UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND-WATER QUALITY AT THE SITE OF A PROPOSED DEEP-WELL INJECTION SYSTEM FOR TREATED WASTEWATER, WEST PALM BEACH, FLORIDA

OPEN-FILE REPORT 76-91

Prepared in cooperation with the
CITY OF WEST PALM BEACH, FLORIDA

Tallahassee, Florida
1976

76-91 Ground-Water Quality at the Site of a Proposed Deep-Well Injection System for Treated Wastewater, West Palm Beach, Florida

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By William A. J. Pitt, Jr., and Frederick W. Meyer

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William A. J. Pitt, Jr.

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ABSTRACT

The U.S. Geological Survey collected scientific and technical information before, during, and after construction of a deep test well at the location of a future regional waste-water treatment plant to be built for the city of West Palm Beach, Florida. Data from the test well will be used by the city in the design of a proposed deep-well injection system for disposal of effluent from the treatment plant. Shallow wells in the vicinity of the drilling site were inventoried and sampled to provide a data base for detecting changes in ground water quality during construction and later operation of the deep wells. In addition, 16 small-diameter monitor wells, ranging in depth from 10 to 162 feet, were drilled at the test site. During the drilling of the deep test well, water samples were collected weekly from the 16 monitor wells for determination of chloride content and specific conductance. Evidence of small spills of salt water were found in monitor wells ranging in depth from 10 to 40 feet. Efforts to remove the salt water from the shallow unconfined aquifer by pumping were undertaken by the drilling contractor at the request of the city of West Palm Beach. The affected area is small and there has been a reduction of chloride concentration.

INTRODUCTION

An urgent wastewater disposal problem exists in Palm Beach County (fig. 1), one of the most rapidly developing counties in Florida. In 1970, Federal and State conferees at Miami recommended that all wastewater discharge to inland waters of Dade County, Florida, cease (U.S. Department of Interior, 1970, p. 700). In 1972, the Florida Department of Pollution Control extended this policy to include Palm Beach County. At the same time water shortages were predicted for southeast Florida unless fresh-water discharges to the ocean were reduced. A Federal-State Ad Hoc Technical Committee on Wastewater Reuse in southeast Florida recommended that pilot studies be undertaken to determine feasibilities of various alternatives for storage and reuse of wastewater and storm runoff. Among the recommended alternatives was the utilization of deep saline-water-bearing aquifers as receptacles for injected wastewater and storm runoff.

In 1973 EPA (U.S. Environmental Protection Agency) issued a grant to the city of West Palm Beach to construct a secondary wastewater treatment plant on city-owned property. The first phase of construction would be a plant capable of treating an average flow of 20 Mgal/d (million gallons per day) and a peak flow of 40 Mgal/d. The ultimate capacity of that plant is expected to be 64 Mgal/d.

FACTORS FOR CONVERTING ENGLISH UNITS TO METRIC UNITS

Multiply English units	By	To obtain SI units
	Length	
inches (in.)	2.54×10^{1}	millimetres (mm)
	2.54×10^{-2}	metres (m)
feet (ft)	3.048×10^{-1}	metres (m)
miles (mi)	1.609	kilometres (km)
	Volume	
gallons (gal)	3.785	litres (l)
	3.785×10^{-3}	cubic metres (m^3)
million gallons (Mgal)	3.785×10^{3}	cubic metres (m^3)
	Flow	
cubic feet per second (ft^3/s)	2.832×10^{1}	litres per second (l/s)
	2.832×10^{-2}	cubic metres per second (m^3/s)
gallons per minute (gal/min)	6.309×10^{-2}	litres per second (l/s)
	6.309×10^{-5}	cubic metres per second (m^3/s)
million gallons per day (Mgal/d)	4.381×10^{1}	litres per second (l/s)
	4.381×10^{-2}	cubic metres per second (m^3/s)

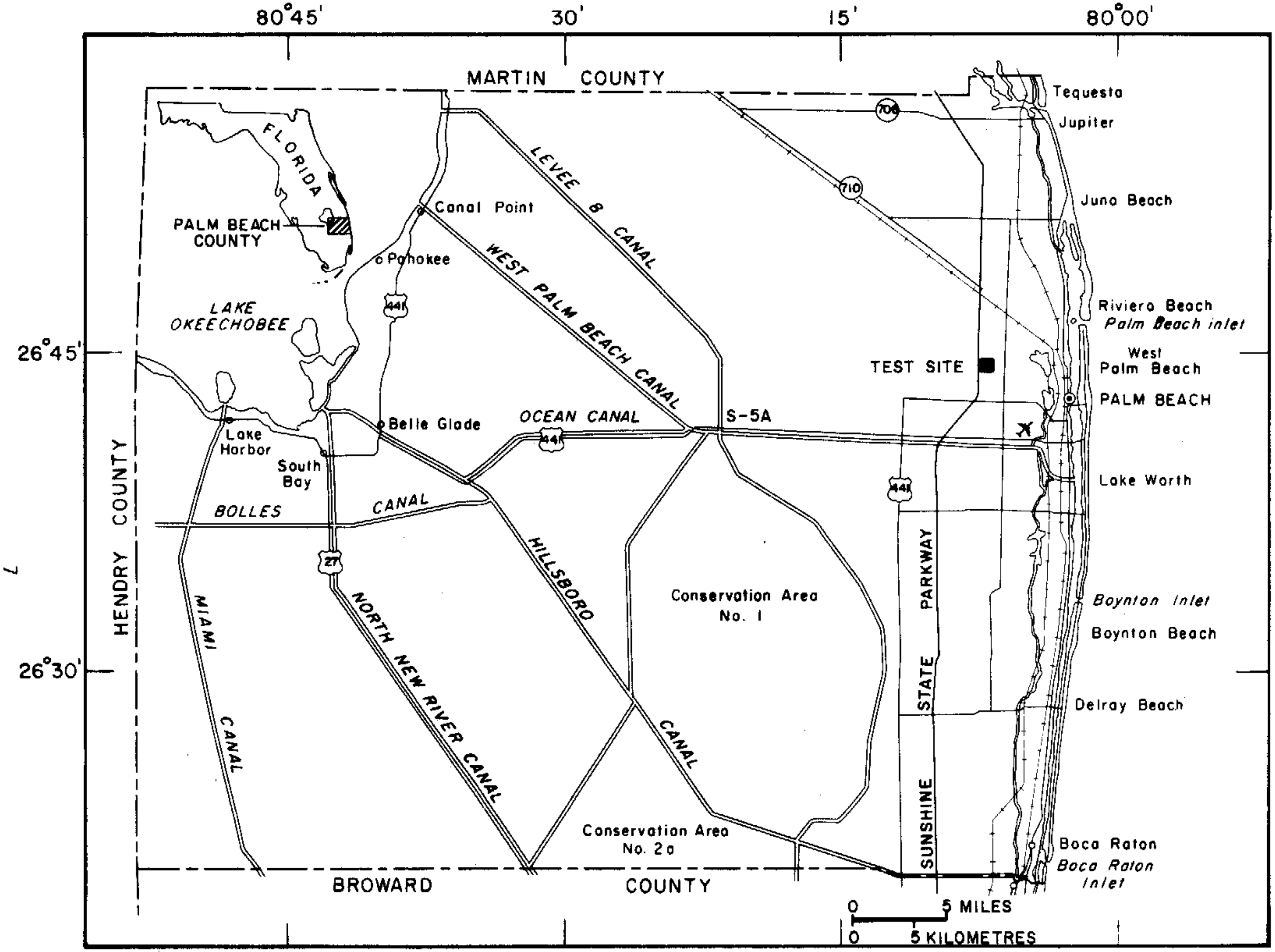

Figure 1.--Location of proposed regional sewage treatment facility in Palm Beach County.

As a part of that grant, the EPA authorized the city to drill a 3,500-foot test well at the plant site to determine the feasibility of injecting the treated wastewater into a cavernous limestone that is believed to underlie the area at a depth of about 3,000 feet. If the test well was successful then several wells of sufficient size to handle the effluent from the first phase of the plant would be drilled on the site. If the results of the deep test well project were unfavorable, alternative disposal would be into the ocean through a proposed 6,000-foot outfall.

The deep aquifer, which has been designated by the State as the zone for storage of secondary treated wastewater, is commonly called the Boulder Zone (Kohout, 1965, p. 256). The Boulder Zone contains salt water in excess of 20,000 mg/l chloride. Disposal of these fluids during drilling operations is often a problem. Because of this, it was necessary for the city to take preventative measures to insure the protection of the unconfined aquifer, the sole source of fresh ground water in the area.

First and foremost was the early construction of a 1,315-foot brine injection well to store salt water from the drilling and testing of the deep test well. This well terminates in the principal artesian zone of the Floridan aquifer system (Meyer, 1971, p. 65) which contains brackish water in this vicinity. Other measures taken include the use of heavy drilling mud to prevent artesian flow during construction of the deep test well, and the use of a closed circulation system to separate rock cuttings and salt water. After separation, the salt water was injected into the brine-injection well and the rock cuttings were trucked from the site to a distant land fill. These measures, however, do not rule out the possibility of salt-water contamination during and after drilling because accidental spills can still occur; therefore, monitoring of water quality in the unconfined aquifer near the test well was an important part of the project.

