GROUND-WATER HYDROLOGY OF VOLUSIA COUNTY, FLORIDA, WITH EMPHASIS ON OCCURRENCE AND MOVEMENT OF BRACKISH WATER

By A. T. Rutledge

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than U.S. inch-pound units, the conversion factors for the terms used in this report are listed below:

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 foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
gallon per minute (gal/min)	0.003785	cubic meter per minute (m^3/min)
million gallons per day (Mgal/d)	0.0438	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)

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ABSTRACT

Volusia County is a 1,200-square-mile area in east-central Florida which includes the communities of Daytona Beach, Ormond Beach, New Smyrna Beach, De Land, and Deltona. The area is oriented toward tourism, especially along the coast.

The two aquifers underlying the area are the unconfined surficial aquifer and the confined Floridan aquifer system. The surficial aquifer consists of sand, clay, and shell beds of Pleistocene and Holocene age, and the Floridan aquifer system consists of limestone and dolomite of Eocene age. The two aquifers are separated by confining clay beds of Miocene or Pliocene age. Both aquifers contain good quality water in most of Volusia County, but brackish water is present in the eastern and western fringes of the county in the surficial aquifer and in the upper zones of the Floridan aquifer system presently tapped by wells. Saltwater is present throughout the county in the relatively untapped lower zones of the Floridan aquifer system. Development in the fringes has caused movement of the brackish water. There is a need for an understanding of this movement so that future problems can be avoided.

Average ground-water withdrawal in 1980 in Volusia County was 66 million gallons per day, of which 30 was for public supply, 24 was for agricultural irrigation, and 12 was for other uses. Ground-water use quadrupled between 1955 and 1980. More than 95 percent of the ground water pumped is from the Floridan aquifer system.

Water levels in Floridan aquifer system wells declined more than 10 feet over an area of 70 square miles from 1955 to 1982. This drawdown, which occurred in the area of Ormond Beach, Daytona Beach, and Port Orange, was caused by pumping.

The annual water budget of the surficial layer consists of 53 inches rainfall, 1 inch upward leakage from the Floridan aquifer system, 0.5 inch recharge from Floridan aquifer system withdrawals, and 0.5 inch stream inflow, counterbalanced with 39 inches evapotranspiration, 11 inches stream outflow, and 5 inches downward leakage to the Floridan aquifer system.

The annual water budget of the Floridan aquifer system consists of 5 inches downward leakage inflow, 1 inch upward leakage outflow, 1 inch horizontal inflow, 1.5 inches horizontal outflow, 2.5 inches discharge from springs and flowing wells, and 1 inch pumpage.

Brackish water movement, or intrusion, apparently is occurring in the surficial aquifer on the barrier island in the northeast part of the study area. Intrusion is probably occurring in other sections of the barrier island, but there is no evidence that it is occurring in inland areas. Future intrusion is likely in the surficial aquifer on the barrier island as ground-water withdrawals increase.

There is little evidence that intrusion is occurring uniformly over large areas in the Floridan aquifer system. Most nonpublic supply wells have not exhibited long-term changes in salinity, although significant increases in chloride concentration in water from five nonpublic supply wells in the coastal area of Ormond Beach and Daytona Beach may be associated with ground-water withdrawals in northeast Volusia County. Vertical intrusion is occurring at sites of public supply pumping because these wells are usually deeper, are pumped a greater amount of the time, and are pumped at higher rates. Many of these wells in the eastern and western fringes of Volusia County have been abandoned and replaced by new wells closer to the central part of the county.

Water-management practices that may minimize future movement of brackish water in the Floridan aquifer system include minimizing well depths, minimizing drawdown, installing wells where the freshwater zone is thickest, increasing head in the freshwater zone by using injection wells, and reducing head in the saltwater zone. Drawdown can be reduced by increasing the number of supply wells per desired water-use rate. Minimizing well depth may be the single most effective step against intrusion.

INTRODUCTION

Background and Problems

Volusia County, in east-central Florida, is oriented toward tourism, especially along the coast. The 1,200-square-mile county is 15 miles north of Orlando and includes the coastal communities of Daytona Beach, Ormond Beach, and New Smyrna Beach in addition to the inland communities of De Land and Deltona (fig. 1). Rapid population growth has greatly increased demand on public-water supplies. The two aquifers that supply most of the water are the Floridan aquifer system, a limestone aquifer under artesian conditions in Volusia County, and the surficial aquifer, an unconfined sand aquifer. Although both contain good quality water in most of Volusia County, brackish water is present in the eastern and western fringes of the county in the surficial aquifer and in upper zones of the Floridan aquifer system presently tapped by wells. Saltwater is present throughout the county in lower zones of the Floridan aquifer system not presently tapped. Many of the fringe areas, especially to the east, are populated and are characterized by heavy pumping of ground water and the accompanying drawdown of water levels.

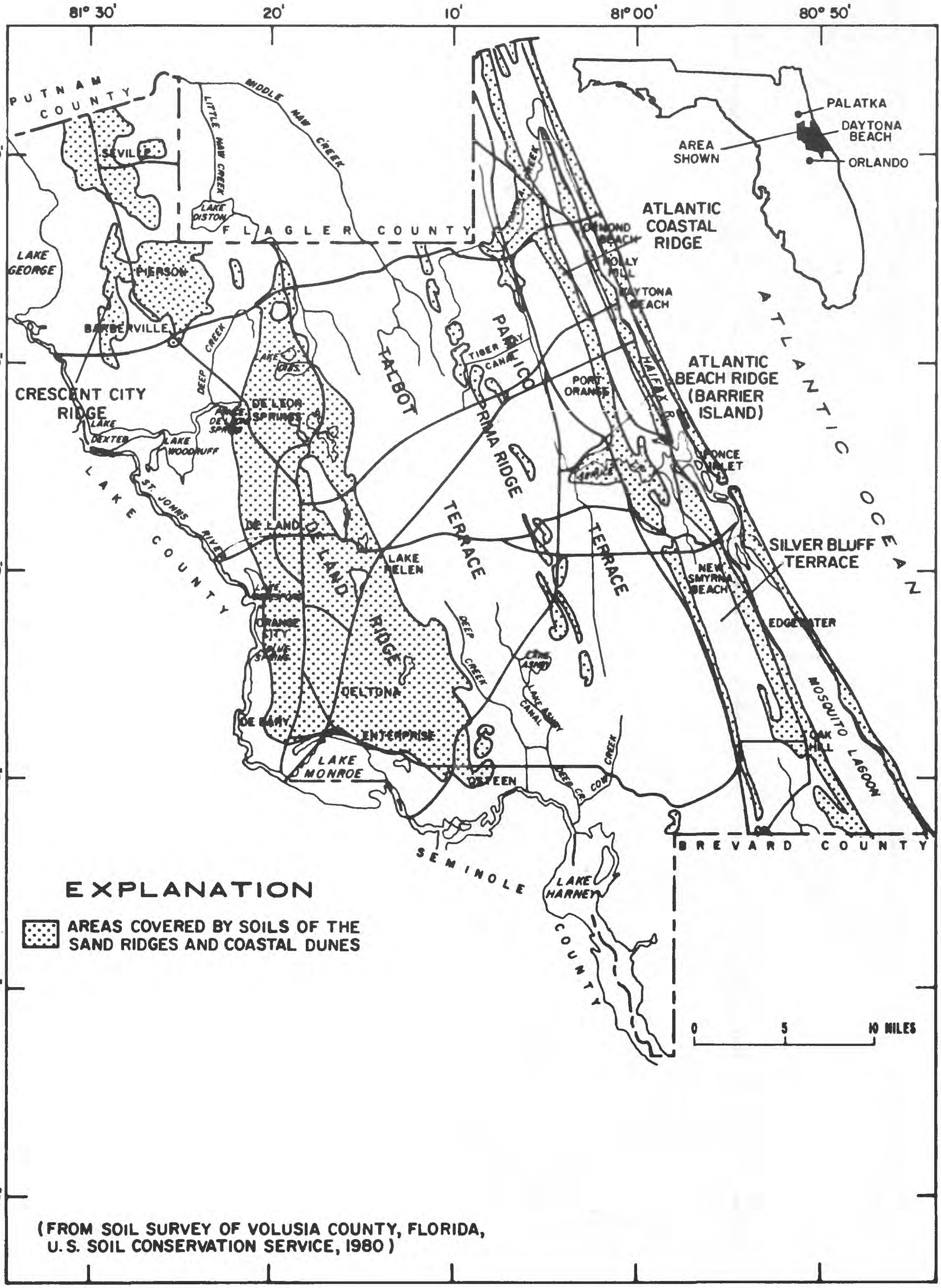

Figure 1.--Location of Volusia County and ridge areas and major physiographic features in Volusia County.

The extent of brackish water has apparently increased in recent years in both aquifers. There is a need to determine the extent, mechanism, and rate of movement of brackish water in the aquifers of Volusia County. Furthermore, there is a need to understand how further movement can be minimized.

Purposes and Scope

The study of brackish-water occurrence in Volusia County is one of many water-resources investigations that have been conducted by the U.S. Geological Survey in cooperation with Volusia County. The purposes of this study, which was conducted during 1980-82, were to:

1. Evaluate ground-water use, water-level trends, and the water budget for both aquifers;

2. Determine the occurrence of brackish water in the upper part of the Floridan aquifer system and in the surficial aquifer;

3. Differentiate between areas of naturally occurring brackish ground water and areas of recent intrusion;

4. Differentiate between areas of lateral and vertical brackish water intrusion and investigate the cause and extent of the intrusion; and

5. Describe the effects of alternative water-management actions that could minimize future saltwater intrusion.

This report is the full documentation of all results of the study. The information here includes the following: an assessment of ground-water withdrawals from both aquifers, a detailed description of water-level trends for the Floridan aquifer system, estimates of the water budgets of the surficial layer and the Floridan aquifer system, maps showing chloride concentration in both aquifers throughout the study area, an assessment of evidence of saltwater intrusion in surficial-aquifer wells and in nonpublic supply wells open to the Floridan aquifer system, a separate assessment of evidence of intrusion in public-supply wells open to the Floridan aquifer system, and descriptions of possible countermeasures against future intrusion.

The study encompassed the entire county, although emphasis was on data collection in the eastern and western fringes where brackish water is present in the upper Floridan aquifer system and in the surficial aquifer. Most data collection for this study was done during 1981-82, although numerous analyses in this report involve pre-1981 data. For the purpose of determining changes in water levels and water quality due to development, recent data were compared to data collected mainly during 1953-56.

Detailed analysis is limited generally to the surficial aquifer and the upper Floridan aquifer system. Detailed analyses of the lower zones of the

Floridan are not possible because of the scarcity of data. For the purposes of areal calculations, the study area does not include the areas of Lake George, Lake Monroe, and Lake Harney.

Previous Work

The general ground-water hydrology of Volusia County was described by Wyrick (1960, 1961). His investigation is most valuable to this report because it provides the historical water-level and water-quality data base which is needed to determine long-term changes caused by development. Knochenmus and Beard (1971) assessed the quality and quantity of the surface-water and ground-water resources of Volusia County; the section on ground water in that report provides additional water-quality data for many wells that had been previously sampled by Wyrick. A map report by Knochenmus (1968) discussed drainage feasibility throughout the county. Bush (1978) presented a ground-water flow model of Volusia County. Simonds and others (1980) demonstrated relations between water-level trends in the surficial aquifer and vegetative classifications in central Volusia County. Rutledge (1982) evaluated the effects of irrigation withdrawals on the Floridan aquifer system in northwest Volusia County.

Water-resources data collected in the county include several daily or periodic records of stream discharge, stream stage, and water levels in wells. Many of these records span more than 20 years. Long-term records of water-quality and discharge have been maintained for two springs in Volusia County and long-term records of stage have been maintained for two lakes. All of these records exceed 15 years in length.

Data Collection

Data collection for this study included water-level measurements in wells, water sampling from wells, and operation of water-level recorders to monitor variation of water level with time. Specific-capacity tests were made to provide a better understanding of the hydrologic properties of the Floridan aquifer system.

Much of the data collection effort involved the inventory update of many wells that were inventoried by Wyrick (1960, 1961). Additional wells were inventoried where needed. All major public-supply (municipal) wells were inventoried.

Well-Numbering System

Wells inventoried by the U.S. Geological Survey are referenced by local well numbers based on latitude and longitude coordinates derived from a grid of 1-minute parallels of latitude and longitude. Numbers consist of the last digit of the degree and the two digits of the minute of the line of latitude on the south side of the quadrangle, the last digit of the degree and the two digits of the minute of the line of longitude on the east side of the quadrangle, and the two-digit sequence number assigned in the order in which the well within the quadrangle was inventoried. For example, well 905-116-02 was the second well inventoried in the 1-minute quadrangle north of lat 29°05' and west of long 81°16'.

Table 1 gives information about the wells referenced by local well number in this report. Additional data for a well may be retrieved from the computer files of the U.S. Geological Survey. This data is retrieved by the 15-digit station numbers shown in the table. As of the date of this publication, more than 1,000 wells have been inventoried by the U.S. Geological Survey in Volusia County.

ENVIRONMENTAL SETTING

Climate

The climate in Volusia County is subtropical; the average temperature is 71°F and the average rainfall is 53 inches per year. The coldest months are December, January, and February, when temperatures average around 60°F; the warmest are June, July, and August which average around 80°F. More than half of the yearly rainfall occurs during the humid summer months of June-September.

Long-term yearly rainfall records are shown in figure 2. Rainfall has been slightly higher than average at the De Land site in recent years, and slightly below average at the Crescent City site. Long-term rainfall is noticeably lower near the coast than it is inland.

Geography

From a broad perspective, the topography in Volusia County is of two types: Karst topography and leveled terraces. Karst topography is the name applied to the undulating, pitted land surface that occurs where sinkholes are numerous and drainage is primarily downward. This type of topography is common in the areas in Volusia County where land surface is highest--the Crescent City Ridge and the De Land Ridge (fig. 1). The remaining areas are characterized as leveled terraces. Surface drainage is more typical of these leveled terraces.

Terrace formation during the Pleistocene played an important part in shaping the land surface in Volusia County (Cooke, 1945; Wyrick, 1960). Terraces are expanses of land of relatively uniform altitude which were the sea floor when the sea level stood higher than present sea level. Terrace formation accounts for the flatness of much of Volusia County. The Crescent City Ridge and the De Land Ridge are remnants of the Penholoway Terrace, which has been eroded largely by sinkhole activity. The other three terraces in Volusia County (fig. 1) are relatively unchanged and are therefore relatively level.

Table 1.--Data on wells referenced in this report which have been inventoried

STATION NO.	LOCAL NO. AND WELL NAME	AQUIFER PENETRATED 1/	ALTITUDE OF LAND SURFACE DATUM (FT ABOVE NGVD)	DEPTH OF WELL (FT)
284736080515101	84705106 COUNTY LINE WELL NR MAYTOWN,FL	FLRD	6.00	200
284821081075501	84810701 LEMON BLF FSH CMP WELL,S.OF OSTEEN,FL	FLRD	10.00	138
284857081081201	84810801 LEMON BLUFF WATER ASSOC., S. OF OSTEEN	FLRD	--	202
285105080515801	85105101 PUTNAM GROVES WELL, SW OF OAK HILL	FLRD	6.00	90
285341080532401	85305302 BROWN & COPELAND WELL, NR ARIEL	FLRD	8.00	225
285403080514390	85405103 INDIAN HARB. ESTATES,S OF EDGEWATER	FLRD	10.00	150
285512081202801	85512001 USGS WELL 1.9MI S.OF BLUE SPG NR OR.CTY	FLRD	9.52	200
285636081175501	85611702 ORAN.CITY P.S. WELL #3, ORANGE CITY	FLRD	23.00	257
285745081054001	85710501 USGS OBSER WELL AT ALAMANA, FL.	FLRD	35.90	121
285716081053901	85710502 USGS TEST WELL 12, N.OF LK.ASHBY	FLRD	35.00	241
285953080574701	85905709 NSB PS WELL NUMBERED 4 IN 1980,N.SMYRNA	FLRD	22.12	190
290107081062001	90110602 USGS TEST WELL E 1, W.SAMSULA	FLRD	41.00	111
290129081072901	90110701 USGS TEST WELL 8, W.SAMSULA	FLRD	40.00	241
290138081203202	90112002 USGS J-2 TEST WELL,W.OF DELAND	FLRD	42.00	500
290251081001401	90210001 USGS TEST WELL I,NE OF SAMSULA	FLRD	26.00	700
290324080580501	90305801 HENDRICKS WELL TURNBULL BAY ROAD, NSB	FLRD	7.00	104
290447081102301	90411004 I-4 DEEP WELL, E OF DELAND	FLRD	39.90	241
290541081132902	90511304 USGS 04 DP TEST W. NR. DELAND,FL.6"CSG	FLRD	38.35	639
290606080581901	90605803 S. SIDE OF ROSE BAY, ALLANDALE	FLRD	5.00	125
290651080582802	90605814 HARBOUR OAKS SUP.WELL,ALLANDALE	FLRD	3.72	150
290646081213701	90612101 16S29E W.WAROS WELL,W DELEON SPRINGS	FLRD	57.00	325
290612081214101	90612107 HAGSTROM DSL WELL, N. GLENWOOD	FLRD	46.00	--
290704081155301	90711502 16S30E11 HAGSTROMS 10"MARSH RD WELL	FLRD	54.00	600
290804081215601	90712101 12" FLOW W OF DELEON SPRINGS	FLRD	5.00	210
290752081220901	90712102 8"FLOW WELL W.OF DELEON SPRINGS	FLRD	5.00	96
290816080574101	90805701 DON MEMBRY WELL IN WILBUR-BY-THE-SEA	FLRD	12.00	130
290920081063001	90910601 USGS OBSER NR DAYTONA BEACH, FL.	FLRD	27.04	235
290959081231601	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	FLRD	12.00	241
291025081050201	91010501 USGS OBSER NR I-95 AT DAYTONA BCH., FL	FLRD	26.05	498
291032081065201	91010601 DAYTONA P.S. WELL #49, SW OF DAYTONA	FLRD	28.00	210
291004081101401	91011001 TIGER BAY TEST WELL 1A, W OF DAYTONA	FLRD	41.00	220
291007081101613	91011013 TIGER BAY TEST WELL 350 SH NR DAYTONA	SURF	41.17	20
291036081175801	91011701 HENDRIX WELL ON SR11, E OF BARBERVILLE	FLRD	43.93	180
291107080591601	91105902 BLUE WATERS MOTEL WELL, DAYTONA BCH SHR	FLRD	25.00	133
291133081035801	91110302 DAYTONA P.S. WELL #37, DAYTONA	FLRD	28.00	205
291133081040601	91110404 G.E. PLANT 6-INCH W. AT DAYTON BEACH, F	FLRD	27.55	235
291124081043401	91110410 DAYTONA P.S. WELL #41, DAYTONA	FLRD	28.00	290
291105081052301	91110504 DAYTONA P.S. WELL #46, DAYTONA	FLRD	33.00	210
291155081022901	91210237 DAYTONA P.S. WELL #32, TUSC., DAYTONA	FLRD	--	160
291353081160401	91311601 UNION CAMP SHALLOW WELL NR BARBERVILLE	SURF	34.13	20
291429081024702	91410213 HOLLY HILL P.S. WELL #7A, HOLLY HILL	FLRD	9.20	200
291425081024501	91410214 HOLLY HILL P.S. WELL #8, HOLLY HILL	FLRD	9.00	215
291436081024701	91410216 HOLLY HILL P.S. WELL #9, HOLLY HILL	FLRD	8.02	216
291435081025501	91410218 HOLLY HILL P.S. WELL #11, HOLLY HILL	FLRD	8.00	--
291646081034601	91610306 ORMOND P.S. WELL #6, ORMOND BEACH	FLRD	8.00	200
291715081281801	91712801 J.C. MEW WELL AT SEVILLE, FL.	FLRD	14.90	180
291835081324201	91813201 USED 426 PINE ISLAND, W.OF SEVILLE	FLRD	4.36	155
291904081055501	91910504 TOMOKA ESTATES 2" WELL NW OF ORMOND	FLRD	8.59	140

1/ FLRD: Floridan aquifer system, SURF: Surficial aquifer

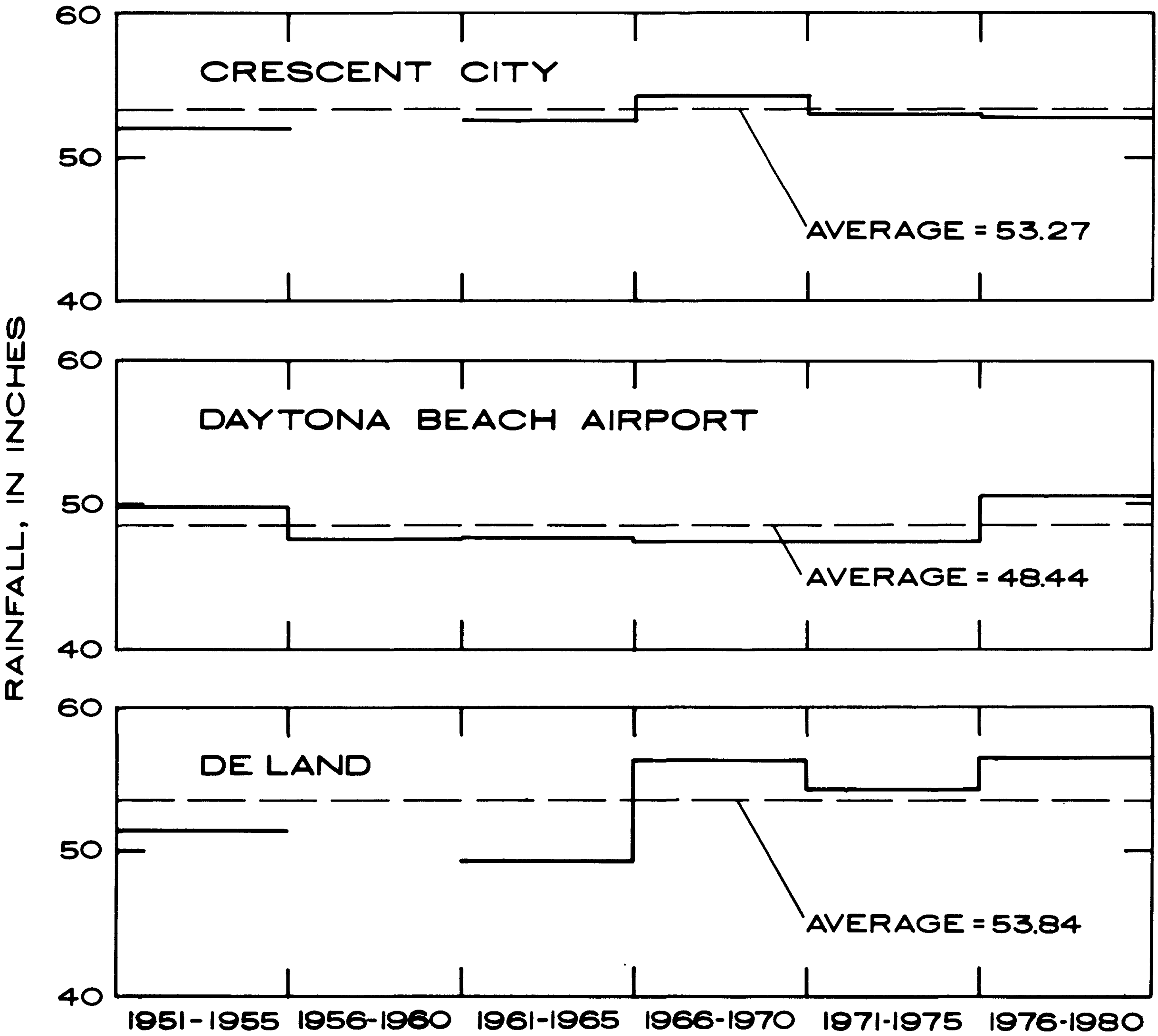

Figure 2.--Average yearly rainfall during 5-year intervals at three rain gages, 1951-80 (sites in fig. 22, data from records of National Oceanic and Atmospheric Administration).

Land surface altitude ranges from 0 to 120 feet in Volusia County. The topographic highs are in the Crescent City Ridge and the De Land Ridge. Lowest areas are along the coast and in the St. Johns River valley (fig. 3). Generally, land surface altitude rises in a steplike progression from the Silver Bluff Terrace to the Pamlico Terrace to the Talbot Terrace to the ridges in western Volusia County.

Geology

Four stratigraphic units are discussed in the following paragraphs and are illustrated in figure 4. Descriptions of the formations are from Wyrick (1960) and figure 4 was derived from geologic logs of the Florida Bureau of Geology (formerly Florida Geological Survey). Well numbers on these figures are assigned by the Florida Bureau of Geology. The Oldsmar Limestone of early Eocene age, although illustrated, is not discussed because no known water wells penetrate it in the study area.

The sediments of Pleistocene and Holocene age consist of fine- to medium-grained quartz sand, sandy clays, and locally, small amounts of shell. In some areas, the sand has been cemented into "hardpan" by deposition of iron oxide at the water table. The Pleistocene and Holocene deposits are generally 20 to 50 feet thick, but locally they can be as much as 100 feet thick.

The Miocene and Pliocene deposits consist of unconsolidated beds of fine sand, shells, and calcareous silty clays. The overall thickness of the Miocene or Pliocene deposits in Volusia County is generally 20 to 70 feet.

The Ocala Limestone, of late Eocene age, is composed of cream to white limestone mottled with gray zones. The Ocala Limestone is generally only slightly dolomitized in Volusia County. Because of extensive erosion the formation is thin in most of Volusia County, and absent in much of the De Land Ridge.

The Avon Park Limestone of late middle Eocene age, varies in color from chalky white to light brown or ashen gray, and consists of layers of dark-brown dolomite separated by layers of chalky limestone. The dolomite is crystalline and contains few fossils, but the limestone is very fossiliferous. The limestone is extensively dolomitized. Some of the Avon Park Formation was removed by erosion before the overlying Ocala Limestone was deposited.

Hydrogeology

The aquifers discussed are the surficial aquifer and the Floridan aquifer system. The surficial aquifer is composed of poorly consolidated sand, clay, and shell beds of Pleistocene and Holocene ages. The Floridan aquifer system is made up of the limestone and dolomite of Eocene age. Although the shell beds of Miocene and Pliocene ages may yield some water, these beds are excluded from discussion because few wells in Volusia County are open to them. Of

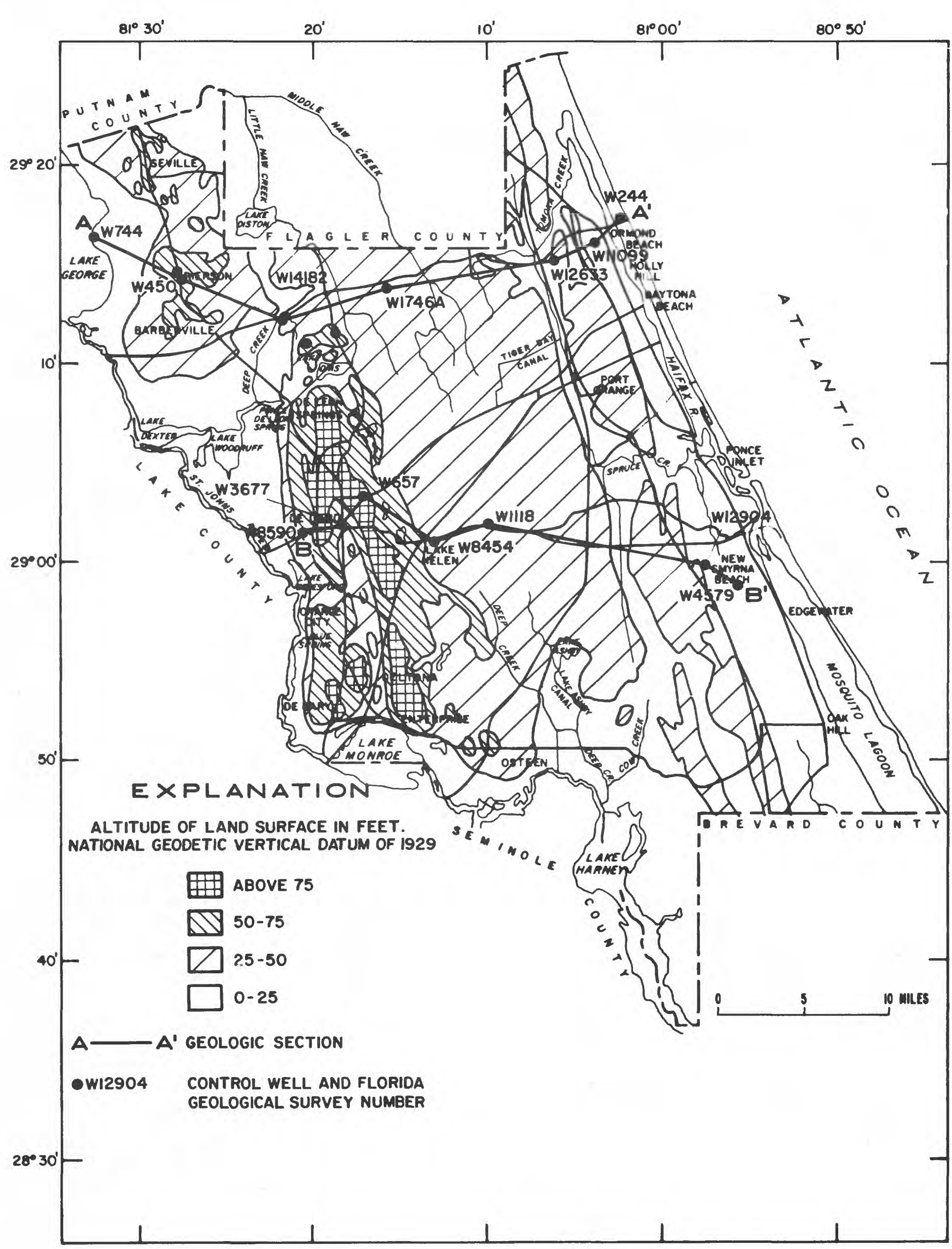

Figure 3.--Topography in Volusia County.

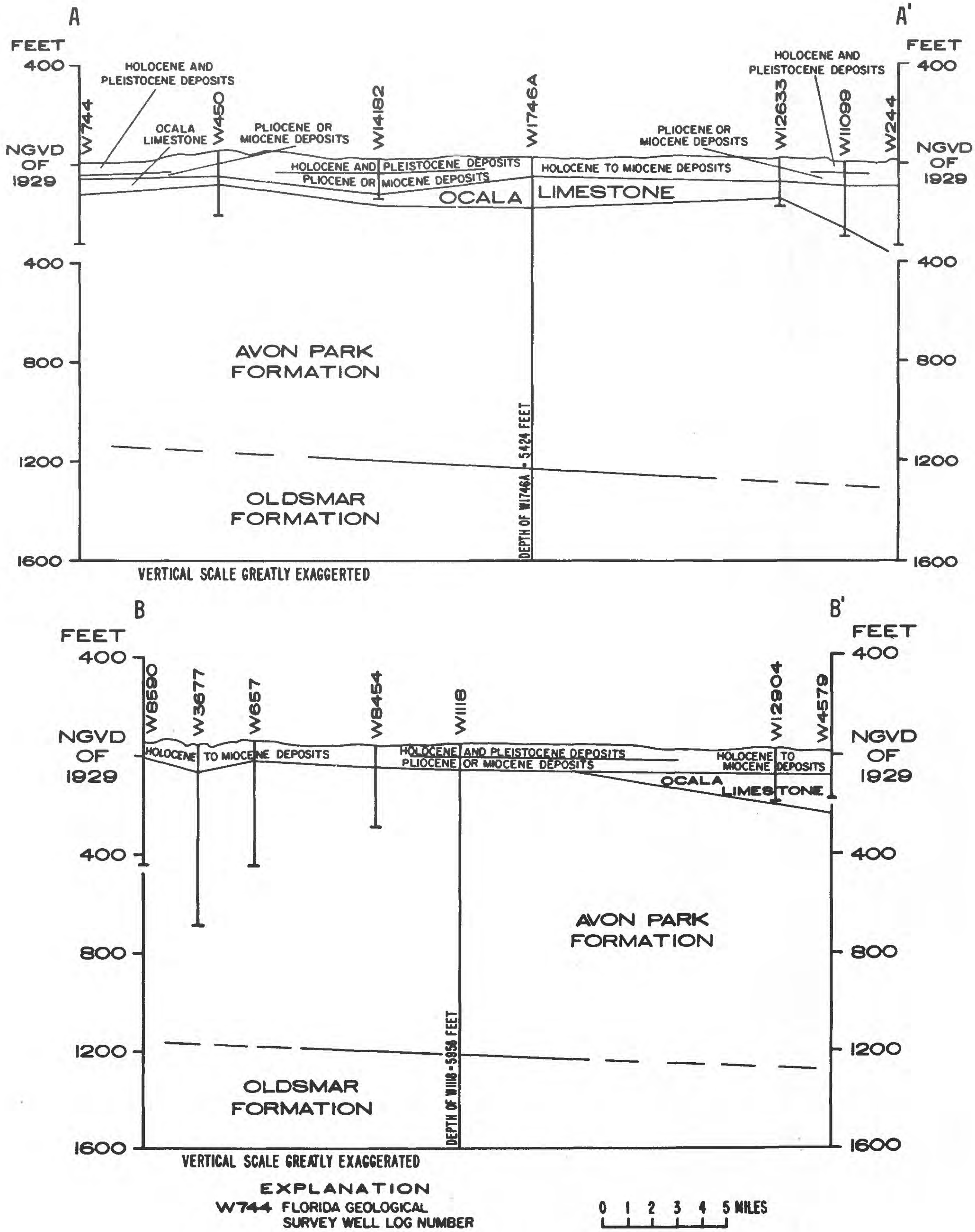

Figure 4.--Geologic sections (traces of sections in fig. 3).

greater importance from a hydraulic standpoint are the clay layers of Miocene or Pliocene age which form the confining bed that retards water movement between the surficial aquifer and the Floridan aquifer system.

The surficial aquifer is the layer of sand and shell from land surface down to the first areally persistent and relatively impermeable layer of clay, or down to the limestone if no clay bed thus described is present. Although the surficial aquifer may contain local zones of clay and hardpan, the clay zones are inconsistent enough and the hardpan is permeable enough that these do not significantly retard the flow of water in the aquifer. The surficial aquifer is generally 10 to 50 feet thick. It is thickest in the De Land Ridge area, where it reaches 100 feet in some places.

