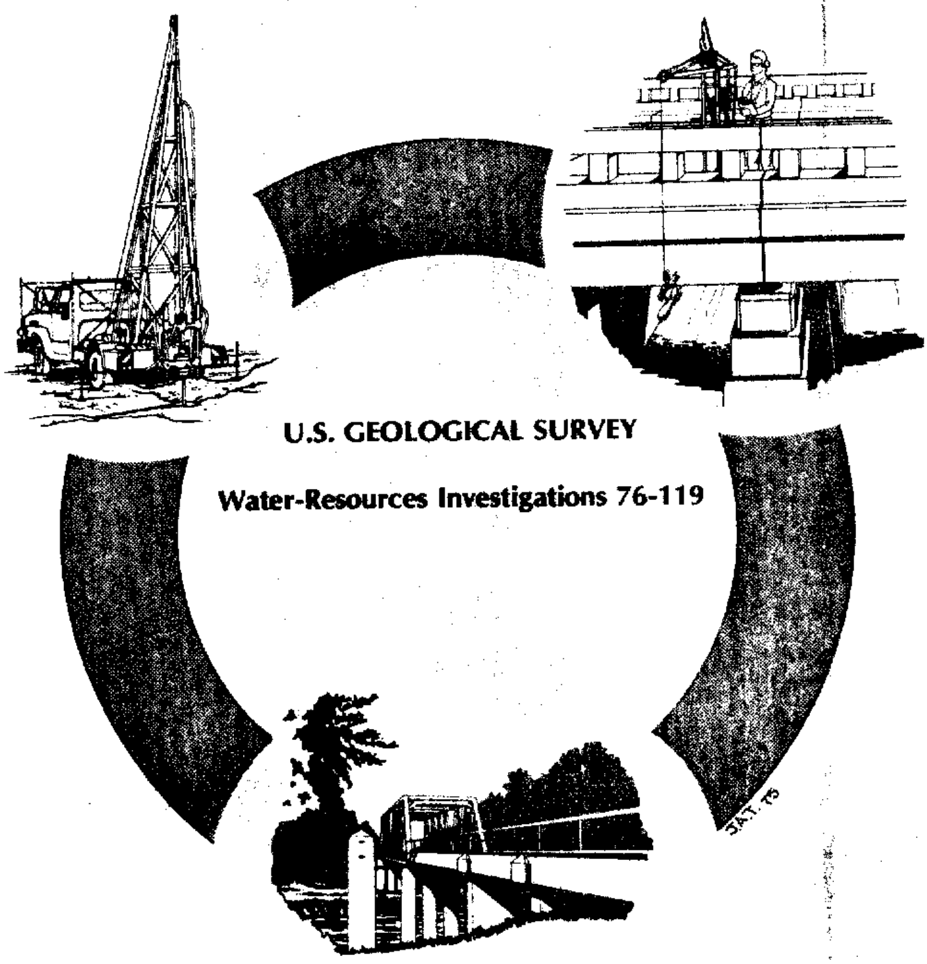
HYDRAULIC CONDUCTIVITY AND WATER QUALITY OF THE SHALLOW AQUIFER PALM BEACH COUNTY, FLORIDA



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-119

Prepared in cooperation with
PALM BEACH COUNTY BOARD OF COMMISSIONERS
and
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

WRI 76-119 HYDRAULIC CONDUCTIVITY AND WATER QUALITY OF THE SHALLOW AQUIFER, PALM BEACH COUNTY, FLORIDA

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Water samples were collected from different depths throughout the county and analyzed for chemical constituents. Stiff diagrams are used in this report to illustrate the changes in types of water by depth and area. Chemical analyses indicate that water of suitable quality is in the eastern parts of the county. In this area the aquifer is the thickest and most permeable. The concentration of chemical constituents in the water increase in a westerly direction. The water in the western parts of the county is unsuitable for most purposes.

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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
Water Resources Division
325 John Knox Rd., Suite F-240
Tallahassee, Florida 32303

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FACTORS FOR CONVERTING ENGLISH UNITS TO METRIC UNITS

Multiply English unit	By	To obtain metric unit
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
gallons per minute (gal/min)	.06309	liters per second (L/s)

HYDRAULIC CONDUCTIVITY AND WATER QUALITY OF THE SHALLOW AQUIFER, PALM BEACH COUNTY, FLORIDA

By

W. B. Scott

ABSTRACT

The identification of discrete water-bearing zones in the shallow aquifer of Palm Beach County solely by well cuttings is difficult because of the similarity of material in water-bearing and non-water bearing zones. Frequently, water-bearing zones are penetrated without being recognized at the time of drilling. There is no way of determining by examining the drill cuttings whether one or more than one water-bearing zone is present; and, if more than one is present, whether the chemical quality of the water in each is different or the same. Accurate identification of water-bearing zones, however, can be made by correlating the data from lithologic and geophysical logs. The use of a single lithologic or geophysical log may be misleading because of the similarity of materials in water-bearing and nonwater-bearing zones, or in adjacent water-bearing zones. Also, the mineralization of formation water may affect the interpretation of the electrical geophysical logs. Water quality can be determined from chemical analyses of water sampled from wells penetrating the zones.

Subsurface geophysical and lithologic logs were correlated with aquifer tests and laboratory test data to estimate the hydraulic conductivity of selected zones of the shallow aquifer. These zones are, in order of decreasing hydraulic conductivity, Z-1, Z-2, and Z-3. The hydraulic conductivity of the shallow aquifer is estimated to range from 1 to 130 feet per day (0.3 to 40 meters per day), based on lithology and physical properties. The yield of wells penetrating this aquifer ranges from 100 to more than 1,000 gallons per minute (6 to 60 liters per second).

Zone Z-4 represents the upper part of the numerous confining layers which separate the underlying Floridan artesian aquifer from the nonartesian shallow aquifer. Its hydraulic conductivity generally is less than 1 ft/day (0.3 meter per day). The yield of wells penetrating this zone is less than 100 gal/min (6 liters per second).

Water samples were collected from different depths throughout the county and analyzed for chemical constituents. Stiff diagrams are used in this report to illustrate the changes in types of water by depth and area. They indicate visually that the concentration of mineral constituents tends to increase with depth in a westerly direction, making the water unsuitable for most purposes in the western part of the county.

Most of the water of suitable quality is in the eastern parts of the county. In this area the aquifer is thicker than elsewhere and more permeable.

INTRODUCTION

The shallow aquifer is the chief source of potable water in the east half of Palm Beach County. It is the source of water for all the municipal systems along the coast (except for West Palm Beach which uses lake water), as well as for most, if not all, the residential supplies in areas not served by public systems. Also, the shallow aquifer yields water to hundreds of irrigation wells. As the urban water demands increase, municipal water systems, particularly those whose wells are near the coast and are being threatened by salt-water intrusion, must seek additional sources of fresh water from inland areas. Because of the general inadequacy of hydrogeologic information concerning the shallow aquifer inland from the coast, the U.S. Geological Survey, in cooperation with the Board of Palm Beach County Commissioners and the South Florida Water Management District, investigated the ground-water conditions of the interior parts of the county. The data obtained are needed for managing and protecting the ground-water resource.

Scope and Method of Investigation

The investigation included a compilation of existing data on well depth, yield and water quality, an inventory of selected wells in the coastal area as well as in the interior, exploratory test drilling, borehole geophysical logging, and analyses of the chemical constituents of selected producing and exploratory wells.

Exploratory test drilling was by hydraulic rotary method. The test holes fully penetrated the shallow aquifer. Samples of rock cuttings were taken at 10-ft (3-m) intervals and at each change in lithology. The cuttings were examined and a lithologic log was prepared for each well drilled.

At the completion of each test hole, selected borehole geophysical logs were run. These included the spontaneous potential (SP), single-point resistance, and natural gamma logs (Patten and Bennett, 1963; Keys and MacCary, 1971). Borehole geophysical data can be used to interpret differences in density and permeability of subsurface materials, and the fluid content in these materials.

Correlations of borehole geophysical and lithologic data, and chemical constituents of water made possible the delineation of subsurface zones of similar permeability and water-quality characteristics.

Acknowledgments

Many residents, land owners and public and private agencies in Palm Beach County aided the investigation by permitting the collection of water samples from their wells, and by furnishing information on well depths, well yield, hydrology and geology.