Purpose and Scope

In 1974, the city of West Palm Beach requested the U.S. Geological Survey to evaluate the impact of the project on the water resources of eastern Palm Beach County. The investigation will provide the city of West Palm Beach with scientific and technical information necessary for the evaluation of a deep saline water-bearing aquifer underlying Palm Beach County as a waste-management system for storage, possible supplementary treatment, and possible recovery of treated wastewater. The objective of the first phase of the investigation is to evaluate the effects of well construction and effluent injection on subjacent and overlying aquifers. The second-phase objective is to evaluate the data obtained from the deep test well to determine the geologic and hydrologic characteristics of the aquifer and, in particular, to determine its capacity to accept the injected treated wastewater.

This report, concerned chiefly with the first phase, describes the hydrologic conditions and ground-water quality at and near the drilling site prior to and during the early stages of well construction. Supply wells within 1 mile and artesian wells within 3 miles of the drilling site were inventoried during early 1974; and a network of 16 monitor wells ranging in depth from 10 to 162 feet were drilled within 300 feet of the deep test well during March-July, 1974. Samples of water from 8 of the 12 private wells inventoried and the 16 monitor wells were analyzed for physical, chemical, and bacteriological parameters prior to the construction of the deep test well. These data supply the necessary background information on the quality of ground water in the vicinity of the deep test well so that comparisons can be made to detect changes which may relate to the drilling and testing of the deep test well and the operation of the deep-well injection system. In addition, samples of water were collected periodically from the on-site network of shallow monitor wells and analyzed for chloride and specific conductance to detect possible increases in salinity due to salt spills during the drilling of the deep test well.

Acknowledgments

The authors express their appreciation to the many residents who provided information about their wells; and to John G. Simmons, Director of Utilities, city of West Palm Beach, and J. H. "Buck" Weaver, Managing Engineer, Robert and Company Associates, West Palm Beach, for their cooperation during the investigation.

LOCATION AND HYDROLOGIC SETTING

The city of West Palm Beach has reserved part of Section 11, Township 43 South, Range 42 East, for its regional sewage treatment facility (fig. 2). The site for the deep test well is located about one quarter mile southeast of the proposed plant. The site itself is a shallow circular depression which becomes a shallow pond during the rainy season. The area is rural and lightly populated.

The unconfined aquifer is the principal source of fresh ground water in Palm Beach County. The aquifer was estimated to be at least 250 to 300 feet thick (fig. 3) by Land and others (1972). The principal formations that make up the aquifer have been identified as the Pamlico Sand and the Anastasia Formation, of Pleistocene age, and the Caloosahatchee Marl of Pliocene age (Schroeder and others, 1954; and Land and others, 1972). The unconfined aquifer extends from land surface to the top of a clay confining bed in the Tamiami Formation of Pliocene age (written communication, J.E. Hazel, Chief, Branch of Paleontology and Stratigraphy, January 20, 1976). Confining beds, which include clay beds of the Tamiami Formation and Hawthorn Formation (Miocene), separate the unconfined aquifer from the underlying artesian water-bearing zones of the Floridan aquifer. The principal artesian water-bearing zone is about 900 feet deep at the drilling site. Salinity in native ground water from this depth is about 10 to 15 percent of that of sea-water (1,900 to 2,850 mg/l chloride). Salinity concentration normally increases with depth in the Floridan aquifer and is probably equivalent to sea water in the Boulder Zone (Meyer, 1974, p. 9).

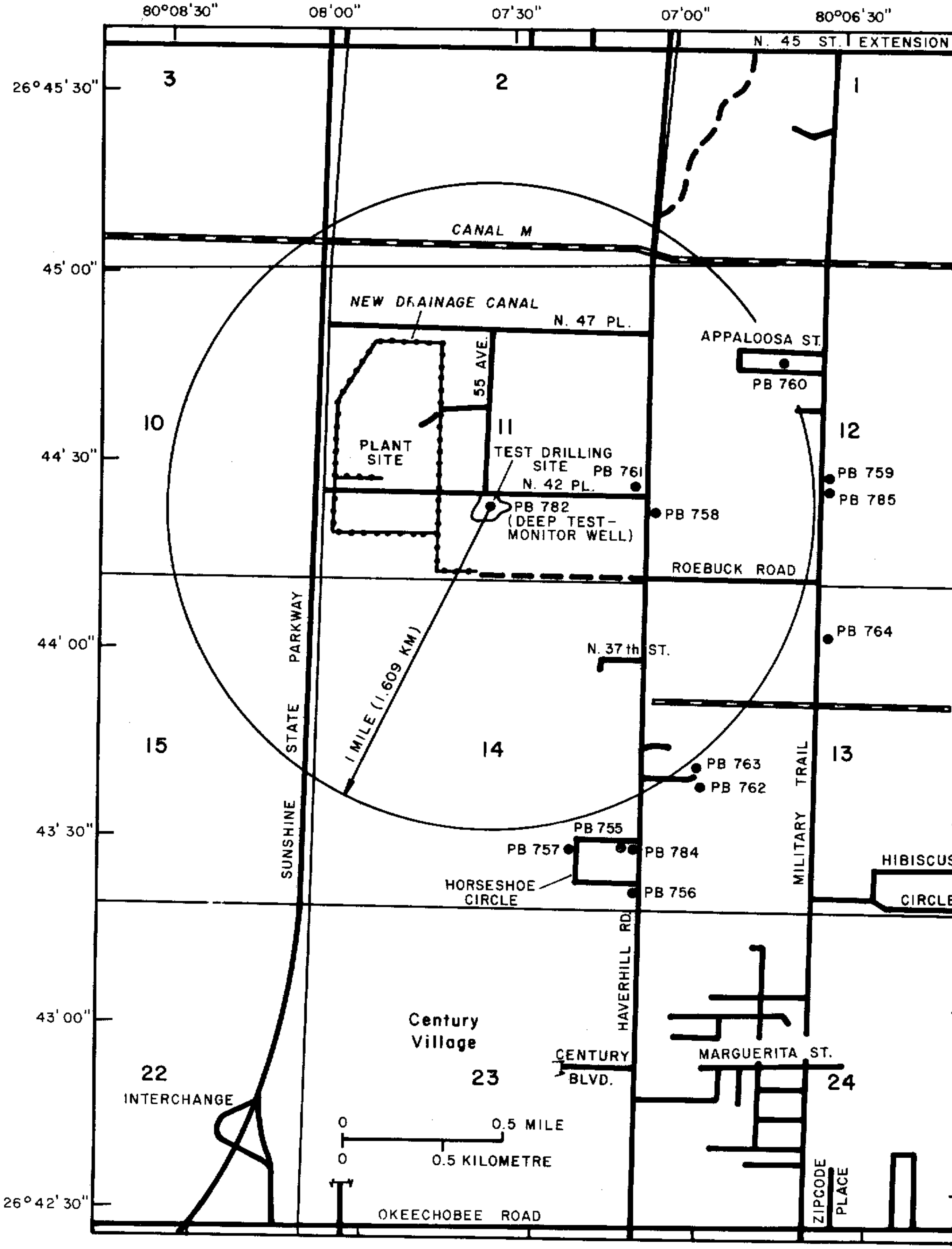

Figure 2.--Location of drilling site and selected supply wells.

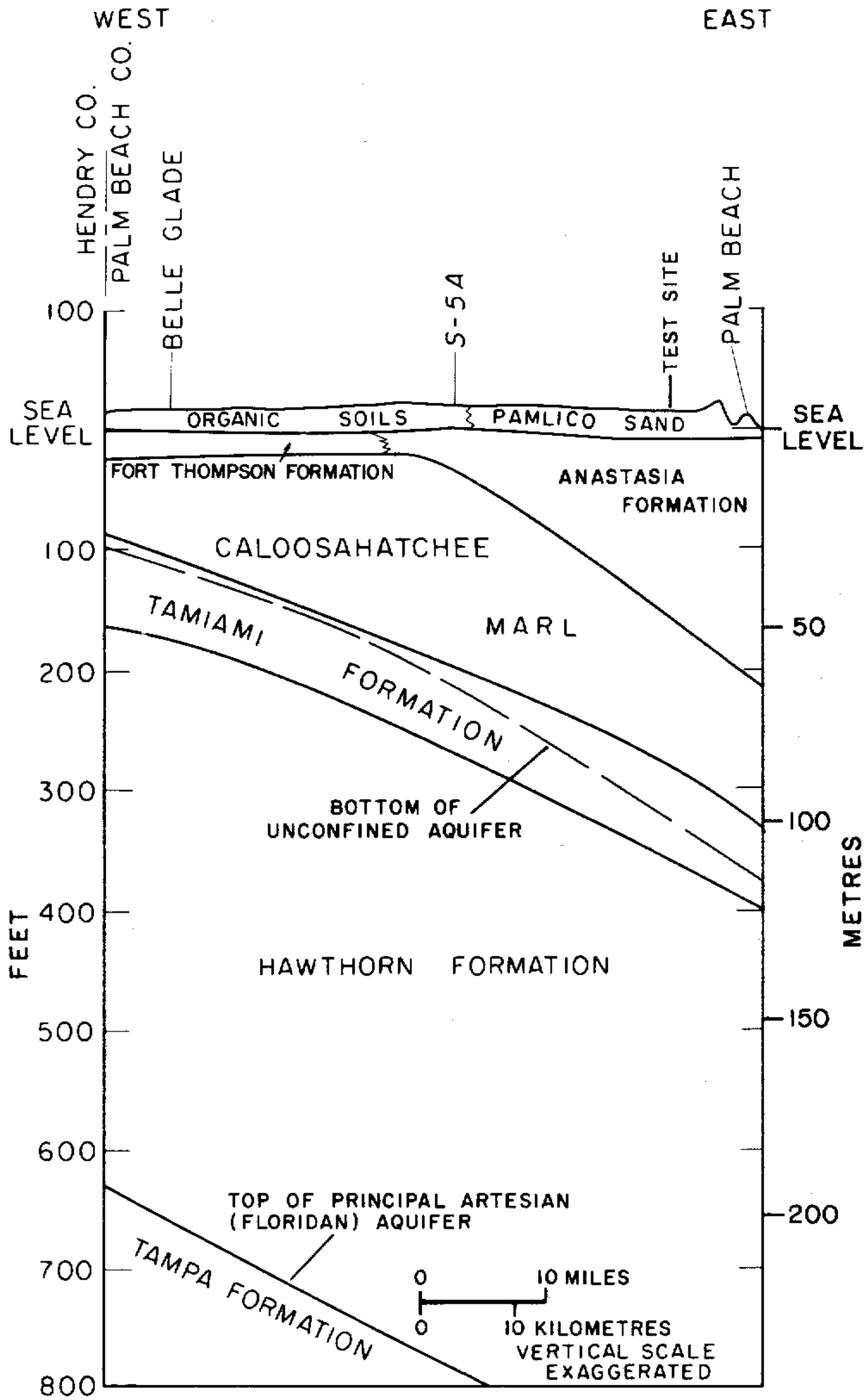

Figure 3.--Generalized geologic section through central Palm Beach County. After Land and others, 1972.