The surficial aquifer is unconfined because it contains the top of the zone of saturation, the water table, which is free to rise and fall in the aquifer. Typical seasonal water-table fluctuations range from 4 to 5 feet. The average depth to the water table in most of Volusia County is less than 10 feet, although in the De Land Ridge area depths typically exceed 20 feet. In other ridge areas (fig. 1), the average depth to the water table is typically 5 to 15 feet, but in nonridge areas the average depth to the water table is only 0 to 5 feet. Simonds and others (1980) showed relations between depth to the water table and vegetative classification.

Water enters the surficial aquifer by direct infiltration of rainfall, recharge caused by application to the land surface of Floridan aquifer system withdrawals, streamflow, and leakage in areas of upward gradient from the Floridan aquifer system. It leaves as evapotranspiration, streamflow, and leakage in areas of downward gradient to the Floridan aquifer system. Lateral movement into or out of the study area in the surficial aquifer is small because hydraulic gradients are small and the ability of the aquifer to transmit water is slight.

Water levels in wells open to the Floridan aquifer system in Volusia County are above the top of the aquifer. In areas of artesian flow (fig. 5) the water level in wells is above land surface. In other parts of Volusia County, the water level in Floridan aquifer system wells is generally 10 to 40 feet below land surface. Because the Floridan aquifer system is artesian, it is completely saturated from bottom to top. Although water levels cannot rise and fall within the aquifer, they can rise and fall in wells that penetrate the aquifer. This fluctuation is indicative of pressure changes within the aquifer. Typical seasonal water-level fluctuations are 4 feet in undeveloped areas and 5 to 10 feet in areas of pumping. The surface defined by water levels in wells tapping the Floridan aquifer system is called the potentiometric surface of the Floridan aquifer system. The slope of this surface denotes the direction of lateral ground-water flow within the aquifer. Furthermore, the difference in altitude between the water table and the potentiometric surface determines the direction of leakage between the aquifers. If the water table is higher than the potentiometric surface, then the leakage is from the surfical aquifer down to the Floridan aquifer system. Conversely, if the potentiometric surface is higher than the water table, then the leakage is from the Floridan aquifer system up to the surficial aquifer.

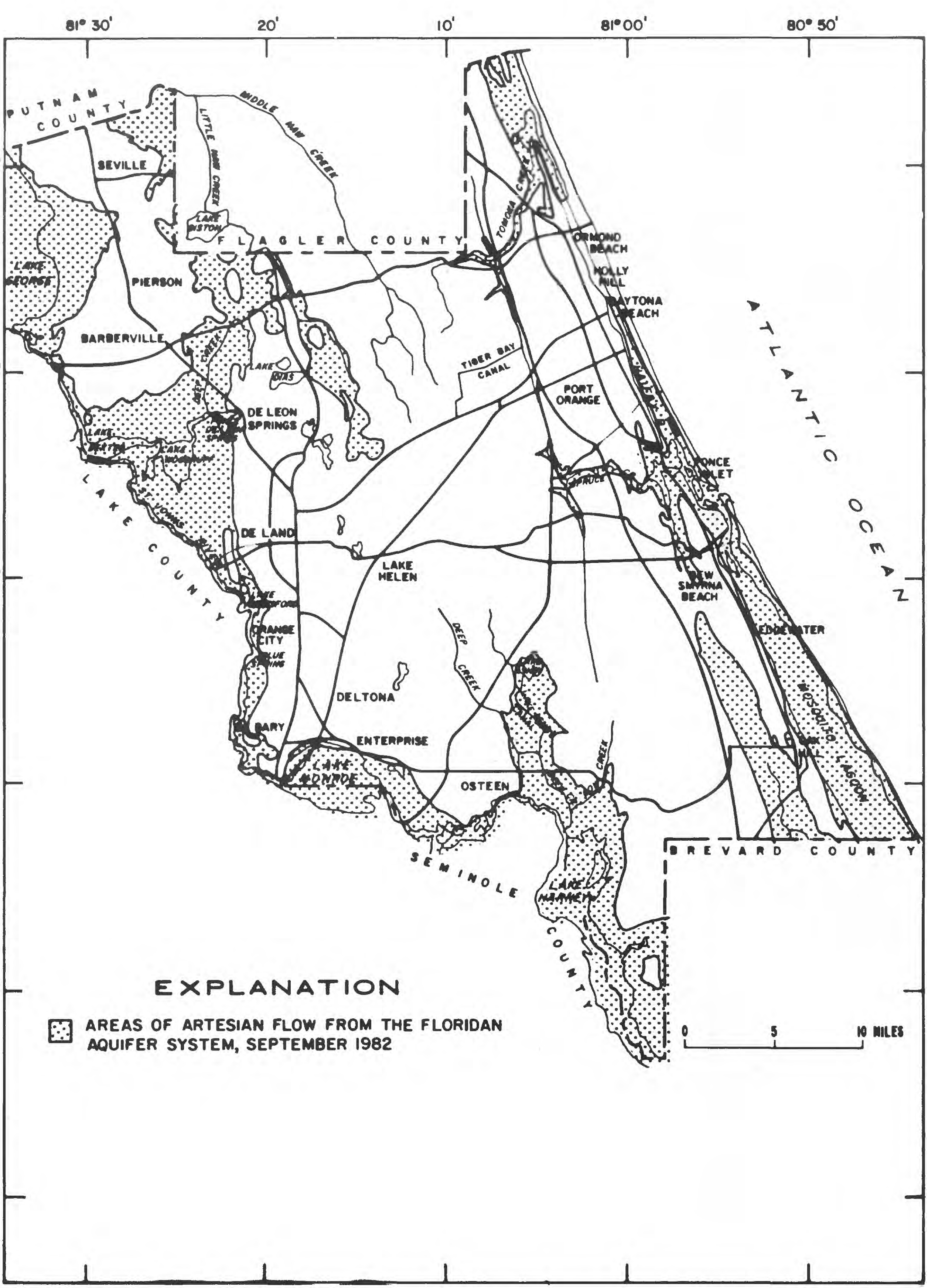

Figure 5.--Areas of artesian flow from the Floridan aquifer system in Volusia County, September 1982.

Water enters the Floridan aquifer system in Volusia County by downward leakage from the surficial aquifer through the confining layer and by horizontal inflow from outside Volusia County. It leaves as upward leakage through the confining layer, spring discharge, well discharge, and horizontal outflow to other areas.

Figure 6 shows the altitude of the top of the Floridan aquifer system. The top of the freshwater zone is located at this surface and the thickness of this zone is zero to 1,400 feet depending on location. The freshwater zone is thinnest in coastal areas and near the St. Johns River and thickest in central Volusia County. Below this freshwater zone are limestone and dolomite formations that are saturated with saltwater.

GROUND-WATER USE

Estimates of ground-water use are given in table 2. Withdrawal rates have approximately tripled during 1955-80 for all uses except irrigation. Irrigation use has increased more than tenfold, probably because of the increased use of water for irrigating the leather leaf fern, which is grown commercially on the Crescent City Ridge and the De Land Ridge. The largest withdrawals are for public-supply use; irrigation water use ranks second. In 1980, all other water uses combined made up less than the public supply or the irrigation use. Total ground-water use has quadrupled between 1955 and 1980.

Table 2.--Estimated ground-water use in Volusia County[1/]

[In million gallons per day]

	1955	1967	1980
Public supply	10	15.8	30.2
Agricultural irrigation	1.7	6.1	23.7
Domestic, self-supplied	1.8	2.0	4.5
Heat pump and lawn irrigation	2.0	3.4	6.2
Other	0.5	0.6	1.2
Totals	16.0	27.9	65.8

[1/] Source
- 1955 - Knochenmus and Beard, 1971, and Florida Bureau of Geology project files
- 1967 - Files of U.S. Geological Survey
- 1980 - Project files of U.S. Geological Survey and St. Johns River Water Management District

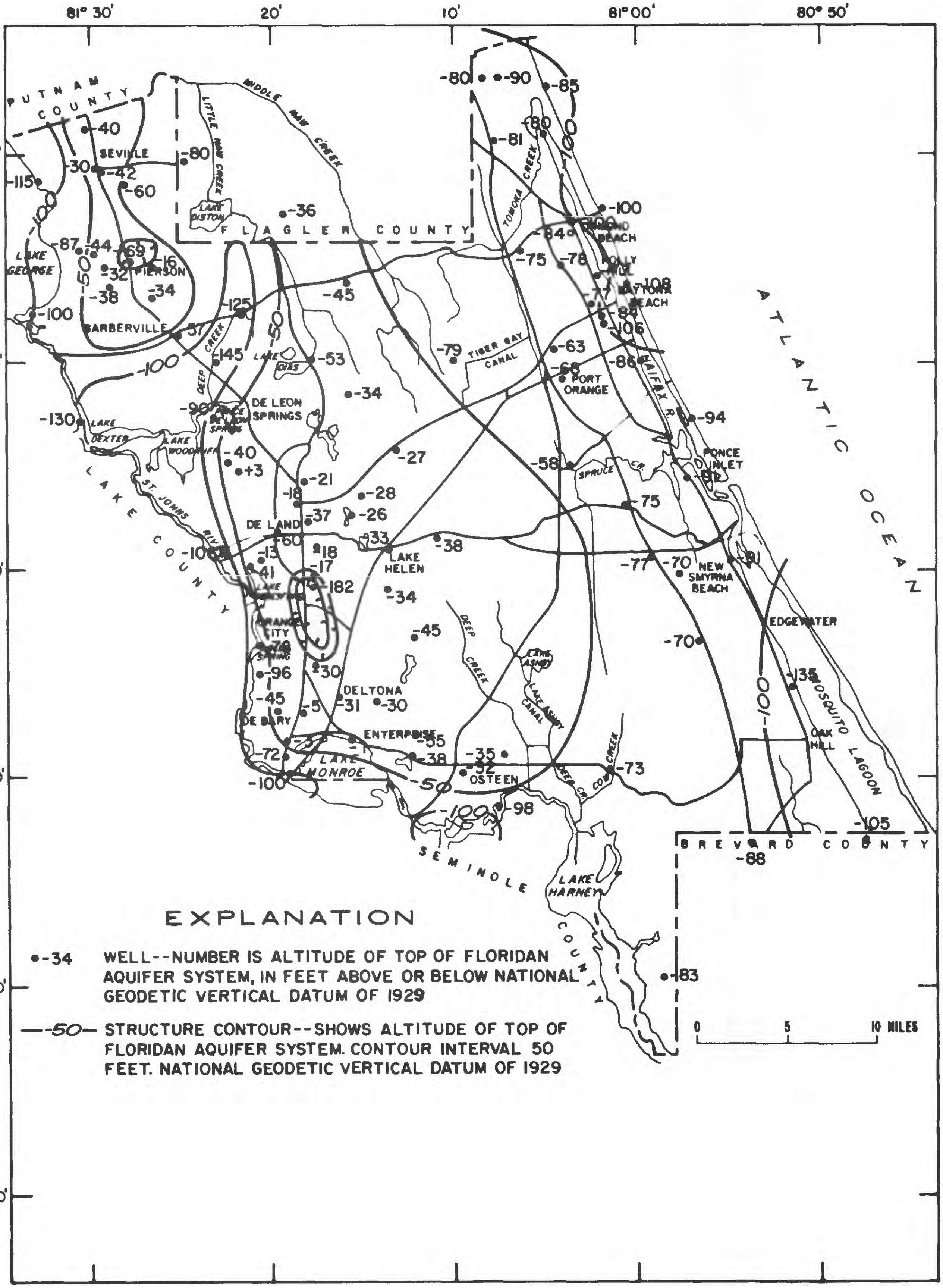

Figure 6.--Altitude of top of Floridan aquifer system.

More than 95 percent of the ground water withdrawn in Volusia County is pumped from the Floridan aquifer system, and the remainder is taken from the surficial aquifer. The following discussion deals with the various categories of water use for both aquifers and shows how withdrawals for each category are distributed in the study area.

The VOLDATA file, which is mentioned in this section, is a data file maintained by the Volusia County Building Inspection Department and includes data on all wells permitted by that department since 1976. It is useful as a source of information pertaining to water use. Additional data continue to be added to VOLDATA.

Surficial Aquifer

In Volusia County, the total present (1980) pumpage from the surficial aquifer is approximately 3 Mgal/d. There are very few agricultural irrigation wells and no public-supply wells that are open to the surficial aquifer. Most of the agricultural irrigation wells tapping the surficial aquifer are located in the Crescent City Ridge area and are used for irrigating ferneries. The total pumpage from these wells is probably much less than 1 Mgal/d.

Water from the surficial aquifer is used mostly for lawn irrigation. Figure 7 shows the distribution of surficial aquifer irrigation wells in the VOLDATA file. In January 1983, there were 1,952 surficial aquifer irrigation wells in the VOLDATA file out of a total of 7,257 for all well types, or 27 percent. An estimate of the pumpage in Volusia County from the surficial aquifer for lawn irrigation purposes is about 2 Mgal/d. This is based on these assumptions: (1) there are approximately 5,000 lawns irrigated with water from the surficial aquifer, (2) the average lawn is 8,000 ft^2, (3) the average application rate is 30 in/yr. As figure 7 shows, most surficial aquifer irrigation wells are in coastal areas. Although the surficial aquifer is an important source for lawn irrigation, its contribution to total agricultural irrigation is small.

The second largest use of water from the surficial aquifer is for domestic purposes. The VOLDATA file contained data for 390 surficial aquifer domestic wells of a total of 2,600 domestic wells on January 1983. An estimate of the domestic pumpage from the surficial aquifer may be obtined by multiplying the ratio 390/2600 by the total domestic ground-water use in table 2; the pumpage from the surficial aquifer for domestic use is thus 0.7 Mgal/d. Figure 8 shows that most of these wells are located in the New Smyrna Beach and Edgewater areas.

Floridan Aquifer System

All but a small fraction of the ground water used in Volusia County is from the Floridan aquifer system. All public-supply wells and most agricultural irrigation wells are open to the Floridan aquifer system.

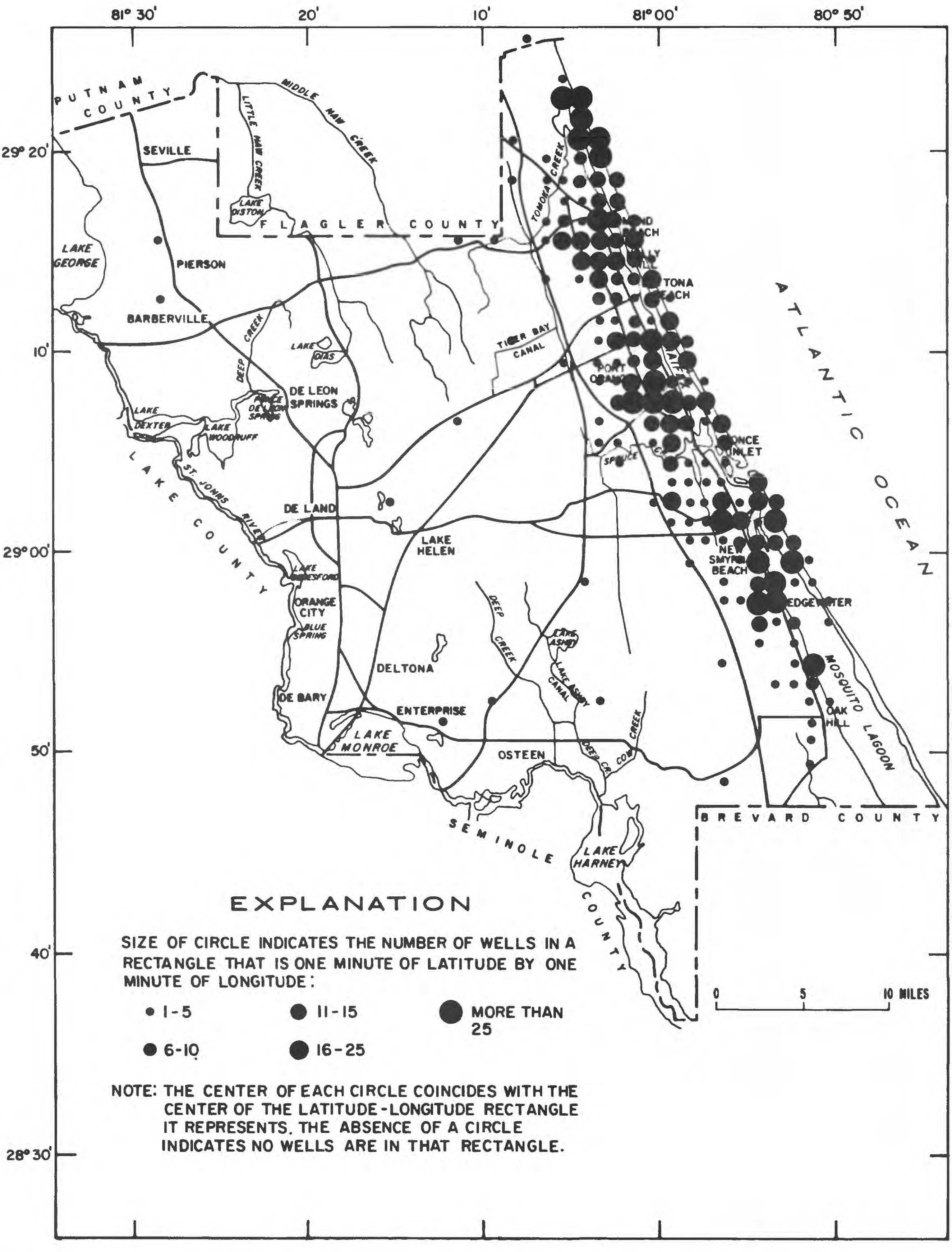

Figure 7.--Distribution of surficial-aquifer wells that are used for irrigation purposes (documented in the VOLDATA file).

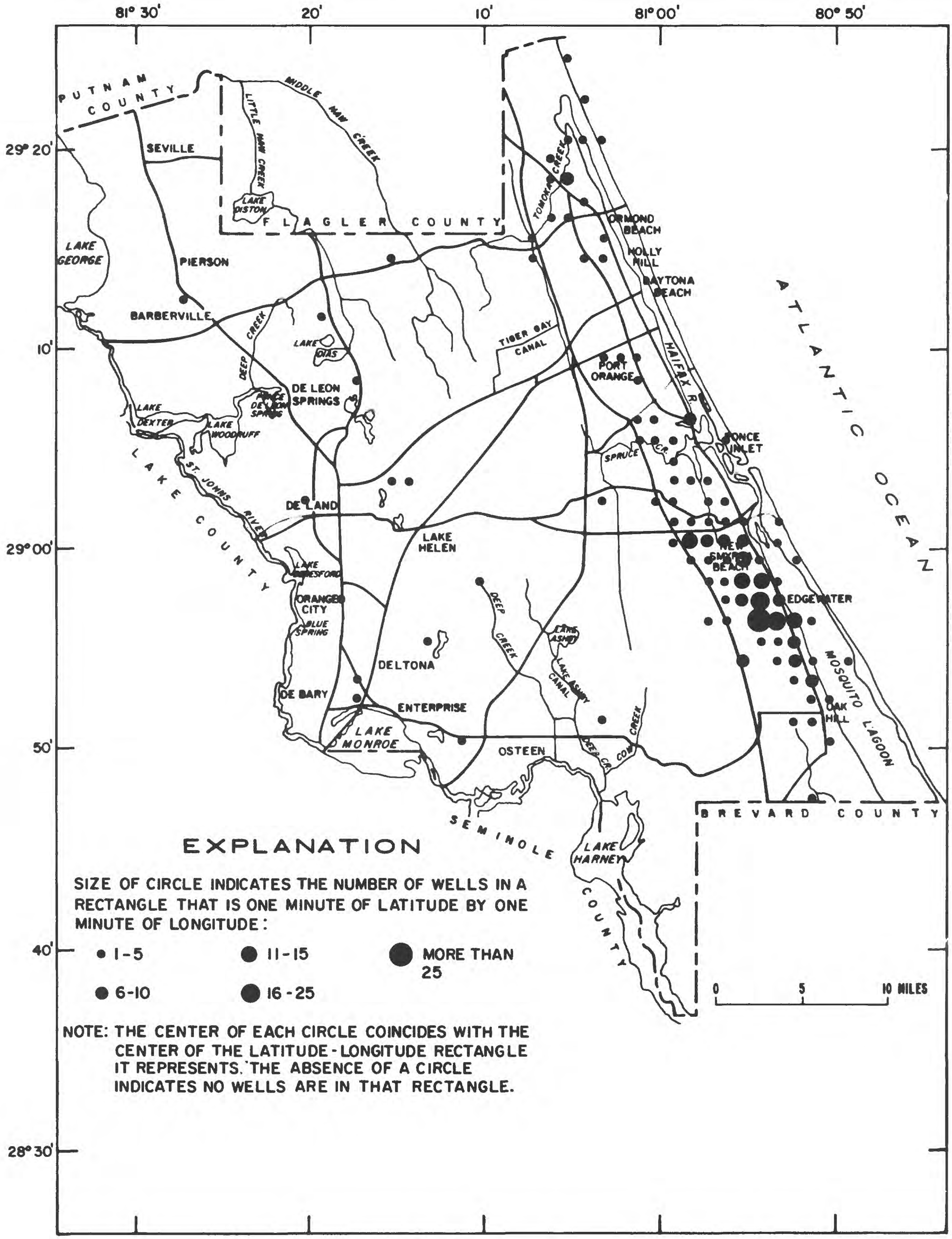

Figure 8.--Distribution of surficial-aquifer wells that are used for domestic purposes (documented in the VOLDATA file).

Figures 9 and 10 show the distributions of public-supply wells in 1955 and 1980. Also shown are the pumping rates for each supplier. Daytona Beach is the largest supplier. Public suppliers shown in figure 10 that are not shown in figure 9 were not in existence in 1955.

Figure 11 shows that the greatest concentration of agricultural irrigation wells is in northwest Volusia County, where most of the fern industry is located. The map shows the distribution, as documented in the VOLDATA file, of Floridan aquifer system wells used for irrigation which are greater than 4 inches in diameter. The 1980 withdrawal rate for agricultural irrigation was 23.7 Mgal/d.

Figure 12 is a plot of Floridan aquifer system wells documented in the VOLDATA system that are used for irrigation and which are 4 inches or less in diameter. A few of the wells in this group may be used for agricultural irrigation, but most are used for lawn irrigation. The greatest concentrations are in the areas of Ormond Beach, Daytona Beach, and Port Orange.

Figure 13 is a map showing the distribution of Floridan aquifer wells documented in the VOLDATA file that are used for domestic purposes. The greatest numbers of these wells are in the De Land Ridge.

WATER-LEVEL TRENDS

In Volusia County, the practices that cause lowering of water levels are pumping or drainage or a combination of the two. Drainage most directly causes water-level declines in the surficial aquifer, but may also induce declines in the Floridan aquifer system because the surficial aquifer acts as a reservoir for recharge to the Floridan aquifer system. The lowering of water levels caused by development may be estimated by comparing recent water levels with water levels measured during a time of less development. Water-level declines due to development are difficult to ascertain because they often are masked by water-level fluctuations caused by variations in rainfall.

Surficial Aquifer

Water levels in the surficial aquifer have not been monitored extensively in Volusia County. Nonetheless, it is possible to define areas of greatest water-level decline in the surficial aquifer based on amounts of drainage and pumpage. Figures 7 and 8 show that most of the wells open to the surficial aquifer are located in coastal areas where about 3 Mgal/d are pumped for lawn irrigation. The other developmental stress on the surficial aquifer is artificial drainage. Figure 14 shows that the areas of greatest artificial drainage are the Daytona Beach area, the Port Orange area, and the Lake Ashby area. The largest declines in the surficial aquifer due to development are, therefore, in the coastal areas and in the Lake Ashby area.

Figure 15 shows two water-level records for surficial-aquifer wells unaffected by development, beginning in 1978. The hydrographs show typical

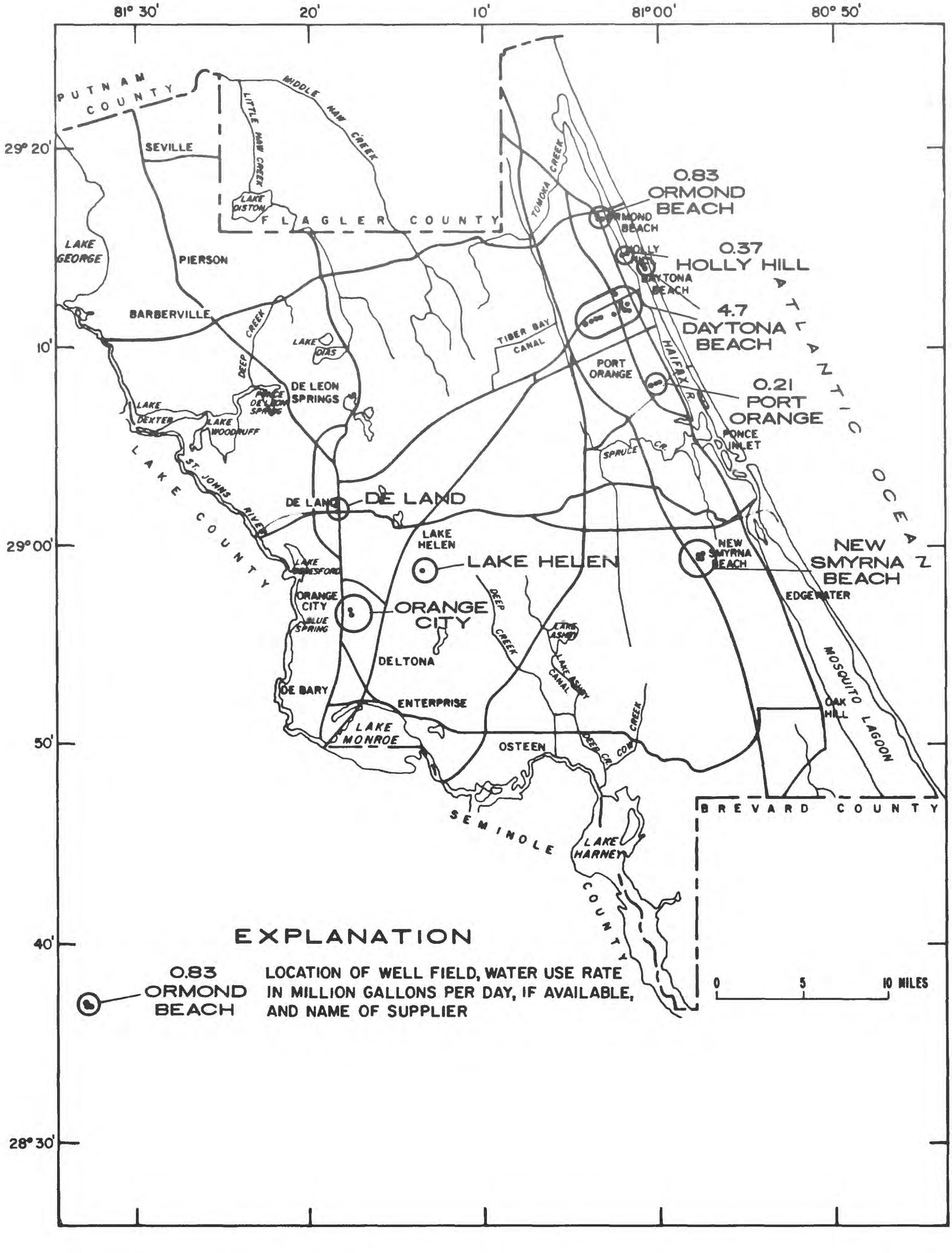

Figure 9.--Locations of public-supply wells and available water-use rates, 1955 (water-use rates from Knochenmus and Beard, 1971).

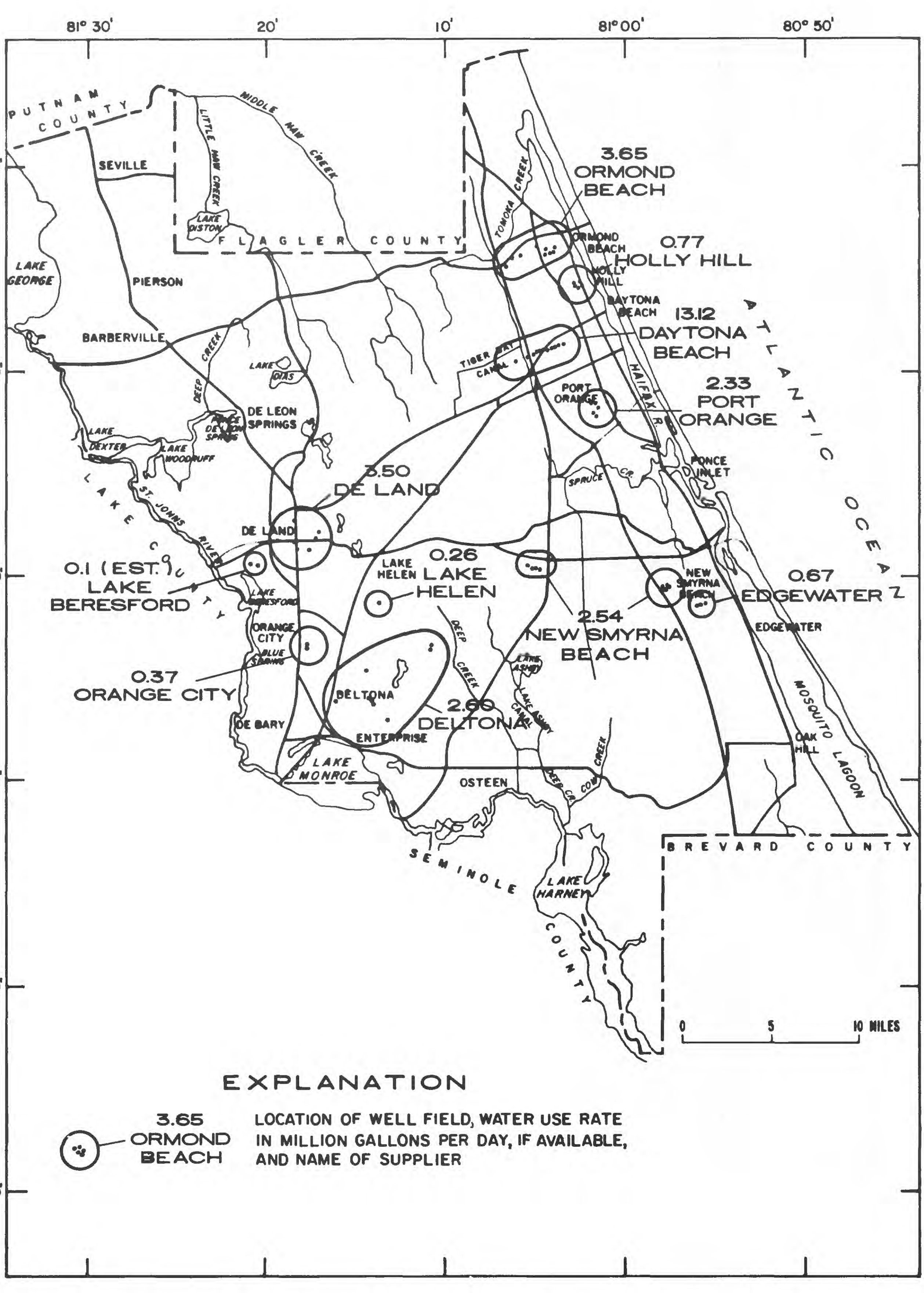

Figure 10.--Locations of public-supply wells and water-use rates, 1980 (water-use rates from files of St. Johns River Water Management District).

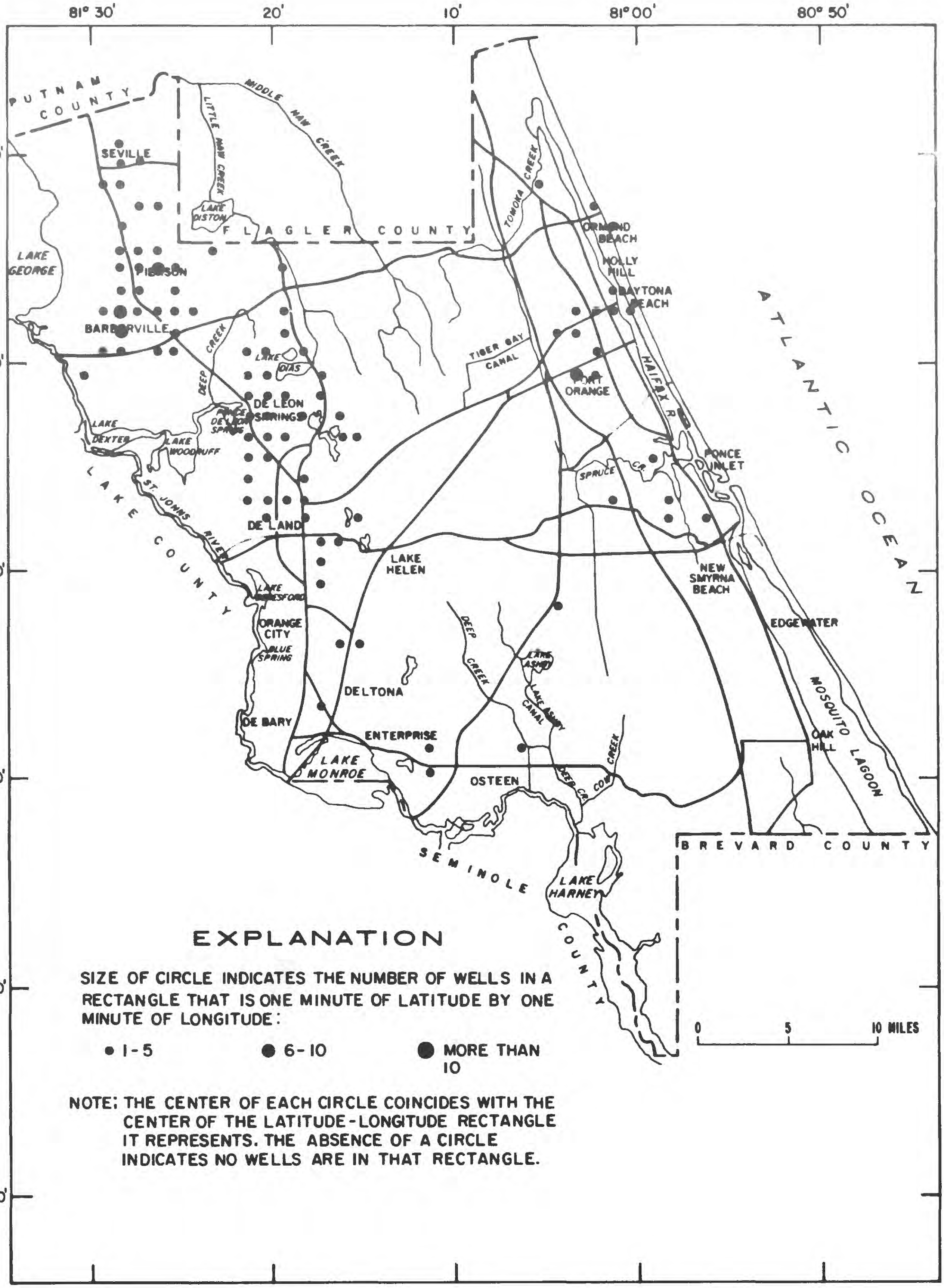

Figure 11.--Distribution of Floridan aquifer system wells that are used for irrigation and which are greater than 4 inches in diameter (documented in the VOLDATA file).

