CHLORIDE CONCENTRATIONS IN THE COASTAL MARGIN OF THE FLORIDAN AQUIFER, SOUTHWEST FLORIDA

By K. W. Causseaux and J. D. Fretwell

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ABBREVIATIONS AND CONVERSION FACTORS

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

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Leakance	
foot per day per foot [(ft/d)/ft]	1.000	meter per day per meter [(m/d)/m]

* * * * * * * * * * * * * * *

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 the text of this report, NGVD of 1929 is referred to as sea level.

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ABSTRACT

The Floridan aquifer is the principal source of freshwater in southwest Florida. The freshwater part of the aquifer is underlain by saltwater in lower formations and is bounded on the coast by saltwater in the coastal parts of the aquifer. Management of water resources in the coastal margin of the area is important because of the potential for saltwater intrusion in areas of ground-water withdrawals.

Saltwater and freshwater are mixed in the coastal zone. The saltwater boundary on the Gulf of Mexico side of the mixed zone is defined by chloride concentrations of 19,000 milligrams per liter, equal to that of seawater. On the landward side, the freshwater boundary of the mixed zone is defined by chloride concentrations of 25 milligrams per liter, which generally represents background levels of inland waters. The freshwater boundary of the mixed zone is probably moving inland in some areas because of lowering of the potentiometric surface of the Floridan aquifer and increasing ground-water withdrawals along the coast. Areas that are most subject to increasing chloride concentrations lie immediately inland from the 250-milligram-per-liter line of equal chloride concentration, near centers of heavy pumpage.

Saltwater is present in the coastal margin of the aquifer in Citrus, Hernando, Pasco, Pinellas, and Hillsborough Counties north of Tampa Bay. Saltwater is absent in the coastal margin, at least in the upper part of the aquifer, in central Hillsborough County and in Manatee and Sarasota Counties. Freshwater is present above the saltwater in the coastal margin of the aquifer in Citrus, Hernando, Pasco, Pinellas, and Hillsborough Counties. A mixture of freshwater and saltwater is present in all coastal margins with the mixed zone much thicker and wider in Sarasota County than in Citrus County.

Seventy wells at 54 sites are proposed to monitor chloride concentrations along the 250-milligram-per-liter line of equal chloride concentration in the coastal margin of the Floridan aquifer. Sixteen of the sites are proposed for areas of increasing chloride concentrations and heavy ground-water withdrawals. The remaining wells are needed to improve understanding of chloride-concentration distribution and to monitor long-term changes in chloride concentrations in the coastal margin of the Southwest Florida Water Management District.

INTRODUCTION

Ground-water withdrawals in southwest Florida are increasing because of population growth, industrial expansion, and increasing agricultural irrigation. Although there is an abundance of potable ground water in inland areas, management of water resources in the coastal margin is necessary to protect aquifers containing freshwater from saltwater intrusion.

The Floridan aquifer is the source of most water supplies in southwest Florida. Saltwater occurs in the aquifer in the vicinity of the coastline and withdrawal of freshwater from the aquifer can induce saltwater to move inland from the coast. As an increasing amount of water is withdrawn to meet demands, the likelihood of saltwater intrusion also is increased.

From July 1977 to September 1980, the U.S. Geological Survey, in cooperation with the Southwest Florida Water Management District, studied the distribution of chloride concentrations along coastal southwest Florida (fig. 1) for the purpose of delineating the location of the zone of mixing between freshwater and saltwater and for selecting well locations to monitor chloride concentrations in the coastal margin. Results of the early part of this study were released in a report on the 1979 position of the 250-milligram-per-liter (mg/L) line of equal chloride concentration in the upper part of the Floridan aquifer (Causseaux and Fretwell, 1982). The secondary maximum contaminant level of chloride recommended for drinking water is 250 mg/L (U.S. Environmental Protection Agency, 1977).

Purpose and Scope

The purpose of the study was to design an effective network of wells for monitoring the location and movement of the saltwater-freshwater mixed zone in the Floridan aquifer in west-central Florida. This report presents proposed locations of wells for monitoring chloride concentrations in the coastal margin of the Southwest Florida Water Management District. Selection of well sites was based on ground-water movement, centers of ground-water withdrawals, areas of increasing chloride concentrations, and the 1979 position of the 250-mg/L line of equal chloride concentration in the upper part of the Floridan aquifer.

Previous Investigations

The ground-water resources of southwest Florida have been discussed in varying detail in numerous reports of the Florida Bureau of Geology, the U.S. Geological Survey, and private organizations. Matson and Sanford (1913) described the geology and ground-water resources of the study area in a statewide report. In reports of investigations of five Florida counties, Stringfield (1933a; 1933b) discussed the geography, geology, and ground-water conditions in parts of southwest Florida. He called attention to the problem of saline-water contamination of the freshwater-bearing units. He also discussed the geohydrology of the study area in his regional reports (Stringfield, 1936; 1966). Cooke (1945) and Vernon (1951) described the geology of southwest Florida, and Parker and others (1955) named and described the Floridan aquifer. Cooper and others (1953) and Cherry and others (1970) treated the general hydrology of parts of southwest Florida.

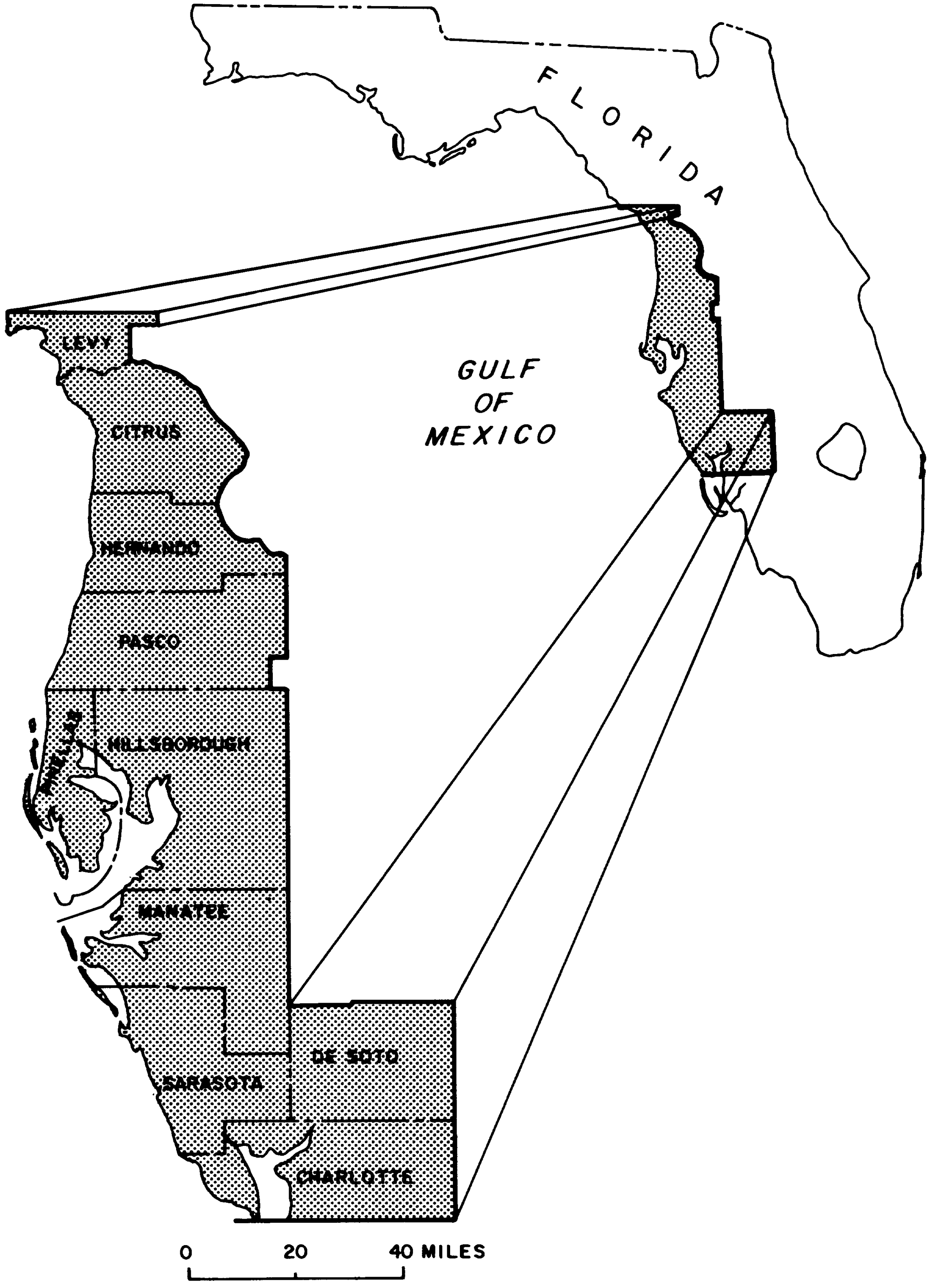

Figure 1.--Location of study area.

In an appraisal of the geology and hydrology of Charlotte County, Sutcliffe (1975) discussed the problems of saline water intrusion in the aquifer. Wilson (1977) found that chloride concentrations in De Soto and Hardee Counties are higher in the lower part of the Floridan aquifer than in the upper part. Peek (1959) and Menke and others (1961) noted variations in concentration of selected dissolved constituents with fluctuations in water levels in the coastal parts of Manatee and Hillsborough Counties. Peek (1958) estimated the extent of saline contamination in the Manatee County coastal area.

Pinellas County first experienced a salinity problem in the 1920's when water-quality degradation became significant (Heath and Smith, 1954). Cherry (1966) found that salinity problems had not escalated significantly since 1950 because ground-water withdrawals had not increased significantly in the county from 1950 to 1960.

Wetterhall (1964) noted that vertical layering of freshwater and saline water occurs along the coast in Hernando and Pasco Counties. In his report on the geology of Citrus and Levy Counties, Vernon (1951) briefly discussed ground-water conditions, including the possible occurrence of saltwater near the coast. The location of the 250-mg/L line of equal chloride concentration was delineated by Reichenbaugh (1972) in Pasco County and by Mills and Ryder (1977) in Citrus and Hernando Counties. Other studies that provide information about water quality and geohydrology in southwest Florida are Shattles (1965), Kaufman and Dion (1967), Hunn (1974), Duerr (1975), Fretwell and Stewart (1981), and Hickey (1981; 1982a; 1982b).

Description of the Area

The study area (fig. 1) covers about 5,000 mi^2 and includes all or parts of 10 counties of the Southwest Florida Water Management District. The area lies in the Coastal Lowlands (Cooke, 1939). Land-surface altitudes range from sea level at the coast to about 300 feet above sea level. The Coastal Lowlands consist of low, nearly level plains, gently undulating to rolling hills, and many ponds, swamps, marshes, lakes, and perennial streams.

The climate is characterized by warm, humid summers and mild, moderately dry winters. The proximity to the gulf and wetland areas contributes to the humid, temperate climate. The average annual rainfall ranges from 50 to 56 inches. About 60 percent of the rain falls during the months of June through September, and it usually occurs as afternoon and evening thundershowers. Spring months are generally warm and dry and are the months of heaviest irrigation of crops.

Along the coast of southwest Florida, rainfall exceeds evapotranspiration by 0 to 6 inches per year (Visher and Hughes, 1969). Most of the excess water runs off through stream systems to the Gulf of Mexico or percolates to the ground-water system where it becomes available for withdrawal.

In Levy, Citrus, and Hernando Counties, surface drainage is almost nonexistent. Highly permeable soils capture most of the precipitation and sinkholes receive much of the surface runoff. Streams generally originate at springs and carry little overland flow. Extensive tidal marshes occur along most of the coastline. In Pasco, Pinellas, and Hillsborough Counties, streams flow to the

Gulf of Mexico or Tampa Bay. Ground-water discharge is mostly by springs or ground-water seepage. In Manatee, De Soto, Sarasota, and Charlotte Counties, where topography is characterized by gently sloping marine terraces, natural streams are poorly developed and are bordered by extensive swampy areas.

