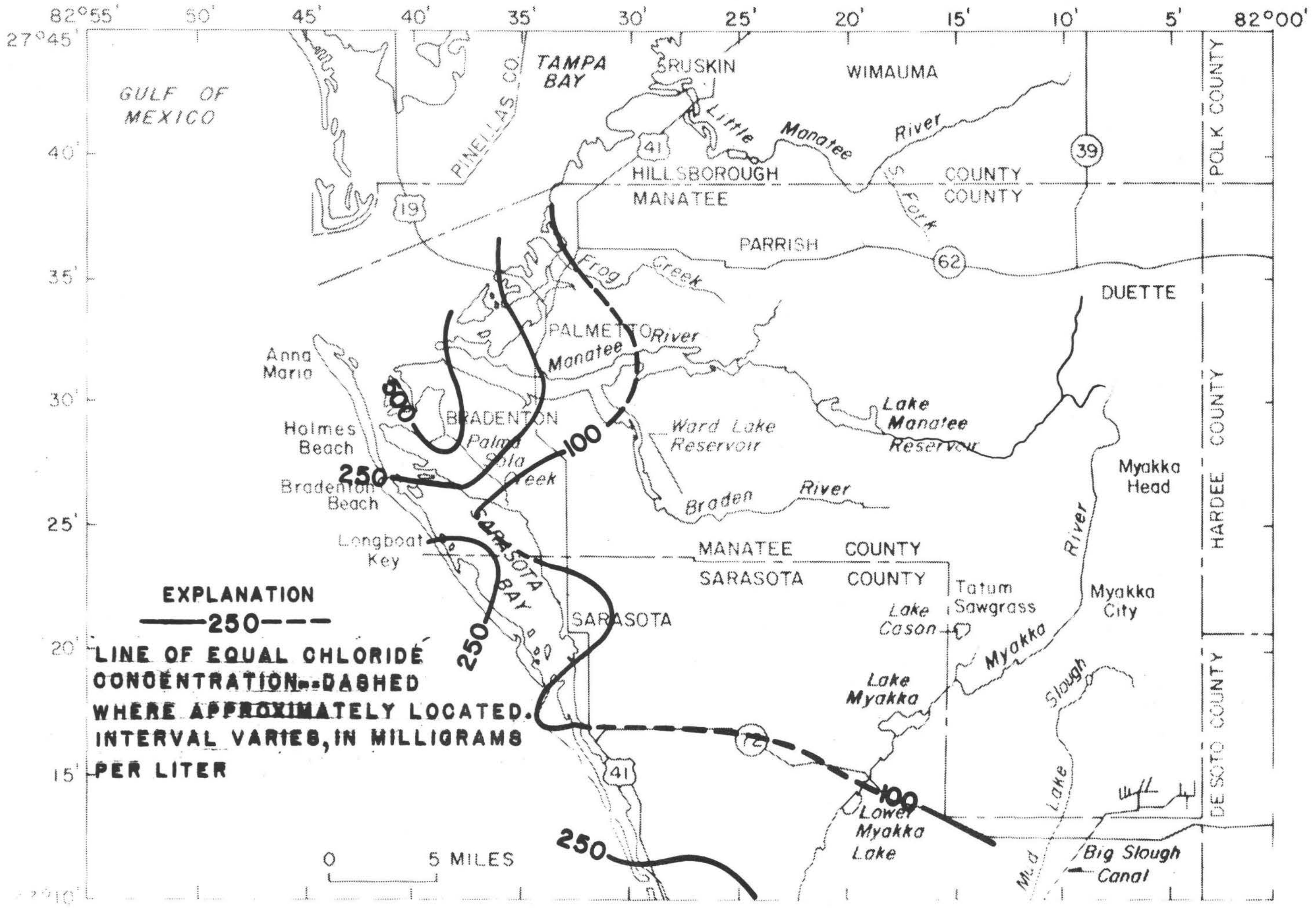


Figure 26a.--Concentrations of chloride in water from the Tampa (upper zone) Limestone.

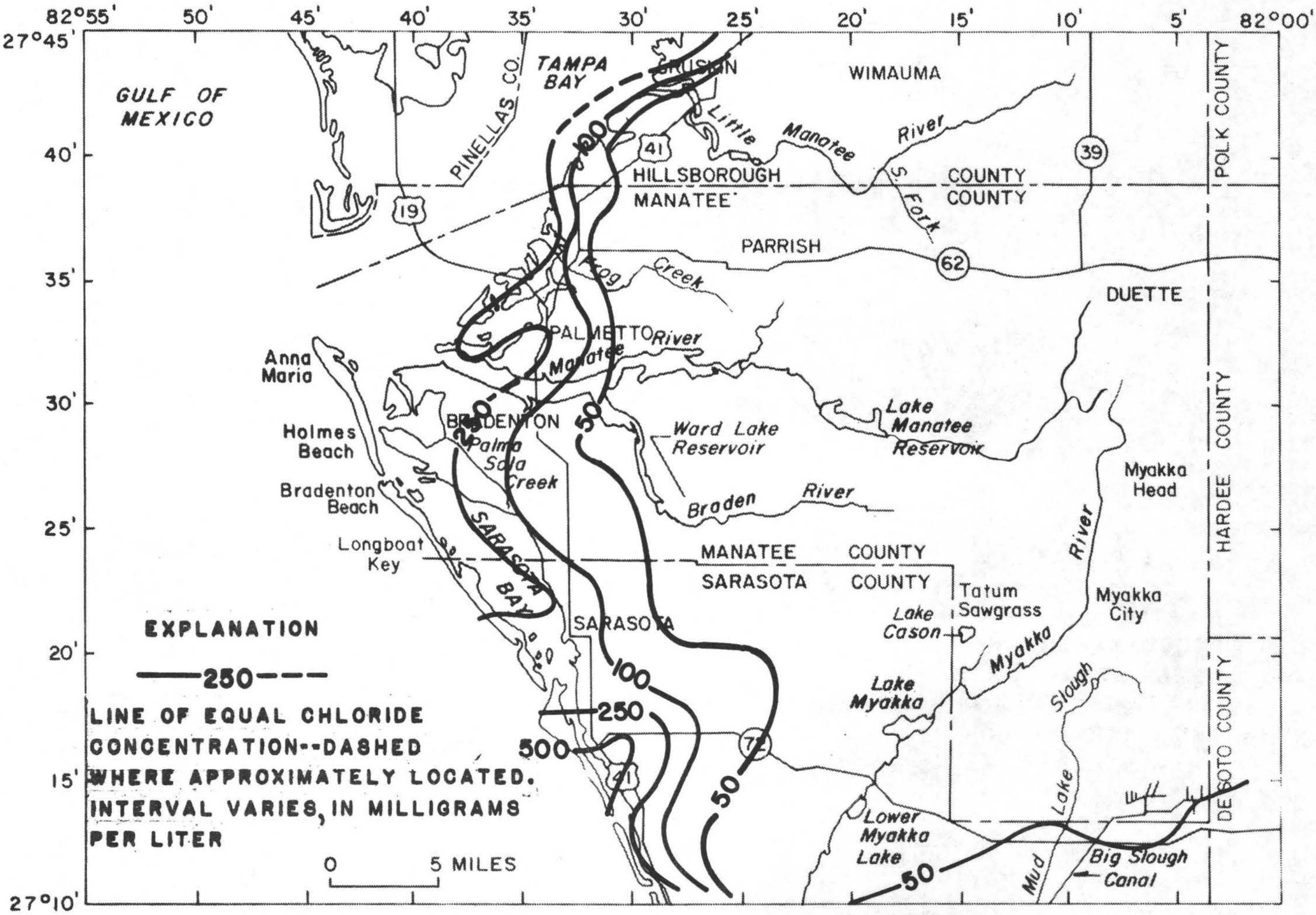


Figure 26b.--Concentrations of chloride in water from the Suwannee-Ocala (middle zone) Limestones.

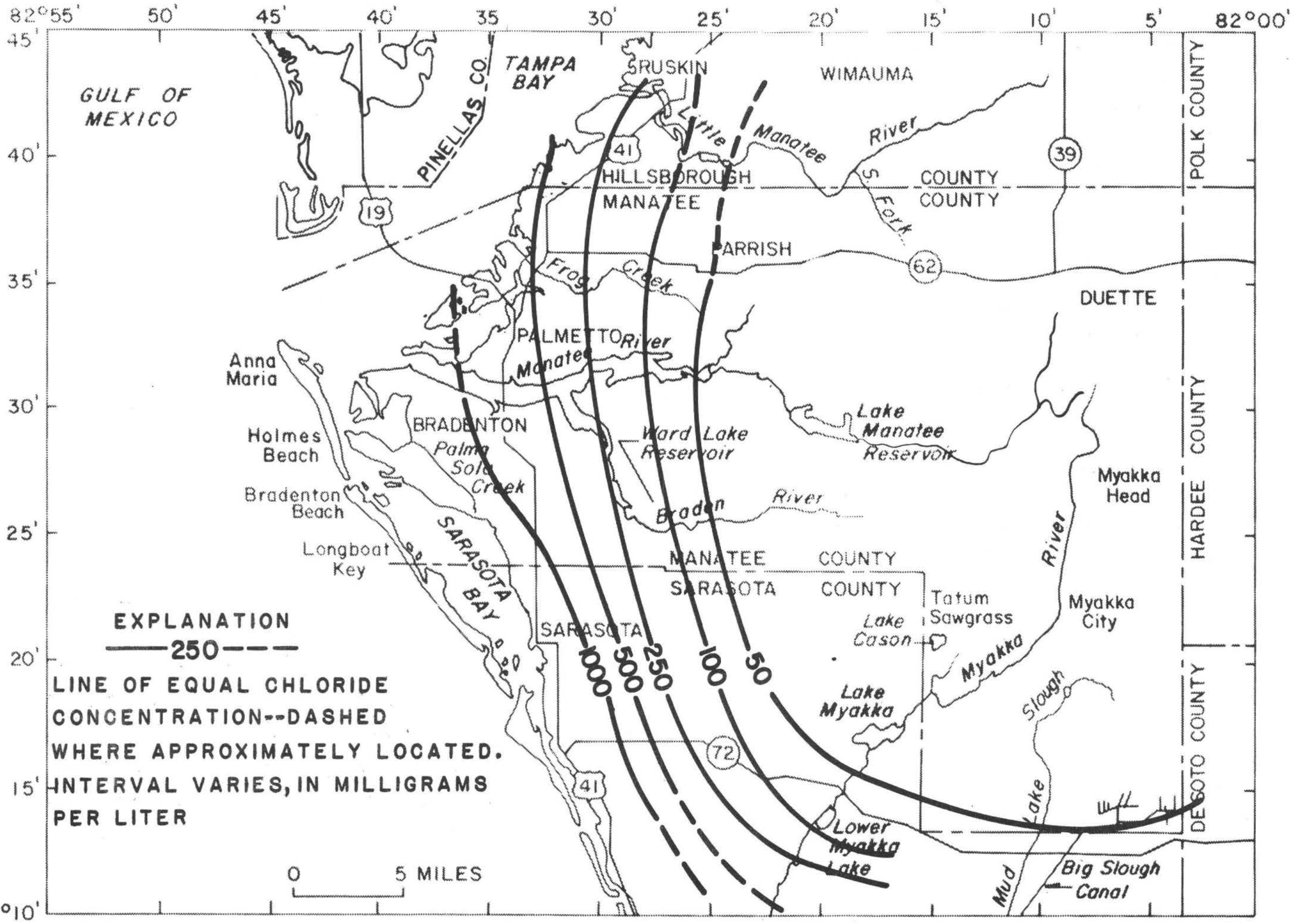


Figure 26c.--Concentrations of chloride in water from the Avon Park (lower zone) Limestone.

Table 15.--Concentrations of chloride in water from wells open to the Floridan aquifer, 1950-55 and 1975-76

Well number	1950-55		1975-76	
	Date (month and year)	Chloride, Cl (mg/L)	Date (month and year)	Chloride, Cl (mg/L)
272902082342801	2-51	60	6-76	81
272604082234501	11-54	45	5-76	20
273347082354101	1-54	202	6-76	210
273134082344601	12-51	875	6-76	390
273821082323301	9-51	45	5-76	88
			2-75	80
273104082240701	3-55	20	5-76	17
273159082373101	2-51	230	5/6-76	230
272731082414602	1-55	235	6-76	410
			2-75	380
272731082414601	1-55	190	6-76	200
			2-75	200
272750082380301	1-54	300	6-76	770
272818082405101	1-54	232	6-76	760
272931082331901	1-51	50	6-76	230
272949082404001	9-54	335	6-76	84
272946082380401	1-53	180	6-76	130
273343082334301	2-55	208	6-76	210
272542082405101	3-55	143	2-75	180
272324082383101	3-55	280	2-75	310
			6-76	320
271747082112401	3-52	12	4-75	12
273821082324501	2-55	50	2-75	59
273631082314001	7-51	63	3-75	54
273135082354701	3-51	865	6-76	760
273629082322401	8-54	70	6-76	130

In western Manatee County, there has been little or no change in concentrations of chloride from the middle 1950's to the 1970's in water from wells that penetrate the upper, middle, and lower zones.

