UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

FRESHWATER RESOURCES OF BIG PINE KEY, FLORIDA

OPEN-FILE REPORT 80-447

Prepared in cooperation with
MONROE COUNTY
and the
RIDGE AND LOWER GULF COAST WATER MANAGEMENT DISTRICT

CONVERSION FACTORS

The conversion factors and abbreviations for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric (SI) unit
inch (in)	2.54	millimeter (mm)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,234.0	cubic meter (m^3)

* * * * * * *

mean sea level (msl)	----------	National Geodetic Vertical Datum of 1929 (Datum of 1929)

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By C. E. Hanson

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Tallahassee, Florida

1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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FRESHWATER RESOURCES OF BIG PINE KEY, FLORIDA

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ABSTRACT

The principal freshwater-bearing unit underlying Big Pine Key is a layer of oolitic limestone averaging 19 feet in thickness. The freshwater exists in two separate lenses, one in the northern half of the island and one in the southern half. The slightly larger north lens is separated from the south lens by a low-lying area 1 to 3 feet above NGVD of 1929. The lenses float on saltwater in the aquifer and are affected by tidal fluctuations. The areal and depth configuration of the lenses fluctuate in response to rainfall, evapotranspiration, lateral and vertical losses, and pumpage from local wells. The lenses are not a major source of freshwater. Only a small amount of the freshwater in the lenses can be removed before saltwater intrusion will occur.

INTRODUCTION

Big Pine Key, a reef limestone island in the lower Florida Keys (fig. 1), has an area of approximately 14 mi^2. The northern part is primarily undeveloped pinelands and a buttonwood and mangrove fringe; it includes the Key Deer National Wildlife Refuge. The southern part has similar vegetation but is developed for residential and commercial use.

Big Pine Key lies within a tropical climatic zone. The average temperature is 29°C in summer and 22°C in winter. Temperatures seldom fall below 4°C due to the moderating effect of the Florida current and Florida Bay. Average annual rainfall is 39 inches, of which 75-85 percent falls from May through October (U.S. Weather Service, written commun., February 1977).

Development of Big Pine Key and other Florida Keys has accelerated since the middle 1960's. To protect the natural resources and minimize further environmental changes, the Florida Legislature declared the Florida Keys an "area of critical state concern."

The permanent population of Big Pine Key is about 800. During the winter the influx of tourists increases the population by about 2,000. This increase corresponds with the dry season when the island freshwater resources are lowest, and any increased pumpage stresses the available water supply.

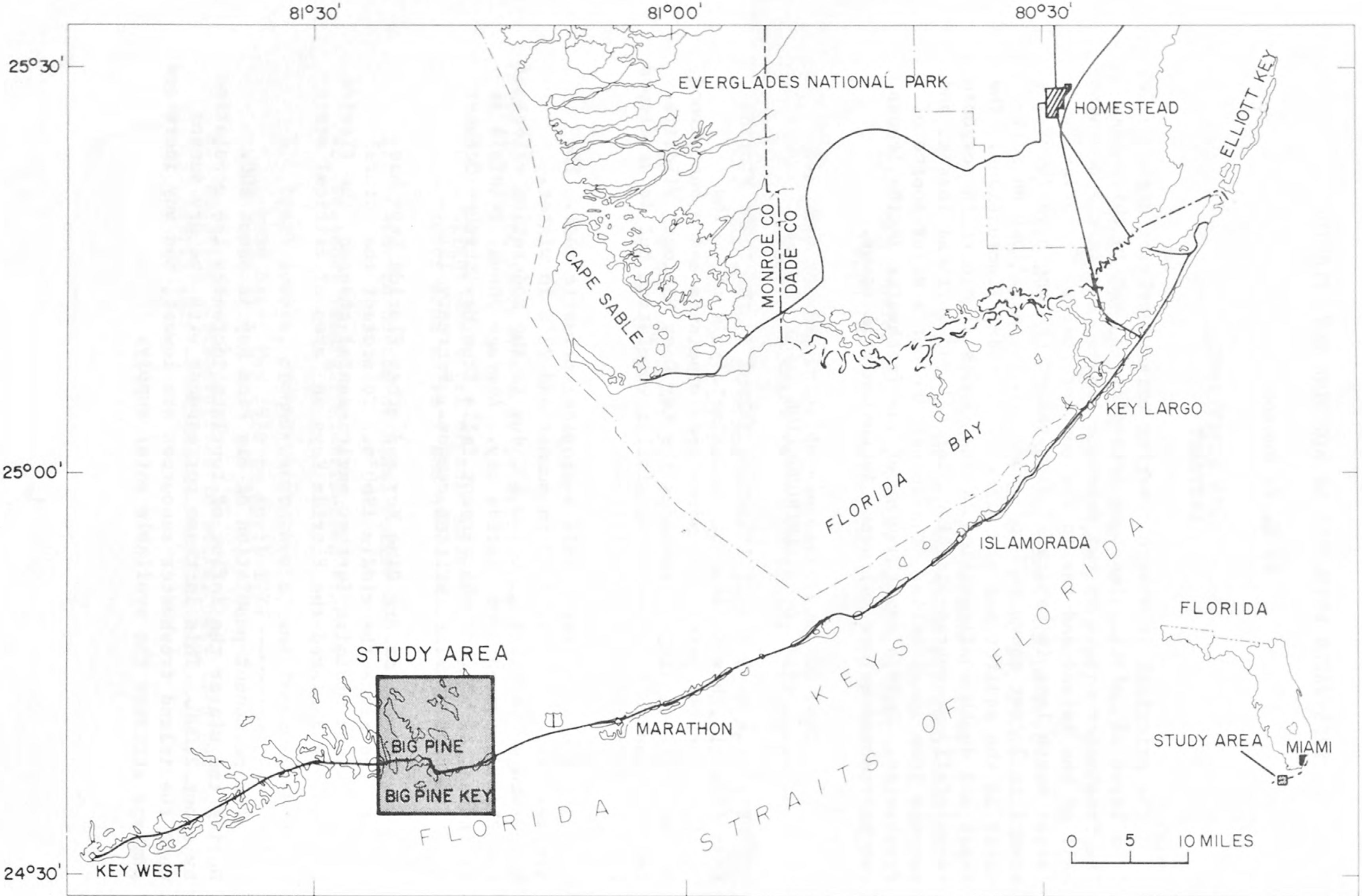

Figure 1.--Location of Big Pine Key, Florida

The main source of water for the island is the Florida Keys Aqueduct Authority pipeline from the mainland. Supplemental sources are shallow wells and rainfall cisterns. These sources have met the needs of residents and tourists, but concern for freshwater supplies has recently been generated because of increasing demands on the local ground-water resources by commercial and residential users. Proposed tropical plant nurseries would further increase freshwater demand.

Saltwater intrusion is the main threat to the fresh ground-water supply of Big Pine Key. Intrusion has occurred in some areas as a result of channelization for waterfront property, and in low parts of the island as a result of channelization for mosquito control.

In March 1976 the Ridge and Lower Gulf Coast Water Management District and Monroe County began a cooperative program with the U.S. Geological Survey to investigate the freshwater resources underlying Big Pine Key. This information will assist water managers in planning for the efficient use of water, as well as in short and long-range planning for the development of the Florida Keys freshwater resources.

Purpose and Scope

Increasing pressures on the water available from the Florida Keys Aqueduct Authority (FKAA) pipeline require water managers to look for new and alternate sources of freshwater. Knowledge of the availability of freshwater on Big Pine Key is needed for long-range planning and managing the freshwater resources of the island. This report includes information on the areal and vertical configuration of the freshwater lenses beneath the island, and describes how the lenses change seasonably.

Acknowledgments

The author wishes to thank Monroe County and the Ridge and Lower Gulf Coast Water Management District for support in this water-resources investigation. Acknowledgment is extended to the U.S. Fish and Wildlife Service, Key Deer National Wildlife Refuge; Florida State Division of Forestry; and the residents of Big Pine Key for valuable cooperation and assistance.

DATA COLLECTION

Between May 1976 and February 1977, 22 uncased wells were drilled to obtain geologic data and to monitor changes in chloride concentrations in the ground water. Ten wells were drilled along the north-south centerline of the island (fig. 2). Other wells were drilled perpendicular to the centerline in the northern and southern parts of the island. Four additional wells were drilled near the center of the island in an area of low elevation. Wells 1 through 20 range in depth from 20 to 26 feet (fig. 2). Wells 2A and 6A are 36.9 and 37.6 feet deep and were drilled to define the top of the saltwater zone. Chloride concentrations and specific conductance of ground water in the wells were determined by sampling at the water table, at successive 5-foot depth intervals, and at the bottom of each well. Specific conductance measurements were made in place with a conductance probe. Chloride concentrations were determined from specific conductance and by titration of the samples. Samples were collected and analyzed at monthly intervals from June 1976 through April 1977. Samples were also collected and analyzed for chloride concentrations at 14 surface-water sites. Continuous water levels were obtained at two wells and one tidal gage.

Geological data were obtained from rock core samples which were taken during drilling of the monitor wells. Relative changes in porosity and degree of cementation or solution were noted at various depths.

Water samples were taken from wells 2 and 6 at a depth of 1 foot below the water table in October 1976 and April 1977. These samples were analyzed for major inorganic ions and macronutrients to determine differences during wet and dry seasons (tables 1 and 2).

Rainfall data from 1969 through June 1976 were obtained from records kept by the late Ralph Higgs at the meteorological station in the northern part of the island. Rainfall data were also supplied by the U.S. Weather Service in Key West, Florida.

GEOLOGY

The Florida Keys can be classified into two groups, distinguished by rock characteristics, orientation, shape, and origin. The Upper Keys (islands between Big Pine Key and the mainland) are oriented along a northeast-southwest arc. The Lower Keys (Big Pine Key to Key West) are almost at right angles to the arc and are separated by narrow channels that run northwest-southeast.

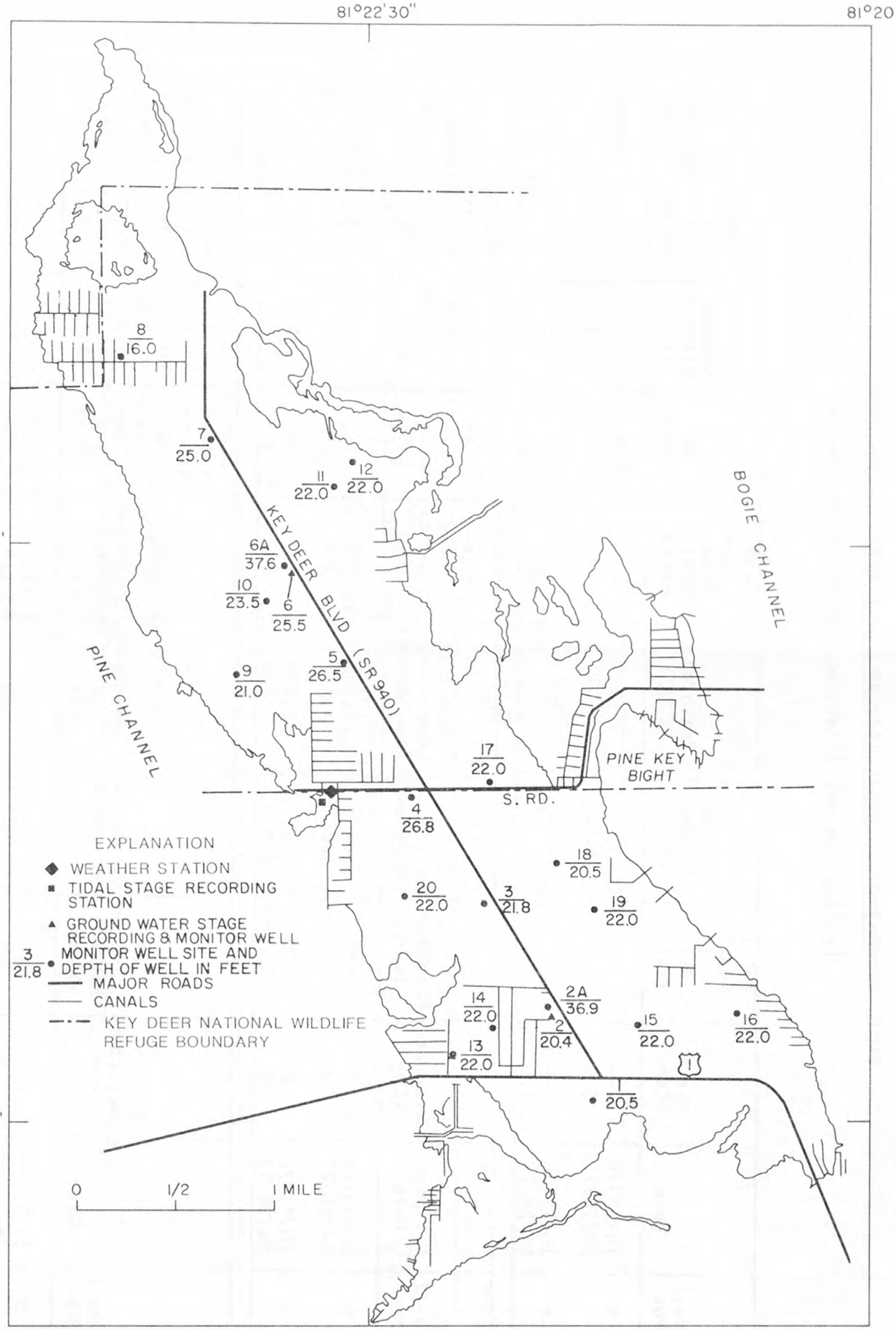

Figure 2.--Location of monitor wells and ground-water and tidal-stage recording gages

