GROUND-WATER RESOURCES OF THE RIVIERA BEACH AREA, PALM BEACH COUNTY, FLORIDA

U.S. GEOLOGICAL SURVEY

Water Resources Investigation 77-47

Prepared in cooperation with the
CITY OF RIVIERA BEACH

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle
GROUND-WATER RESOURCES OF THE RIVIERA BEACH AREA, PALM BEACH COUNTY, FLORIDA

5. Report Date
September 1977

6.

7. Author(s)
L. F. Land

8. Performing Organization Rept. No. USGS/WRI 77-47

9. Performing Organization Name and Address
U.S. Geological Survey, Water Resources Division
325 John Knox Road, Suite F-240
Tallahassee, Florida 32303

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
U.S. Geological Survey, Water Resources Division
325 John Knox Road, Suite F-240
Tallahassee, Florida 32303

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes
Report prepared in cooperation with the City of Riviera Beach

16. Abstracts
The so-called "shallow aquifer" composed chiefly of sand, shells, sandstone, and limestone, is the principal source of freshwater in the Riviera Beach area. The major water-bearing zone consists of cemented layers of sand and shells, about 100 ft thick, in the lower part of the aquifer. The quality of the water in the shallow aquifer is generally suitable for public supply except locally along C-17 Canal where the dissolved solids concentration exceeds 500 milligrams per liter. The configuration of the water table is greatly influenced by Lake Worth, C-17 Canal, West Palm Beach water catchment area, rainfall, and municipal pumpage. The major threat to development of water supplies, and possibly to the continuation of a current withdrawal rate of over 5 Mgal/d, is seawater (Lake Worth), but the combined effects of increased pumpage, reduced recharge resulting from increased land development, and below normal rainfall, have caused seawater to advance inland in the aquifer. Additional supplies could be developed to the west.

17. Key Words and Document Analysis. 17a. Descriptors
Aquifer, Water quality, Hydrology, Water supply, Saltwater intrusion

17b. Identifiers/Open-Ended Terms
Florida, Palm Beach County, Riviera Beach

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on Distribution	UNCLASSIFIED	38
	20. Security Class (This Page)	22. Price
	UNCLASSIFIED	

GROUND-WATER RESOURCES OF THE RIVIERA BEACH AREA, PALM BEACH COUNTY, FLORIDA

By L. F. Land

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-47

Prepared in cooperation with the

CITY OF RIVIERA BEACH

September 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

For additional information write to:

U.S. Geological Survey
325 John Knox Road
Suite F-240
Tallahassee, Florida 32303

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd.)

TABLES

GROUND-WATER RESOURCES IN THE

RIVIERA BEACH AREA, PALM BEACH COUNTY, FLORIDA

By

L. F. Land

ABSTRACT

The principal source of freshwater that has been developed in the Riviera Beach area is the so-called shallow aquifer, which is composed of sand, shells, sandstone, limestone, marl, and occasionally clay strata. Often a stratum contains mixtures of two or more of these materials and occasionally they are cemented. The aquifer ranges in thickness from approximately 300 feet at Lake Worth to less than 175 feet in the interior. The major water-bearing zone usually consists of cemented layers of sand and shells, about 100 feet thick, in the lower part of the aquifer.

The quality of water in the shallow aquifer is generally suitable for municipal use except for an area along C-17 Canal where the dissolved solids concentration exceeds 500 milligrams per liter.

The primary source of recharge to the shallow aquifer is rainfall. Discharge is mainly by evapotranspiration. Other discharges include seepage into drainage canals and Lake Worth, and pumpage.

The configuration of the water table is greatly influenced by Lake Worth, C-17 Canal, West Palm Beach water catchment area, rainfall, and municipal pumpage.

The major threat to development of water supplies, and possibly to the continuation of a current withdrawal rate of over 5 million gallons per day, is seawater intrusion. The municipal supply wells are almost 1 mile inland from the source of the seawater (Lake Worth), but the combined effects of increased pumpage, reduced recharge resulting from increased land development, and below normal rainfall, have caused seawater to advance inland in the aquifer. Additional supplies could be developed to the west, away from the threat of seawater intrusion.

INTRODUCTION

Riviera Beach is one of the many cities in the coastal area of south Florida that are experiencing rapid growth in population. The city and all other parts of the area, except West Palm Beach, use the so-called shallow aquifer as the sole source of freshwater. To assure an adequate freshwater supply in the future, hydrologic information is needed for planning and water-management decisions. To obtain this information the Riviera Beach City Council and the U.S. Geological Survey started a cooperative water-resources investigation of the area in April 1972.

Purpose and Scope

The purpose of this report is to furnish information that is needed for the planned development and protection of freshwater supplies in the Riviera Beach area. Information is provided on: 1) geologic and hydraulic characteristics of the shallow aquifer; 2) extent of seawater intrusion; 3) water movement and water-level fluctuations, 4) quality of water and 5) the impact of the increased municipal pumping and various climatic factors on the hydrologic conditions. The study area is a 4.5-mi-wide strip centering on Riviera Beach and extending 7 mi inland. It covers approximately 30 mi^2 (fig. 1).

Previous Investigations

General information on the hydrology and geology of the area has been published in a report by Parker and others (1955). Additional information on the area is included in reports by Schroeder and others (1954) and by Land and others (1973). This report is the first to supply detailed information on the water resources in the Riviera Beach area.

Acknowledgments

Special appreciation is expressed to Edward Dwyer, Director of Utilities for Riviera Beach; to George Johnson, former Superintendent of Water Works, to Jack Walden, Superintendent of Water Works, and to other employees of the city of Riviera Beach for their assistance, information and cooperation during this investigation. An expression of appreciation is also extended to residents of the area for furnishing information on their wells and permission to sample them; and to the firm of Barker, Osha, and Anderson, Consulting Engineers, for permitting access to their files and other information on the city's water supply system.

_ _ _

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below.

Multiply English unit	By	To obtain metric unit
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
gallon per minute (gal/min)	.063	liter per second (L/s)
million gallon per day (Mgal/d)	.04381	cubic meter per second (m^3/s)
square foot (ft^2)	.093	square meter (m2)

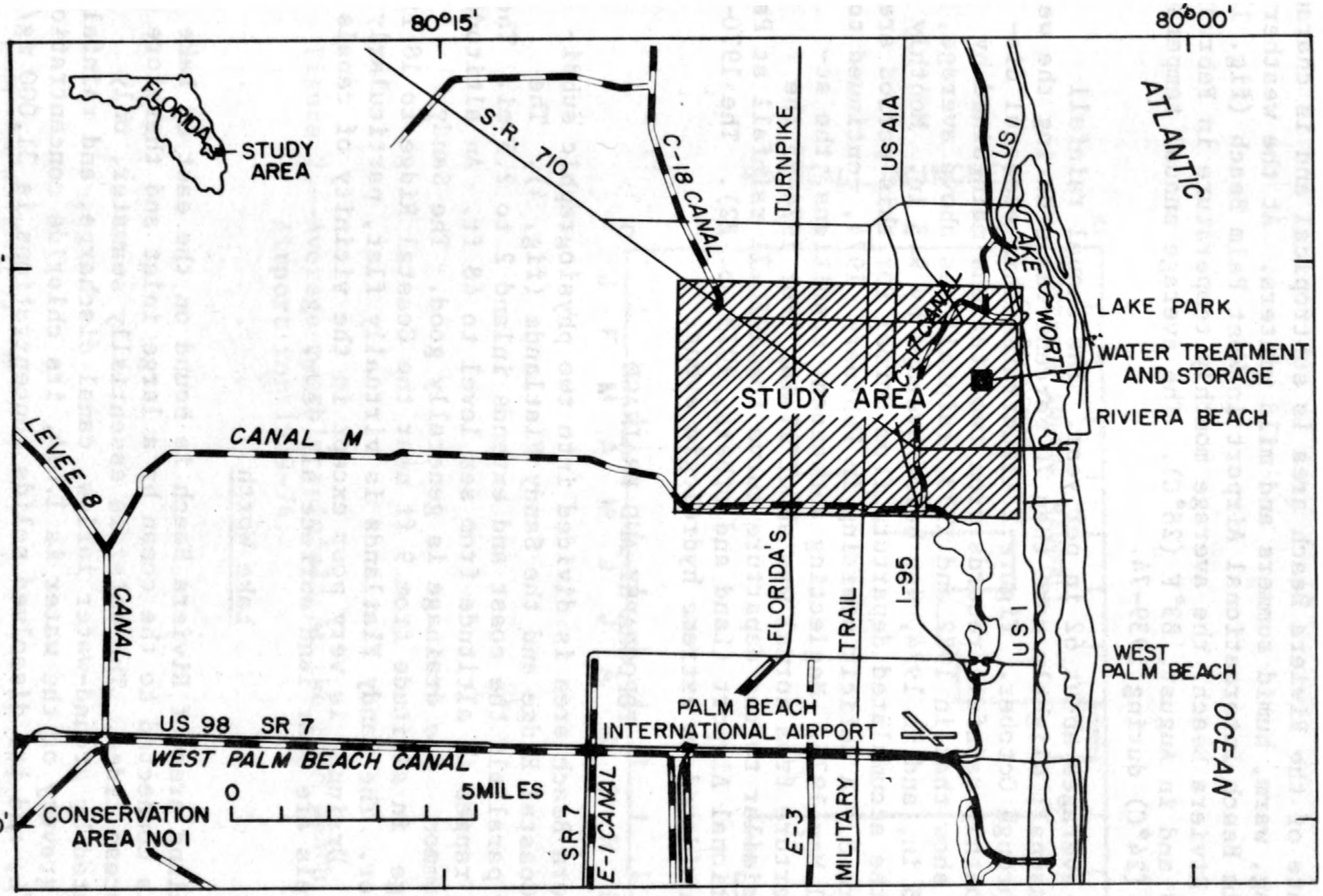


Figure 1.--Location of the Riviera Beach study area.

CLIMATE

The climate of the Riviera Beach area is subtropical and is characterized by long, warm, humid summers and mild winters. At the weather station at Palm Beach International Airport in West Palm Beach (fig. 1), 7 mi south of Riviera Beach, the average monthly temperature in February is 67°F (19°C) and in August, 83°F (28°C). The average annual temperature was 76°F (24°C) during 1939-74.

Rainfall averages about 62 in per year. The annual rainfall pattern is seasonal; slightly more than 70 percent falls during the wet season, May through October. Figure 2 illustrates this seasonal distribution. Monthly rainfall records from two stations maintained by Riviera Beach show that in 1972 and 1973, rainfall was above average, by 4.1 in and 6.6 in, and in 1974, was below average by 9.3 in. Monthly rainfall and the accumulated departure from normal for this period are shown in figure 3. A deficit starting in February 1974, continued to increase until May 1975. Neglecting antecedent conditions, the accumulated departure from normal was about 17 in. For 1974-75 the departure is similar to the departure curve for 1970-71 rainfall at Palm Beach International Airport (Land and others, 1973, p. 22). The 1970-71 drought is considered an extreme hydrologic event.

TOPOGRAPHY AND DRAINAGE

The Riviera Beach area is divided into two physiographic subdivisions, the Coastal Ridge and the Sandy Flatlands (fig. 4). The Coastal Ridge parallels the coast and extends inland 2 to 2.5 mi. The Coastal Ridge ranges in altitude from sea level to 48 ft. An altitude of 35 ft is common. The drainage is generally good. The Sandy Flatlands range in altitude from 9 ft near the Coastal Ridge to 18 ft in the interior. The Sandy Flatlands is virtually flat, particularly in the interior. Drainage is very poor except in the vicinity of canals, and water levels are near land surface all year.

Lake Worth

The mainland area of Riviera Beach is bound on the east by Lake Worth which is connected to the ocean by a large inlet and therefore is affected by ocean tides. The water is essentially seawater, only slightly diluted by ground-water inflow, canal discharge, and rainfall. The specific gravity of the water is 1.024, its chloride concentration is 18,000 mg/L, and its dissolved solids concentrations is 31,000 mg/L.

Records from the gaging station on Lake Worth, near Blue Heron Blvd., in operation since April 1971, show that the mean high tide elevation is 1.93 ft; mean low tide is -1.14 ft; mean half tide is 0.40 ft and tidal range is 3.07 ft. In addition to the daily tidal cycle, an annual tidal cycle is also observed (fig. 5).

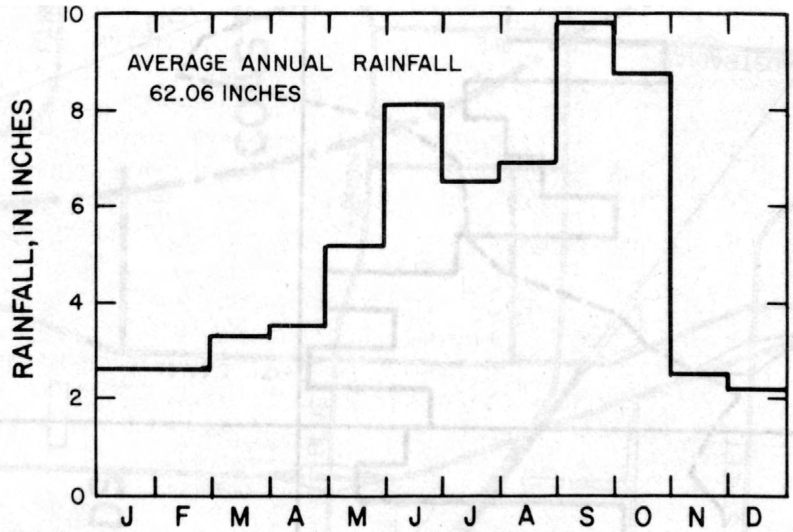


Figure 2.--Average monthly rainfall at the Palm Beach International Airport for 1939-74.