Sulfate.--Water in the Floridan aquifer is generally high in sulfate. Concentrations of sulfate range from less than 5 mg/L to about 900 mg/L, generally increasing with depth and from the northeast towards the west and south (tables 12, 13, and 14 and fig. 27). In the upper zone, high concentrations (greater than 250 mg/L) occur only in western and coastal areas (fig. 27).

In water from wells penetrating the middle zone, relatively high concentrations of sulfate extend inland east of Parrish and north of Verna (fig. 27). In water from wells penetrating the upper part of the lower zone, concentration of sulfate generally exceeds 250 mg/L except in the northeast (fig. 27).

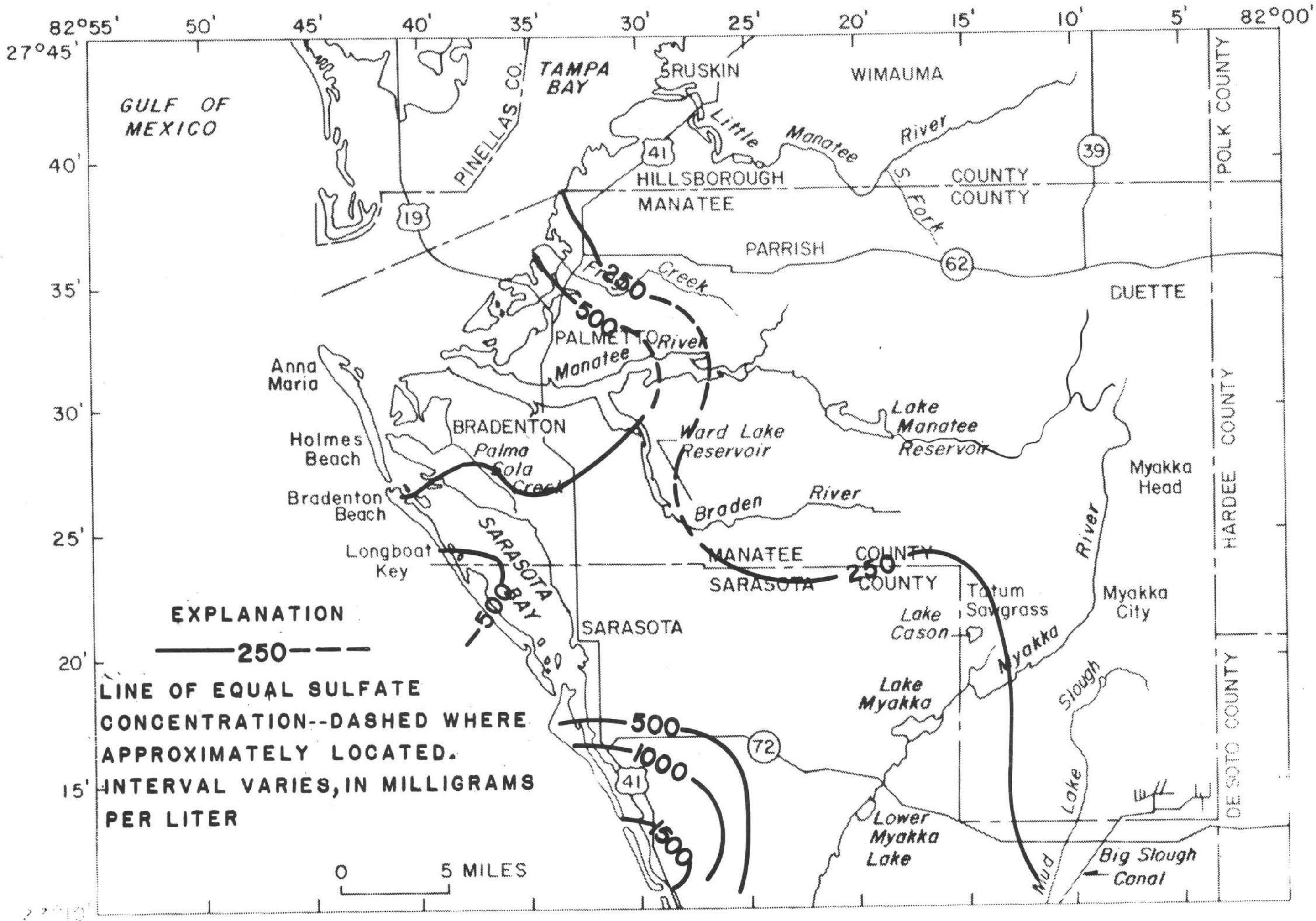


Figure 27a.--Concentrations of sulfate in water from the Tampa (upper zone) Limestone.

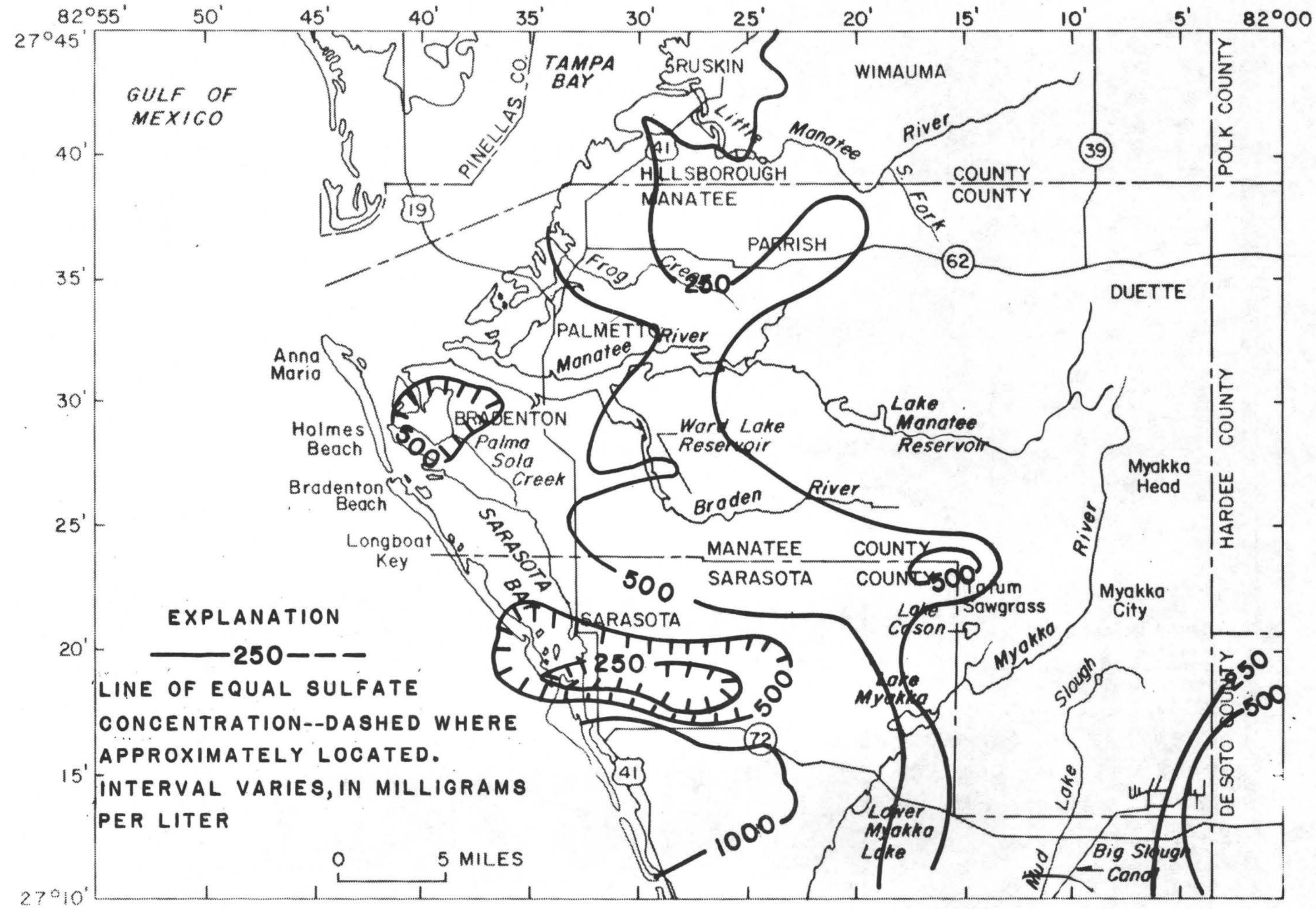


Figure 27b.--Concentrations of sulfate in water from the Suwannee-Ocala (middle zone) Limestones.

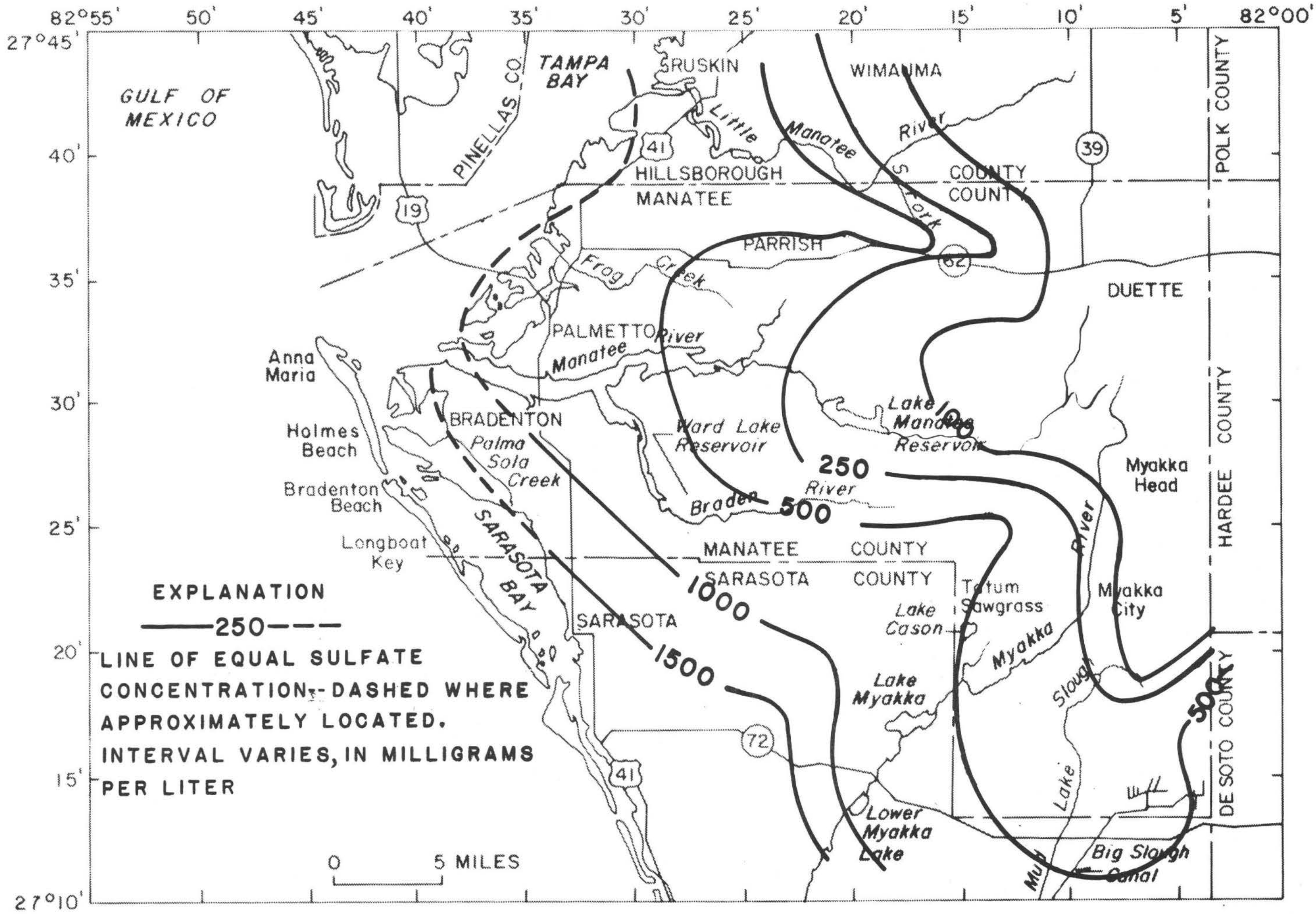


Figure 27c.--Concentrations of sulfate in water from the Avon Park (lower zone) Limestone.