Table 1.--Major inorganic ions in water from wells 2 and 6

[milligrams per liter, unless otherwise indicated]

Well No.	Date	Depth (feet)	Total depth of well (feet)	Temperature (°C)	Turbidity (JTU)	Color (platinum cobalt units)	pH (units)	Carbon dioxide (CO_2)	Alkalinity as ($CaCO_3$)	Bicarbonate (HCO_3)
2	10/13/76	—	21	28.0	100	0	7.2	28	230	280
	04/28/77	1.0	21	26.0	450	0	7.5	13	220	264
6	10/13/76	—	25	27.0	220	0	7.4	20	259	316
	04/28/77	1.0	25	26.0	25	0	7.4	16	200	248

Well No.	Date	Carbonate (CO_3)	Hardness (Ca,Mg)	Carbonate hardness	Specific conductance (micromhos)	Dissolved chloride (Cl)	Dissolved sulfate (SO_4)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)
2	10/13/76	0	290	64	1,350	290	52	77	24	170
	04/28/77	0	330	120	1,675	380	63	84	29	220
6	10/31/76	0	330	76	1,830	470	60	79	33	250
	04/28/77	0	450	240	2,540	740	86	100	47	380

Well No.	Date	Sodium adsorption ratio	Percent sodium	Dissolved potassium (K)	Dissolved fluoride (F)	Dissolved silica (SiO_2)	Dissolved strontium (micrograms per liter)	Dissolved solids (residue at 180°C)	Dissolved solids (sum of constituents)	Dissolved solids (tons per acre-feet)
2	10/13/76	4.3	55	10	.5	1.7	2,100	742	765	1.01
	04/28/77	5.3	58	13	.3	1.6	2,200	977	923	1.33
6	10/13/76	6.0	61	11	.2	1.3	1,500	1,010	1,060	1.37
	04/28/77	7.9	64	15	.2	1.4	2,000	1,580	1,490	2.15

Table 2.--Nutrient and total organic carbon analyses of water from wells 2 and 6

[milligrams per liter]

Well No.	Date	Total nitrogen (N)	Total organic nitrogen (N)	Total kjeldal nitrogen (N)	Total ammonia nitrogen (N)	Total ni-trite (N)	Total ni-trate (N)	Total ni-trite plus ni-trate (N)	Total phos-phorus (P)	Total ortho-phos-phorus (P)	Total organic carbon (C)
2	10/13/76	.18	.08	.17	.09	.01	.00	.01	.01	.00	47
	04/28/77	.44	.34	.44	.10	.00	.00	.00	.08	.00	4
6	10/13/76	.19	.09	.18	.09	.01	.00	.01	.01	.00	10
	04/28/77	.18	.07	.18	.11	.00	.00	.00	.01	.00	4

The Upper Keys are of coral lime origin, known as the Key Largo Limestone, (Parker and others, 1955, p. 99-100), formed during the Pleistocene age as part of a coral reef. The islands are elongate parallel to the coastline along which the reef grew (Hoffmeister, 1974). The Key Largo Limestone is composed primarily of corals and some amorphous calcium carbonate, coral sand, breccia, and limey muds. The formation is very permeable, contains cavities, and has a porosity coefficient of about 0.2 (Parker and others, 1955).

The Lower Keys are an offshore extension of the Miami Oolite of Pleistocene age present in southeast Florida (Parker and others, 1955). Porosity of the Miami Oolite is moderately high, but the permeability is low. The porosity coefficient is approximately 0.4, but the interconnection of the voids between the oolids is very small, causing low permeability (oral commun., Robert Halley, 1977). The Miami Oolite was deposited in a warm, shallow sea as a shoal deposit (Parker and others, 1955).

The Miami Oolite extends from land surface to depths of 14 to 19 feet at the southern part of Big Pine Key and 16 to 23 feet at the northern part (table 3 and fig. 3); the thickness generally increases toward the centerline of the island where land surface altitude is highest. Key Largo Limestone underlies the Miami Oolite.

Three layers of hard, dense limestone were identified in test wells penetrating the Miami Oolite to the Key Largo Limestone. These layers are 2 to 8 inches thick and have low permeability. The first layer is near land surface, the second is 6 to 7 feet below land surface, and the third is 16 to 20 feet below land surface. The third layer is approximately at the Miami Oolite and Key Largo Limestone contact. These layers are probably discontinuous.

HYDROLOGY

The areal and depth configuration of the lenses of freshwater underlying Big Pine Key are influenced by five factors: (1) freshwater recharge (rainfall); (2) freshwater discharge; (3) response to tidal fluctuations; (4) proximity to saltwater bodies; and (5) permeability of subsurface materials.

Rainfall, which averages 39 inches per year, is the only source of freshwater recharge. During the study annual rainfall was 46.03 inches, with 86 percent occurring between May and October (table 4).

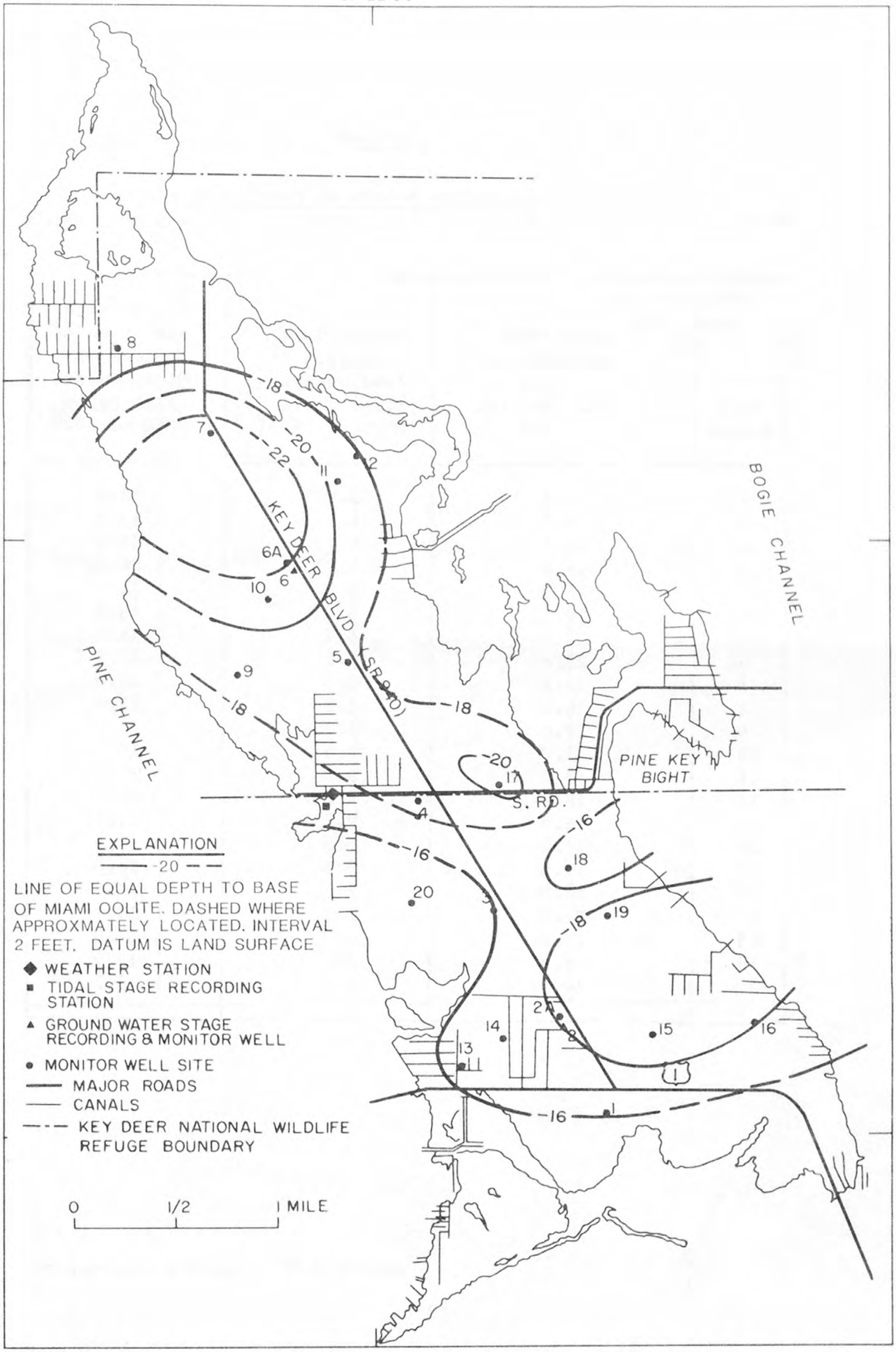

Figure 3.--Depth below land surface of base of the Miami Oolite

Table 3.--Depths to bottom of Miami Oolite

Well Number	Depth from land surface to bottom of Miami Oolite (feet)	Approximate elevation of land surface (feet above NGVD of 1929)	Approximate elevation of bottom of Miami Oolite (feet below NGVD of 1929)
1	16.0	3.0	13.0
2	18.0	4.1	13.9
2A	19.7	4.2	15.5
3	16.0	1.75	14.25
4	18.5	4.5	14.0
5	18.5	5.0	13.5
6	22.0	5.3	16.7
6A	22.6	5.1	17.5
7	23.5	2.5	21.0
8	16.0	3.0	13.0
9	19.0	1.7	17.3
10	21.0	4.5	16.5
11	19.0	3.2	15.8
12	18.0	4.0	14.0
13	16.5	2.75	13.75
14	17.0	3.5	13.5
15	19.5	3.5	16.0
16	18.0	2.5	15.5
17	21.0	3.0	18.0
18	14.0	3.0	11.0
19	18.5	2.6	15.9
20	14.5	2.3	12.2

Table 4.--Seasonal rainfall distribution since 1969

Year	Total precipitation (inches)	Total precipitation for wet season (May-October) (inches)	Percent of total precipitation in wet season (%)
1969	61.63	49.12	79.7
1970	41.06	27.13	66.0
1971	41.11	33.45	81.3
1972	45.58	35.13	76.9
1973	55.98	43.02	76.8
1974	INCOMPLETE DATA		
1975	32.90	25.86	78.6
1976	47.01	39.68	84.4
Period of study--May 1976 April 1977	46.03	39.68	86.2
Average since 1969*	46.48	36.19	77.8

*Long-term average - 39.0 inches

Freshwater discharge is by surface runoff and losses from the lenses by evapotranspiration, lateral seepage, and pumpage. Average evapotranspiration in south Florida is about 70 percent of the rainfall (Parker and others, 1955). Much of the surface of Big Pine Key is riddled with solution cavities which allow rainfall to rapidly infiltrate, thereby, reducing evapotranspiration. In some parts of the island hard, dense limestone at or near the surface locally causes temporary ponding. This retards but does not prevent infiltration. Heavy vegetation in some areas near the lenses also increases evapotranspiration.