Vegetation indicates that the drilling site is an intermittent pond. The site is encircled by pine which is intolerant to prolonged inundation. Inside the circle of pine is another circle of cocoplum which tolerates several months of inundation or a high water table. Intermingled with the cocoplum and forming yet another belt about the center of the area is a thin stand of melaleuca trees which are even more tolerant of a high water table than cocoplum. Inside these tree belts are marsh grasses indicative of seasonal flooding.

Locating the drilling site in the middle of a natural intermittent pond provides both benefits and problems. On the positive side, the risk of widespread surface contamination by salt-water spills is reduced, drainage into the depression will partly dilute salt spills, and the need for land clearing is minimized. On the negative side, access to the site during the wet season is poor and some fill is required.

Natural surface drainage of the area is generally poor and appears to be through shallow natural drainage-ways to the south and southeast during the wet season. During the dry season, the water table is normally several feet below land surface and drainage occurs chiefly by subsurface flow to areas of lower head to the east.

Fluctuations of the water table are the direct result of changes in storage in the aquifer. These changes in storage are chiefly attributed to infiltration of local rainfall, evapotranspiration, and drainage. Water-table contour maps prepared for eastern Palm Beach County for May 7-8, 1974 at the end of the 1974 dry season (fig. 4) and for October 9-10, 1974 at the end of the 1974 wet season (fig. 5) show that

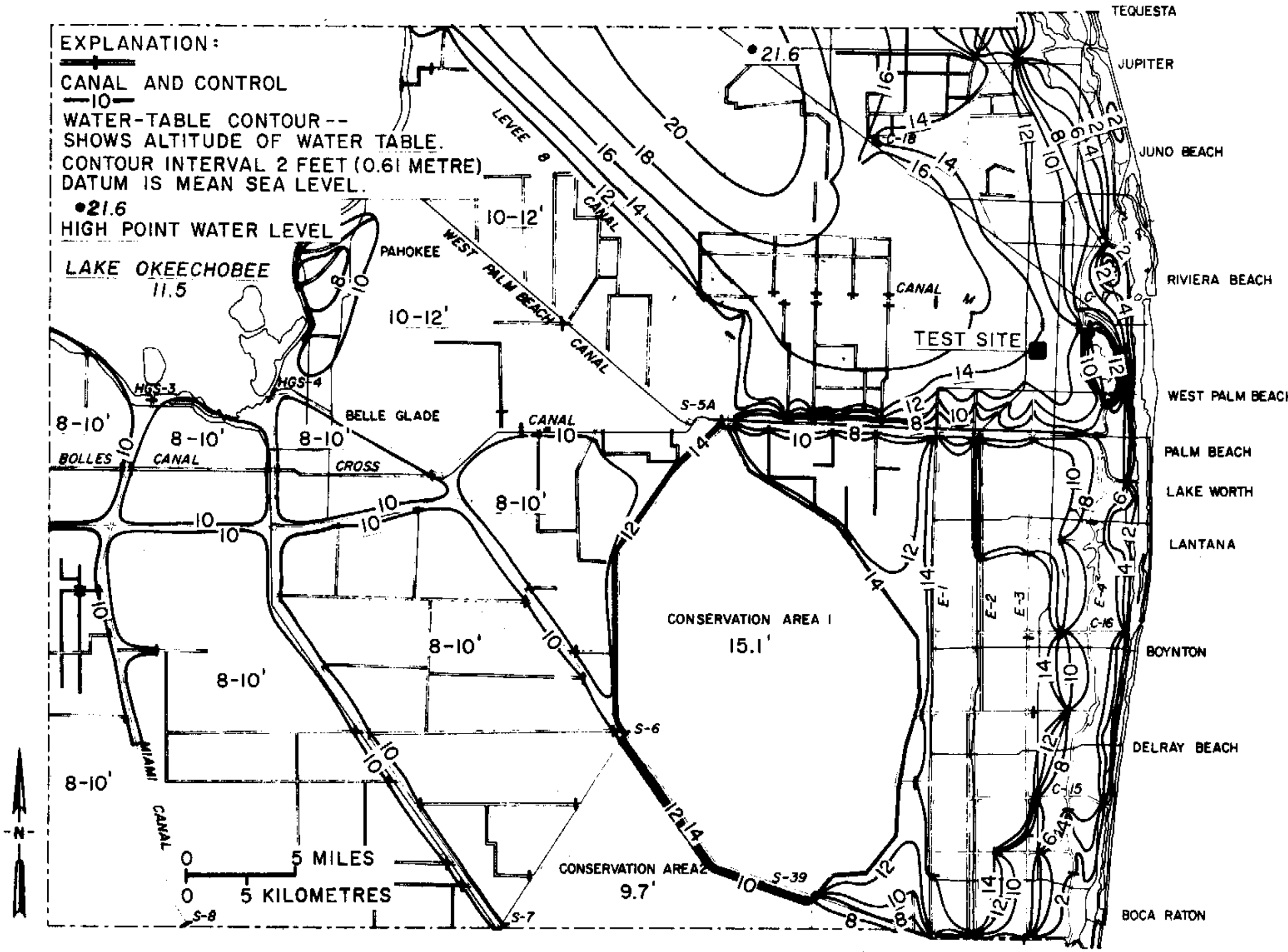

Figure 4.--Water-table contours in Palm Beach County on May 7, 8, 1974.

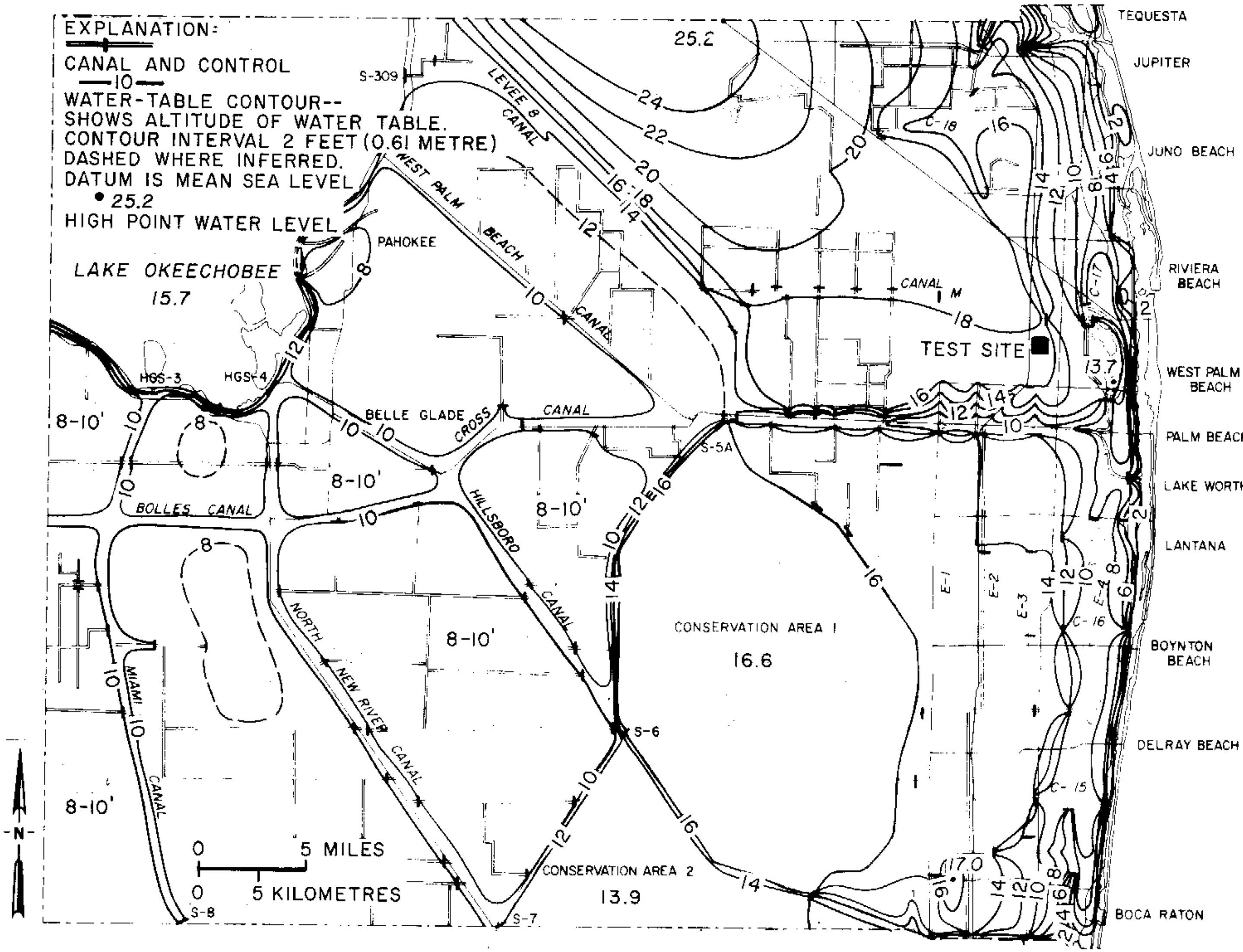

Figure 5.--Water-table contours in Palm Beach County on October 9-10, 1974.

the water table fluctuated more than 4 feet at the drilling site. The general direction of ground-water flow at the site is towards the east. The normal direction of flow, however, was altered in mid 1974 by artificially lowering and raising water levels north and west of the drilling site.