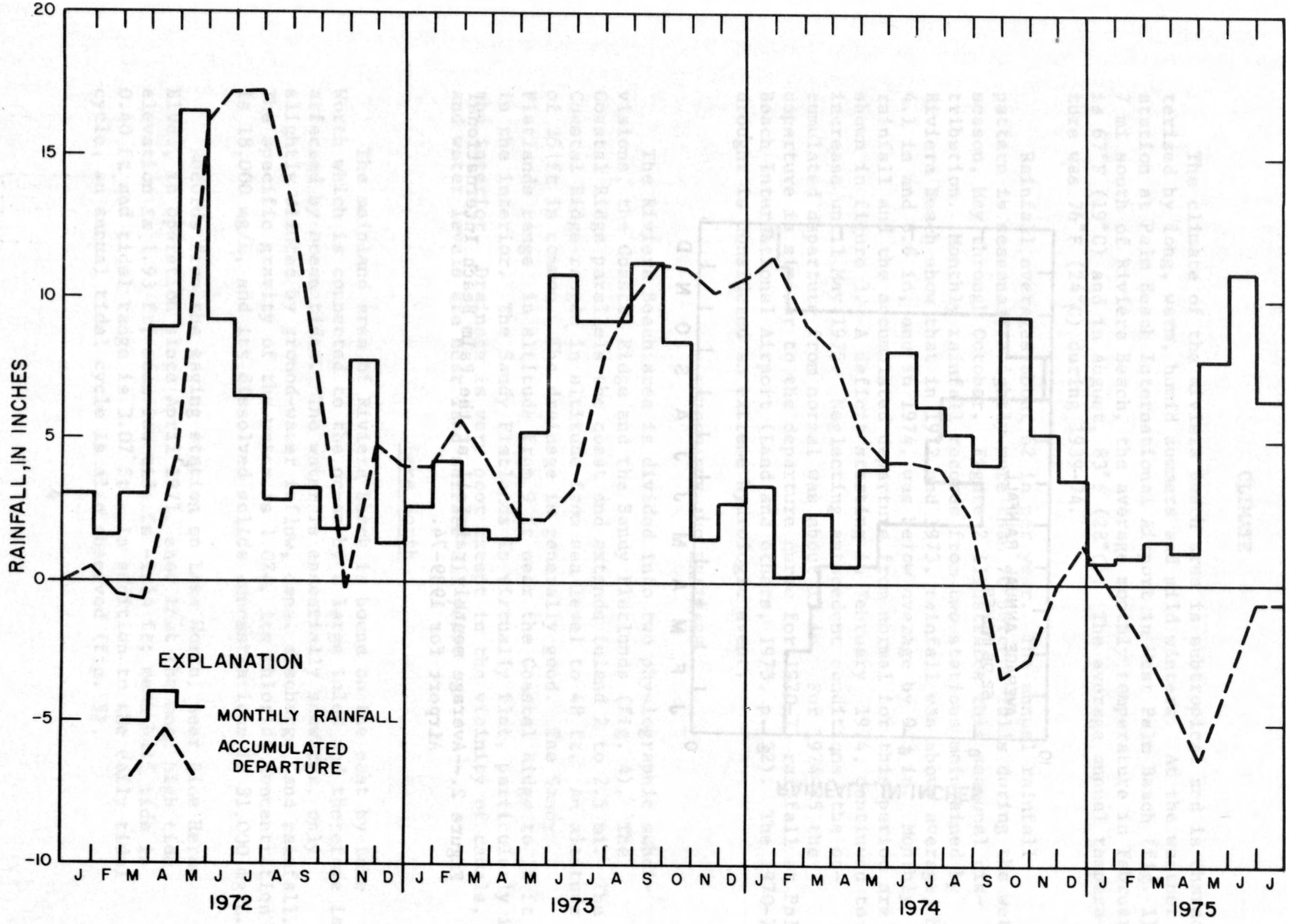


Figure 3.--Monthly rainfall and accumulated departure from normal for January 1972 to July 1975 at the water and wastewater treatment plants in Riviera Beach.

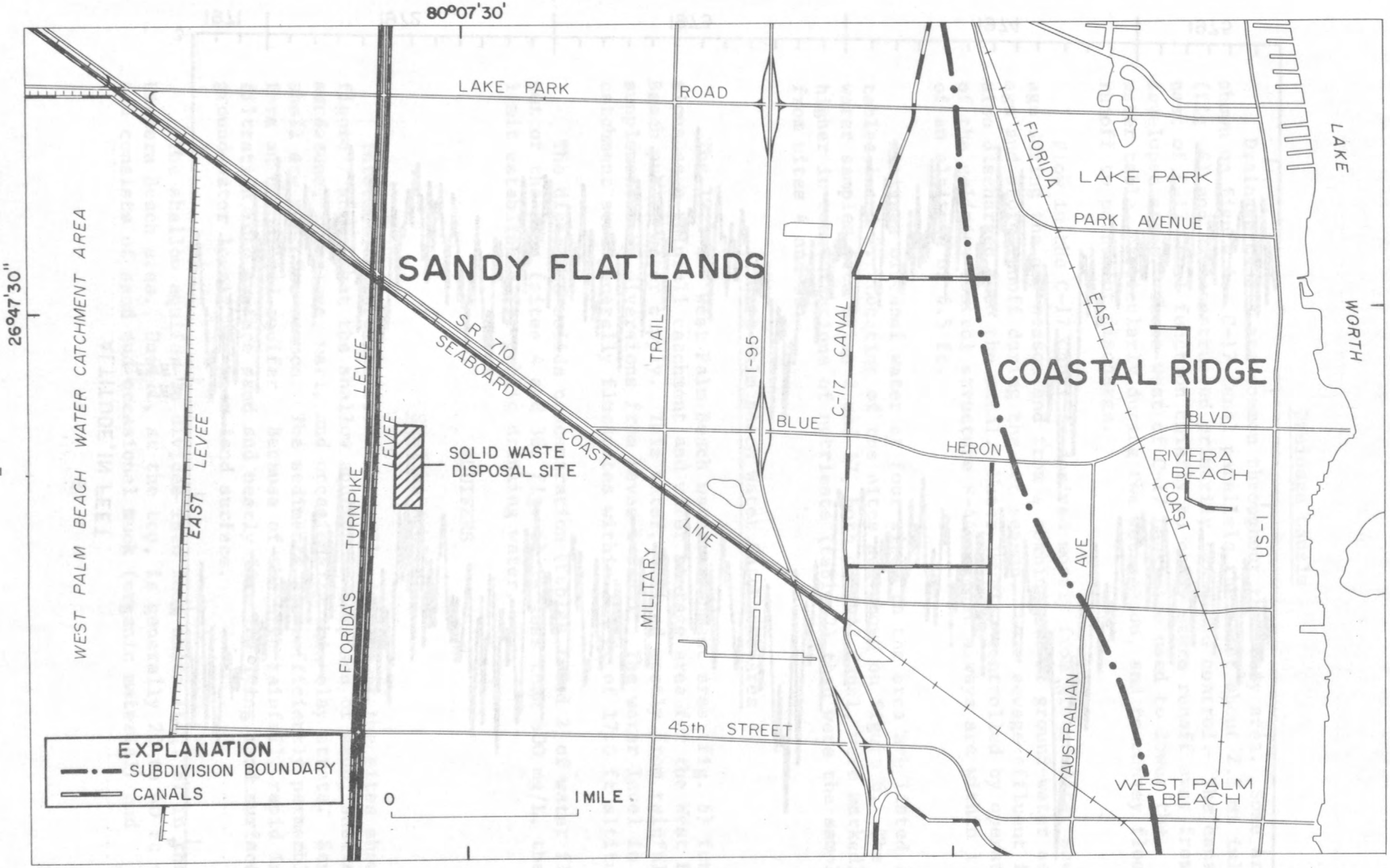


Figure 4.--Location of the physiographic subdivisions and various other features in the Riviera Beach study area.

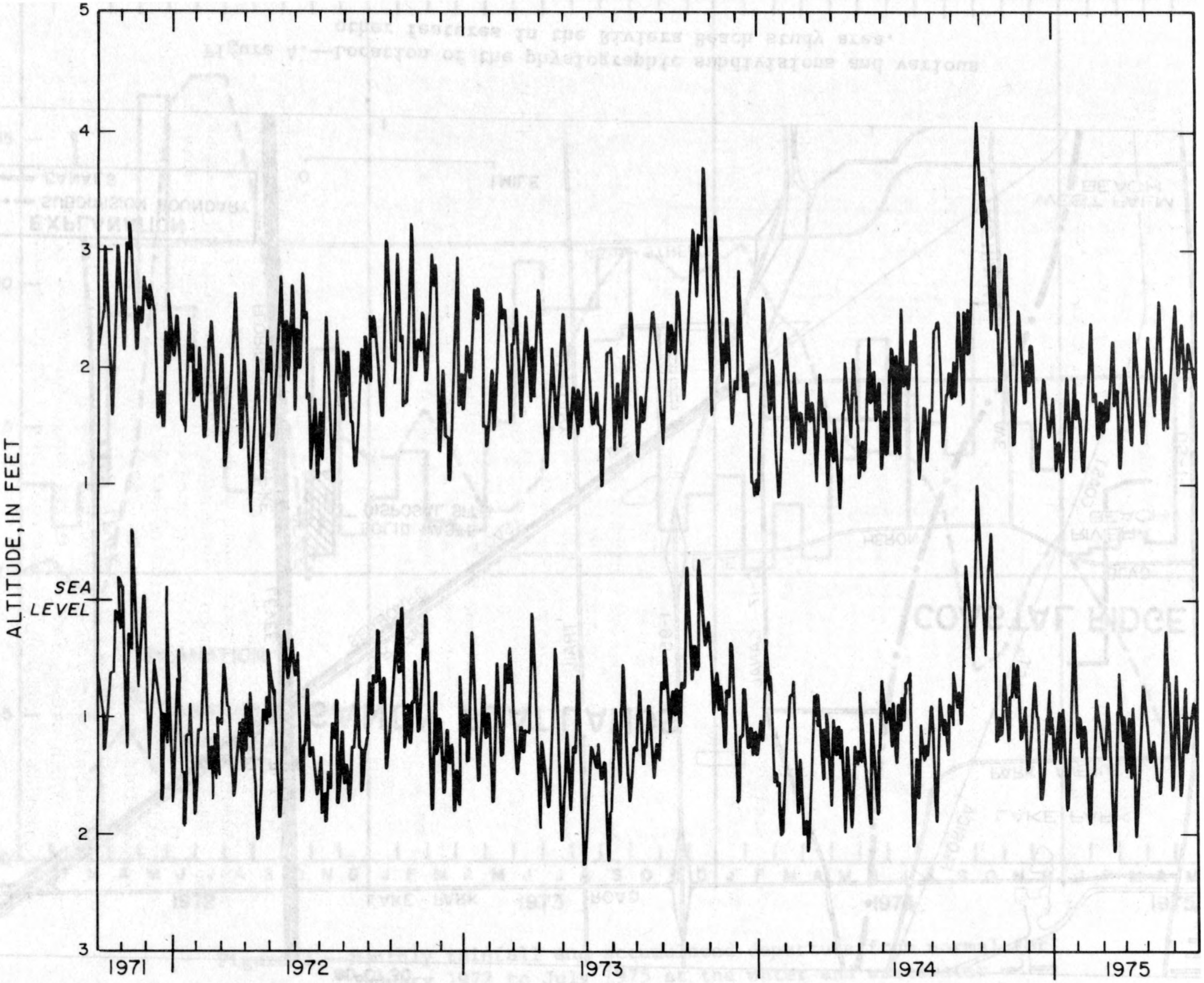


Figure 5.--Hydrograph of daily high and low water level in Lake Worth.

Drainage Canals

Drainage canals are common throughout the study area. Some are shown on figure 4. C-17 Canal parallels the coast about 2.5 mi inland (fig. 4) and was constructed primarily for flood control. The canals east of C-17 Canal function chiefly to carry storm runoff away from developed areas. Those west of C-17 Canal are used to lower the water table, particularly during the wet season, and to convey flood runoff to points of discharge.

Flow in the C-17 Canal is derived mostly from ground-water seepage during the dry season and from a combination of ground-water seepage and storm runoff during the wet season. Some sewage effluent is also discharged into the canal. Water levels, controlled by operation of the salinity control structure S-44, almost always are within 1 ft. of an altitude of 6.5 ft.

Analyses of canal water at four sites in the area are listed in tables 1 and 2. Location of the sites are shown on figure 6. The water samples from sites 2 and 17, both on C-17 Canal, were markedly higher in concentrations of nutrients (table 2) than were the samples from sites 4 and 38.

West Palm Beach Water Catchment Area

The 19.2-mi^2 West Palm Beach water catchment area (fig. 6) functions as a rainfall catchment and water storage area for the West Palm Beach public water supply. This water, derived mostly from rainfall, is supplemented by diversions from Levee 8 Canal. The water level in the catchment area generally fluctuates within 1.5 ft of 17.0 ft altitude.

The dissolved solids concentration (tables 1 and 2) of water flowing out of the area (sites 4 and 38, fig. 6) is less than 500 mg/L, the limit established for public drinking water.

AQUIFERS

Shallow Aquifer

Information obtained from test wells drilled at the sites shown on figure 7 shows that the shallow aquifer is composed of sand, shells, sandstone, limestone, marl, and occasionally thin clay strata. Sand and shell are the most common. The sediments are sufficiently permeable to form an unconfined aquifer. Because of the high rainfall, rapid infiltration into surface sand and nearly flat low-lying land surface, the ground-water levels are near land surface.