Freshwater losses by surface runoff have not been determined, but low relief on Big Pine Key suggests that this loss is small. Canals dug from the coast to inland parts of the island to obtain fill for housing construction and to provide waterfront properties tend to accelerate runoff of freshwater. The canals penetrate the water-bearing material, increasing natural discharge from the freshwater lenses and allowing saltwater to move farther inland. The largest canal networks are on the west side in the northern and central parts of the island.

Between May 1976 and April 1977, monthly average water levels in well 6 in the northern part of the island and well 2 in the southern part varied by up to 0.98 feet. The highest monthly average water level in well 6 was 1.44 feet above NGVD of 1929 in September 1976, and the lowest was 0.81 feet in February 1977 (table 5). In well 2 the highest monthly average water was 1.61 feet in October 1976, and the lowest was 0.63 feet in February 1977. Monthly average water levels at the tide recorder on Big Pine Channel were above NGVD of 1929 in all months except February when the average level was 0.10 feet below NGVD of 1929.

Water-table fluctuations on Big Pine Key are influenced primarily by rainfall and tides. During the wet season rainfall is probably the overriding influence causing the peaks in the hydrographs of wells 2 and 6 (fig. 4). During the dry season tides are the dominant influence. Fluctuations caused by evapotranspiration are subdued and are usually masked by those caused by tides and rainfall.

The tides in the Lower Keys result from the phasing together of the Atlantic Ocean and Gulf of Mexico tides. Tides from the Atlantic are a predictable two-cycle (diurnal) tidal movement, while the tides of the Gulf are normally one-cycle daily. The phasing together of these tide systems results in mixed tides. Varying amounts of this phasing cause large differences in the amplitudes and times of the tides in the Lower Keys. Tides at the recorder on Pine Channel on the west side of Big Pine Key (fig. 2) are mixed tides (fig. 5). Tide charts prepared by the National

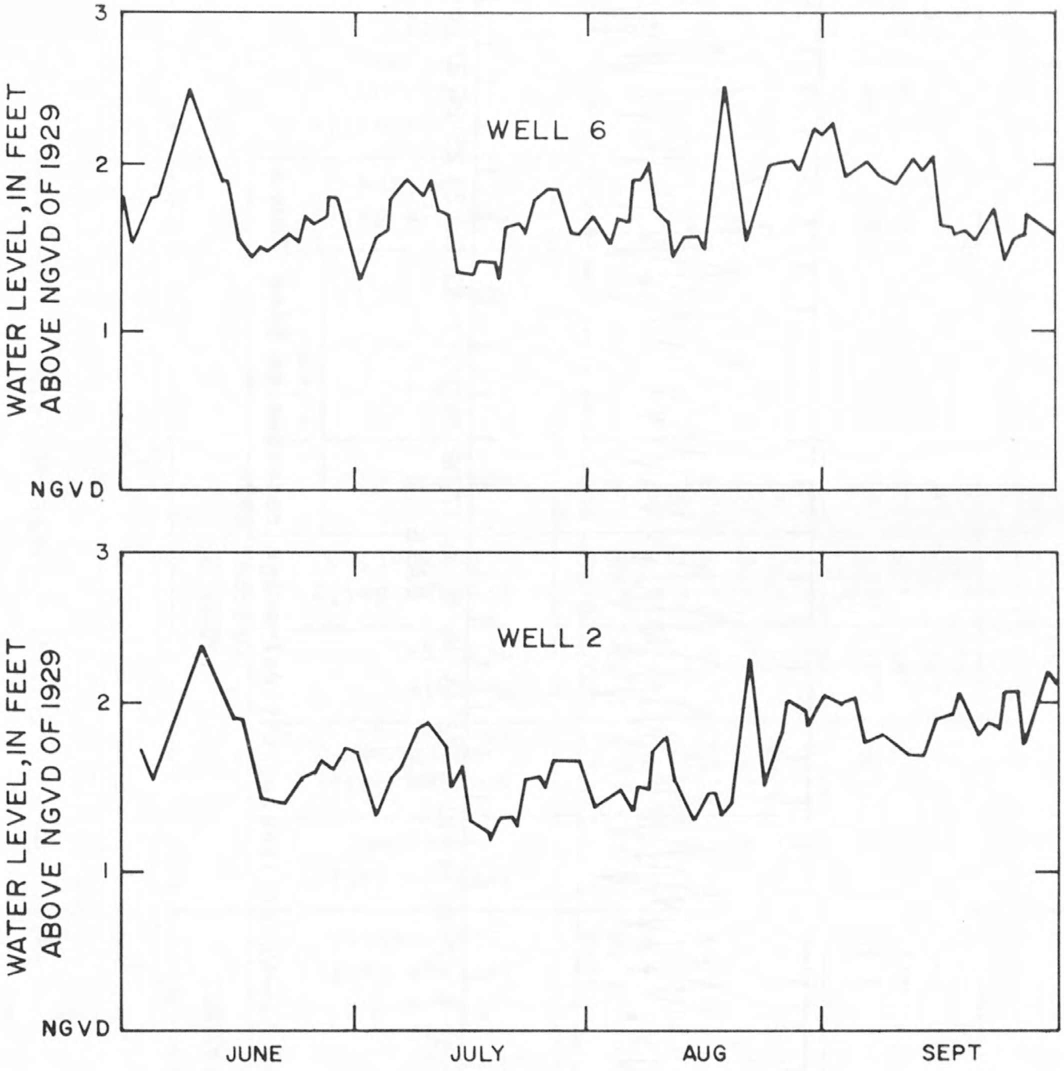

Figure 4.--Daily high water levels in wells 2 and 6, June to September 1976

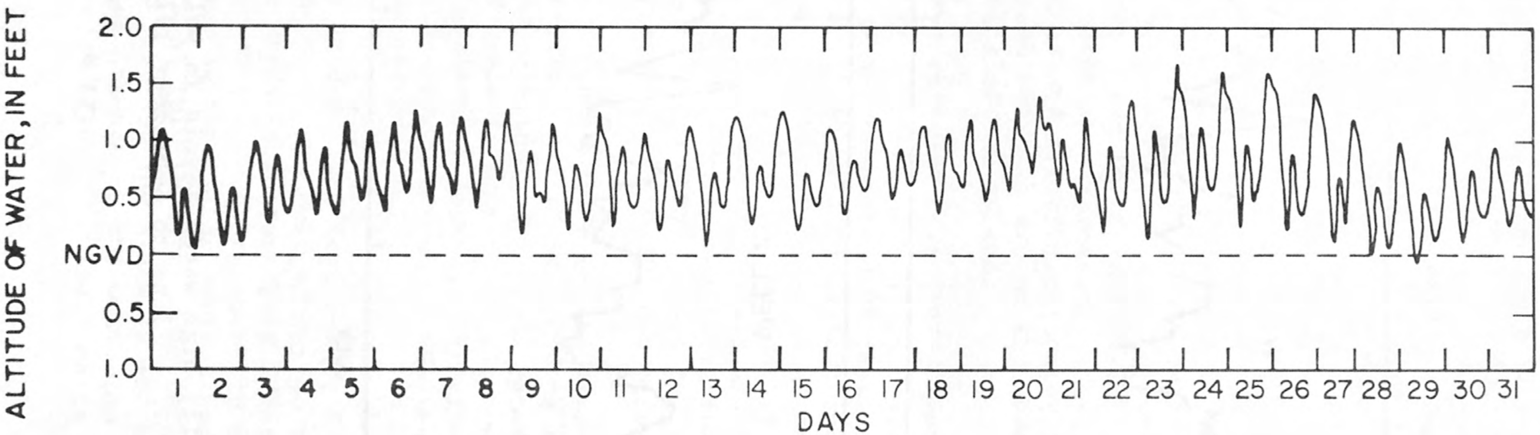

Figure 5.--Water levels at tidal-stage recorder on Pine Channel, October 1976

Table 5.--Tidal levels, ground-water levels, and freshwater head data, May 1976 to April 1977

[all values in feet above NGVD of 1929, unless otherwise noted]

		BIG PINE CHANNEL				WELL 2							WELL 6						
										Freshwater head in feet							Freshwater head in feet		
Year	Month	Average daily maximum	Average daily minimum	Monthly average	Average daily fluctuation	Average daily maximum	Average daily minium	Monthly average	Average daily fluctuation	Maximum	Minimum	Mean	Average daily maximum	Average daily minimum	Monthly average	Average daily fluctuation	Maximum	Minimum	Mean
1976	May	1.30	0.18	0.72	1.12	1.53	0.67	1.07	0.86	0.49	0.23	0.35	1.63	0.63	1.14	1.00	0.45	0.33	0.42
	June	1.25	.16	.67	1.09	1.70	.82	1.22	.88	.66	.45	.55	1.80	.84	1.31	.96	.68	.55	.64
	July	.98	-.10	.40	1.08	1.47	.69	1.03	.78	.79	.49	.63	1.62	.77	1.19	.85	.87	.64	.79
	Aug.	1.06	.00	.50	1.06	1.63	.83	1.17	.79	.83	.57	.67	1.83	.97	1.36	.86	.97	.77	.86
	Sept.	1.21	.27	.70	.94	2.02	1.10	1.49	.92	.83	.79	.81	1.85	1.08	1.44	.77	.81	.64	.74
	Oct.	1.24	.26	.73	.99	2.04	1.18	1.61	.86	.92	.80	.88	1.77	1.03	1.37	.73	.77	.53	.64
	Nov.	1.11	.08	.58	1.03	1.94	1.05	1.48	.90	.97	.83	.90	1.77	.93	1.31	.83	.85	.66	.73
	Dec.	1.08	.02	.54	1.06	1.81	.91	1.32	.90	.89	.73	.78	1.83	.92	1.34	.91	.90	.75	.80
1977	Jan.	.79	-.40	.16	1.19	1.35	.50	.87	.85	.90	.56	.71	1.76	.69	1.14	1.08	1.09	.97	.98
	Feb.	.50	-.49	-.10	1.09	1.07	.29	.63	.79	.88	.57	.73	1.17	.46	.81	.72	1.05	.67	.91
	March	.64	-.33	.12	.97	1.20	.47	.81	.73	.80	.56	.69	1.38	.57	1.01	.81	.90	.74	.89
	April	.79	-.21	.28	1.00	1.35	.58	.95	.77	.79	.56	.67	1.36	.57	1.00	.79	.76	.57	.72
Study period average		.00	-.05	.44	1.05	1.59	.76	1.14	.84	.81	.60	.70	1.65	.79	1.20	.86	.84	.65	.76

Oceanographic and Atmospheric Administration for 1976 indicate that tide schedules in Bogie Channel on the eastern side of the island vary from those in Pine Channel by as much as several hours. Due to the shallow waters in the Lower Keys, local winds and weather systems offshore affect both the amplitude and times of tides in the area.

The extreme variability of the tides in the vicinity of Big Pine Key make it impossible to correlate water-table fluctuations with the tides or determine tidal efficiency at the monitor wells with data available.

The amount and distribution of freshwater in an island lens is determined by several factors which include rainfall, permeability of the sediments, and land-surface elevation. The depth at which saltwater underlies the freshwater is governed by the Ghyben-Herzberg relation (Chow, 1964) where conditions are homogeneous and under a steady state. These conditions do not exist in nature, but the relation is a useful tool for estimating the approximate depth of the fresh-saltwater interface. The relation states that for every foot of freshwater above NGVD of 1929, 40 feet of saltwater will be displaced below NGVD of 1929 due to the density difference between saltwater and freshwater. Freshwater has a density of 1.0 gram per cubic centimeter (g/cm^3) and seawater has a density of 1.025 g/cm^3; therefore, the freshwater is lighter and floats on the saltwater. Land-surface elevations on Big Pine Key are highest in the center of the island, and the freshwater head is greater there than at the coast. The resulting body of freshwater is lens-shaped. The transition between freshwater and saltwater is a zone of dispersion maintained by fluctuations of the water levels and tidal action (Cooper and others, 1964). This zone grades from freshwater to saltwater. The freshwater lens expands during the wet season and contracts during the dry season. Parker (1955, p. 177) stated that Big Pine Key was one of the islands containing the largest amounts of freshwater in the Florida Keys. He also states pumpage of several thousand gallons per day (gal/d) would soon exhaust the island's freshwater even during the wet season.