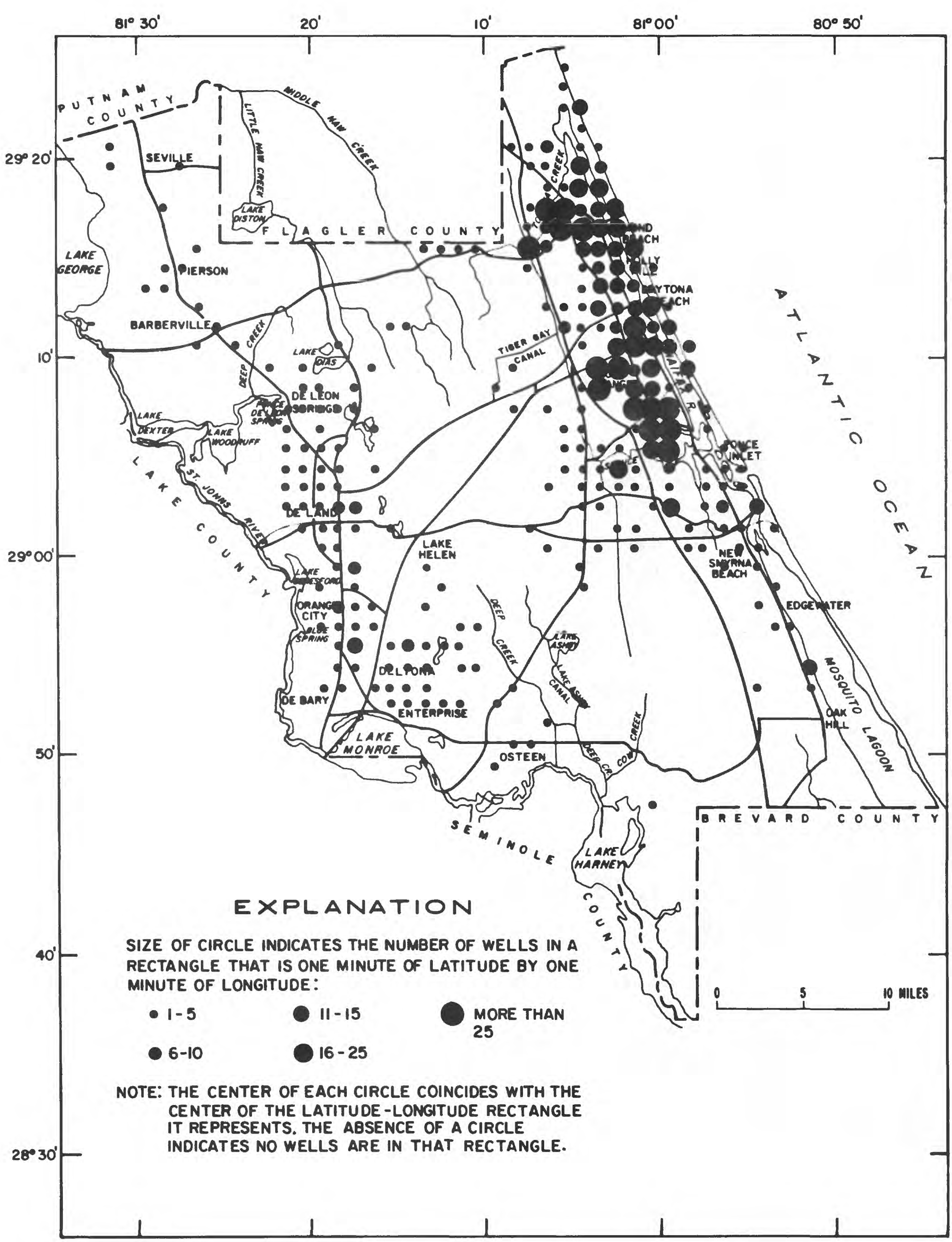

Figure 12.--Distribution of Floridan aquifer system wells that are used for irrigation and which are 4 inches or less in diameter (documented in the VOLDATA file).

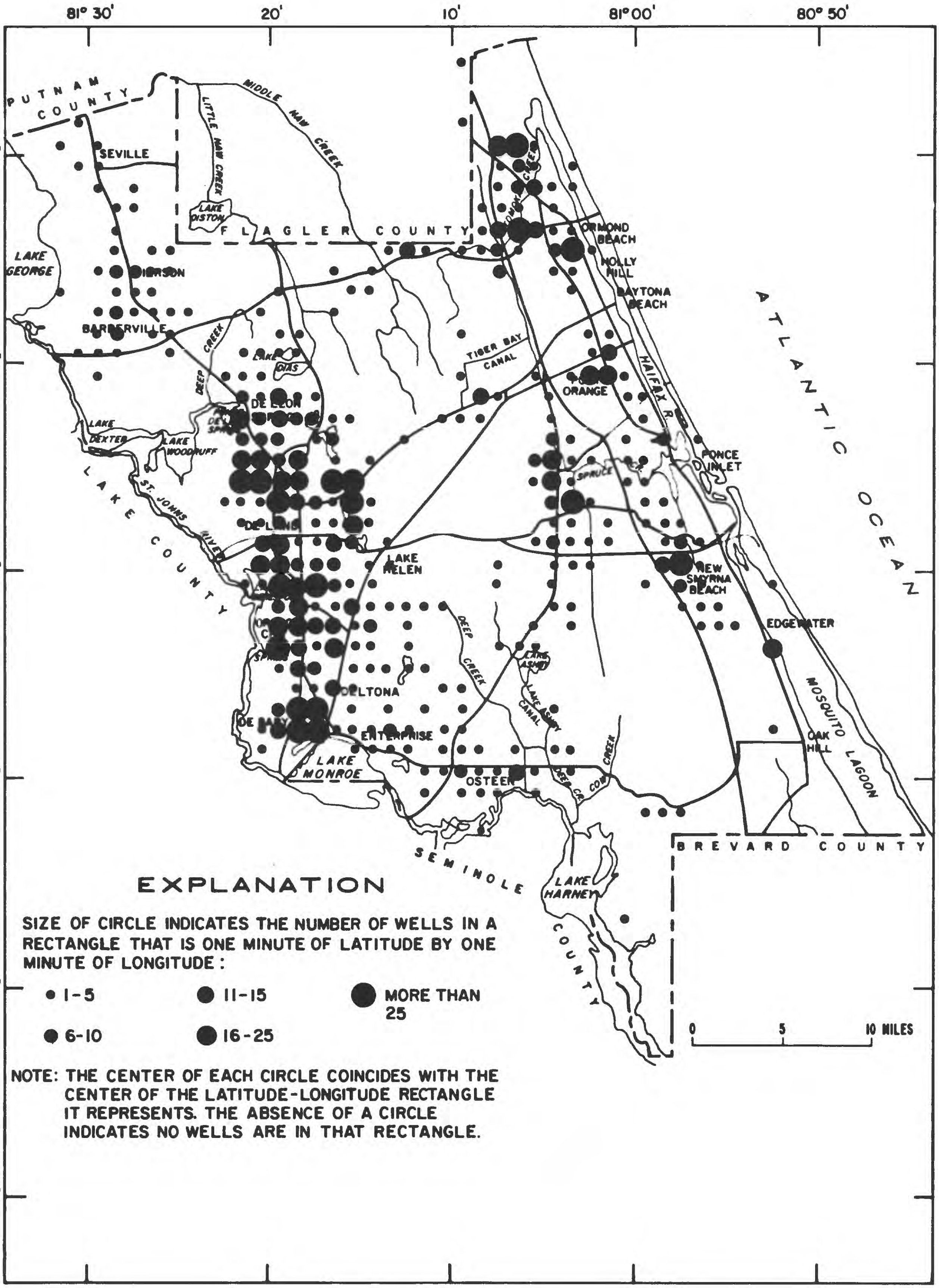

Figure 13.--Distribution of Floridan aquifer system wells that are used for domestic purposes (documented in the VOLDATA file).

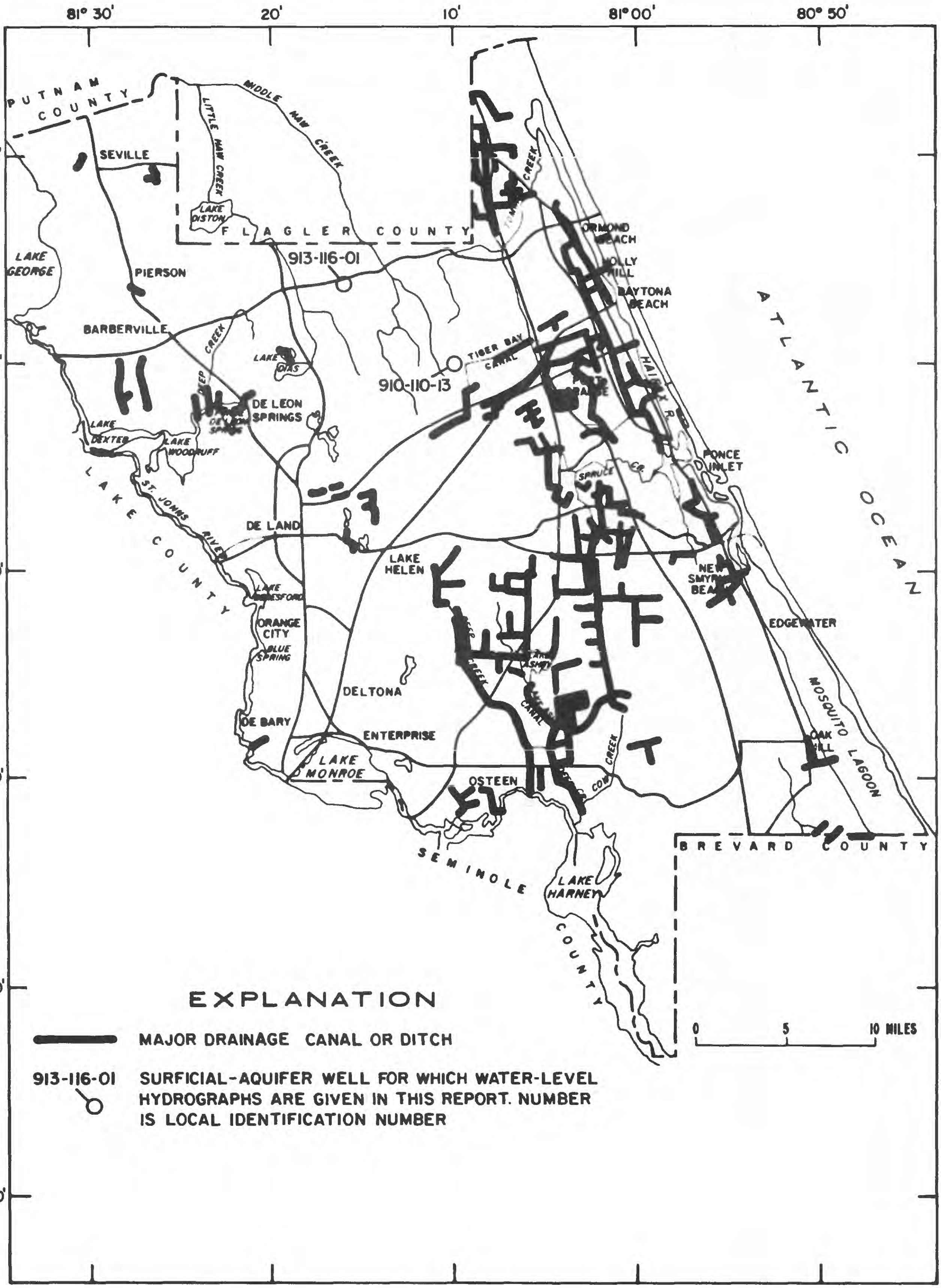

Figure 14.--Locations of the major artificial drainage systems in Volusia County.

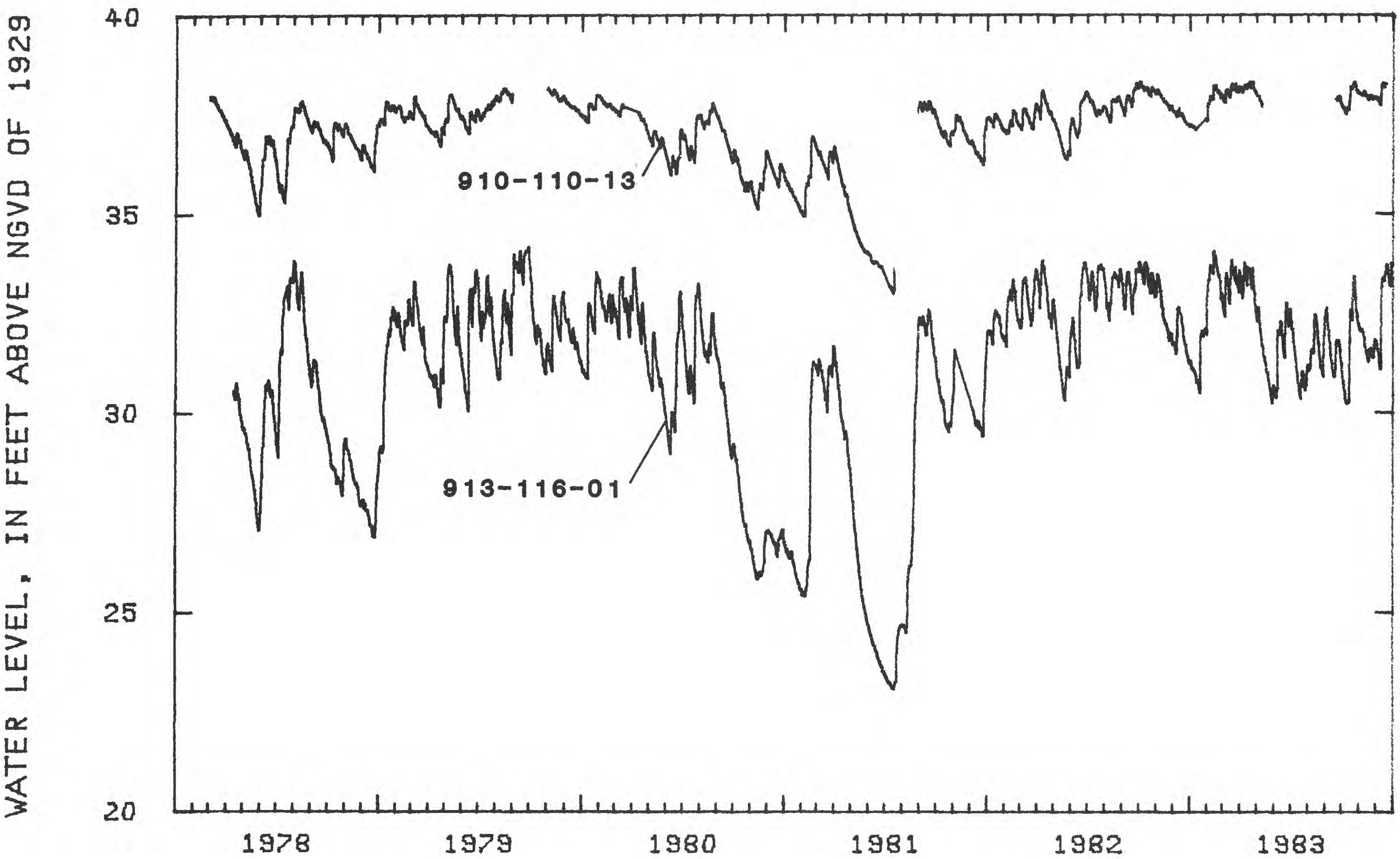

Figure 15.--Daily maximum water levels in surficial-aquifer wells 910-110-13 and 913-116-01, January 1978-December 1983 (well sites in fig. 14).

fluctuations due to rainfall variations. The troughs in the records during the summer of 1981 were caused by a drought that caused record low water levels at many sites in Volusia County.

Floridan Aquifer System

Water levels in the Floridan aquifer system measured during the mid-1950's can be compared to levels measured recently to determine water-level declines due to pumping and drainage. To accomplish this, the water levels obtained at three different times--November 1955, May 1981, and September 1982, are compared. Changes in the potentiometric surface are caused by the net effects of rainfall variations and ground-water development. Figure 16 shows that rainfall totals for the 6 months ending November 1955 and September 1982 were 28.5 and 32.5 inches, respectively. Any significant differences between the respective potentiometric surface maps are, therefore, caused mainly by development. The rainfall trend up to May 1981, on the other hand, is different from the other two. Although the periods up to November 1955 and September 1982 represent average rainfall, the period up to May 1981 represents unusually deficient rainfall. The differences between the November 1955 and the May 1981 potentiometric surface maps are, therefore, caused by both rainfall trends and development.

Figures 17, 18, and 19 show the potentiometric surface of the upper part of the Floridan aquifer system for November 1955, September 1982, and May 1981. Also shown in figure 18 is the area in which the potentiometric surface decline from November 1955 to September 1982 exceeds 10 feet. This is a 70-square-mile area which includes much of Ormond Beach, Daytona Beach, and Port Orange. All of this decline may be attributed to pumping. Figure 19 shows a potentiometric surface which has been affected by development and drought. Most of the water-level measurements made in Volusia County for the May 1981 potentiometric surface map were the lowest ever measured. In the Ormond Beach, Daytona Beach, and Port Orange area, the potentiometric surface was below sea level in an area exceeding 100 square miles; in November 1955, potentiometric surface levels there ranged from 3 to 20 feet above sea level.

Figure 20 shows long-term water-level hydrographs for five Floridan aquifer system wells. Significant downward trends are apparent for well 911-104-04, located within 300 feet of a public-supply well in Daytona Beach, and for well 909-106-01, southwest of Daytona Beach. The downward trends are caused predominantly by increased pumping, and the seasonal fluctuations are caused by variations in rainfall and pumpage. The seasonal fluctuations at the other three wells are caused by variations in rainfall rates. The lowest water levels generally occurred in the summer of 1981 because of drought conditions.

Further detail of seasonal fluctuations is shown in figure 21. Largest fluctuations occur in areas of pumping. Well 859-057-09 is within a public-supply well field and 912-102-37 is in a populated area of Daytona Beach. Well 857-105-01, in south-central Volusia County, is farthest from areas of pumping.

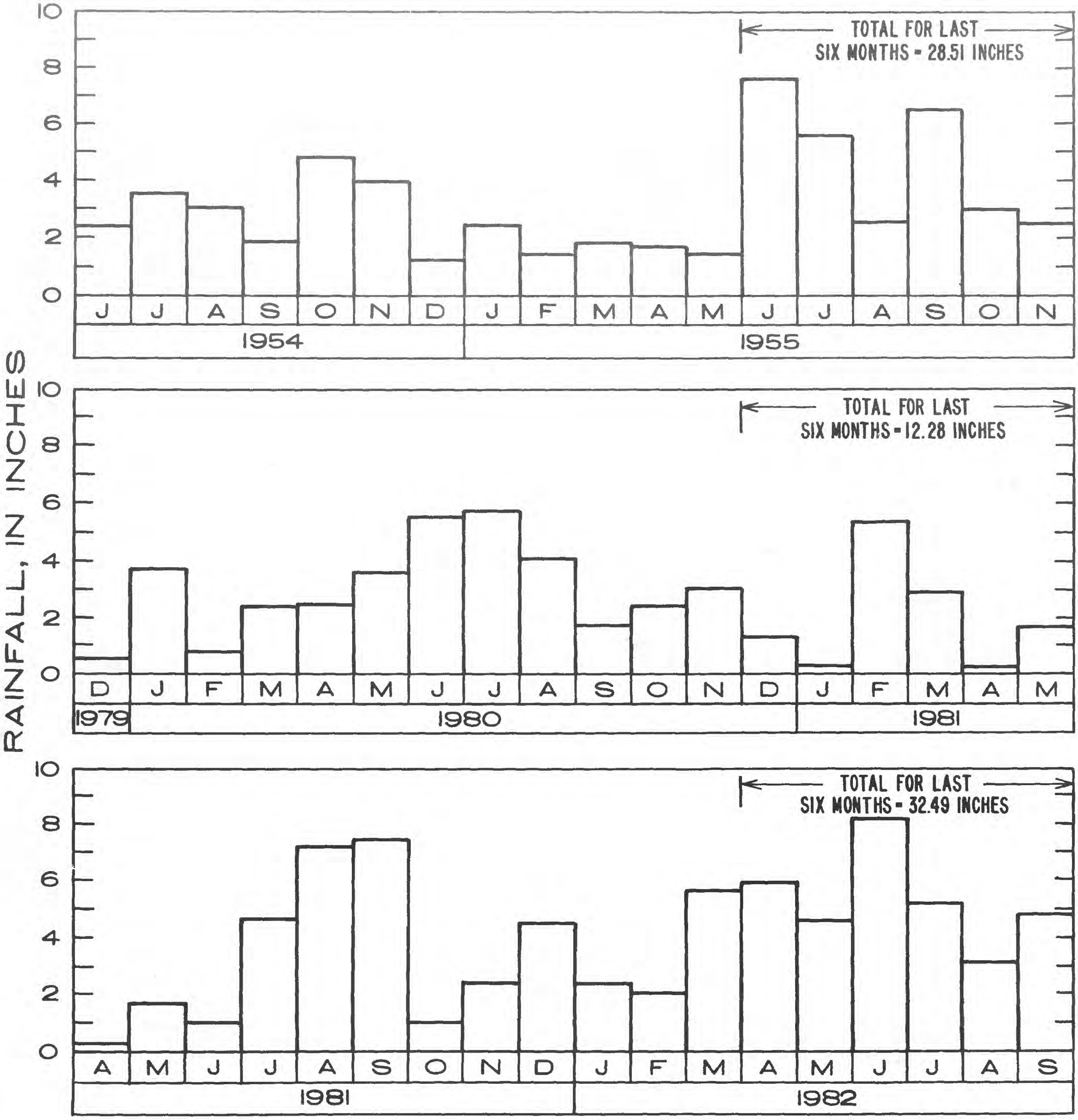

Figure 16.--Monthly rainfall for the 18-month periods up to and including months of of three mass water-level measurements on Floridan aquifer system wells (from records of National Oceanic and Atmospheric Administration, Daytona Beach WB AP station).

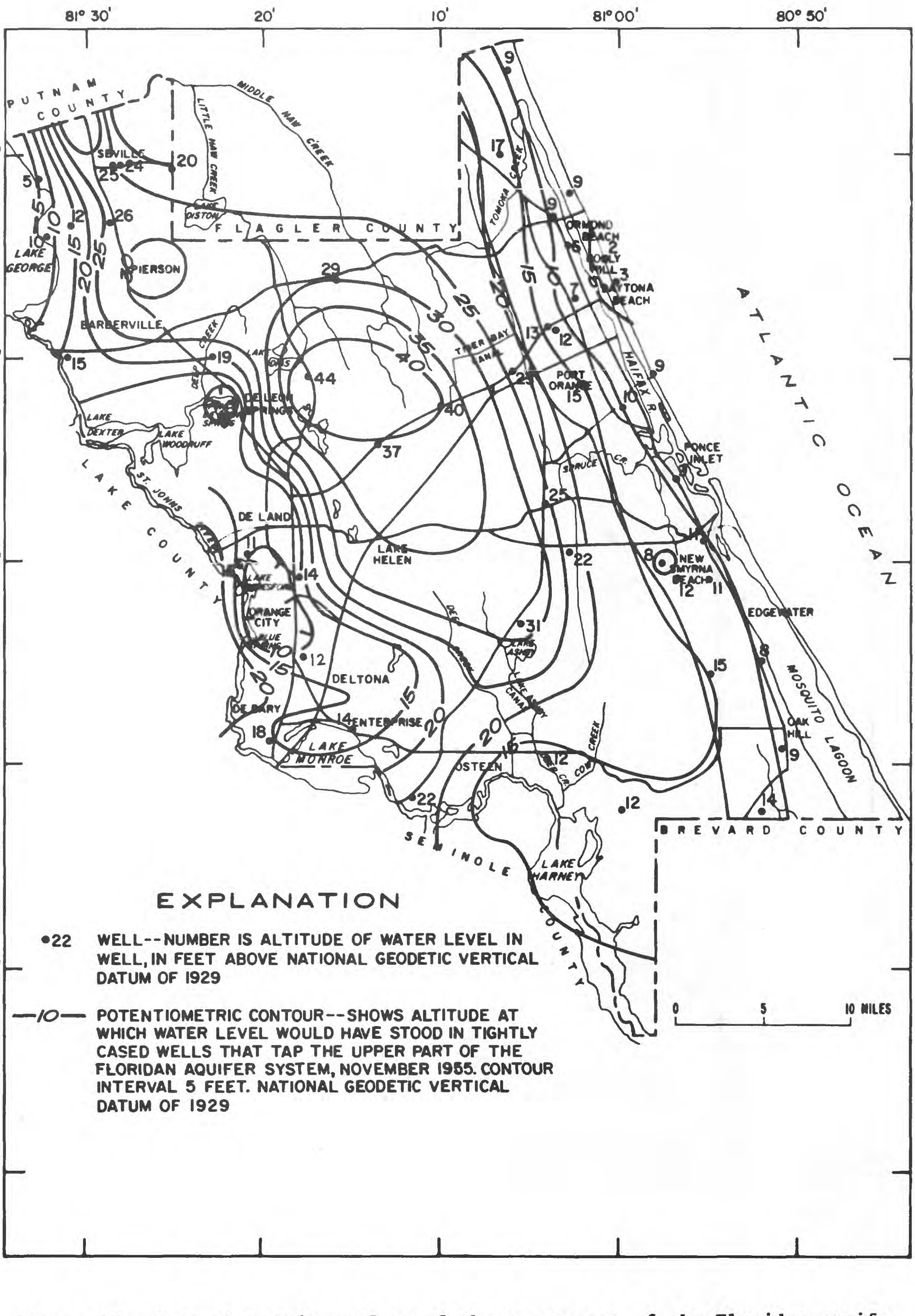

Figure 17.--Potentiometric surface of the upper part of the Floridan aquifer system, November 1955 (modified from Wyrick, 1960).

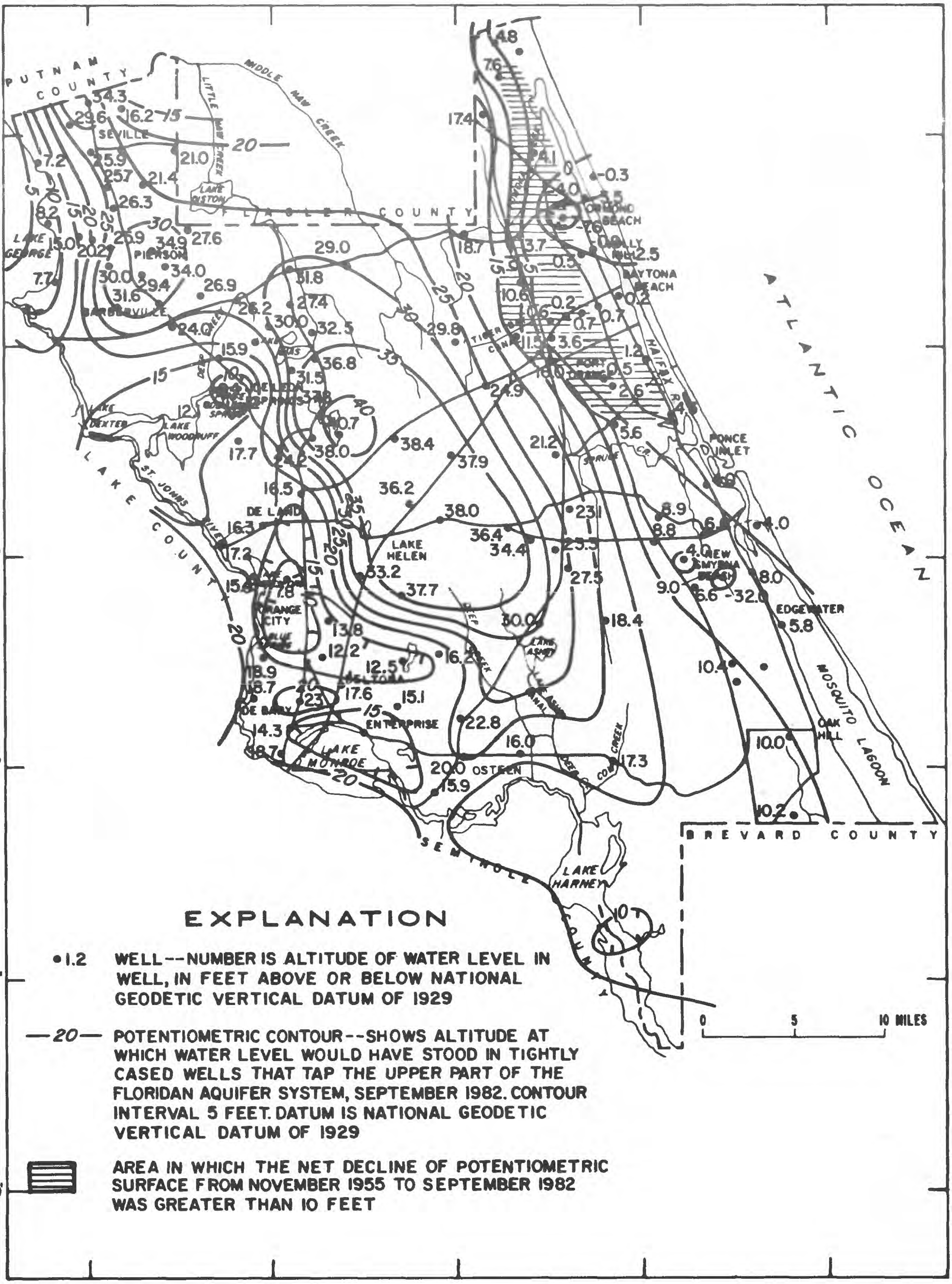

Figure 18.--Potentiometric surface of the upper part of the Floridan aquifer system, September 1982, and area in which the potentiometric surface declined more than 10 feet from November 1955 to September 1982.

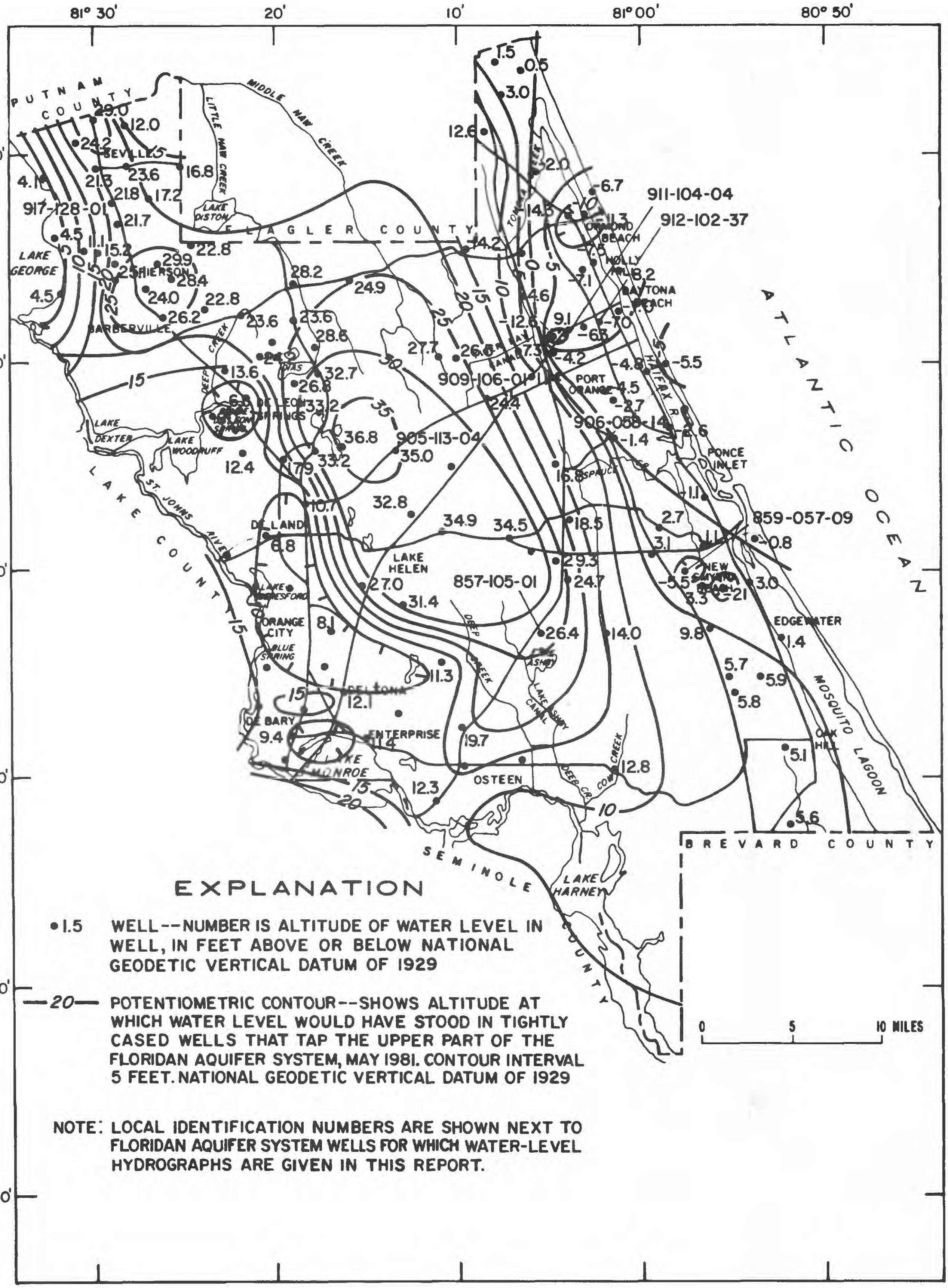

Figure 19.--Potentiometric surface of the upper part of the Floridan aquifer system, May 1981.