The shallow aquifer is divided into four units (fig. 8) in the Riviera Beach area. Unit 1, at the top, is generally 20 to 40 ft thick and consists of sand and occasional muck (organic material) and

Table 1.--Surface-water sampling sites:

(Concentrations in milligrams per liter, except as noted)

Site number (location shown on fig. 6)	Date of Collection	Specific conductance in micromhos per cm at 25°C	Dissolved Solids (Residue at 180°C)	pH	Temperature (°C)	Color (Cobalt platinum units)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Strontium (Sr)	Chloride (Cl)	Fluoride (F)	Sulfate (SO_4)	Iron (Fe)	Bicarbonate	Hardness		Alkalinity as $CaCO_3$	Carbon		
																		Noncarb.	Total		Inorganic	Total Organic	Total
2	3-17-70	439	274	7.2		50	5.8	64	3.2	1.4	22	0.82	37	0.2	15	0.12	187	20	174	153	--	--	--
	11-13-73	587	343	7.3	21.0	60	8.6	84	5.2	2.3	25		42	.3	22	--	250	26	230	205	52	20	72
	12-11-74	565	388	7.3	18.5	40	8.5	77	4.6	3.1	36	.97	59	.3	27	.08	234	20	210	--	--	--	--
	5- 1-75	710	445	7.9	28.0	38	5.2	73	7.2	3.7	61	.80	98	.4	24	.02	228	26	210	--	--	--	--
17	8-11-70	388	239	8.0	28.0	40	6.7	60	3.1	1.6	19	.50	31	.2	14	.22	166	27	163	136	--	--	--
	12-11-74	510	322	7.5	18.0	40	8.1	74	4.4	1.7	30	.81	50	.1	16	.11	204	37	200	--	--	--	--
	5- 1-75	430	335	7.5	26.5	42	3.6	49	4.9	1.9	32	.67	53	.2	14	.11	212	19	190	--	--	--	--
4	3-17-70	240	146	7.0	20.0	30	.9	25	3.8	1.7	18	.23	29	.2	9.2	.04	80	13	79	66	--	--	--
	11-13-73	370	210	7.7	21.0	50	4.2	37	3.7	2.2	21		36	1.2	12	--	116	12	110	95	25	23	48
	12-11-74	580	384	7.2	17.5	40	4.7	52	11	3.6	55	.69	83	.4	37	.04	166	40	180	--	--	--	--
	5- 1-75	700	449	7.5	26.5	55	7.1	56	15	3.9	67	.80	100	.4	43	.02	184	52	200	--	--	--	--
38	12-10-74	240	132	7.8	17.0	50	.7	25	2.1	.8	15	.22	26	.0	3.8	.10	70	14	71	--	--	--	--
	5- 1-75	380	239	8.1	25.0	23	6.2	40	4.5	.7	33	.30	56	.4	6.0	.00	124	17	120	--	--	--	--

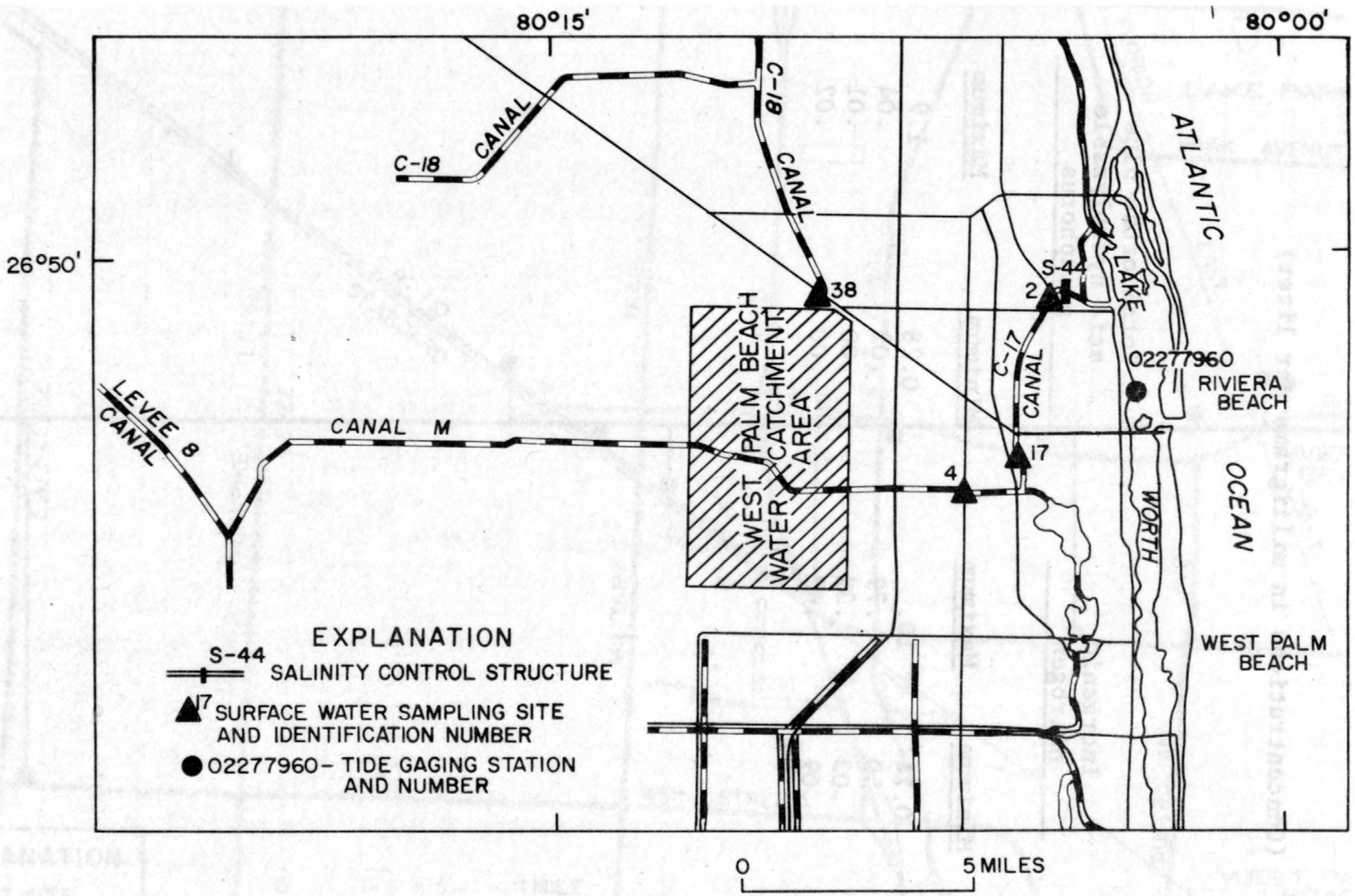


Figure 6.--Location of surface-water sampling sites and gaging station in Lake Worth (Intracoastal Waterway).

Table 2.--Maximum and minimum observed nutrient concentrations at selected surface-water sampling sites.

(Concentrations in milligrams per liter)

Sampling site no.	Inorganic nitrogen		Total ortho plus acid hydrolyzable phosphorus	
	Minimum	Maximum	Minimum	Maximum
2	0.74	10.	0.28	1.9
17	.50	.79	.02	.04
4	.03	.32	.00	.01
38	.09	.43	.00	.02

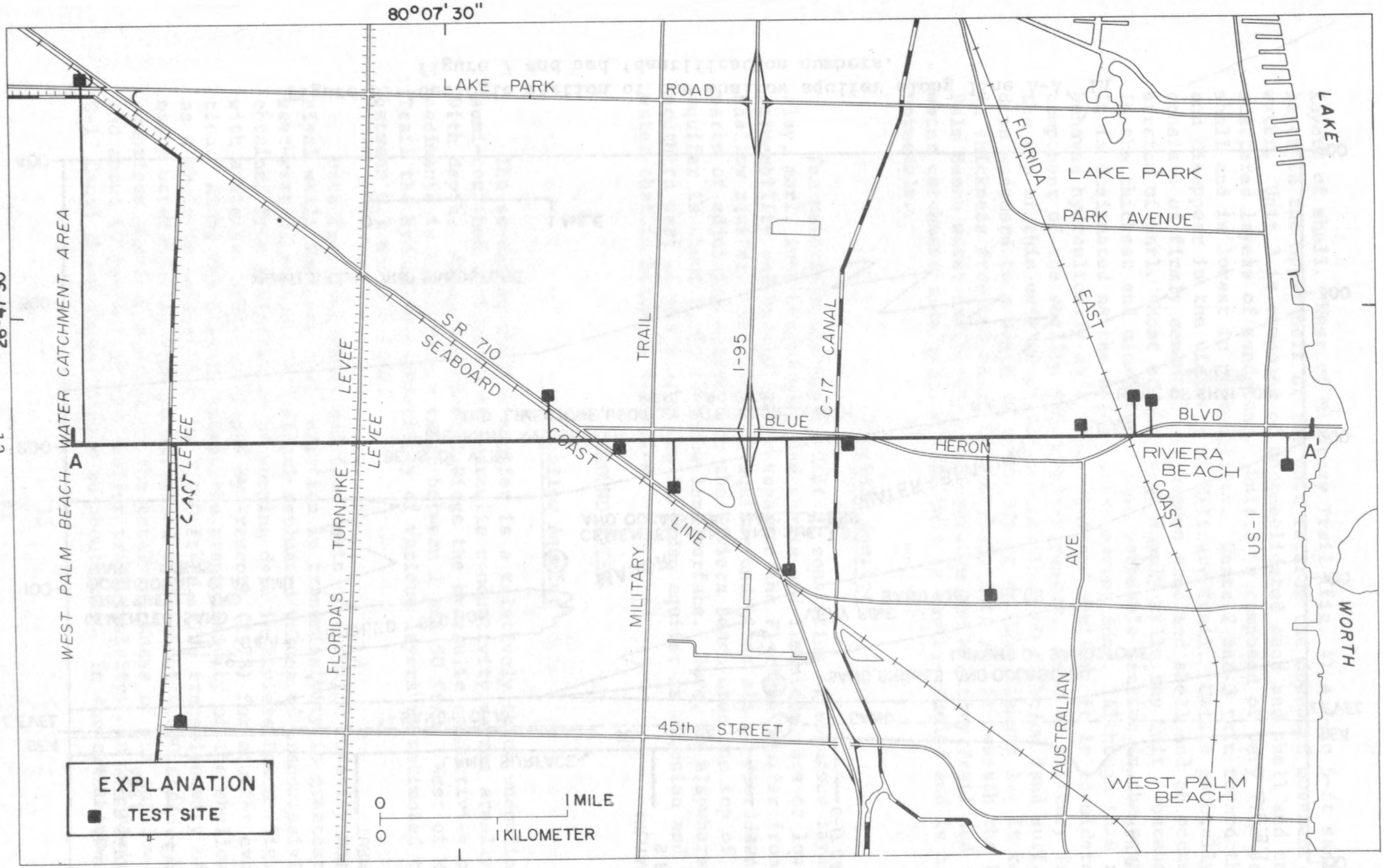


Figure 7.--Locations of test drilling sites and geologic section A-A'.

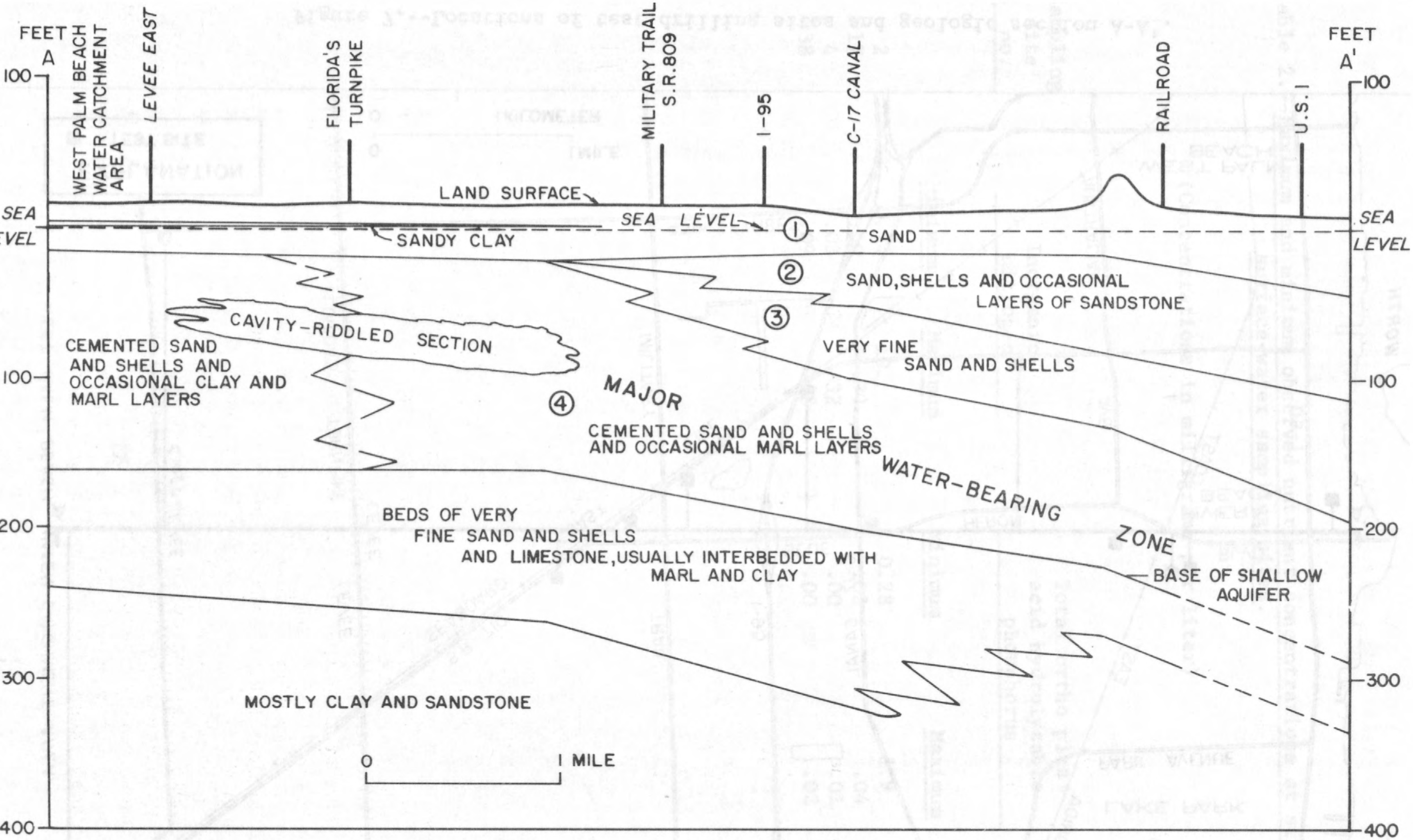


Figure 8.--Geologic section of the shallow aquifer along line A-A' in figure 7 and bed identification numbers.

layers of shell. West of Military Trail (fig. 4) a 2-to 5-ft sandy clay layer in the upper half of the unit retards the downward movement of water. Unit 2 is composed of unconsolidated sand and shell and contains scattered layers of sandstone. Unit 3 is composed of very fine sand and shell and is lowest in permeability. Units 2 and 3 thin toward the west and disappear in the vicinity of Military Trail. Unit 4 generally consists of firmly cemented calcareous sand and shell and an occasional stratum of marl. Most of the large supply wells tap Unit 4 because it is the thickest and usually the most permeable section in the aquifer. It is designated as the major water-bearing zone. Although this zone behaves hydraulically as a leaky confined aquifer, it is considered a component of the shallow ground-water system. West of Military Trail the top of this unit generally is less than 50 ft below land surface but dips eastward to a depth of about 200 ft at U.S. Highway 1. It ranges in thickness from 100 ft at U.S. Highway 1 to 150 ft beneath the West Palm Beach water catchment area. Between the Military Trail and the water catchment area part of this unit is cavity-riddled and is highly permeable.