On Big Pine Key the average freshwater head for March 1977 was 0.69 foot in well 2 and 0.89 foot in well 6 (table 5). According to the Ghyben-Herzberg relation, the freshwater lens theoretically should extend about 27 feet below NGVD of 1929 at well 2 and about 35 feet below NGVD of 1929 at well 6. Depth traverses of specific conductance profiles of water in well 2A (southern part of island) and well 6A (northern part of island) indicate that the relatively low salinity of the water is constant to a depth of about 20 feet below NGVD of 1929 (figs. 6 and 7). At that point the salinity increases rapidly with depth. The apparent zone of dispersion is about 10 feet thick. Samples taken 29 feet below NGVD of 1929 in well 6A had chloride concentrations of 6,600 mg/L.

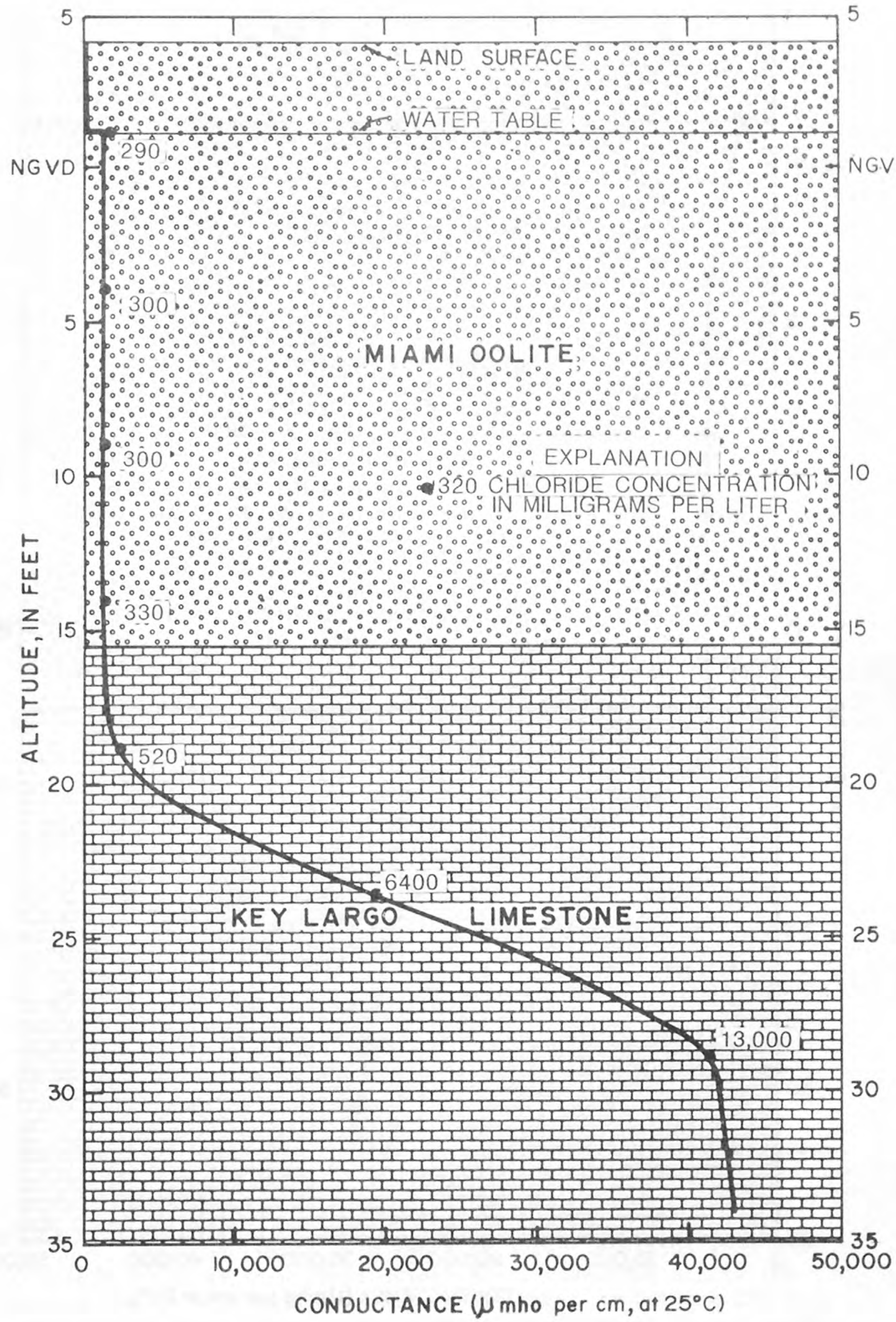

Figure 6.--Conductivity and chloride concentration in relation to geology at well 2A, March 1977

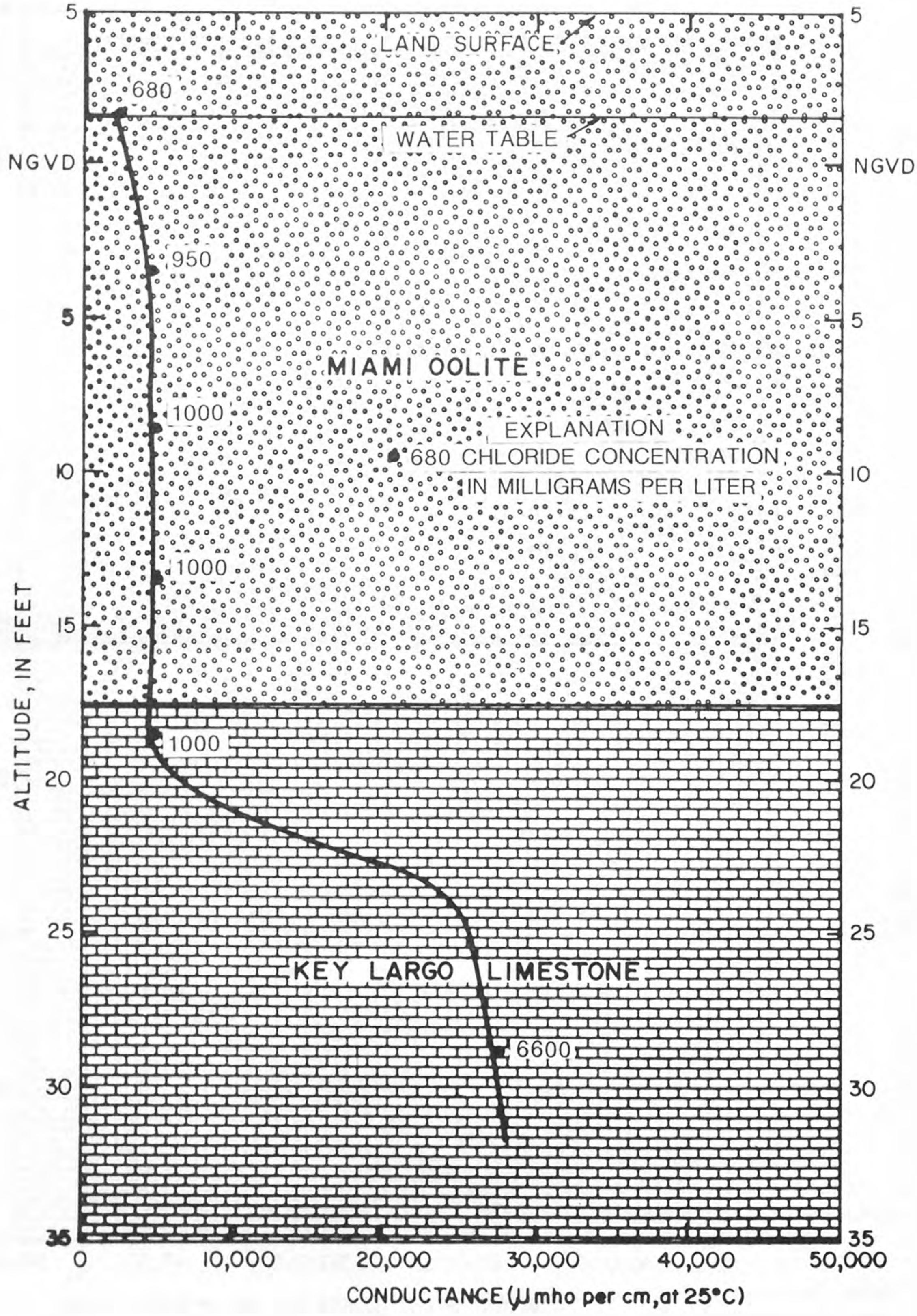

Figure 7.--Conductivity and chloride concentration in relation to geology at well 6A, March 1977

Configuration of Freshwater Lenses

During most of the year two separate freshwater lenses persist on Big Pine Key, one near well 6 in the north and one near well 2 in the south. These general areas are where land elevation above NGVD of 1929 is greatest. The lenses are separated by an area of low land-surface elevation, 1 to 3 feet above NGVD of 1929, extending from near Pine Key Bight southwest to Pine Channel. Monthly chloride determinations of ground water in the uncased monitor wells were made at the water table and at 5-foot intervals below the water table (table 6). Chloride concentrations increased rapidly with depth in some wells and more gradually in others.

Monthly changes in chloride concentrations between June 1976 and April 1977 at a depth of 10 feet below the water table in selected wells in the north and south freshwater lenses are shown in figures 8 and 9. The graphs indicate that chloride concentrations respond to rainfall on Big Pine Key. The greatest and most rapid response of chloride concentrations to rainfall variations occurs in well 7 near the northern end of the island and well 4 near the center. Both wells are located short distances from tidally affected canals. The canals provide channels for inland movement of seawater in addition to accelerating discharge of freshwater from storage in the lenses.

Chloride concentration fluctuations in wells other than 7 and 4 were more subdued, with concentrations decreasing as recharge from rainfall caused the lenses to expand and increasing during dry periods when evapotranspiration and pumpage reduced the lenses size. The somewhat larger chloride fluctuations in wells in the south lens probably are due to withdrawal of water for irrigation and domestic use. The increase in chloride concentration at well 6 in the north lens is probably due to pumping from a nearby rock quarry. The pumping temporarily lowers water levels and permits upward migration of saltwater from deeper zones. The data show that none of the monitor wells yields water whose chloride content meets drinking water standards (U.S. Environmental Protection Agency, 1976, p. 205) on a year-round basis.