PHYSIOGRAPHIC REGIONS

Palm Beach County lies within the Coastal Plain Province (Fenneman 1938, p. 43). The county comprises three physiographic subdivisions: (1) Atlantic Coastal Ridge, (2) Sandy Flatlands, and (3) Everglades. Each region is characterized by a range in land elevation and distinct soil types or vegetation cover. Each plays an important role in governing the county's ground-water hydrology and chemistry. The three subdivisions are shown in figure 1.

Atlantic Coastal Ridge

The Atlantic Coastal Ridge extends inland 2 to 3 mi (3 to 5 km) from the ocean, and ranges in altitude from 25 to 40 ft (8 to 12 m). In places it is as much as 30 ft (9 m) above the Sandy Flatlands. The coastal ridge is blanketed by relatively permeable fine-to medium-grained sand, which permits rapid infirltration of rainfall. Because of the good subsurface drainage, the relatively high altitudes and the system of canals which extend to the ocean, the coastal ridge is seldom flooded. Most of the urbanization is along the coastal ridge.

Sandy Flatlands

The Sandy Flatlands occupies all the area from the coastal ridge west to the Everglades. The eastern part lacks a well-defined soil zone and is characterized by surficial quartz sand. The western part has a mixture of sand and organic matter. The Sandy Flatlands ranges in altitude from 10 to 18 ft (3 to 6 m) in the south part of the county to about 25 ft (7.6 m) in the north part of the county.

Drainage throughout the Sandy Flatlands is chiefly underground. Both surface and subsurface drainage are very sluggish owing to the low gradients. Ponds are formed throughout much of the region during the rainy season. Drainage is improved in the eastern part of the flatlands by canals of the Central and Southern Florida Flood Control District and by canals of the Lake Worth Drainage District, south of the West Palm Beach Canal.

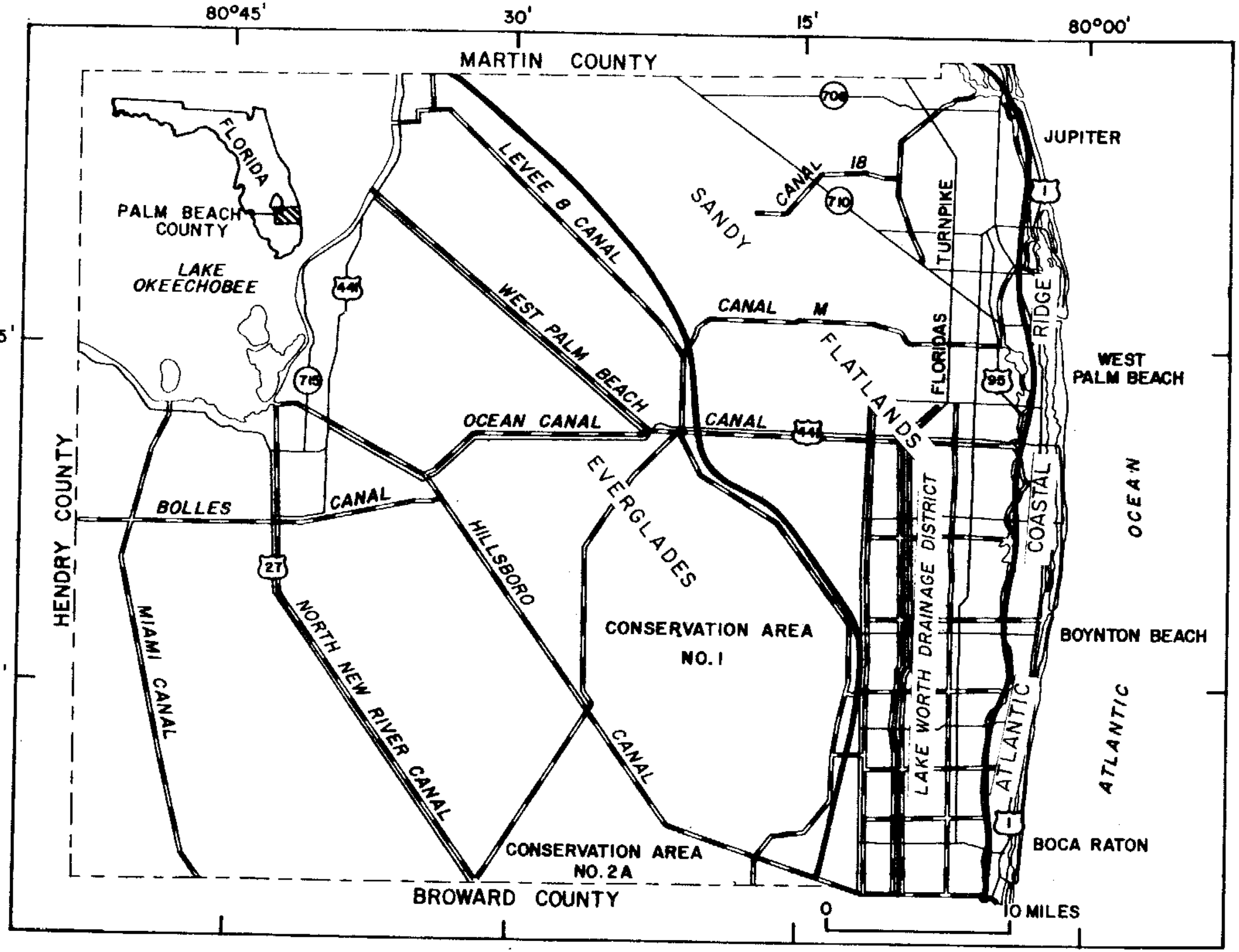

Figure 1.--Physiographic subdivisions of Palm Beach County.

Everglades

The Everglades is a flat region covered by organic soils. The Everglades, which occupies the west and southwest two-thirds of the county, ranges in altitude from 16 ft (5 m) in the north to 14 ft (4 m) in the south. The boundary between the Everglades and the Sandy Flatlands is poorly defined because of intermixing of the organic soils of the Everglades and the quartz sands of the Sandy Flatlands.

Water levels are controlled in the agricultural areas of the Everglades by drainage canals, levees, and large pumping stations. In the conservation areas which hold excess water for later release, subsurface drainage is very sluggish owing to the low gradients. Surface drainage is controlled mainly by controls on canals and pumping.

ESTIMATED HYDRAULIC CONDUCTIVITY

Hydraulic conductivity is a measure of the ease of movement of ground water through aquifers and confining beds. It is largely a function of the size, shape, and degree of sorting of the component grains. Sediments composed of large, well sorted particles have large connected pore spaces, thus creating a high hydraulic conductivity. Sediments composed of fine-grained materials such as clay, silt or marl have extremely small pore spaces, thus creating low hydraulic conductivity. Poorly sorted sediments generally are of lower hydraulic conductivity than well sorted sediments because the fine-grained material fills the spaces between the larger particles. Deposits such as limestone, whose pore spaces have been enlarged by dissolution of soluble minerals generally have high hydraulic conductivity.

Estimates of hydraulic conductivity in this report are based on lithology and physical properties as determined from drill cuttings and selected geophysical logs. Table 1 shows the estimated hydraulic conductivity and well yield of the shallow deposits in Palm Beach County at different depths.

Data define the limits of hydraulic conductivity shown in table 1 as follows: (1) upper limit (high) determined from aquifer tests run in the county, (2) lower limit (low) determined from report by Klein and Sherwood (1961), (3) intermediate limits (moderate to high) determined from lithology verses laboratory results in W.S.P. 887 (Wenzel, 1942).

METHOD OF CONSTRUCTING HYDRAULIC CONDUCTIVITY PROFILES

Differences in hydraulic conductivity were determined using information from geophysical logs (SP, resistance, and natural gamma) and lithologic logs obtained from test drilling in Palm Beach County. Geophysical logs served mainly as a basis for determining bed boundaries,

Table 1.--Generalized log and estimated hydraulic conductivity and yield of wells penetrating the shallow deposits and the upper part of confining zone in Palm Beach County.

Estimated Hydraulic Conductivity, ft/d	Description of Materials	Estimated Well Yield, gal/min
Z-1 High 60-130 (20-40 m/d)	Well sorted gravel, beds of large shells and low sand content, coarse coquina, calcareous sandstone or limestone with solution cavities.	More than 1000 (60 l/s)
Z-2 Moderate to high 10-60 (3-20 m/d)	Sand and gravel, well sorted coarse sand, sandy shell beds or sandy coquina, solutionalized calcareous sandstone or limestone with openings filled with sand.	500-1000 (30-60 l/s)
Z-3 Moderate 1-10 (0.3-3 m/d)	Medium grained well sorted sand, sand and shell, porous limestone and calcareous sandstone.	100-500 (6-30 l/s)
	- - - - Top of confining zone - - - -	
Z-4 Low Less than 1 (0.3 m/d)	Fine sand, and sandstone, sandy limestone, and shell beds or sand and gravel containing small amount of clay.	Less than 100 (6 l/s)

and physical properties of the sediment. Lithologic logs were used to identify characteristics and type of sediment.