Floridan Aquifer

The materials underlying Unit 4, consisting of numerous layers of clay, marl, interbedded sand and shells and limestone, are of low permeability and hydraulically separate the Floridan aquifer from the shallow aquifer. The Floridan aquifer underlies all of Florida and parts of adjoining states. In the Riviera Beach area the top of this aquifer is about 1,000 ft below land surface. Here, as elsewhere in the southern part of the State, the Floridan aquifer is artesian and yields water that is brackish or saline.

GROUND WATER

Shallow Aquifer

The so-called shallow aquifer is a relatively thick unconfined to semi-confined aquifer whose hydraulic conductivity varies areally and with depth. Along the Coastal Ridge the hydraulic conductivity of the sediments is estimated to range between 1 and 50 ft/d. West of Military Trail the hydraulic conductivity of various layers is estimated to range between 0.1 and 500 ft/d.

Data from test wells and from tests of specific capacity on municipal wells indicate that variation in transmissivity is greatest in an east-west direction. Additional estimated values of transmissivity were obtained from a simulation of pumping data in Riviera Beach (fig. 12) with a digital model developed by Trescott (1973) for aquifer evaluation. Along the Coastal Ridge, the transmissivity of the shallow aquifer as a whole is estimated to be 7,000 ft^2/d. The transmissivity of the major water-bearing zone is estimated to be about 4,000 ft^2/d. Unit 4 comprises about 40 percent of the total thickness of the shallow aquifer and about 60 percent of the aquifer transmissivity. In the vicinity of C-17 Canal these values reduce to about half. In the area between

Military Trail and the east levee of the West Palm Beach water catchment area, the transmissivity of Unit 4 is estimated to range from 15,000 to 30,000 ft^2/d.

The storage coefficient of Unit 4 is estimated to be in the range of $1x10^{-4}$ to $1x10^{-5}$, reflecting the semi-confined nature of the unit. By correlation of water-table fluctuations with rainfall during selected storms it is estimated that the storage coefficient of Unit 1 ranges from 0.15 to 0.25.

Recharge and Discharge

Recharge to the shallow aquifer is primarily from rainfall. The infiltration rate is generally high so that much of the rainfall on the area enters ground-water storage, and a rapid response in water levels occurs. The aquifer is also recharged by seepage from controlled reaches of canals when the canal level is higher than the water table in the adjacent areas. Only during extreme dry periods does this condition occur along the C-17 Canal. The aquifer may also receive some recharge from applications of irrigation water.

Discharge from the shallow aquifer occurs by evapotranspiration, seepage into drainage canals, seepage into Lake Worth, and pumping. Evapotranspiration is the main form of discharge and it is highest where the water table is near land surface in heavily vegetated areas. Ground water lost by seepage into Lake Worth retards seawater intrusion into the shallow aquifer.

Water-Level Fluctuations

Unit 1

Water-level fluctuations in Unit 1 (fig. 8) are caused primarily by infiltration from rainfall and evapotranspiration. Other changes are due to downward leakage replacing water that has been (1) removed by pumping from Unit 4 and (2) lost by seepage to drainage canals and Lake Worth.

Hydrographs of observation wells PB 612, PB 619, PB 633 and PB 646 are shown in figure 9. Figure 10 shows well locations; well PB 646 is located about 6,000 ft southwest of the municipal well field. The greatest range in fluctuation is for well PB 612. During the three dry seasons of 1973-75 the water level in well PB 612 fell below sea level. The water level in PB 646, southwest of the pumping wells, is influenced slightly by pumping and moderately by a shallow canal in the vicinity. Below normal rainfall for 1974, and possibly higher pumpage, kept the water levels from making a normal wet season recovery during 1974.

Units 2 and 3

Units 2 and 3 of the shallow aquifer form a semi-confining layer in the eastern part of the study area. Together they are about 150 ft

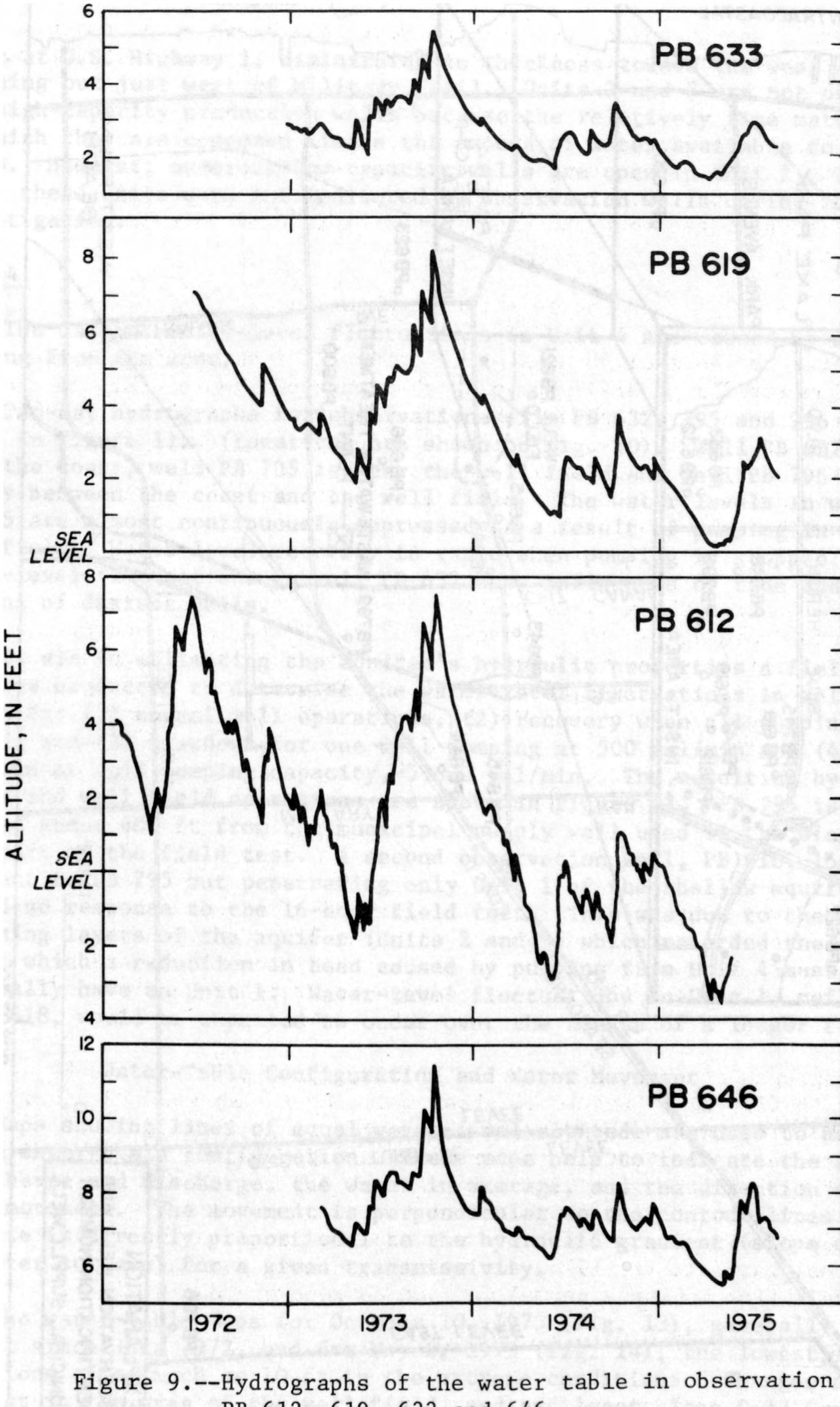


Figure 9.--Hydrographs of the water table in observation wells PB 612, 619, 633 and 646.

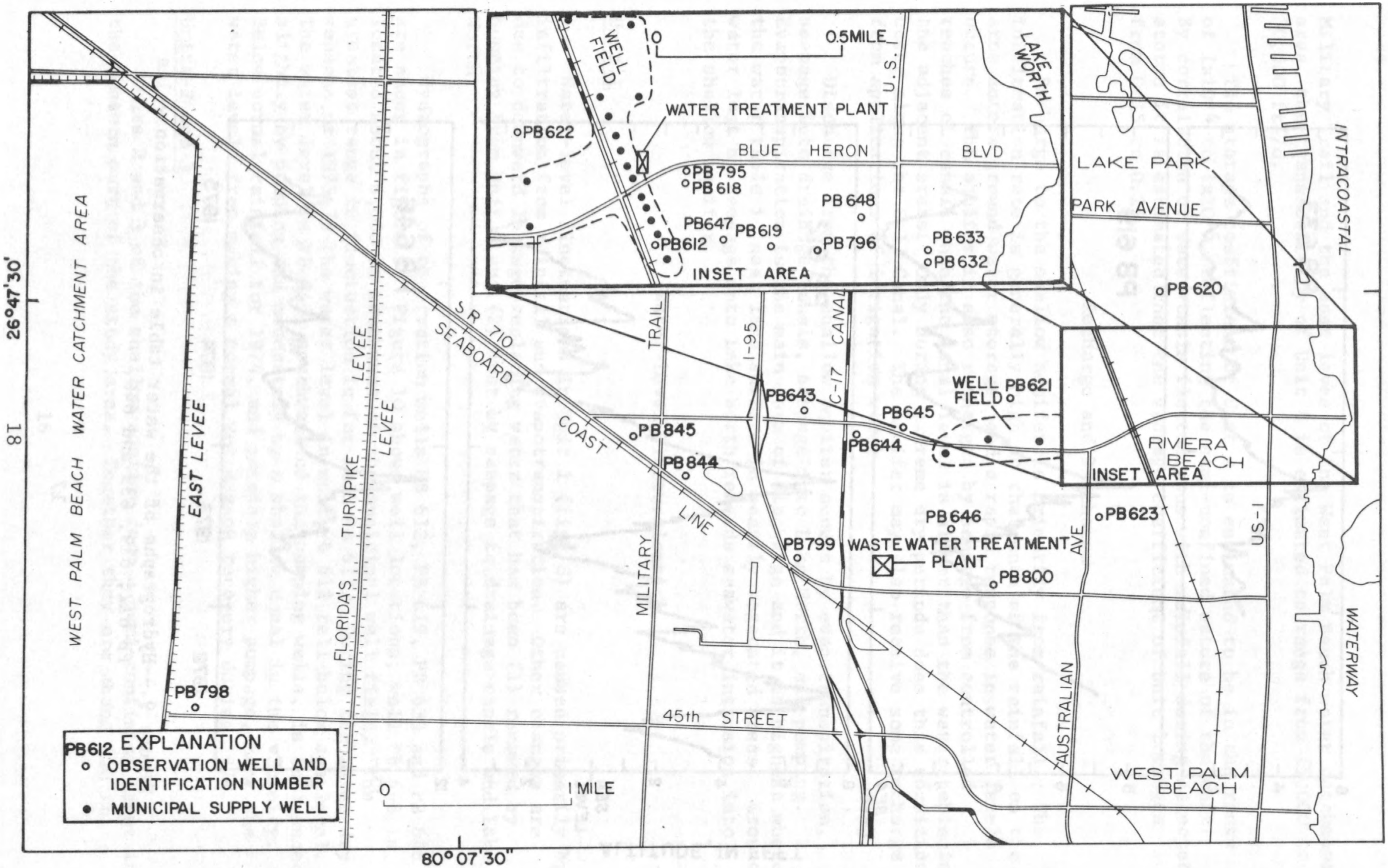


Figure 10.--Location of observation wells, Riviera Beach supply wells and treatment plants.

thick at U.S. Highway 1, diminishing in thickness toward the west and pinching out just west of Military Trail. Units 2 and 3 are not used for high-capacity production wells because the relatively fine material of which they are composed limits the amount of water available to wells. However, numerous low-capacity wells are open in Unit 2. Therefore, these units were not monitored by observation wells during this investigation.

Unit 4

The largest water-level fluctuations in Unit 4 are caused by wells pumping from the zone.

Two-day hydrographs for observation wells PB 632, 795 and 796 are shown in figure 11. (Locations are shown on fig. 10). Well PB 632 is near the coast, well PB 795 is near the well field and well PB 796 is midway between the coast and the well field. The water levels in well PB 795 are almost continuously depressed as a result of pumping in the well field. Water-level recovery is rapid when pumping is stopped. The water-level fluctuations in well PB 632 show influences of tide and the pumping of distant wells.

To aid in estimating the aquifer's hydraulic properties a field test was conducted to determine the water-level fluctuations in well PB 795 for (1) normal well operations, (2) recovery when all pumping ceased, and (3) drawdown for one well pumping at 500 gal/min and (4) drawdown at full pumping capacity, 5,600 gal/min. The resulting hydrographs and well field operations are shown in figure 12. PB 795 is located about 600 ft from the municipal supply well used in the single well part of the field test. A second observation well, PB 618, located adjacent to PB 795 but penetrating only Unit 1 of the shallow aquifer, showed no response to the 16-hour field test. This was due to the semiconfining layers of the aquifer (Units 2 and 3) which retarded the effect which a reduction in head caused by pumping from Unit 4 must eventually have on Unit 1. Water-level fluctuations in Unit 1, reflected in PB 618, would be expected to occur over the course of a longer test.

Water-Table Configuration and Water Movement

Maps showing lines of equal water-level altitude are used to describe water-table configuration. These maps help to indicate the areas of recharge and discharge, the water in storage, and the direction of water movement. The movement is perpendicular to the contour lines and its rate is directly proportional to the hydraulic gradient (slope of the water surface) for a given transmissivity.