Maps of equal chloride concentration at various depths below the water table were prepared to obtain synoptic configurations of the freshwater lenses during the investigation. The maps for September 14, 1976, when the freshwater resources were near maximum, show that water to a depth of 5 feet contains less than 500 mg/L chloride in a longitudinal strip extending nearly the entire length of the island (fig. 10). Water containing 250 mg/L chloride or less occurs in three areas, the largest in the north lens. At a depth of 10 feet below the water table (fig. 11), the

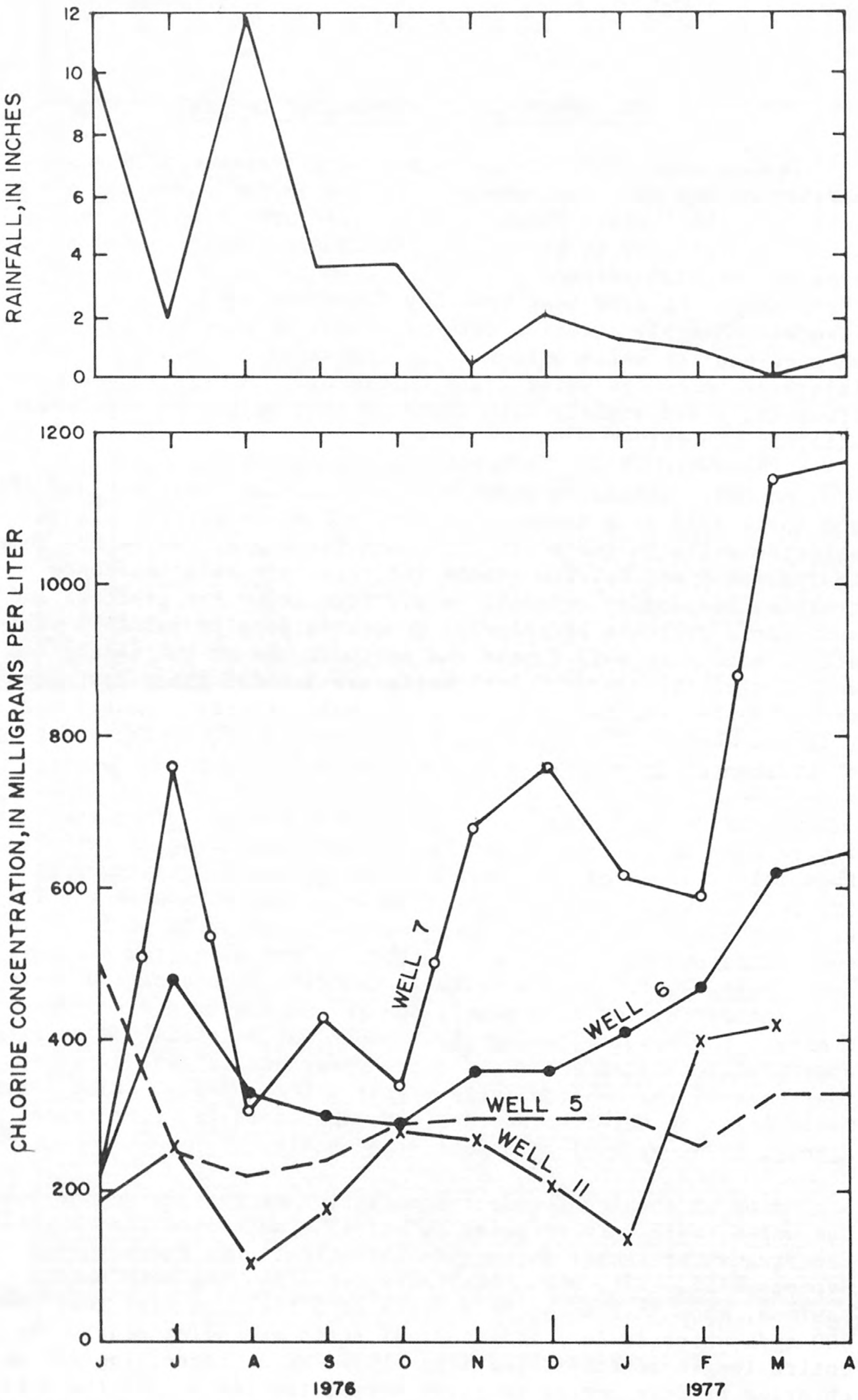

Figure 8.—Fluctuations of chloride concentrations 10 feet below the water table in selected wells in the northern part of Big Pine Key and rainfall, June 1976 to April 1977

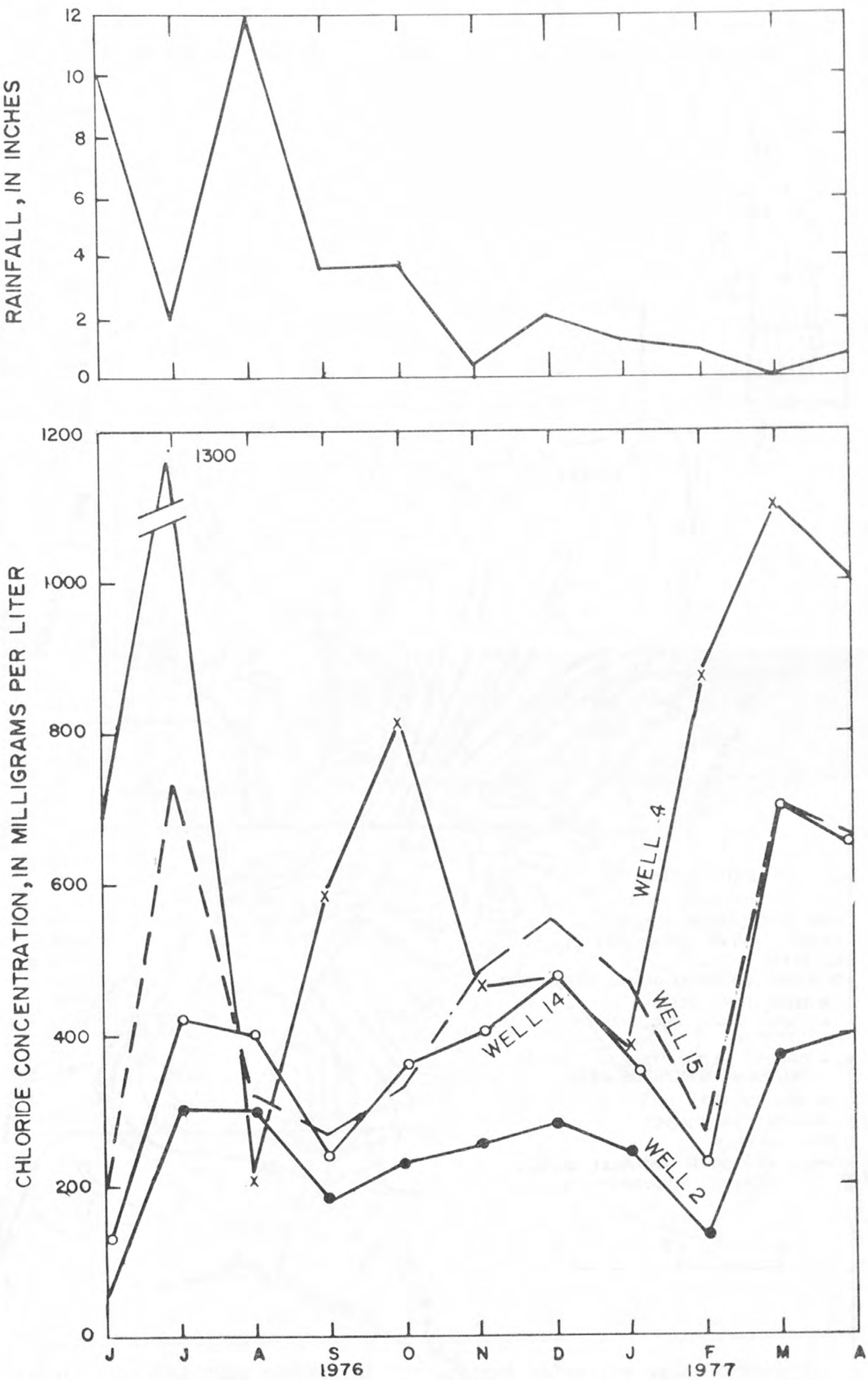

Figure 9.—Fluctuations of chloride concentrations 10 feet below the water table in selected wells in the southern part of Big Pine Key and rainfall, June 1976 to April 1977

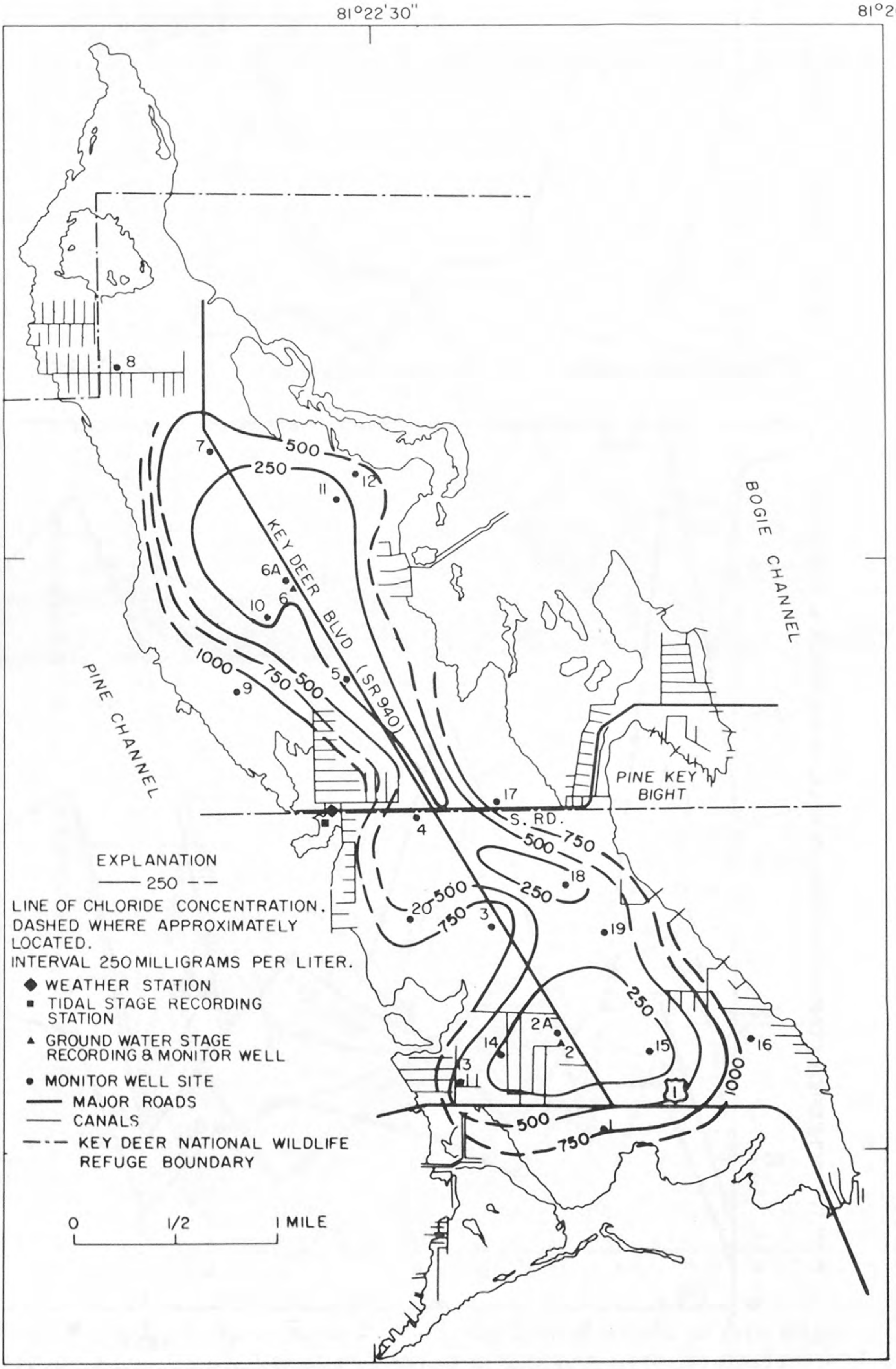

Figure 10.--Chloride concentrations 5 feet below the water table, September 14, 1976