In the west, concentrations of sulfate have changed little since the 1950's in water from wells that penetrate the upper zone. Concentrations in water from wells that penetrate the upper and middle zones have increased slightly east of Parrish and near Verna.

Fluoride.--Concentrations of fluoride in water from the Floridan aquifer vary areally and with depth, ranging from less than 0.5 to more than 3.0 mg/L. Highest concentrations are usually in water from the upper zone. In water from wells penetrating the upper, middle, and lower zones, concentrations of fluoride generally increase from the north towards the south and west (fig. 28).

Temperature.--The temperature of the ground water increases with depth on an average gradient of about $1^{\circ}C$ per 100 feet (Peek, 1958a). The temperature of water from wells penetrating the upper and middle water-bearing zones ranges from about 25° to $29^{\circ}C$. The temperature of the water from wells penetrating the lower water-bearing zone ranges from about 25° to $31^{\circ}C$.

Saltwater contamination

Under natural and undisturbed conditions, ground water is discharged to the gulf or to Tampa Bay. Where aquifers are hydraulically connected to the sea, the depth to saltwater is related to the height that freshwater stands above sea level. When freshwater and saltwater are in hydrostatic balance, the Ghyben-Herzberg relation can be used to calculate the approximate depth of the freshwater-saltwater interface. The Ghyben-Herzberg relation as given by Walton (1970) is:

$$h_s = \frac{p_f}{p_s - p_f} h_f$$

where h_s is the difference between the elevation of the surface of the ocean and the elevation of the interface, p_f is the freshwater density, p_s is the saltwater density, and h_f is the difference between the elevation of the surface of the ocean and the elevation of the water table or potentiometric surface. If $p_s = 1.025\ g/cm^3$ and $p_f = 1.000\ g/cm^3$, then $h_s = 40\ h_f$. In September 1975 and 1976, the potentiometric surface of the Floridan aquifer along the coast ranged from about 10 to 20 feet above sea level. Based on the Ghyben-Herzberg relation, the depth to the saltwater-freshwater interface should range from about 400 to 800 feet below sea level.

Because of tidal action, wet and dry periods, pumpage, and other natural and manmade forces, hydrostatic conditions do not exist in aquifers, and a zone of diffusion exists between saltwater and freshwater. It is the thesis of Cooper (Cooper and others, 1964, p. C1) that when a zone of diffusion exists a cyclic flow is generated in the saltwater from the floor of the sea into the zone of diffusion and back into the sea. This cyclic flow tends to lessen the landward extent to which saltwater moves in the aquifer. Hence, the interface estimated by the Ghyben-Herzberg relation represents a "worst case" or maximum possible landward movement under natural conditions.

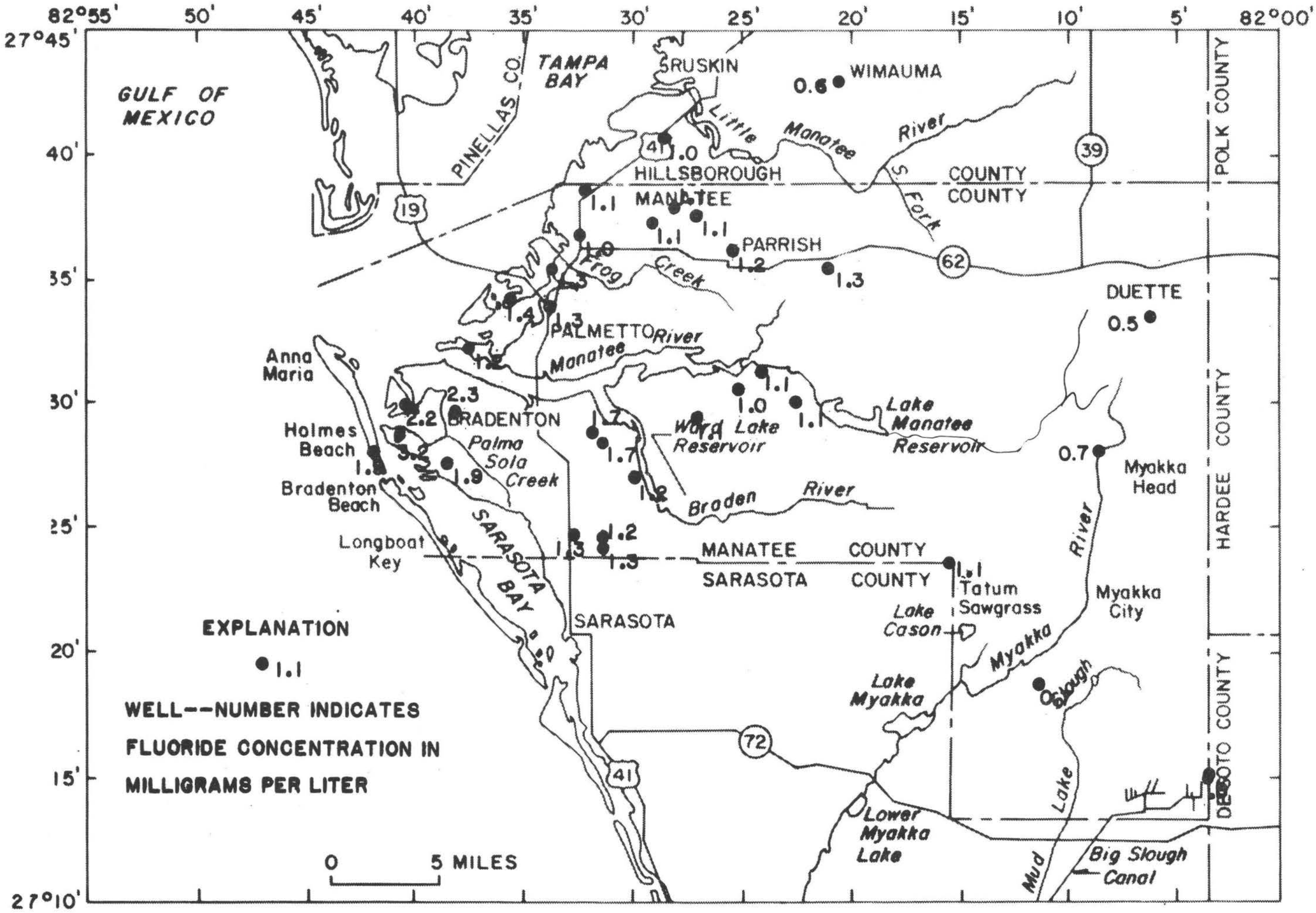


Figure 28a.--Concentrations of fluoride in water from the Suwannee (middle zone) Limestone.

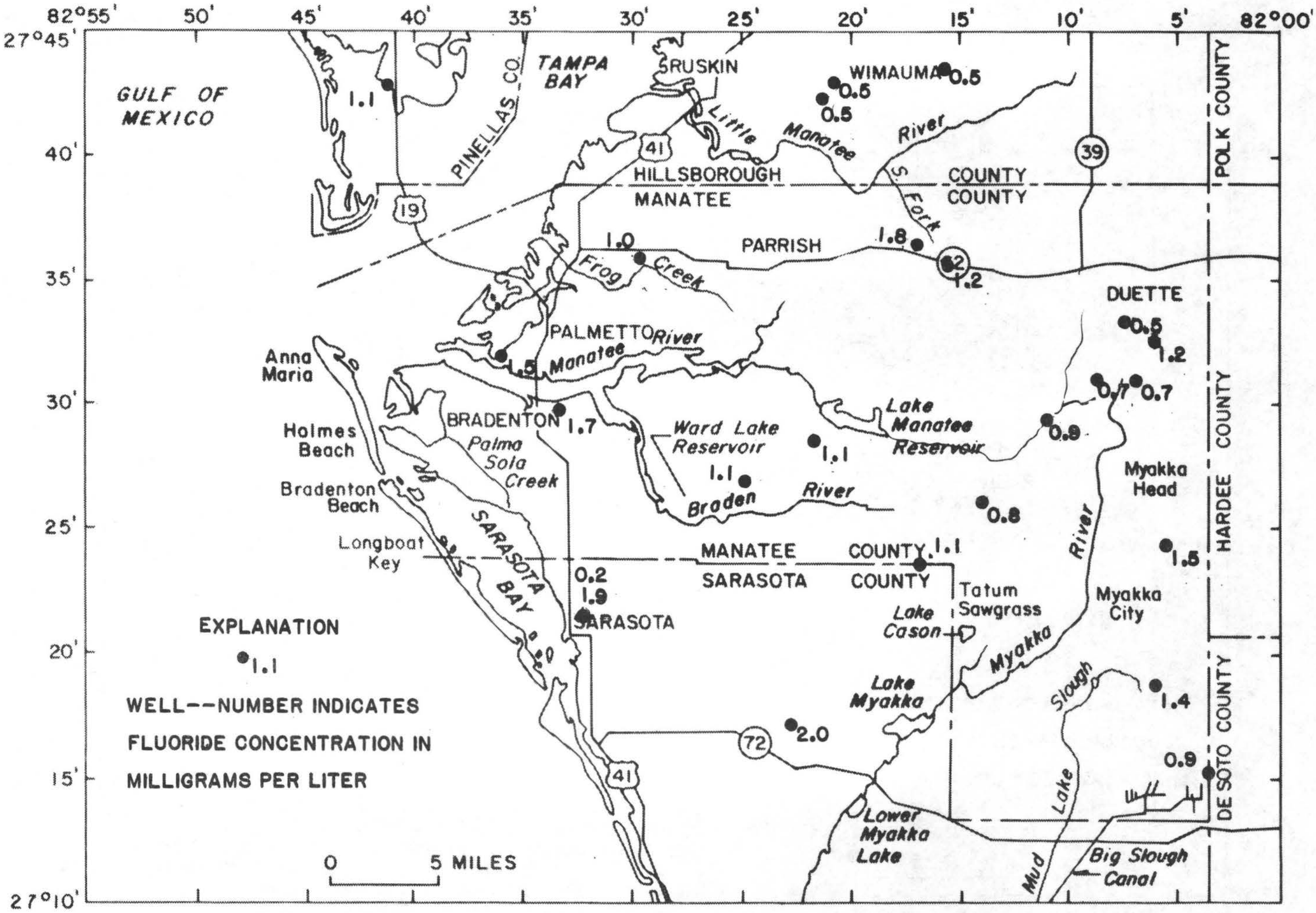


Figure 28b.--Concentrations of fluoride in water from the Avon Park (lower zone) Limestone.

Lowering of water levels of aquifers in coastal areas may permit seawater to enter and contaminate the freshwater aquifer (Peek, 1958a). Highly saline water is present in the Floridan aquifer at relatively shallow depths throughout much of coastal Manatee County. In this area, however, the potentiometric surface is sufficiently high to prevent encroachment of water directly from the sea. Thus, Peek (1958a) suggests that extensive occurrences of highly saline water are due to residual seawater that entered the aquifer prior to recent times. These occurrences are probably due to incomplete flushing and dilution of residual seawater by ground water.

Present seasonal fluctuations of the potentiometric surface (1975-76) reduce or reverse the natural hydraulic gradient that slopes towards the sea. The potentiometric surface has fallen below sea level in large areas of the county (fig. 16). Although only slight changes in water quality have been observed, the possibility of saltwater intrusion has increased. Migration of the saltwater front is relatively slow and occurrence of saline water in wells may be years after the decline in the potentiometric surface has reached "serious proportions" (Hem, 1970, p. 313).

Chloride is the major anion of saltwater and moves through aquifers at nearly the same rate as intruding water (Hem, 1970). In areas where other sources of saline contamination do not exist, an increase in chloride concentrations in ground water is an index to saltwater contamination. The concentration of chloride in water from wells that penetrate the upper and middle zones has shown little variation since the early and middle 1950's.

During 1972-74, chloride concentrations of water from an 800-foot deep irrigation well, about 6 miles southwest of Ruskin that penetrated the lower zone, increased from 260 to 980 mg/L. Chloride concentrations in water from nearby wells ranged from 25 to 50 mg/L. These wells ranged in depth from 250 to 600 feet and penetrated the upper and middle zones (Duerr, 1974).

From 1962 to 1976, concentrations of chloride in water from a deep industrial supply well (2729130823304.01) in Bradenton increased from 200 to 670 mg/L. The 1,060-foot deep well penetrated the lower zone. In a nearby well (2729310823319.01), water samples were collected at depths of 470, 600, and 930 feet below sea level. Chloride concentrations were 230, 88, and 61 mg/L, respectively. The well penetrated the upper and middle zones.

WATER-RESOURCES DEVELOPMENT

Surface Water

Water from the Manatee River at Lake Manatee Reservoir (fig. 29) and from its principal tributary, the Braden River at Ward Lake Reservoir, are used for public supplies. Water from the Little Manatee River is used for makeup water for a thermoelectric powerplant and cooling pond.