FLORIDAN AQUIFER

The Floridan aquifer, the most productive and widely used aquifer in southwest Florida, extends downward from the top of the first persistent limestone sequence to the top of a persistent intergranular gypsum and anhydrites (table 1). Parker and others (1955) defined the Floridan aquifer to include the Lake City and Avon Park Limestones of middle Eocene age, the Ocala Limestone of late Eocene age, the Suwannee Limestone of Oligocene age, and the Tampa Limestone of early Miocene age. Also, where the lower beds of the Hawthorn Formation of middle Miocene age are in hydraulic contact with the underlying formations, these beds form the upper part of the aquifer. The top of the Floridan aquifer ranges in altitude from about 100 feet above sea level in the northern part of the study area to about 750 feet below sea level in the southeastern part (fig. 2).

The lower confining bed of the Floridan aquifer is generally considered to be that part of the Lake City Limestone where intergranular anhydrite or gypsum is vertically persistent. The top of the lower confining bed ranges in altitude from about 600 feet below sea level in Citrus County to 3,000 feet below sea level in Charlotte County (Wolansky and others, 1979). The intermediate aquifers and confining beds between the Floridan aquifer and the surficial aquifer consist of a mixture of limestone, dolomite, sand, and clay. Absent in some northern areas, the thickness of these intermediate units increases to the south and is about 650 feet in Charlotte County (Buono and others, 1979). The intermediate aquifers are an important source of water in the southern part of the study area where water in the Floridan aquifer is too saline for most uses. The major and lowermost unit of the intermediate aquifers and confining beds is the Hawthorn Formation.

Potentiometric Surface

Water in the Floridan aquifer is confined except in coastal parts of Levy, Citrus, and Hernando Counties. Fluctuations in the potentiometric surface of water in the aquifer respond to seasonal variations in rainfall and ground-water withdrawal. As shown in hydrographs of water levels for selected wells (fig. 3), the potentiometric surface is highest in the autumn and winter and lowest in the spring. The low-water conditions are generally related to seasonally low rainfall, but the levels can be significantly affected by pumping, especially in the central and southern counties. Long-term lowering of the potentiometric surface has been very gradual in some parts of the coastal margin and the surface has begun to recover in others (fig. 3).

Table 1.--Hydrogeologic framework of coastal southwest Florida

(Modified from Wilson and Gerhart, 1980)

System	Series	Stratigraphic unit	General lithology	Major lithologic unit	Hydrogeologic unit
Quaternary	Holocene Pleistocene	Surficial sand, terrace sand, phosphorite	Predominantly fine sand; interbedded clay, marl, shell, limestone, phosphorite	Sand	Surficial aquifer
Tertiary	Pliocene	Undifferentiated deposits	Clayey and pebbly sand; clay, marl, shell, phosphatic	Carbonate and clastic	Upper confining bed of Floridan aquifer and intermediate aquifer
	Miocene	Hawthorn Formation	Dolomite, sand, clay, and limestone; silty, phosphatic		
		Tampa Limestone	Limestone, sandy, phosphatic, fossiliferous; sand and clay in lower part in some areas		
	Oligocene	Suwannee Limestone	Limestone, sandy limestone, fossiliferous		Floridan aquifer
	Eocene	Ocala Limestone	Limestone, chalky, foraminiferal, dolomitic near bottom	Carbonate	
		Avon Park Limestone	Limestone and hard brown dolomite		
		Lake City and Oldsmar Limestones	Dolomite and chalky limestone, with intergranular gypsum and anhydrite	Carbonates with intergranular evaporites	Lower confining bed of Floridan aquifer
	Paleocene	Cedar Keys Limestone			

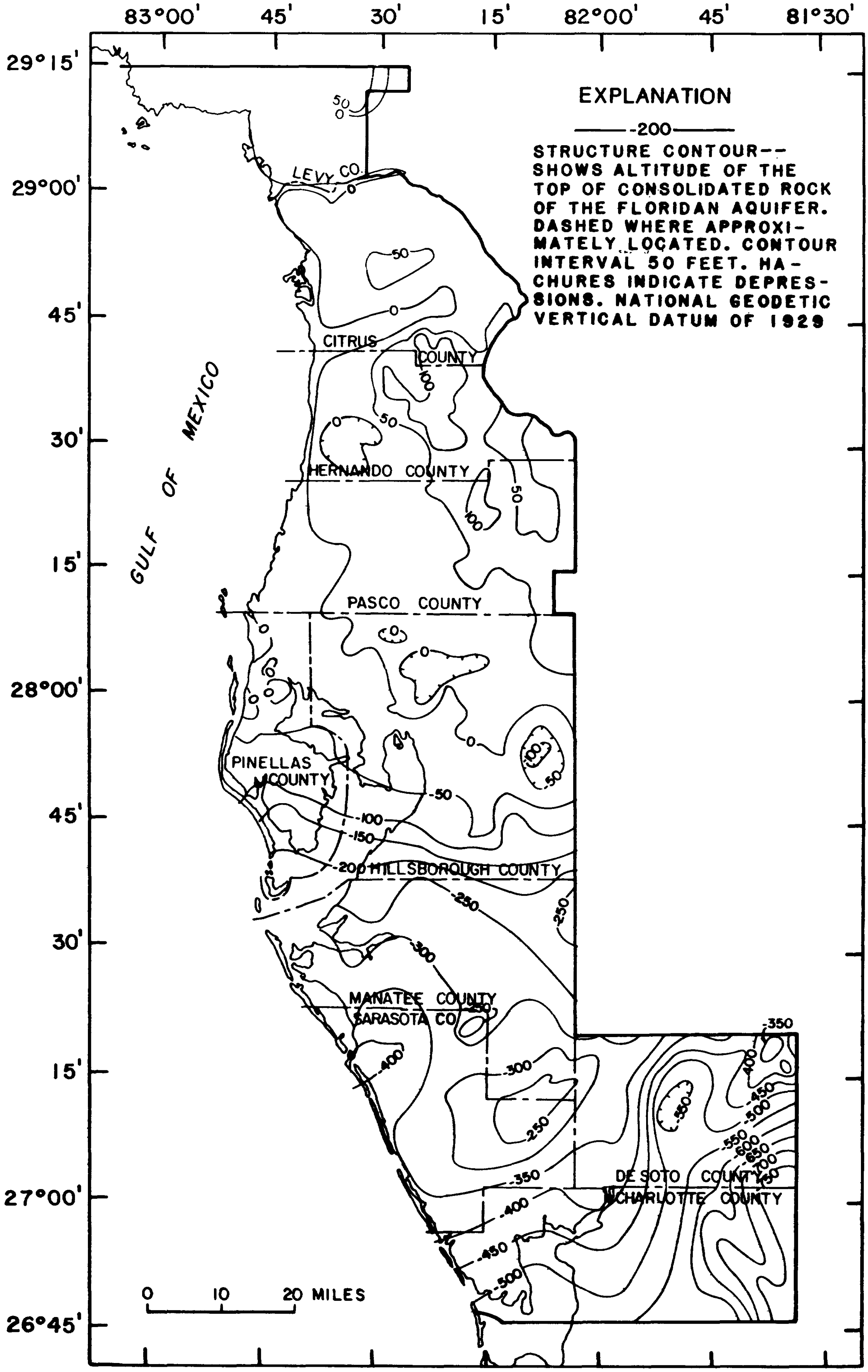

Figure 2.--Altitude of the top of the Floridan aquifer (from Buono and Rutledge, 1979).

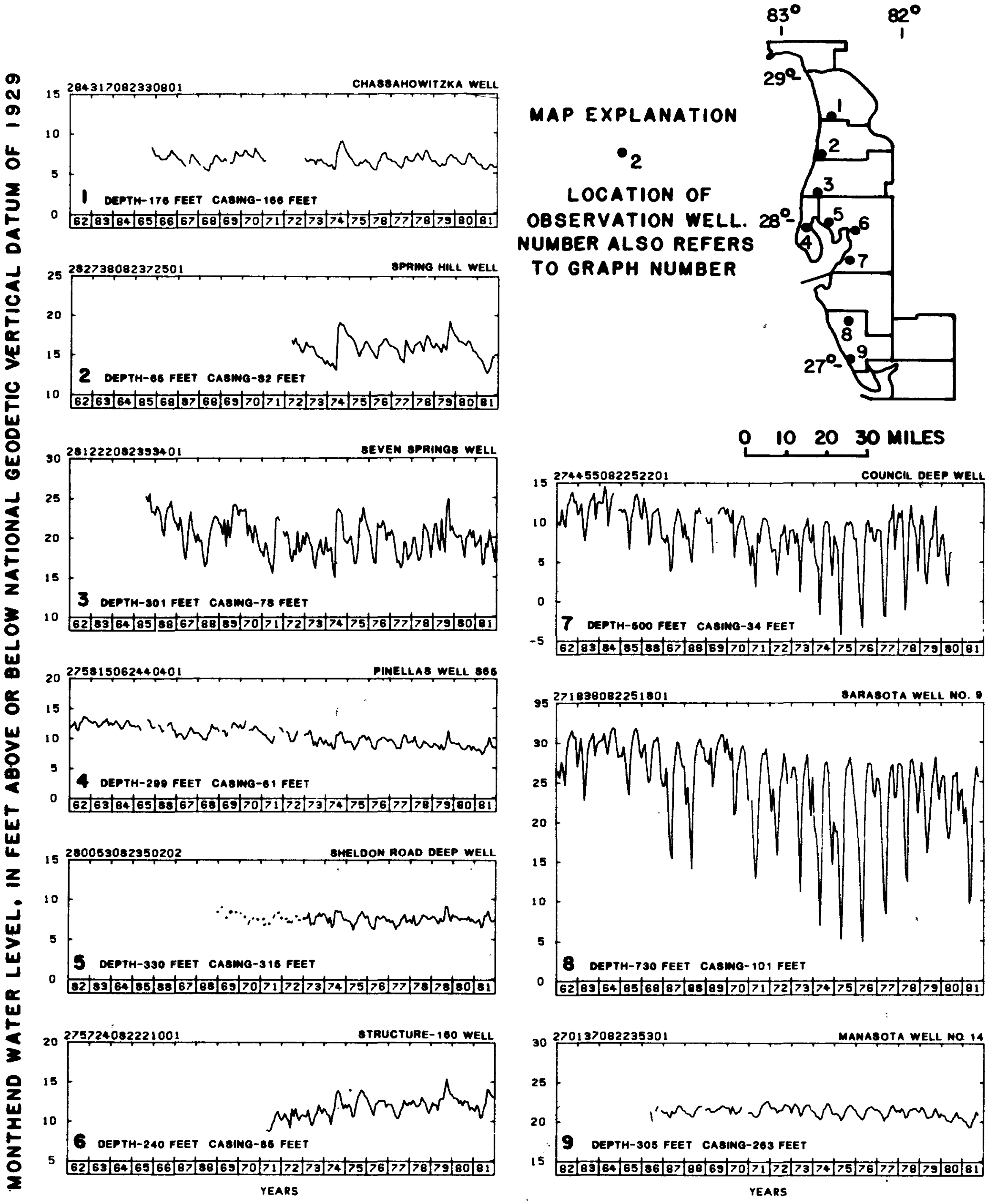

Figure 3.--Water levels for selected Floridan aquifer wells in coastal southwest Florida.

Generalized directions of ground-water flow in the Floridan aquifer can be determined from potentiometric maps that are prepared semiannually in the spring and autumn by the U.S. Geological Survey. Configuration of the potentiometric surface near the end of the rainy season, when withdrawals from the aquifer are minimal (fig. 4), shows that ground-water flow is generally toward the west. However, a depression in Hillsborough County indicates that withdrawals in the vicinity of Tampa Bay exceed that for other parts of the coastal margin. The potentiometric surface for the dry period, when withdrawals from the aquifer are high (fig. 5), shows that closed depressions in Hillsborough County extend into Manatee County. The increase in extent and depth of the depression is related to less rainfall and increased pumping for agriculture. These depressions show a change in direction of flow between September and May that causes increased mixing of saltwater and freshwater.

Ground-Water Withdrawal

Ground-water pumped from the Floridan aquifer is the principal source of water for agricultural, industrial, and public supplies in most of southwest Florida. The largest single use of ground water is for irrigation of crops, principally citrus and vegetables (Duerr and Trommer, 1981). Pumpage for irrigation varies because of the unequal distribution of rainfall, but most pumping occurs during the spring when rainfall is low.