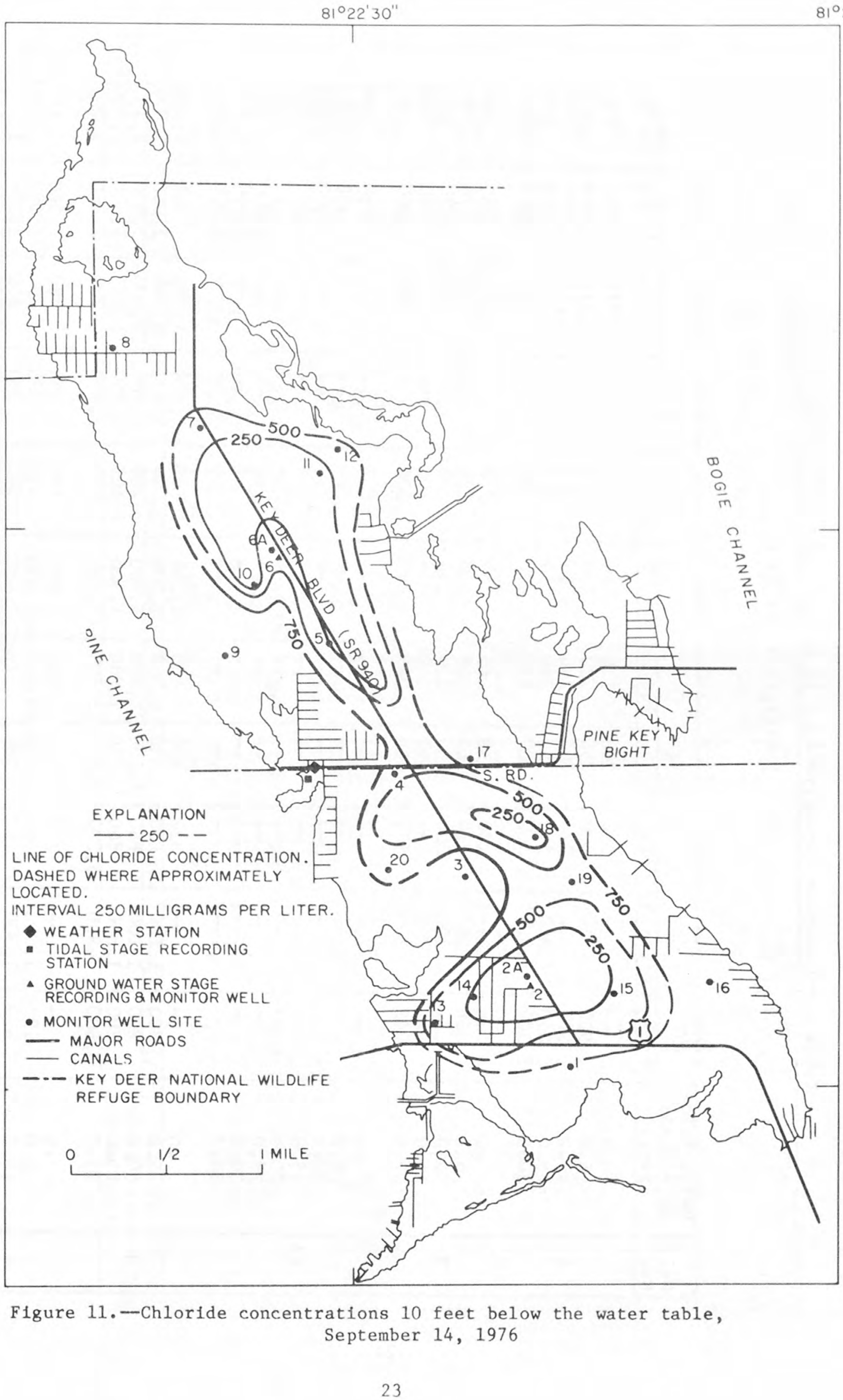

Figure 11.--Chloride concentrations 10 feet below the water table, September 14, 1976

Table 6.--Chloride concentrations in wells, July 1976 to April 1977

[milligrams per liter]

Well No.	Depth below water table (feet)	1976							1977			
		6/14	7/14-15	8/18	9/14	10/12	11/16	12/14	1/11	2/18	3/29	4/29
1	0.0	—	—	280	200	130	480	760	760	720	860	800
	5.0	900	650	300	750	730	760	760	760	730	820	800
	10.0	900	850	330	760	740	760	760	740	740	860	780
	15.0	850	850	350	740	740	850	800	770	750	940	900
	20.5	1,300	1,300	560	1,000	950	1,200	1,300	1,200	790	1,100	1,300
2	.0	—	—	180	48	65	250	270	200	130	350	360
	5.0	38	200	270	160	180	240	270	210	120	370	390
	10.0	37	300	300	180	230	250	280	240	130	370	400
	15.0	42	300	—	190	240	—	300	260		380	390
	20.4	42	300	300	210	240	260	300	270	140	380	400
2A	.0	—	—	—	—	—	—	—	—	—	290	280
	5.0	—	—	—	—	—	—	—	—	—	300	280
	10.0	—	—	—	—	—	—	—	—	—	300	320
	15.0	—	—	—	—	—	—	—	—	—	330	360
	20.0	—	—	—	—	—	—	—	—	—	520	650
	25.0	—	—	—	—	—	—	—	—	—	6,400	7,200
	30.0	—	—	—	—	—	—	—	—	—	13,000	15,000
	33.7	—	—	—	—	—	—	—	—	—	13,000	16,000
3	.0	—	—	820	950	890	1,100	1,100	1,200	1,200	960	1,200
	5.0	800	1,100	860	880	1,000	1,300	1,700	1,400	1,200	1,000	1,300
	10.0	800	1,100	860	1,600	1,000	1,300	1,600	1,400	1,200	1,000	1,200
	15.0	1,200	1,800	860	1,600	1,900	1,300	1,600	1,300	1,200	1,600	1,700
	21.2	3,600	3,800	3,200	3,000	3,400	3,100	3,000	2,700	2,700	2,800	3,200
4	.0	—	—	170	120	240	440	450	350	380	560	470
	5.0	192	1,000	160	310	320	440	450	370	390	1,000	700
	10.0	650	1,300	210	580	810	460	470	380	870	1,100	1,000
	15.0	650	1,300	290	900	850	560	590	480	900	1,200	1,300
	24.7	2,300	3,300	1,700	2,200	2,500	2,500	2,400	2,300	2,400	2,500	2,800

Table 6.--Chloride concentrations in wells, July 1976 to April 1977 (Continued)

[milligrams per liter]

Well No.	Depth below water table (feet)	1976							1977			
		6/14	7/14-15	8/18	9/14	10/12	11/16	12/14	1/11	2/18	3/29	4/29
5	0.0	—	—	200	56	39	300	300	310	260	320	340
	5.0	62	230	200	140	160	300	300	300	260	330	330
	10.0	500	250	220	240	290	300	300	300	260	330	330
	15.0	500	300	260	280	330	310	300	290	300	320	350
	25.0	1,100	1,300	260	880	980	1,300	1,600	1,600	1,600	1,600	2,200
6	.0	—	—	280	180	240	360	370	410	480	610	610
	5.0	190	310	300	250	260	350	360	390	450	590	650
	10.0	230	480	330	300	290	360	360	410	470	620	650
	15.0	270	500	350	360	360	360	370	410	450	600	640
	25.0	750	800	560	490	500	560	470	470	590	780	820
6A	.0	—	—	—	—	—	—	—	—	—	680	700
	5.0	—	—	—	—	—	—	—	—	—	950	1,200
	10.0	—	—	—	—	—	—	—	—	—	1,000	1,300
	15.0	—	—	—	—	—	—	—	—	—	1,000	1,400
	20.0	—	—	—	—	—	—	—	—	—	1,000	1,400
	25.0	—	—	—	—	—	—	—	—	—	1,200	2,500
	30.0	—	—	—	—	—	—	—	—	—	6,600	—
	32.8	—	—	—	—	—	—	—	—	—	8,000	11,000
7	.0	—	—	180	110	100	380	780	640	620	780	840
	5.0	180	650	270	450	330	680	760	640	620	960	940
	10.0	180	760	300	430	340	680	760	620	590	940	960
	15.0	180	750	300	450	330	710	760	650	640	940	940
	24.4	180	850	290	450	370	800	760	620	640	1,000	960
8	.0	—	—	7,200	5,800	8,200	15,000	19,000	20,000	18,000	13,000	13,000
	5.0	3,000	11,000	7,500	9,500	8,800	—	—	—	—	—	—
	9.8	3,000	11,000	--	--	--	21,000	23,000	22,000	18,000	14,000	13,000

Table 6.—Chloride concentrations in wells, July 1976 to April 1977 (Continued)

[milligrams per liter]

Well No.	Depth below water table (feet)	1976							1977			
		6/14	7/14-15	8/18	9/14	10/12	11/16	12/14	1/11	2/18	3/29	4/29
	0.0	—	—	1,200	1,400	1,400	1,400	1,500	1,500	1,500	1,400	1,500
	5.0	1,300	1,400	1,300	1,400	1,400	1,400	1,500	1,500	1,400	1,600	1,600
9	10.0	1,400	2,000	1,200	1,400	1,300	1,400	1,500	1,500	1,400	1,600	1,600
	15.0	1,400	2,700	1,200	1,400	1,400	1,500	1,600	1,500	1,400	2,100	1,600
	21.0	1,600	2,900	1,300	1,300	1,400	1,600	1,600	1,600	1,900	2,200	2,400
	.0	—	—	140	96	200	310	290	260	230	370	350
	5.0	180	270	160	210	220	300	290	240	230	370	340
10	10.0	170	490	160	240	220	300	280	260	230	370	340
	15.0	170	780	200	260	240	400	390	260	230	610	450
	23.4	170	800	200	270	270	410	480	320	230	780	770
	.0	—	—	220	51	160	280	270	220	140	340	380
	5.0	58	180	260	100	160	280	260	210	140	390	410
11	10.0	60	190	260	110	180	280	270	210	140	400	420
	15.0	60	190	260	110	190	280	270	230	140	400	430
	21.0	65	190	270	120	200	310	280	220	140	420	430
	.0	—	—	310	280	300	410	470	450	360	600	450
	5.0	280	600	270	360	300	400	450	440	360	910	490
12	10.0	310	650	330	420	450	480	490	480	390	960	730
	15.0	310	750	430	430	480	560	630	530	460	990	880
	22.0	310	600	430	450	470	560	660	560	480	1,100	960
	.0	—	—	340	130	440	460	490	470	530	520	540
	5.0	400	320	400	440	500	460	460	450	490	970	1,400
13	10.0	400	350	390	470	630	460	480	470	520	1,100	1,500
	15.0	400	350	440	1,200	860	1,500	930	1,400	610	1,600	1,600
	21.1	1,300	1,400	1,500	1,600	1,900	1,900	1,700	2,100	1,200	1,700	2,400

Table 6.--Chloride concentrations in wells, July 1976 to April 1977 (Continued)

[milligrams per liter]

Well No.	Depth below water table (feet)	1976							1977			
		6/14	7/14-15	8/18	9/14	10/12	11/16	12/14	1/11	2/18	3/29	4/29
14	0.0	—	--	400	140	110	400	470	360	220	650	450
	5.0	94	350	400	180	300	400	460	360	220	680	500
	10.0	130	420	400	240	360	400	470	370	230	700	650
	15.0	160	500	460	450	430	500	590	600	680	830	770
	21.1	770	950	860	720	690	750	820	800	740	830	1,000
15	.0	—	--	250	87	100	470	550	430	240	700	650
	5.0	130	650	330	190	230	460	540	460	240	700	680
	10.0	170	730	320	270	330	480	550	470	270	700	660
	15.0	170	730	440	340	400	490	570	490	290	700	670
	21.2	170	700	420	390	420	500	580	550	290	700	690
16	.0	—	--	2,400	530	350	1,100	3,100	2,600	3,000	2,900	3,000
	5.0	250	2,200	3,100	1,900	2,800	2,900	3,200	3,000	3,100	2,900	3,600
	10.0	250	2,200	3,100	1,900	2,800	2,900	3,200	3,100	3,200	3,000	3,700
	15.0	250	2,200	3,200	1,800	2,800	2,900	3,200	3,100	3,200	3,000	3,400
	21.2	240	3,300	3,200	2,200	2,900	3,400	4,000	4,000	4,000	3,200	4,500
17	.0	—	—	1,100	500	670	1,200	1,800	2,200	1,800	1,600	2,200
	5.0	1,200	1,300	2,100	900	1,000	2,200	2,600	2,300	1,700	2,800	2,100
	10.0	1,300	1,600	2,100	950	1,000	2,200	2,600	2,200	1,800	2,800	2,600
	15.0	1,400	1,700	2,100	950	1,000	2,200	3,200	2,500	1,800	3,000	3,100
	20.5	1,500	2,800	3,100	950	2,000	2,900	4,000	3,400	3,000	3,600	3,800
18	.0	—	—	95	55	100	210	240	200	210	450	350
	5.0	310	260	120	190	230	200	230	210	210	490	370
	10.0	300	260	100	210	280	220	350	340	230	510	390
	15.0	290	280	120	600	440	560	660	590	320	690	440
	20.3	800	800	530	920	730	960	1,100	1,000	660	920	--

Table 6.—Chloride concentrations in wells, July 1976 to April 1977 (Continued)

[milligrams per liter]

Well No.	Depth below water table (feet)	1976							1977			
		6/14	7/14-15	8/18	9/14	10/12	11/16	12/14	1/11	2/18	3/29	4/29
19	0.0	—	—	220	150	160	520	570	500	440	740	640
	5.0	300	600	320	440	440	520	580	490	400	870	760
	10.0	330	750	360	560	520	530	600	540	440	880	800
	15.0	340	750	420	660	570	580	690	610	420	870	820
	21.4	350	800	420	690	630	640	810	700	540	1,600	960
20	.0	—	—	190	220	500	640	670	640	440	850	750
	5.0	650	900	290	670	700	610	730	590	460	850	1,100
	10.0	850	1,100	290	600	700	630	770	600	450	850	1,300
	15.0	1,100	1,200	1,400	1,600	1,400	2,500	2,500	2,400	2,100	2,000	2,300
	20.3	4,500	4,600	4,200	2,800	3,400	3,300	4,000	3,800	3,700	3,700	4,400

areas containing water with 250 and 500 mg/L chloride have decreased considerably. At a depth of 15 feet (fig. 12) these areas continue to decrease. Figure 12 shows that at 15 feet below the water table, the two freshwater lenses are separated by an area in which the water contains more than 750 mg/L chloride.