Drainage of the area was modified by construction of new drainage canals around the plant site (fig. 2). In October 1974 the drilling site was flooded due partly to spillover from a spur of the new canal located southwest of the drilling site. The spillover was caused by excessive water levels in the canal due to dewatering at the plant site. During the decline in water levels from November 1974 through February 1975, the newly constructed drainage canals and dewatering at the plant site caused a shift in the direction of ground-water flow at the drilling site toward the northwest. The new canals will probably cause a permanent change in the direction of ground-water flow at the site.

GROUND-WATER QUALITY

The ground-water-quality investigation has three principal areas of concern: 1) supply wells in the unconfined aquifer within 1 mile of the test well; 2) artesian wells within 3 miles of the drilling site; and 3) monitor wells in the unconfined aquifer at the drilling site itself. Parameters selected as indicators of contamination from salt-water spills while drilling were chloride and specific conductance. Additional parameters which might indicate contamination from failure of the injection system are the nitrogen and phosphorus species, total organic carbon, dissolved solids, and sulfate. Samples will be analyzed as the investigation progresses, and samples of the treated wastewater will be analyzed to determine the background concentration of potential contaminants.

Analyses of Water from Supply Wells Tapping the Unconfined Aquifer in the Vicinity of the Drilling Site

Although the drilling site is in a rural area, a few residential water supplies could be affected by inferior water originating from the site. As one step in defining possible effects, an inventory was made of privately-owned supply wells within 1 mile of the site.

The area west of the site is virtually uninhabited. East of the site, however, there are a few homes which depend on individual private wells (table 1, see figure 2 for locations). The wells range in depth from about 40 to 160 feet, in diameter from 1½ to 4 inches, and tap the unconfined aquifer. Eight of the 12 wells inventoried were sampled on July 12, 1974, and the water was analyzed for selected parameters (table 2).

The analyses show that the water is of good bacteriological quality although hard. Coliform bacteria were found in low numbers in three of the wells. Fecal coliform and fecal streptococci bacteria were absent in samples from all wells. Chloride concentration in the samples ranged from 12 to 54 mg/l (milligrams per litre). Specific conductance ranged from 465 to 640 micromhos/cm. Dissolved solids concentration ranged from 300 to 426 mg/l; sulfate concentration ranged from 1.1 to 13 mg/l; total nitrogen concentration ranged from 0.41 to 1.42 mg/l; total phosphorus, from 0.07 to 0.25 mg/l; and total organic carbon, from 7 to 12 mg/l.

Table 1.--Record of supply wells in the vicinity of the deep test well site.

Well Number	Depth (feet)	Casing Diameter (inches)	Owner	Address	Date Sampled
PB 755	86	1 1/2	Rosengrant	5140 Horseshoe Cir N.	7/12/74
PB 756	66	2	Higgins	5032 Horseshoe Cir S.	7/12/74
PB 757	80	2	Woodward	3169 Horseshoe Cir W.	7/12/74
PB 758	40	2	Jones	4080 N Haverhill Rd.	7/12/74
PB 759	< 100	2	Stewart	4208 N Military Trail	7/12/74
PB 760	57	2	Snow	4607 Appaloosa St.	7/12/74
PB 761	88	2	Herndon	4335 N Haverhill Rd.	7/12/74
PB 762	75	3	Galbraith	3472 N Haverhill Rd.	Not Sampled
PB 763	105	4	Galbraith	3472 N Haverhill Rd.	7/12/74
PB 764	157	2	Unknown	0.3 mi S of Roebuck Rd on N Military Tr	Not Sampled
PB 784	88	2	Parks	5066 Horseshoe Cir N.	Not Sampled
PB 785	< 100	2	Dosey	4200 N Military Trail	Not Sampled

< Denotes a value less than the indicated value.

Table 2.--Analyses of water from supply wells, in milligrams per litre, unless specified.

PARAMETER	WELL NUMBERS PB 755	PB 756**	PB 757	PB 758	PB 759	PB 760**	PB 761	PB 763
Alkalinity total (as $CaCO_3$)	233	259	236	205	225	299	201	236
Bicarbonate	284	316	288	250	274	364	245	288
Calcium, dissolved	96	12	100	84	97	2.5	80	100
Carbon dioxide	29	20	29	63	28	46	16	12
Carbonate	0	0	0	0	0	0	0	0
Chloride, dissolved	47	54	54	18	26	12	33	32
Color (Cobalt Platinum units)	20	30	30	200	90	40	50	60
Conductivity (micromhos/cm)	590	640	610	465	490	590	475	540
Depth (feet from surface)	86	66	80	40	<100	57	88	105
Fluoride, dissolved	0.3	0.4	0.3	0.2	0.3	0.3	0.5	0.3
Hardness, noncarbonate	30	0	37	24	30	0	15	34
Hardness, total	260	31	270	230	250	8	220	270
Magnesium, dissolved	5.3	0.3	5.3	4.5	2.8	0.5	3.8	4.7
pH	7.2	7.4	7.2	6.8	7.2	7.1	7.4	7.6
Potassium, dissolved	0.8	0.5	0.7	0.4	0.4	0.1	0.9	0.8
Solids, dissolved calculated sum	330	409	344	259	293	368	271	312
Solids, dissolved Ton/A - ft	0.45	0.58	0.51	0.41	0.43	0.55	0.41	0.45
Solids, dissolved 180 C	334	426	374	300	314	404	302	332
Sodium adsorption ratio	0.6	13	0.7	0.2	0.4	23	0.5	0.4
Silica, dissolved	14	14	13	9.1	12	9.8	12	14
Sodium, dissolved	24	170	26	8.2	16	150	18	16
Sodium, percent	17	92	17	7	12	97	15	11
Strontium, dissolved	1.40	0.03	1.40	0.77	0.77	0.03	0.57	1.30
Sulfate, dissolved	1.6	1.7	1.1	11	3.0	13	1.7	1.3
Turbidity (Jackson turbidity units)	3	6	2	2	7	2	4	4
Chemical oxygen demand	27	43	32	46	42	32	29	29
Nitrogen, total as N	1.22	0.41	1.22	0.87	0.85	0.47	1.02	1.42

Table 2.-- (Continued) Analyses of water from supply wells, in milligrams per litre, unless specified.

PARAMETER	WELL NUMBERS PB 755	PB 756**	PB 757	PB 758	PB 759	PB 760**	PB 761	PB 763
Nitrogen, organic as N	.39	.39	.33	.47	.46	.35	.26	.42
Nitrogen, total NH_3 as N	.83	.01	.89	.40	.39	.12	.76	1.00
Nitrite, total as N	.00	.00	.00	.00	.00	.00	.00	.00
Nitrate, total as N	.00	.01	.00	.00	.00	.00	.00	.00
Nitrogen, total Kjeldahl as N	1.22	.40	1.22	.87	.85	.47	1.02	1.42
NO_2, NO_3 as N total	.00	.01	.00	.00	.00	.00	.00	.00
Phosphorus, total as P	.09	.25	.07	.12	.22	.18	.16	.10
Carbon, total organic	7.00	10.0	9.00	12.0	12.0	7.00	10.0	7.00
Carbon, total inorganic	63.0	69.0	63.0	70.0	60.0	[illegible]	52.0	59.0
Carbon, total	70.0	79.0	72.0	82.0	72.0	92.0	62.0	66.0
Phosphorus, total orthophosphate	.06	.25	.06	.12	.19	.17	.13	.10
Total Coliform (col/100 ml)	<1	6	<1	<1	1	5	< 1	10***
Fecal Coliform (col/100 ml)	<1	<1	<1	< 1	<1	< 1	< 1	<1
Fecal Streptococci (col/100 ml)	<1	<1	1	< 1	< 1	< 1	< 1	<1

< Denotes a value less than the indicated value.

** Samples collected after water had passed through a softener

*** Plates not at optimum count.

Analyses of Water from Monitor Wells Tapping the Unconfined Aquifer at the Drilling Site

During March through July 1974, 16 2-inch diameter wells were drilled at the drilling site to supplement the data from the inventoried private wells and to monitor for salt-water contamination during construction of the deep test well. Data are presented in table 3 for these wells (fig. 6). Also included are data for a 12-inch supply well (PB 765) and the 12-inch brine-injection well (PB 783) which were completed as a part of the deep test well project. Data for the deep test monitor well (PB 782) and the two piezometer tubes (PB 860 and PB 861) will be presented in a subsequent report dealing with the results of drilling and testing.