Industry accounts for the second largest use of ground water. Phosphate mining, citrus processing, chemical processing, food processing, and air conditioning account for the bulk of industrial use of ground water. Public-supply systems and rural users account for the remainder of ground water used. Public-supply systems furnish water for households and small industries, and most rural use is for domestic and livestock purposes. As population of the area grows, an increase in pumpage for public-supply and industrial use can be expected.

Since 1975, consumptive-use permits have been required by the Southwest Florida Water Management District for wells that have a diameter of 6 inches or more or smaller wells that will be withdrawing more than 100,000 gal/d. The pattern of ground-water withdrawal is shown by a plot (fig. 6) of the rates of permitted withdrawal (Robert G. Perry, Southwest Florida Water Management District, written commun., 1980). This map shows permitted average daily withdrawal and does not reflect actual pumpage or seasonal variations in pumpage.

CHLORIDE-CONCENTRATION DISTRIBUTION IN THE COASTAL MARGIN

Freshwater, saltwater, and a mixture of freshwater and saltwater commonly occur in the Floridan aquifer in the coastal margin of southwest Florida. In this report, saltwater is defined by a chloride concentration of 19,000 mg/L or greater, which is equal to that of seawater. Freshwater is defined by a chloride concentration of 25 mg/L or less, which is the background concentration in ground water from the aquifer at locations several miles inland from the Gulf of Mexico.

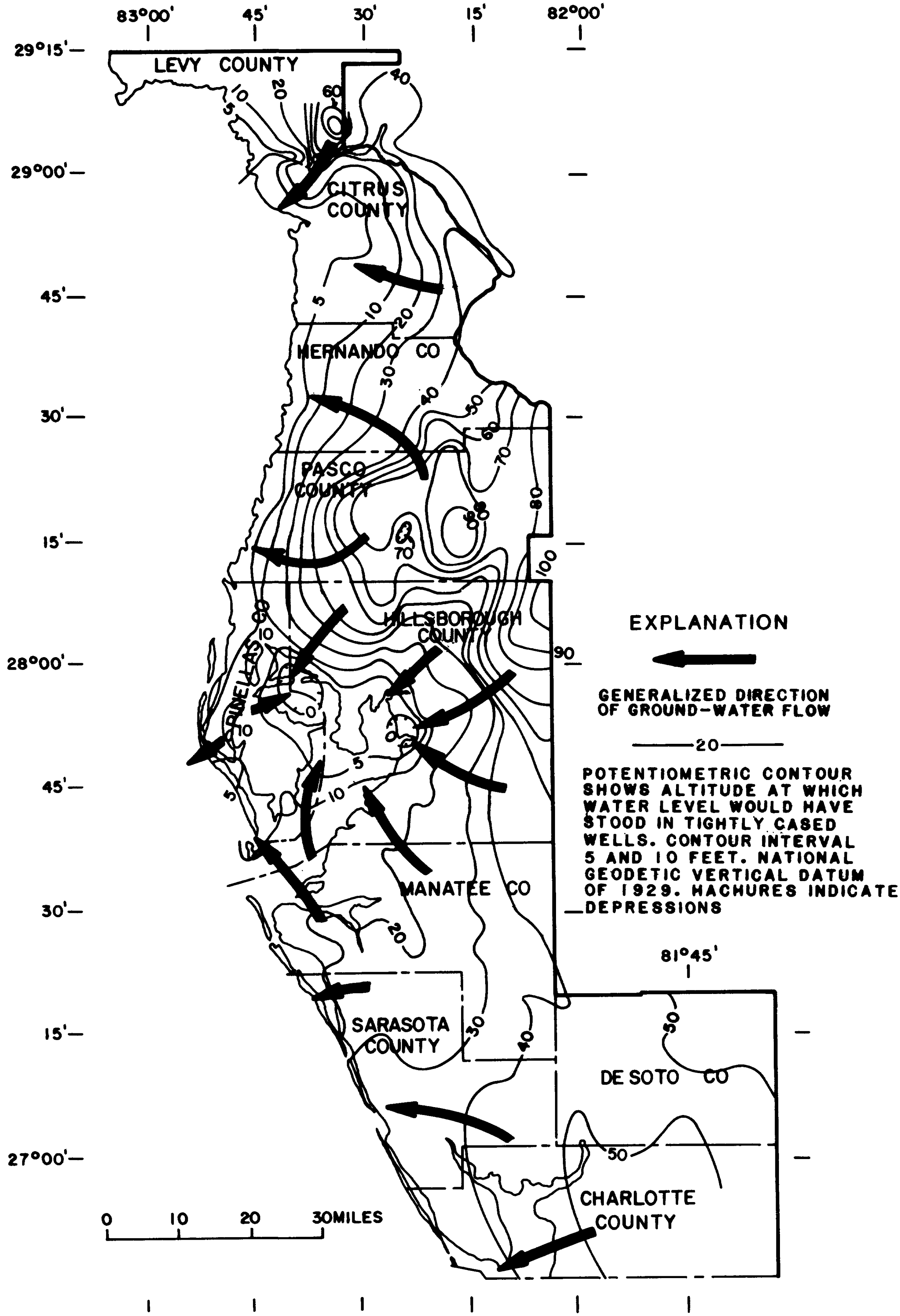

Figure 4.--Potentiometric surface of the Floridan aquifer, September 1979 (from Yobbi, Woodham, and Laughlin, 1980).

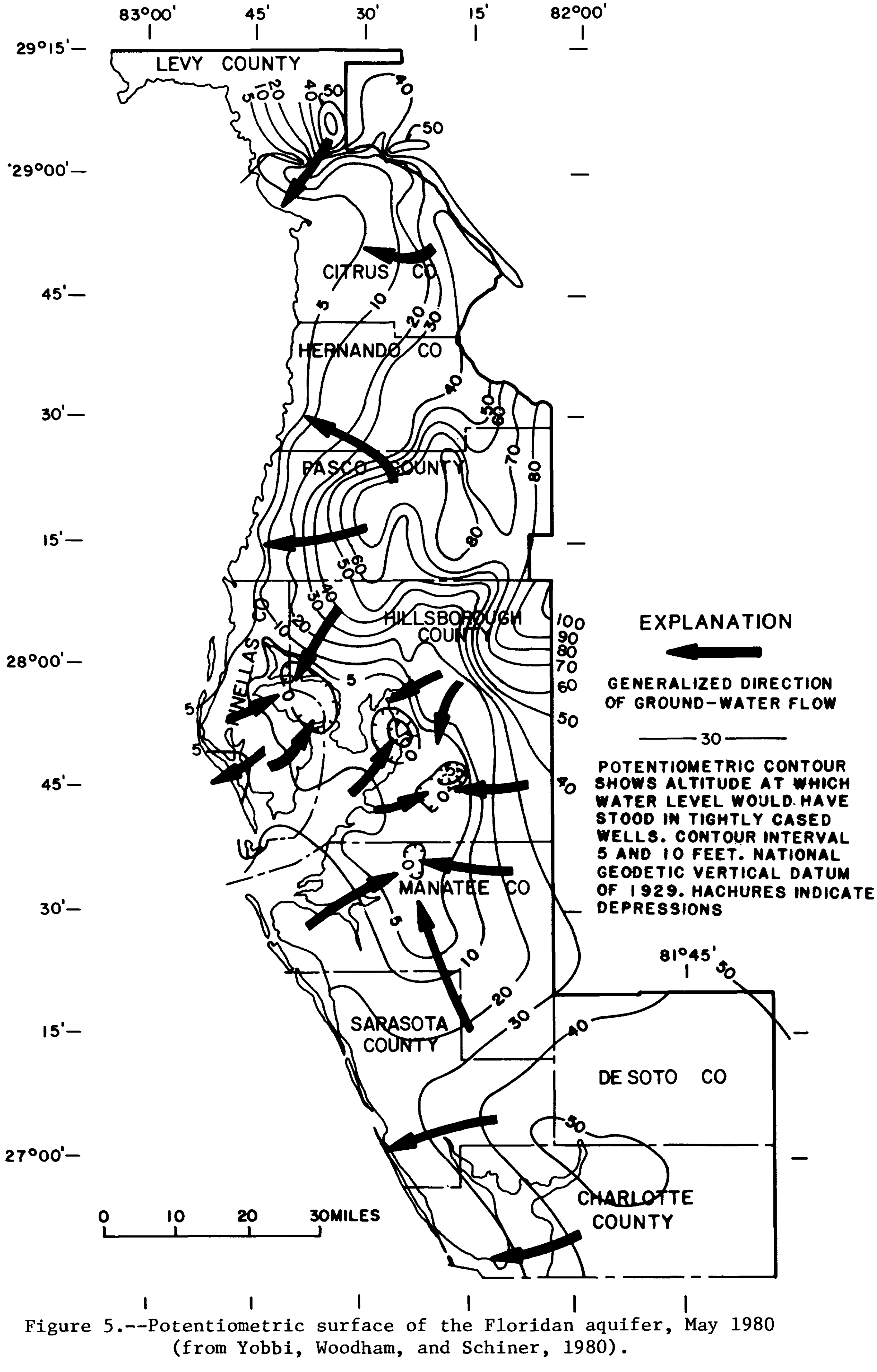

Figure 5.--Potentiometric surface of the Floridan aquifer, May 1980 (from Yobbi, Woodham, and Schiner, 1980).

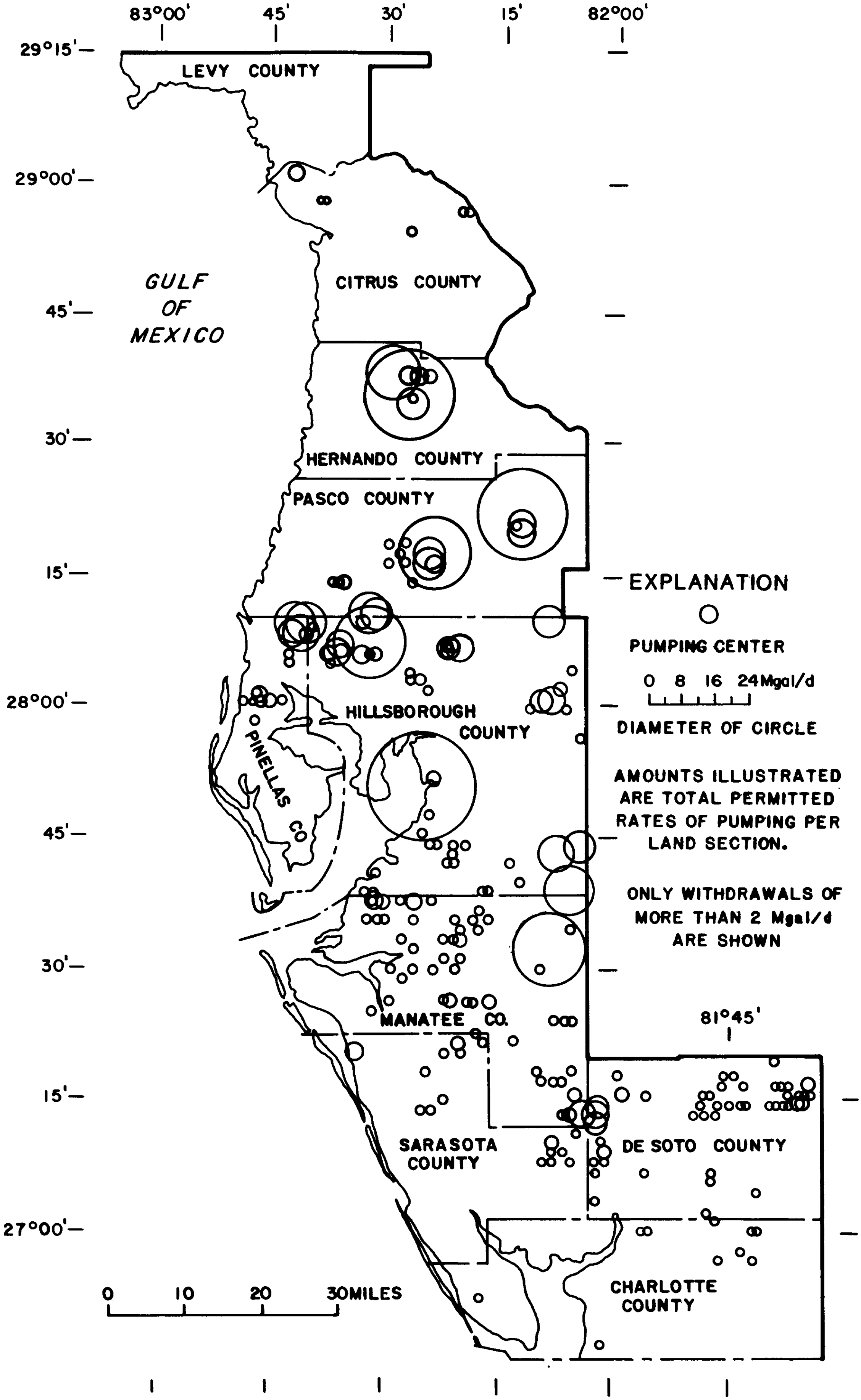

Figure 6.--Permitted withdrawals of ground water in southwest Florida.