Maps of equal chloride concentrations at depths of 5, 10, and 15 feet below the water table were prepared for samples collected on March 29, 1977, when freshwater resources were near minimum (figs. 13, 14, and 15). The maps show that none of the water on Big Pine Key had chloride concentrations less than or equal to the drinking water criteria of 250 mg/L (U.S. Environmental Protection Agency, 1976, p. 205). Water from several wells in both lenses was found to have chloride concentrations less than 500 mg/L (table 6).

SURFACE-WATER QUALITY

Water samples were taken from 15 surface-water sites in April 1976 and March 1977 and analyzed for chloride concentrations (fig. 16). These sites represent areas of freshwater available to wildlife, primarily deer. Chloride concentrations ranged from 102 to 5,600 mg/L and exceeded 250 mg/L in about 80 percent of the samples.

POTENTIAL FRESHWATER SUPPLIES

The amount of freshwater remaining in the shallow lenses near the end of the dry season (fig. 16) does not represent the potential supply or the perennial yield available from the lenses. The quantity of freshwater that remains in the lenses at the end of the dry season will fluctuate depending upon the amount and timing of rainfall. During years of above normal rainfall the lenses will contain more freshwater and cover a larger area at the end of the dry season than shown in figure 16. During extended droughts the freshwater lenses may totally dissipate. Also any substantial increase in pumping would probably reduce water levels and increase saltwater intrusion.

Water is presently being withdrawn from the lenses from about 150 private and commercial wells. In most cases these wells are a secondary source of water; the Florida Keys Aqueduct Authority pipeline is the primary source. The principal use of water from the lenses is irrigation of lawns and plant nurseries. Due to the sporadic nature of pumpage of these wells, no estimates of withdrawals from the lenses were made.

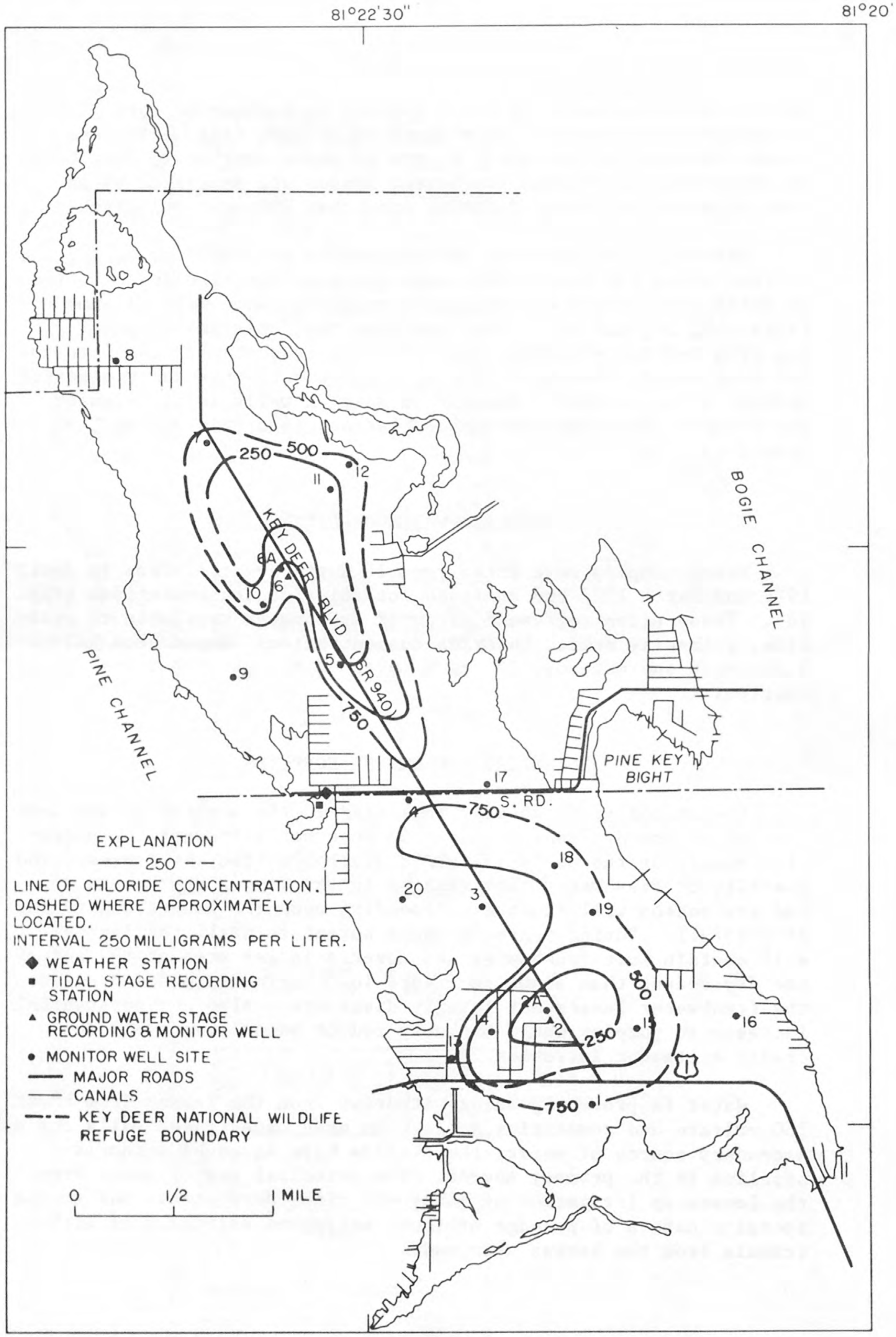

Figure 12.--Chloride concentrations 15 feet below the water table, September 14, 1976