Discharge of the Manatee River is regulated by gates in an earthen dam at Lake Manatee Reservoir about 29 miles upstream from the river's mouth. The reservoir impounds water from a drainage area of 123 mi^2. At a pool elevation of

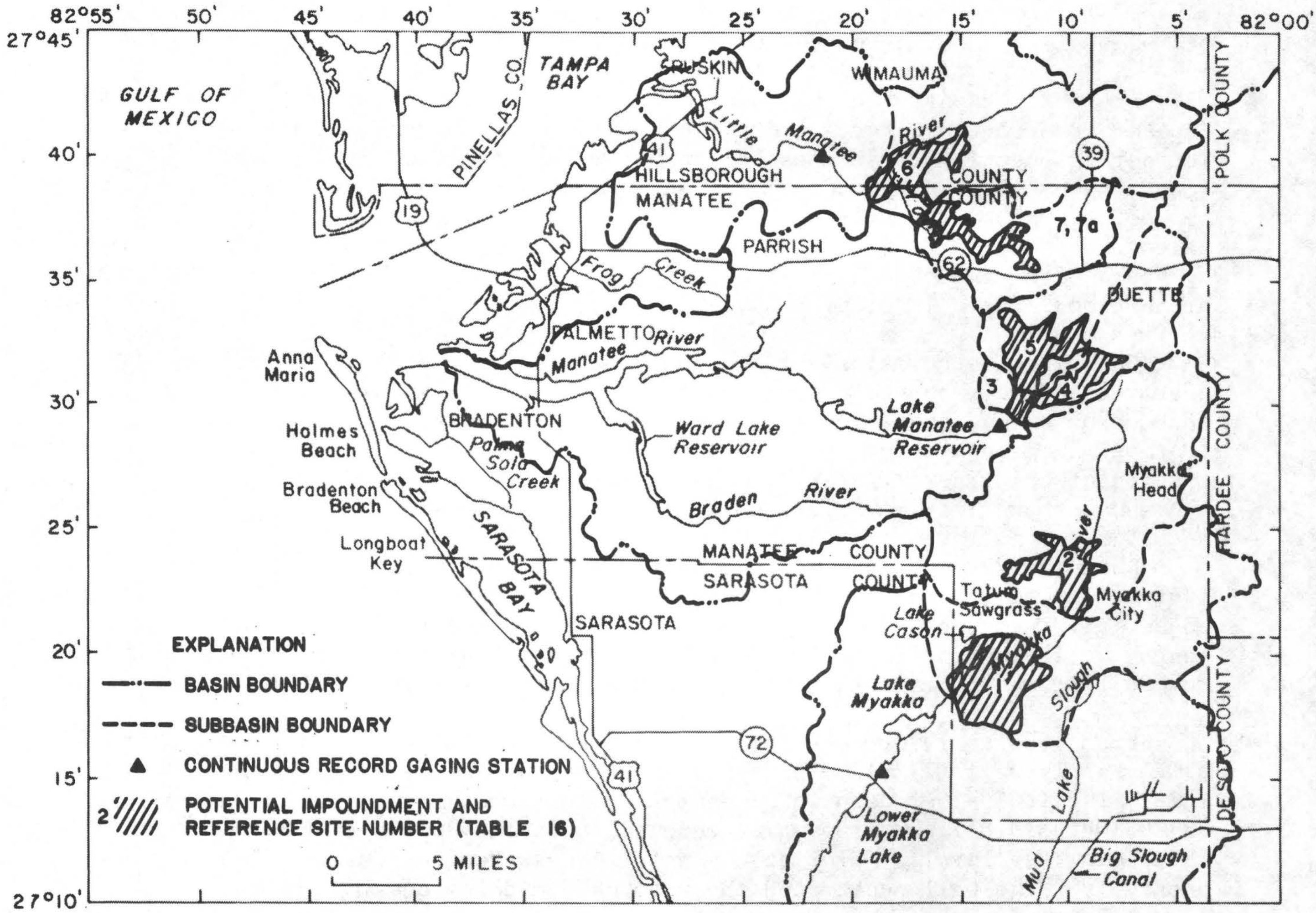


Figure 29.--Locations of potential impoundments, existing reservoirs, and stream-gaging stations, Manatee County and adjacent areas.

40 feet above sea level, the reservoir has a surface area of about 1,850 acres and a storage capacity of about 7,000 Mgal (fig. 30). In 1977, an average of 19.1 Mgal/d was pumped from the reservoir. Peak day pumpage was 27.6 Mgal/d.

The low-flow characteristics of streams often control their value and utilization as a source of water. Since draft rates often exceed minimum flow of the streams, storage is required to meet expected demands. The amount of storage required is dependent upon the draft rate, magnitude and frequency of annual low flows, and the length of periods of low flow. The magnitude and frequency of annual low flows for selected periods are presented in table 5 (Myakka River near Sarasota), table 6 (Manatee River near Bradenton), table 7 (Manatee River near Myakka Head), and table 8 (Little Manatee River near Wimauma).

Draft-storage frequency relations for the Lake Manatee Reservoir (fig. 31) indicate that at a 5 percent risk of inadequate storage (once in 20 years) the present reservoir could supply a continuous draft of about 38 Mgal/d, assuming a full reservoir at the beginning of the period and usable storage of 6,000 Mgal (storage between the 25- and 40-foot pool elevations). By increasing the pool elevation to 50 feet and usable storage to 15,000 Mgal, as has been proposed, the reservoir could supply a continuous draft of about 74 Mgal/d at a 5 percent risk of being inadequate.

Ward Lake Reservoir has a surface area of 57.6 acres and impounds water from a drainage area of 59.5 mi^2. The elevation of the crest of the control structure is about 4.2 feet above sea level. The storage capacity of the reservoir is about 585 Mgal. In 1977, the city of Bradenton pumped an average of 4.0 Mgal/d from the reservoir. Peak day pumpage was 5.25 Mgal/d. At the demand rate of 4.0 Mgal/d, the reservoir has about a 40 percent risk of being inadequate (Smith and Gillespie Engineers, Inc., 1971).

Draft-storage frequency relations at the continuous record gaging stations for Myakka River near Sarasota, Manatee River near Myakka Head, and Little Manatee River near Wimauma (fig. 29) are shown in figures 32, 33, and 34, respectively. These relations indicate the amount of storage needed to maintain continuous drafts with 10- and 20-year risks of being inadequate. For example, to provide a continuous draft rate of 50 Mgal/d at a 5 percent risk of failure (once in 20 years), an estimated storage of about 11,000 Mgal is required at Myakka River near Sarasota (fig. 32), 11,000 Mgal at Manatee River near Myakka Head (fig. 33), and 8,400 Mgal at Little Manatee River near Wimauma (fig. 34).

Seven sites have been identified that may be suitable for impoundment of water. Two sites are in the Myakka River basin, three sites in the Manatee River basin, and two in the Little Manatee River basin (fig. 29). The sites, their approximate drainage areas, surface areas, and storage (not adjusted for evaporation) at selected stages, are listed in table 16. The reservoirs would be small and have surface areas ranging from 0.140 to 0.97 mi^2 and storage ranging from 3,100 to 15,000 Mgal.

Ground Water

Development of ground water is largely dependent upon the hydraulic properties of aquifers and confining beds and quality of water. The estimated range of selected hydraulic properties is presented in table 17.

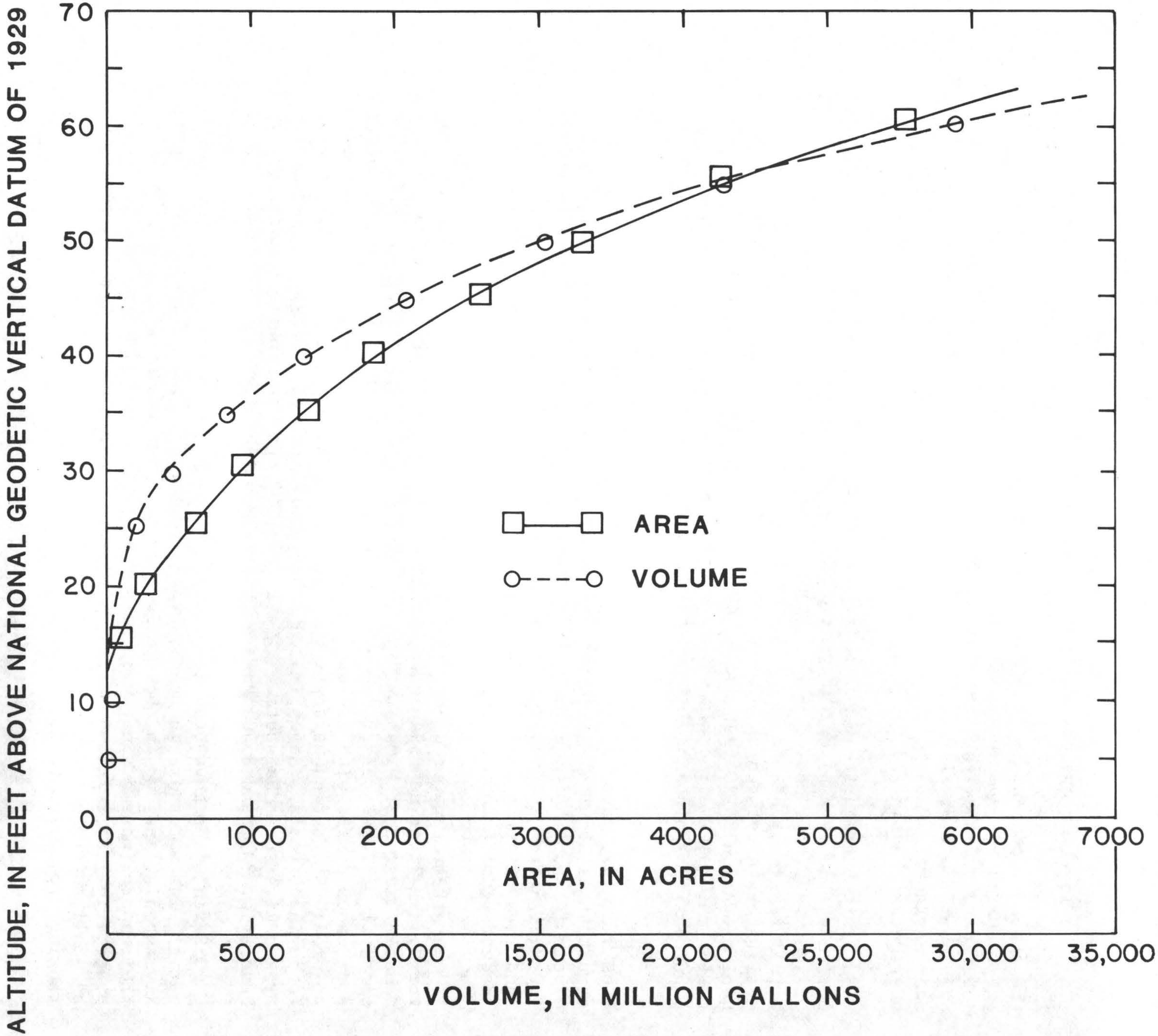


Figure 30.--Surface area and storage capacity of Lake Manatee Reservoir.