From the correlation of the geophysical with lithologic logs a lithologic column was developed for each test hole showing the bed boundaries and giving a description of the material within each bed. An estimate of hydraulic conductivity from table 1 was given to each bed to develop the estimated hydraulic conductivity column (fig. 2-4). Then each bed having the same class of hydraulic conductivity was grouped to form a specific zone representing that class.

The locations of test holes used to determine the lithologic and hydraulic conductivity characteristics of the shallow materials are shown in figure 5. From these data subsurface sections were prepared to show tentative correlations of the different units (figs. 6-9). The correlations are based primarily on the ability of the units to transmit water.

HYDRAULIC CHARACTERISTICS AND EXTENT OF WATER-BEARING ZONES

The shallow aquifer underlying Palm Beach County was divided into water-bearing zones which are based on ranges of well yields and estimated hydraulic conductivity. These zones are designated, Z-1, Z-2, and Z-3, in order of decreasing hydraulic conductivity and well yield. Zone Z-4 is the water-bearing upper part of the major confining bed separating the shallow aquifer and the deep artesian aquifer. The following section describes, in general, each zone, its areal extent, thickness, lithology, estimated well yield, and hydraulic conductivity.

Zone Z-1 occurs only in the eastern part of the county as a bed within zone Z-3. Its hydraulic conductivity is estimated to be between 60-130 ft/d (20-40 m/d). Zone Z-1 is thickest in the southeast part of the county and thins towards the northeast. The deposits are chiefly coarse coquina (a cemented mass of shells), beds of large shells with low sand content, and calcareous sandstone or limestone with solution cavities. Wells penetrating this zone yield more than 1,000 gal/min (60 l/s).

Zone Z-2 is found only in the eastern part of the county and also is a bed within Zone Z-3. The estimated hydraulic conductivity of Z-2 ranges from 10 to 60 ft/d (3-20 m/d). It is thickest in the mid-eastern part of the county and thins toward the northeast and southeast. The deposits are chiefly beds of sandy shell or sandy coquina, solutionalized calcareous sandstone or limestone whose openings are filled with sand and beds of sand and gravel or well sorted coarse sand. The yield of wells penetrating this zone vary from 500-1000 gal/min (30-60 l/s).

Zone Z-3 crops out throughout the county. Its hydraulic conductivity ranges from 1 to 10 ft/d (0.3-3 m/d). Zone Z-3 is thin in the northwest part of the county and thickens toward the east and south; it is thickest in the southeast part of the county. The zone is

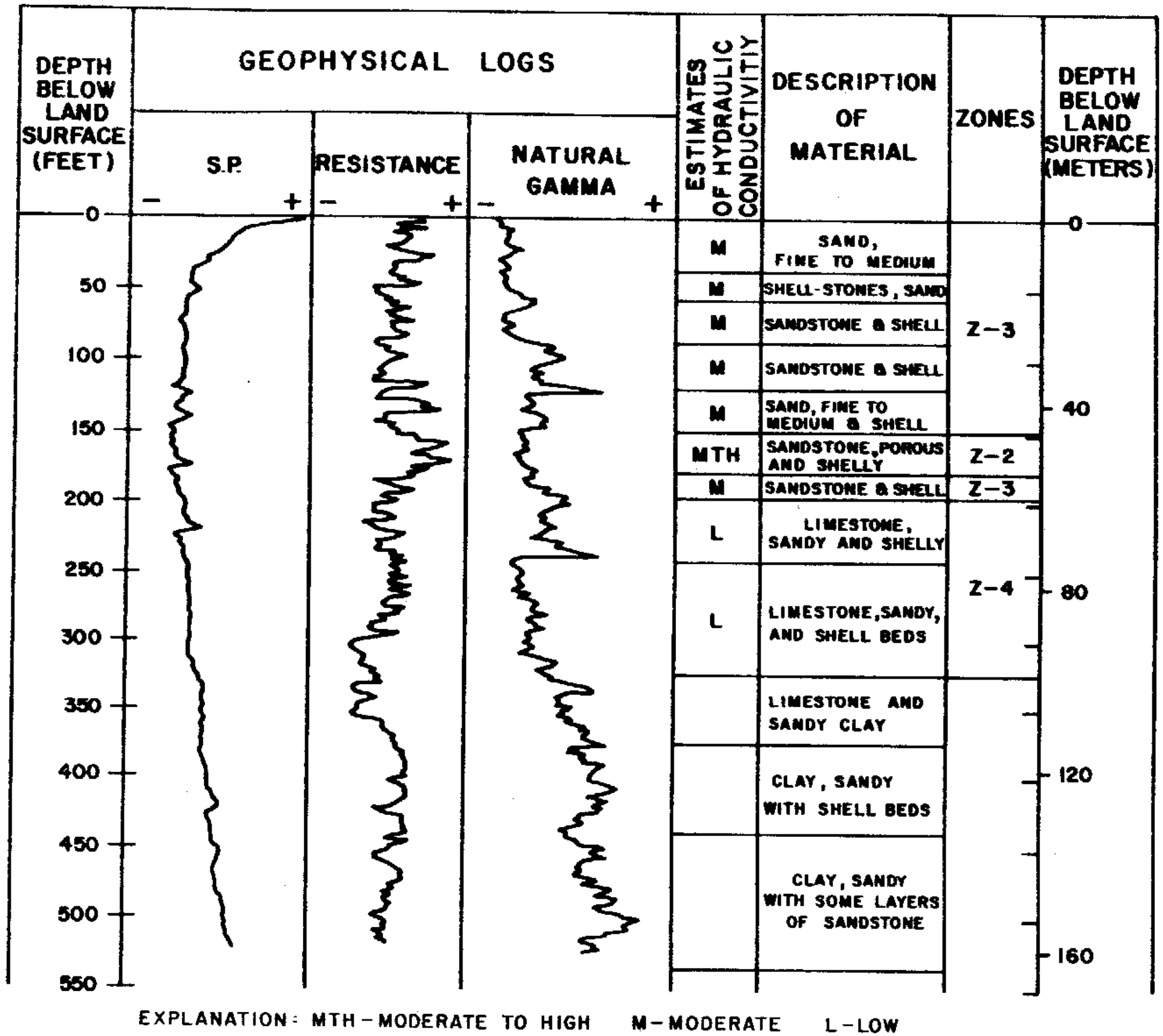

Figure 2.--Geophysical logs, lithologic column, and estimated hydraulic conductivity of test-hole PB-833, eastern Palm Beach County.