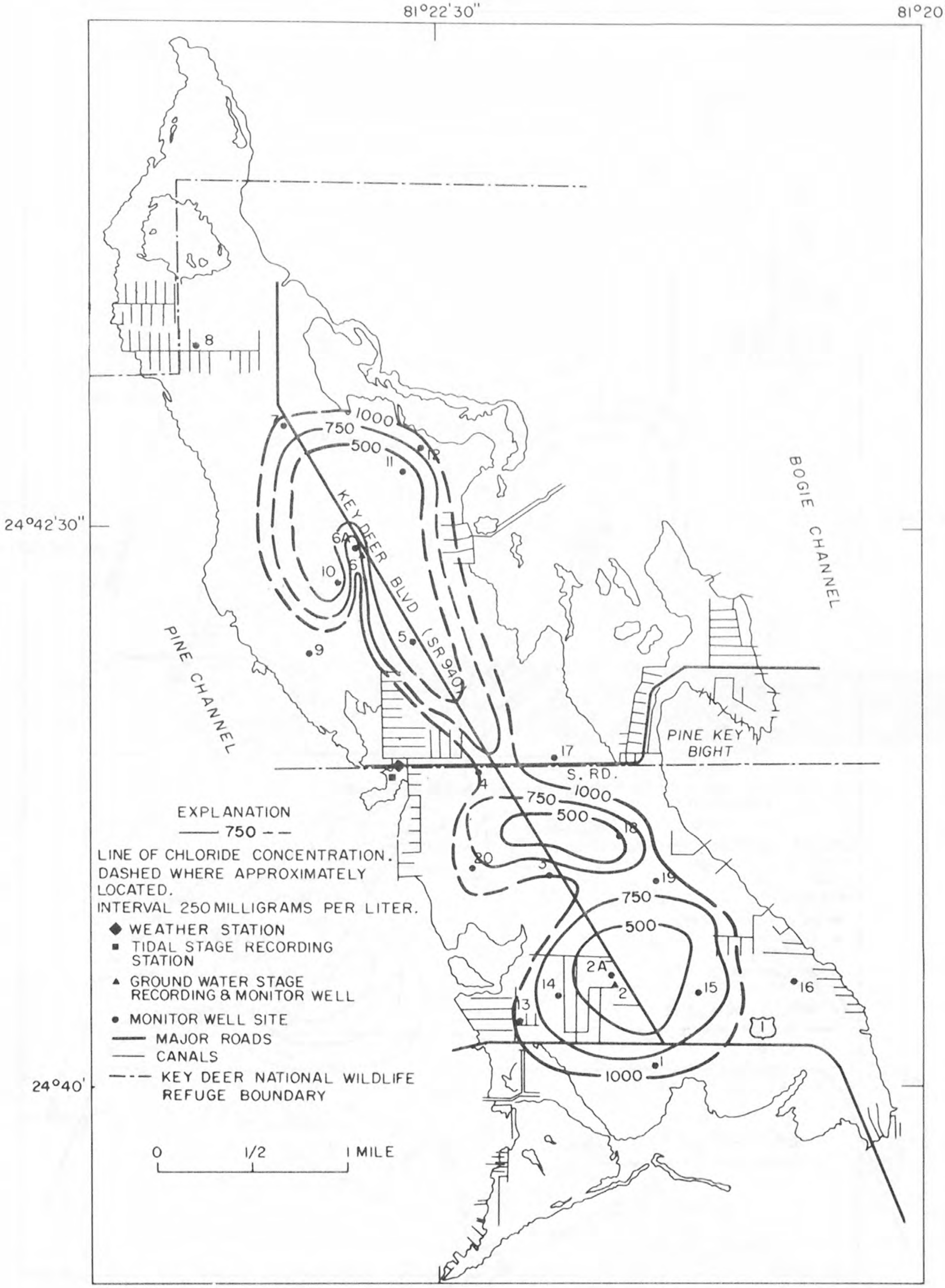

Figure 13.—Chloride concentrations 5 feet below the water table, March 29, 1977

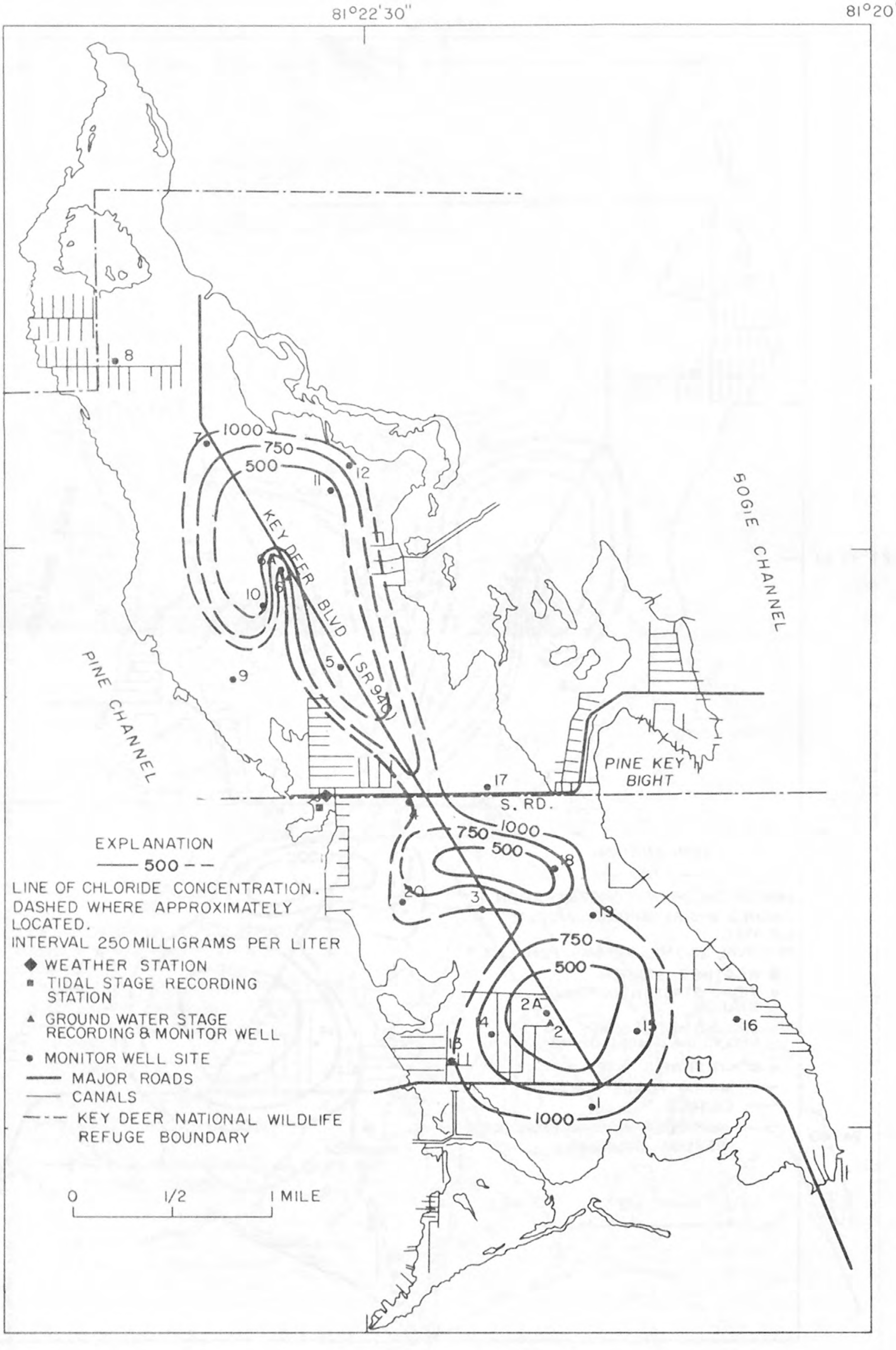

Figure 14.—Chloride concentrations 10 feet below the water table, March 29, 1977

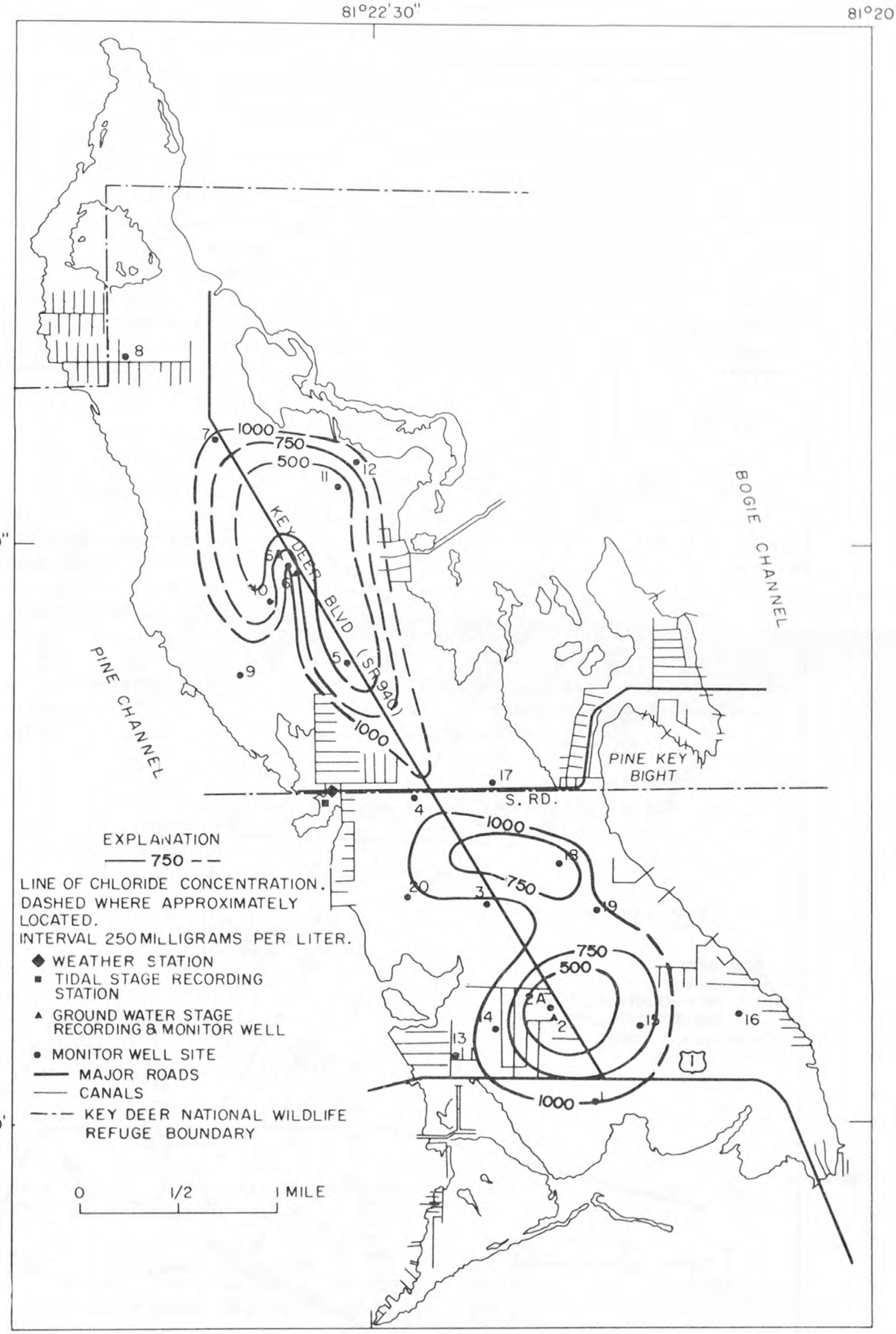

Figure 15.—Chloride concentrations 15 feet below the water table, March 29, 1977

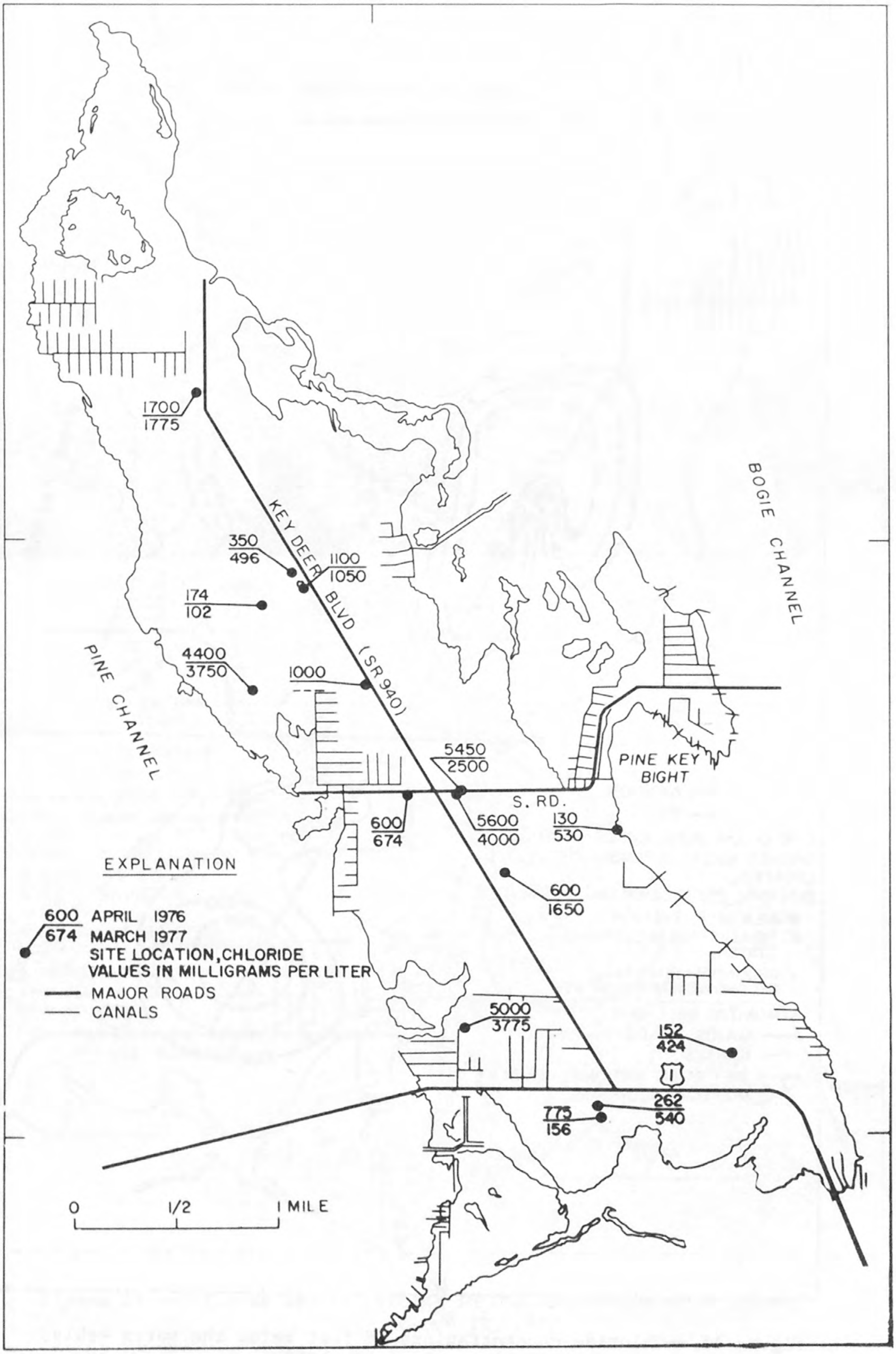

Figure 16.--Chloride concentrations at surface-water sites

Much of the south end of Big Pine Key has been zoned for residential use. This use, along with new or enlarged plant nurseries, will increase the stress on the freshwater lenses which can only supply moderate amounts without detrimental effects during most years. Most of the area north of the east-west State Road is in the Key Deer National Wildlife Refuge and is not subject to private development. Large increases in water pumpage are not anticipated there.

SUMMARY

Miami Oolite, the primary freshwater bearing unit underlying Big Pine Key, averages 19 feet thick. Most of the freshwater is in two separate lenses, one in the northern half of the island and the other in the southern half. The slightly larger north lens is separated from the south lens by a low-lying area 1 to 3 feet above NGVD of 1929. Ground-water levels fluctuate in response to tides.

The areal and depth configuration of the lenses fluctuate in response to recharge by rainfall and to discharge by evapotranspiration, pumpage, and ground-water discharge to the sea.

The freshwater lenses under Big Pine Key do not constitute a major source of freshwater. Continued pumping of freshwater from shallow wells will probably not damage the system. However, a continued point withdrawal or large scale general withdrawal would induce saltwater intrusion into freshwater lenses.

It is doubtful that the north lens will be subjected to excessive withdrawals, because most of this area is part of the Key Deer National Wildlife Refuge and is not subject to development. However, the area which overlies the south freshwater lens is platted for residential and commerical development. Future increased withdrawals will probably be from this area and will increase the threat of saltwater intrusion.

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