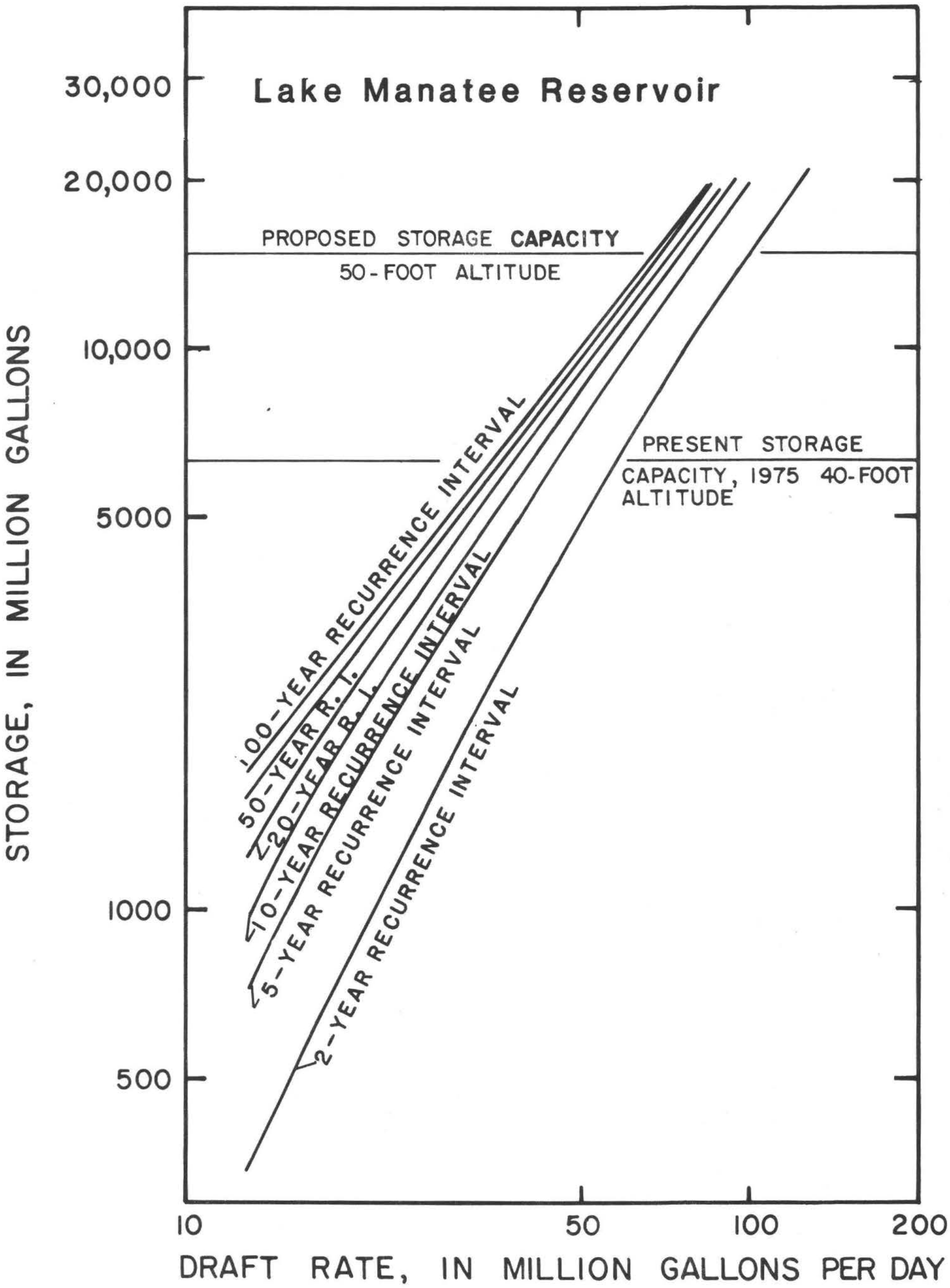


Figure 31.--Draft-storage frequency relations for Lake Manatee Reservoir.

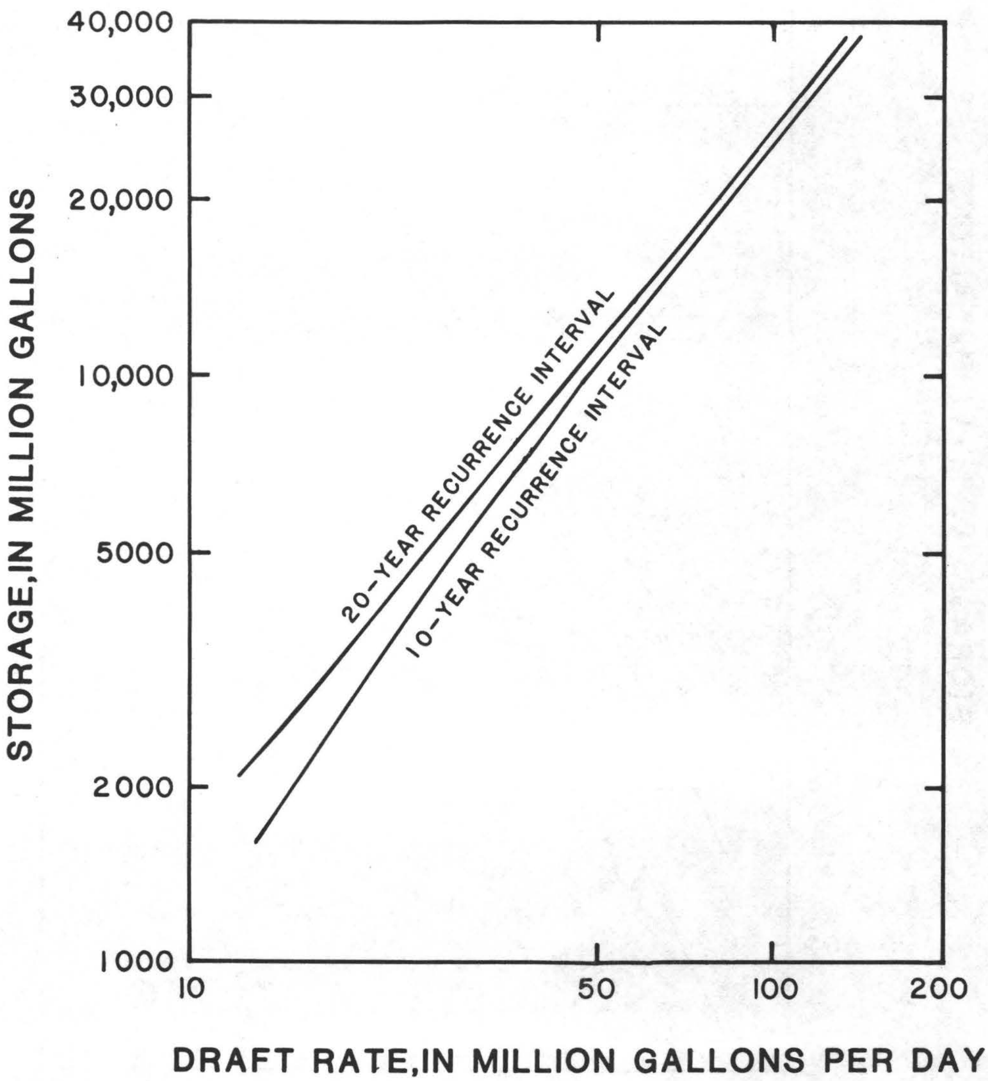


Figure 32.--Draft-storage frequency relations for Myakka River near Sarasota.

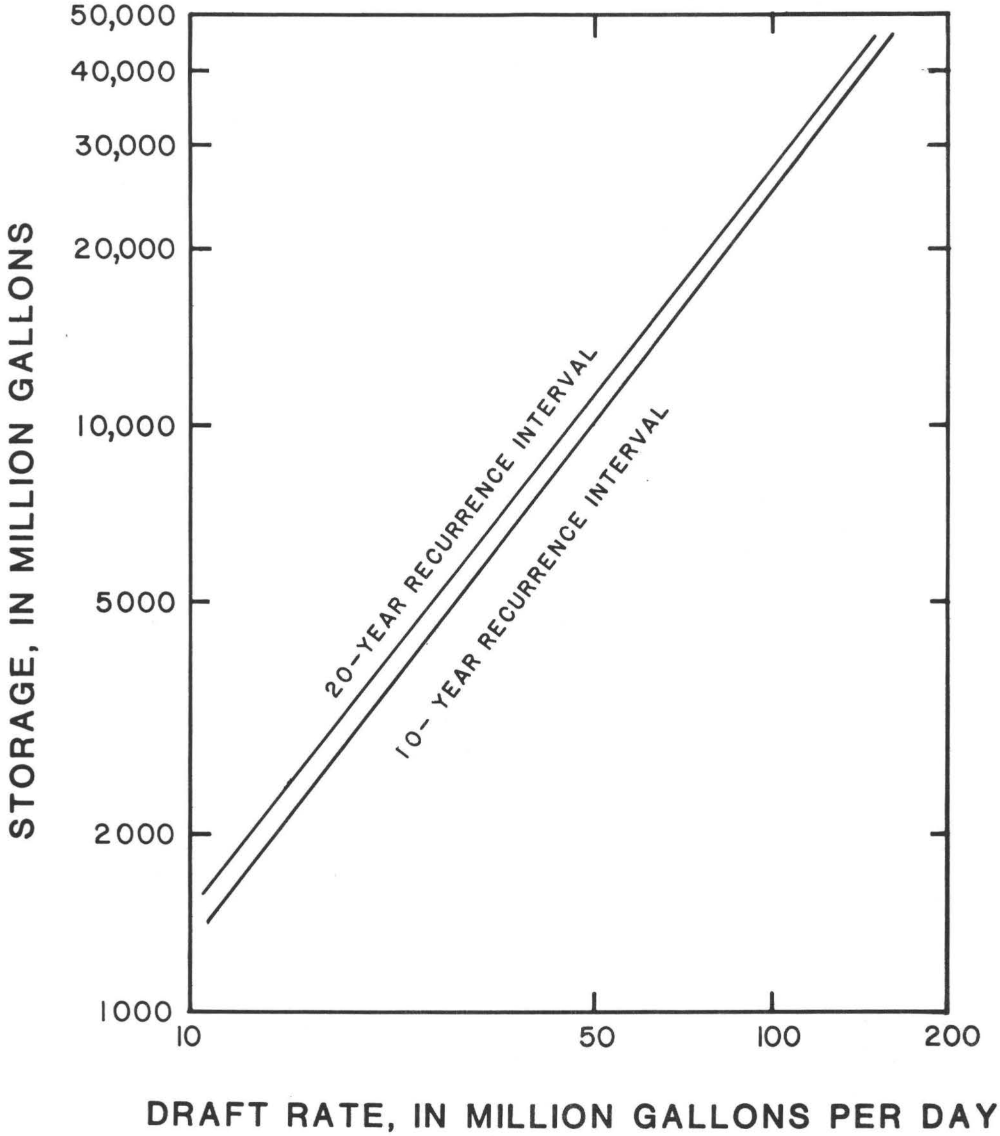


Figure 33.--Draft-storage frequency relations for Manatee River near Myakka Head.

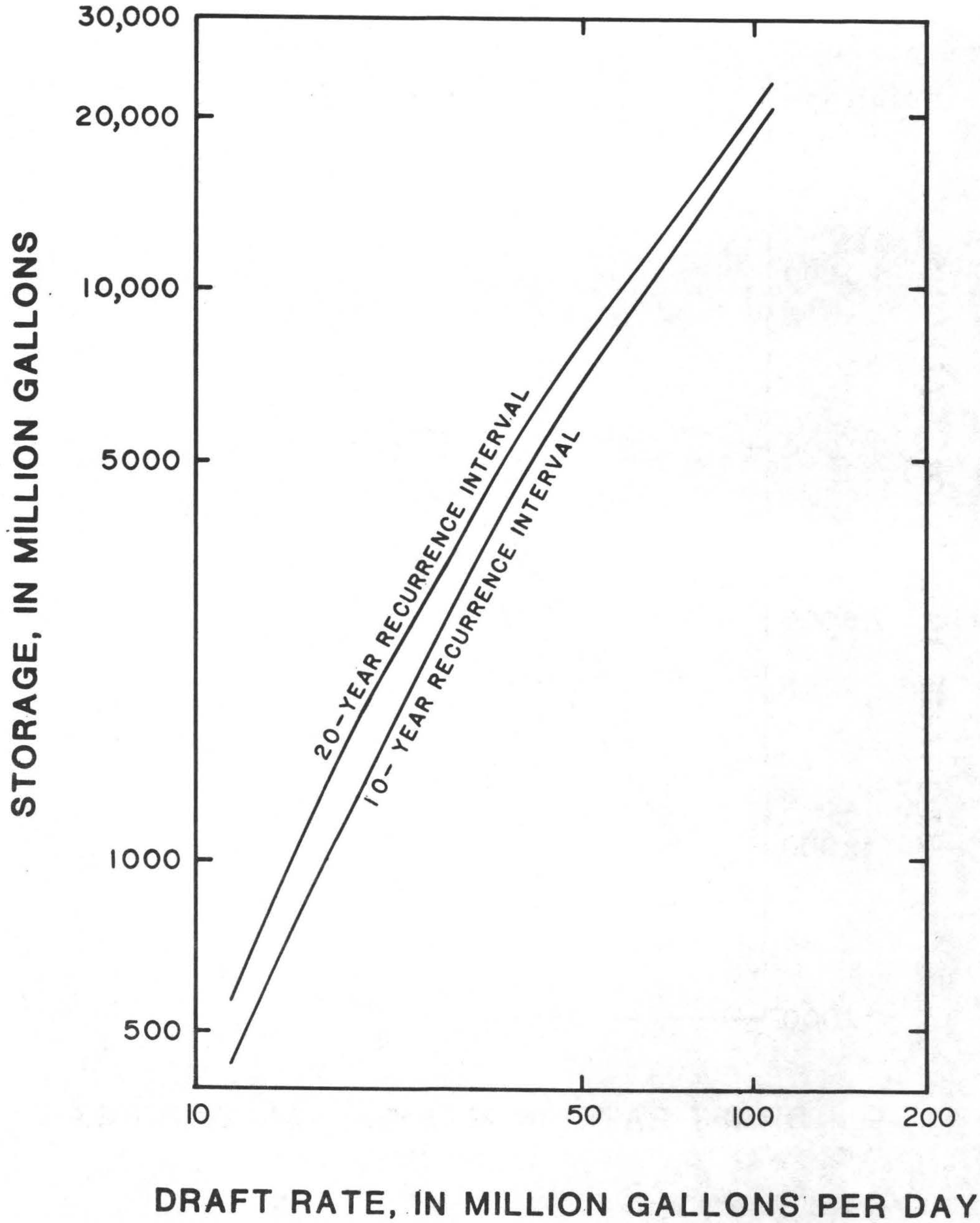


Figure 34.--Draft-storage frequency relations for Little Manatee River near Wimauma.