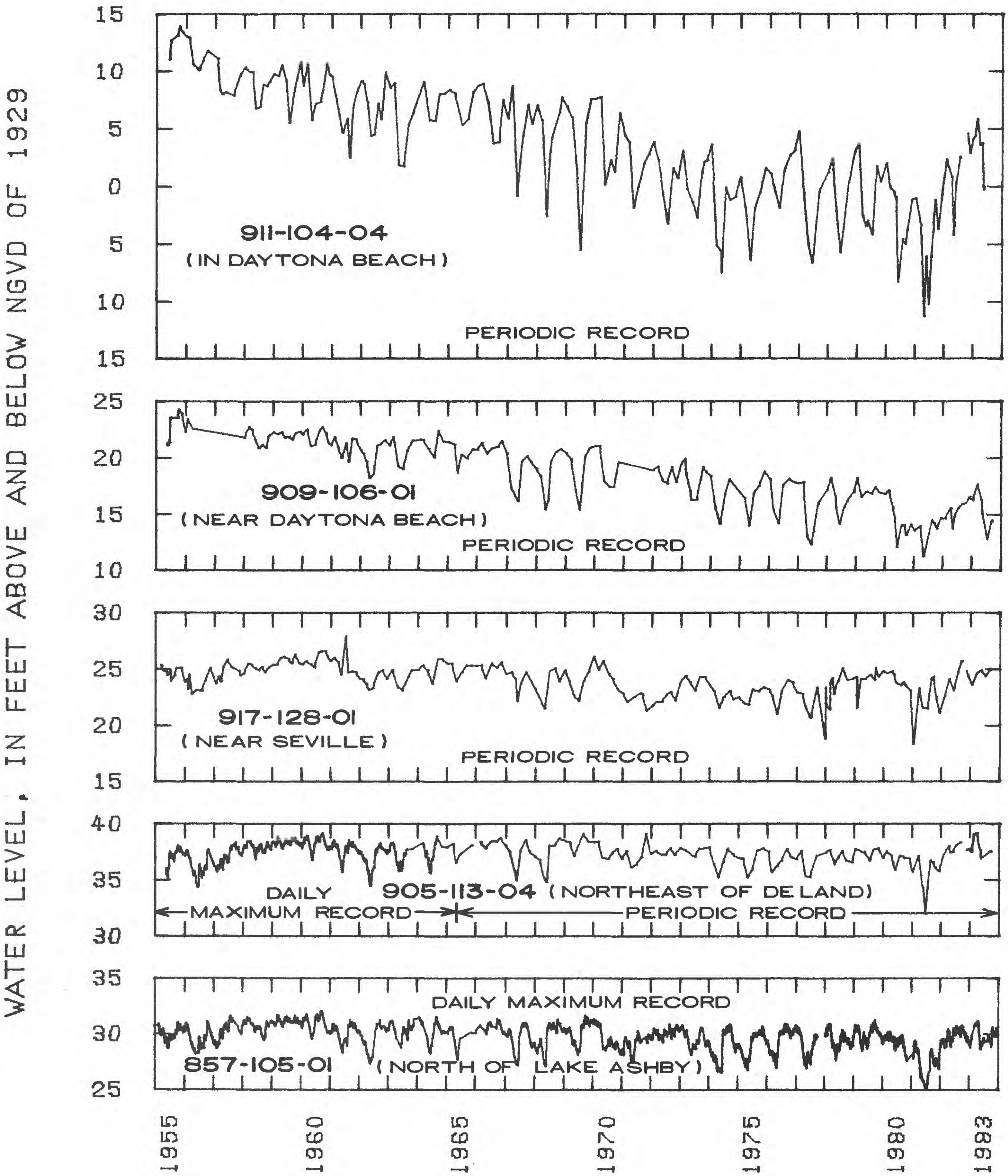

Figure 20.--Water-level records of five Floridan aquifer system wells, 1955-83 (well sites in fig. 19).

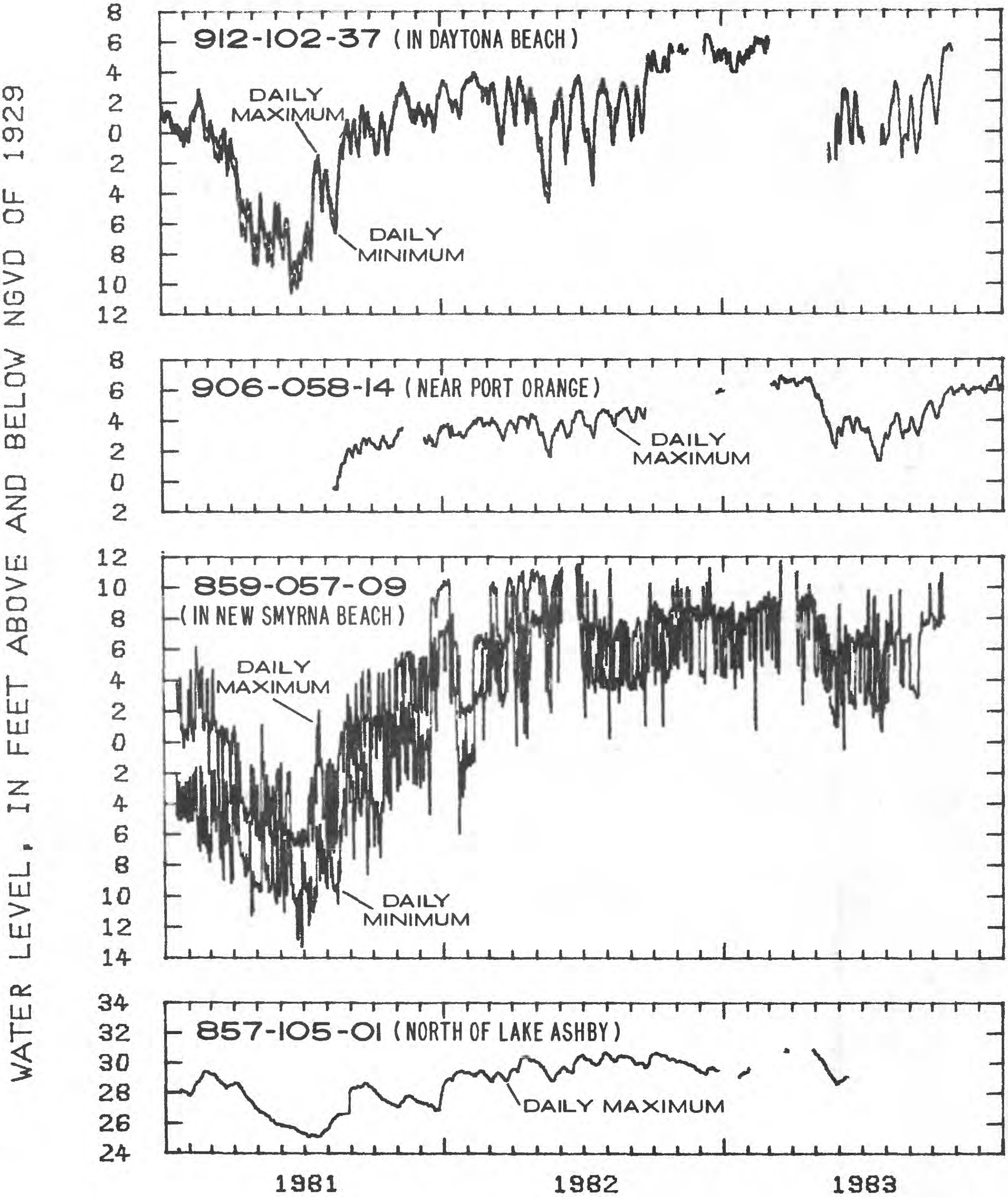

Figure 21.--Daily water levels in four Floridan aquifer system wells, January 1981-December 1983 (well sites in fig. 19).

WATER BUDGET

Surficial Layer

The surficial layer consists of the land surface, the lakes, streams, ditches, the surficial aquifer, and the vegetation. Generally, the surficial layer includes everything between the atmosphere and the confining layer. An assessment of the water budget of this layer aids the determination of the water budget of the Floridan aquifer system.

The water budget of the surficial layer may be expressed generally as:

$$R + LI + SI + RW = ET + LO + SO \quad (1)$$

where

R = rainfall;
LI = leakage inflow through a confining layer;
SI = stream inflow;
RW = return water from pumping of Floridan aquifer system;
ET = evapotranspiration;
LO = leakage outflow; and
SO = stream outflow.

Rainfall and Evapotranspiration

The average annual rainfall in Volusia County for the period 1951-80 was approximately 53 inches based on an average of five stations in and near Volusia County. The locations of five rain gages, and their corresponding 30-year average annual rainfall, are shown in figure 22. Rainfall comprises more than 95 percent of the inflow (recharge) to the surficial layer in Volusia County.

Evapotranspiration is the return of water from the land surface to the atmosphere. The average evapotranspiration for Volusia County is estimated at 39 inches per year based on values used by other investigators in central Florida. Lichtler and others (1968, p. 145) estimated that in Orange County, evapotranspiration is 70 percent of rainfall. Knochenmus and Beard (1971, p. 45) estimated an evapotranspiration rate of 35 inches per year in Volusia County based on a rainfall rate of 52 inches per year. Grubb and Rutledge (1979, p. 21) calculated an average evapotranspiration of 40 inches per year in the Green Swamp, an area about 40 miles southwest of Volusia County. The evapotranspiration rate is somewhat variable from place to place depending on the rainfall, the depth to the water table, and other factors such as vegetation type.

Streamflow

Streamflow is the second largest outflow from the surficial layer. Volusia County can be subdivided into three major surface drainage areas (fig. 22). One drains north to Middle Haw and Little Haw Creeks, one drains

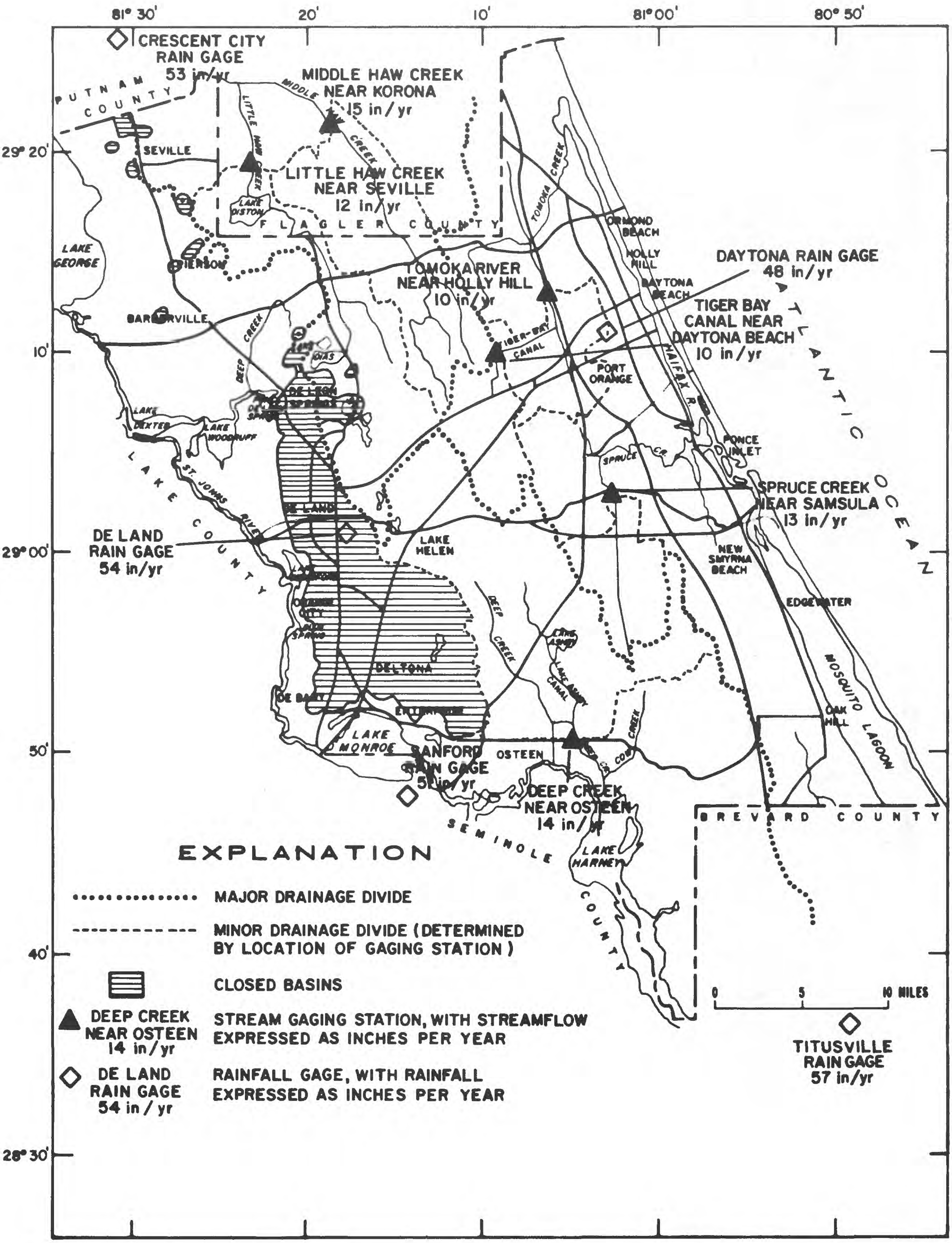

Figure 22.--Surface-drainage features, stream-gaging stations, and rain gages.

west into the St. Johns River, and the other drains seaward. Waters in the first two areas are separate in Volusia County, but eventually converge north of Volusia County near Palatka.

The locations of six continuous stream-gaging stations are shown in figure 22 along with the long-term streamflow rate, in inches per year, for the area upstream from each gage. These long-term streamflow rates are purported to represent the average flow during the 31-year period 1952-82. A 31-year record exists for Little Haw Creek near Seville and for Spruce Creek near Samsula. The records from these two sites were used as indices for estimating the long-term average discharges for the other stations. For example, the 7-year average discharge at Middle Haw Creek for 1976-82 was multiplied by the ratio of the 31-year average of Little Haw Creek over the 7-year average of Little Haw Creek for 1976-82 to obtain the 31-year average of Middle Haw Creek. The mean of the long-term average discharge estimated using Little Haw Creek as an index, and the long-term discharge estimated using Spruce Creek as an index, is the streamflow rate shown in figure 22. Table 3 shows measured average discharges for the six streams and shows long-term estimates of discharge for each.

The streamflow from a basin is influenced by the type of topography and surface hydrologic conditions in the basin. For example, a basin which includes more areas of artesian flow than ridges will have more streamflow than a basin that includes more ridges than areas of artesian flow. The topography-hydrology types and the characteristic streamflow rate for each may be as follows:

Topography-hydrology type	Estimated streamflow rate (in/yr)
Areas of artesian flow	18
Nonridge areas without artesian flow	11
Ridge areas with surface drainage	6
Ridge areas in closed basins	0

Streamflow is mostly outflow from the surficial layer in Volusia County because all significant surface-drainage systems in Volusia County have their headwaters within the county. There is, however, a slight eastward stream inflow from Flagler County into northeast Volusia County and a westward stream inflow from Brevard County into south Volusia County (fig. 22). The total area from which these streamflows originate is about 60 square miles, whereas the entire 1,200-square-mile area of Volusia County is contributing to stream outflow. If stream discharge per unit area is about the same for the three counties, then stream inflow is only about 5 percent of stream outflow.

Vertical Leakage

Although values for vertical leakage between the surficial aquifer and the Floridan aquifer system may be small, they are important in the understanding of the water budget of the two aquifers. Leakage is outflow from the surficial

Table 3.--Measured and estimated average streamflow for six gaging stations

Station	Measured average streamflow (ft^3/s) Water years (October through September) 1965-66	1979-82	1976-82	1965-82	1952-82	Estimated long-term average streamflow (ft^3/s) Index: Little Haw Creek	(ft^3/s) Index: Spruce Creek	(in/yr) Index: Little Haw Creek	(in/yr) Index: Spruce Creek	Drainage area (mi^2)
Middle Haw Creek near Korona	--	--	81.7	--	--	92.9	82.0	16.1	14.2	78.3
Little Haw Creek near Seville	78.1	66.7	74.9	80.4	85.2	85.2	--	12.4	--	93.0
Tomoka River near Holly Hill	--	--	--	55.2	--	58.5	58.3	10.3	10.3	76.8
Tiger Bay Canal near Daytona Beach	--	18.3	--	--	--	23.4	20.1	11.0	9.4	29
Spruce Creek near Samsula	22.8	29.5	32.3	30.7	32.4	--	32.4	--	13.2	33.4
Deep Creek near Osteen	113	--	--	--	--	123	161	11.9	15.6	140

layer in most of Volusia County, but also is inflow to the surficial layer in areas of artesian flow from the Floridan aquifer system.

The net leakage to the Floridan aquifer system may be estimated as rainfall minus evapotranspiration and streamflow. If it is assumed that rainfall and evapotranspiration are 53 and 39 inches per year, respectively, and that the average streamflow for the six basins shown in figure 22 is 12 inches per year, then the estimated leakage to the Floridan aquifer system in these basins is 2 inches per year. Leakage is estimated as a small residual that results after accounting for the other elements of the water budget. Rainfall and streamflow are measured but have error built in. Evapotranspiration is only estimated and is subject to greater error. Therefore, the errors in these components place a high degree of uncertainty in the leakage estimate.

Water Budget of the Surficial Layer

Table 4 gives estimates of the water budget of the surficial layer for four topography-hydrology types. Ridge areas in closed basins have rainfall and evapotranspiration rates that are slightly different from the others. Reported rainfall is slightly higher because most ridge areas in closed basins are located near the De Land rain gage which has an average rainfall of 54 inches per year. Evapotranspiration is lower because the depth to the water table is as much as 50 feet. Upward leakage from the Floridan aquifer is zero with the exception of one topography-hydrology type. Streamflow rates vary as estimated previously. Streamflow and downward leakage supplement each other in that an area of high streamflow will have low downward leakage, and an area of low streamflow will have high downward leakage. Additional components of the water budget are stream inflow, discussed earlier, and recharge to the surficial layer caused by Floridan aquifer system withdrawals, estimated as the total withdrawal from the Floridan aquifer system for irrigation and heat pump supply, from table 2.

The components of inflow and outflow for the entire Volusia County surficial layer are estimated as the areally-weighted averages of each inflow and outflow component in table 4. The annual water budget is thus 53 inches rainfall, 1 inch upward leakage from the Floridan aquifer system, 0.5 inch recharge from Floridan aquifer system withdrawals, and 0.5 inch stream inflow, counterbalanced with 39 inches evapotranspiration, 11 inches stream outflow, and 5 inches downward leakage to the Floridan aquifer system. As discussed earlier, these water-budget values are subject to considerable error.

Floridan Aquifer System

The purpose of this section is to assemble a water budget of the Floridan aquifer system in Volusia County. If transmissivity and potentiometric surface of the Floridan aquifer system are known, some of the recharge (inflow) rates previously estimated may be tested. Spring discharge rates are also used to

Table 4.--Estimated water budget of the surficial layer for each topography-hydrology type

[In inches per year]

Topography-hydrology type	Percent of study area	Inflow				Outflow		
		Rainfall	Upward leakage from Floridan aquifer system	Recharge from Floridan aquifer system withdrawals	Streamflow	Evapotranspiration	Streamflow	Downward leakage to Floridan aquifer system
Areas of artesian flow	28	53	4	0	0	39	18	0
Nonridge areas without artesian flow	47	53	0	0	1	39	11	4
Ridge areas with surface drainage	15	53	0	2	0	39	6	10
Ridge areas in closed basins	10	54	0	2	0	38	0	18

test these recharge estimates. Then, these tested recharge and discharge rates are placed into a budget of the Floridan aquifer system along with estimates of horizontal inflow and outflow rates derived from the transmissivity estimates.

The equation for the water budget of the Floridan aquifer system is a modified version of equation 1:

$$LI + HI = LO + HO + P + FW + SPG \qquad (2)$$

where

HI = horizontal ground-water inflow;
HO = horizontal ground-water outflow;
P = pumpage;
FW = flowing well discharge;
SPG = spring discharge;

and other terms are as previously defined.

Specific Capacities

The specific capacity of a well is related to transmissivity of the penetrated aquifer. The specific capacity is the ratio of pumping rate from a well to the drawdown in the well. Because transmissivity is a characteristic of the entire aquifer thickness, and because most wells penetrate only a fraction of that thickness, it is necessary to adjust data to estimate the specific capacity of fully-penetrating wells. This may be done by dividing the specific capacity of each well by the length of well that is open to the aquifer, then multiplying this ratio by the aquifer thickness to estimate the specific capacity that would have been obtained had the well penetrated the entire thickness of the aquifer. It is assumed that the aquifer contributes water to the well uniformly from top to bottom.

Ratios of specific capacities to lengths of open hole are shown in figure 23. All wells shown are at least 6 inches in diameter and all but one are used for public supply or irrigation. Although these values vary, it is possible to discern general areal trends. Five physiographic areas and the average ratio from figure 23 are as follows:

Area	Average ratio of specific capacity to length of open hole, in gallons per minute per foot per foot
Crescent City Ridge	0.3
De Land Ridge	1.9
Talbot Terrace and Rima Ridge	0.5
Pamlico Terrace and Atlantic Coastal Ridge	1.5
Coastal areas	1.3

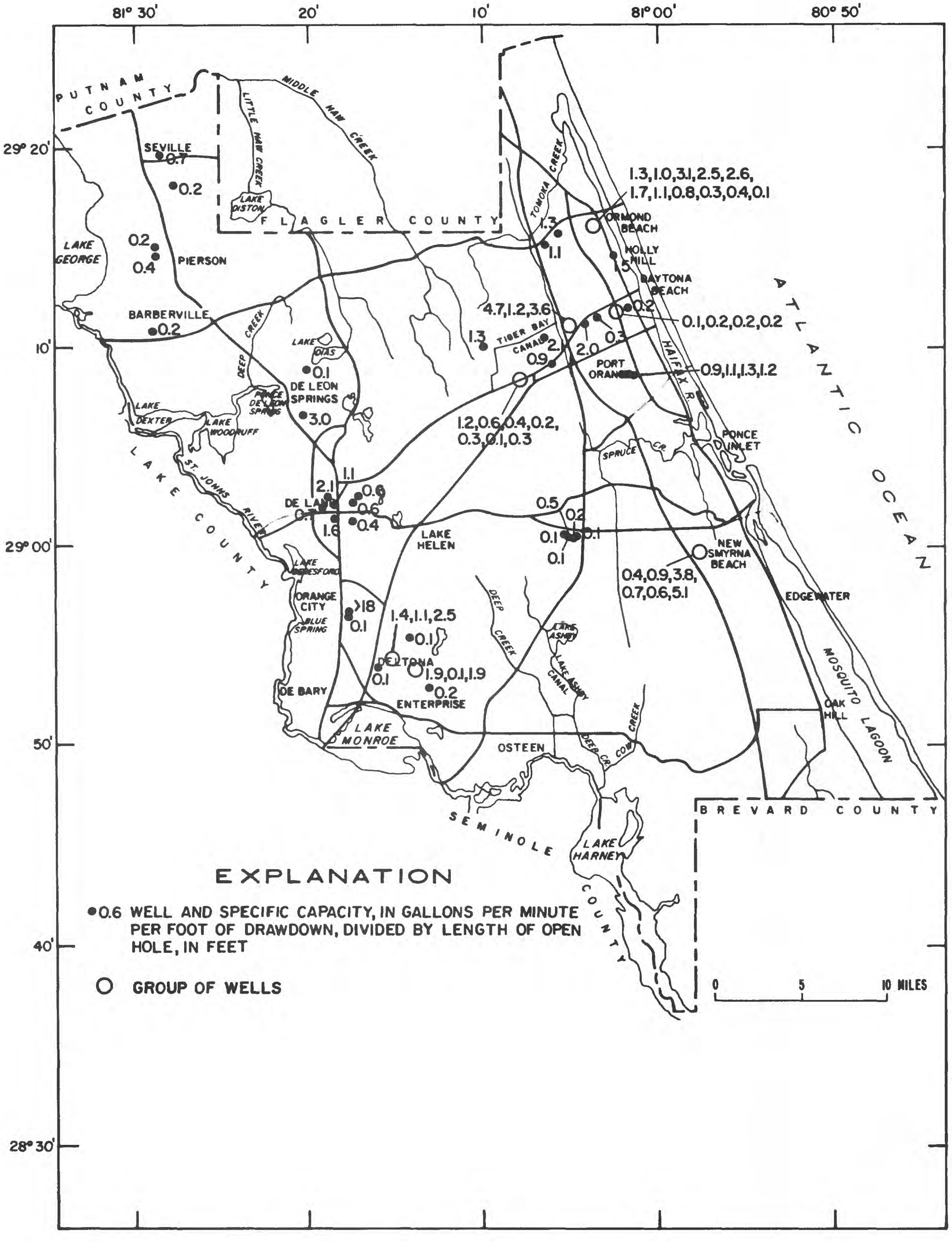

Figure 23.--Ratios of specific capacity to length of open hole for Floridan aquifer system wells of 6-inch and larger diameters.

If it is assumed that the Floridan aquifer system is an isotropic, homogeneous, and nonleaky aquifer, then the specific capacity of wells fully penetrating the aquifer is related to transmissivity by the following:

$$\frac{Q}{s_w} \approx \frac{4\pi T}{2.30 \log_{10} 2.25Tt/r_w^2 S} \quad \text{(from Lohman, 1979, p. 52)} \qquad (3)$$

where

- T = transmissivity (feet squared per day);
- S = storage coefficient (dimensionless);
- Q = discharge rate from pumping well (cubic feet per day);
- t = time after discharge started (days);
- s_w = drawdown at production well, (feet); and
- r_w = radius of production well, (feet).

The equation shows that specific capacity, Q/s_w, is nearly proportional to T at a given value of t, but gradually diminishes as t increases by the amount $1/\log_{10}t$. The value of transmissivity calculated for a given test is sensitive to specific capacity but relatively insensitive to values of t, r_w, and S. Some error is built into this analysis because leakage is not considered and because some of the assumptions about the aquifer's properties may not be accurate. If it is assumed that t = 0.03 day, that r_w = 1 foot, that S = 0.0005, and that the aquifer thickness is that of the upper permeable zone of the Floridan aquifer system as defined by Miller (1981), which is 300 feet in Volusia County, then the relation between the ratio derived above and transmissivity is as follows:

Average ratio of specific capacity to length of open hole, in gallons per minute per foot per foot	Transmissivity, in ft^2/d
0.5	35,000
1.0	74,000
1.5	114,000

Testing Estimates of Flow in the Floridan Aquifer System Against Recharge Estimates

The flow within an aquifer may be compared to the net recharge (leakage) estimated for areas upgradient to determine if estimates of recharge rates are realistic. Figure 24 shows four areas for which these comparisons are made. The flow rates from areas 2, 3, and 4 are measured discharges from springs, and that of area 1 is determined from hydraulic gradient and transmissivity.

If the head gradient across the outflow boundary of a recharge area is known and the transmissivity at that boundary is also known, then the average recharge rate for the area may be calculated. Considering area 1 as an area bounded by a ground-water divide on the west and by an outflow line on the

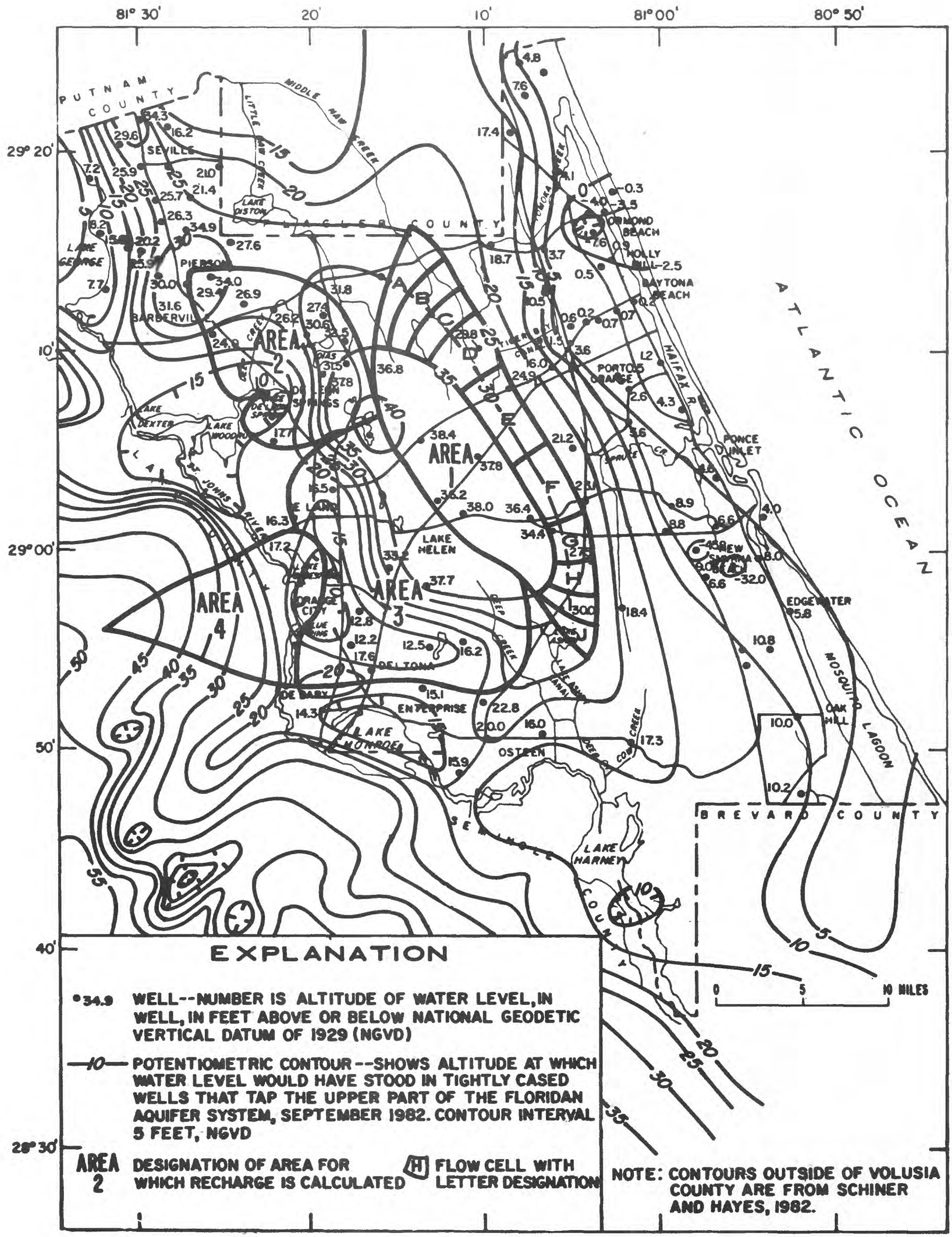

Figure 24.--Potentiometric surface of the upper part of the Floridan aquifer system, September 1982, and four drainage areas for which flow analyses are given.

east, the outflow line may be subdivided into segments A through J for the purpose of calculating outflow. The flow through each segment may be calculated from the expression:

$$Q = T\ I\ L \tag{4}$$

where

Q = rate of flow perpendicular to a potentiometric contour, in cubic feet per day;
T = transmissivity of the aquifer in feet squared per day;
I = hydraulic gradient approximated as the change in head between the two contours, in feet, divided by the distance between the two contours, in feet; and
L = width of the segment midway between contours, in feet.

Because this outflow line is on the Rima Ridge and the Talbot Terrace, where the average ratio of specific capacity to length of open hole is 0.5 gallons per minute per foot per foot, the average transmissivity is estimated as 35,000 ft^2/d. Total flow through segments A through J is thus 31.4 ft^3/s. Because the area upgradient is 99 mi^2, this rate corresponds to an average net recharge inflow to the Floridan aquifer system of 4.3 in/yr.

Area 1 consists of 6 percent areas of artesian flow, 92 percent nonridge areas without artesian flow, and 2 percent ridge areas having surface drainage. The weighted-average net recharge calculated using table 4 is 3.6 in/yr, which compares reasonably with the 4.3 in/yr calculated from flow in the Floridan aquifer system.

Area 2, which is the drainage area of Ponce de Leon Springs, consists of 38 percent areas of artesian flow, 19 percent nonridge areas without artesian flow, 21 percent ridge areas with surface drainage, and 22 percent ridge areas in closed basins. Using the estimates in table 4, the weighted-average net recharge is 5.3 in/yr. For a 76-square-mile area, total flow is 30 ft^3/s. This is equal to the measured long-term average discharge of Ponce de Leon Springs.

The drainage area of Blue Springs is divided into areas 3 and 4 so that the flow which originates in Volusia County may be separated from that which originates predominantly in Lake County. Area 3 is 138 mi^2 consisting of 1 percent areas of artesian flow, 29 percent nonridge areas without artesian flow, 12 percent ridge areas having surface drainage, and 58 percent ridge areas in closed basins. The weighted-average recharge, 12.8 in/yr, is equivalent to a flow of 130 ft^3/s. Most of the 59 mi^2 in area 4 are in Lake County, but 7 mi^2 are ridge areas in closed basins in Volusia County. This latter area yields 9.4 ft^3/s of recharge whereas the remaining area yields only 4.7 ft^3/s because most of it is an area of artesian flow in the St. Johns River basin. The net recharge calculated for areas 3 and 4 is thus 144 ft^3/s, which compares reasonably to the long-term average discharge of Blue Springs, 161 ft^3/s. It is assumed in this analysis that all recharge is discharged by the local spring. It is possible that some of this recharged water is moving downward to more distant points of discharge, or that water recharged outside of the study area is entering this ground-water basin.