The 2-inch shallow monitor wells range in depth from 10 to 162 feet. Wells greater than 40 feet deep are finished with about 2 feet of open hole; those less than 40 feet deep are finished with sand points. The wells are clustered in 5 sites, shown as sites 1-4 and 6 on figure 6. Each cluster consists of wells that are approximately 10, 40, and 80 feet deep, except at site 1, where an additional well (PB 733) is 162 feet deep. The water-supply well (PB-765) taps the aquifer between 79 and 119 feet. Water samples were collected for analyses from the 16 monitor wells on September 19 and 20, 1974, and from the water-supply well on July 15, 1974.

The analyses are presented in tables 4-6. Data for wells that are about 10 feet deep are presented in table 4; data for wells that are about 40 feet deep are presented in table 5; and data for wells that are about 80 feet deep or more are presented in table 6.

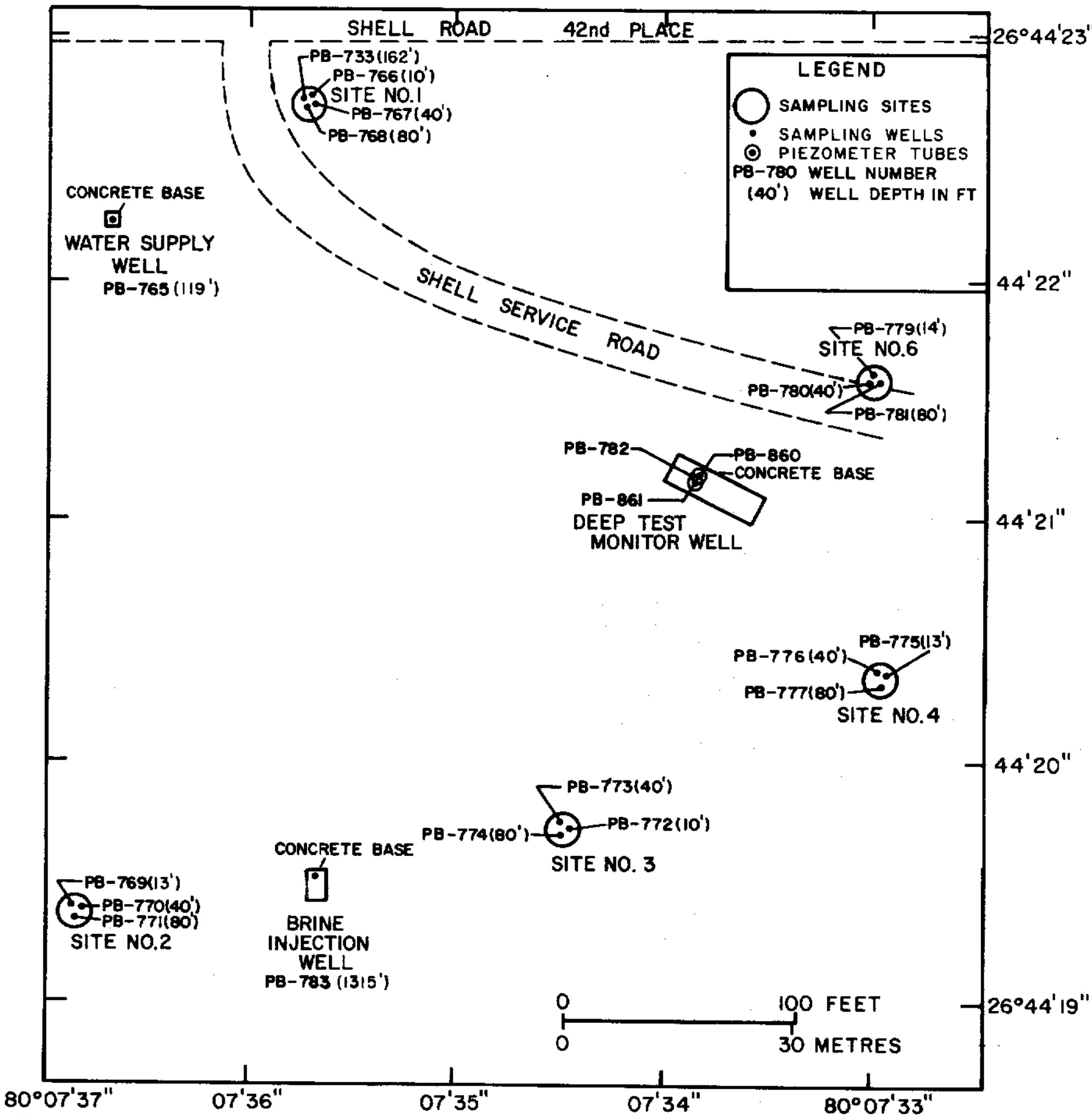

Figure 6.--Location of wells at the drilling site.

Table 3.--Record of monitor wells at the site of deep test well.

Well Number	Depth (feet)	Casing Diameter (inches)	Casing Depth (feet)	Finish	Owner	Date Sampled
* PB 765	119	12	79	10-inch Screen	WPB [a]	7/15/74
PB 766	10	2	9	2-inch Screen	USGS	9/20/74
PB 767	40	2	39	Open hole	Do.	9/20/74
PB 768	80	2	78	Open hole	Do.	9/20/74
PB 733	162	2	160	Open hole	Do.	9/20/74
PB 769	13	2	8	2-inch Screen	Do.	9/19/74
PB 770	40	2	38	Open hole	Do.	9/19/74
PB 771	80	2	78	Open hole	Do.	9/19/74
PB 772	10	2	9	2-inch Screen	Do.	9/19/74
PB 773	40	2	38	Open hole	Do.	9/19/74
PB 774	80	2	79	Open hole	Do.	9/19/74
PB 775	13	2	8	2-inch Screen	Do.	9/19/74
PB 776	40	2	38	Open hole	Do.	9/19/74
PB 777	80	2	79	Open hole	Do.	9/19/74
PB 779	14	2	9	2-inch Screen	Do.	9/19/74
PB 780	40	2	38	Open hole	Do.	9/19/74
PB 781	80	2	78	Open hole	Do.	9/19/74
** PB 783	1,315	12	1,020	Open hole	WPB	Not sampled

* Water supply well
** Brine-injection well
a City of West Palm Beach

Table 4.--Analyses of water from monitor wells about 10-feet deep. (All data in milligrams per litre except where noted.)

PARAMETER	PB-766	PB-769	PB-772	PB-775	PB-779
*Aluminum, dissolved	0	10	60	60	0
*Aluminum, suspended	190	470	840	210	390
*Aluminum, total	190	480	900	270	390
*Arsenic, dissolved	0	0	0	0	0
*Arsenic, suspended	1	0	1	1	1
*Arsenic, total	1	0	1	1	1
Bicarbonate	378	212	49	356	188
Calcium, dissolved	130	72	27	100	60
Carbonate	0	0	0	0	0
Chloride, dissolved	34	22	27	61	23
Color (Cobalt-platinum units)	30	10	30	20	20
Conductivity (Micromhos/cm)	730	490	295	710	390
*Copper, dissolved	0	3	2	2	1
*Copper, suspended	4	2	3	2	9
*Copper, total	4	5	5	4	10
Fluoride, dissolved	0.1	0.1	0.1	0.2	0.2
Hardness, noncarbonate	45	20	46	0	6
Hardness, total	360	190	86	270	160
*Iron, dissolved	5000	60	10	210	40
*Iron, total	6100	310	150	300	330
*Lead, dissolved	1	1	0	1	1
*Lead, suspended	1	5	1	0	3
*Lead, total	2	6	1	1	4
Magnesium, dissolved	7.1	3.1	4.5	4.5	2.3
*Manganese, dissolved	77	30	27	10	10
*Manganese, suspended	8	5	9	0	0
*Manganese, total	85	35	36	10	10
*Mercury, total	0.0	0.0	0.1	0.1	0.3
*Nickel, dissolved	3	8	2	5	5
*Nickel, suspended	6	2	1	1	3
*Nickel, total	9	10	3	6	8
pH	7.2	7.6	7.4	7.6	7.9
Potassium, dissolved	1.7	1.3	1.5	0.9	1.2
Solids, dissolved calculated sum	432	243	166	401	224
Solids, dissolved Ton/ A-ft	0.66	0.42	0.29	0.66	0.35
Solids, dissolved 180 C	482	312	216	484	254
Sodium adsorption ratio	0.3	0.4	0.8	0.8	0.6
Silica, dissolved	9.8	7.7	8.5	11	8.1
Sodium, dissolved	14	14	18	30	16
Sodium, percent	8	14	31	20	18
*Strontium, dissolved	1200	720	340	1300	740
Sulfate, dissolved	43	16	54	2.0	20
Water, temperature (Degrees Celcius)	30.1	26.5	29.2	26.7	26.9
*Zinc, dissolved	8	1900	360	14000	180
*Zinc, suspended	2	500	2200	0	1000
*Zinc, total	10	2400	2600	14000	1200
Turbidity (Jackson turbidity units)	57	38	22	10	32
Chemical oxygen demand	25	4	24	28	19
Nitrogen, total as N	1.54	.76	1.58	1.35	.95
Nitrogen, organic as N	.57	.46	.45	.53	.47
Nitrogen, total NH_3 as N	.97	.29	1.10	.82	.48
Nitrite, total as N	.00	.01	.03	.00	.00
Nitrate, total as N	.00	.00	.00	.00	.00
Nitrogen, total Kjeldahl as N	1.54	.75	1.55	1.35	.95
NO_2, NO_3 as N total	.00	.01	.03	.00	.00
Phosphorus, total as P	.00	.04	.04	.05	.05
Carbon, total organic	57.00	9.00	1.00	14.00	6.00
Carbon, total inorganic	79.00	46.00	15.00	72.00	36.00
Carbon, total	136.00	55.00	16.00	86.00	42.00
Phosphorus, total orthophosphate as P	.00	.01	.03	.03	.01
Carbon dioxide (CO_2)	38	8.5	3.1	142	3.8
Alkalinity (as $CaCO_3$)	310	174	40	292	154
Biochemical oxygen demand	0.1	0.5	0.3	1.9	1.1
Total Coliform (Colonies/100 ml)	<1	20**	<1	40**	<1
Fecal Coliform (Colonies/100 ml)	<1	<1	<1	<1	<1
Fecal Streptococci (Colonies/100 ml)	<1	<1	<1	<1	<1

*Micrograms per litre
**Plates not at optimum count.
< Denotes a value less than the indicated value.