The water-table maps for October 10, 1973 (fig. 13), generally the highest since June 1972, and for May 2, 1975 (fig. 14), the lowest, show variations of as much as 10 ft in the extreme conditions. Changes are greatest in the area of the well field, and are least along C-17 Canal and the coast. The water-table map for March 1, 1973 (fig. 15) reflects

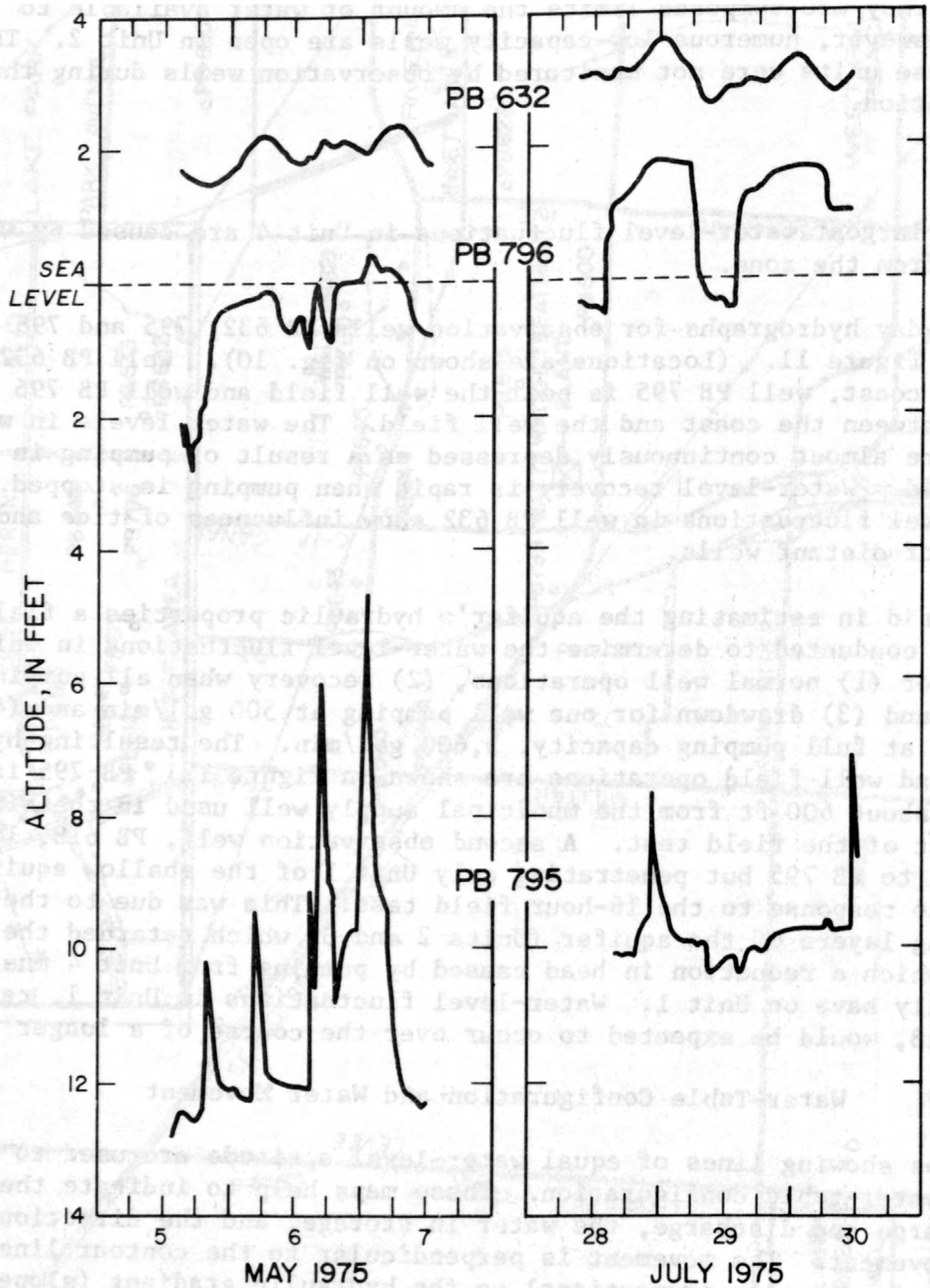


Figure 11.--Hydrographs of observation wells PB 795, 796 and 632 in the major water-bearing zone of the shallow aquifer.

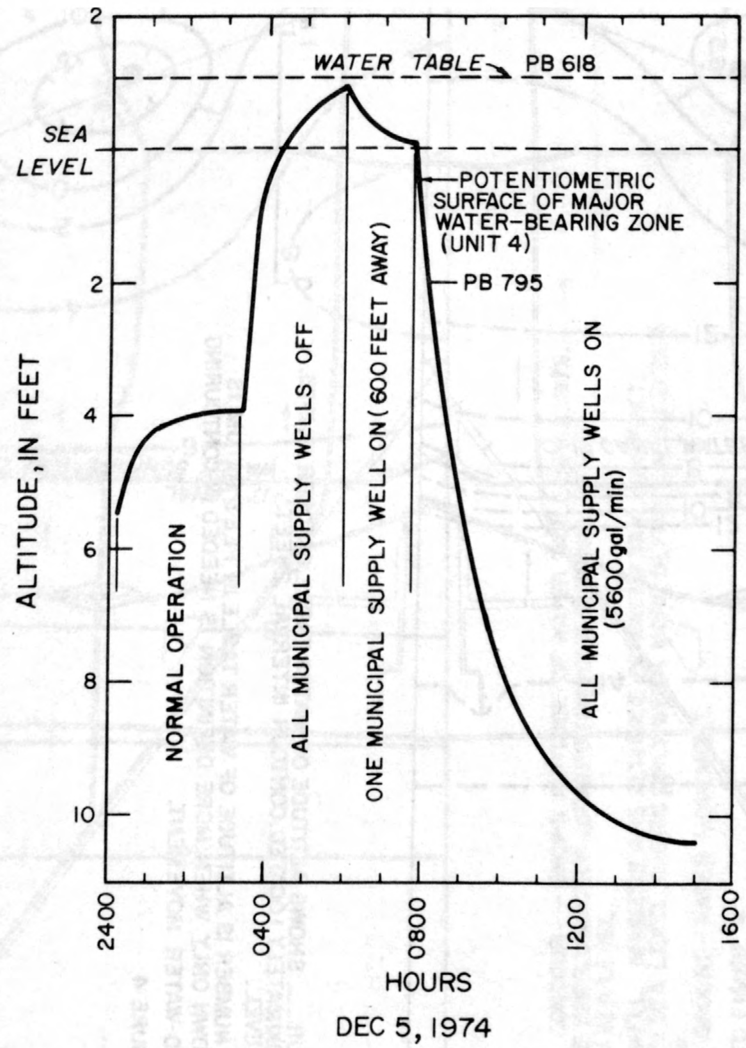
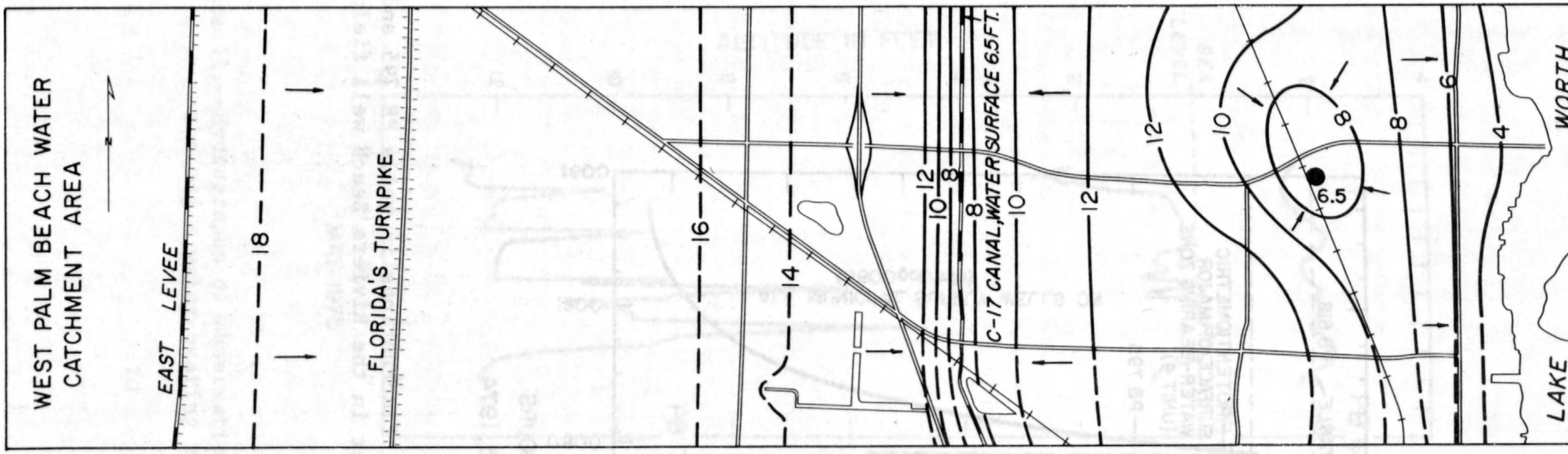


Figure 12.--Hydrograph of water-level fluctuations in wells PB 795 and 618 during an aquifer test in the Riviera Beach well field.



EXPLANATION

—— 10 — — WATER-TABLE CONTOUR --- SHOWS ALTITUDE OF WATER TABLE, OCTOBER 10, 1973. DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 2 FEET. DATUM IS MEAN SEA LEVEL.

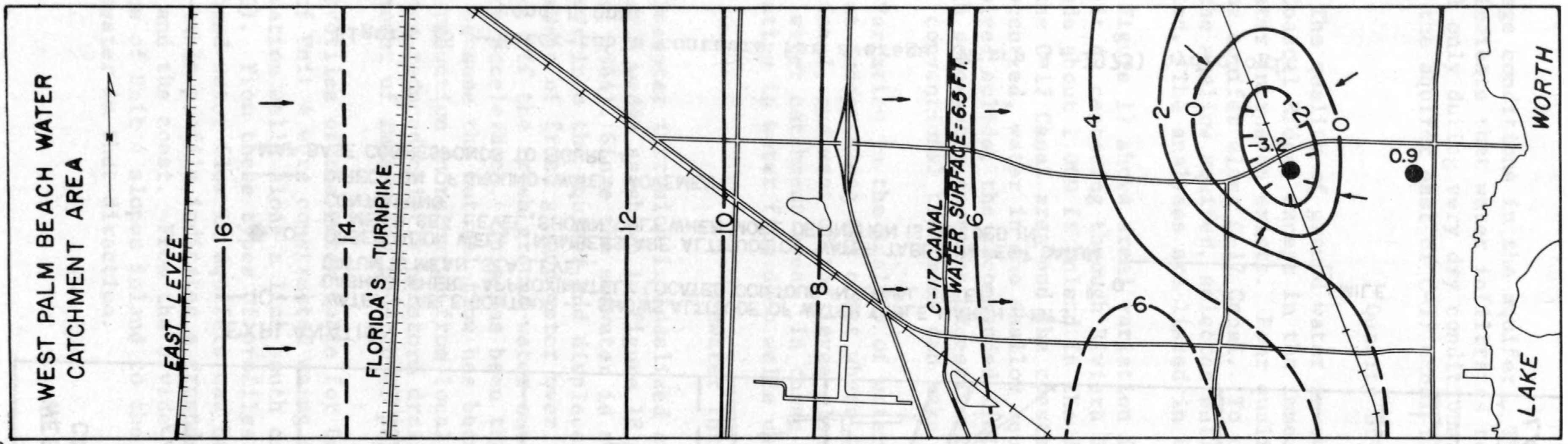
● 6.5 OBSERVATION WELL. NUMBER IS ALTITUDE OF WATER TABLE IN FEET. DATUM IS MEAN SEA LEVEL, SHOWN ONLY WHEN MORE DEFINITION IS NEEDED IN CONTOURING

⟶ DIRECTION OF GROUND-WATER MOVEMENT.

MAP BASE CORRESPONDS TO FIGURE 4

0 — 1 MILE

Figure 13.--Water-table contours for October 10, 1973, highest levels on record since June 1972.



EXPLANATION

—10— — WATER-TABLE CONTOUR-- SHOWS ALTITUDE OF WATER TABLE, MAY 2. 1975. DASHED WHERE APPROXIMATELY LOCATED, CONTOUR INTERVAL 2 FEET. DATUM IS MEAN SEA LEVEL.

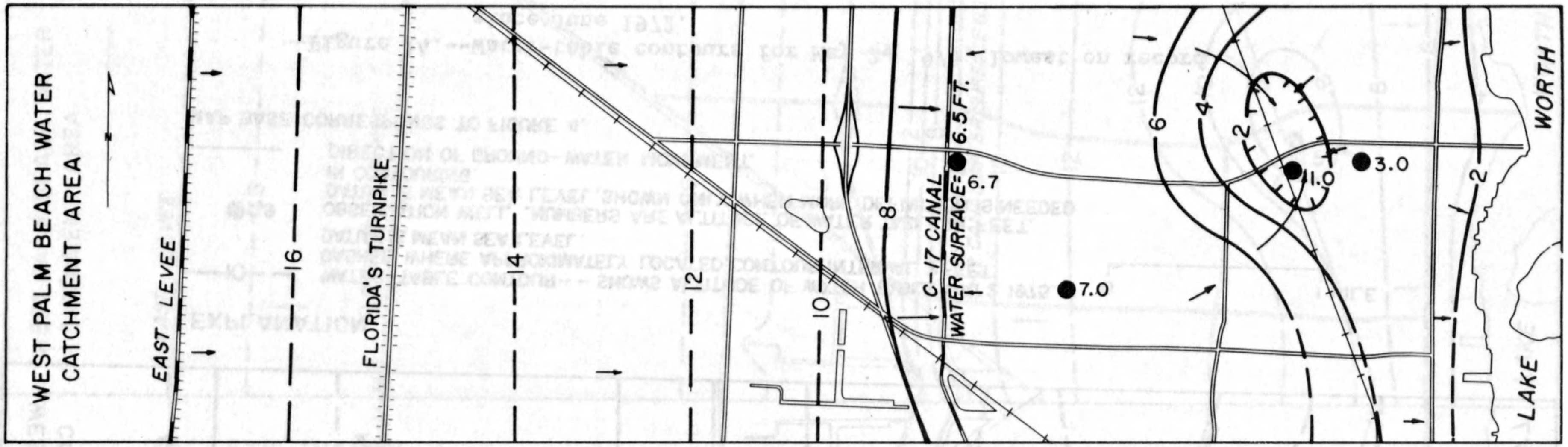
●0.9 OBSERVATION WELL, .NUMBERS ARE ALTITUDE OF WATER TABLE IN FEET. DATUM IS MEAN SEA LEVEL, SHOWN ONLY WHEN MORE DEFINITION IS NEEDED IN CONTOURING.

⟶ DIRECTION OF GROUND-WATER MOVEMENT.

MAP BASE CORRESPONDS TO FIGURE 4.

0 — 1 MILE

Figure 14.--Water-table contours for May 2, 1975, lowest on record since June 1972.



EXPLANATION

—10— — WATER-TABLE CONTOUR---SHOWS ALTITUDE OF WATER TABLE, MARCH 1, 1973 DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 2 FEET. DATUM IS MEAN SEA LEVEL.

● 1.0 OBSERVATION WELL, NUMBERS ARE ALTITUDE OF WATER TABLE IN FEET. DATUM IS MEAN SEA LEVEL, SHOWN ONLY WHEN MORE DEFINITION IS NEEDED IN CONTOURING.