Saltwater is separated from freshwater in the Floridan aquifer by a zone of mixing, within which chloride concentrations generally increase with depth. Cross sections of the mixing zone for 11 locations along the coast (figs. 7-13) indicate that the general shape and thickness of the zone varies along the coast. These variations are attributed to differences in aquifer characteristics and data irregularities. Lines of equal chloride concentration for the sections were determined on the basis of data collected from wells located within 1 mile of each section. Analyses of chloride concentrations are generally from the period 1954 to 1979 and are from the files and publications of the U.S. Geological Survey.

Chloride concentrations in the coastal margin of Citrus, Hernando, and Pasco Counties are shown in figures 8 and 9. Saltwater generally occurs at relatively shallow depths near the coast in Citrus and Pasco Counties and probably persists in the lower part of the aquifer for several miles inland. In Hernando County (fig. 8, section B-B'), the zone of mixing extends more than 3 miles inland in the upper part of the Floridan aquifer. Section C-C' (fig. 9) in Pasco County indicates that saltwater occurs in the upper part of the aquifer for more than 4 miles inland. Freshwater occurs as a thin layer near the coast with a very gradual thickening of the layer inland. The mixed freshwater and saltwater zone in Citrus and Pasco Counties occurs in the upper part of the aquifer for several miles inland from the coast and is about as thick as the freshwater layer. Chloride concentrations gradually change vertically and laterally within this mixed zone, indicating a high degree of mixing between freshwater and saltwater. The extent of the mixed zone and saltwater inland in Citrus, Hernando, and Pasco Counties is not known.

Figure 10 shows chloride concentrations in the coastal margin of Pinellas and Hillsborough Counties. Sections E-E' and F-F' show that saltwater occurs at shallow depths near the coast and probably persists inland in the lower part of the aquifer. Uncertainty about the shape of the mixed zone in section F-F' is indicated by the apparently anomalous values of 23 and 13,000 mg/L approximately 7 and 5 miles from the coast, respectively. In both sections, the zone of mixed freshwater and saltwater is relatively thick and persists inland in the lower part of the aquifer more than 9 miles from the coast.

Figure 11 shows chloride concentrations in the coastal margin of central Hillsborough County where saltwater appears to be absent from the Floridan aquifer near the coast. Freshwater occurs close to the coast and thickens rapidly inland, occupying the upper and lower parts of the aquifer to within 2 to 3 miles from the coast. The mixed zone of freshwater and saltwater occurs in the aquifer near the coast and appears to extend only a few miles inland in the lower part.

Figures 12 through 13 show chloride concentrations in the coastal margin of Manatee and Sarasota Counties, respectively. Mixed freshwater and saltwater predominate in the upper part of the aquifer in these counties. The only occurrence of freshwater is more than 6 miles inland in northern Manatee County (section H-H'). Chloride concentrations in water from the lower part of the Floridan aquifer in the coastal margin of Manatee and Sarasota Counties are unknown.

CHLORIDE-CONCENTRATION CHANGES IN THE COASTAL MARGIN

Chloride concentrations in water from wells open to the Floridan aquifer have been monitored for many years at some locations in the coastal margin of the Southwest Florida Water Management District. Chloride concentrations versus time for 11 of these wells are shown in figure 14.

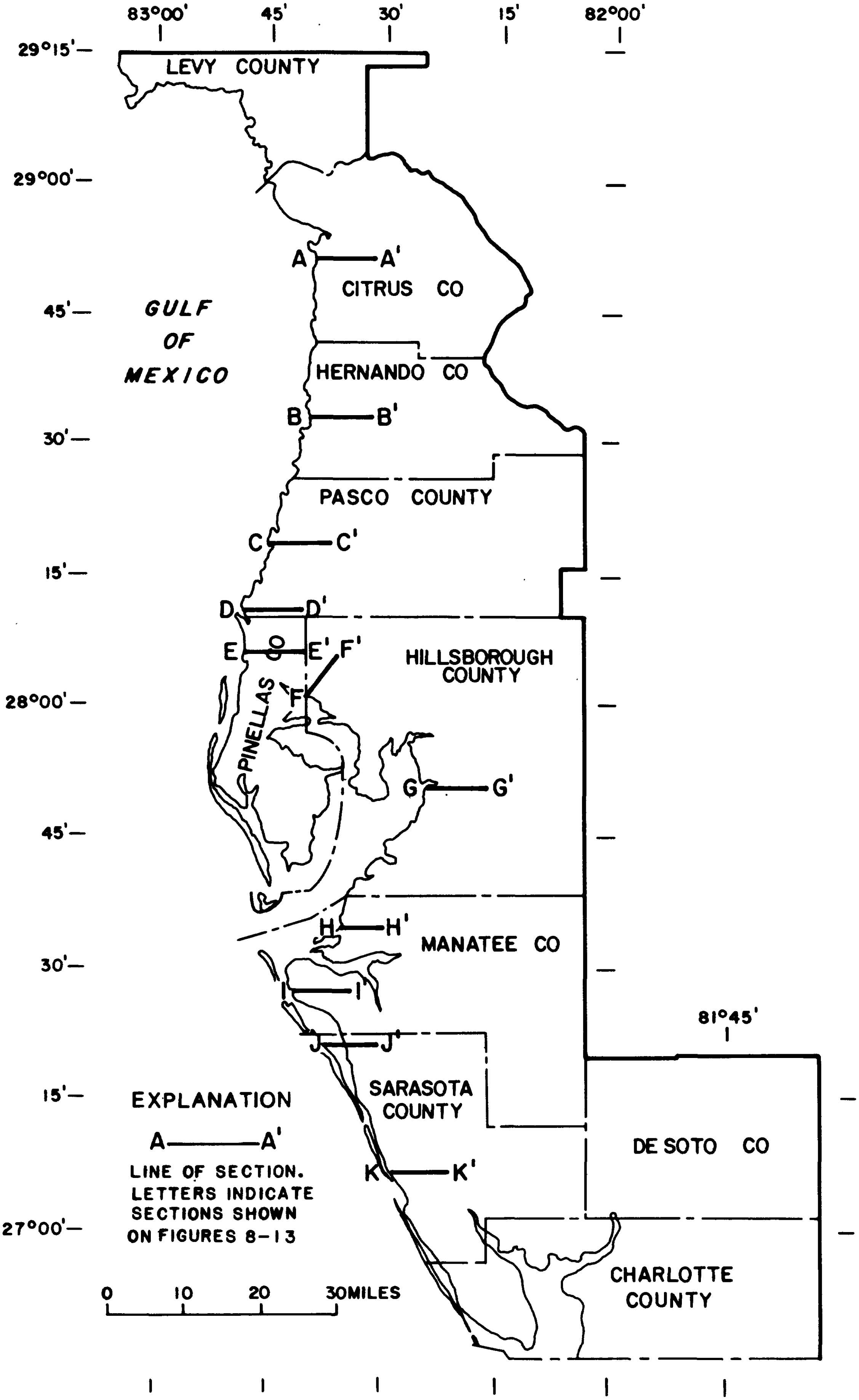

Figure 7.--Locations of lines of sections where chloride concentrations are defined.

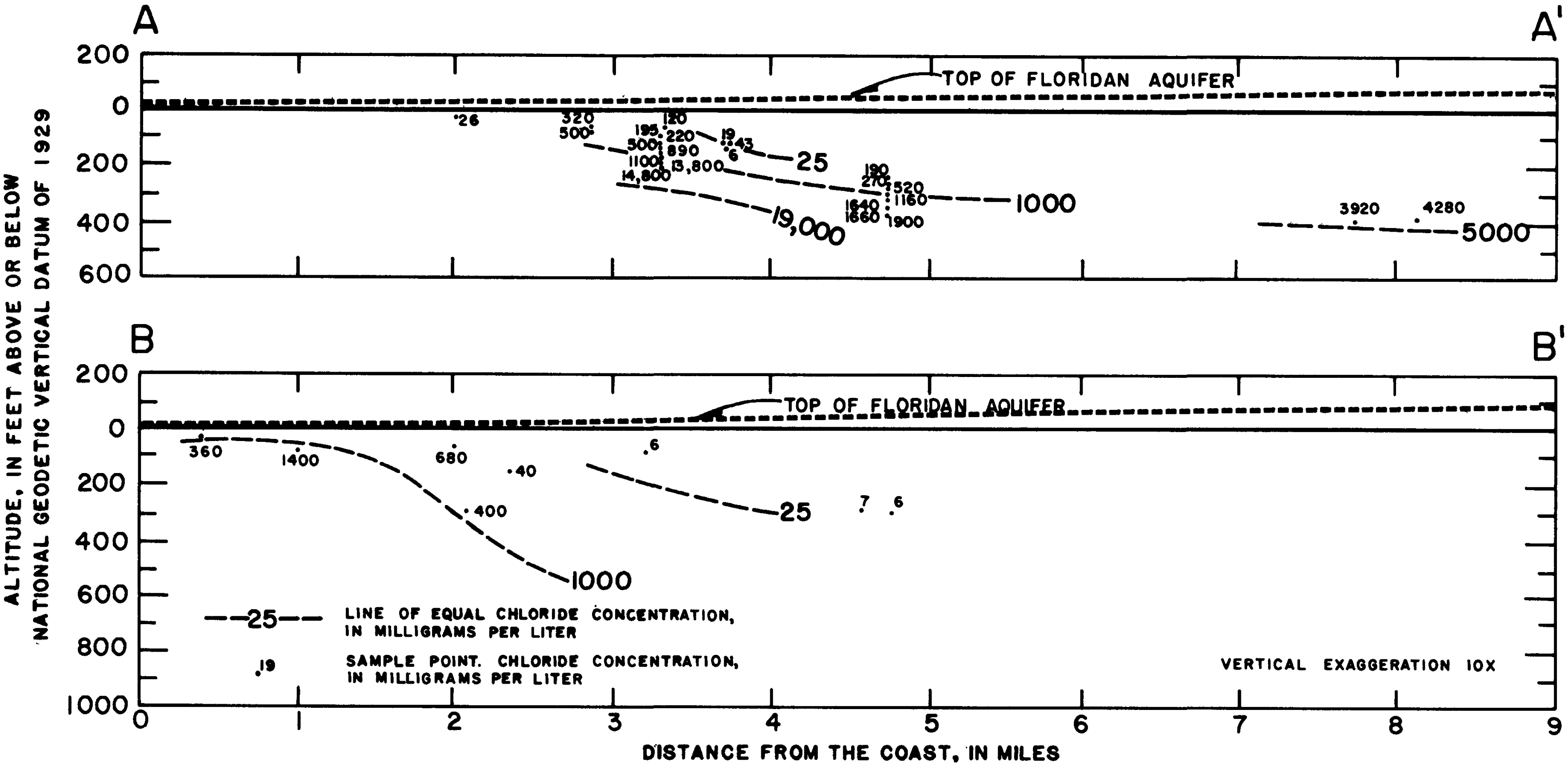

Figure 8.--Sections through Floridan aquifer showing chloride concentrations in the coastal margin of Citrus and Hernando Counties. (See figure 7 for locations of sections.)