Table 5.--Analyses of water from monitor wells about 40-feet deep. (All data in milligrams per litre except where noted.)

PARAMETER	PB-767	PB-770	PB-773	PB-776	PB-780
*Aluminum, dissolved	40	0	10	30	0
*Aluminum, suspended	0	4600	1200	180	240
*Aluminum, total	40	4600	1200	210	240
*Arsenic, dissolved	1	1	1	1	0
*Arsenic, suspended	0	4	2	0	1
*Arsenic, total	1	5	3	1	1
Bicarbonate	242	440	464	368	275
Calcium, dissolved	74	130	87	130	87
Carbonate	0	0	0	0	0
Chloride, dissolved	32	17	46	73	41
Color (Cobalt-platinum units)	20	7	30	20	20
Conductivity (Micromhos/cm)	485	710	595	840	565
*Copper, dissolved	1	1	1	1	1
*Copper, suspended	3	5	6	4	4
*Copper, total	4	6	7	5	5
Fluoride, dissolved	0.2	0.1	0.3	0.1	0.2
Hardness, noncarbonate	0	0	0	48	8
Hardness, total	200	340	230	350	230
*Iron, dissolved	510	60	390	830	550
*Iron, total	520	2800	6400	970	730
*Lead, dissolved	1	1	1	3	0
*Lead, suspended	0	4	8	0	0
*Lead, total	1	5	9	3	0
Magnesium, dissolved	3.0	4.5	3.3	5.7	3.8
*Manganese, dissolved	10	0	10	10	10
*Manganese, suspended	0	0	0	0	0
*Manganese, total	10	0	10	10	10
*Mercury, total	0.2	0.3	0.1	0.0	0.0
*Nickel, dissolved	6	10	3	5	9
*Nickel, suspended	5	4	0	0	0
*Nickel, total	11	14	3	2	9
pH	7.5	7.6	7.4	7.1	7.2
Potassium, dissolved	0.9	1.2	0.7	1.3	1.0
Solids, dissolved calculated sum	262	420	406	437	309
Solids, dissolved Ton/ A-ft	0.42	0.63	0.52	0.78	0.45
Solids, dissolved 180 C	306	466	382	572	334
Sodium adsorption ratio	0.6	0.6	0.8	0.7	0.7
Silica, dissolved	8.8	9.3	9.0	11	9.7
Sodium, dissolved	20	24	28	30	26
Sodium, percent	18	13	21	16	19
*Strontium, dissolved	840	1300	860	1200	900
Sulfate, dissolved	2.3	12	1.6	1.8	2.8
Water, temperature (Degrees Celcius)	27.1	26.8	26.5	26.0	25.5
*Zinc, dissolved	360	3800	540	960	370
*Zinc, suspended	10	2500	660	340	0
*Zinc, total	370	6300	1200	1300	370
Turbidity (Jackson turbidity units)	5	42	320	23	7
Chemical oxygen demand	18	31	30	28	32
Nitrogen, total as N	.84	.66	1.06	1.25	.94
Nitrogen, organic as N	.33	.39	.52	.48	.31
Nitrogen, total NH3 as N	.51	.26	.53	.77	.63
Nitrite, total as N	.00	.01	.01	.00	.00
Nitrate, total as N	.00	.00	.00	.00	.00
Nitrogen, total Kjeldahl as N	.84	.65	1.05	1.25	.94
NO2, NO3 as N total	.00	.01	.01	.00	.00
Phosphorus, total as P	.09	.02	.05	.23	.11
Carbon, total organic	6.00	44.00	5.00	50.00	11.00
Carbon, total inorganic	53.00	92.00	92.00	90.00	60.00
Carbon, total	59.00	136.00	97.00	140.00	71.00
Phosphorus, total orthophosphate as P	.09	.02	.04	.09	.10
Carbon dioxide (CO2)	12	18	30	42	28
Alkalinity (as CaCO3)	199	361	381	302	226
Biochemical oxygen demand	0.1	0.7	0.9	0.6	0.2
Total Coliform (Colonies/100 ml)	< 1	< 1	< 1	4**	< 1
Fecal Coliform (Colonies/100 ml)	< 1	< 1	< 1	< 1	< 1
Fecal Streptococci (Colonies/100 ml)	< 1	< 1	< 1	< 1	< 1

*Micrograms per litre
**Plates not at optimum count.
< Denotes a value less then the indicated value.

Table 6.--Analyses of water from monitor wells ranging from 80 to 160 feet in depth. (All data in milligrams per litre except where noted.)

PARAMETER	PB-765	PB-768	PB-733	PB-771	PB-744	PB-777	PB-781
*Aluminum, dissolved	-	10	30	10	10	10	0
*Aluminum, suspended	-	30	60	90	260	180	1600
*Aluminum, total	-	40	90	100	270	190	1600
*Arsenic, dissolved	-	0	1	0	0	1	1
*Arsenic, suspended	-	0	0	1	1	0	0
*Arsenic, total	-	0	1	1	1	1	1
Bicarbonate	340	274	407	376	344	380	584
Calcium, dissolved	-	84	120	110	110	100	100
Carbonate	0	0	0	0	0	0	0
Chloride, dissolved	49	41	50	55	54	58	43
Color (Cobalt-platinum units)	20	30	30	20	30	40	20
Conductivity (Micromhos/cm)	659	560	785	700	670	685	630
*Copper, dissolved	-	1	1	2	1	1	2
*Copper, suspended	-	4	14	3	4	2	5
*Copper, total	-	5	15	5	5	3	7
Fluoride, dissolved	0.3	0.2	0.2	0.4	0.2	0.3	0.3
Hardness, noncarbonate	-	0	0	0	12	0	0
Hardness, total	-	220	330	290	290	270	270
*Iron, dissolved	-	710	2400	650	820	90	310
*Iron, total	-	730	2800	940	1300	290	1800
*Lead, dissolved	-	6	1	1	1	1	1
*Lead, suspended	-	0	1	5	4	0	0
*Lead, total	-	6	2	6	5	1	1
Magnesium, dissolved	-	3.2	5.9	3.9	4.3	4.1	3.8
*Manganese, dissolved	-	10	10	10	16	10	10
*Manganese, suspended	-	0	2	0	4	0	39
*Manganese, total	-	10	12	10	20	10	49
*Mercury, total	-	0.3	0.0	1.1	0.0	0.0	0.2
*Nickel, dissolved	-	17	2	11	5	6	8
*Nickel, suspended	-	0	0	0	0	3	2
*Nickel, total	-	17	2	11	5	9	10
pH	7.6	7.4	7.3	7.3	7.4	7.4	7.4
Potassium, dissolved	-	0.8	0.9	1.1	0.9	0.9	0.9
Solids, dissolved calculated sum	-	303	437	406	385	399	480
Solids, dissolved Ton/ A-ft.	0.58	0.44	0.66	0.58	0.57	0.61	0.56
Solids, dissolved 180 C	428	324	488	426	416	448	414
Sodium adsorption ratio	-	0.7	0.8	0.8	0.8	0.8	0.7
Silica, dissolved	12	9.6	18	12	11	12	11
Sodium, dissolved	-	25	35	30	30	30	26
Sodium, percent	-	20	19	18	18	20	18
*Strontium, dissolved	-	1000	1400	1600	1200	1300	1500
Sulfate, dissolved	0.0	2.2	2.3	2.3	2.0	2.1	3.0
Water, temperature (Degrees Celcius)	-	25.6	23.4	26.5	26.4	25.6	26.0
*Zinc, dissolved	-	330	20	3400	1100	3300	2000
*Zinc, suspended	-	0	0	0	0	100	200
*Zinc, total	-	330	20	3400	1100	3400	2200
Turbidity (Jackson turbidity units)	-	8	130	40	26	96	220
Chemical oxygen demand	-	20	29	32	27	28	22
Nitrogen, total as N	-	81	1.24	1.35	1.55	1.35	1.14
Nitrogen, organic as N	-	23	.50	.44	.65	.51	.35
Nitrogen, total NH_3 as N	-	.58	.74	.91	.90	.84	.79
Nitrite, total as N	-	.00	.00	.00	.00	.00	.00
Nitrate, total as N	-	.00	.00	.00	.00	.00	.00
Nitrogen, total Kjeldahl as N	-	.81	1.24	1.35	1.55	1.35	1.14
NO_2, NO_3 as N total	-	.00	.00	.00	.00	.00	.00
Phosphorus, total as P	-	.03	.00	.18	.08	.25	.12
Carbon, total organic	-	11.00	50.00	38.00	12.00	41.00	44.00
Carbon, total inorganic	-	58.00	100.00	80.00	73.00	77.00	98.00
Carbon, total	-	69.00	150.00	118.00	85.00	118.00	142.00
Phosphorus, total orthophosphate as P	-	.02	.00	.06	.06	.09	.03
Carbon dioxide (CO_2)	14	16	37	30	22	24	37
Alkalinity (as $CaCO_3$)	279	225	334	40	282	312	479
Biochemical oxygen demand	-	0.0	0.4	0.3	0.5	0.0	0.8
Total Coliform (Colonies/100 ml)	<1	10**	<1	<1	18**	<1	<1
Fecal Coliform (Colonies/100 ml)	<1	<1	<1	<1	<1	<1	<1
Fecal Streptococci (Colonies/100 ml)	<1	<1	<1	<1	<1	<1	<1

