EVALUATION OF THE SHALLOW AQUIFER, HILTON HEAD ISLAND, SOUTH CAROLINA

COMPILATION AND REVIEW OF EXISTING DATA

by

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CONTENTS

FIGURES

TABLES

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ABSTRACT

Shallow aquifers on Hilton Head Island are formed in three geologic units, beach deposits of 7,000 and 100,000 years age and a shelf deposit of 100,000 years age. Summer rainfall is highly variable, and ground water flow direction in shallow aquifers is controlled by the local topography. Water chemistry is controlled by the initial composition of rainfall and the effects of the processes of soil-zone evapotranspiration and shallow-aquifer mixing. Water quality is generally dominated by sodium chloride or calcium bicarbonate, and pH values range between 4.1 and 7.8. Dissolved solids concentrations are low and high iron concentrations are likely to be common. Data suggest the water level in lower section of the shallow aquifer responds to changes in the water level in the underlying upper Floridan aquifer. Aquifer transmissivity is as high as 1,200 feet squared per day, and well yields in the range of 5 to 15 gallons per minute should be expected.

INTRODUCTION AND PURPOSE

Hilton Head Island is home to about 25,000 people (1990 census, U.S Department of Commerce, shows 23,452) and a vacation destination for thousands more. The Island relies on the upper Floridan aquifer for its water supply. Presently the upper Floridan supplies on average 11.5 mgd (million gallons per day), and about 60 percent of the water pumped from the upper Floridan is eventually used for irrigation (McCready, 1989, p. 22).

Alternative sources of water for irrigation are of great concern to the Island. Treated wastewater is one source, and in 1992 about 5 mgd (unpublished SCDNR-WRD data) of wastewater was applied to golf courses and common areas. Water from shallow aquifers is a second possible source. From a consideration of porosity it is estimated that the shallow aquifer stores more than 115,000 acre-feet of freshwater. (One acre-foot equals 325,851 gallons.) Water from this reservoir, if it is of suitable quality and if it can be produced in usable quantities, coupled with the volume of available wastewater could reduce the demand on the upper Floridan. Investigation of the hydrologic characteristics of the shallow aquifer is the subject of a study undertaken by the SCDNR-WRD for the town of Hilton Head Island. The purpose of this report is to document the present knowledge of the hydrology of the shallow aquifer; identify the data available; evaluate the scale of data collection necessary; and identify, where possible from existing work, problems that could arise during the study.

PREVIOUS INVESTIGATIONS

Reports from nine previous studies specifically devoted to the hydrology of the Island's shallow aquifer have been reviewed. The general theme of four of the nine reports is minimizing impacts from land disposal of treated waste water.

In an unpublished report prepared for Beaufort County (Feasibility Study of Requirements for Main Drainage Canals, 1970) the Soil Conservation Service derived the design capacity for a drainage system of approximately 19,400 acres (30 square-miles) of the Island. The design criterion used was the 10-year rainfall event for a 24-hour period (4.4 inches or 0.367 ft). It was assumed that the area would become urban and the peak discharge (Q) could be estimated with the runoff formula: $Q = 118(A^{5/6})$. Units are Q, in cubic feet per second and A (area) in square miles. Calculated Q is 1,930 cfs. The design approach used in this study does not consider the shape of the runoff hydrograph. A runoff-design criterion is necessarily conservative, that is, calculated Q can be much larger than any event actually observed. The design assumes that a large flow is available from storm runoff; hence a large volume of water might be available if a system designed to store it is constructed.

Glowacz and others (1980) investigated the potential for shallow-aquifer contamination from wastewater at the Hilton Head No. 1 Public Service District waste disposal ponds (since redesigned and reconstructed). They noted that shallow ground water near the lagoons was chemically similar to the wastewater and concluded that the shallow-aquifer water was contaminated by alkalinity, Cl (chloride), TKN (total Kjeldahl nitrogen), NH_3 (ammonia), TOC (total organic carbon), TDS (total dissolved solids), and Na (sodium) (p. 97).

They also concluded that permeable soil and a shallow watertable make the shallow aquifer vulnerable to contamination everywhere on Hilton Head Island.