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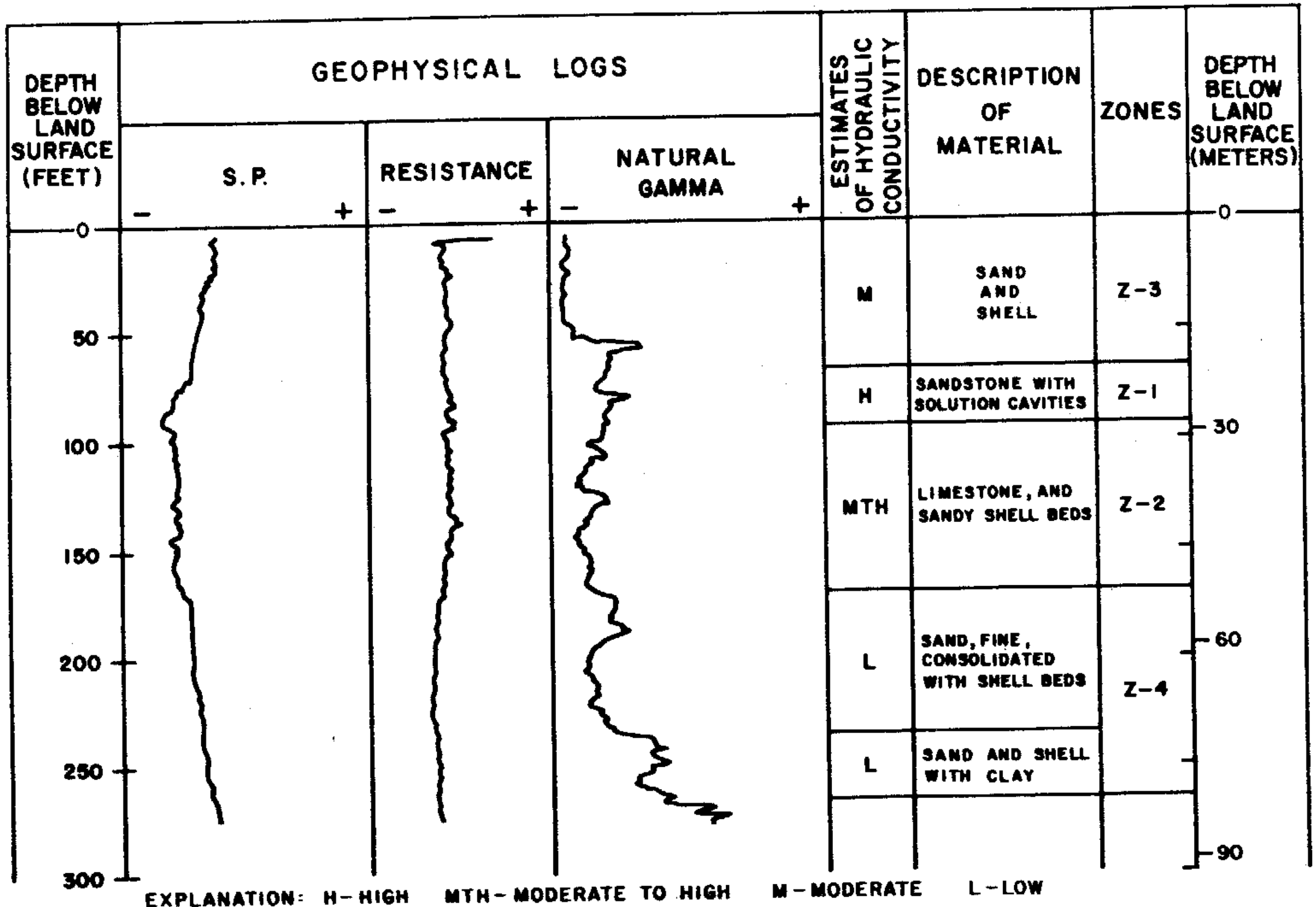


Figure 3.--Geophysical logs, lithologic column, and estimated hydraulic conductivity of test-hole PB-657, east-central part of Palm Beach County.

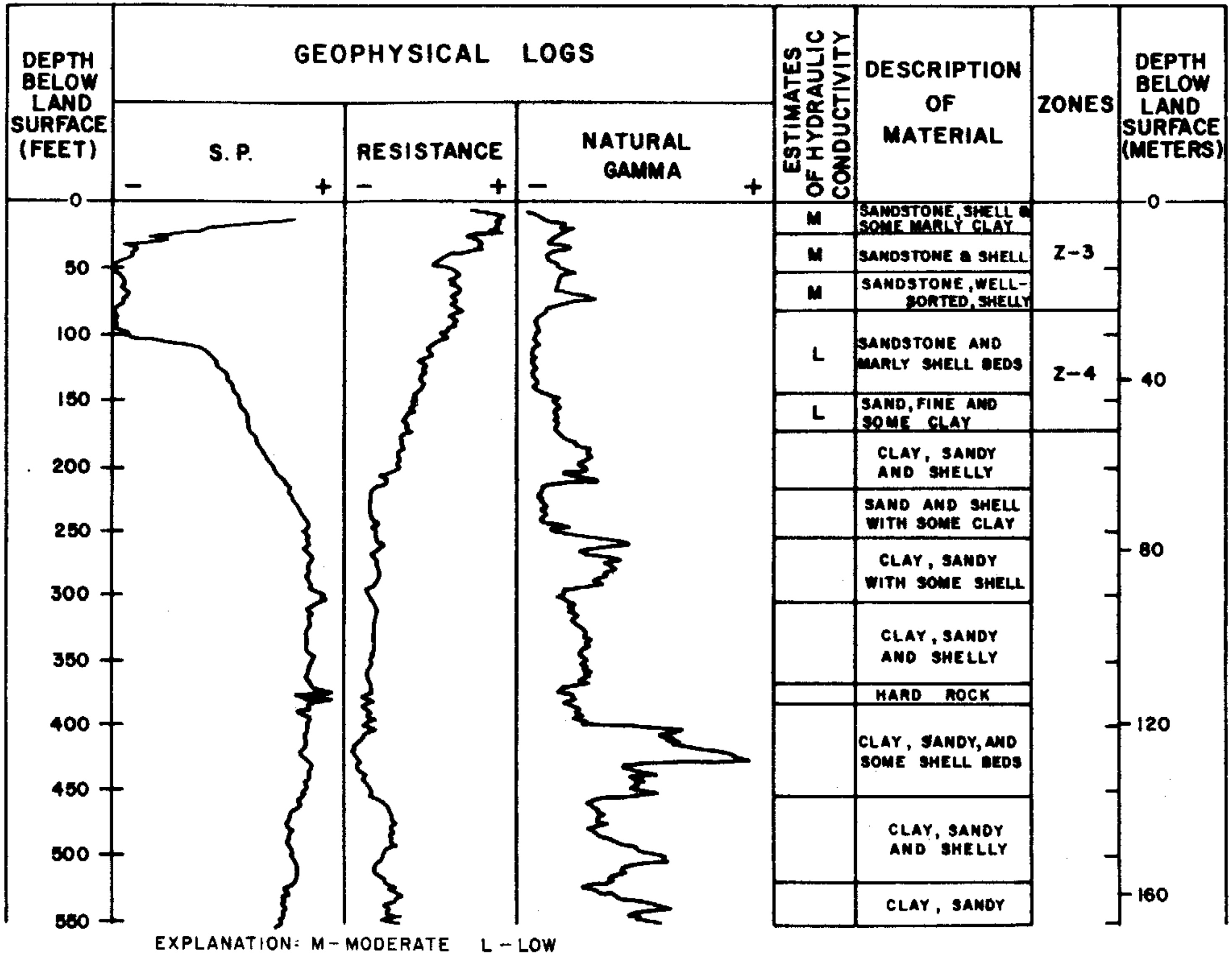


Figure 4.--Geophysical logs, lithologic column, and estimated hydraulic conductivity of test-hole PB-843, western part of Palm Beach County.