→ DIRECTION OF GROUND-WATER MOVEMENT.

MAP BASE CORRESPONDS TO FIGURE 4.

0 — 1 MILE

Figure 15.--Water-table contours for average (March 1, 1973) hydrologic conditions.

average conditions in the aquifer. The water-table maps (figs. 13, 14, 15) indicate that water infiltrates to the shallow aquifer from C-17 Canal only during very dry conditions. Most of the water that is pumped from the aquifer east of C-17 Canal is derived from local rainfall.

Quality of Water

The quality of ground water in the Riviera Beach area is best along the Coastal Ridge, except in the immediate vicinity of the coast where seawater intrusion exists. Poor quality water exists at deeper depths in the aquifer along C-17 Canal. To define the quality of water throughout the shallow aquifer, selected wells (fig. 16) in the area were sampled. The analyses are listed in tables 3 and 4.

Figure 17 shows areal variation in dissolved solids concentrations in Unit 4, centering through Riviera Beach. Along the coast, saltwater extends about 1,000 ft inland in the deep part of the aquifer. Except for the C-17 Canal area and the coastal area where seawater intrusion has occurred, water in the shallow aquifer has less than 500 mg/L of dissolved solids, the recommended limit for public drinking water. Although some water contains excessive iron and color, and generally is hard, conventional treatment can make it potable.

Variation in the quality of water with depth is slight and inconsistent except along the coast where there is seawater intrusion, along C-17 Canal, and west of the levee along the east side of the West Palm Beach water catchment area. In these areas the dissolved solids concentration in water from deep wells usually exceeds 500 mg/L.

Seawater Intrusion

Seawater intrusion in idealized coastal aquifers takes the general form of a wedge as shown in figure 18 (Kohout, 1960; Cooper and others, 1964). Since the seawater is slightly heavier than freshwater, it moves into the aquifer and displaces the freshwater. Only the seaward sweep of fresh ground water over the wedge retards its advancement inland. If the fresh ground-water outflow is reduced, seawater intrusion accelerates. This has been the case in Riviera Beach in recent years because the natural flow has been reduced by ground-water pumpage and a reduction in recharge from local rainfall. Recharge from rainfall has been reduced chiefly by storm drainage systems and by an increase in the amount of impervious cover over parts of the area.

Profiles of the water table for Unit 1 and the potentiometric surface of Unit 4 were constructed using measurements of water levels in observation wells along a line south of Blue Heron Boulevard (figs. 19 and 20). From these types of profiles the relative rate and direction of ground-water flow in aquifers can be estimated. In this case, the water-table profile indicates a ground-water divide between the well field and the coast. From the divide, the profile of the potentiometric surface of Unit 4 slopes inland to the well field indicating a movement of seawater in that direction.

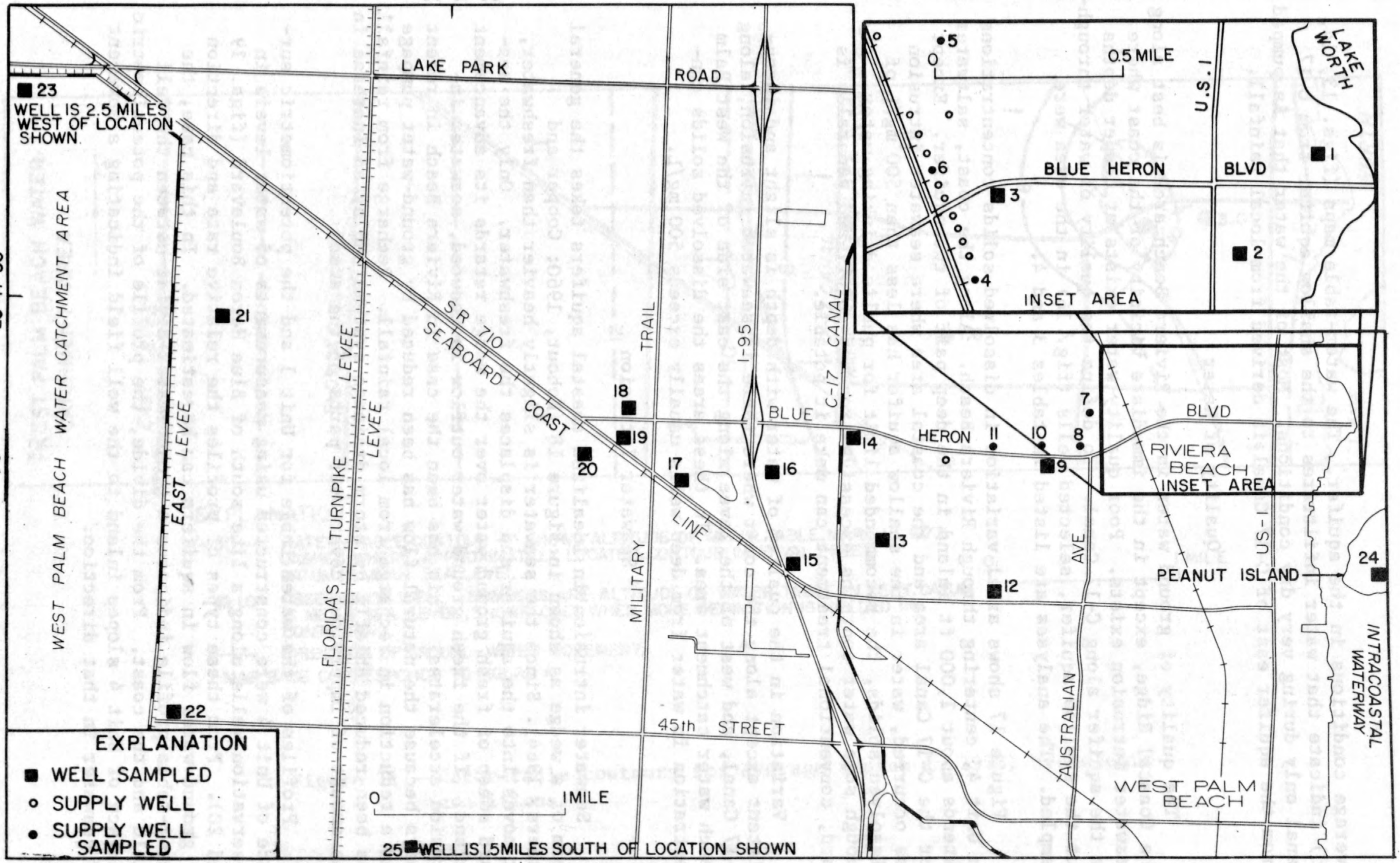


Figure 16.--Location of selected wells from which water samples were collected for chemical analysis. (Numbers refer to analyses listed in table 3.)

Table 3.--Chemical analyses of water from selected wells that tap the shallow aquifer or the Floridan aquifer.

(Concentrations in milligrams per liter)

Well location number on figure 16	Date of Collection	Depth (ft)	Specific conductance in micromhos per cm at 25°C	Dissolved Solids (Residue at 180°C)	pH	Temperature (°C)	Color (Cobalt platinum units)	Silica (SiO2)	Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Strontium (Sr)	Chloride (Cl)	Fluoride (F)	Sulfate (SO4)	Iron (Fe)	Bicarbonate	Hardness Noncarb.	Hardness Total	Alkalinity as CaCO3
									SHALLOW AQUIFER												
1	8-25-72	100	410	241	8.2	26.0	35	8.0	70	1.8	0.6	12	0.20	20	0.1	3.2	0.80	208	12	180	171
2	10-17-72	190	396	248	8.4	26.5	90	9.8	67	1.9	.8	14	1.0	18	.3	2.4	.07	254	40	250	210
3	2-12-75	36	500	311	7.3	27.5	100	10	96	4.5	1.1	8.9	.28	17	.0	46	7.1	240	62	260	197
4	8-25-72	200	420	246	8.1	26.0	20	10	74	1.8	.6	12	.88	20	.2	.0	.01	232	3	190	190
5	8-25-72	200	400	230	8.0	26.0	20	8.2	70	2.0	.6	11	.68	18	.2	8.8	.06	208	13	180	171
6	8-25-72	60	410	246	7.6	26.0	45	6.4	74	2.4	2.0	8.3	.20	13	.1	22	3.1	208	25	190	171
7	1-23-75	250	600	268	7.6	25.0	5	11	85	1.6	.5	9.9	1.1	14	.2	0.0	.03	276	0	220	220
8	12-18-72	100	520	308	8.6	26.5	50	7.3	88	2.3	.7	14	.4	22	.2	20	.60	237	10	230	220
9	8-25-72	200	435	251	8.1	26.0	25	5.8	76	1.8	.6	13	.84	24	.2	2.4	2.2	228	11	200	187
10	8-25-72	100	660	390	7.7	26.0	50	6.7	96	2.4	1.6	33	.76	52	.2	23	.52	272	28	250	223
11	12-18-72	100	436	251	8.5	26.5	40	6.7	76	2.0	1.0	9.1	.40	16	.6	9.6	.60	198	15	200	185
12	1-23-75	67	520	248	7.6	25.0	100	8.2	71	2.5	.9	14	.63	5.5	.1	11	.31	248	0	190	190
13	2-12-75	200	1400	897	7.7	25.0	30	18	160	14	3.1	160	1.9	220	.4	18	.23	544	13	460	446
14	8-20-75	23	281	217	6.6	26.0	140	7.6	43	3.0	.3	3.9	.35	9.0	.4	32	.34	88	48	120	72
15	2-11-75	151	1240	677	7.5	27.5	20	13	110	12	3.6	140	1.8	170	.3	3.8	.10	680	0	330	558
16	2-11-75	135	1360	821	8.0	25.0	20	18	160	9.7	1.9	130	1.9	210	.3	8.7	.26	500	32	440	410
17	2-11-75	110	960	537	7.4	27.5	40	16	120	6.4	1.5	68	1.9	93	.5	3.6	3.3	448	0	330	367
18	8-25-72	160	600	372	8.0	26.0	70	12	96	3.9	0.7	24	1.3	36	0.8	.0	1.1	312	2	260	256
19	1-23-75	88	1000	356	7.4	24.0	100	12	98	3.8	.6	25	1.3	32	.3	1.5	.88	352	0	260	260
20	12-23-70	94	686	378	8.6	20.0	25	11	104	4.2	1.0	26	1.5	44	.3	.0	--	302	5	279	274
21	2-11-75	80	760	455	7.4	24.5	30	21	150	5.3	.9	18	1.8	19	.2	.5	.52	520	0	400	427
22	1-22-75	87	1550	576	7.1	26.0	40	23	140	16	3.5	84	2.1	75	.4	5.6	2.3	704	0	420	420
23	12-30-70	76	612	380	8.3	24.0	20	16	92	3.8	.8	35	.31	66	.3	8	--	268	20	246	226
									FLORIDAN AQUIFER												
24	7-15-74	1000	5100	3360	7.8	23.5	7	22	65	94	60	1000	--	1600	2.6	430	--	228	360	550	187
25	1-16-75	3540	51100	37700	7.6	18.0	3	4.5	460	1300	460	11000	--	20000	1.4	2600	3100	159	6400	6500	130

Table 4.--Analyses of trace metals, nutrients, and carbon in water from the shallow aquifer.

(Concentrations of metals in micrograms per liter; concentrations of nutrients and carbon in milligrams per liter)

Well location number on figure 16	Date of Collection	HEAVY METALS (Total Recoverable) Aluminum (Al)	Zinc (Zn)	Lead (Pb)	Copper (Cu)	Chromium (Cr^{+6})	Arsenic (As)	Mercury (Hg)	NUTRIENTS Nitrite as (N)	Nitrate as (N)	CARBON Inorganic	Total Organic	Total
1	8-25-72	0	50	0	10	0	0	0.2	0.01	0.00	--	--	--
2	10-17-72	--	--	--	--	--	--	--	.01	.04	--	--	--
4	8-25-72	--	--	--	--	--	--	--	--	--	44	10	54
5	8-25-72	0	0	6	10	0	10	.0	.03	.00	42	9	51
6	8-25-72	--	--	--	--	--	--	--	.00	.08	42	11	53
8	12-18-72	30	10	0	0	0	--	.5	.00	.00	--	--	51
9	8-25-72	10	10	4	220	15	10	.0	.00	.00	33	17	55
10	8-25-72	--	--	--	--	--	--	--	.00	.00	67	25	92
	12-18-72	30	20	0	10	0	--	1.0	--	--	88	5	93
11	12-18-72	10	10	0	0	0	--	.6	--	--	52	2	54
18	8-25-72	0	10	20	10	0	10	.0	.08	.00	75	25	100

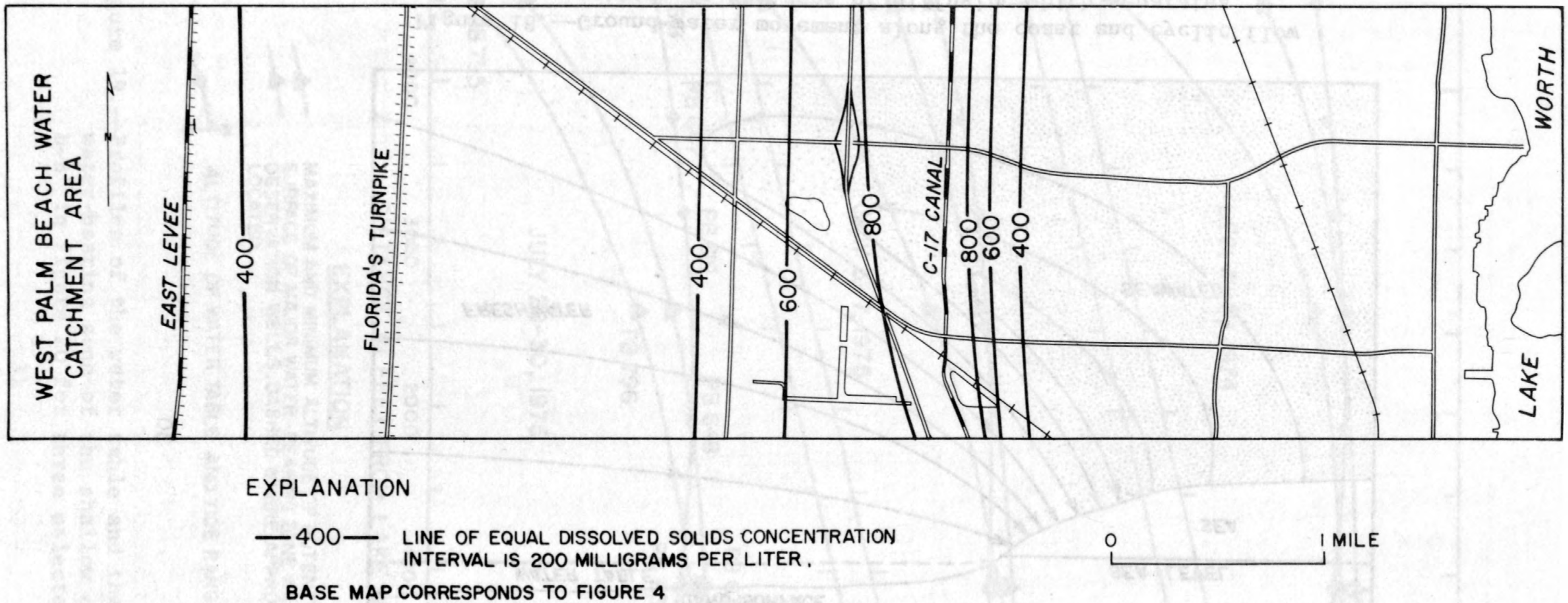


Figure 17.--Dissolved solids concentrations of ground water from Unit 4 of the shallow aquifer.