**Plates not at optimum count.
< Denotes a value less than the indicated value
*Micrograms per litre

Chloride concentration of samples from the 10-foot deep wells (table 4) ranged from 22 to 61 mg/l; specific conductance ranged from 295 to 730 micromhos/cm; dissolved solids concentration (calculated) ranged from 166 to 432 mg/l; sulfate concentration ranged from 2 to 54 mg/l; total nitrogen concentration ranged from 0.76 to 1.58 mg/l; total phosphorus concentration ranged from 0.00 to 0.05 mg/l; and total organic carbon concentration ranged from 1 to 57 mg/l. There was only a trace of bacterial contamination.

Samples from the 40-foot deep wells (table 5) also showed only a trace of bacterial contamination. Chloride concentration ranged from 17 to 73 mg/l; specific conductance ranged from 485 to 840 micromhos/cm; dissolved solids concentration (calculated) ranged from 262 to 437 mg/l; sulfate concentration ranged from 1.6 to 12 mg/l; total nitrogen concentration ranged from 0.66 to 1.25 mg/l; total phosphorus concentration ranged from 0.02 to 0.23 mg/l; and total organic carbon concentration ranged from 5 to 50 mg/l.

Chloride concentration of samples from wells ranging in depth from 80 to 160 feet (table 6) ranged from 41 to 58 mg/l; specific conductance ranged from 560 to 785 micromhos/cm; sulfate concentration ranged from 0.0 to 3.0 mg/l; total nitrogen concentration ranged from 0.81 to 1.55 mg/l; total phosphorus concentration ranged from 0.00 to 0.25 mg/l; and total organic carbon concentration ranged from 11 to 50 mg/l. Again, bacterial contamination was very slight.

Analyses of Water from Artesian Wells in the Vicinity of the Drilling Site

A reconnaissance within 3 miles of the site showed that there were no wells tapping the artesian Floridan aquifer (wells greater than 900 feet in depth). Figure 7 shows the locations of artesian wells in Palm Beach County for which data are available (table 7). The wells range in depth from 958 to 2,242 feet. The chloride concentration in the artesian water ranged from 1,600 to 2,400 mg/1.

In July 1974, prior to construction of deep test well PB-782, brine-injection well PB 783 was drilled at the site to dispose of the salt water generated during the drilling of the deep test well. The brine-injection well was cased with 12-inch casing to 1,020 feet below land surface and was completed with open hole in limestone to 1,315 feet. This well could be used to monitor for future changes in water quality in the upper part of the Floridan aquifer provided that the injected salt water is removed and original water quality is restored in the well.

On October 22, 1974, during construction of the deep test well, a sample of water was obtained from a depth of 1,080 feet. The sample is considered to be representative of the native water at that depth. The analysis (table 8) indicates the following: chloride concentration, 2,700 mg/1; specific conductance, 8,160 micromhos/cm; dissolved solids (calculated) 5,180 mg/1; sulfate, 490 mg/1; total nitrogen, 1.71 mg/1; total phosphorus, 0.04 mg/1; and total organic carbon, 1.00 mg/1.

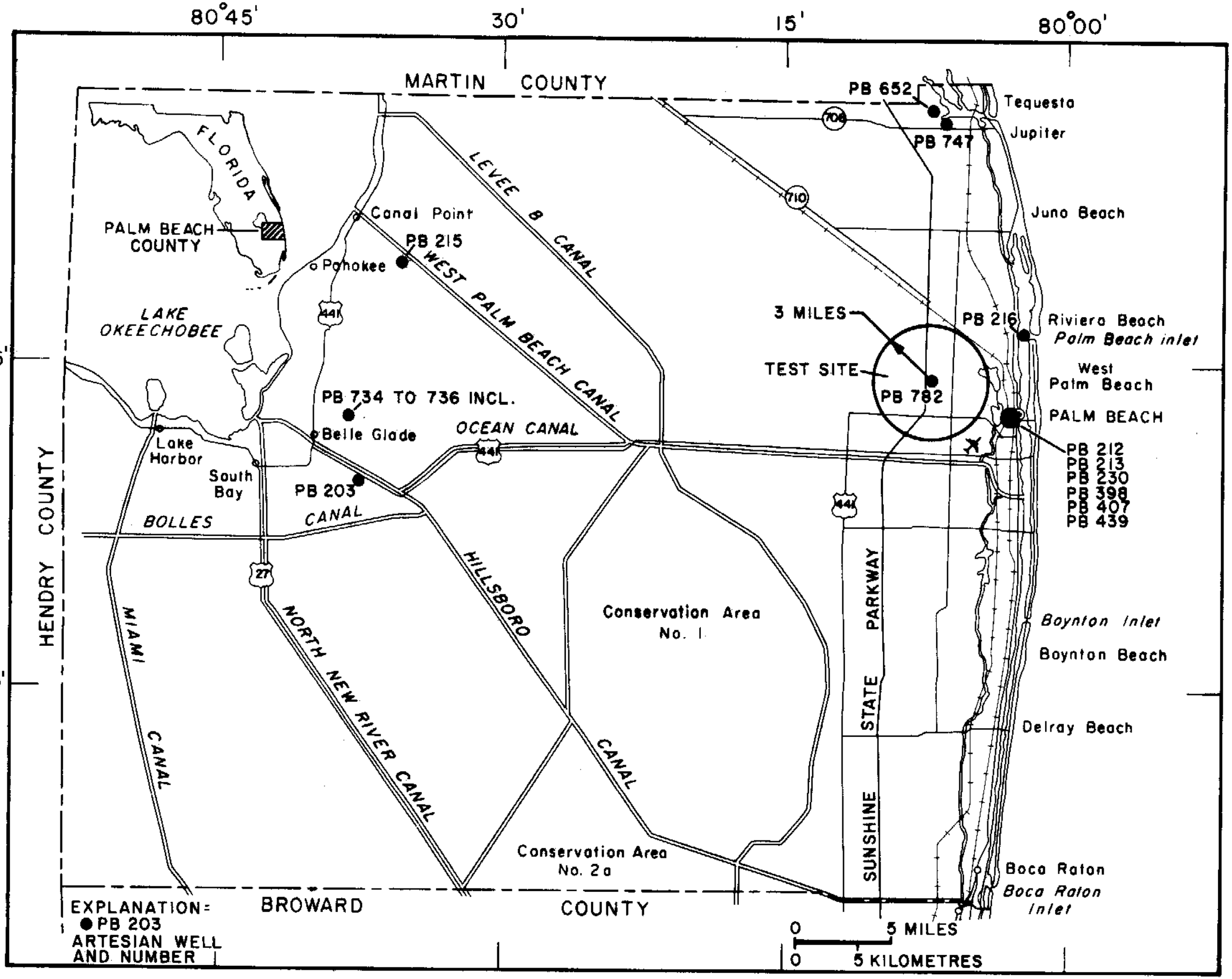

Figure 7.--Location of artesian wells in Palm Beach County.

Table 7.--Record of artesian wells in Palm Beach County, Floridan aquifer.

Well Number	Location Sec. T. R.	Depth Feet	Cased Feet	Diameter (inches)	Chloride mg/1	Owner
PB 203	Near Belle Glade	1,332	957	8	1,620	Belle Glade Exp. Station
PB 212	At West Palm Beach	1,080	1,080	12	2,400	Fla. Power & Light
PB 213	Do	1,050	--	12	2,350	Do.
PB 215	Near Canal Point	958	850	6		U.S. Sugar Corp.
PB 216	At Riviera Beach	1,000	--	6	1,600	U.S. Coast Guard
PB 230	At West Palm Beach	1,050	--	12		Fla. Power & Light
PB 398	Do	1,100	--	12		City Ice & Fuel
PB 407	Do	1,035	--	12	2,110	Royal Palm Ice
PB 439	Do	1,150	--	12		City Ice & Fuel
PB 734	Near Belle Glade	1,400	648	6		Quaker Oats Co.
PB 735	Do	2,067	1,490	12		Do.
PB 736	Do	2,242	1,938	8	2,200	Do.
PB 652	Near Jupiter	1,385	600	12		R.Wilson of Hobe Sound
PB 747	Do	1,210	990	12	1,850	Fla. Dept. Nat. Resources

Table 8.--Analysis of artesian water from the deep-test well (PB 782) at 1,080 feet, in milligrams per litre unless specified.