Table 16.--Potential impoundment sites in and near Manatee County

Reference number (fig. 29)	Name	Impoundment surface area (mi^2)	Stage (feet, sea level)	Approximate drainage area (mi^2)	Storage (Mgal)
1	Tatum Sawgrass	6.5	24	174	8,800
2	Myakka River near Myakka City	7.9	50	97	13,000
3	Manatee River near Myakka Head	2.4	80	63	5,200
4	East Fork Manatee River	1.8	90	28	3,100
5	North Fork Manatee River	1.9	90	33	3,200
6	Little Manatee River near Wimauma	7.1	50	140	15,000
7	South Fork Little Manatee River	1.5	75	39	4,400
7a	South Fork Little Manatee River	4.1	95	38	14,000

Surficial Aquifer

The surficial aquifer is generally undeveloped as a source of water. Small volumes of water are used for domestic, lawn irrigation, or stock watering. Most wells that tap the surficial aquifer have small diameters and usually yield less than 50 gal/min of water. Most wells are finished as open holes; some are screened.

The surficial aquifer has the greatest potential as a dependable water supply because it is readily recharged by precipitation. The potential varies as the physical characteristics of the aquifer and the conditions of recharge to and discharge from the aquifer vary. It also has the greatest potential for contamination from surface sources. The aquifer can be developed by means of conventional wells, collector wells, and tile drains.

Collector wells provide an effective means of developing shallow wells in sand, gravel, and shell deposits. Collector wells consist of a cylindrical caisson plugged at the bottom. One or more tiers of horizontal perforated pipe (laterals) are connected to the caisson wall (Walton, 1970). The well has an advantage in that it creates a cone of depression of large radius and of small depth (Wolansky, 1978).

Table 17.--Estimated hydraulic properties of aquifers and confining beds

[Modified from R. M. Wolansky, U.S. Geological Survey, Tampa, Florida (written commun., 1977)]

Hydrologic unit			Approximate thickness (feet)	Yields of wells (gal/min)	Specific capacity [(gal/min)/ft]	Transmissivity (ft^2/d)	Storage coefficient	Vertical hydraulic conductivity (ft/d)
Surficial aquifer			0-100	5-750	1-75	<100-10,000	0.05-0.25	--
Floridan aquifer system	Upper confining beds	Confining bed	0-75	--	--	--	Specific storage $1x10^{-5}-1x10^{-4}$	$1x10^{-4}-1x10^{-3}$
Floridan aquifer system	Upper confining beds	Minor artesian aquifer	>50-300	10-300	5-75	1,000-15,000	$1x10^{-5}-3x10^{-4}$	$1x10^{-3}-10^{-1}$
Floridan aquifer system	Upper confining beds	Confining bed	0-100	--	--	--	Specific storage $1x10^{-5}-1x10^{-4}$	$1x10^{-4}-1x10^{-3}$
Floridan aquifer system	Floridan aquifer		1,000-1,700	1,000-5,000	25-2,500	20,000-900,000	$1x10^{-3}-1.7x10^{-3}$	--
Floridan aquifer system	Lower confining bed		--	--	--	--	--	$1x10^{-5}-1x10^{-3}$

Tile drains are primarily used to drain agricultural land but provide a method of developing water supplies in areas where the surficial aquifer is thin and transmissivity is low. In northwestern Hillsborough County, Sinclair (1977) showed that an array of subsurface tile drains, about 1,000 feet long and 5 feet below land surface, produced about 19 gal/min from a 3-acre area.

Minor Artesian Aquifer

Water from the minor artesian aquifer is primarily used for domestic supply in Manatee County. Other uses include stock watering, irrigation, and small public supplies. Most irrigation wells that penetrate the Floridan aquifer are also open to the minor artesian aquifer.

Wells open to the minor artesian aquifer are generally finished as open hole. Small diameter wells (2 inches) may produce 25 to 30 gal/min. Large diameter wells (6 inches or larger) that fully penetrate the aquifer usually yield more than 200 gal/min. The aquifer is most productive in the western and southern parts of Manatee County, but yields little water in the northeastern part. The minor artesian aquifer is a major source of water for the Verna well field in northeast Sarasota County (fig. 1).

High concentrations of dissolved solids, chloride, and sulfate (more than 500, 250, and 250 mg/L, respectively) limit its potential for development in the coastal and southern parts of the county. Elsewhere, the quality of the water is suitable for most purposes.

Floridan Aquifer

The Floridan aquifer is the principal source of ground water in Manatee County. Water from the aquifer is primarily used for irrigation. Minor amounts are used for industrial purposes, air conditioning, and public and domestic supplies. The aquifer was a major source for public supply in Manatee County before development of surface-water sources.

Depending on the thickness penetrated and diameter of the well, the Floridan aquifer yields from less than 500 gal/min for wells 6 inches or less in diameter and only partially penetrating the aquifer to more than 5,000 gal/min for wells 8 inches or more in diameter and fully penetrating the aquifer. Most wells are finished as open hole and are usually cased to the first consistent rock unit. In eastern and southern Manatee County, the depth of casing generally ranges from less than 200 feet to more than 500 feet below land surface. The wells range in depth from about 500 to 1,500 feet, depending on the quality and quantity of water needed. In the western and coastal parts of the county, casing depths generally range from less than 50 to about 200 feet below land surface. Well depths are generally less than 700 feet, primarily because of poor water quality at depth.

Hydrologic properties that limit development of an aquifer system are transmissivity and storage. Leakage of water to a confined aquifer during pumping has a bearing on the time when an aquifer reaches equilibrium and maximum drawdown.

To determine the effects of development, hydrologic properties were used to estimate water-level drawdowns. Time-drawdown curves and distance-drawdown curves were developed using a transmissivity of 100,000 ft^2/d, a storage coefficient of $1x10^{-3}$, a leakance (K'/b') of $5.3x10^{-6}$ (ft/d)/ft [$4x10^{-5}$ (gal/d)/ft^3], and a pumpage rate of 2,000 gal/min (fig. 35). As shown, after 100 days of pumping a single well at 2,000 gal/min, drawdowns of about 3 feet and 1 foot would occur at distances of 1,000 and 10,000 feet from the well, respectively. Assuming steady-state conditions when the aquifer system is in equilibrium, maximum drawdowns would be 5.9, 4.5, and 3.1 feet at distances of 10, 100, and 1,000 feet, respectively (fig. 35).

Long-range projections of water use in west-central Florida indicate that substantial increases in withdrawals will occur for municipal supplies, irrigation, and phosphate mining (Wilson, 1977b). The potential effects of proposed phosphate mining in the county on the potentiometric surface of the Floridan aquifer are discussed by Wilson (1977b). Preliminary results indicated that maximum simulated drawdown in Manatee County would be about 15 feet by 1985 and about 14 feet by 2000.

The combined effects of withdrawal from the Floridan aquifer for municipal supplies, irrigation, and phosphate mining from 1976 to 2000 are discussed by Wilson and Gerhart (1979). The projected potentiometric surface in May 2000 ranges from about 10 feet below sea level in the central part of the county to about 20 feet above sea level in the southeast (fig. 36). Projected declines in the potentiometric surface from May 1976 to May 2000 range from about 5 feet along the coast to 30 feet in the northeast. By October 2000, the projected altitude of the potentiometric surface will range from about 10 feet above sea level along the coast to 30 feet in the northeastern part of the county (fig. 37). Projected declines from November 1976 to October 2000 range from zero along the coast to more than 20 feet in the northeast. The effect of the projected declines on surface-water supplies will probably be minimal because of the relatively thick confining beds separating the surficial aquifer from the Floridan aquifer.

The principal chemical constituents that determine the potability of water in the Floridan aquifer are chloride, sulfate, and dissolved solids. Figure 38 shows areas where concentrations of chloride, sulfate, or dissolved solids exceed 250, 250, and 500 mg/L, respectively, in water from wells open to the water-bearing zones of the Suwannee Limestone-Ocala Limestone (middle water-bearing zone) and the Avon Park Limestone (lower water-bearing zone). Water supplies from these zones that would require minimum treatment occur only in the northeastern part of the county.

WATER USE

A knowledge of types and distribution of present water use is needed in evaluating the water resources. Background information on water use was provided by statewide water-use surveys in 1970 and 1975 (Pride, 1973; Leach, 1977). Results from these surveys are summarized in table 18. In 1975, an estimated 45 Mgal/d of surface water and 31 Mgal/d of ground water were used in Manatee County. The principal uses of surface water were for public supply and for cooling water for thermoelectric power generation. Ground water was primarily used for irrigation.