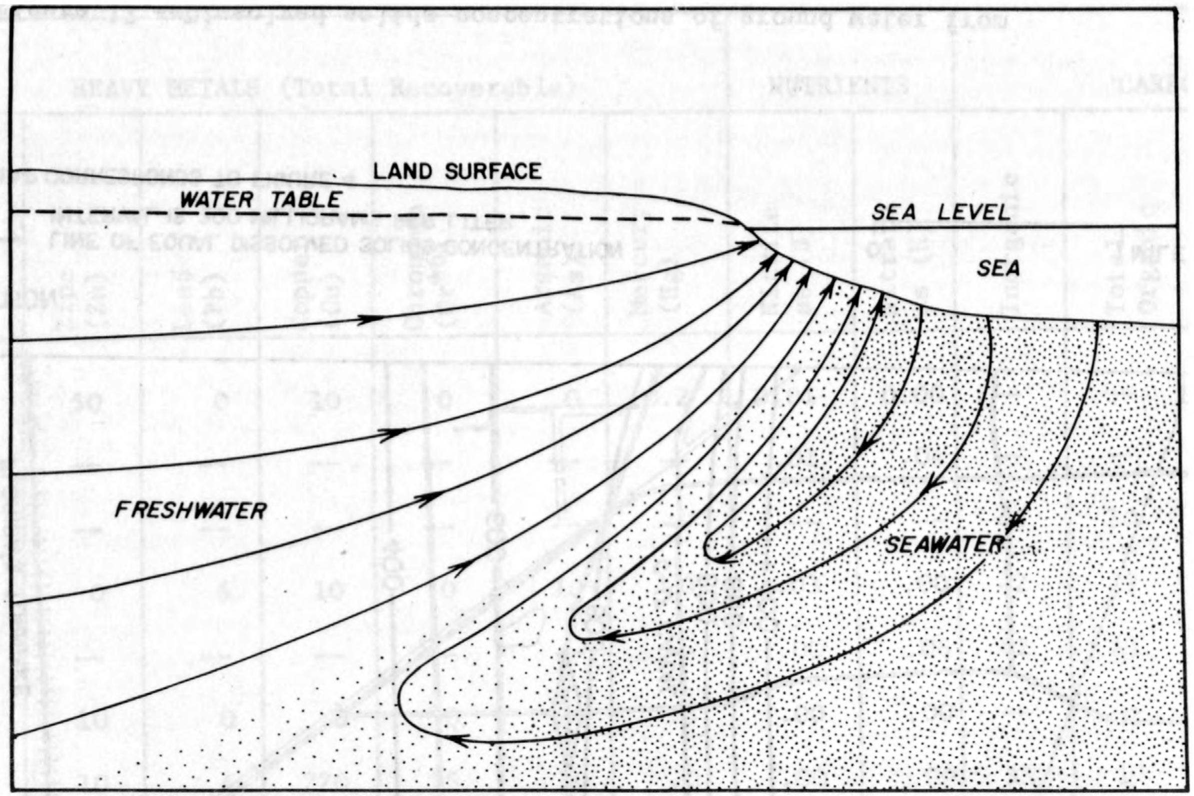


Figure 18.--Ground-water movement along the coast and cyclic flow pattern in the zone of diffusion which separates freshwater and seawater (Kohout, 1960).

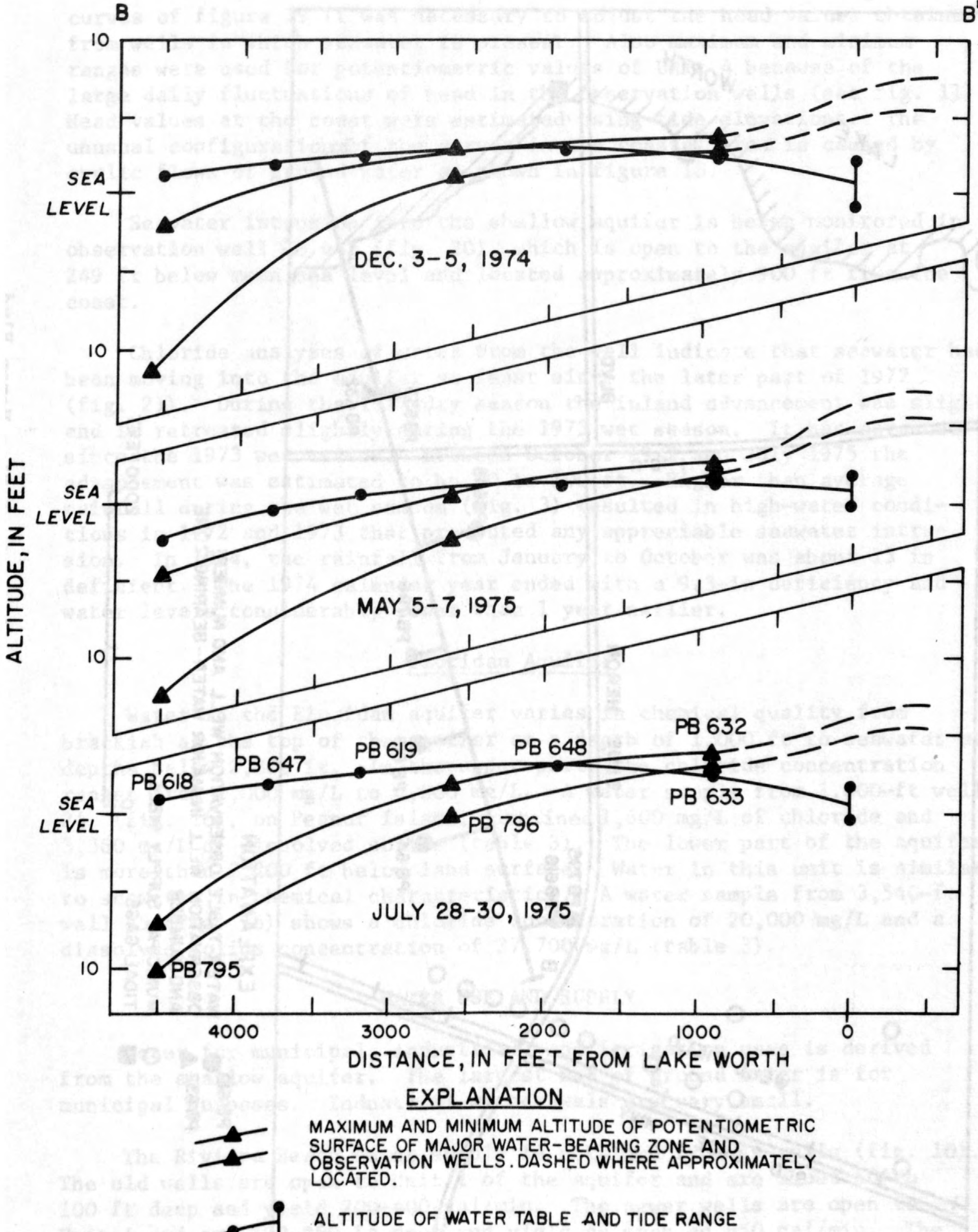


Figure 19.--Profiles of the water table and the head in the major water-bearing zone of the shallow aquifer along line B-B' in figure 20 for three selected two-day periods.

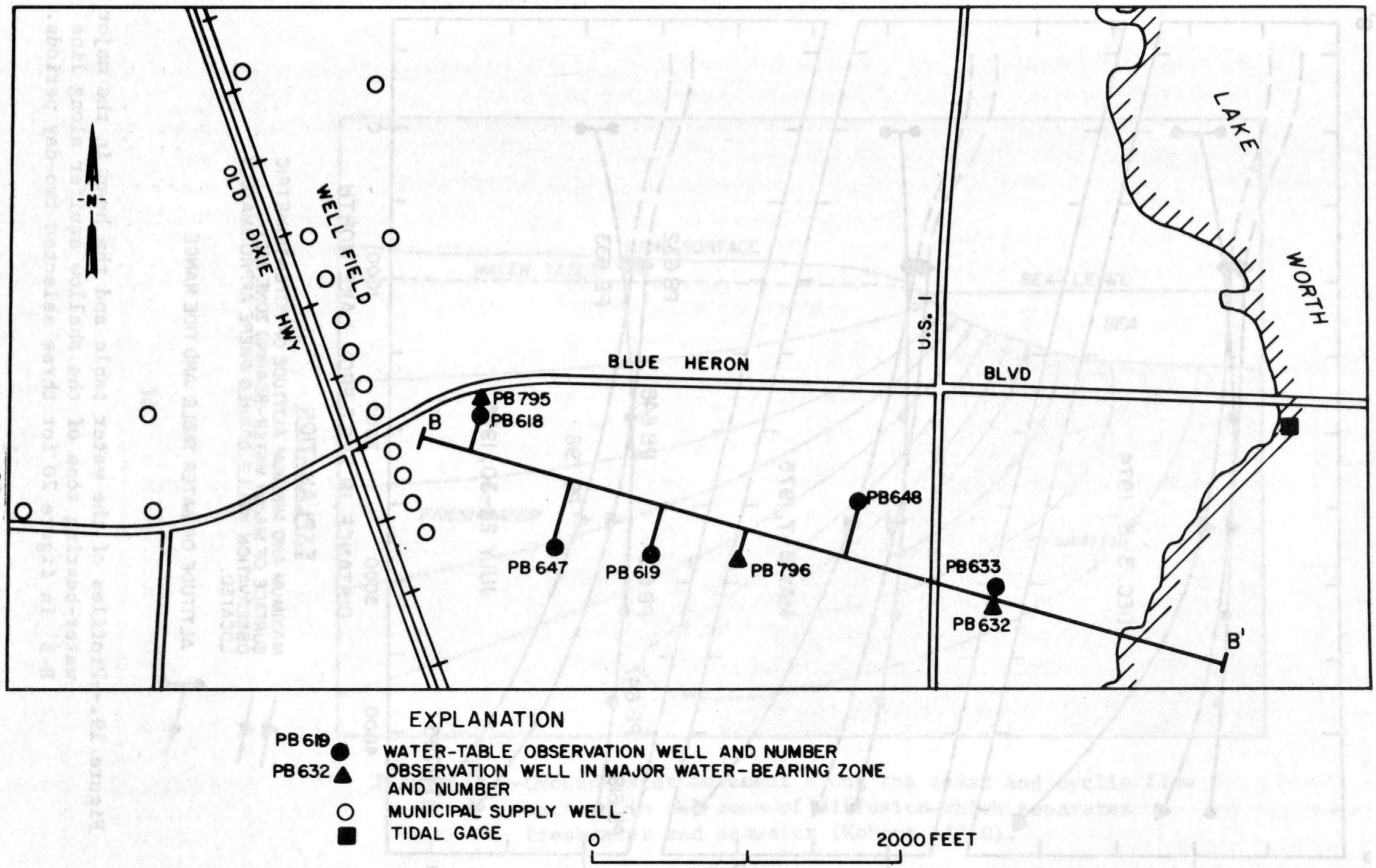


Figure 20.--Observation wells along line B-B' south of Blue Heron Blvd.

Because seawater is more dense than freshwater, in drawing the curves of figure 19 it was necessary to adjust the head values obtained from wells in which seawater is present. Also maximum and minimum ranges were used for potentiometric values of Unit 4 because of the large daily fluctuations of head in the observation wells (see fig. 11). Head values at the coast were estimated using tide elevations. The unusual configuration of the curves in the coastal area is caused by cyclic flows of ground water as shown in figure 18.

Seawater intrusion into the shallow aquifer is being monitored in observation well PB 632 (fig. 20), which is open to the aquifer at 249 ft below mean sea level and located approximately 900 ft from the coast.

Chloride analyses of water from the well indicate that seawater has been moving into the aquifer at least since the later part of 1972 (fig. 21). During the 1973 dry season the inland advancement was slight and it retreated slightly during the 1973 wet season. It has advanced since the 1973 wet season. Between October 1972 and July 1975 the advancement was estimated to be 50 to 100 ft. Higher than average rainfall during the wet season (fig. 3) resulted in high-water conditions in 1972 and 1973 that prevented any appreciable seawater intrusion. In 1974, the rainfall from January to October was about 13 in deficient. The 1974 calendar year ended with a 9.3-in deficiency and water levels considerably lower than 1 year earlier.

Floridan Aquifer

Water in the Floridan aquifer varies in chemical quality from brackish at the top of the aquifer at a depth of 1,000 ft to seawater at depths below 2,200 ft. In the upper part, the chloride concentration ranges from 1,000 mg/L to 4,000 mg/L. A water sample from 1,000-ft well 24 (fig. 16), on Peanut Island, contained 1,600 mg/L of chloride and 3,360 mg/L of dissolved solids (table 3). The lower part of the aquifer is more than 2,200 ft below land surface. Water in this unit is similar to seawater in chemical characteristics. A water sample from 3,540-ft well 25 (fig. 16) shows a chloride concentration of 20,000 mg/L and a dissolved solids concentration of 37,700 mg/L (table 3).

WATER USE AND SUPPLY

Water for municipal, industrial, and irrigation uses is derived from the shallow aquifer. The largest use of ground water is for municipal purposes. Industrial withdrawals are very small.