Water Budget of the Floridan Aquifer System

Table 5 gives the estimated flow budget of the Floridan aquifer system in Volusia County. Leakage figures were derived from the rates given in table 4 which have been substantiated by analyses of flow in the Floridan aquifer system. The figure for spring discharge is the sum of discharges from Blue Springs, Ponce de Leon Springs, and 8 ft^3/s for two small springs near Lake Monroe. The discharge from flowing wells is an estimate. Pumpage is equal to the 1980 water-use rate. The horizontal flow into and out of Flagler County and the horizontal flow into the Atlantic Ocean were calculated from the equation Q = T I L. Finally, the horizontal inflow and outflow at "other boundaries" was estimated. These boundaries are the east shore of Lake George and Lake Harney, the north shore of Lake Monroe, and the Lake County, Seminole County, and Brevard County boundaries. These flow rates through "other

Table 5.--Estimated water budget of the Floridan aquifer system in Volusia County

Inflow	Cubic feet per second	Inches per year
Downward leakage	460	5.2
Horizontal inflow:		
From Flagler County	20	0.23
From other boundaries	50	0.57
Total	530	6.0
Outflow	**Cubic feet per second**	**Inches per year**
Upward leakage	100	1.1
Spring discharge	190	2.1
Flowing-well discharge	20	0.23
Pumpage	100	1.1
Horizontal outflow:		
To Atlantic Ocean	30	0.34
To Flagler County	10	0.11
To other boundaries	80	1.0
Total	530	6.0

boundaries" were calculated as residuals to the other components. The estimated annual water budget of the Floridan aquifer system in Volusia County thus consists of 5 inches downward leakage inflow, 1 inch upward leakage outflow, 1 inch horizontal inflow, 1.5 inches horizontal outflow, 2.5 inches discharge from springs and flowing wells, and 1 inch pumpage. These water-budget figures are subject to considerable error. The largest component of this budget, leakage, was derived as a residual in the budget of the surficial aquifer, and that budget was constructed from other estimates.

CONCEPTS OF BRACKISH WATER OCCURRENCE AND MOVEMENT

Baseline Salinity

Chloride concentration is used in this report as the index of salinity because chloride ions make up the largest component of the total salinity of seawater and because chloride analysis is a relatively simple laboratory determination. Most naturally occurring waters have chloride in some amount. For this report, water having a chloride concentration less than 50 milligrams per liter (mg/L) is considered freshwater. If the concentration is about 19,000 mg/L, the water has a salt concentration close to that of the ocean, and is considered saltwater. Waters having chloride concentrations intermediate between these extremes may be considered brackish.

Fresh ground water in Volusia County contains some of the salts present in the ocean. This mixture probably exists because salt-laden aerosols from the ocean precipitate on land. Ground water also contains constituents dissolved from the rocks and the soil.

Values of chloride concentration in water from individual sites not exhibiting intrusion may vary because of seasonal effects. Figure 25 shows variations in the chloride concentration in water from freshwater wells. Most fresh ground water in Volusia County has a chloride concentration exceeding 10 mg/L and varying within a range of 10 mg/L. Figure 26 shows variations in chloride concentrations in brackish water wells. The records shown, with the exception of the record for 911-059-02, exhibit changes caused by seasonal fluctuations, as opposed to changes caused by a trend. Many records vary in such a way that the maximum is more than twice as much as the minimum.

Chloride Concentration Change Ratio

The terms "brackish water movement" or "intrusion" used herein, refer to a significant increase in chloride concentration, with time, at given monitoring sites. Intrusion may be assessed by comparing chloride concentrations in water from wells during 1951-57 with data collected from the same wells during 1977-82 as follows:

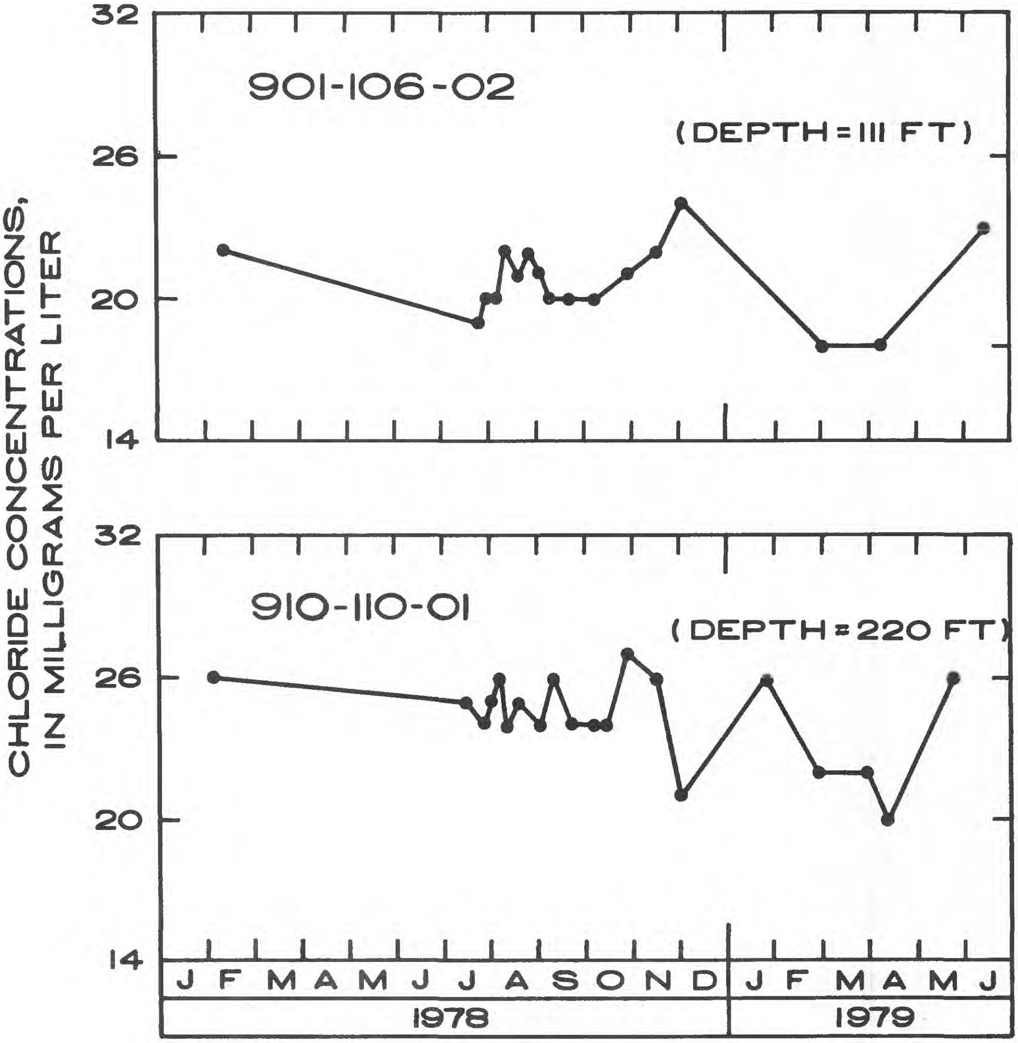

Figure 25.--Periodic records of chloride concentration in water from Floridan aquifer system wells that have not been used for public supply, January 1978-June 1979 (well sites in fig. 30).

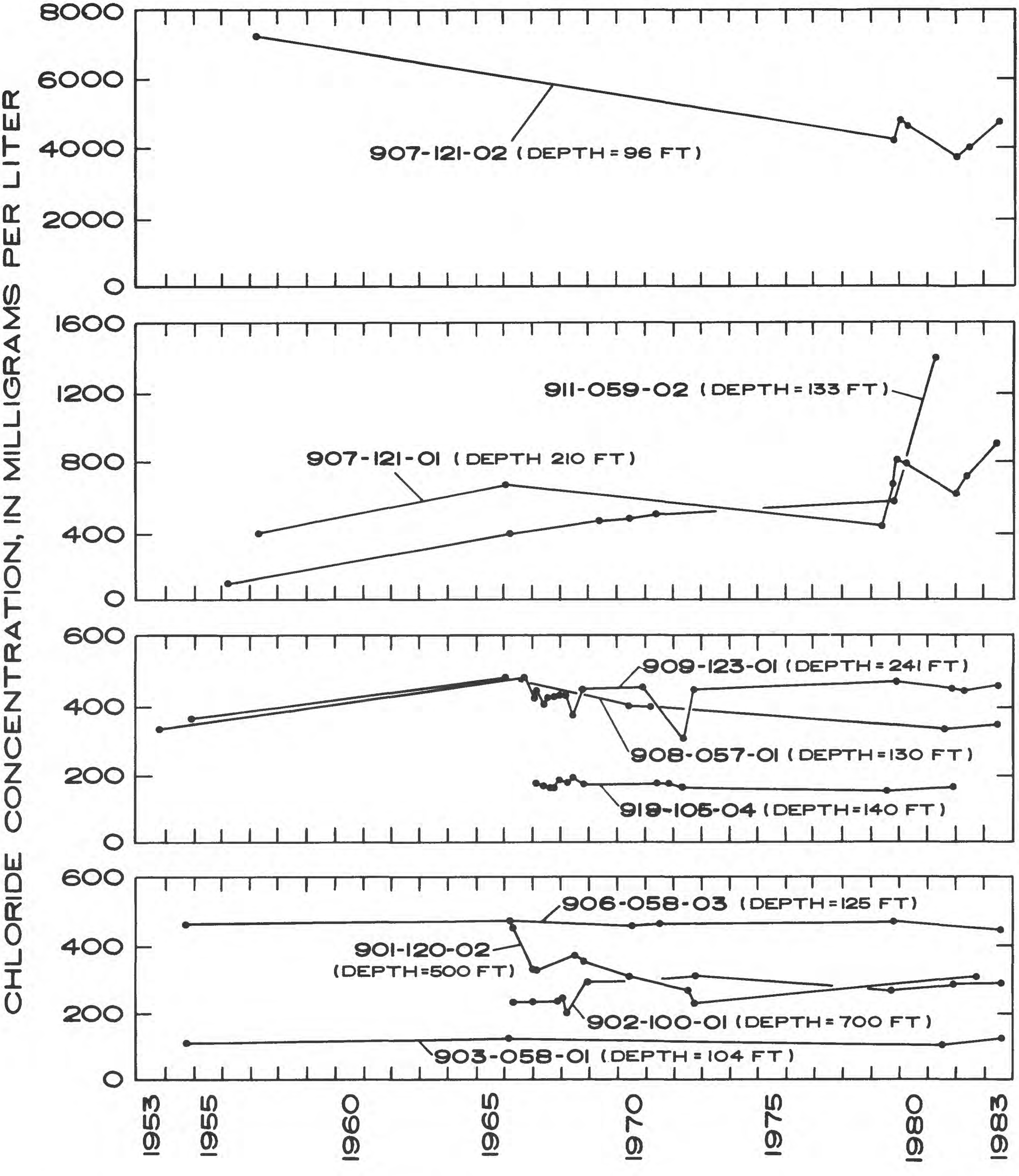

Figure 26.--Periodic records of chloride concentration in water from Floridan aquifer system wells that have not been used for public supply, 1953-83 (well sites in fig. 30).

$$\text{chloride concentration change ratio} = \frac{F(C_n - C_t)}{\frac{C_n + C_t}{2}} \quad (5)$$

where

C_n = chloride concentration now (1977-82), in milligrams per liter;

C_t = chloride concentration then (1951-57), in milligrams per liter; and

$F(C_n-C_t)$ = C_n-C_t-10, if C_n-C_t is greater than +10

= C_n-C_t+10, if C_n-C_t is less than -10

= zero, if C_n-C_t falls in the -10 to +10 range

This ratio is more meaningful than a simple ratio of concentration change over average concentration because the latter ratio would be the same for a change of 10 to 20 mg/L as it would for a change of 1,000 to 2,000 mg/L, which is much more significant.

If the chloride concentration change ratio exceeds +0.5 or falls below -0.5, then the change is probably larger than that which can be attributed to seasonal variations. Changes thus described may be evidence of intrusion or freshening.

Physical Nature of Freshwater-Saltwater Interface

In coastal aquifers within Volusia County, the freshwater is bounded by saltwater laterally and vertically. The theoretical altitude of the freshwater-saltwater interface may be calculated using the Ghyben-Herzberg principle as modified by Hubbert (1940). This principle states that when freshwater in a coastal aquifer is in equilibrium with the underlying saltwater, the altitude of the interface between them is -40 times the head of the freshwater system immediately above the interface. Because the freshwater head immediately above the interface differs from the head that is measured in wells that tap the upper parts of the aquifer, and because the saltwater system is usually not static, estimates of the altitude of the interface are subject to error. It is reasonable to assume, though, that the position of the interface becomes lower as the measured water level in the upper part of the aquifer increases.

Figure 27a shows that the transition from freshwater to saltwater is a zone of mixing which contains brackish water. This transition zone is formed because of mixing caused by water-level fluctuations and dispersion. Generally, the thickness of this zone becomes greater as the vertical component of ground-water flow increases. Figure 27b shows, conceptually, the movement of the transition zone caused by pumping.

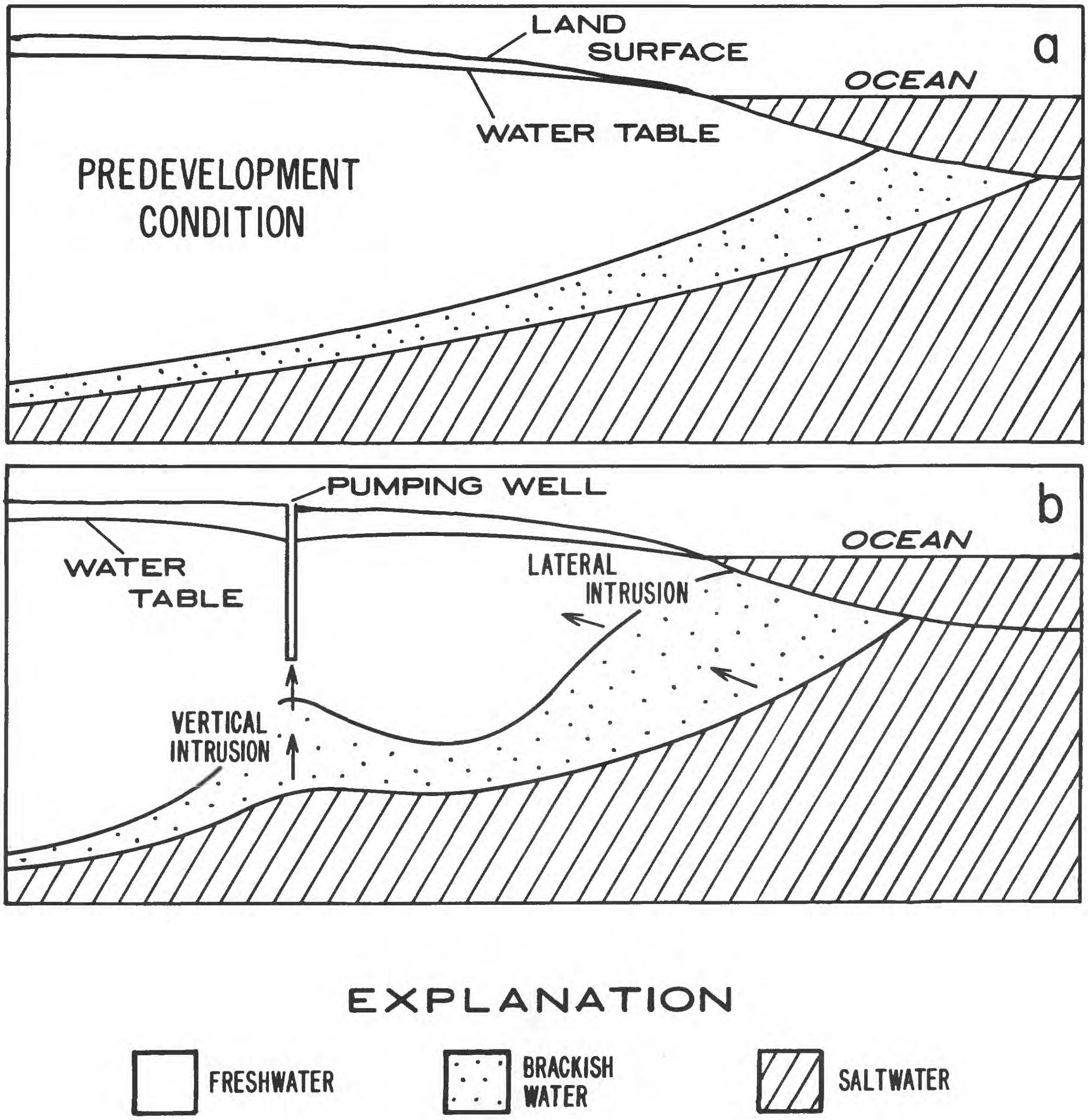

Figure 27.--Conceptual cross sections showing the occurrence of brackish ground water and the movement of brackish water caused by pumping.

BRACKISH WATER IN THE SURFICIAL AQUIFER

Present Distribution

Most of the surficial aquifer in Volusia County contains freshwater. Figure 28 shows that the barrier island is generally the only area where chloride concentrations exceed 250 mg/L. Brackish water occurs in coastal areas and, to a lesser extent, in the St. Johns River valley area. The areal distribution of chloride concentrations shown in the figure was obtained from samplings of approximately 70 wells. Most wells sampled are in coastal areas.

In freshwater zones of the surficial aquifer, the water is considerably less mineralized than water in the freshwater zones of the Floridan aquifer system. Most of the freshwater in the surficial aquifer is a calcium bicarbonate-type water, although sodium and chloride are locally prevalent. Figure 29 shows average ionic compositions for eight surficial-aquifer wells in the central Volusia County area, where the dissolved solids concentration of water from the surficial aquifer is approximately one-third of that from the upper part of the Floridan aquifer system in the same area. The brackish water in the surficial aquifer is a sodium chloride-type water that is less mineralized than the brackish water in the Floridan aquifer system at the same location. Sodium chloride and calcium bicarbonate concentrations are less in the surficial aquifer than in the Floridan aquifer system.

Comparison of Past and Present

Chloride-concentration change ratios for 10 surficial aquifer wells are shown in figure 28. Depths of these wells are 12 to 45 feet. Four ratios are above +0.5, one is below -0.5, and five are between -0.5 and +0.5. The four that exceed +0.5 are on the barrier island north of Ormond Beach and indicate that intrusion is apparently occurring there. The meaning of the one value below -0.5 is somewhat dubious because the well had a measured depth of only 14 feet in 1981 versus the 40 feet reported depth. The five wells for which the chloride concentration change ratio was insignificant (between -0.5 and +0.5) are all located in areas where the surficial aquifer has freshwater.

It is apparent that intrusion is occurring in the surficial aquifer on the barrier island. Unfortunately, no surficial aquifer wells sampled during 1951-57 are currently available for resampling south of Ormond Beach on the barrier island. This is because the few that were sampled then were destroyed or covered before this study.

BRACKISH WATER IN THE FLORIDAN AQUIFER SYSTEM

Present Distribution

Figure 30 shows the distribution of brackish water in the upper part of the Floridan aquifer system derived from sampling approximately 250 wells during 1977-82. Depths of these wells are 50 to 400 feet. The Floridan

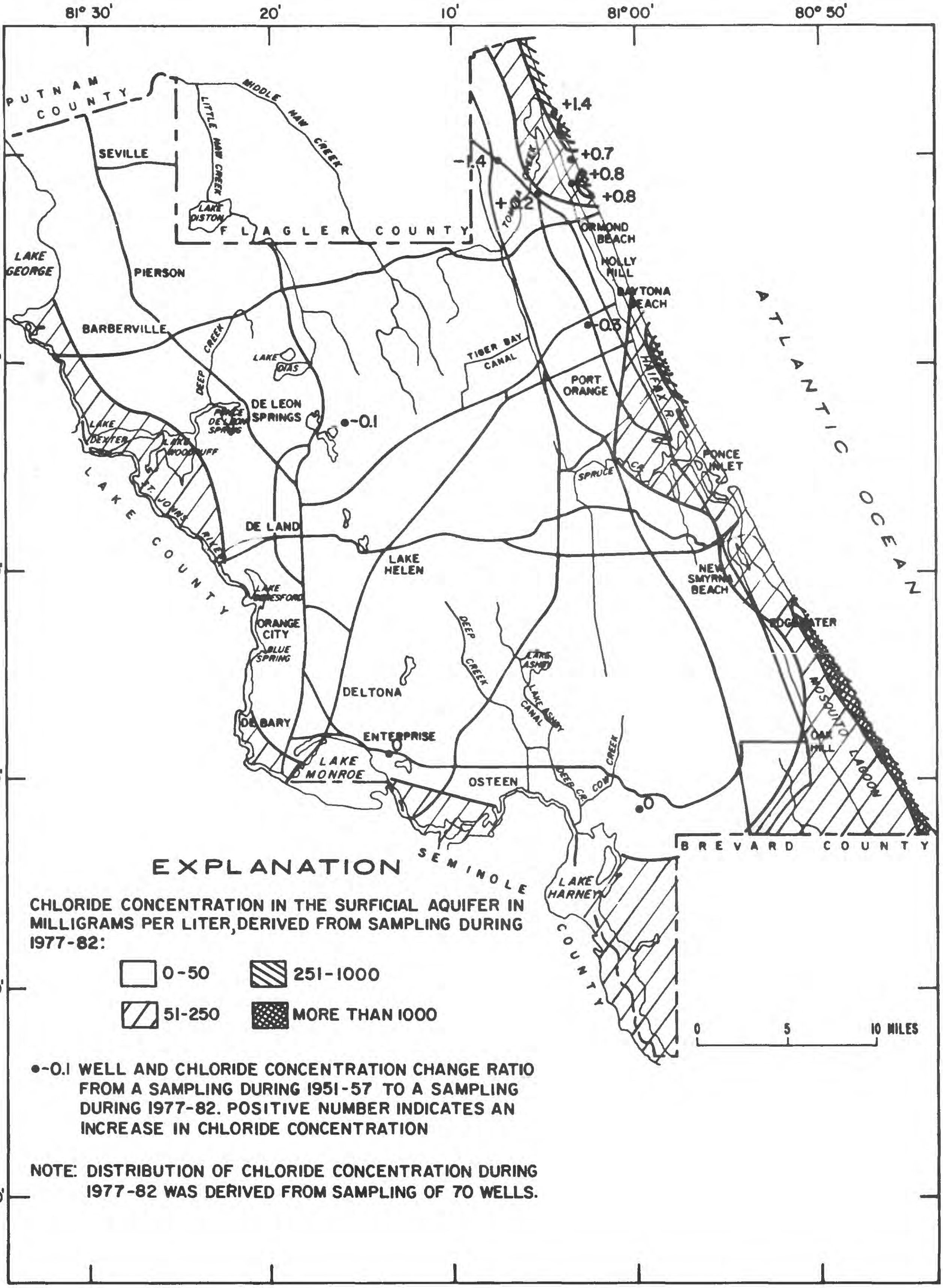

Figure 28.--Chloride concentration in the surficial aquifer and chloride concentration change ratios for water from wells that tap the surficial aquifer.

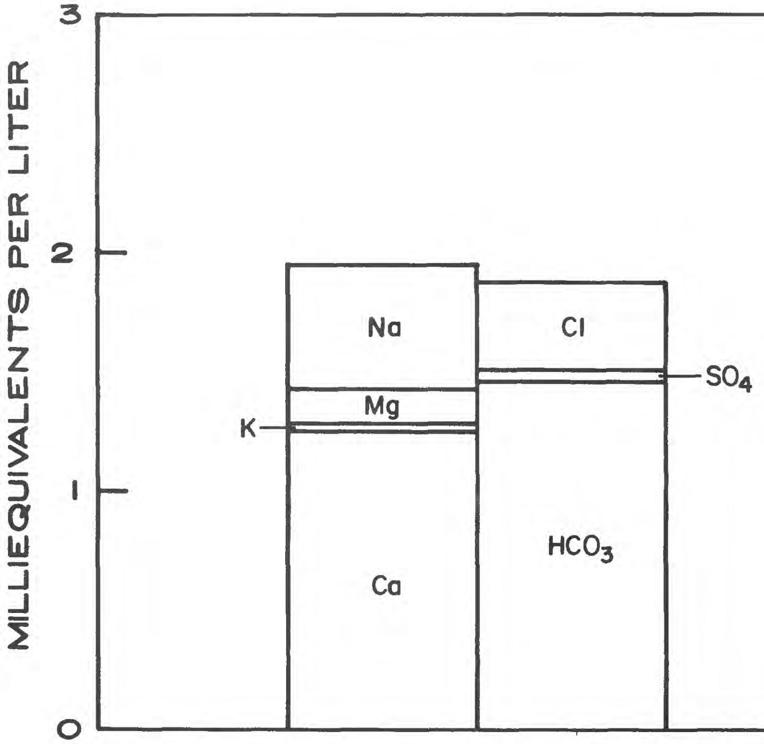

Figure 29.--Average ionic composition of water from eight surficial-aquifer wells in central Volusia County.

aquifer system is generally more brackish than the surficial aquifer. Areas of highest salinity are in the St. Johns River valley and in the coastal areas and tend to coincide with areas of artesian flow (fig. 5). In coastal Volusia county, water is least brackish in the vicinity of Daytona Beach.

Figure 31 shows the thickness of the zone in the Floridan aquifer system in which chloride concentrations are less than 250 mg/L. Much of this was constructed from estimates of the altitude of the freshwater-saltwater interface using the Ghyben-Herzberg principle, as modified by Hubbert (1940). The November 1955 potentiometric surface (fig. 17) was used in conjunction with a knowledge of the way hydraulic head changes with depth in the freshwater flow system to estimate this altitude. The areas shown in figure 31, where the chloride concentration in the upper Floridan exceeds 250 mg/L, were taken from figure 30. Some data from test drilling contributed to figure 31. The maximum thickness of this zone containing fresh or slightly brackish water is located beneath the Talbot Terrrace (fig. 1).

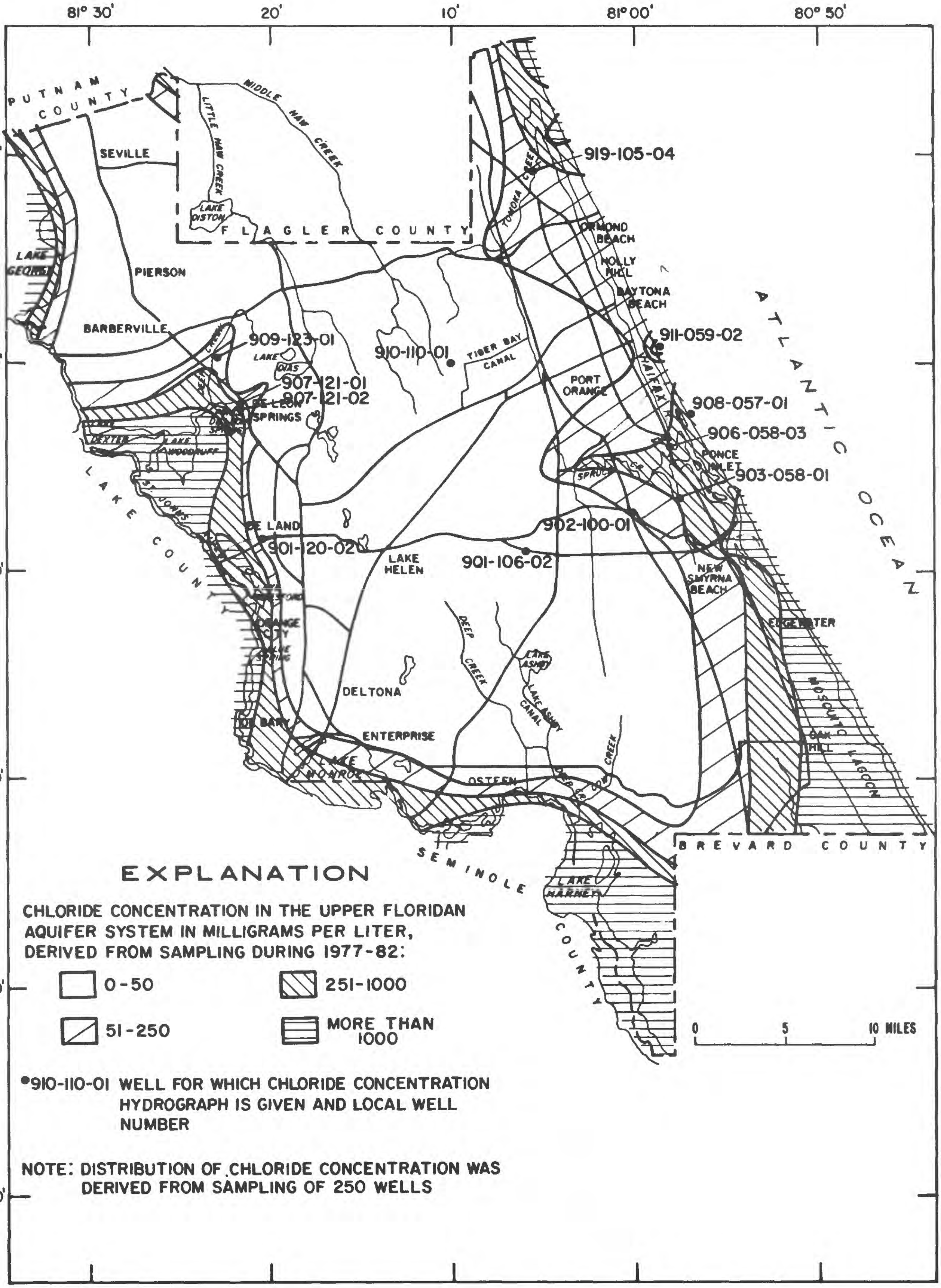

Figure 30.--Chloride concentration in water from wells that tap the upper part of the Floridan aquifer system.

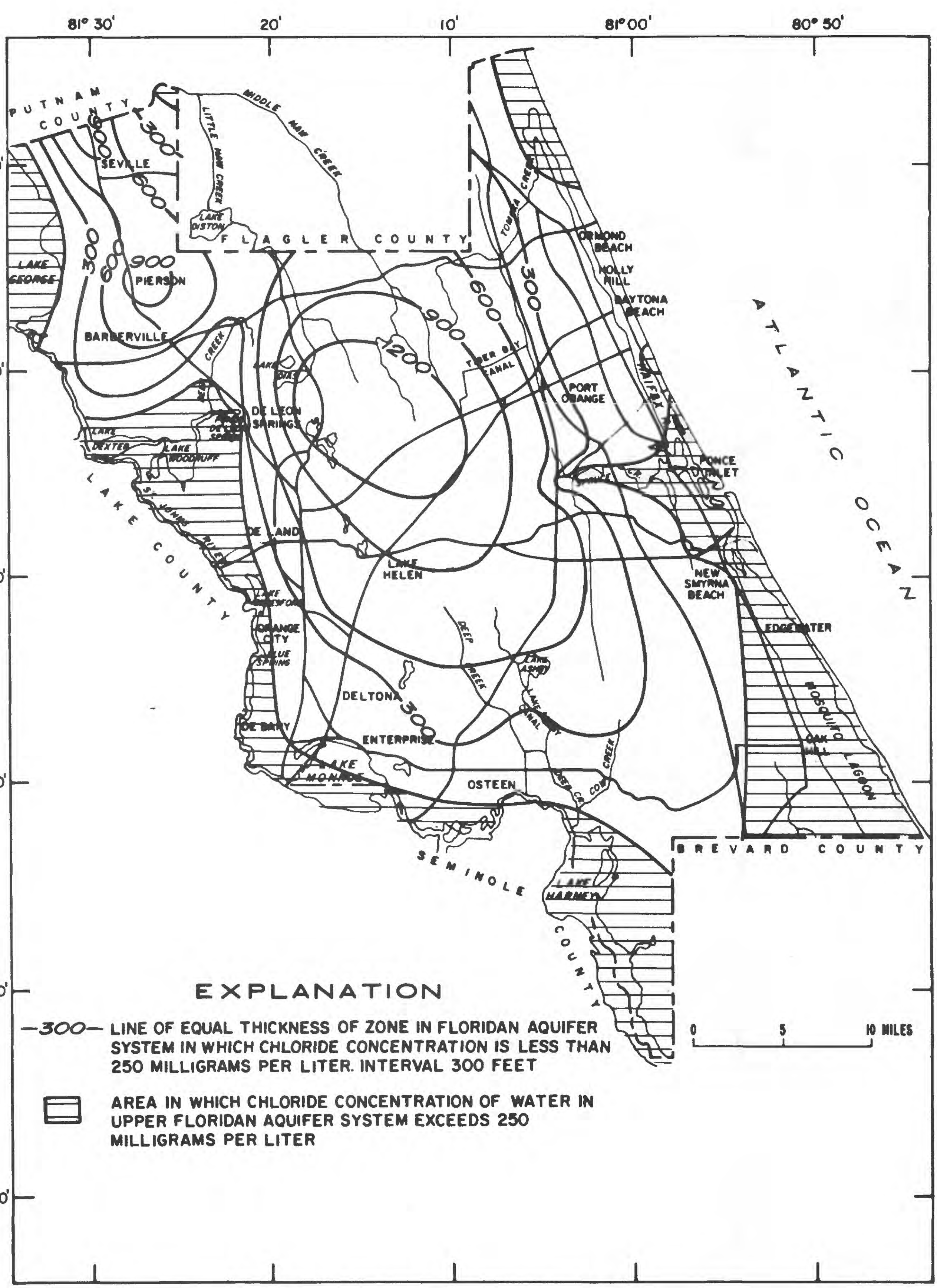

Figure 31.--Estimated maximum thickness of zone in the Floridan aquifer system in which the water is fresh or slightly brackish.

Average ion concentrations of water from Floridan aquifer system wells in three different parts of the Volusia County ground-water system are shown in figure 32, and the locations of the wells used are in figure 33. The three water types shown are the brackish water in the St. Johns River area, the brackish water of the coastal areas, and the freshwater in between. All three have a calcium bicarbonate "background" caused by dissolution of the limestone that makes up the aquifer. This dissolution causes freshwater in the Floridan aquifer system to be more mineralized than freshwater in the surficial aquifer. Superimposed upon this calcium bicarbonate background is a mixture of the salts found in seawater. This mixture is very dilute in the freshwater in central Volusia, (calcium bicarbonate-type water) and is stronger for the two brackish-water areas (sodium chloride-type water). The ratio of calcium ions to bicarbonate ions is about 1 for fresh ground water but is noticeably higher for brackish water in the Floridan. The reason for this may be that cation exchange is taking place. The sodium and magnesium ions in the brackish waters are switching places with calcium ions in the limestone, thus creating a higher calcium to bicarbonate ratio in the water.

The ratio of sodium to chloride ions in freshwater in central Volusia, 1.00, is equal to that of table salt and that of brackish areas is nearly that of seawater, 0.85. The ratio of sodium to chloride in brackish Floridan aquifer system water is actually slightly smaller than that of seawater because of the cation exchange previously mentioned.