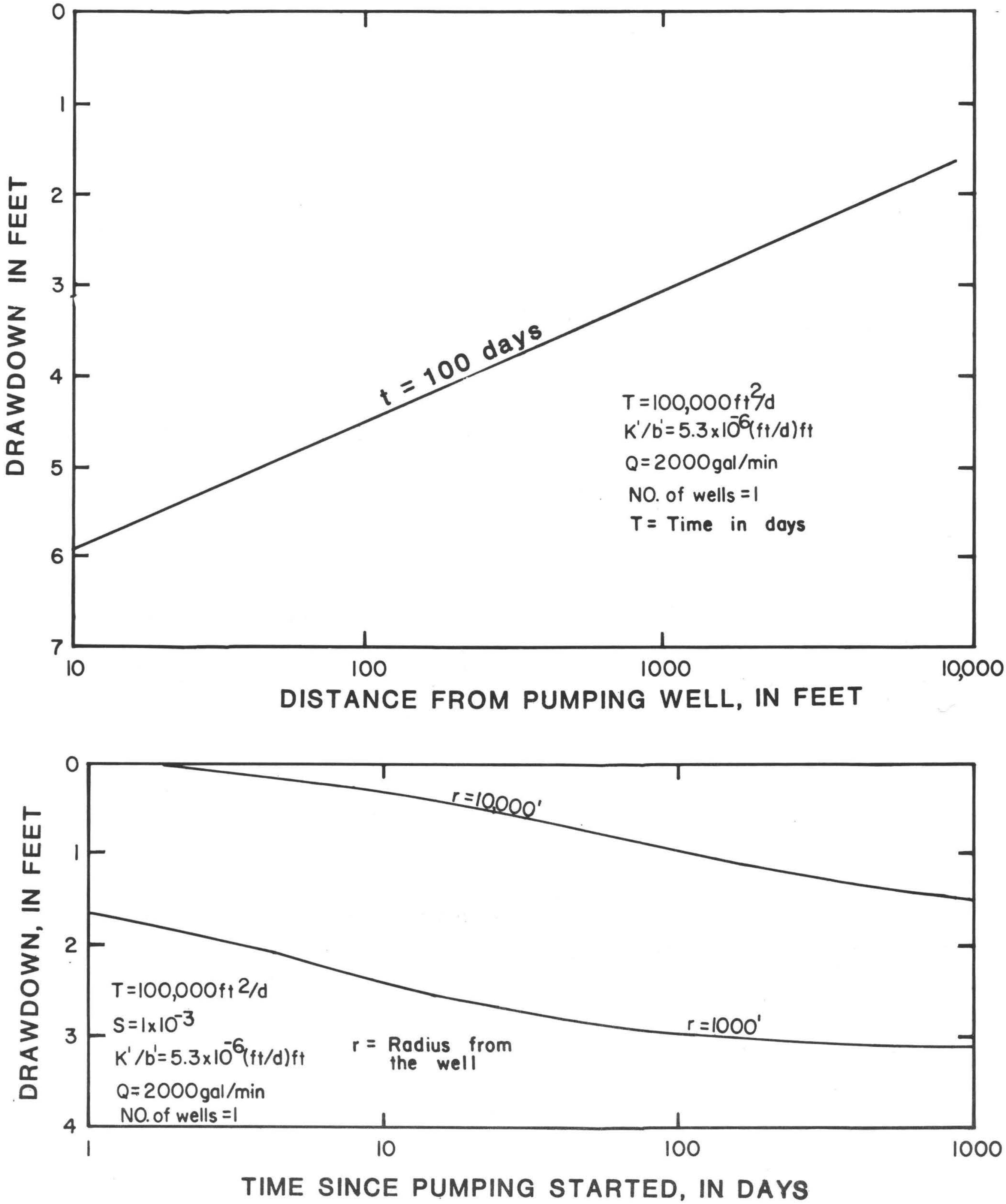
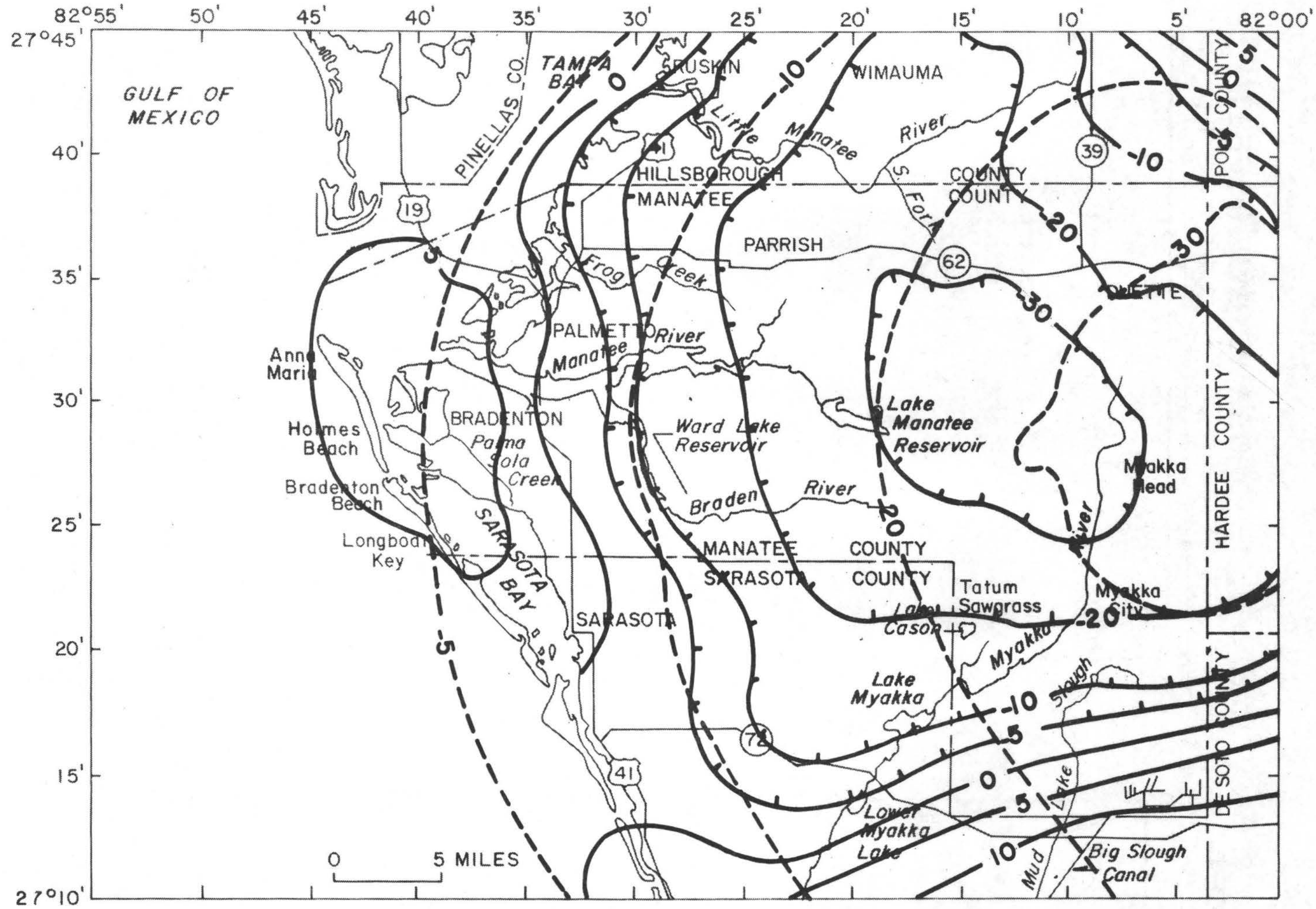


Figure 35.--Steady-state distance-drawdown and time-drawdown curves for the Floridan aquifer.

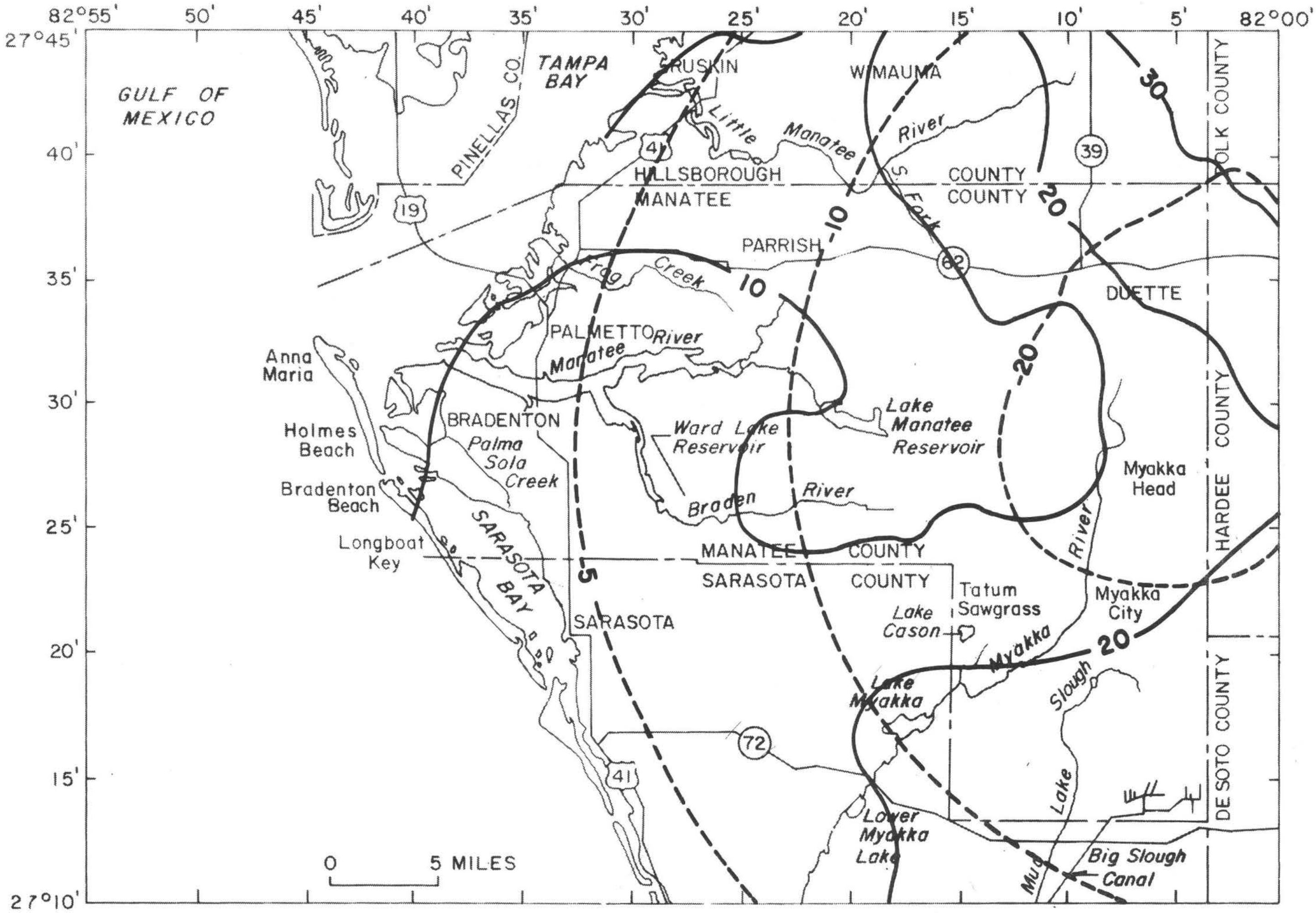


EXPLANATION

—— 5 —— POTENTIOMETRIC CONTOUR--SHOWS ALTITUDE AT WHICH WATER LEVEL WOULD HAVE STOOD IN TIGHTLY CASED WELLS. CONTOUR INTERVAL 5 AND 10 FEET. DATUM IS NGVD OF 1929

- - 5 - - LINE OF EQUAL WATER-LEVEL DECLINE-- INTERVAL 5 AND 10 FEET

Figure 36.--Projected potentiometric surface of the Floridan aquifer, May 2000, and decline in the potentiometric surface, May 1976 to May 2000 (modified from Wilson and Gerhart, 1979).

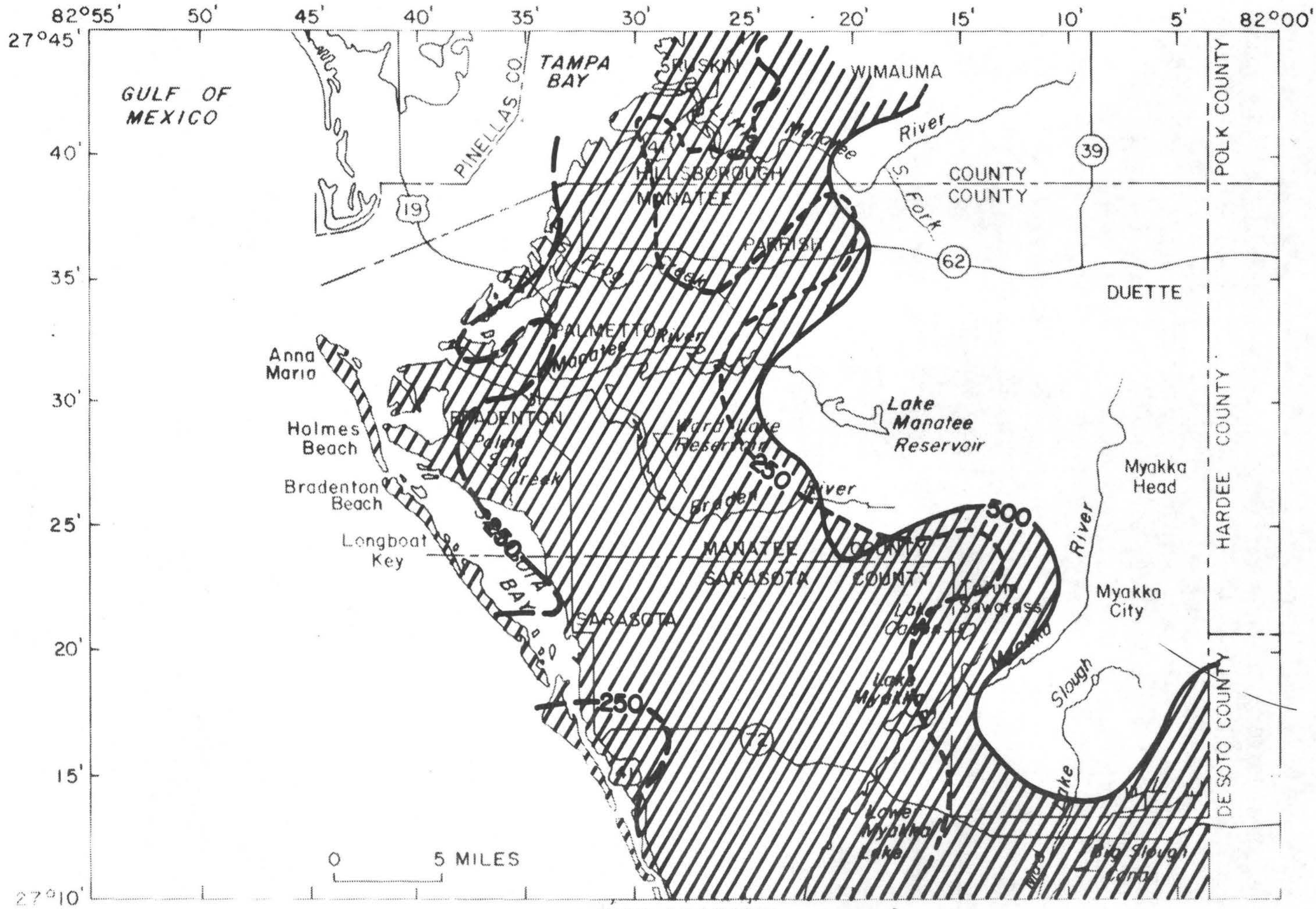


EXPLANATION

—10— POTENTIOMETRIC CONTOUR--SHOWS ALTITUDE AT WHICH WATER LEVEL WOULD HAVE STOOD IN TIGHTLY CASED WELLS. CONTOUR INTERVAL 5 AND 10 FEET. DATUM IS NGVD OF 1929

– –10– – LINE OF EQUAL WATER-LEVEL DECLINE-- INTERVAL 5 AND 10 FEET

Figure 37.--Projected potentiometric surface of the Floridan aquifer, October 2000, and decline in the potentiometric surface, November 1976 to October 2000 (modified from Wilson and Gerhart, 1979).