The Riviera Beach water supply is obtained from 19 wells (fig. 10). The old wells are open to Unit 2 of the aquifer and are about 60 to 100 ft deep and yield 200-400 gal/min. The newer wells are open to Unit 4 and are 200-250 ft deep and yield as much as 650 gal/min. The operating capacity of the well field is approximately 8 Mgal/d. The total estimated 1974 municipal pumpage is equivalent to 25 in of water over the area estimated to be influenced by the supply wells. This is approximately 40 percent of the average annual rainfall.

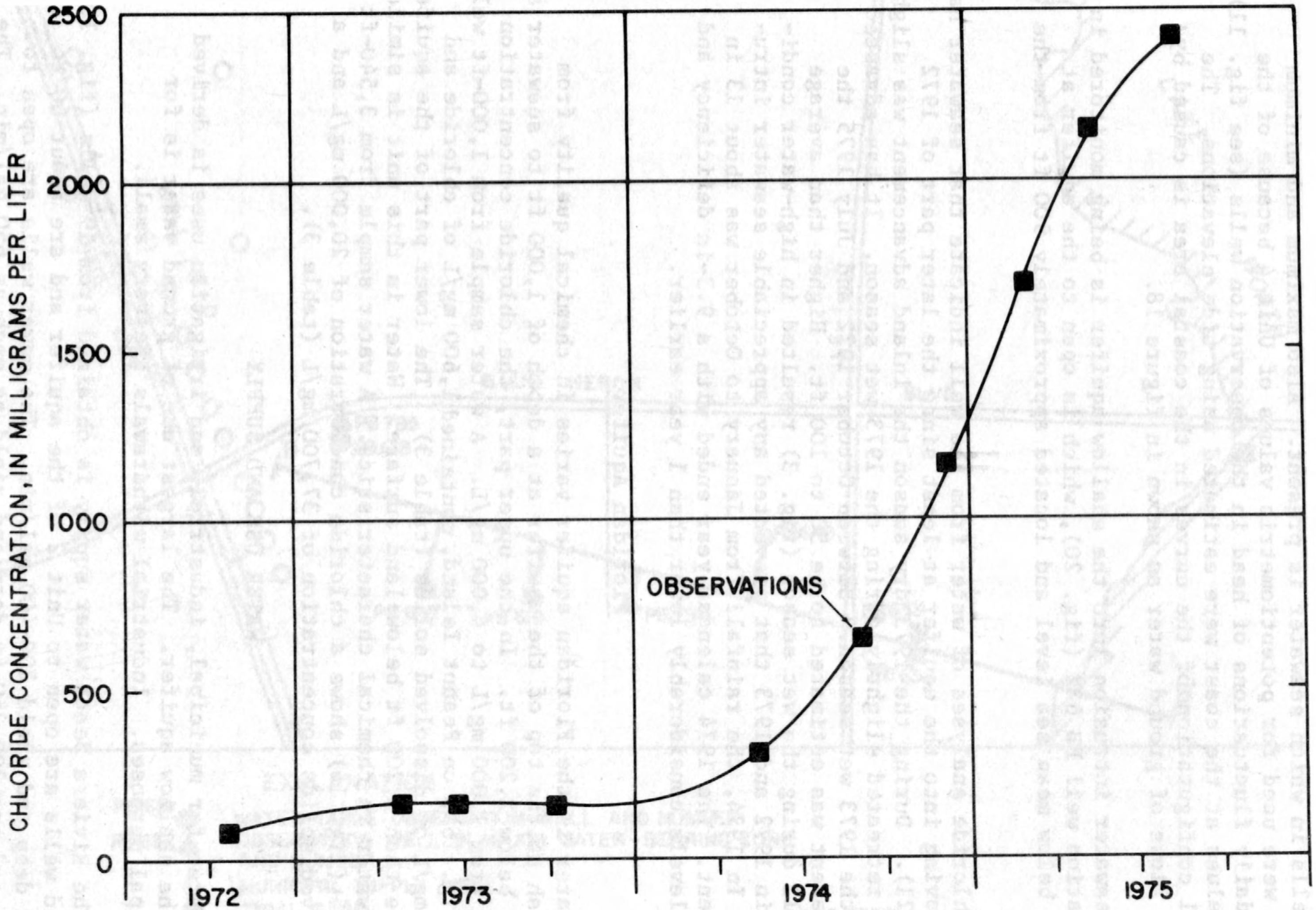


Figure 21.--Chloride concentrations of water in observation well PB 632 for 1972-75.

The average municipal withdrawal rate has increased from 3.0 Mgal/d in 1969 to 5.2 Mgal/d in 1974, an increase of 73 percent (fig. 22). Seasonal pumping loads are generally highest in late winter and early spring (fig. 23) when the tourist population and irrigation needs are the greatest. Demands are lowest in late summer, at the height of the rainy season. These monthly peaks and troughs in the pumpage graph vary about 20 percent from the annual average.

Large quantities of freshwater are available in the shallow aquifer for future needs, but it will require good planning and management to minimize damage from seawater intrusion.

Changing the distribution and spacing of municipal supply wells would help in obtaining the maximum amount of ground water from the aquifer under the Coastal Ridge. The rate of municipal pumping from the closely-spaced network of supply wells in the vicinity of the water treatment plant is causing water-level declines in Unit 4 that extend seaward off the coast most of the time. Spacing wells more widely and placing them at greater distances from the coast would reduce this decline in water levels. The effect of lowering would then be spread over a larger inland area which would result in less decline at the center of the well field. As a result, it might be possible to develop a hydraulic gradient in Unit 4 that would slope toward the coast most of the year.

Additional quantities of freshwater can be developed west of Military Trail and east of the West Palm Beach water catchment area, although the quality of water is less desirable than that along the Coastal Ridge. Wells with capacities of about 1,000 gal/min can be developed in that area.

Another means of increasing the city's freshwater supply is to divert surplus freshwater to the drainage canals near the well field to provide increased infiltration to the aquifer.

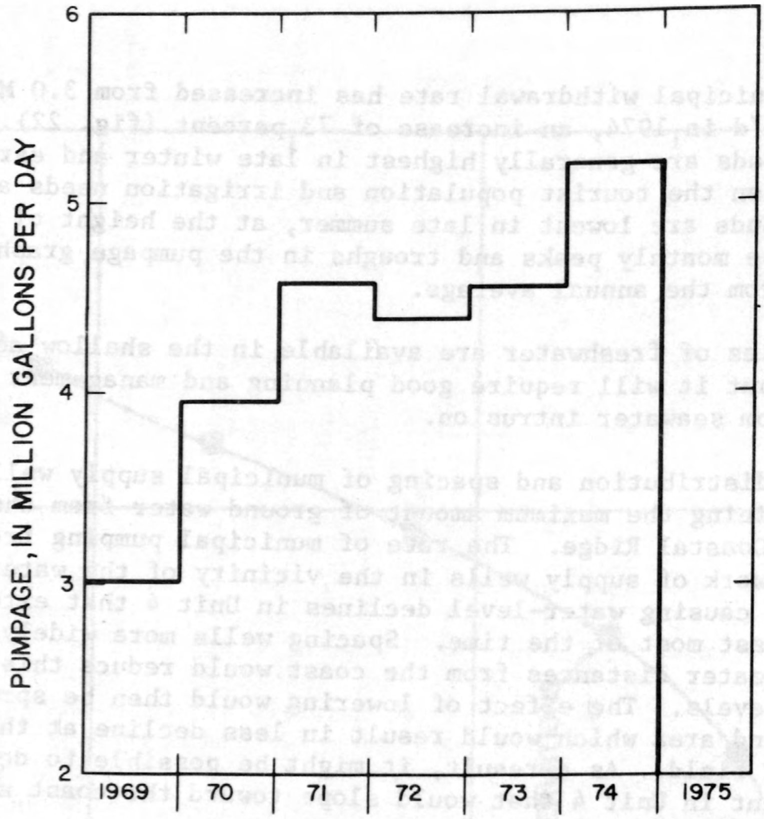


Figure 22.--Average annual pumpage from the Riviera Beach municipal supply wells for 1969-74.

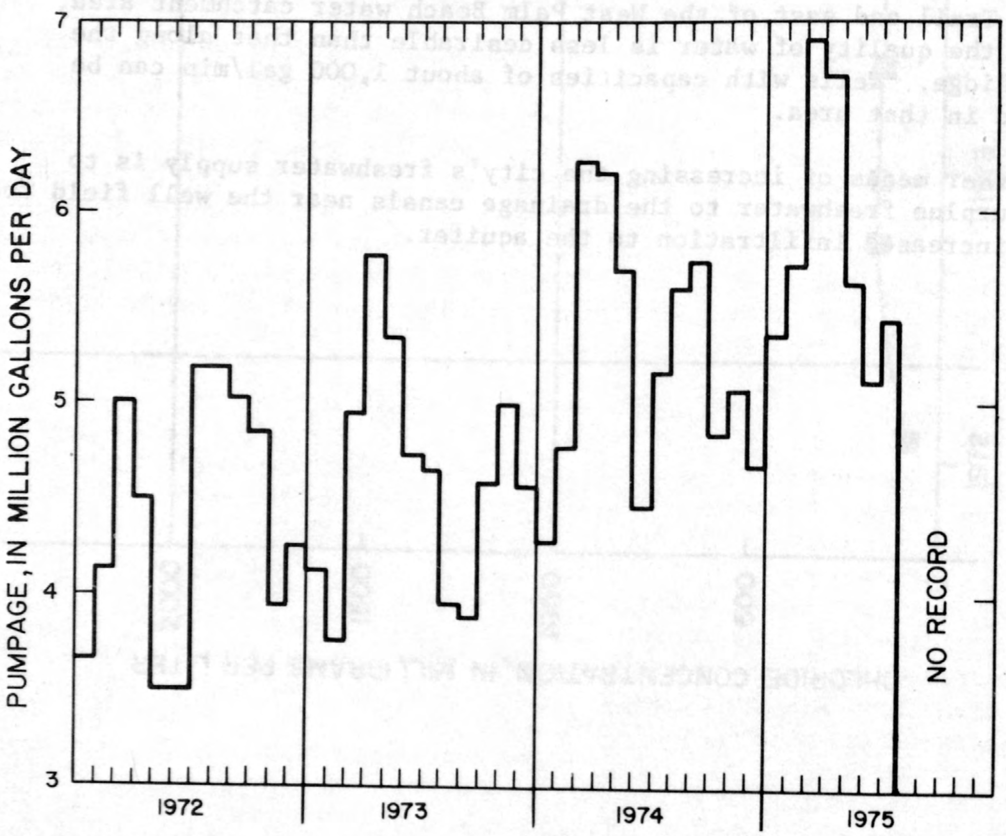


Figure 23.--Total monthly pumpage from Riviera Beach municipal supply wells for 1972-75.

SUMMARY

The so-called shallow aquifer is the sole source of fresh ground water used in the Riviera Beach area. It extends from the land surface to a depth of 175 ft beneath the West Palm Beach water catchment area and to 300 ft near the coast. The aquifer is divided into four units. The uppermost, Unit 1, consists of 20 to 40 ft of sand. Units 2 and 3 occur almost entirely east of Military Trail. Unit 2 is composed mostly of sand, shells, and occasional layers of cemented sand. Unit 3 consists of very fine sand and shells and has the lowest permeability of the four units. Unit 4 is composed primarily of cemented sand and shells. It is the deepest and most permeable of the four units. Transmissivities range from 2,000 ft^2/d along C-17 Canal to 30,000 ft^2/d in the cavity-riddled section west of Military Trail. Most of the large supply wells in the area pump from Unit 4.

Recharge to the shallow aquifer is chiefly from rainfall although recharge from this source is gradually being reduced by an increase in the amount of impervious cover and expansion of storm sewer systems. Discharge is chiefly by evapotranspiration. Other important discharges include seepage into C-17 Canal, drainage canals, and Lake Worth, and pumping from municipal and domestic wells. Municipal withdrawals are increasing at the greatest rate: the 1974 municipal pumpage is estimated to have been equivalent to 40 percent of the average annual rainfall over the area estimated to be influenced by the municipal pumping.

The increase in pumping has reduced the flow of fresh ground water into Lake Worth. This flow has acted as a barrier to seawater encroachment. Between the fall of 1972 and the summer of 1975, the inland advancement of seawater is estimated to have been 50 to 100 ft.

Fluctuations of water levels in the shallow aquifer are influenced mainly by rainfall, by regulation of flow in C-17 Canal and by pumping of wells. Water fluctuations are greatest in the vicinity of the municipal well field. Ground water generally moves eastward; part is intercepted by the C-17 Canal and part is diverted by the well field. Because of the high annual rainfall and low relief, water levels generally are within a few feet of land surface.

The quality of water in the shallow aquifer is generally satisfactory for the municipal use except along C-17 Canal where the dissolved solids concentration often exceeds 500 mg/L. The quality of water in the deep Floridan aquifer is generally poor. The chloride concentration ranges from 1,000 to 4,000 mg/L in the upper part whereas water in the lower part is similar to seawater in chemical characteristics.

Additional quantities of freshwater are available in the interior of the area although the quality of the water is less desirable than that under the Coastal Ridge.

REFERENCES

Cooper, H.H., Jr., Kohout, F.A., Henry, H.R. and Glover, R.E., 1964, Sea water in coastal aquifers: U.S. Geol. Survey Water Supply Paper 1613-C.

Kohout, F.A., 1960, Cyclic flow of salt water in the Biscayne Aquifer of southeastern Florida: Jour. Geophys. Research, v. 65, no. 7, p. 2133-2141.

Land, L.F., Rodis, H.G., and Schneider, J.J., 1973, Appraisal of the water resources of eastern Palm Beach County, Florida: Florida Dept. Nat. Resources, Bur. Geology Rept. Inv. 67, 63 p.

Parker, G.G., Ferguson, G.E., Love, S.K. and others, 1955, Water resources of southeastern Florida: U.S. Geol. Survey Water-Supply Paper 1255, 965 p.

Schroeder, M.C., Milliken, D.L., and Love, S.K., 1954, Water resources of Palm Beach County, Florida: Florida Div. Geology Survey Rept. Inv. 13, 63 p.

Trescott, P.C., 1973, Iterative digital model for aquifer evaluation: U.S. Geol. Survey open-file rept., 63 p.

☆U.S. GOVERNMENT PRINTING OFFICE: 1977-744-056

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
325 John Knox Rd--Suite F240
Tallahassee, Florida 32303

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTERIOR
INT. 413

U.S. MAIL

FIRST CLASS