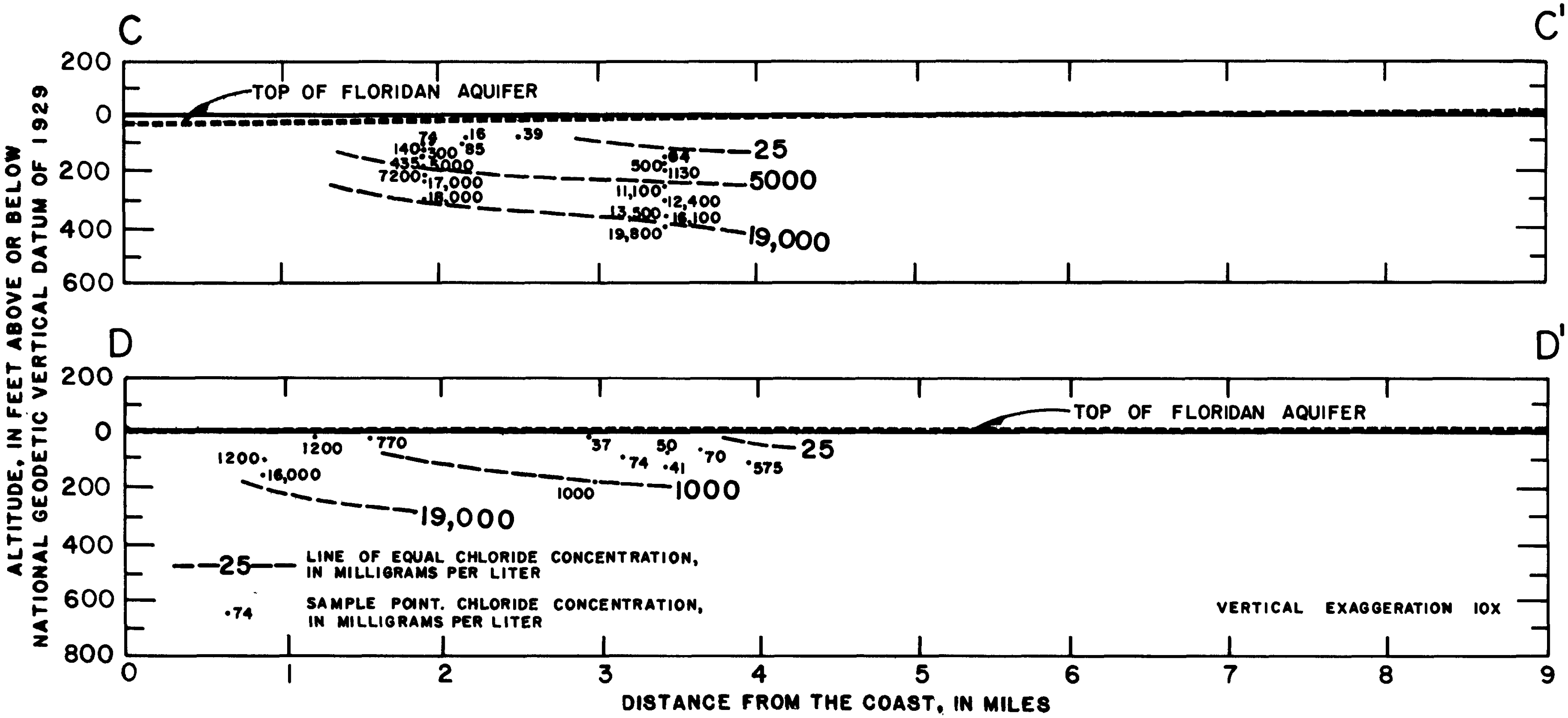

Figure 9.--Sections through Floridan aquifer showing chloride concentrations in the coastal margin of Pasco County. (See figure 7 for locations of sections.)

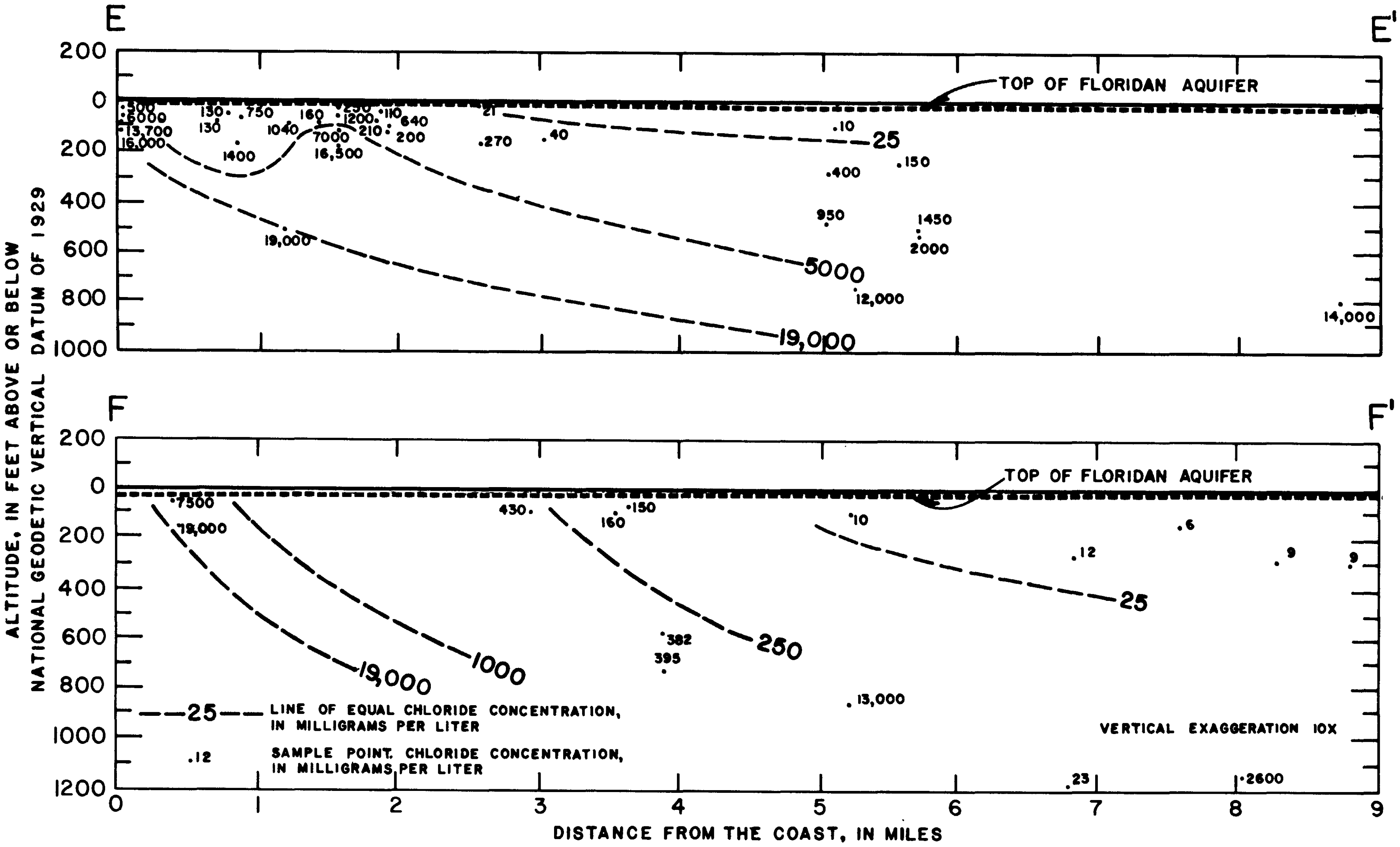

Figure 10.--Sections through Floridan aquifer showing chloride concentrations in the coastal margin of Pinellas and Hillsborough Counties. (See figure 7 for locations of sections.)

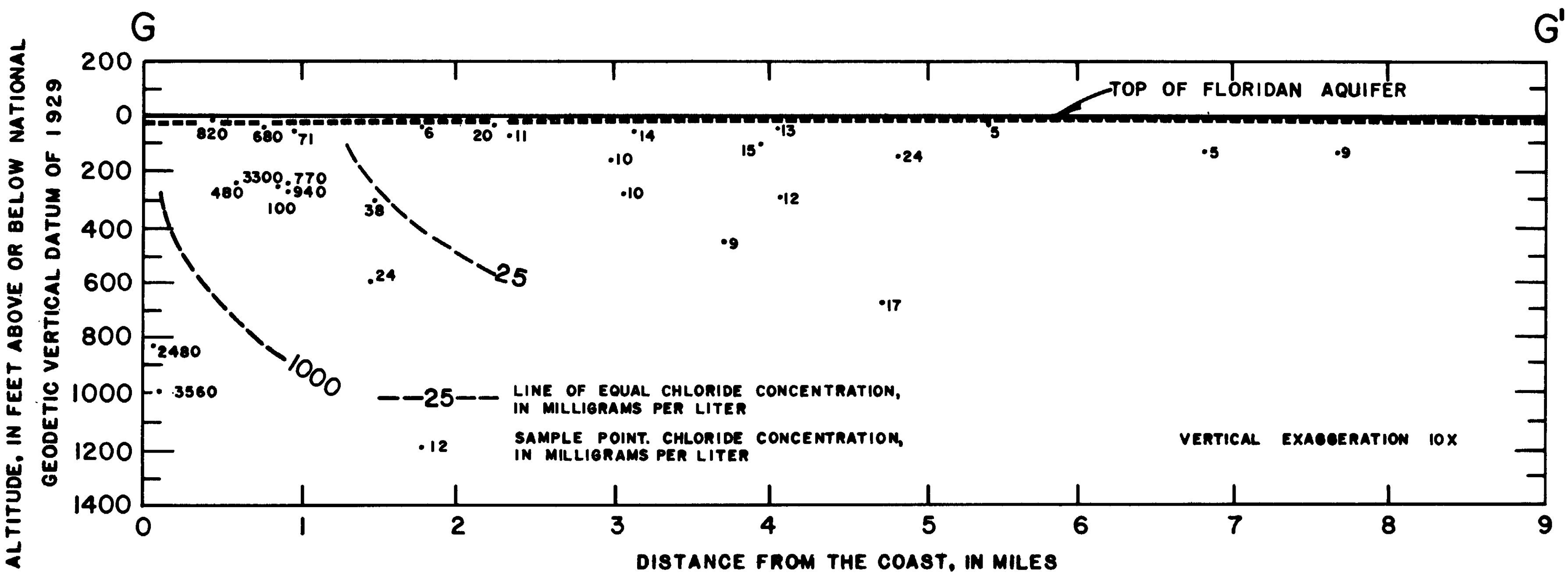

Figure 11.--Section through Floridan aquifer showing chloride concentrations in the coastal margin of central Hillsborough County. (See figure 7 for location of section.)