The sulfate concentration in coastal brackish ground water is disproportionately low compared to the concentration in the St. Johns River basin brackish ground water and seawater. The ratio of sulfate to chloride ions is 0.042 for the former type and 0.10 for the latter two water types. The reason for these differences is unclear; a possibility is that sulfate reduction is occurring preferentially in coastal ground water.

Comparison of Past and Present

Chloride concentrations in the past were compared with recent concentrations to determine brackish water trends in the Floridan aquifer system. This analysis is separated into two parts--one for wells that have not been used for public supply and another for wells that have been so used. The latter category includes abandoned public-supply wells. Public-supply wells are discussed separately because results found for public-supply wells were markedly different from results found for other wells.

Nonpublic-Supply Wells

Ranges of chloride-concentration change ratios for 154 wells are shown in figure 34. Most wells sampled are in areas where the Floridan aquifer system contains brackish water. If change ratios indicating a significant change are those above or equal to +0.5 and below or equal to -0.5, then 10 wells showed a significant increase and 11 showed a significant decline. Neither group exhibited distinct areal trends. A few generalizations may be made, however: five

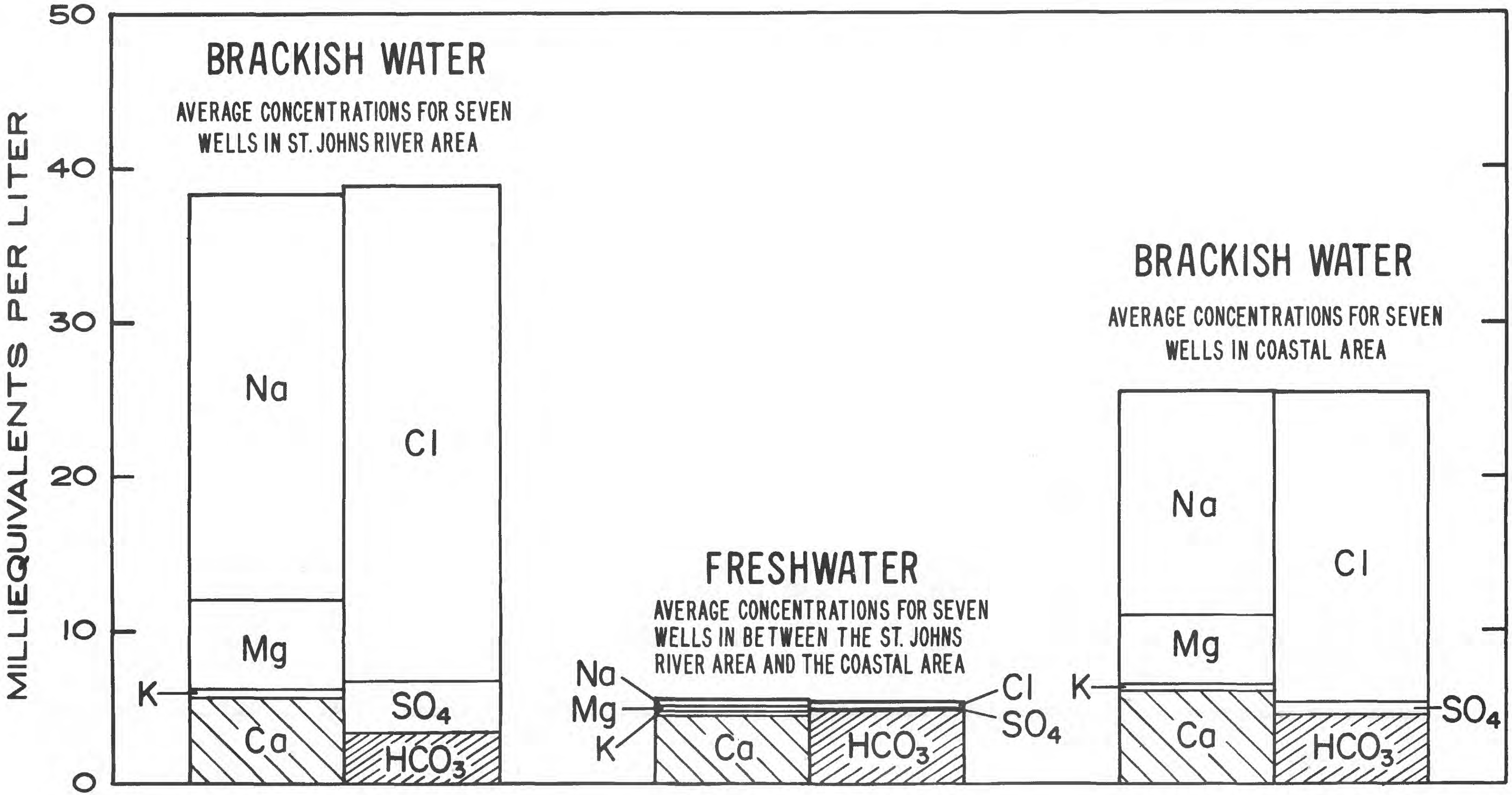

Figure 32.--Average ionic compositions of water in three parts of the Floridan aquifer system.

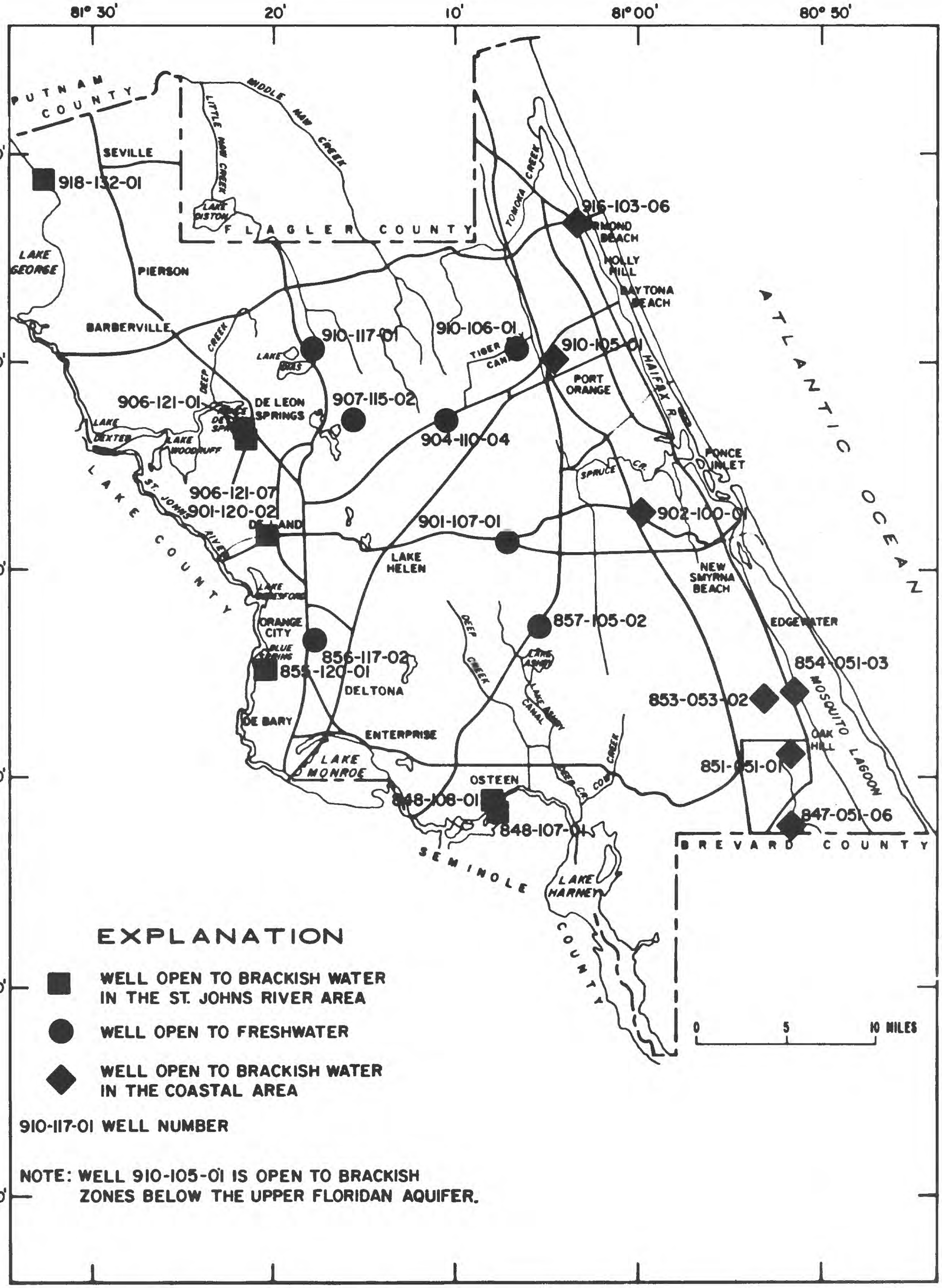

Figure 33.--Locations of 21 Floridan aquifer system wells for which analyses of ion concentrations in water are given.

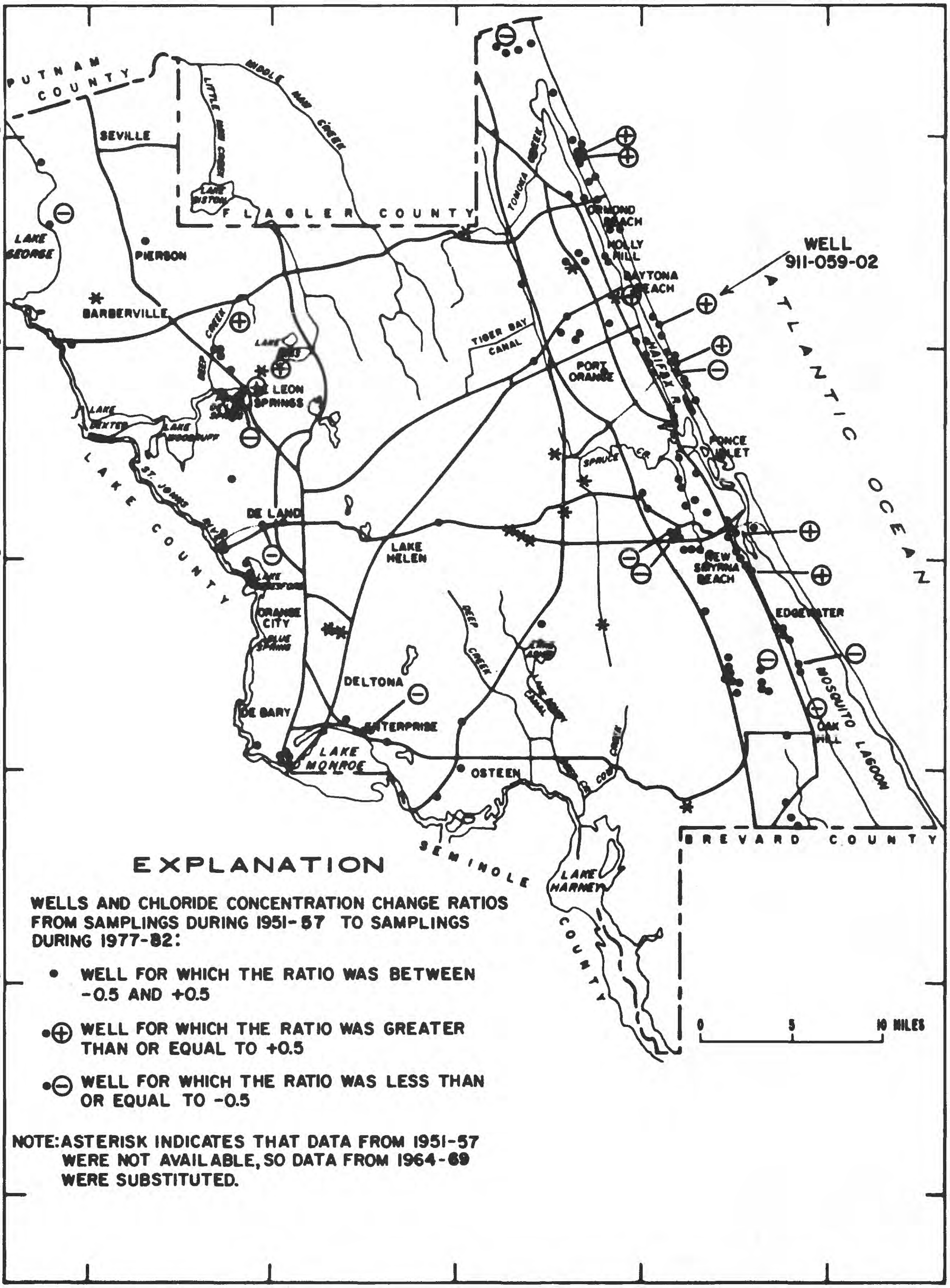

Figure 34.--Chloride-concentration change ratios for wells open to the Floridan aquifer system that have not been used for public supply.

wells showing a significant increase are in the coastal area from Daytona Beach to north of Ormond Beach; three wells showing significant increases are in the Ponce de Leon Springs area; and five wells showing a significant decline are in the inland areas from Oak Hill to New Smyrna Beach. All of these groups, however, are intermixed with wells that did not exhibit significant changes. Wells for which chloride-concentration change ratios were within the -0.5 to +0.5 range likewise did not show areal patterns.

The significant increases in chloride concentration in the water from five wells in the coastal area of Ormond Beach and Daytona Beach may be associated with ground-water withdrawals in northeast Volusia County. Figures 10 and 12 indicate that many wells exist there and figure 18 shows large drawdown in the area.

The most marked increase in chloride concentration in a nonpublic-supply well is in well 911-059-02 on the barrier island in Daytona Beach. This well showed a gradual increase from 110 mg/L in 1956 to 580 mg/L in 1979, followed by a jump to 1,400 mg/L in 1981 (fig. 26). Well 911-059-02 is one of the five wells in northeast Volusia County which exhibited significant changes (fig. 34).

Twenty-two irrigation wells were resampled in January 1983, as part of an intrusion monitoring network that was suggested by Rutledge, (1982). Table 6 gives chloride concentrations in the wells resampled. Of the 22 wells, only one showed a marked change. Well 907-122-01 yielded water with a chloride concentration of 280 mg/L in 1980 and 500 mg/L in 1983. It is noteworthy that this well is in the area of Ponce de Leon Springs, near the three wells previously mentioned that exhibited chloride-concentration change ratios greater than +0.5 (fig. 34).

Generally, there is little evidence that intrusion is occurring uniformly over large areas in the Floridan aquifer system in Volusia County. This means that if intrusion is taking place, it is local upconing of brackish water. Such a movement would tend to be noticeable from samplings of wells that are deeper, are pumped a greater amount of the time, and are pumped at higher rates.

Public-Supply Wells

For the purpose of evaluating chloride-concentration change ratios for public-supply wells, samplings during three periods of 1982 are compared to previous samplings. Figures 35, 36, and 37 show the ratios thus determined during March-April, August, and December 1982, respectively. Of the 14 wells sampled during March-April 1982, 9 exhibited chloride concentration change ratios that equaled or exceeded +0.5. The remaining 5 ratios are in the range of -0.5 to +0.5. Of the 23 wells sampled in August 1982 (fig. 36), 8 yielded ratios that equaled or exceeded +0.5, and the remainder fell in the range of -0.5 to +0.5. Of the 27 wells sampled in December 1982 (fig. 37), 5 yielded ratios that equaled or exceeded +0.5 and 4 yielded ratios below or equal to -0.5. Increases in chloride concentration occur primarily during the dry

Table 6.--Chloride concentrations in water from wells in the monitoring network suggested in the northwest Volusia County report

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
290532081213501	90512101 C.F. GREENS #1 WELL, GLENWOOD	79-02-10	0816	142
	90512101 C.F. GREENS #1 WELL, GLENWOOD	79-11-30	0600	110
	90512101 C.F. GREENS #1 WELL, GLENWOOD	80-02-05	0550	130
	90512101 C.F. GREENS #1 WELL, GLENWOOD	80-03-03	0635	65
	90512101 C.F. GREENS #1 WELL, GLENWOOD	83-01-18	0505	120
290538081213501	90512102 C.F. GREENS DEEP WELL, GLENWOOD	78-12-14	1600	500
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	79-01-23	--	665
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	79-02-10	0535	655
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	79-02-10	0818	650
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	79-12-27	0630	360
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	80-01-02	0555	800
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	80-02-05	0600	670
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	80-03-03	0640	620
	90512102 C.F. GREENS DEEP WELL, GLENWOOD	83-01-18	0500	360
290512081213801	90512111 BOOKERS IRR. WELL, GLENWOOD	80-01-02	0820	64
	90512111 BOOKERS IRR. WELL, GLENWOOD	80-03-03	0655	58
	90512111 BOOKERS IRR. WELL, GLENWOOD	83-01-18	0515	46
290635081202101	90612005 C.RICHARDSON'S #24 WELL, DELEON SPGS	79-12-27	0700	31
	90612005 C.RICHARDSON'S #24 WELL, DELEON SPGS	83-01-18	0615	30
290646081213701	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	78-12-18	1000	930
	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	79-01-23	--	790
	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	79-02-10	0608	920
	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	79-02-10	0758	880
	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	79-12-01	0700	790
	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	80-02-05	0635	700
	90612101 16S29E W.WARDS WELL,W DELEON SPRINGS	80-03-03	0610	640
290642081214001	90612102 LAWRENCE WELL, DELEON SPRINGS	79-12-27	0610	430
	90612102 LAWRENCE WELL, DELEON SPRINGS	80-03-03	0620	400
	90612102 LAWRENCE WELL, DELEON SPRINGS	83-01-18	0550	380
290612081214101	90612107 HAGSTROM DSL WELL, N. GLENWOOD	78-12-18	0915	450
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	79-01-23	--	490
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	79-02-10	0603	478
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	79-02-10	0804	480
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	79-12-01	0645	470
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	79-12-27	0615	400
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	80-01-02	0540	500
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	80-03-03	0625	440
	90612107 HAGSTROM DSL WELL, N. GLENWOOD	83-01-18	0525	450
290613081213001	90612108 LUCAS IRRIG WELL, S OF DELEON SPGS	78-12-18	1015	710
	90612108 LUCAS IRRIG WELL, S OF DELEON SPGS	79-02-10	0556	798
	90612108 LUCAS IRRIG WELL, S OF DELEON SPGS	79-02-10	0808	792
	90612108 LUCAS IRRIG WELL, S OF DELEON SPGS	80-02-05	0630	710
	90612108 LUCAS IRRIG WELL, S OF DELEON SPGS	83-01-18	0535	660
290804081215601	90712101 12" FLOW W OF DELEON SPRINGS	57-04-29	--	390
	90712101 12" FLOW W OF DELEON SPRINGS	66-01-20	--	670
	90712101 12" FLOW W OF DELEON SPRINGS	79-06-15	1400	438
	90712101 12" FLOW W OF DELEON SPRINGS	79-09-10	1340	678
	90712101 12" FLOW W OF DELEON SPRINGS	79-12-10	1500	810
	90712101 12" FLOW W OF DELEON SPRINGS	80-02-05	0700	780
	90712101 12" FLOW W OF DELEON SPRINGS	81-12-15	1310	510
	90712101 12" FLOW W OF DELEON SPRINGS	82-04-14	1020	720
	90712101 12" FLOW W OF DELEON SPRINGS	83-06-02	0900	830
	90712101 12" FLOW W OF DELEON SPRINGS	84-05-03	0905	810

Table 6.--Chloride concentrations in water from wells in the monitoring network suggested in the northwest Volusia County report--Continued

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
290752081220901	90712102 8"FLOW WELL W.OF DELEON SPRINGS	57-04-30	--	7200
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	79-09-10	1350	4275
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	79-12-10	1515	4800
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	80-02-05	0650	4700
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	81-12-15	1340	3800
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	82-04-14	1030	4000
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	83-06-02	0900	4500
	90712102 8"FLOW WELL W.OF DELEON SPRINGS	84-05-03	0850	4200
290737081220301	90712201 HAGSTROM IRRIG WELL, W OF DELEON SPGS	80-05-13	1030	280
	90712201 HAGSTROM IRRIG WELL, W OF DELEON SPGS	83-01-18	0600	500
290815081194801	90811902 FG INTERNAT #1 WELL, DELEON SPGS	80-01-02	0640	8.7
	90811902 FG INTERNAT #1 WELL, DELEON SPGS	80-03-03	0750	11
	90811902 FG INTERNAT #1 WELL, DELEON SPGS	83-01-18	0625	9.8
290849081202601	90812004 MCBLICK #4 WELL, E OF DELEON SPGS	79-06-21	1600	266
	90812004 MCBLICK #4 WELL, E OF DELEON SPGS	79-12-05	1530	230
	90812004 MCBLICK #4 WELL, E OF DELEON SPGS	79-12-05	1630	230
	90812004 MCBLICK #4 WELL, E OF DELEON SPGS	80-03-03	0855	260
	90812004 MCBLICK #4 WELL, E OF DELEON SPGS	83-01-18	0640	274
290910081202801	90912003 CRIBB'S IRRIG WELL, N OF DELEON SPGS	79-12-27	0730	10
	90912003 CRIBB'S IRRIG WELL, N OF DELEON SPGS	80-03-03	0915	10
	90912003 CRIBB'S IRRIG WELL, N OF DELEON SPGS	83-01-18	0655	9.1
290917081222201	90912203 DAWSON BRN FLOW WELL SE OF BARBERVILLE	56-04-23	--	14
	90912203 DAWSON BRN FLOW WELL SE OF BARBERVILLE	66-01-20	--	11
	90912203 DAWSON BRN FLOW WELL SE OF BARBERVILLE	79-12-05	1600	11
	90912203 DAWSON BRN FLOW WELL SE OF BARBERVILLE	82-04-14	1000	11
290959081231601	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	53-11-06	--	326
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	66-09-13	--	478
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	67-01-03	1530	422
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	67-02-27	0930	445
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	67-05-01	1145	400
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	67-07-10	1215	425
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	67-09-11	1025	425
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	67-11-01	1145	430
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	68-01-04	1000	435
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	68-03-08	1110	430
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	68-05-03	1030	370
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	68-10-25	0850	445
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	69-05-06	1110	450
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	70-09-26	--	455
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	70-11-04	--	455
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	72-05-10	1900	300
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	72-09-06	1115	450
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	79-12-10	1430	470
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	80-01-23	1100	470
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	81-12-16	1400	450
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	82-04-14	0930	440
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	83-08-04	1715	450
	90912301 DAIRY FLOW WELL #1,SW OF BARBERVILLE	83-08-04	1715	450
290959081283501	90912801 B.F. TURNER WELL, SR40, NR EMPORIA	79-02-10	0730	15
291017081205001	91012006 BLACKWELDER N WELL, DELEON SPGS	79-02-01	0725	14
	91012006 BLACKWELDER N WELL, DELEON SPGS	83-01-18	0700	11

Table 6.--Chloride concentrations in water from wells in the monitoring network suggested in the northwest Volusia County report--Continued

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
291112081282601	91112802 RICHARDSON'S #13 WELL, EMPORIA	78-12-14	1115	11
	91112802 RICHARDSON'S #13 WELL, EMPORIA	79-02-10	0755	13
291111081291401	91112915 MCCOLLOUGH EMPOR. RD WELL, EMPOR.	78-12-13	0940	11
	91112915 MCCOLLOUGH EMPOR. RD WELL, EMPOR.	83-01-18	0940	10
291216081215601	91212101 STRWMD TEST WELL, SR40, E OF BARBERVILL	79-02-09	1310	22
291208081292501	91212906 S.SMITH HARP+PET. RD SW WELL, EMPORIA	79-02-10	0800	12
291426081224001	91412205 UNDERHILL 10" WELL, NR BARBERVILLE	78-12-15	1310	10
291422081254701	91412505 14S28E36 TAYLOR'S MISERY WELL, PIERSON	78-12-08	1445	8.0
	91412505 14S28E36 TAYLOR'S MISERY WELL, PIERSON	79-02-10	0705	13
	91412505 14S28E36 TAYLOR'S MISERY WELL, PIERSON	83-01-18	0715	8.8
291435081255301	91412509 R.JONES 8"WELL,MISERY+WASH. RD,PIERSON	78-12-14	1330	9.0
291452081261701	91412610 R.JONES WELL N OF WASH. ST, PIERSON	78-12-20	1315	8.4
	91412610 R.JONES WELL N OF WASH. ST, PIERSON	83-01-18	0725	8.9
291454081291101	91412903 T.TAYLOR CARLYLE WELL, W. PIERSON	83-01-18	0825	9.6
291522081265201	91512611 WORTHINGTON PINE ST WELL, NE PIERSON	79-02-10	0635	11
	91512611 WORTHINGTON PINE ST WELL, NE PIERSON	83-01-18	0800	8.2
291525081260601	91512619 CARTER'S IRRIG WELL, NE PIERSON	80-01-02	0545	7.9
	91512619 CARTER'S IRRIG WELL, NE PIERSON	83-01-18	0745	7.2
291507081290601	91512903 BRADDOCK WELL, W OF WASH RD, PIERSON	78-01-10	0955	8.0
	91512903 BRADDOCK WELL, W OF WASH RD, PIERSON	79-02-10	0840	12
	91512903 BRADDOCK WELL, W OF WASH RD, PIERSON	83-01-18	0815	7.5
291508081302801	91513001 SJRWMD WELL 2 MI W OF PIERSON	78-12-20	1210	11
	91513001 SJRWMD WELL 2 MI W OF PIERSON	79-02-09	0950	14
	91513001 SJRWMD WELL 2 MI W OF PIERSON	79-09-27	1445	11
	91513001 SJRWMD WELL 2 MI W OF PIERSON	79-12-18	1530	11
291621081304901	91613002 14S28E19 KELLY'S2"WELL NW OF PIERSON	79-12-18	1600	200
291724081275701	91712703 M.SMITH L.B.C. RD 8" WELL, SEVILLE	79-01-29	0800	13
	91712703 M.SMITH L.B.C. RD 8" WELL, SEVILLE	83-01-18	0920	9.4
291715081281801	91712801 J.C. MEW WELL AT SEVILLE, FL.	79-09-06	1915	10
	91712801 J.C. MEW WELL AT SEVILLE, FL.	80-01-08	1410	11
291838081280601	91812803 W.COLMANS COWART RD WELL, SE SEVILLE	78-11-30	1115	12
	91812803 W.COLMANS COWART RD WELL, SE SEVILLE	79-01-29	0730	15
	91812803 W.COLMANS COWART RD WELL, SE SEVILLE	80-01-02	0740	11
	91812803 W.COLMANS COWART RD WELL, SE SEVILLE	83-01-18	0850	13
291834081281101	91812804 M.COLMANS COWART RD WELL, SE SEVILLE	78-01-11	0820	29
	91812804 M.COLMANS COWART RD WELL, SE SEVILLE	79-02-10	0555	29
	91812804 M.COLMANS COWART RD WELL, SE SEVILLE	80-01-02	0745	21
	91812804 M.COLMANS COWART RD WELL, SE SEVILLE	83-01-18	0900	31
291910081312401	91913101 13S27E36 MILLICAN'S WELL W OF SEVILLE	78-12-20	1350	17
	91913101 13S27E36 MILLICAN'S WELL W OF SEVILLE	79-01-29	0845	16

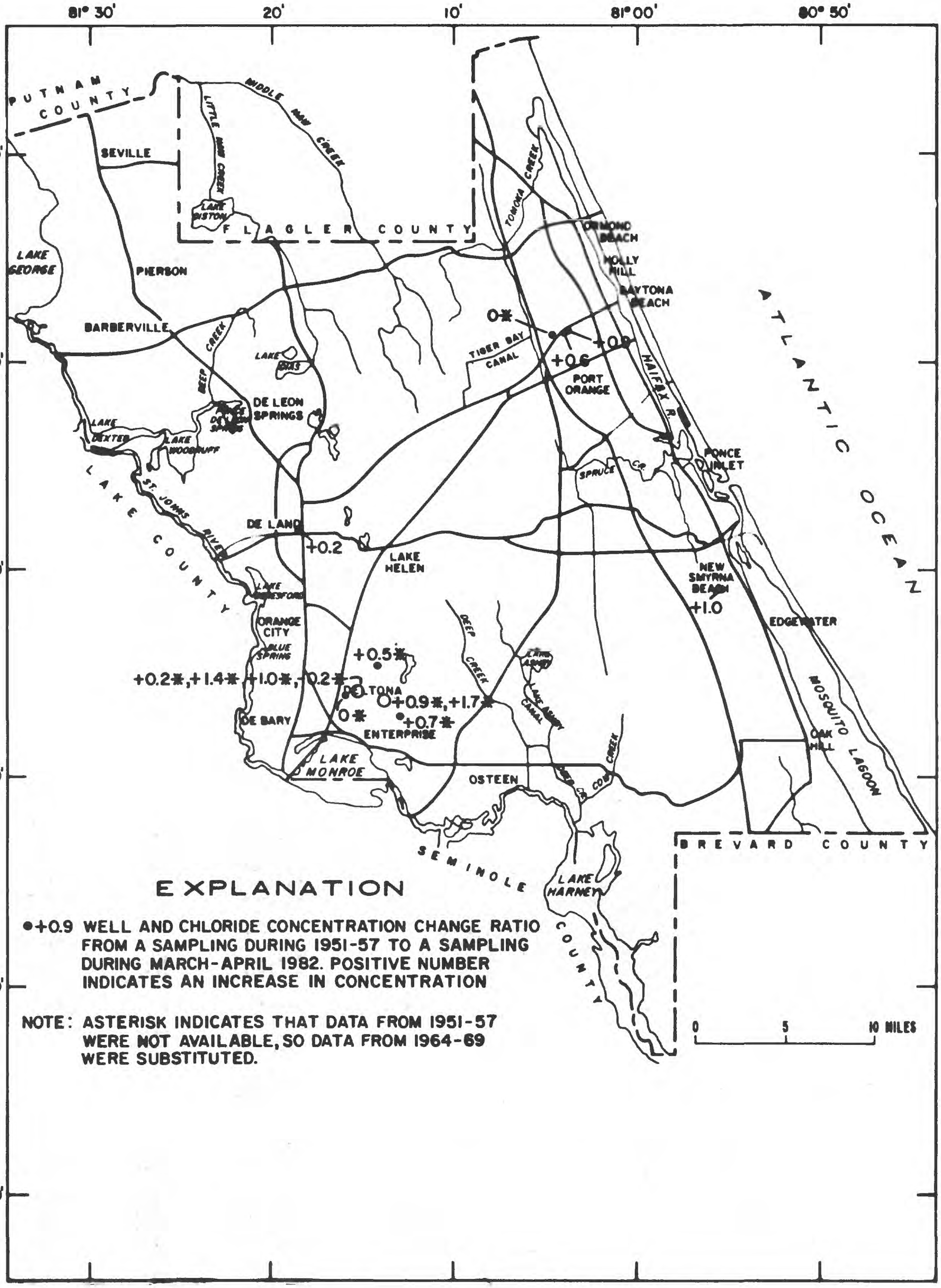

Figure 35.--Chloride-concentration change ratios based on old data versus data from March-April 1982 for public-supply wells.

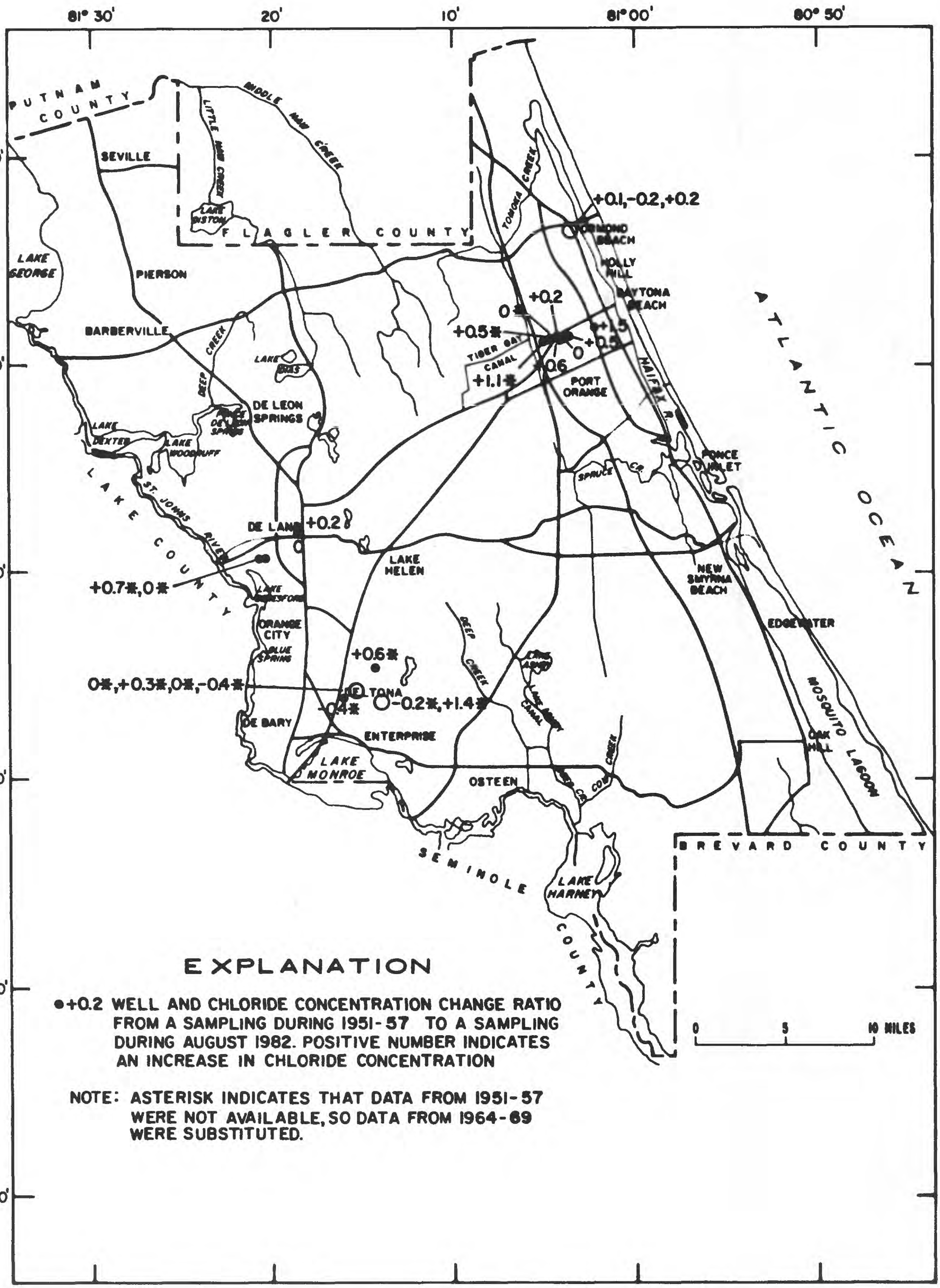

Figure 36.--Chloride-concentration change ratios based on old data versus data from August 1982 for public-supply wells.