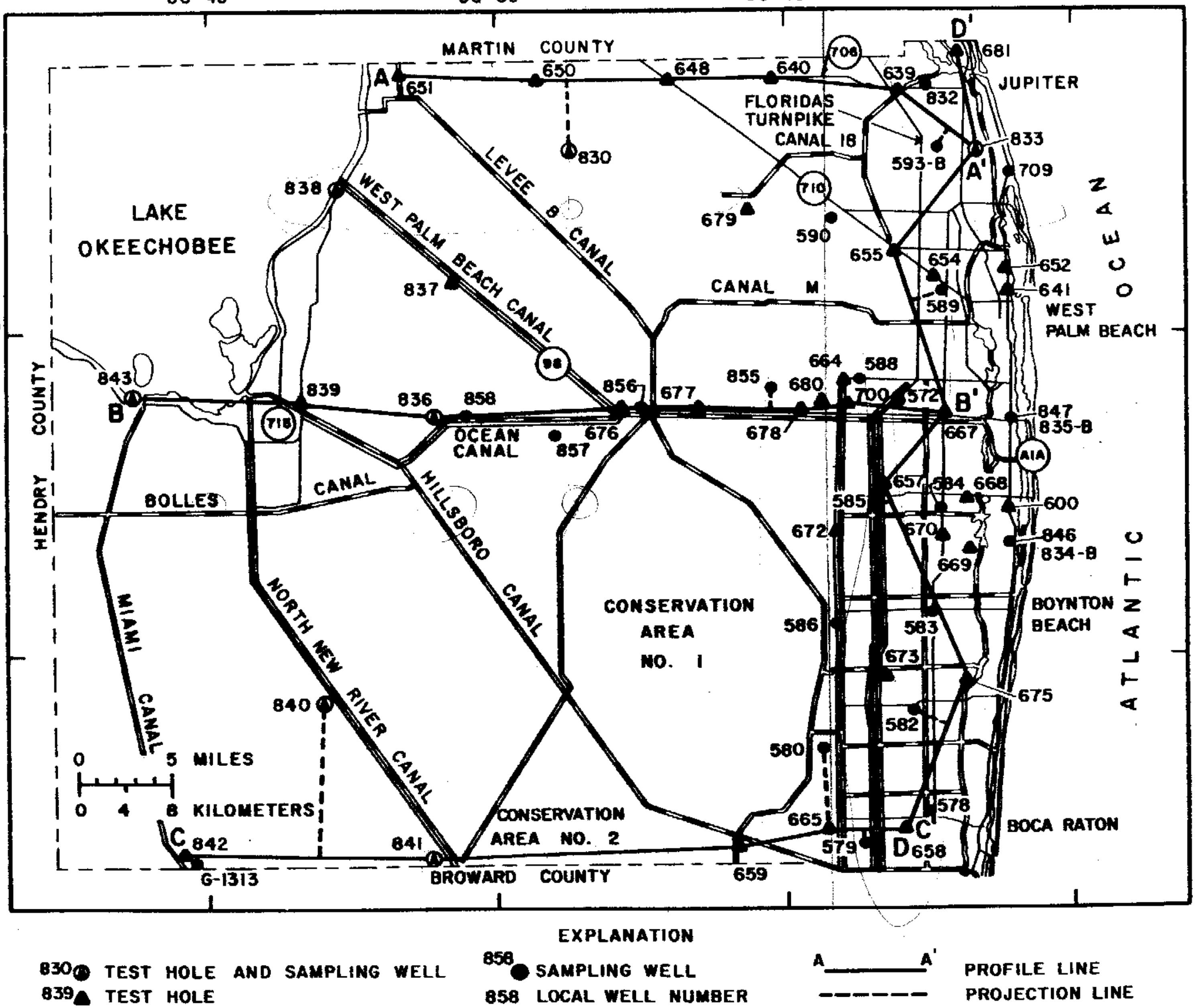


Figure 5.--Location of test holes used to determine lithologic and hydraulic conductivity, test holes and wells sampled for chemical analysis