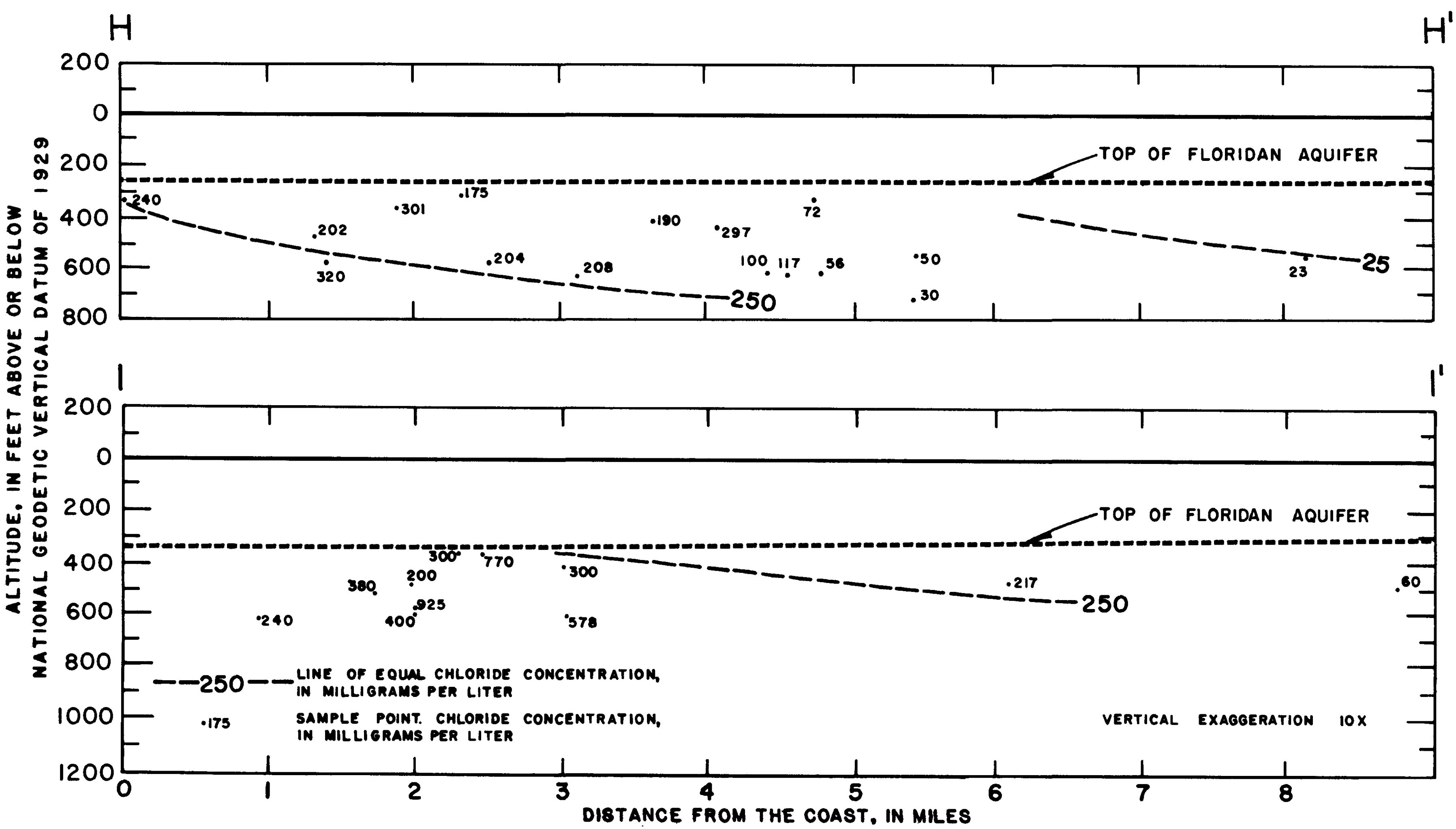

Figure 12.--Sections through Floridan aquifer showing chloride concentrations in the coastal margin of Manatee County. (See figure 7 for locations of sections.)

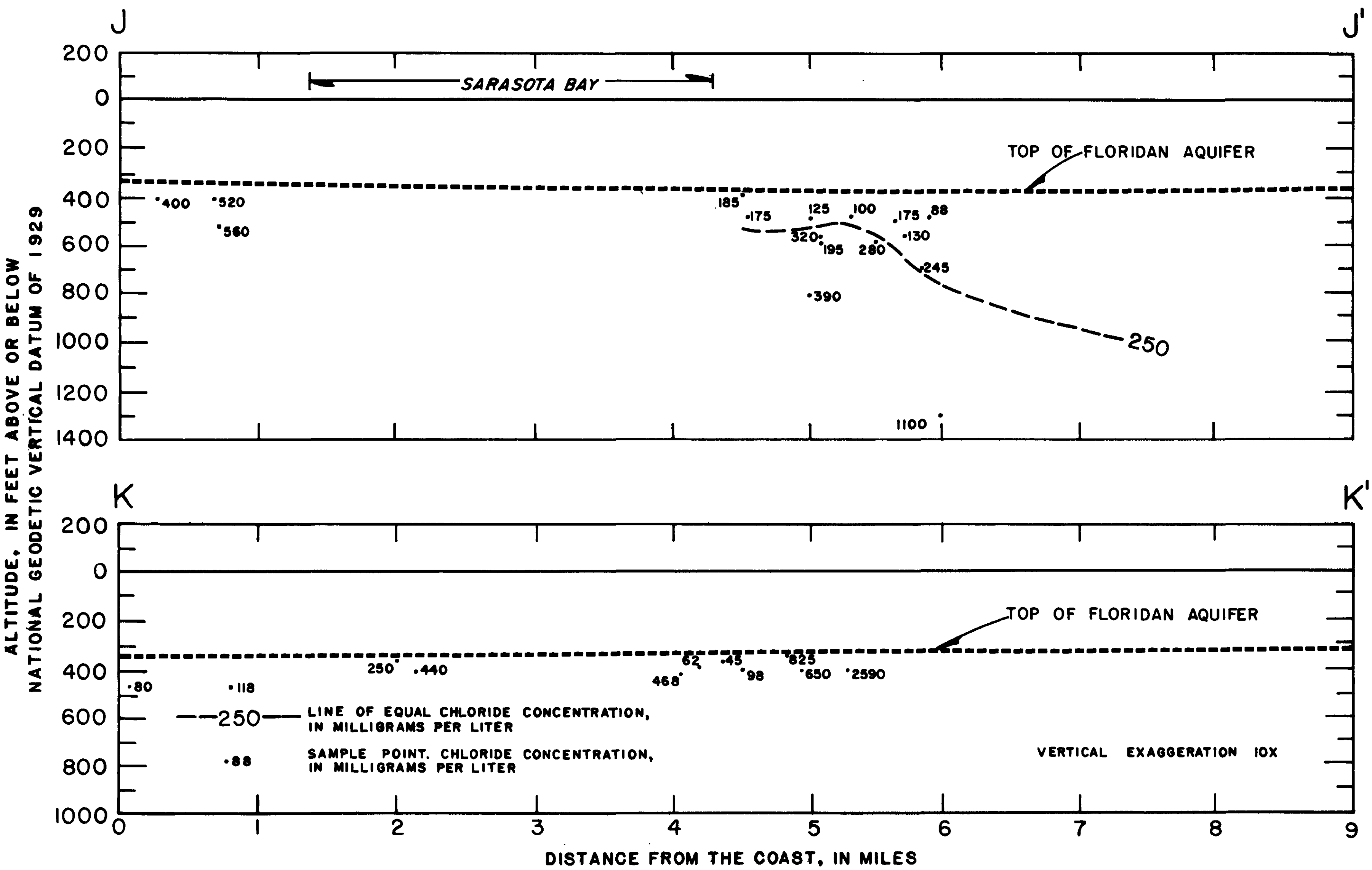

Figure 13.--Sections through Floridan aquifer showing chloride concentrations in the coastal margin of Sarasota County. (See figure 7 for locations of sections.)

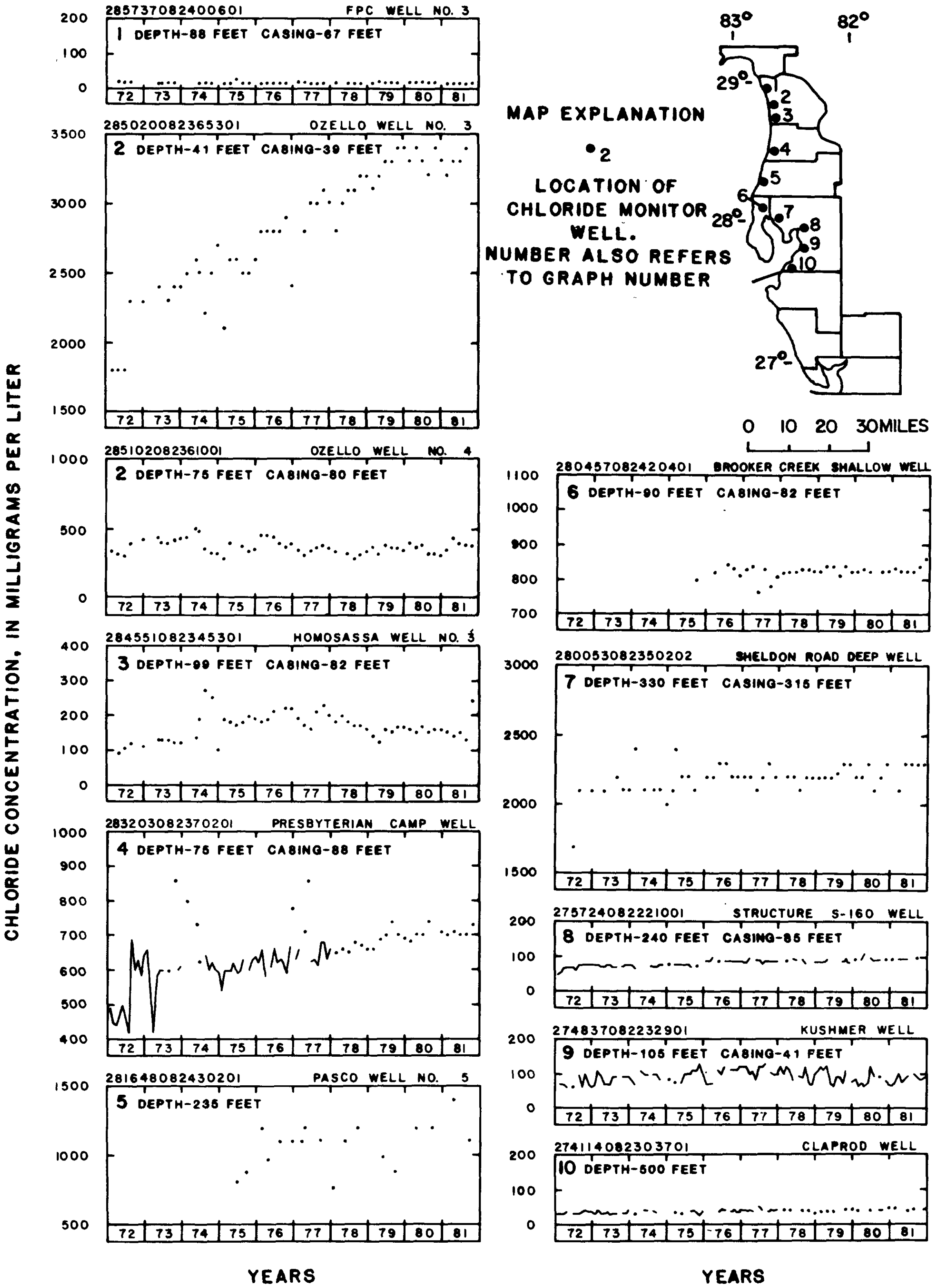

Figure 14.--Chloride concentrations in water from wells open to the Floridan aquifer in coastal southwest Florida.

In Citrus County, chloride concentrations are increasing near the surface (Ozello well No. 3) but are not increasing in wells fully penetrating the upper part of the aquifer (FPC well No. 3, Ozello well No. 4, and Homosassa well No. 3). At the Ozello well No. 4, concentrations are higher during the dry season but no long-range changes are apparent.

In Hernando County, chloride concentrations are increasing at a very slow rate in water from the Presbyterian Youth Camp well near Weeki Wachee. At this site, concentrations increased from about 600 mg/L in 1972 to 700 mg/L in 1981.

Chloride concentrations are increasing in some areas of Pasco County and decreasing in other areas. At coastal Pasco well No. 5, located near the middle of the county's coastline, concentrations increased about 20 mg/L per year from 1975 to 1981.

In northern Pinellas County and northwest Hillsborough County, chloride concentrations are not changing rapidly, as indicated by data from the Brooker Creek and Sheldon Road wells. The Sheldon Road deep well remained relatively constant from 1972 to 1981. The Sheldon Road well lies in an area where the freshwater aquifer is less than 300 feet thick and ground-water withdrawals are small.

In central Hillsborough County, chloride concentrations in water from well S-160 increased very gradually between 1972 and 1981. In southern Hillsborough County, changes in chloride concentrations are indicated by samples from the Kushmer and Claprod wells. In water from the Kushmer well, concentrations show a gradual increase between 1969 and 1977 and a gradual decrease thereafter. In water from the Claprod well, concentrations were virtually unchanged between 1972 and 1981.

PROPOSED SITES TO MONITOR CHLORIDE CONCENTRATIONS

Fifty-four monitor sites consisting of 70 wells are proposed in the coastal margin from Levy County in the north to Charlotte County in the south (figs. 15-18). Sixteen of the proposed sites have two wells, one open to the upper part and one open to the lower part of the Floridan aquifer in areas of increasing chloride concentrations and in areas where large withdrawals are presently occurring or are predicted to occur. Wells at the remaining proposed sites would be open to the upper part of the aquifer because of the need for improving knowledge of chloride-concentration distribution in the coastal margin and to monitor long-term changes in chloride concentrations.