PARAMETER	VALUE
* Arsenic, total	0
Bicarbonate	200
* Cadmium, total	1
Calcium, dissolved	140
Chloride, dissolved	2700
* Chromium, hexavalent	0
* Chromium, total	10
Color (Cobalt-platinum units)	8
Conductivity (micromhos/cm)	8160
* Copper, total	23
Depth (feet from surface)	1080
Fluoride, dissolved	1.1
Hardness, noncarbonate	890
Hardness, total	1100
* Lead, total	8
Magnesium, dissolved	170
pH	8.7
Potassium, dissolved	55
Solids, dissolved calculated sum	5180
Solids, dissolved Ton/ A-ft	7.30
Solids, dissolved 180 C	5370
Solids, suspended 110 C	115
Sodium adsorption ratio	20
Silica, dissolved	21
Sodium, dissolved	1500
Sodium, percent	74
Sulfate, dissolved	490
Water Temperature (Degrees Celsius)	23.8
* Zinc, total	20
Turbidity (Jackson turbidity units)	92
Chemical oxygen demand	77
Nitrogen, total as N	1.71
Nitrogen organic as N	.00
Nitrogen, total NH_3 as N	1.70
Nitrite, total as N	.00
Nitrate, total as N	.01
Nitrogen, Total Kjeldahl as N	1.70
NO_2, NO_3 as N total	.01
Phosphorus, total as P	.04
Carbon, total organic	1.00
Carbon, total inorganic	27.0
Carbon, total	28.0
Phosphorus total orthophosphate as P	.00
Specific Gravity	1.00
Total Coliform (Colonies/100 ml)	<1
Fecal Coliform (Colonies/100 ml)	<1

* Micrograms per litre

< Denotes a value less than the indicated value.

RESULTS OF ON-SITE MONITORING OF WATER QUALITY DURING DRILLING

An important aspect of the investigation was the periodic collection and analysis of water samples from the 16 monitor wells to detect contamination of the unconfined aquifer from spills during the test drilling.

Drilling of the water-supply well (PB 765) and the brine-injection well (PB 783) began on July 1, 1974 (see locations on figure 6). The water-supply well was completed on August 9, 1974 and by August 22, the brine-injection well had been drilled to a depth of 1,008 feet. At that depth the well had penetrated the principal artesian zone of the Floridan aquifer and measures were taken to prevent contamination of the nonartesian aquifer by the saline artesian water. Between August 27 and September 3, no salt-water spills occurred and casings were installed and cemented in the well. The brine-injection well was completed on September 6 at which time some artesian water was spilled while the well was being capped and fitted with a valve.

Drilling of the deep test well (PB 782) began on July 17, 1974. The well was drilled to 1,010 feet (the principal artesian zone) by October 7. Measures were taken to prevent salt-water spills, but small spills were observed during the drilling (mainly each time the drill stem was withdrawn and when the separator tanks overflowed).

Beginning on August 29, 1974 samples were collected weekly from the nonartesian monitor wells for measurements of chloride concentration and specific conductance. These data were reported routinely to the City officials, their consultants, and to the local, State, and Federal regulatory agencies.

Sampling during August 29 through December 2 showed no significant change in chloride. However, on December 11, 1974, the chloride concentration in well PB 775, the 13-foot deep monitor at site 4, was 206 mg/l, which was an increase of 172 mg/l above the previous value.

The observed chloride concentration in PB 775 peaked at 510 mg/l on December 12, 1974 and declined to 76 mg/l on January 6, 1975. But by February 5, 1975 the chloride concentration again increased to 1,000 mg/l, and slight increases were measured in well PB 776, the 40-foot deep well at site 4, and in well PB 772, the 10-foot deep well at site 3. These data suggest that the salt water spilled at the deep test well was moving both laterally and downward.

By February 10, the chloride concentration in well PB 775 increased to 1,250 mg/l while concentrations in wells at sites 3 and 6 increased slightly. Figure 8 shows the approximate size of the area affected by the salt-water spills on February 10, 1975. Efforts by the driller to remove the salt water commenced on February 19, 1975 at the request of the city's consultants; and the affected monitor wells (PB 775, PB 776, and PB 772) were pumped intermittently and discharged to the brine injection well. By the end of February some reduction of chloride level had been observed. Because the extent of contamination is small, continued pumping of the shallow wells should result in continued lowering of chloride concentrations at the site.

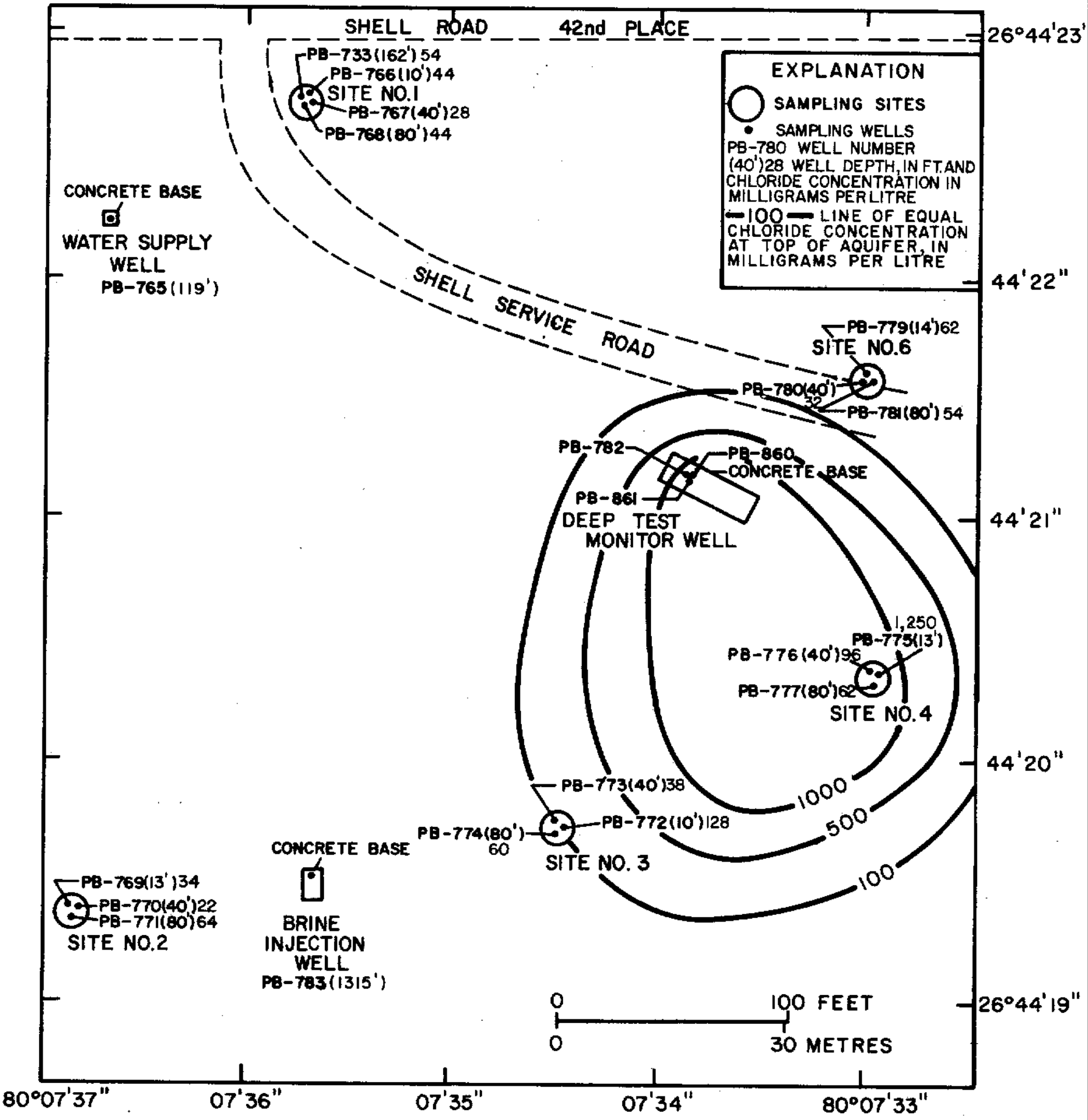

Figure 8.--Areal extent of the salt-water spill on February 10, 1975.

SUMMARY

In 1974 the U.S. Geological Survey, as part of its statewide cooperative program of water resources investigations, entered into an agreement with the city of West Palm Beach that included collection of scientific and technical information before, during, and after construction of a deep test well at the location of a future regional wastewater treatment plant. Data from the test well will be used by the city to design a deep-well injection system for disposal of plant effluent if results of the test program are favorable. As a part of that agreement, wells in the vicinity of the drilling site were located and sampled to provide a data base for detecting changes in water quality during construction and operation of the deep wells.

A reconnaissance of the surrounding area indicated that a few domestic wells were located within 1 mile of the drilling site. Water samples were collected and analyzed from 8 of the 12 wells inventoried. In addition, 16 small diameter monitor wells were drilled ranging in depth from 10 to 162 feet at the drilling site. Water samples from these wells were also analyzed. No artesian wells are within 3 miles of the drilling site. In order to provide background data on water quality in the artesian aquifer, a water sample from a depth of 1,080 feet was collected and analyzed during the drilling of the deep test well.

An important part of the investigation was monitoring for possible effects of drilling activities on water quality at the site. During the drilling of the deep test well, samples were collected weekly from the

16 monitor wells for measurement of chloride concentration and specific conductance. Evidence of small spills of saltwater were found in monitor wells ranging from about 10 to 40 feet in depth near the deep test well. Efforts to reduce the spills and to remove the salt water by pumping from the unconfined aquifer were begun by the drilling contractor at the request of the city of West Palm Beach. The affected area is small and there has been a continued reduction of chloride concentration at the site.

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