of water, and lines of hydraulic conductivity profiles.

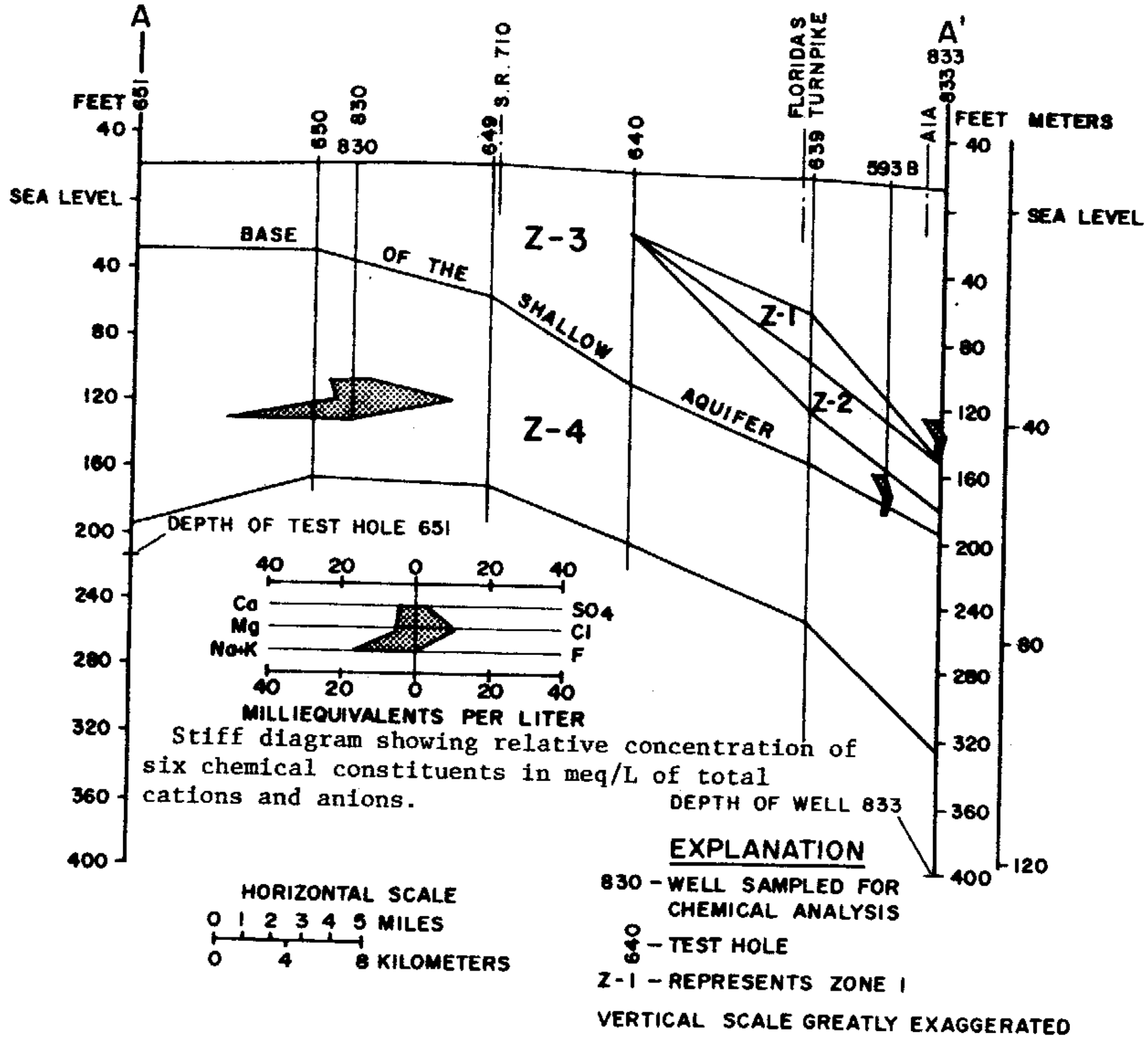
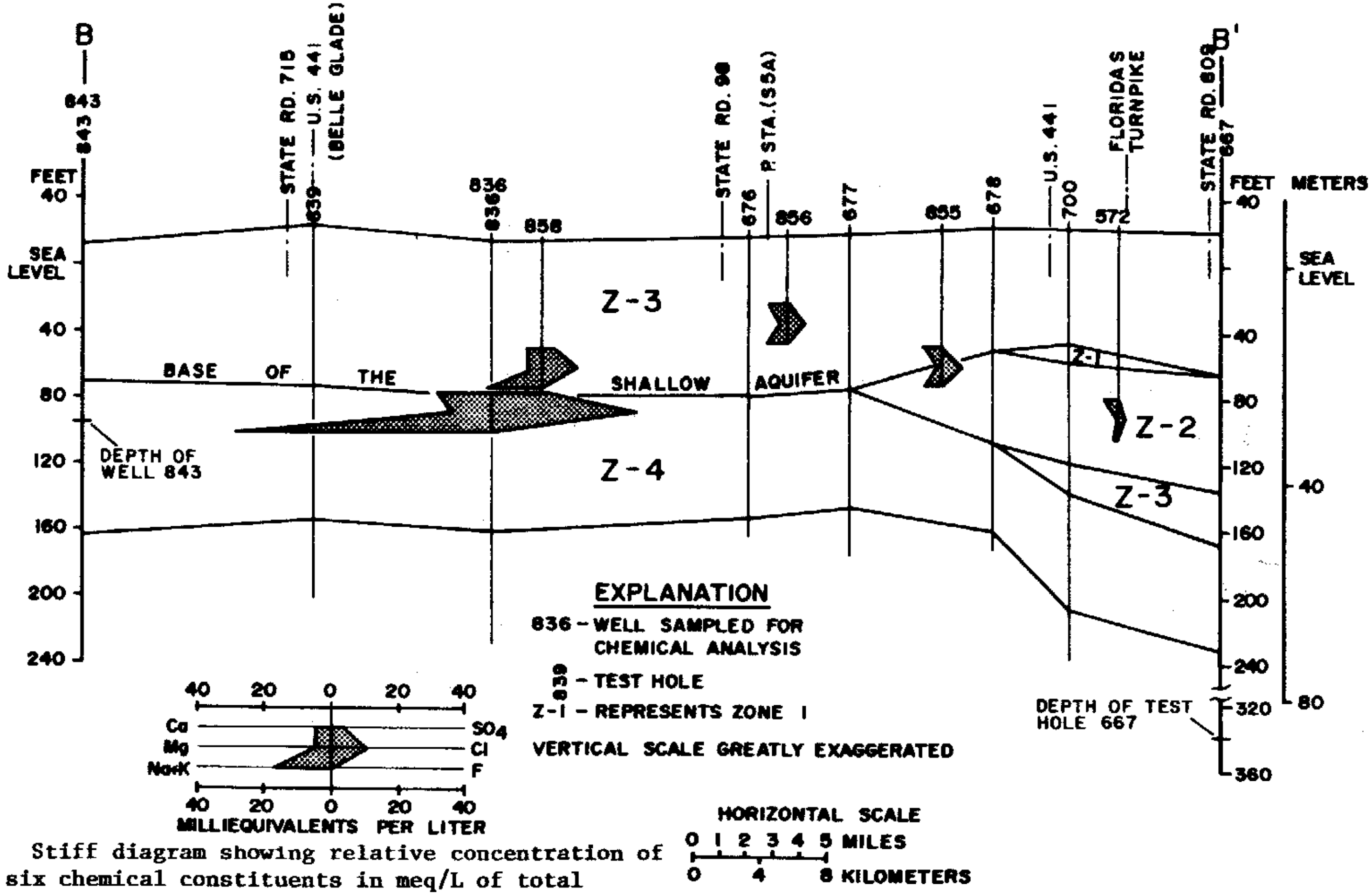
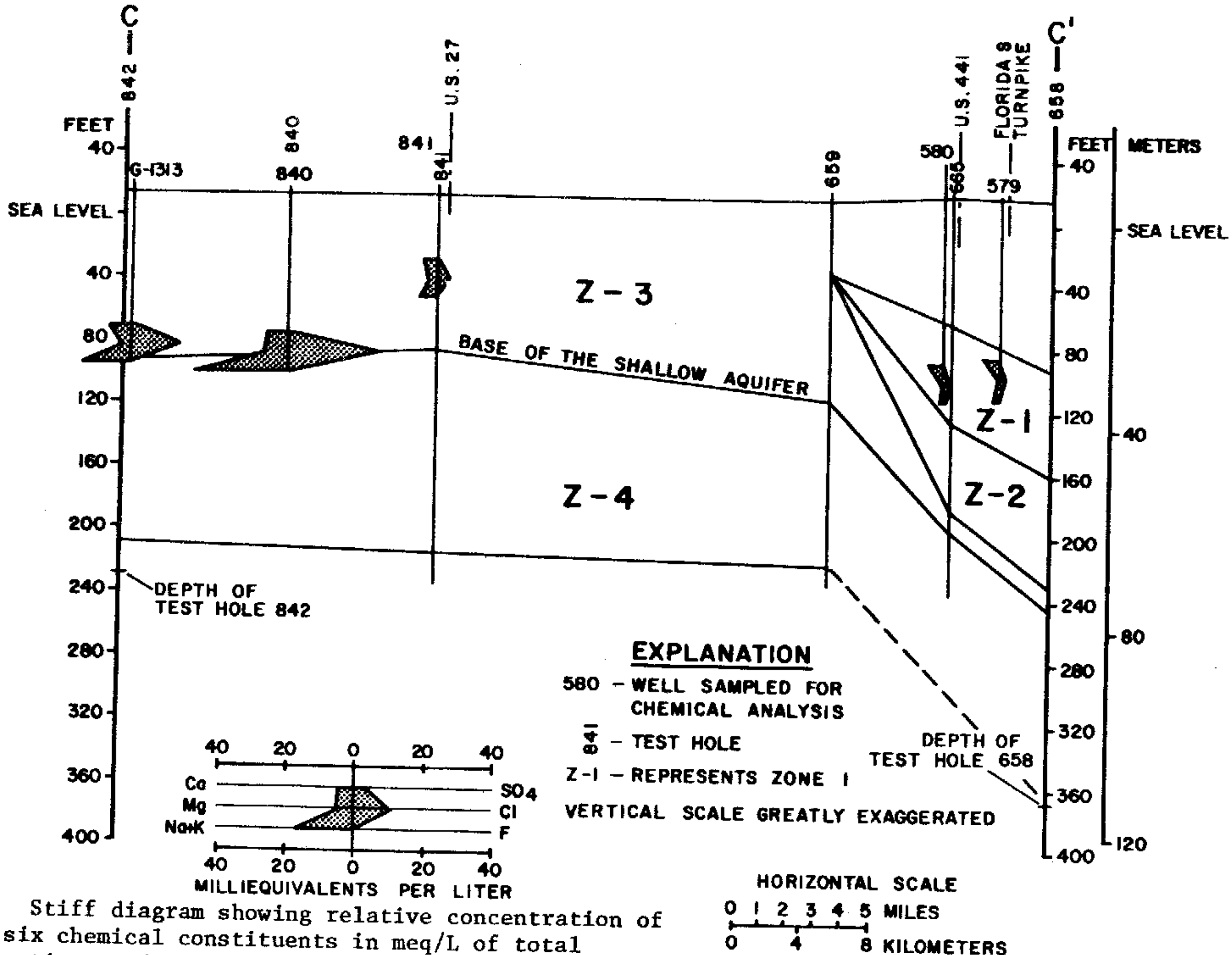