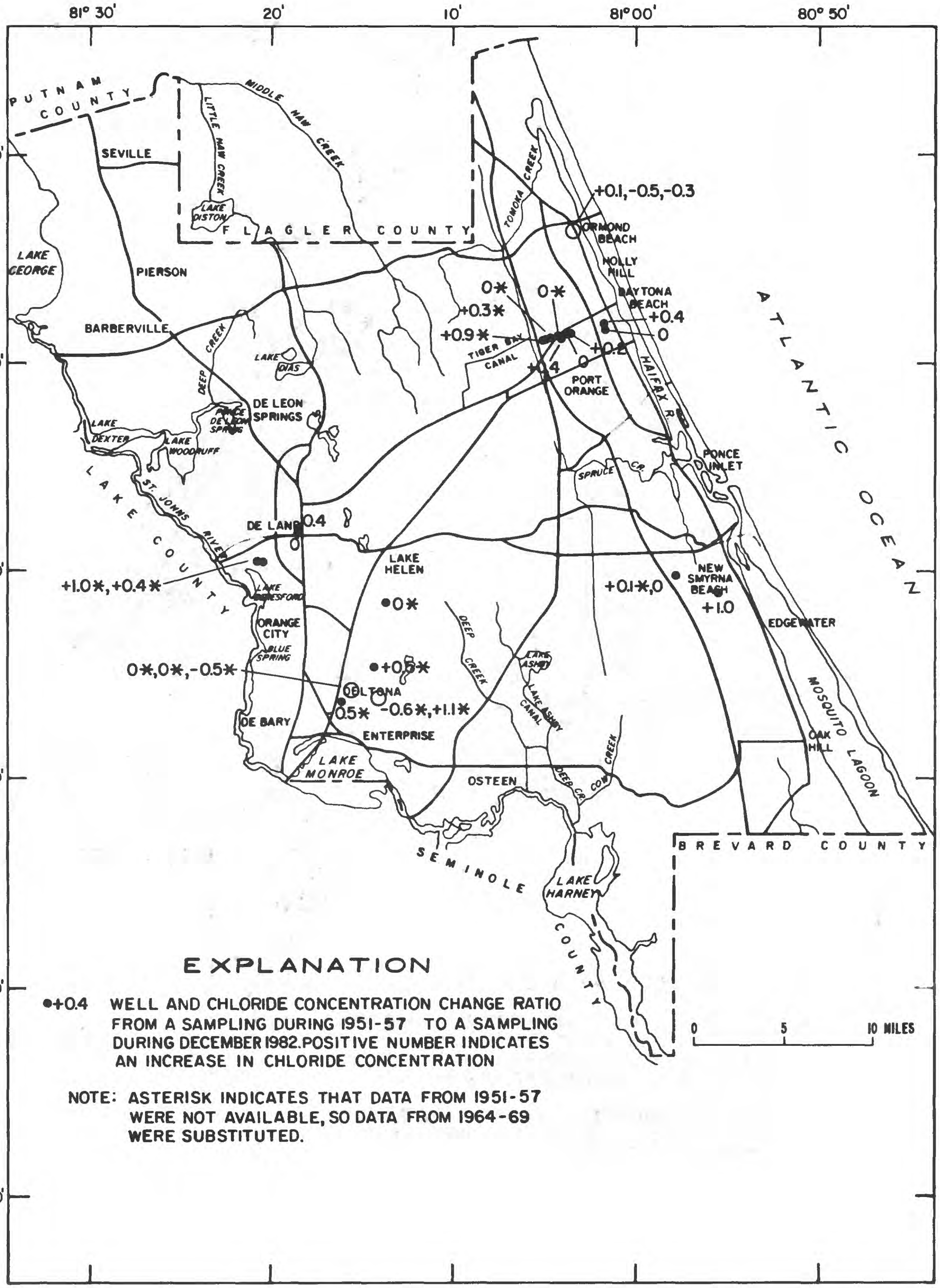

Figure 37.--Chloride-concentration change ratios based on old data versus data from December 1982 for public-supply wells.

seasons when water levels are low and water withdrawals are high. Concentrations decrease temporarily during periods of higher water levels and reduced water use such as December 1982. Figures 38 and 39 show large fluctuations in the chloride concentration of water from public-supply wells.

The fact that the water from many public-supply wells has undergone a net worsening over the years is best exemplified by the abandonment of production wells and by the replacement of abandoned wells with new wells in areas of fresher ground water. Figures 40 and 41 show public-supply wells in use in the mid-1950's and in 1982, respectively, for northeast Volusia County. The well fields belonging to the city of Daytona Beach have changed dramatically. In 1954-57, the city was supplied by three sets of wells--one on the barrier island, one near the intersection of U.S. 92 and S.R. 5A, and the third north of the airport. In 1982, the first two sets of wells had been abandoned entirely and three of the wells north of the airport had also been abandoned. A new well field near the intersection of Indian Lake Road and U.S. 92 was put into operation in 1982. Pumping stress for the cities of Ormond Beach, Port Orange, and Holly Hill has also shifted toward central Volusia County. A new well field belonging to the city of New Smyrna Beach was installed 7 miles inland of the old well field (figs. 9 and 10) in 1981. The newest wells belonging to the Deltona Corporation are northeast of the older wells (fig. 10), away from the brackish ground water in the St. Johns River area (fig. 30).

The table of supplemental data at the back of this report shows chloride concentrations in public-supply wells.

EFFECTS OF MANAGEMENT ALTERNATIVES ON MOVEMENT OF BRACKISH WATER

Surficial Aquifer

The movement of brackish water in the surficial aquifer will probably continue on the barrier island. This intrusion is difficult to manage because of lack of control of withdrawals. Reduction of withdrawals during dry seasons may slow the rate of intrusion.

Most intrusion in the surficial aquifer is caused by pumping in areas close to brackish water. Little intrusion is therefore likely in mainland areas.

Floridan Aquifer System

Possible water-management alternatives include minimizing well depths, minimizing drawdown, installing new wells where the freshwater zone is thickest, increasing head in the freshwater zone using injection wells, and reducing head in the saltwater zone. The best approach may be a combination of the above practices.

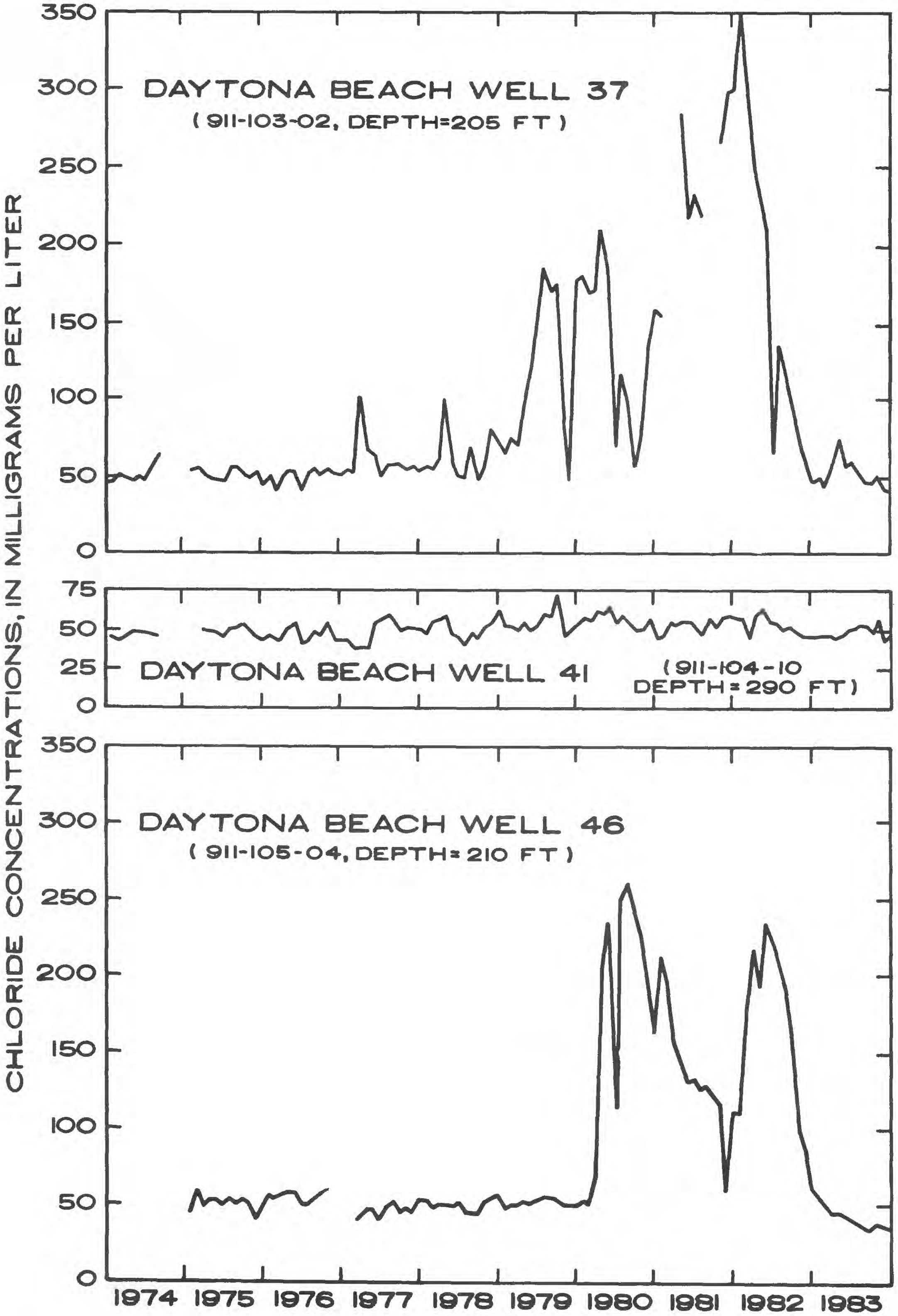

Figure 38.--Chloride concentration of water from three Daytona Beach public-supply wells, 1974-83 (records from city of Daytona Beach).

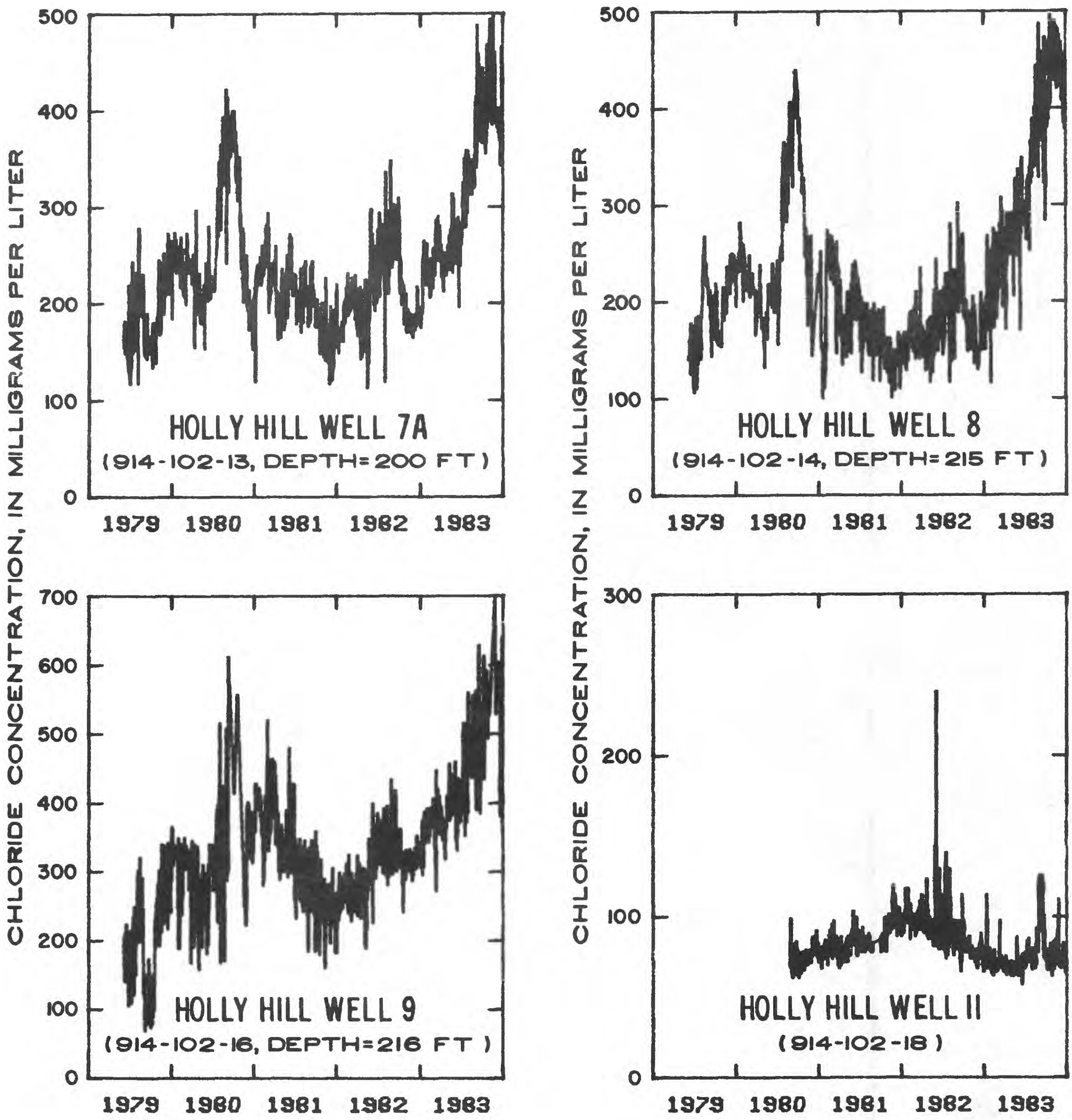

Figure 39.--Chloride concentration of water from four Holly Hill public-supply wells, 1979-83 (records from city of Holly Hill).

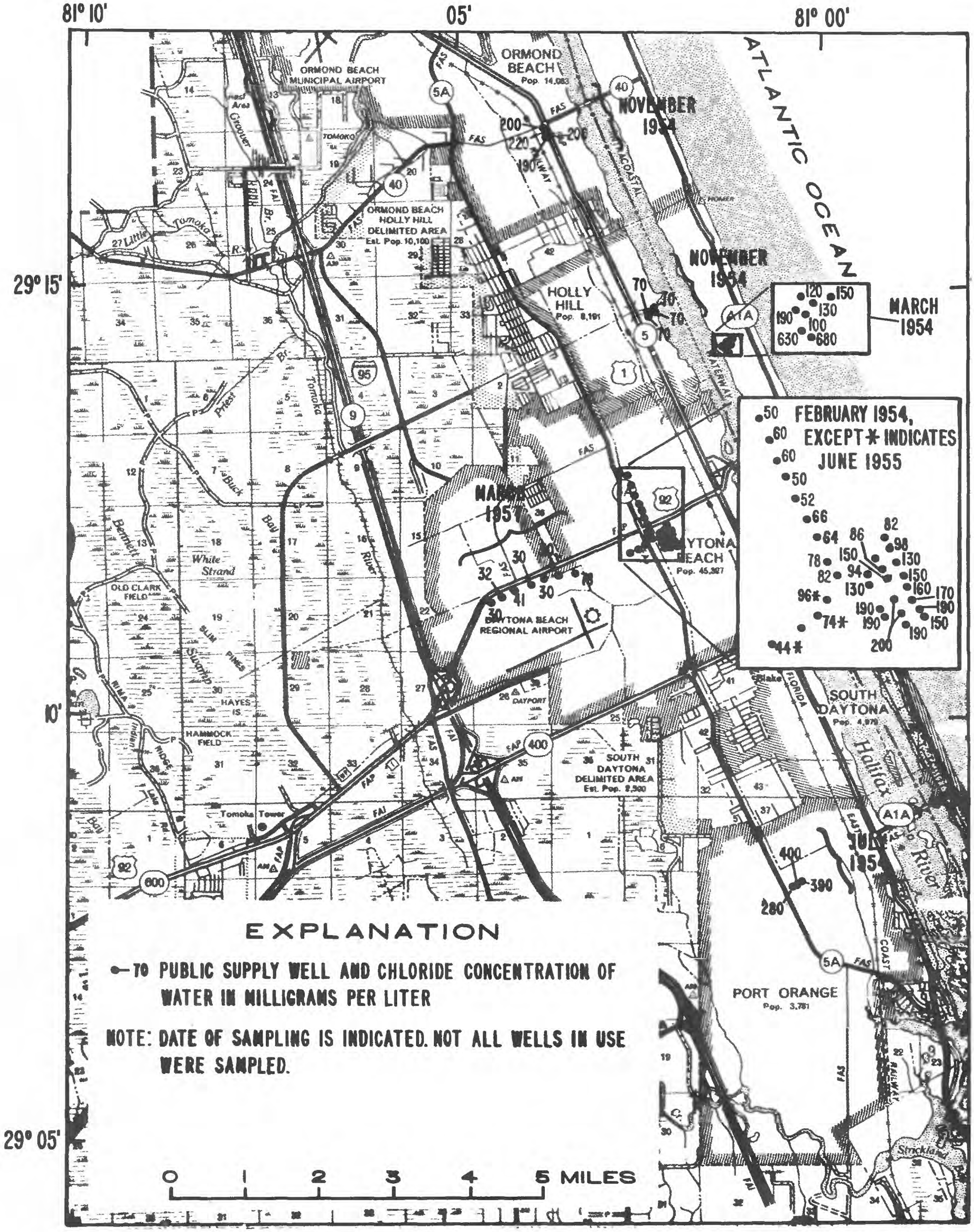

Figure 40.--Public-supply wells in use during 1954-57 and chloride concentrations of water from public-supply wells in northeast Volusia County.

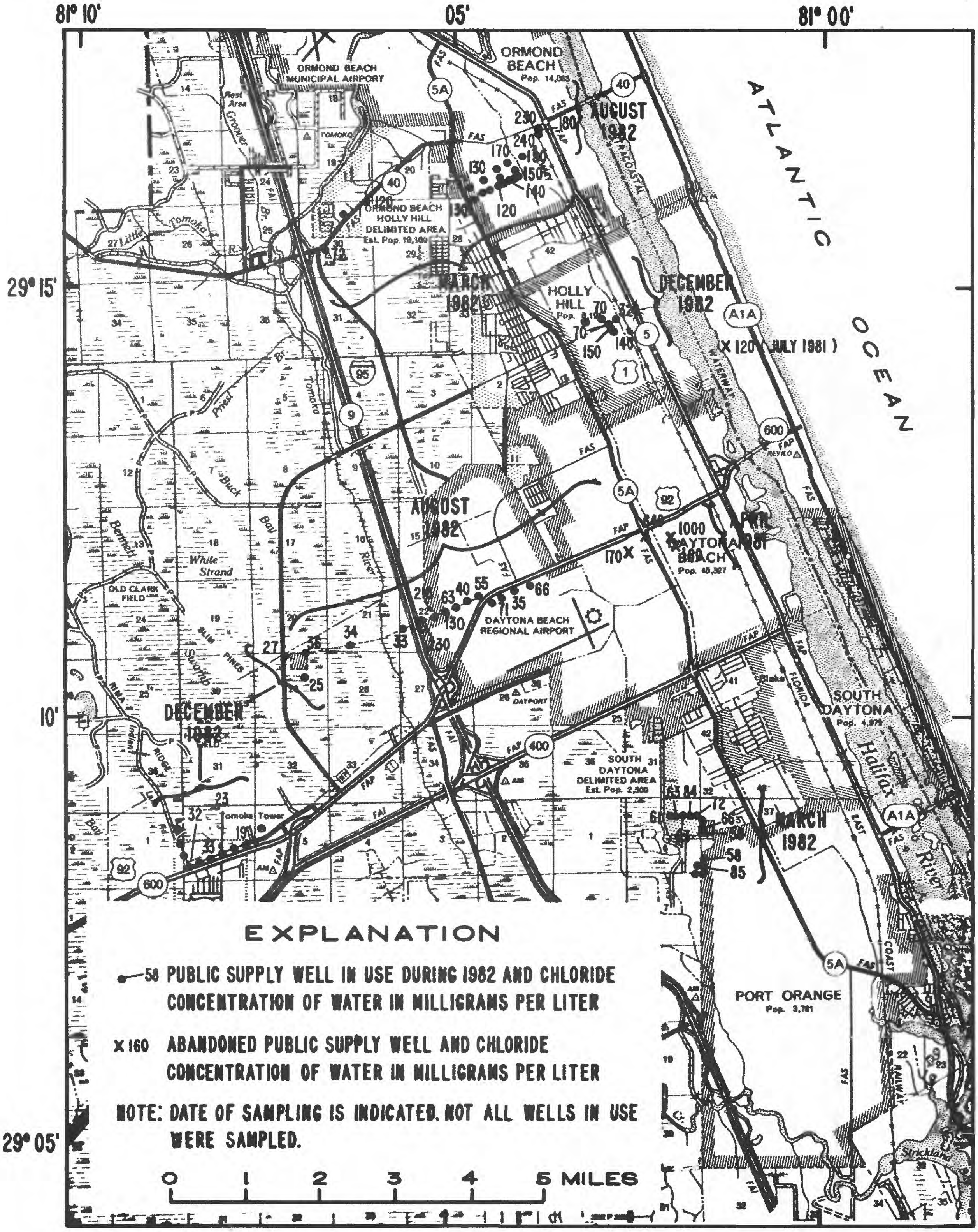

Figure 41.--Public-supply wells in use during 1982 and chloride concentrations of water from public-supply wells in northeast Volusia County.

Minimizing well depth may be the single most effective step against intrusion. The idea is to keep as much distance as possible between the bottom of the well and the underlying brackish water. Because the thickness of the freshwater zone increases toward central Volusia (fig. 31), the maximum safe well depth also increases in that direction.

Numerous management alternatives may reduce drawdown. One of the most practical possibilities is to increase the distance between pumping wells to reduce mutual well interference. Cycling pumping among production wells so that no individual well is pumped for more than a limited time may reduce drawdown. If the number of supply wells per desired water-use rate is maximized, drawdown could be reduced. Two wells 1,000 feet apart each pumping 300 gallons per minute will create less drawdown than one well pumping 600 gallons per minute. Although the area of influence will actually be larger for the former situation, the "point drawdown" at the wells would be less. It is this point drawdown that influences the movement of the transition zone below the well the most.

Although increasing the penetration of the aquifer tends to reduce drawdown, it may defeat the purpose of avoiding intrusion if well depths become excessive. This concept is illustrated in figure 42. Pumpage is equal for these two conditions, but one well penetrates 200 feet of the aquifer and the other penetrates 400 feet. Assuming that hydraulic properties of the aquifer are uniform, the drawdown in the shallow well is approximately twice the drawdown in the deep well. However, the drawdown below the deeper well near the interface is enough to induce an upward movement of the interface three times greater than the movement under the shallow well. If the interface is induced upward by approximately one-half the original distance between the interface and the bottom of the pumped well, the condition is unstable, and the interface may suddenly move to the bottom of the well (Bouwer, 1978).

If all other things remain equal, the best locations for public-supply wells are areas where the potentiometric surface was highest during times of no pumping because these areas are characterized by maximum thickness of the freshwater zone. Figure 31 shows that the maximum thickness of the zone containing fresh or slightly brackish water is located beneath the Talbot Terrace (fig. 1). Generally, if a well is installed in this area, there will be a thicker safety zone between the bottom of the well and the transition zone. Unfortunately, the transmissivity of the Floridan aquifer system under the Talbot Terrace may not be as high as it is elsewhere, so greater drawdown may occur there.

Injection wells may be used to increase hydraulic head in the freshwater zone and control intrusion. This would involve injection of storm runoff or tertiary-treated sewage, and therefore would require that steps be taken to avoid pollution.

Reducing hydraulic head in the saltwater zone below production wells may be an effective way of controlling intrusion, but is expensive relative to other methods. This method would involve installing deep wells open to

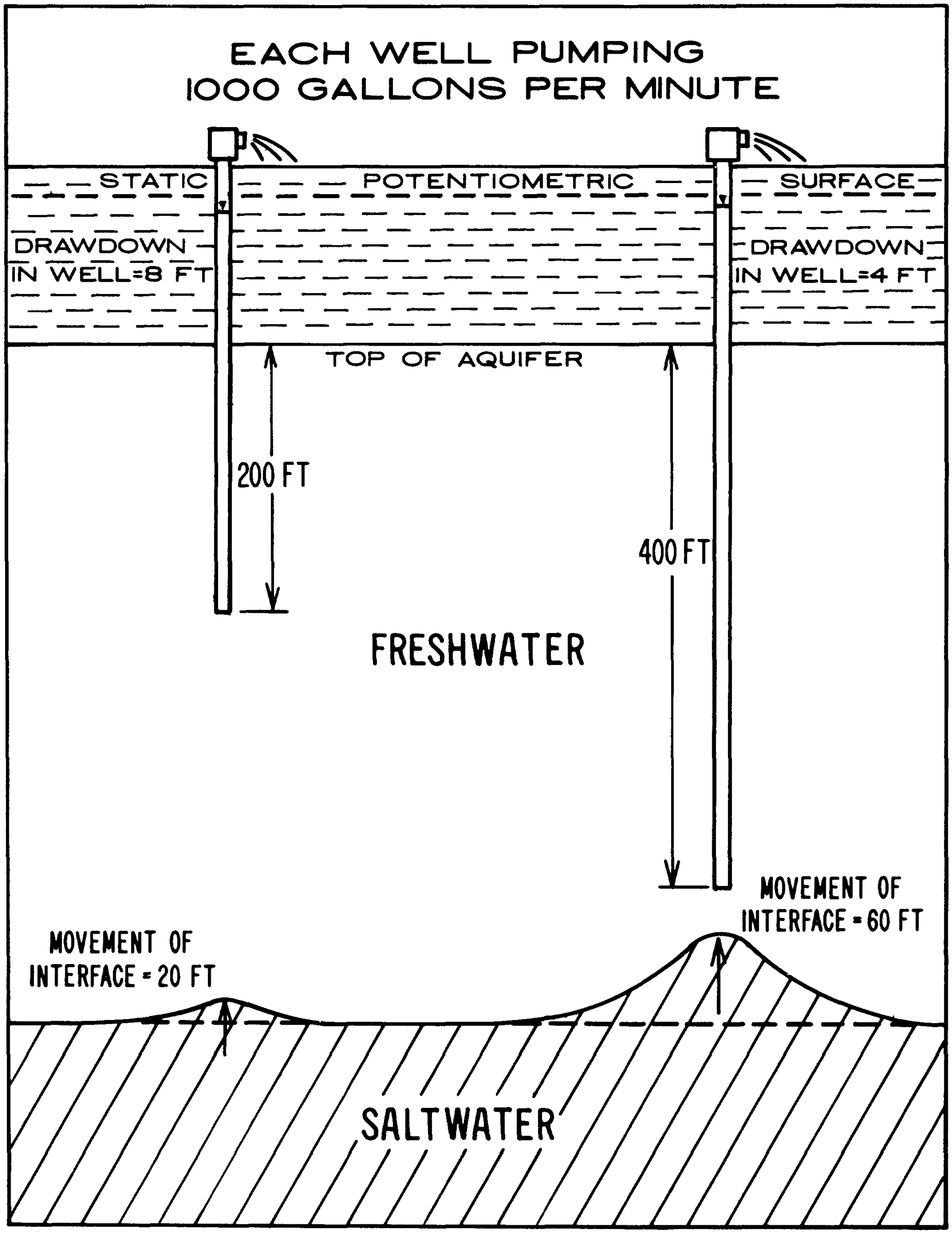

Figure 42.--Conceptual cross section showing movement of freshwater-saltwater interface under pumping wells. (Thickness of prepumping freshwater zone = 500 ft; hydraulic conductivity of aquifer = 200 ft/d. Interface movement calculated per Bouwer, 1978, p. 405.).

saltwater zones and sealed tightly from freshwater zones. These deeper wells would be pumped continuously to reduce saltwater head and the water would be discharged into natural saltwater bodies at the surface.

SUMMARY

Volusia County is a 1,200-square-mile area in east-central Florida which includes the communities of Daytona Beach, Ormond Beach, New Smyrna Beach, De Land, and Deltona. The area is oriented toward tourism, especially along the coast. The two aquifers underlying the area are the unconfined surficial aquifer and the confined Floridan aquifer system. The surficial aquifer consists of sand, clay, and shell beds of Pleistocene and Holocene age, and the Floridan aquifer system consists of limestone and dolomite of Eocene age. The two aquifers are separated by confining clay beds of Miocene or Pliocene age.

Both aquifers contain good quality water in most of Volusia County, but brackish water is present throughout the eastern and western fringes of the county in the surficial aquifer and in the upper zones of the Floridan aquifer system presently tapped by wells. Saltwater is present throughout the county in the relatively untapped lower zones of the Floridan aquifer system. Increased use of water because of development in the fringes has caused intrusion.

In 1980, the average ground-water withdrawal in Volusia County was 66 million gallons per day. Ground-water use quadrupled between 1955 and 1980. More than 95 percent of the ground water pumped is from the Floridan aquifer system. All public-supply wells and most agricultural-irrigation wells are open to this aquifer. The total withdrawals for public supply and agricultural irrigation were 30 and 24 million gallons per day, respectively. Most of the 3 million gallons per day pumpage from the surficial aquifer is used for lawn irrigation.

Water levels in Floridan aquifer system wells declined more than 10 feet over an area of 70 square miles from November 1955 to September 1982. This drawdown, which occurred in the areas of Ormond Beach, Daytona Beach, and Port Orange, was caused by pumping. Considerably greater declines were observed for May 1981 because of drought conditions.

The annual water budget of the surficial layer consists of 53 inches rainfall, 1 inch upward leakage from the Floridan aquifer system, 0.5 inch recharge from Floridan aquifer system withdrawals, and 0.5 inch stream inflow, counterbalanced with 39 inches evapotranspiration, 11 inches stream outflow, and 5 inches downward leakage to the Floridan aquifer system.

The annual water budget of the Floridan aquifer system consists of 5 inches downward leakage inflow, 1 inch upward leakage outflow, 1 inch horizontal inflow, 1.5 inches horizontal outflow, 2.5 inches discharge from springs and flowing wells, and 1 inch pumpage.

Chloride concentration, which is used as an index of salinity, may vary at individual sites not exhibiting trends because of seasonal fluctuations. Chloride concentrations in brackish-water wells may fluctuate in such a way that the maximum is more than twice the minimum.

Brackish water movement, or intrusion, is apparently occurring in the surficial aquifer on the barrier island in the northeast part of Volusia County. It is likely that intrusion has also occurred in other sections of the barrier island, although this is difficult to ascertain because of the scarcity of long-term chloride concentration data from these areas. The barrier island is generally the only part of the study area where chloride concentrations in the surficial aquifer exceed 250 milligrams per liter. Intrusion is likely to continue in the surficial aquifer on the barrier island. Little or no intrusion is occurring in the surficial aquifer in inland areas.

There is little evidence that intrusion is occurring uniformly over large areas in the Floridan aquifer system. Most nonpublic-supply wells have not exhibited long-term changes in salinity. Of 154 nonpublic-supply wells sampled, 10 showed a significant increase and 11 showed a significant decline in chloride concentration over time. Significant increases in chloride concentration in water from five such wells in the coastal area of Ormond Beach and Daytona Beach may be associated with ground-water withdrawals in northeast Volusia County.

There is upconing or vertical intrusion at sites of public-supply pumping. Public-supply wells are usually deeper, are pumped a greater amount of the time, and are pumped at higher rates than other wells. Intrusion manifests itself as surges that are greatest during times of low rainfall and heavy water use. Many public-supply wells located close to brackish water zones in the fringes of Volusia County have been abandoned and replaced by new wells in the central part of the county, where the freshwater zone is thickest.

Possible water-management alternatives to intrusion in the Floridan aquifer system include minimizing well depths, minimizing drawdown, installing wells where the freshwater zone is thickest, increasing head in the freshwater zone using injection wells, and reducing head in the saltwater zone. Drawdown can be reduced by increasing the number of supply wells per desired water-use rate. Minimizing well depth is probably the single most effective step in controlling intrusion.

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TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS IN PUBLIC-SUPPLY WELLS.