The proposed well sites, locations, nearby existing potential monitor wells, and selection criteria are listed in table 2. Locations of the suggested well sites are given by section, township, and range. Where practical, sites were selected in proximity to existing wells that are periodically measured or sampled by the U.S. Geological Survey. More precise well locations will need to be determined by field reconnaissance of chloride concentrations in the upper part of the Floridan aquifer.

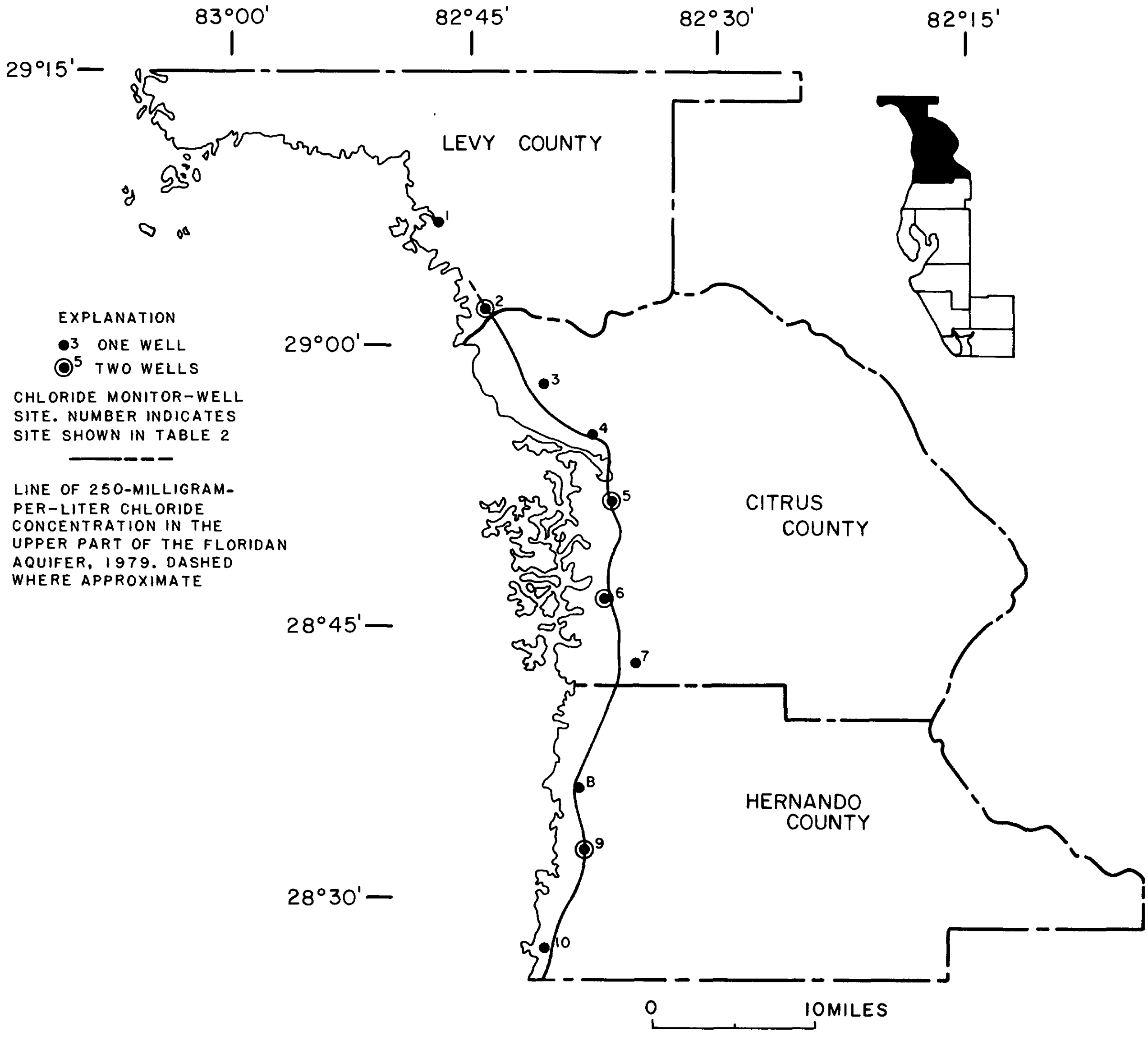

Figure 15.--Proposed locations for chloride-concentration monitor wells open to the Floridan aquifer in the coastal margin of Levy, Citrus, and Hernando Counties.

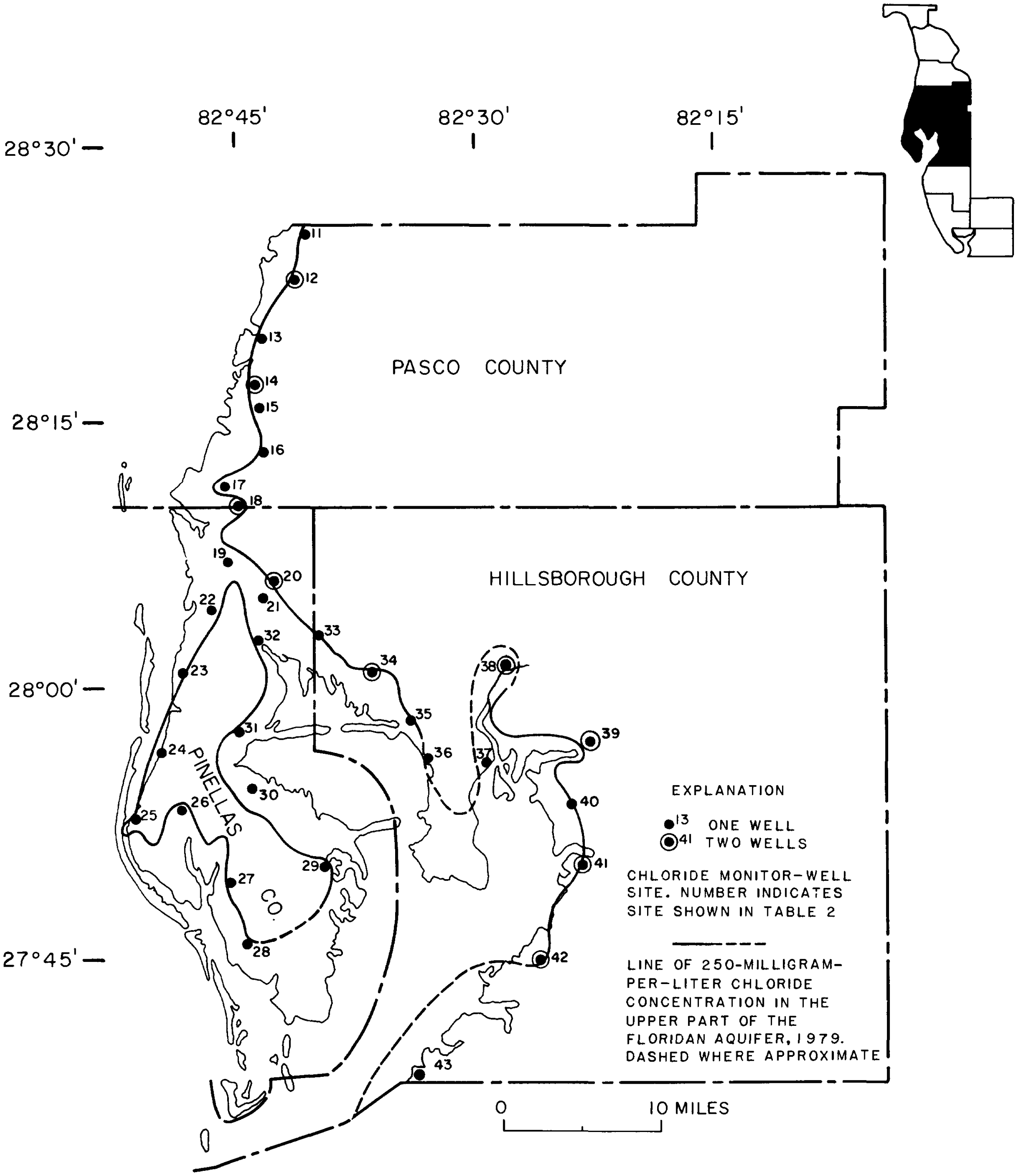

Figure 16.--Proposed locations for chloride-concentration monitor wells open to the Floridan aquifer in the coastal margin of Pasco, Pinellas, and Hillsborough Counties.

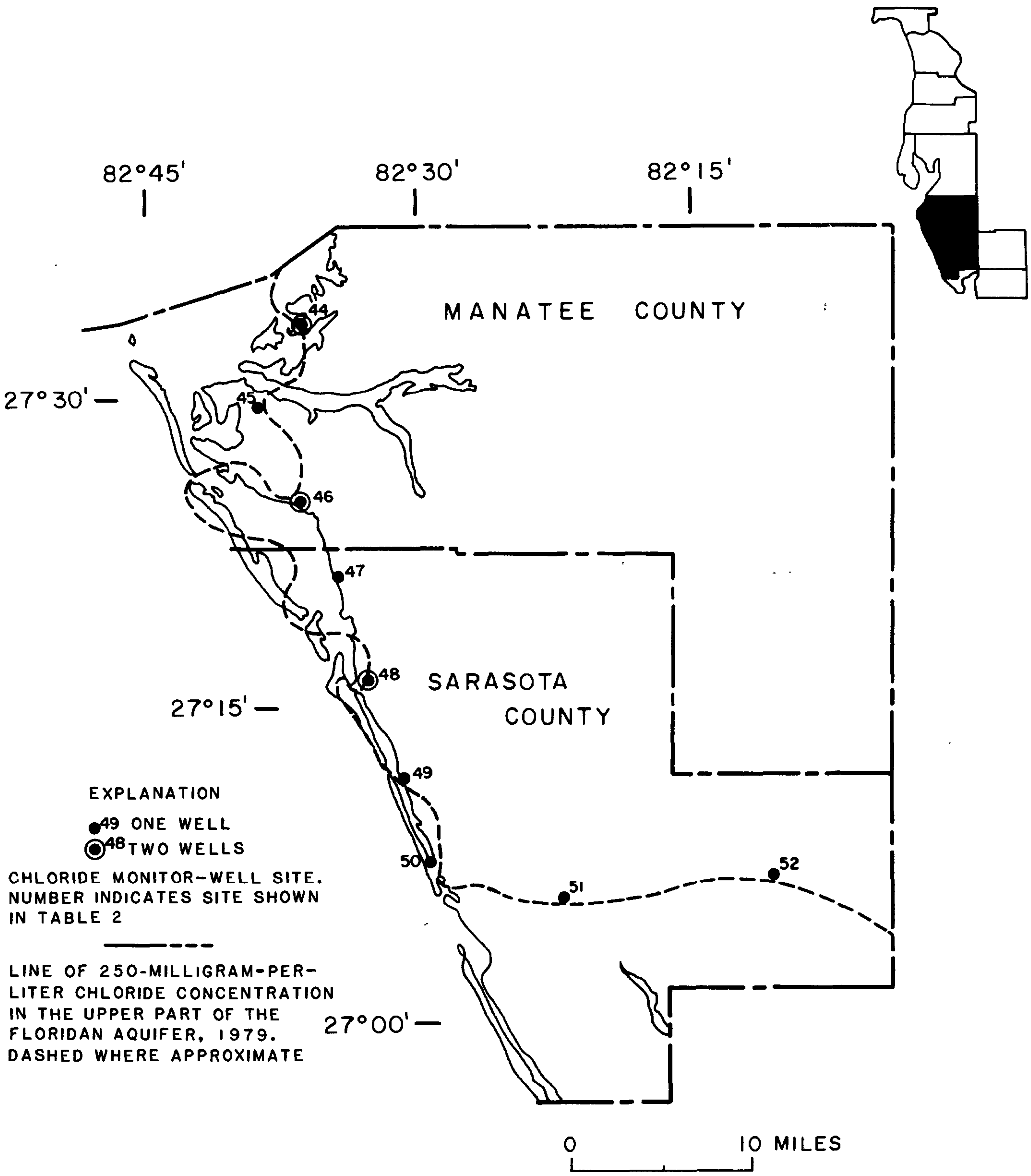

Figure 17.--Proposed locations for chloride-concentration monitor wells open to the Floridan aquifer in the coastal margin of Manatee and Sarasota Counties.