Figure 6.--Hydraulic conductivity profile with Stiff diagrams showing the relative concentrations for six chemical constituents in milliequivalents: A-A', northwest to northeast.



Stiff diagram showing relative concentration of six chemical constituents in meq/L of total cations and anions.

Figure 7.--Hydraulic conductivity profile with Stiff diagrams showing the relative concentrations for six chemical constituents in milliequivalents: B-B', west-central to east-central



Stiff diagram showing relative concentration of six chemical constituents in meq/L of total cations and anions.

Figure 8.--Hydraulic conductivity profile with Stiff diagrams showing the relative concentrations for six chemical constituents in milliequivalents: C-C', southwest to southeast.

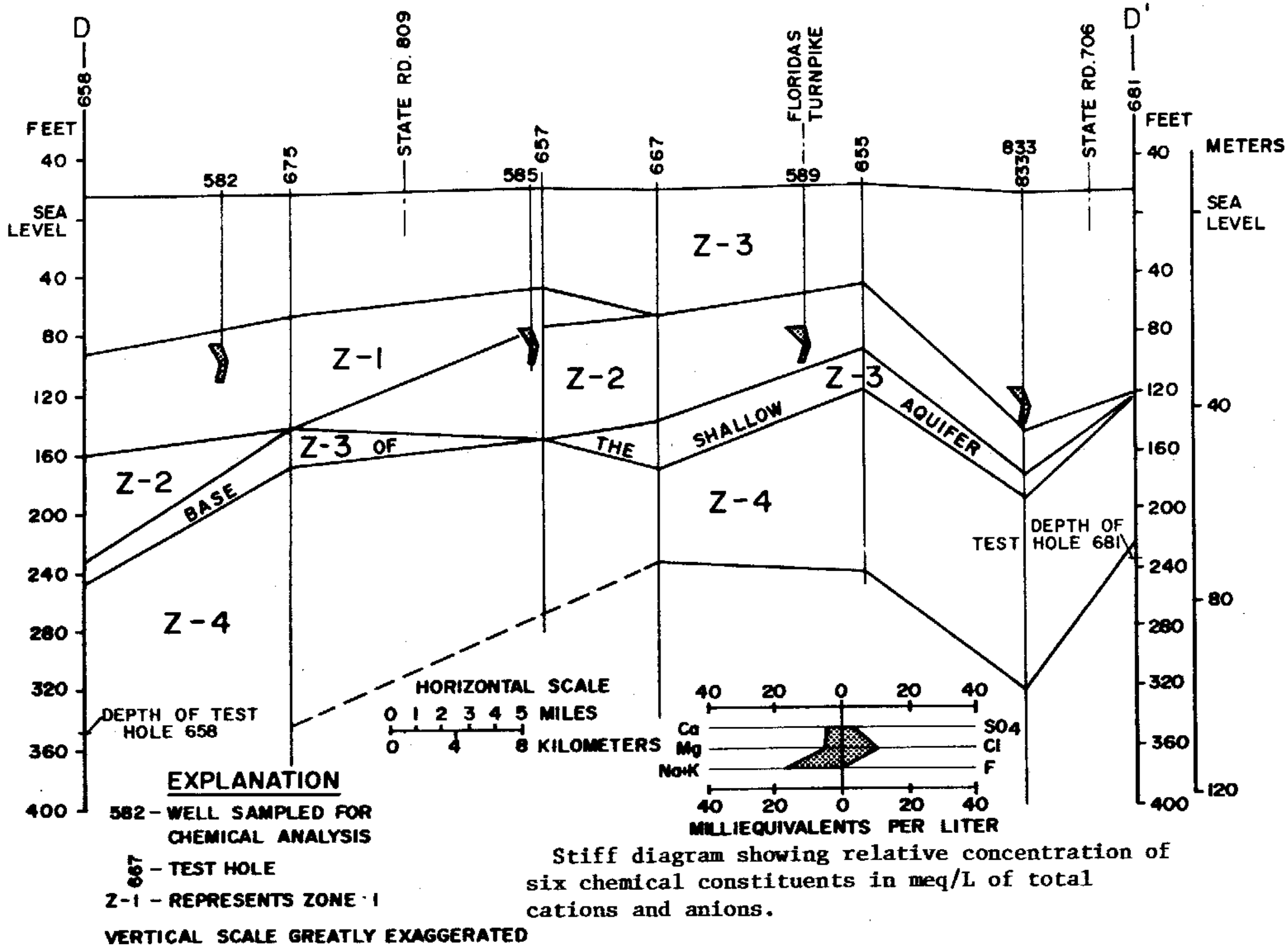


Figure 9.--Hydraulic conductivity profile with Stiff diagrams showing the relative concentrations for six chemical constituents in milliequivalents: D-D', southeast to northeast.

composed chiefly of well sorted medium-grained sand, shell beds, sandstone and locally thin lenses of sandy limestone. In the west part of the county the surface material and upper layer deposits are composed of organic sand, peat-muck, marl, and clay, which grade laterally and vertically into each other. The yield of wells penetrating this zone vary from 100-500 gal/min (6-30 l/s).

Zone Z-4 also occurs throughout the county. Its hydraulic conductivity generally is less than 1 ft/d (0.3 m/d) and decreases rapidly with increasing depth. Zone Z-4 is thickest in the west part of the county and thins slightly in the east part of the county. This zone represents the upper part of the few hundred feet of poorly permeable material atop the Floridan aquifer. Its top is the base of the shallow aquifer. Zone Z-4 and subjacent confining layers hydraulically separates the shallow aquifer system from the deep brackish, artesian aquifer (Floridan). The deposits making up this zone are chiefly well cemented sandstone, thin beds of non-porous sandy limestone, silty shelly marls and sandy clay. The yield of wells penetrating this zone is less than 100 gal/min (6 l/s).

GROUND WATER QUALITY BY TYPE

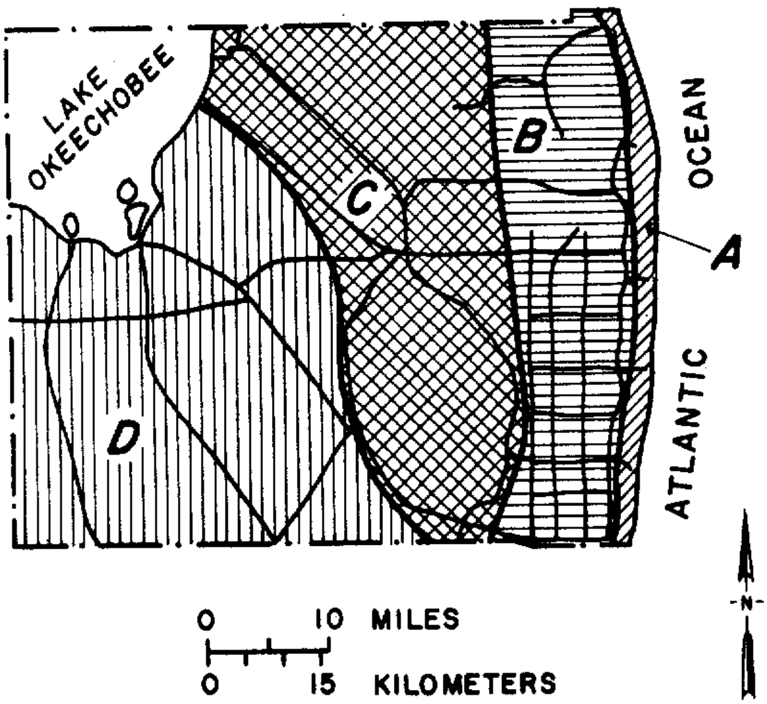
The utility of the shallow aquifer depends in part of the quality of its contained water, which is influenced by the composition, character, distribution, and structure, of the earth material through which it moves. Chemical analyses of water from wells throughout the county (table 2) indicate that the quality of water contained in the shallow aquifer varies with physiographic regions and depth below land surface. Areas of similar quality are categorized as follows: Coastal Ridge (Area A), eastern Sandy Flatlands (Area B), western Sandy Flatlands and eastern Everglades (Area C), and western Everglades (Area D) (Fig. 10). Locations of wells sampled are shown in figure 5.

Analyses were compared graphically according to techniques described by Stiff (1951). Two cations, one cation pair, and three major anions were selected from each analysis for comparison (table 3). Stiff diagrams can be a distinctive tool for comparing water composition. The shape of the diagram depicts the general type of water and the relative length of the "spears" is an approximate indication of total ionic content. Thus, water from different sources whose dissolved mineral content is similar will have Stiff diagrams of the same general size and shape.

The plotted diagrams were placed on the profiles (figs. 6-9) at the finished depth of the sampled wells to illustrate the different ionic concentration of the ground water. This enabled a quick and easy comparison of the water contained in the shallow aquifer.

Table 2.--Chemical analyses of ground-water samples from selected wells in the shallow aquifer by water quality types.
(▲ Treated water)
(Results in milligrams per liter except where noted)

Local Well No.	Date of Collection	Specific conductance in micromhos /cm at 25°C	pH	Temperature (°C)	Color - (Hazen units)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Hardness (total as $CaCO_3$)	Dissolved Solids: Residue at 180° C	Dissolved Solids: Calculated	Sampling Depth (ft)
									Area A and B - Coastal Ridge and Eastern Sandy Flatlands										
572	12-74	680	7.3	23.5	60	13	2.6	110	4.2	0.24	33	1.3	3.1	52	0.3	290	384	-	100
▲578	12-74	270	10.1	22	5	7.7	0	37	2.2	0.36	20	1.4	21	39	0.1	100	180	-	125
579	12-74	650	7.2	23	40	14	0.6	120	3.3	1.2	22	1.2	2	37	0.4	310	390	-	100
580	12-74	680	7.4	21	80	13	1.7	120	3	1.5	28	1.2	5.7	56	0.3	310	390	-	105
582	12-74	510	7.5	24	30	13	0.26	89	2.9	1.4	22	0.7	1.5	38	0.2	240	312	-	100
▲583	12-74	1550	7.4	24	60	12	0.12	2.5	0.3	0.09	120	0.9	11	36	0.3	8	346	-	100
584	12-74	560	7.5	22	60	14	1.5	89	3.6	1.4	28	0.7	1.8	43	0.2	240	320	-	111
585	12-74	648	7.4	28	200	10	6.3	93	3.8	1.5	29	1	0.5	50	0.3	250	354	350	95
586	12-74	640	7.2	21.5	70	14	1.6	99	3.7	1.3	30	1.5	1.6	52	0.3	260	390	-	96
588	12-74	1320	7.3	21	20	17	0.13	140	16	1.5	180	6.0	23	260	0.2	420	894	-	66
589	12-74	680	7.4	21	60	13	1	140	7.6	2	36	10	10	37	0.3	380	432	-	94
590	12-74	640	7.1	24	30	17	0.43	120	4.5	0.57	39	0.9	2.6	66	0.2	320	428	-	76
593B	12-74	570	7.5	23.5	30	16	0.24	100	3.9	0.91	24	0.7	2.8	36	0.2	270	360	-	170
709	12-74	22,000	7.8	27	20	14	-	-	-	-	-	-	1100	8300	0.3	-	17000	-	189
832	12-74	450	8.1	29.5	20	1.8	0.1	-	-	-	-	-	0.9	53	-	-	274	-	141
833	12-74	630	7.3	24.5	30	17	1.7	120	4.2	1.6	30	0.5	1.5	45	0.2	320	470	-	131
834B	12-74	1560	7.3	24.5	3	14	0.52	260	8.4	2.4	420	1.4	2.1	520	0.2	690	1250	-	185
835B	12-74	930	7.4	24.5	6	15	0.75	130	5	2	55	1	0.7	130	0.2	350	550	-	91
846	12-74	510	7.7	25.5	3	11	2	99	2.6	0.83	15	0.5	0.7	22	0	260	308	-	91
847	12-74	470	7.7	25	5	6.4	0.53	72	2.1	0.46	16	1.6	7.6	25	0.2	190	242	-	66
									Area C - Western Sandy Flatlands and Eastern Everglades										
830	12-74	4100	7.3	27	30	28	2.9	150	71	2	840	30	290	1100	0.3	670	2780	-	131
855	12-74	1340	7.9	28.5	20	17	0.03	120	11	0.91	130	3.5	16	230	0.4	350	777	687	70
856	12-75	1460	7.3	27.5	100	22	0.23	120	26	0.98	150	5.5	37	200	0.6	410	863	811	40
									Area D - Western Everglades										
836	12-75	9100	7.4	28.5	100	31	8	360	150	7.4	1800	35	850	1600	1.2	1500	6730	5220	89
838	12-74	30000	7.0	24	70	26	1.2	130	150	4.6	7400	260	2200	10000	0.7	950	21600	-	89
840	12-74	4300	7.1	23.5	3	29	1.3	130	87	4.3	700	16	54	1100	0.7	690	2500	-	89
841	12-74	1100	7.7	24.5	60	14	1.7	88	27	2.7	110	3.4	28	160	1	330	663	-	40
843	12-74	1550	7.3	23.5	60	40	1.1	120	91	3.5	650	26	210	140	0.7	680	1060	-	91
857	2-75	2150	7.5	28.5	100	27	0.13	86	39	4.9	300	12	70	400	1.2	380	1240	1180	-
858	2-75	2350	7.4	28.5	100	41	0.12	96	50	6.5	390	34	190	400	1.5	450	1600	1580	-
G1313	12-74	2720	7.2	27	4	23	0.16	150	34	2	380	6.5	44	600	0.6	520	1530	-	85