EXPLANATION

—500— LINE OF EQUAL DISSOLVED SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER

--250-- LINE OF EQUAL SULFATE CONCENTRATION, IN MILLIGRAMS PER LITER

— —250— —LINE OF EQUAL CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER

▨ AREA WHERE CONCENTRATIONS OF DISSOLVED SOLIDS, CHLORIDE, OR SULFATE ARE EQUAL TO OR GREATER THAN 500, 250, OR 250 MILLIGRAMS PER LITER, RESPECTIVELY

Figure 38a.--Areas where water from the Suwannee-Ocala (middle zone) Limestones exceed upper limits in concentrations of dissolved solids, chloride, and sulfate.

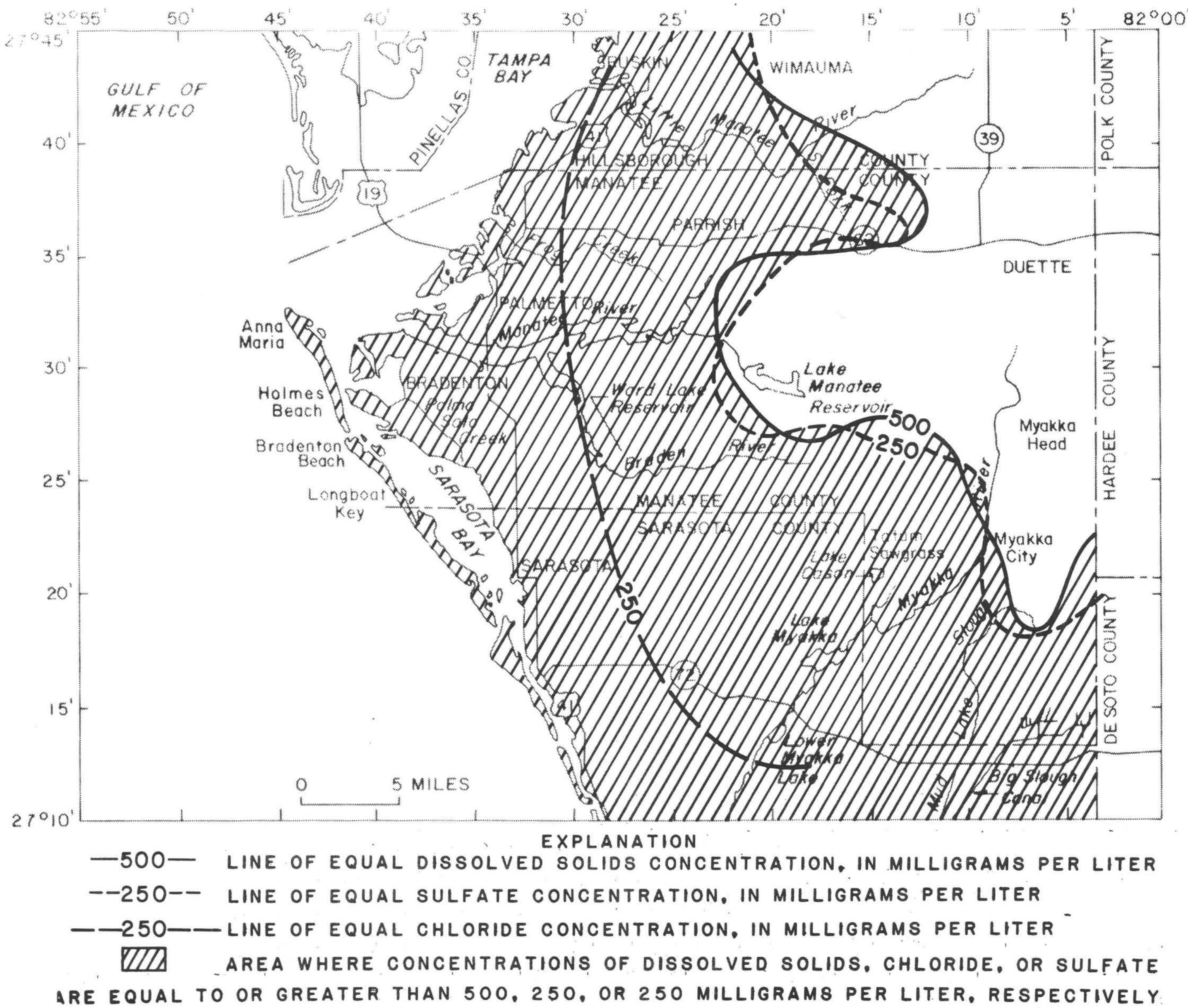


Figure 38b.--Areas where water from the Avon Park (lower zone) Limestone exceed upper limits in concentrations of dissolved solids, chloride, and sulfate.

Table 18.--Water use, 1970-75

[In million gallons per day]

Year	Population served (thousands)	Public supply		Industrial self-supplied		Thermoelectric power	
		Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
1970	64.8	0.3	9.6	3.0	-	-	-
1975	80.0	0	18.9[a]	2.0	-	-	25.0[b]

Year	Acres	Irrigation		Population served (thousands)	County self-supplied			
					Domestic		Livestock	
		Ground water	Surface water		Ground water	Surface water	Ground water	Surface water
1970	28,900	49.5	-	ND	ND	ND	ND	ND
1975	25,750	22.8	1.2	43.5	4.4	-	1.6	0.2

[a]Includes 6 Mgal/d raw water supplied for industrial use.
[b]Freshwater used to fill reservoir only, not in operation during 1975.
ND-No data.

Surface Water

The Manatee County Utility System supplies water to Palmetto, Holmes Beach, Longboat Key, Anna Maria and Bradenton Beach, and the city of Bradenton. The county system in 1978 contracted to supply the Sarasota County Utility District No. 1 up to 10 Mgal/d. In 1975, the average daily municipal pumpage was 9.9 Mgal/d serving an estimated 55,000 people (table 19). An additional 6.0 Mgal/d was supplied for industrial use. By 1985, the average daily pumpage is estimated to be 27.4 Mgal/d (Texas Instruments Incorporated, 1978).

In 1975, the city of Bradenton supplied an average of 3.8 Mgal/d of water to a population of about 25,000. Of the total supply, about 3.1 Mgal/d was pumped from the Braden River (Ward Lake Reservoir) and 0.7 Mgal/d was purchased from the county system. During 1975, the water supply ranged from a monthly high of 4.26 Mgal/d in December to a monthly low of 3.31 Mgal/d in July. By 1985, the projected water demand for Bradenton will be 5.0 Mgal/d.

Florida Power and Light's Manatee powerplant uses an estimated 14 Mgal/d of water from the Little Manatee River for its cooling system. By 1985, the projected water use for condenser cooling and for generating electric power will be 15 Mgal/d.

Table 19.--Water use for public supply, 1975 and 1977, and projected water use, 1980 and 1985

Public supply	Source	Water use (Mgal/d)			
		1975[a]	1977[b]	1980[b]	1985[b]
Manatee County Utility System	Lake Manatee Reservoir (Manatee River)	9.9	19.1	22.2	27.4
City of Bradenton	Ward's Lake (Braden River)	3.8	4.0	4.5	5.0

[a]Leach, 1977.
[b]Donald Smally, written commun., March 13, 1978.

Ground Water

The principal use of ground water is for agricultural irrigation, which averaged 49.5 Mgal/d in 1970 and 22.8 Mgal/d during 1975 (table 18). The decline in irrigation is probably due to more efficient methods of application. Irrigation is heaviest during the fall and winter-spring growing seasons.

SUMMARY

Manatee County, on the lower west coast of Florida, contains about 739 mi^2 of land area and 46 mi^2 of inland water. The county lies within three physiographic units: the Gulf Coastal Lowlands, the DeSoto Plain, and the Polk Upland. Altitudes of land surface range from sea level along the coast to 130 feet above sea level in the northeast.

The major land uses are range, agricultural, urban, and mining. By the year 2000, projected major land uses are expected to remain rangeland and agricultural. Urban or built-up land is expected to increase about 30 percent. Projected land use in mining is expected to increase by 1985 and then decrease by 2000, reflecting projected phosphate mining and reclamation in eastern Manatee County.

The source of freshwater is from rainfall in the county or adjacent areas. The average annual rainfall is about 55 inches. During the rainy season (June through September), rainfall ranges from about 6 to 9 inches per month. During the dry season (October through May), rainfall ranges from 1.5 to 3 inches per month. Evapotranspiration has been estimated to be about 39 inches per year.

Most streams have small drainage basins, short channel lengths, and do not yield high volumes of flow. Major streams draining Manatee County are the Myakka and Manatee Rivers. The Myakka River, near Sarasota, drains about 229 mi^2 in Manatee County and has a 41-year average discharge, measured 36 miles upstream from its mouth, of 253 ft^3/s (15 inches of runoff per year). The river has a

highly variable discharge that equals or exceeds 500 ft^3/s 50 percent of the time. Discharge may cease for extended periods of time, or on the average, 14 consecutive days every 2 years and 90 days once in 10 years.

The Manatee River and its principal tributary, the Braden River, drain about 345 mi^2 in Manatee County. The 26-year average discharge at Manatee River near Bradenton is 109 ft^3/s (about 17 inches of runoff per year). Discharge equals or exceeds 24 ft^3/s 50 percent of the time.

The surface water in Manatee County is generally less mineralized than ground water except in the tidally affected and coastal areas. The quality of surface water generally is suitable for most purposes. From June through September, streamflow is mainly a combination of ground-water discharge and direct runoff; concentrations of dissolved minerals and hardness are low and color is high. From October through May, streamflow is maintained by ground-water discharge; dissolved mineral concentrations and hardness increase and color decreases.

Water from the Manatee River (Lake Manatee Reservoir) and the Braden River (Ward Lake) is used for public supplies. Water from the Little Manatee River is used for a thermoelectric powerplant and cooling pond. At a pool elevation of 40 feet above sea level, Lake Manatee Reservoir has a surface area of 2.9 mi^2 and a storage capacity of 7,000 Mgal. Draft-storage frequency relations indicate that at a 5 percent risk of having inadequate storage, the reservoir could supply a continuous draft of about 38 Mgal/d. Ward Lake reservoir has a surface area of 57.6 acres and a storage capacity of about 585 Mgal. For a demand rate of 4.0 Mgal/d there is a 40 percent risk that the present storage will be inadequate. To provide a continuous draft of 50 Mgal/d at a 5 percent risk of failure, an estimated storage of about 11,000 Mgal is required on the Myakka River near Sarasota, 11,000 Mgal on the Manatee River near Myakka Head, and 8,400 Mgal on the Little Manatee River near Wimauma.

Ground water occurs under unconfined and confined conditions. Unconfined conditions occur in the surficial aquifer, which consists of deposits of sand, gravel, shell, and limestone. Confined ground water occurs in permeable zones within the carbonate strata of the Floridan aquifer.

The upper confining bed that separates the surficial and Floridan aquifers consists of sandy clays, clays, and marls. Within the upper confining bed there are permeable sand, gravel, shell, and limestone beds that form the minor artesian aquifer.

The Floridan aquifer consists of at least three permeable zones of limestone and dolomite that generally function as a single hydrologic unit. The principal water-bearing zones are: (1) the uppermost limestone (in part, the Tampa Limestone and, in part, the Hawthorn Formation); (2) the lower part of the Suwannee Limestone--upper part of the Ocala Limestone; and (3) the Avon Park Limestone below the top 100 feet (dolomite unit).

The lower confining bed of the Floridan aquifer consists of limestone and dolomite of the Lake City Limestone. The upper part of the Lake City Limestone contains highly mineralized water and is nearly impermeable.

The quality of ground water is generally good except in the western and southern parts of the county where saltwater intrusion or incomplete flushing of residual seawater has occurred. The quality of water in the surficial and minor artesian aquifers is of acceptable quality except near the coast and tidal-affected streams. The water in the Floridan aquifer is generally more mineralized than water from the surficial and minor artesian aquifers.

The mineral content of the water from the Floridan aquifer generally increases with depth and from the northeastern part of the county towards the west and south. Concentrations of dissolved solids range from about 300 mg/L in the northeastern part of the county to 2,500 mg/L in the western part. Concentrations of chloride are less than 250 mg/L except near the coast where saltwater intrusion has occurred. In eastern Manatee County, concentrations of chloride are generally less than 50 mg/L. Concentrations of sulfate range from about 5 to 900 mg/L, generally increasing with depth and from the northeastern part of the county towards the west and south. Relatively high concentrations of sulfate (more than 250 mg/L) occur in the western and southern parts of the county.

Ground water is used primarily for agricultural irrigation. An average of 22.8 Mgal/d was used during the 1975 fall and 1975-76 winter-spring growing seasons. The minor artesian aquifer is a major source of water for rural domestic supply. The surficial aquifer is generally undeveloped as a source of water.

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