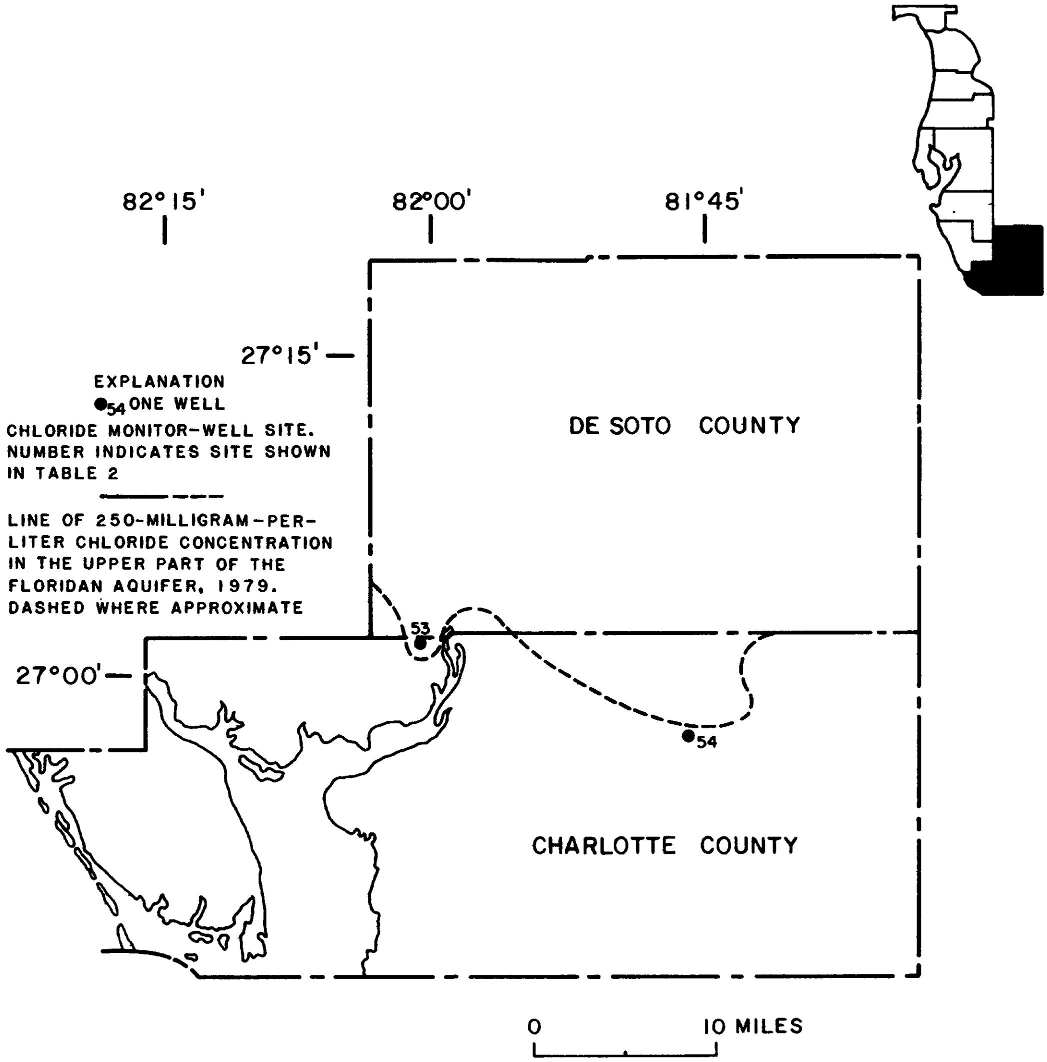

Figure 18.--Proposed locations for chloride-concentration monitor wells open to the Floridan aquifer in the coastal margin of Charlotte County.

Table 2.--Proposed chloride-concentration monitor-well sites open to the Floridan aquifer in coastal southwest Florida

Site	Location			Number of wells	Selection criteria	Identification No. of existing well
	Section	Township	Range			
1	10	16	15	1	Areal monitor	
2	6	17	16	2	Potential withdrawal	ROMP 124
3	34	17	16	1	Areal monitor	285737082400601
4	8	18	17	1	Areal monitor	
5	4	19	17	2	Increasing chlorides	ROMP 21-2
6	3	20	17	2	Increasing chlorides	284551082345301
7	26	20	17	1	Areal monitor	ROMP 20-1
8	5	22	17	1	Areal monitor	283555082572901
9	29	22	17	2	Increasing chlorides	ROMP 19-2
10	25	23	16	1	Areal monitor	ROMP 18-2
11	1	24	16	1	Areal monitor	
12	23	24	16	2	Increasing chlorides	
13	9	25	16	1	Areal monitor	ROMP 17-1
14	28	25	16	2	Increasing chlorides	281648082430201
15	33	25	16	1	Areal monitor	
16	16	26	16	1	Areal monitor	ROMP 16-2
17	30	26	16	1	Areal monitor	
18	32	26	16	2	Increasing chlorides	
19	18	27	16	1	Areal monitor	ROMP 15-3
20	22	27	16	2	Withdrawal area	280611082412101
21	33	27	16	1	Areal monitor	280457082420402
22	1	28	15	1	Areal monitor	
23	26	28	15	1	Areal monitor	ROMP 14-2
24	21	29	15	1	Areal monitor	
25	7	30	15	1	Waste-injection site	
26	3	30	15	1	Areal monitor	
27	31	30	16	1	Waste-injection site	
28	21	31	16	1	Waste-injection site	
29	30	30	17	1	Waste-injection site	
30	32	29	16	1	Areal monitor	
31	17	29	16	1	Areal monitor	
32	16	28	16	1	Areal monitor	ROMP 13-3
33	18	28	17	1	Areal monitor	
34	27	28	17	2	Withdrawal area	280053082350202
35	7	28	18	1	Areal monitor	ROMP 12-1
36	20	29	18	1	Areal monitor	
37	26	29	18	1	Areal monitor	
38	24	28	18	2	Withdrawal area	
39	14	29	19	2	Increasing chlorides	ROMP 11-2
40	3	30	19	1	Areal monitor	ROMP 10-2

Table 2.--Proposed chloride-concentration monitor-well sites open to the Floridan aquifer in coastal southwest Florida--Continued

Site	Location			Number of wells	Selection criteria	Identification No. of existing well
	Section	Township	Range			
41	25	30	19	2	Withdrawal area	
42	23	31	19	2	Withdrawal area	ROMP 9-3
43	32	32	18	1	Areal monitor	
44	34	33	17	2	Potential withdrawal	ROMP 8-2
45	29	34	17	1	Areal monitor	
46	22	35	17	2	Increasing chlorides	ROMP 7-1
47	12	36	17	1	Areal monitor	
48	7	37	18	2	Potential withdrawal	ROMP 6-2
49	3	38	18	1	Areal monitor	271118082285301
50	35	38	18	1	Areal monitor	ROMP 5-1
51	7	39	20	1	Areal monitor	
52	36	38	21	1	Areal monitor	
53	4	40	23	1	Areal monitor	ROMP 10
54	36	40	25	1	Areal monitor	

Proposed monitor-well depths can only be suggested by using broad guidelines. Exact depths have to be determined using borehole data for each site. Hickey (1982a) summarizes borehole data-collection methods that can be used during well construction. Monitor wells at all proposed sites would need to be constructed to such depths that they will be open to the mixed freshwater and saltwater zone in the Floridan aquifer. Locations of the proposed monitor wells inland from the Gulf of Mexico were based on the 1979 position of the 250-mg/L-chloride-concentration line defined by Causseaux and Fretwell (1982).

Wells proposed to monitor the upper part of the aquifer north of Tampa Bay (figs. 15 and 16) would be open to the mixed zone in a principal water-producing interval in the upper 200 feet of the aquifer. South of Tampa Bay (figs. 16-18), wells would be open to the mixed zone in a principal water-producing interval in the upper 300 to 400 feet of the aquifer. Judgments about depth of well penetration into the upper part of the Floridan aquifer can be guided by the map showing the configuration of the top of the aquifer (fig. 2).

Wells proposed to monitor the lower part of the aquifer (where two wells are indicated in table 2) would be open to the mixed zone within a principal water-producing interval in the upper 300 to 400 feet of the dolomitized sequence in the lower part of the Floridan aquifer. The deeper well is needed to detect movement of the mixed zone induced by withdrawal from the dolomite zone, a principal producing interval throughout most of the study area. These changes may not be detected in the upper zone. Judgments about the depth of well penetration into the lower part of the Floridan aquifer can be guided by the map of Wolansky and others (1980), which shows the top of the dolomitized sequence.

Previously constructed wells in the vicinity of proposed monitor sites in the coastal margin (table 2) can be considered for inclusion in the network. These wells are periodically sampled to determine water-quality characteristics of the Floridan aquifer and water levels are measured to determine fluctuations in the potentiometric surface of the aquifer. Results of monitoring are published annually in the report "Water Resources Data for Florida" by the U.S. Geological Survey. Water-quality analyses and ground-water measurements have been published in the series since 1975. Existing wells generally are not in the best locations or at the depths most desirable for monitor wells, but they can serve as interim monitors until their suitability as permanent monitors can be determined. If careful sampling techniques are used, these wells may be adequate to meet network objectives.

To obtain maximum benefit from monitor wells, whether existing or newly drilled, geologic, geophysical, and hydraulic information is needed for each well. At sites where tidal fluctuations are a possibility, wells should be monitored continuously for water-level and specific-conductance changes for a period of at least one tide cycle. Borehole data methods that can be used to gather this information are presented by Hickey (1982a).

After borehole data have been collected at each well and the appropriate open-hole interval of the well has been determined, the well would be completed and water-quality sampling started. At all monitor wells, samples would be collected bimonthly, at a minimum, until the seasonal fluctuation and rate of long-term changes are determined; thereafter, frequency may be reduced to quarterly or semiannually.

SUMMARY AND CONCLUSIONS

The Floridan aquifer, the principal source of water in southwest Florida, contains saltwater in the coastal margin. The freshwater boundary of the mixed freshwater-saltwater zone is probably moving inland in some areas because of increasing ground-water withdrawals along the coast. This inland movement poses a threat to freshwater resources and requires regulated rates of withdrawals in the coastal margin to diminish the adverse impact on the availability of freshwater. Areas most subject to inland movement of saltwater lie immediately inland from the coast in the vicinity of centers of large ground-water withdrawals.

The potentiometric surface of the Floridan aquifer is seasonally low in the spring when pumpage for agriculture is greatest. These low-water conditions reduce freshwater flow to coastal areas and can allow an increase in inland movement of mixed water.

As defined in this report, freshwater has a chloride concentration of 25 mg/L or less and saltwater has a chloride concentration of 19,000 mg/L or more. Saltwater is present in the upper part of the Floridan aquifer in the coastal margin of all of the counties north of the Tampa Bay area. Freshwater is absent in the upper part of the aquifer in the coastal margin of central Hillsborough County and in Manatee and Sarasota Counties. Freshwater is present in the coastal margin of Citrus, Hernando, Pasco, Pinellas, and northern Hillsborough Counties. A mixture of freshwater and saltwater is present in all coastal margins. The mixed zones become thicker and wider southward from Citrus County to Sarasota County.

A gradual lateral variation in chloride concentrations characterizes all the mixed zones along the coast, indicating a high degree of mixing between freshwater and saltwater, especially in the southern counties. Chloride concentrations vary with time throughout the study area, increasing with time in some areas and decreasing in others.

A total of 70 monitor wells are proposed at 54 sites. Sixteen of the sites are proposed to have two wells in areas of increasing chloride concentrations and in areas where large ground-water withdrawals are present or predicted. The remaining wells would be used to improve understanding of chloride-concentration distribution in the coastal margins where current data are lacking.

Many of the proposed sites are near existing chloride monitor wells or other wells that could be included in the monitor program. Geologic, hydraulic, and geophysical data on the wells would aid in determining well depths and designing the water-quality sampling program.

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