EXPLANATION

A-- Coastal Ridge Area
B-- Eastern Sandy Flatlands Area
C-- Western Sandy Flatlands Area
Eastern Everglades Area
D-- Western Everglades Area

Figure 10.--Areal division of county by ground-water quality type

Table 3.--Selected constituents (in milliequivalents per liter) used to plot Stiff diagrams

Well Number	Calcium		Magnesium		Sodium & Potassium		Sulfate		Chloride		Fluoride	
	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L
PB-572	110	5.49	4.6	0.38	34.3	1.47	3.1	0.06	52	1.5	0.3	0.02
579	120	5.99	3.3	.27	23.2	.99	2.0	.04	37	1.0	.4	.02
580	120	5.99	3.0	.25	29.2	1.25	5.7	.12	56	1.1	.3	.02
582	89	4.44	2.9	.24	22.7	.97	1.5	.03	38	1.1	.2	.01
585	93	4.64	3.8	.31	30.0	1.29	.5	.01	50	1.4	.3	.02
589	140	6.99	7.6	.63	46.0	1.82	10.	.21	37	1.0	.3	.02
593-B	100	4.99	3.9	.32	24.7	1.06	2.8	.06	36	1.6	.2	.01
830	150	7.48	71.	5.8	87.0	37.3	290.	6.0	1100	31	.3	.02
833	120	5.79	4.2	.35	30.5	1.32	1.5	.03	45	1.3	.2	.01
840	130	6.49	87.	7.2	716.	30.9	54.	1.1	1100	31	.7	.04
841	88	4.39	27.	2.2	113.	4.87	28	.58	160	4.5	1.0	.05
855	120	5.99	11.	.90	133.	5.74	16	.33	230	6.4	.4	.02
856	120	5.99	26.	2.1	156.	6.67	37	.77	200	5.6	.6	.03
858	96	4.79	50.	4.1	424.	17.8	190	4.0	400	11.	1.5	.08
G-1313	150	7.48	34.	2.8	386.	16.7	44	.92	600	17.	.6	.03
PB-836	360	17.96	150.	12.3	1840.	79.2	850	18.	1600	45.	1.2	.06

Coastal Ridge and Eastern Sandy Flatlands

The best quality ground-water in the county is along the Coastal Ridge and the adjacent eastern part of the Sandy Flatlands, areas A and B (fig. 10). The concentrations of sulfate, chloride, magnesium, and sodium plus potassium are lower in this area than in other parts of the county. Calcium, and fluoride concentrations remained relatively low and constant throughout the county. The suitable quality water in this zone is due to the increase in circulation of fresh water through the very porous and permeable sediments. The combination of moderate to high hydraulic conductivity and steep gradients means a greater volume of water can recharge the aquifer, and move rapidly through it. This rapid circulation of water has leached out much of the soluble salts originally in the aquifer.

Western Sandy Flatlands and Eastern Everglades

The western Sady Flatlands and eastern Everglades, Area C, are transitional for both lithologic and ground-water quality characteristics. Dissolved solids concentrations increase both with depth and in a westerly direction. This increase is due to the sluggish circulation of the water through the moderately permeable deposits. Circulation of fresh water is insufficient to completely reduce the concentration of soluble salts in the aquifer. Therefore, wells yield water of variable quality (table 2). The upper part of the aquifer yields the best quality water in Area C.

Western Everglades

In the western Everglades, Area D, the chemical characteristics of the water in the shallow aquifer differs from that in Areas A, B, and C. Dissolved solids concentrations are so high, particularly in the water originating below a depth of 40 ft (12 m), that water is unsuitable for most purposes. The water from the upper 30-40 ft (9-12 m) is somewhat fresher. The Stiff diagrams (figs. 7 and 8) indicate that sodium plus potassium, chloride, sulfate, and magnesium increase rapidly with depth. Sodium plus potassium and chloride concentrations in this area are the highest in the entire county (table 2). The hydraulic conductivity of the aquifer is low because of the presence of marl and clay beds, and the hydraulic gradient is low because of the relatively flat land surface. These factors contribute to poor circulation of water through the subsurface deposits. This characteristic is common to the logs run in Area D.

The drifting together of the S. P. and resistance logs (fig. 4) is probably caused by the increased chloride concentration with depth in the local ground water. The drift of the resistance curve to the left is best explained by the increasing mineralization of the water thus lowering its resistance to the passage of an electric current. The

S.P. curve is the measure of the difference of the natural electric potential between the fluid in the formation and that of the borehole. The gradual drift to the right of the S.P. curve indicates no major formational change but shows a short-circuiting of potential to that of only the borehole fluid because of the increased mineralization of water in the borehole by inflow of water from the formation.

SUMMARY AND CONCLUSIONS

Based on a correlation of selected geophysical and lithological logs, the strata comprising the shallow aquifer underlying Palm Beach County were grouped into water-bearing zones according to their capacity to transmit water. These zones are designated in order of decreasing hydraulic conductivity, Z-1, Z-2, and Z-3. Zone Z-1 has an estimated hydraulic conductivity of 60 to 130 ft/d (20 to 40 m/d), will yield more than 1,000 gal/min (60 l/s) to wells, and is composed of coarse coquina,beds of large shells with low sand content and calcareous sandstone or limestone with solution cavities. Zone Z-2 has an estimated hydraulic conductivity of 10 to 60 ft/d (3 to 20 m/d), will yield 500 to 1,000 gal/min (30 to 60 l/s) to wells, and is composed of sandy shell beds or sandy coquina, and calcareous sandstone or limestone with sand filled solution openings. Zone Z-3 has an estimated hydraulic conductivity of 1 to 10 ft/d (0.3 to 3 m/d), will yield 100 to 500 gal/min (6 to 30 l/s) to wells, and is composed of well sorted medium sand, sand and shell beds, porous limestone, and calcareous sandstone. In the Eastern part of the county, this aquifer has the capacity to transmit sufficient water to be a source of municipal and industrial water supply.

Zone Z-4 represents the upper part of the few hundred feet of poorly permeable sandstone, sandy limestone, shell beds, and sand and gravel with small amounts of clay on top of the Floridan aquifer. Its top is the base of the shallow aquifer. The hydraulic conductivity of zone Z-4 generally is less than 1 ft/d (0.3 m/d) and decreases rapidly with depth. The yield of wells penetrating this zone is less than 100 gal/min (6 l/s).

Chemical analyses show that the quality of water in the shallow aquifer varies with depth and by physiographic regions. In the eastern part of the county, ground water underneath the Coastal Ridge (Area A) and eastern Sandy Flatlands (Area B), is of suitable quality for most uses. The concentration of mineral constituents tend to increase with depth in a westerly direction, making the water unsuitable for most purposes in the western Everglades (Area D).

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