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
291423081011901	91410101 OLD P.S. WELL, SEABREEZE #1, DAYTONA	54-03-02	--	146
291423081011902	91410102 OLD P.S. WELL, SEABREEZE #2, DAYTONA	54-03-02	--	130
291422081012101	91410103 OLD P.S. WELL, SEABREEZE #3, DAYTONA	54-03-02	--	96
291423081012201	91410104 OLD P.S. WELL, SEABREEZE #4, DAYTONA	54-11-02	--	116
291421081012301	91410105 OLD P.S. WELL, SEABREEZE #5, DAYTONA	54-03-02	--	188
291421081012201	91410106 OLD P.S. WELL, SEABREEZE #6, DAYTONA	54-03-02	--	630
291421081012202	91410107 OLD P.S. WELL, SEABREEZE #7, DAYTONA	54-03-02	--	682
	91410107 OLD P.S. WELL, SEABREEZE #7, DAYTONA	81-05-04	1250	130
	91410107 OLD P.S. WELL, SEABREEZE #7, DAYTONA	81-07-14	1115	120
291204081020501	91210201 DAYTONA P.S. WELL #1, ORANGE AV,DAYTONA	37-07-11	--	1645
	91210201 DAYTONA P.S. WELL #1, ORANGE AV,DAYTONA	37-07-16	--	1585
	91210201 DAYTONA P.S. WELL #1, ORANGE AV,DAYTONA	37-07-24	--	355
	91210201 DAYTONA P.S. WELL #1, ORANGE AV,DAYTONA	37-07-27	--	1160
	91210201 DAYTONA P.S. WELL #1, ORANGE AV,DAYTONA	37-07-29	--	1085
	91210201 DAYTONA P.S. WELL #1, ORANGE AV,DAYTONA	37-08-02	--	890
291158081015801	91210202 DAYTONA P.S. WELL #2, MALEY, DAYTONA	39-00-00	--	100
	91210202 DAYTONA P.S. WELL #2, MALEY, DAYTONA	50-00-00	--	96
	91210202 DAYTONA P.S. WELL #2, MALEY, DAYTONA	54-02-25	--	146
	91210202 DAYTONA P.S. WELL #2, MALEY, DAYTONA	81-04-28	1225	160
	91210202 DAYTONA P.S. WELL #2, MALEY, DAYTONA	81-04-28	1245	160
	91210202 DAYTONA P.S. WELL #2, MALEY, DAYTONA	82-12-08	1415	150
291159081020201	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	39-00-00	--	113
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	50-00-00	--	134
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	54-02-28	--	186
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	79-09-10	--	1010
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	81-04-28	1022	750
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	81-04-28	1032	1000
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	81-04-28	1102	1000
	91210203 DAYTONA P.S. WELL #3, MALEY, DAYTONA	82-12-08	1450	300
291202081020101	91210204 DAYTONA P.S. WELL #4, MALEY, DAYTONA	39-00-00	--	117
	91210204 DAYTONA P.S. WELL #4, MALEY, DAYTONA	50-00-00	--	134
	91210204 DAYTONA P.S. WELL #4, MALEY, DAYTONA	54-02-28	--	182
291205081020301	91210205 DAYTONA P.S. WELL #5, ADAMS, DAYTONA	39-00-00	--	119
	91210205 DAYTONA P.S. WELL #5, ADAMS, DAYTONA	50-00-00	--	134
	91210205 DAYTONA P.S. WELL #5, ADAMS, DAYTONA	54-02-28	--	160
291207081020301	91210206 DAYTONA P.S. WELL #6, ADAMS, DAYTONA	39-00-00	--	102
	91210206 DAYTONA P.S. WELL #6, ADAMS, DAYTONA	50-00-00	--	122
	91210206 DAYTONA P.S. WELL #6, ADAMS, DAYTONA	54-02-28	--	146
291210081020501	91210207 DAYTONA P.S. WELL #7, ADAMS, DAYTONA	39-00-00	--	99
	91210207 DAYTONA P.S. WELL #7, ADAMS, DAYTONA	50-00-00	--	127
	91210207 DAYTONA P.S. WELL #7, ADAMS, DAYTONA	54-02-28	--	132
291213081020701	91210208 DAYTONA P.S. WELL #8, ADAMS, DAYTONA	39-00-00	--	90
	91210208 DAYTONA P.S. WELL #8, ADAMS, DAYTONA	50-00-00	--	86
	91210208 DAYTONA P.S. WELL #8, ADAMS, DAYTONA	54-02-28	--	98
291215081020801	91210209 DAYTONA P.S. WELL #9, ADAMS, DAYTONA	39-00-00	--	99
	91210209 DAYTONA P.S. WELL #9, ADAMS, DAYTONA	50-00-00	--	70
	91210209 DAYTONA P.S. WELL #9, ADAMS, DAYTONA	54-02-28	--	82
291207081020801	91210211 DAYTONA P.S. WELL #11, KEECH, DAYTONA	50-00-00	--	198
	91210211 DAYTONA P.S. WELL #11, KEECH, DAYTONA	54-02-25	--	148
291210081021001	91210212 DAYTONA P.S. WELL #12, KEECH, DAYTONA	50-00-00	--	78
	91210212 DAYTONA P.S. WELL #12, KEECH, DAYTONA	54-02-25	--	86
291212081021101	91210213 DAYTONA P.S. WELL #13, KEECH, DAYTONA	50-00-00	--	62
	91210213 DAYTONA P.S. WELL #13, KEECH, DAYTONA	54-02-25	--	88
291210081021401	91210214 DAYTONA P.S.WELL #14, CAROLINE,DAYTONA	50-00-00	--	60
	91210214 DAYTONA P.S.WELL #14, CAROLINE,DAYTONA	54-02-25	--	94

TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS IN PUBLIC-SUPPLY WELLS--CONTINUED

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
291208081021301	91210215 DAYTONA P.S. WELL 15,CAROLINE,DAYTONA	50-00-00	--	99
	91210215 DAYTONA P.S. WELL 15,CAROLINE,DAYTONA	54-02-25	--	128
291158081020901	91210216 DAYTONA P.S. WELL #16,CAROLINE,DAYTONA	50-00-00	--	123
	91210216 DAYTONA P.S. WELL #16,CAROLINE,DAYTONA	54-02-25	--	186
291156081020701	91210217 DAYTONA P.S.WELL #17,CAROLINE,DAYTONA	50-00-00	--	145
	91210217 DAYTONA P.S.WELL #17,CAROLINE,DAYTONA	54-02-00	--	188
291156081020301	91210218 DAYTONA P.S.WELL #18, KEECH,DAYTONA	50-00-00	--	150
	91210218 DAYTONA P.S.WELL #18, KEECH,DAYTONA	54-02-00	--	186
291159081020401	91210219 DAYTONA P.S. WELL #19, KEECH, DAYTONA	50-01-00	--	145
	91210219 DAYTONA P.S. WELL #19, KEECH, DAYTONA	54-02-00	--	202
291202081020501	91210220 DAYTONA P.S. WELL #20, KEECH, DAYTONA	54-02-00	--	198
291207081022101	91210221 DAYTONA P.S. WELL #21, NOVA, DAYTONA	54-02-28	--	82
	91210221 DAYTONA P.S. WELL #21, NOVA, DAYTONA	54-03-31	--	126
291210081022301	91210222 DAYTONA P.S. WELL #22, NOVA, DAYTONA	54-02-28	--	78
	91210222 DAYTONA P.S. WELL #22, NOVA, DAYTONA	54-03-31	--	92
291215081022501	91210223 DAYTONA P.S. WELL #23, NOVA, DAYTONA	54-02-28	--	64
	91210223 DAYTONA P.S. WELL #23, NOVA, DAYTONA	54-03-31	--	78
291219081022801	91210224 DAYTONA P.S.WELL #24, NOVA, DAYTONA	54-02-28	--	68
	91210224 DAYTONA P.S.WELL #24, NOVA, DAYTONA	54-03-31	--	80
291224081023001	91210225 DAYTONA P.S. WELL #25, NOVA, DAYTONA	54-02-00	--	52
	91210225 DAYTONA P.S. WELL #25, NOVA, DAYTONA	54-03-31	--	48
291229081023201	91210226 DAYTONA P.S. WELL #26, NOVA, DAYTONA	54-02-00	--	48
	91210226 DAYTONA P.S. WELL #26, NOVA, DAYTONA	54-03-31	--	44
291233081023501	91210227 DAYTONA P.S. WELL #27, NOVA, DAYTONA	54-02-00	--	56
	91210227 DAYTONA P.S. WELL #27, NOVA, DAYTONA	54-03-31	--	56
291237081023701	91210228 DAYTONA P.S. WELL #28, NOVA, DAYTONA	54-02-00	--	56
	91210228 DAYTONA P.S. WELL #28, NOVA, DAYTONA	54-03-31	--	52
291242081023901	91210229 DAYTONA P.S. WELL #29, NOVA, DAYTONA	54-02-00	--	52
	91210229 DAYTONA P.S. WELL #29, NOVA, DAYTONA	54-03-31	--	54
291202081022301	91210235 DAYTONA P.S. WELL #30, TUSC., DAYTONA	79-09-00	--	580
	91210235 DAYTONA P.S. WELL #30, TUSC., DAYTONA	79-09-06	1325	581
	91210235 DAYTONA P.S. WELL #30, TUSC., DAYTONA	82-08-24	1200	640
291155081022901	91210237 DAYTONA P.S. WELL #32, TUSC., DAYTONA	80-12-31	--	150
	91210237 DAYTONA P.S. WELL #32, TUSC., DAYTONA	80-12-31	1115	150
	91210237 DAYTONA P.S. WELL #32, TUSC., DAYTONA	80-12-31	1127	140
291152081023701	91110203 DAYTONA P.S. WELL #33, DAYTONA	82-08-24	1120	170
	91110203 DAYTONA P.S. WELL #33, DAYTONA	82-12-01	1545	150
291139081032401	91110305 DAYTONA P.S. WELL #34, DAYTONA	57-03-00	--	78
	91110305 DAYTONA P.S. WELL #34, DAYTONA	57-03-13	--	70
	91110305 DAYTONA P.S. WELL #34, DAYTONA	57-03-21	--	78
291140081033601	91110304 DAYTONA P.S. WELL #35, DAYTONA	57-03-13	--	30
291137081034801	91110303 DAYTONA P.S. WELL #36, DAYTONA	57-03-13	--	30
291133081035801	91110302 DAYTONA P.S. WELL #37, DAYTONA	57-03-00	--	33
	91110302 DAYTONA P.S. WELL #37, DAYTONA	57-03-13	--	30
	91110302 DAYTONA P.S. WELL #37, DAYTONA	57-03-21	--	33
	91110302 DAYTONA P.S. WELL #37, DAYTONA	82-08-20	1135	66
	91110302 DAYTONA P.S. WELL #37, DAYTONA	82-12-01	1325	53
291130081040601	91110407 DAYTONA P.S. WELL #38, DAYTONA	57-03-13	--	32
	91110407 DAYTONA P.S. WELL #38, DAYTONA	82-03-22	1500	99
	91110407 DAYTONA P.S. WELL #38, DAYTONA	82-08-20	1130	35
	91110407 DAYTONA P.S. WELL #38, DAYTONA	82-12-01	1312	40

TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS IN PUBLIC-SUPPLY WELLS--CONTINUED

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
291126081041701	91110406 DAYTONA P.S. WELL #39, DAYTONA	57-03-13	--	32
	91110406 DAYTONA P.S. WELL #39, DAYTONA	82-03-22	1505	71
	91110406 DAYTONA P.S. WELL #39, DAYTONA	82-08-20	1125	71
291120081042701	91110408 DAYTONA P.S. WELL #40, DAYTONA	57-03-13	--	30
	91110408 DAYTONA P.S. WELL #40, DAYTONA	82-12-01	1307	55
	91110408 DAYTONA P.S. WELL #40, DAYTONA	83-01-31	1245	48
291124081043401	91110410 DAYTONA P.S. WELL #41, DAYTONA	63-09-12	--	34
	91110410 DAYTONA P.S. WELL #41, DAYTONA	82-08-20	1115	55
	91110410 DAYTONA P.S. WELL #41, DAYTONA	82-12-01	1303	42
291120081044501	91110412 DAYTONA P.S. WELL #42, DAYTONA	82-03-22	1510	42
	91110412 DAYTONA P.S. WELL #42, DAYTONA	82-08-20	1110	40
291116081045501	91110413 DAYTONA P.S. WELL #43, DAYTONA	66-06-24	--	63
	91110413 DAYTONA P.S. WELL #43, DAYTONA	82-03-22	1515	61
	91110413 DAYTONA P.S. WELL #43, DAYTONA	82-08-20	1105	63
	91110413 DAYTONA P.S. WELL #43, DAYTONA	82-12-01	1254	69
291113081050601	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	66-06-24	--	74
	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	69-05-15	1030	39
	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	71-06-09	--	41
	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	72-05-08	1220	38
	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	82-08-20	1100	130
	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	82-12-01	1250	110
	91110503 CITY WELL 44 AT DAYTONA BEACH, FL	83-01-31	1250	72
291109081051601	91110501 DAYTONA P.S. WELL #45, DAYTONA	66-07-06	--	55
	91110501 DAYTONA P.S. WELL #45, DAYTONA	82-08-20	1050	210
	91110501 DAYTONA P.S. WELL #45, DAYTONA	82-12-01	1232	160
291105081052301	91110504 DAYTONA P.S. WELL #46, DAYTONA	72-06-01	--	35
	91110504 DAYTONA P.S. WELL #46, DAYTONA	79-09-00	--	47
	91110504 DAYTONA P.S. WELL #46, DAYTONA	82-08-20	1040	230
	91110504 DAYTONA P.S. WELL #46, DAYTONA	82-12-01	1240	42
291101081053601	91110505 DAYTONA P.S. WELL #47, DAYTONA	72-06-02	--	30
	91110505 DAYTONA P.S. WELL #47, DAYTONA	82-08-20	1030	33
291047081061301	91010602 DAYTONA P.S. WELL #48, SW OF DAYTONA	82-03-22	1520	33
	91010602 DAYTONA P.S. WELL #48, SW OF DAYTONA	82-08-20	0945	34
291032081065201	91010601 DAYTONA P.S. WELL #49, SW OF DAYTONA	72-07-14	--	34
	91010601 DAYTONA P.S. WELL #49, SW OF DAYTONA	80-03-00	--	30
	91010601 DAYTONA P.S. WELL #49, SW OF DAYTONA	80-03-11	0945	27
	91010601 DAYTONA P.S. WELL #49, SW OF DAYTONA	82-03-22	1525	31
	91010601 DAYTONA P.S. WELL #49, SW OF DAYTONA	82-08-20	1000	36
291031081065601	91010603 DAYTONA P.S. WELL W-1, W. OF DAYTONA	82-12-28	1045	25
291043081071201	91010701 DAYTONA P.S. WELL W-2, W.OF DAYTONA	82-12-28	1105	27
290830081074401	90810705 DAYTONA P.S. WELL W-3,SW. OF DAYTONA	82-12-16	1250	19
290823081080401	90810807 DAYTONA P.S. WELL W-5, SW OF DAYTONA	82-12-16	1245	23
290820081081401	90810808 DAYTONA P.S. WELL W-6,SW OF DAYTONA	82-12-16	1240	33
290812081083201	90810810 DAYTONA P.S. WELL W-8, SW OF DAYTONA	82-12-16	1220	32
290139081182401	90111701 DELAND P.S. WELL #2, DELAND	57-04-22	--	24
	90111701 DELAND P.S. WELL #2, DELAND	82-08-20	1400	19
	90111701 DELAND P.S. WELL #2, DELAND	82-11-30	0850	20
290156081183501	90111801 DELAND P.S. WELL #3, DELAND	57-04-22	--	19
	90111801 DELAND P.S. WELL #3, DELAND	66-02-15	--	19
	90111801 DELAND P.S. WELL #3, DELAND	82-03-23	1400	35
	90111801 DELAND P.S. WELL #3, DELAND	82-08-20	1405	33
	90111801 DELAND P.S. WELL #3, DELAND	82-11-30	0840	40

TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS IN PUBLIC-SUPPLY WELLS--CONTINUED

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
290156081183401	90111802 DELAND P.S. WELL #4, DELAND	57-04-22	--	21
	90111802 DELAND P.S. WELL #4, DELAND	58-07-15	--	17
	90111802 DELAND P.S. WELL #4, DELAND	66-02-00	--	19
	90111802 DELAND P.S. WELL #4, DELAND	66-02-15	--	19
	90111802 DELAND P.S. WELL #4, DELAND	71-06-08	--	26
	90111802 DELAND P.S. WELL #4, DELAND	76-08-17	0820	19
	90111802 DELAND P.S. WELL #4, DELAND	77-09-01	1515	18
	90111802 DELAND P.S. WELL #4, DELAND	80-03-11	0800	46
	90111802 DELAND P.S. WELL #4, DELAND	82-08-20	1410	20
	90111802 DELAND P.S. WELL #4, DELAND	82-11-30	0835	28
	90111802 DELAND P.S. WELL #4, DELAND	83-02-01	1240	28
	90111802 DELAND P.S. WELL #4, DELAND	83-03-31	1250	25
	90111802 DELAND P.S. WELL #4, DELAND	83-04-29	1015	25
	90111802 DELAND P.S. WELL #4, DELAND	83-05-27	1230	27
	90111802 DELAND P.S. WELL #4, DELAND	83-06-30	1135	26
	90111802 DELAND P.S. WELL #4, DELAND	83-09-30	1200	28
	90111802 DELAND P.S. WELL #4, DELAND	83-11-29	0930	30
	90111802 DELAND P.S. WELL #4, DELAND	84-01-31	0920	29
	90111802 DELAND P.S. WELL #4, DELAND	84-04-05	1245	28
	90111802 DELAND P.S. WELL #4, DELAND	84-05-04	0940	33
	90111802 DELAND P.S. WELL #4, DELAND	84-06-07	0930	27
	90111802 DELAND P.S. WELL #4, DELAND	84-07-06	1200	33
290219081190601	90211901 DELAND P.S. WELL #5, DELAND	82-08-20	1415	12
290227081171301	90211701 DELAND P.S. WELL #6, DELAND	65-09-00	--	15
	90211701 DELAND P.S. WELL #6, DELAND	65-09-02	--	15
	90211701 DELAND P.S. WELL #6, DELAND	65-10-28	1620	12
	90211701 DELAND P.S. WELL #6, DELAND	65-11-00	--	12
	90211701 DELAND P.S. WELL #6, DELAND	65-11-01	--	12
	90211701 DELAND P.S. WELL #6, DELAND	65-12-00	1440	10
	90211701 DELAND P.S. WELL #6, DELAND	65-12-00	1540	8.0
	90211701 DELAND P.S. WELL #6, DELAND	65-12-02	--	10
	90211701 DELAND P.S. WELL #6, DELAND	65-12-02	1440	10
	90211701 DELAND P.S. WELL #6, DELAND	65-12-02	1540	8.0
290208081172401	90211702 DELAND P.S. WELL #6A, DELAND	82-08-20	1420	11
290113081173201	90111703 DELAND P.S. WELL #7, DELAND	57-04-22	--	24
	90111703 DELAND P.S. WELL #7, DELAND	58-07-15	--	18
	90111703 DELAND P.S. WELL #7, DELAND	61-05-12	--	18
290308081182301	90311801 DELAND P.S. WELL #7A, DELAND	82-03-23	1405	14
	90311801 DELAND P.S. WELL #7A, DELAND	82-08-20	1425	13
290156081192701	90111902 DELAND P.S. WELL #8, DELAND	82-03-23	1410	16
	90111902 DELAND P.S. WELL #8, DELAND	82-08-20	1430	12
285419081153901	85411505 DELT. P.S. WELL #1, WELLINGTON, DELTONA	62-12-13	--	10
	85411505 DELT. P.S. WELL #1, WELLINGTON, DELTONA	82-03-29	1000	23
	85411505 DELT. P.S. WELL #1, WELLINGTON, DELTONA	82-08-24	0800	16
	85411505 DELT. P.S. WELL #1, WELLINGTON, DELTONA	82-12-01	0955	12
285416081154401	85411504 DELT. P.S. WELL #2, WELLINGTON, DELTONA	67-10-25	--	9.0
	85411504 DELT. P.S. WELL #2, WELLINGTON, DELTONA	82-03-29	1005	79
	85411504 DELT. P.S. WELL #2, WELLINGTON, DELTONA	82-08-24	0805	24
285359081161701	85311601 DELT. P.S. WELL #3, DIAMOND ST, DELTONA	65-07-13	--	28
	85311601 DELT. P.S. WELL #3, DIAMOND ST, DELTONA	82-03-29	1010	19
	85311601 DELT. P.S. WELL #3, DIAMOND ST, DELTONA	82-08-24	0815	10
	85311601 DELT. P.S. WELL #3, DIAMOND ST, DELTONA	82-12-01	0900	9.4
285525081143301	85511401 DELT. P.S. WELL #4, ELKCAM BLVD,DELTONA	67-10-25	--	53
	85511401 DELT. P.S. WELL #4, ELKCAM BLVD,DELTONA	79-09-10	1230	80
	85511401 DELT. P.S. WELL #4, ELKCAM BLVD,DELTONA	82-03-29	1015	105
	85511401 DELT. P.S. WELL #4, ELKCAM BLVD,DELTONA	82-08-24	0820	110
	85511401 DELT. P.S. WELL #4, ELKCAM BLVD,DELTONA	82-12-01	0815	100

TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS IN PUBLIC-SUPPLY WELLS--CONTINUED

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
285259081132101	85211301 DELT. P.S. WELL #5, SAXON, DELTONA	65-11-15	--	38
	85211301 DELT. P.S. WELL #5, SAXON, DELTONA	82-04-13	1100	99
285406081152301	85411501 DELT. P.S. WELL #6, FIRE STA., DELTONA	66-03-14	--	39
	85411501 DELT. P.S. WELL #6, FIRE STA., DELTONA	82-04-13	1105	22
	85411501 DELT. P.S. WELL #6, FIRE STA., DELTONA	82-08-24	0825	18
	85411501 DELT. P.S. WELL #6, FIRE STA., DELTONA	82-12-01	0845	15
285201081150201	85211504 DELT. P.S. WELL #7, WHISKEY L., DELTONA	67-10-25	--	9.0
285410081152301	85411502 DELT. P.S. WELL #8, FIRE STA., DELTONA	67-01-03	--	9.0
	85411502 DELT. P.S. WELL #8, FIRE STA., DELTONA	82-04-13	1110	49
	85411502 DELT. P.S. WELL #8, FIRE STA., DELTONA	82-08-24	0830	12
	85411502 DELT. P.S. WELL #8, FIRE STA., DELTONA	82-12-01	0947	14
285348081140801	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	66-12-13	--	15
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	77-11-02	1330	140
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	82-03-29	1025	240
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	82-08-24	0835	120
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	82-12-01	0833	78
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-02-01	1320	60
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-03-31	1400	89
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-04-29	0930	97
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-05-27	1145	64
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-06-30	1215	58
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-09-30	1300	56
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	83-12-02	0840	66
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	84-01-31	1030	73
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	84-04-05	1410	51
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	84-05-04	1045	64
	85311402 DELT. P.S. WELL #9, SAXON BLVD, DELTONA	84-06-07	1050	66
285503081124701	85511201 DELT. P.S. WELL #11, NEMO ST, DELTONA	68-12-16	--	360
285340081140801	85311401 DELT. P.S. WELL #12, HOLLYHOCK, DELTONA	82-04-13	1115	67
	85311401 DELT. P.S. WELL #12, HOLLYHOCK, DELTONA	82-08-24	0840	70
	85311401 DELT. P.S. WELL #12, HOLLYHOCK, DELTONA	82-12-01	0830	70
285253081141301	85211401 DELT. P.S. WELL #14, SAXON BLVD,DELTONA	70-12-07	--	60
	85211401 DELT. P.S. WELL #14, SAXON BLVD,DELTONA	79-09-10	1140	114
	85211401 DELT. P.S. WELL #14, SAXON BLVD,DELTONA	82-03-29	1030	170
	85211401 DELT. P.S. WELL #14, SAXON BLVD,DELTONA	82-08-24	0840	42
	85211401 DELT. P.S. WELL #14, SAXON BLVD,DELTONA	82-12-01	0836	24
285631081105201	85611001 DELT. P.S. WELL #15, COURTLAND, DELTONA	82-03-29	1035	30
285352081141001	85311403 DELT. P.S. WELL #16, DELTONA	82-03-29	1040	240
	85311403 DELT. P.S. WELL #16, DELTONA	82-08-24	0845	130
	85311403 DELT. P.S. WELL #16, DELTONA	82-12-01	0835	91
285634081105301	85611002 DELT. P.S. WELL #17, COURTLAND, DELTONA	82-03-29	1045	9.0
285904080554601	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	57-12-00	--	64
	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	58-06-10	--	45
	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	72-05-10	1500	73
	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	76-08-27	0945	58
	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	79-09-00	--	110
	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	82-03-22	1145	210
	85905504 EDGEWATER P.S. WELL #1, W. OF EDGEWATER	82-12-08	1240	210
285858080555701	85805501 EDGEWATER P.S. WELL #2, W. OF EDGEWATER	82-03-22	1150	160
	85805501 EDGEWATER P.S. WELL #2, W. OF EDGEWATER	82-12-08	1250	140
285852080561401	85805601 EDGEWATER P.S. WELL #3, W. OF EDGEWATER	82-03-22	1155	58
	85805601 EDGEWATER P.S. WELL #3, W. OF EDGEWATER	82-12-08	1245	55
291444081022201	91410201 HOLLY HILL P.S. WELL #1, HOLLY HILL	50-04-05	--	70
	91410201 HOLLY HILL P.S. WELL #1, HOLLY HILL	50-08-00	--	73
	91410201 HOLLY HILL P.S. WELL #1, HOLLY HILL	50-09-00	--	75
	91410201 HOLLY HILL P.S. WELL #1, HOLLY HILL	54-11-16	--	71
	91410201 HOLLY HILL P.S. WELL #1, HOLLY HILL	77-11-02	1515	160

TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS
IN PUBLIC-SUPPLY WELLS--CONTINUED

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
291434081025002	91410211 HOLLY HILL P.S. WELL #6A, HOLLY HILL	82-12-01	1013	70
291429081024702	91410213 HOLLY HILL P.S. WELL #7A, HOLLY HILL	82-03-22	1630	190
	91410213 HOLLY HILL P.S. WELL #7A, HOLLY HILL	82-12-01	0958	150
	91410213 HOLLY HILL P.S. WELL #7A, HOLLY HILL	83-01-31	1330	240
291425081024501	91410214 HOLLY HILL P.S. WELL #8, HOLLY HILL	80-09-23	1530	440
291425081024502	91410215 HOLLY HILL P.S. WELL #8A, HOLLY HILL	82-12-01	1030	140
291436081024701	91410216 HOLLY HILL P.S. WELL #9, HOLLY HILL	79-09-00	--	74
	91410216 HOLLY HILL P.S. WELL #9, HOLLY HILL	82-03-22	1635	210
	91410216 HOLLY HILL P.S. WELL #9, HOLLY HILL	82-12-01	0955	320
	91410216 HOLLY HILL P.S. WELL #9, HOLLY HILL	83-01-31	1315	340
291435081025501	91410218 HOLLY HILL P.S. WELL #11, HOLLY HILL	82-12-01	1000	70
290039081204701	90012022 L.BERESFORD P.S. WELL #1, SW OF DELAND	65-08-18	--	68
	90012022 L.BERESFORD P.S. WELL #1, SW OF DELAND	82-08-24	1305	170
	90012022 L.BERESFORD P.S. WELL #1, SW OF DELAND	82-12-08	1545	230
290039081204601	90012021 L.BERESFORD P.S. WELL #2, SW OF DELAND	65-08-18	--	25
	90012021 L.BERESFORD P.S. WELL #2, SW OF DELAND	82-08-24	1310	24
	90012021 L.BERESFORD P.S. WELL #2, SW OF DELAND	82-12-08	1550	51
285840081135601	85811301 L. HELEN P.S. WELL, LAKE HELEN	50-11-21	--	10
	85811301 L. HELEN P.S. WELL, LAKE HELEN	66-04-28	--	10
	85811301 L. HELEN P.S. WELL, LAKE HELEN	82-12-08	1015	11
285951080574701	85905705 NSB PS WELL NUMBERED 3 IN 1947,N.SMYRNA	70-05-07	--	73
	85905705 NSB PS WELL NUMBERED 3 IN 1947,N.SMYRNA	71-05-14	--	56
	85905705 NSB PS WELL NUMBERED 3 IN 1947,N.SMYRNA	71-06-08	--	53
	85905705 NSB PS WELL NUMBERED 3 IN 1947,N.SMYRNA	72-05-10	1400	80
	85905705 NSB PS WELL NUMBERED 3 IN 1947,N.SMYRNA	82-12-08	1225	88
285952080574801	85905701 NSB PS WELL NUMBERED 1 IN 1980,N.SMYRNA	82-12-01	1150	100
	85905701 NSB PS WELL NUMBERED 1 IN 1980,N.SMYRNA	83-01-31	1045	98
285951080575101	85905702 NSB PS WELL NUMBERED 2 IN 1980,N.SMYRNA	79-09-00	--	82
	85905702 NSB PS WELL NUMBERED 2 IN 1980,N.SMYRNA	82-03-22	1105	94
285949080575001	85905703 NSB PS WELL NUMBERED 3 IN 1980,N.SMYRNA	55-06-02	--	54
	85905703 NSB PS WELL NUMBERED 3 IN 1980,N.SMYRNA	82-12-01	1200	61
	85905703 NSB PS WELL NUMBERED 3 IN 1980,N.SMYRNA	83-01-31	1040	58
285951080575501	85905712 NSB PS WELL NUMBERED 6 IN 1980,N.SMYRNA	79-09-00	--	71
285953080575902	85905710 NSB PS WELL NUMBERED 7 IN 1980,N.SMYRNA	77-12-05	1130	76
	85905710 NSB PS WELL NUMBERED 7 IN 1980,N.SMYRNA	78-05-00	--	71
285945080580001	85905801 NSB PS WELL NUMBERED 8 IN 1980,N.SMYRNA	82-03-22	1100	51
290040081050101	90010501 NSB P.S. WELL #S3, SAMSULA	82-03-22	1050	13
290047081052301	90010503 NSB P.S. WELL #S5, SAMSULA	82-03-22	1040	9.0
285641081175501	85611703 ORAN.CITY P.S. WELL#1, ORANGE CITY	64-08-24	--	20
	85611703 ORAN.CITY P.S. WELL#1, ORANGE CITY	65-08-19	--	14
285641081175502	85611704 ORAN.CITY P.S.WELL #2,ORANGE CITY	81-12-18	0915	18
285636081175501	85611702 ORAN.CITY P.S. WELL #3, ORANGE CITY	65-08-19	--	11
	85611702 ORAN.CITY P.S. WELL #3, ORANGE CITY	68-08-24	--	16
285638081175501	85611705 ORAN.CITY P.S.WELL #4,ORANGE CITY	82-03-23	1420	19
291645081034801	91610301 ORMOND P.S. WELL #1, ORMOND BEACH	54-11-16	--	200
	91610301 ORMOND P.S. WELL #1, ORMOND BEACH	82-08-20	1215	230
	91610301 ORMOND P.S. WELL #1, ORMOND BEACH	82-12-01	1101	230
291644081034701	91610302 ORMOND P.S. WELL #2, ORMOND BEACH	54-11-16	--	220
	91610302 ORMOND P.S. WELL #2, ORMOND BEACH	82-08-20	1220	180
	91610302 ORMOND P.S. WELL #2, ORMOND BEACH	82-12-01	1101	120

TABLE OF SUPPLEMENTAL DATA--CHLORIDE CONCENTRATIONS IN PUBLIC-SUPPLY WELLS--CONTINUED

STATION NO.	LOCAL NO. AND WELL NAME	DATE OF SAMPLING (YR-MO-DAY)	TIME OF SAMPLING	CHLORIDE CONCENTRATION (MG/L)
291643081034601	91610303 ORMOND P.S. WELL #3, ORMOND BEACH	54-11-16	--	190
	91610303 ORMOND P.S. WELL #3, ORMOND BEACH	82-08-20	1225	240
	91610303 ORMOND P.S. WELL #3, ORMOND BEACH	82-12-01	1103	130
291643081034401	91610304 ORMOND P.S. WELL #4, ORMOND BEACH	54-11-16	--	200
291641081034501	91610307 ORMOND P.S. WELL #5, ORMOND BEACH	82-12-01	1105	130
291646081034601	91610306 ORMOND P.S. WELL #6, ORMOND BEACH	23-07-00	--	146
	91610306 ORMOND P.S. WELL #6, ORMOND BEACH	23-07-08	--	146
	91610306 ORMOND P.S. WELL #6, ORMOND BEACH	54-11-16	--	196
	91610306 ORMOND P.S. WELL #6, ORMOND BEACH	71-06-08	--	192
291616081040301	91610404 ORMOND P.S. WELL #8, ORMOND BEACH	82-03-23	1200	150
	91610404 ORMOND P.S. WELL #8, ORMOND BEACH	82-12-01	1129	110
	91610404 ORMOND P.S. WELL #8, ORMOND BEACH	83-01-31	1410	170
291614081040901	91610406 ORMOND P.S. WELL #10, ORMOND BEACH	82-03-23	1205	140
291607081042301	91610408 ORMOND P.S. WELL #12, ORMOND BEACH	72-05-05	1100	136
	91610408 ORMOND P.S. WELL #12, ORMOND BEACH	79-09-00	--	130
	91610408 ORMOND P.S. WELL #12, ORMOND BEACH	82-12-01	1121	120
291608081042101	91610409 ORMOND P.S. WELL #13, ORMOND BEACH	79-09-00	--	110
	91610409 ORMOND P.S. WELL #13, ORMOND BEACH	82-03-23	1210	120
291558081044301	91510401 ORMOND P.S. WELL #17, ORMOND BEACH	82-03-23	1215	130
291628081040101	91610413 ORMOND P.S. WELL #18, ORMOND BEACH	82-03-23	1220	190
	91610413 ORMOND P.S. WELL #18, ORMOND BEACH	82-12-01	1113	190
	91610413 ORMOND P.S. WELL #18, ORMOND BEACH	83-01-31	1400	200
291623081041101	91610414 ORMOND P.S. WELL #19, ORMOND BEACH	82-03-23	1225	170
291611081043201	91610416 ORMOND P.S. WELL #21, ORMOND BEACH	82-03-23	1230	130
291601081060801	91610603 ORMOND P.S. WELL #22, ORMOND BEACH	82-03-23	1235	120
291527081064601	91510605 ORMOND P.S. WELL #24, ORMOND BEACH	82-03-23	1240	72
290742081013901	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	72-05-10	1300	89
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	76-08-27	0820	68
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	78-04-10	--	93
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	79-08-16	--	68
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	79-09-07	1145	76
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	80-03-25	--	78
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	80-10-08	--	85
	90810103 PORT ORANGE P.S. WELL #4, PORT ORANGE	82-03-22	1300	83
290813081013801	90810104 PORT ORANGE P.S. WELL #5, PORT ORANGE	82-03-22	1305	95
290818081013801	90810105 PORT ORANGE P.S. WELL #6, PORT ORANGE	82-03-22	1310	58
290813081014101	90810106 PORT ORANGE P.S. WELL #7, PORT ORANGE	82-12-01	1100	160
	90810106 PORT ORANGE P.S. WELL #7, PORT ORANGE	83-01-31	1130	150
290835081013801	90810108 PORT ORANGE P.S. WELL #9, PORT ORANGE	82-03-22	1315	59
290840081013801	90810109 PORT ORANGE P.S. WELL #10, PORT ORANGE	82-03-22	1320	66
290846081014401	90810111 PORT ORANGE P.S. WELL #12, PORT ORANGE	82-03-22	1325	72
290846081014901	90810112 PORT ORANGE P.S. WELL #13, PORT ORANGE	82-03-22	1330	84
290846081015501	90810113 PORT ORANGE P.S. WELL #14, PORT ORANGE	82-03-22	1335	63
290846081020101	90810202 PORT ORANGE P.S. WELL #15, PORT ORANGE	82-03-22	1340	63
290846081020701	90810203 PORT ORANGE P.S. WELL #16, PORT ORANGE	82-03-22	1345	61