Hardee (1981) followed up the study of Glowacz and others (1980), investigating the quality of ground water at shallow depths (typically less than 15 ft) near the present-day Sea Pines PSD (Sea Pines Public Service District) wastewater treatment plant. Hardee recommended (p. 49) that land disposal of wastewater be carefully evaluated. Hardee further recommended the use of liners for waste disposal ponds, maximizing spray irrigation on golf courses, and construction of a spray irrigation field on the mainland where Floridan aquifer water was not so vulnerable to seepage contamination as on Hilton Head Island (p. 49 and 50). Hardee also recommended an island-wide drilling program to collect data on the geological continuity of upper Floridan aquifer confining zones (p. 50) on the Island.

Hardee and McFadden (1982, p. 88 - 91) studied sites, across South Carolina, of known ground-water contamination and sites of probable aquifer recharge. They concluded that water from the Hilton Head Island shallow aquifer recharges the underlying upper Floridan and that surface disposal of waste water should be considered a threat to the quality of the upper Floridan water. They (p. 88) noted that little is known of the hydraulic properties of the shallow aquifer. It was concluded (p. 91) that at the Sea Pines study area the shallow flow was predominantly toward nearby streams.

May (1984) investigated the role of shallow wetlands in the Island's hydrology. He concluded that wetlands (Whooping Crane Wetlands and the informally named Palmetto Pond) store water accumulated during the cool season and later discharge it to the shallow aquifer as leakage when shallow water tables decline below wetland pool levels (p. 14).

Speiran (1985) described the effects of spreading treated wastewater at the HHD#1PSD spray site off Marshland Road. He noted (p. 24) that application during hot, dry weather was insufficient to prevent a buildup of solids in the unsaturated zone; he concluded, however, that 5 inches per week of effluent (0.71 in/day) could be applied to the land during times of high evapotranspiration (ET) and during seasonally low water tables, but less during the low-ET rainy winter season owing to flooding in topographically low areas.

Stone and others (1986) used methods of isotope hydrology and concluded that downward flow from the shallow aquifer to the upper Floridan aquifer was occurring over a relatively large section of the northern area of the Island. They also concluded that some recharging is taking place at the south end of the Island near well BFT-701. They discovered tritium at a depth of 68 ft at their southern piezometer site (location not defined) and discovered water less than 30 years old being produced from well BFT-443, at Hilton Head Plantation.

Purvis and others (1988) measured precipitation at eight stations. They documented that precipitation was not evenly distributed over the Island; the winter season precipitation is fairly even, but summer precipitation varied areally. Their data showed that the Calibogue Sound side of Hilton Head Island received more rainfall during the three years of study than did the Atlantic Coast side. They note that the period of record was much too short to say if this is a long-term recurring result and hypothesized, assumming they had observed a long-term trend, that the difference resulted from greater thunderstorm intensity along the sound.

In a private report for the Greenwood Corporation, (Westinghouse Environmental Services, 1989, Assessment of shallow aquifers at Arthur Hills and Palmetto Headlands, Hilton Head Island, South Carolina) Westinghouse Environmental Services examined the feasibility of developing the shallow aquifer for golf course irrigation on the Palmetto Dunes and Palmetto Headlands properties. They drilled a series of shallow observation wells and concluded (p. 1) that the shallow aquifer is actually a system composed of a water-table aquifer separated from a thin confined sand aquifer by a clay-rich confining bed of variable thickness. They opined that the water table could supply 10 gpm (gallons per minute) to a 4-inch diameter well. Their conclusion was that the lower unit at Palmetto Dunes was predominantly sand and would support a small yield, but at Palmetto Headlands the aquifer was poorly sorted (made up of an admixture of sand, silt, and clay sized particles) and it would not supply 2 gpm to a well.

DATA

Data summarized in this report were obtained from (1) previous reports on hydrology and geology; and (2) heretofore unpublished geological data collected during July 1989 and the summer of 1990. Data from 1989 include sedimentological samples from nine drill holes (five of which were converted to monitor wells). Data from 1990 include chemical analyses of water from the five wells.

PHYSICAL SETTING

Hilton Head Island is located at the southern tip of the State and is centered at approximately latitude N 32° 12′ and longitude W 80° 45′. Figure 1 shows Hilton Head Island and the locations of sites referenced in the report. The island is nearly right-triangular in shape. Its longest side

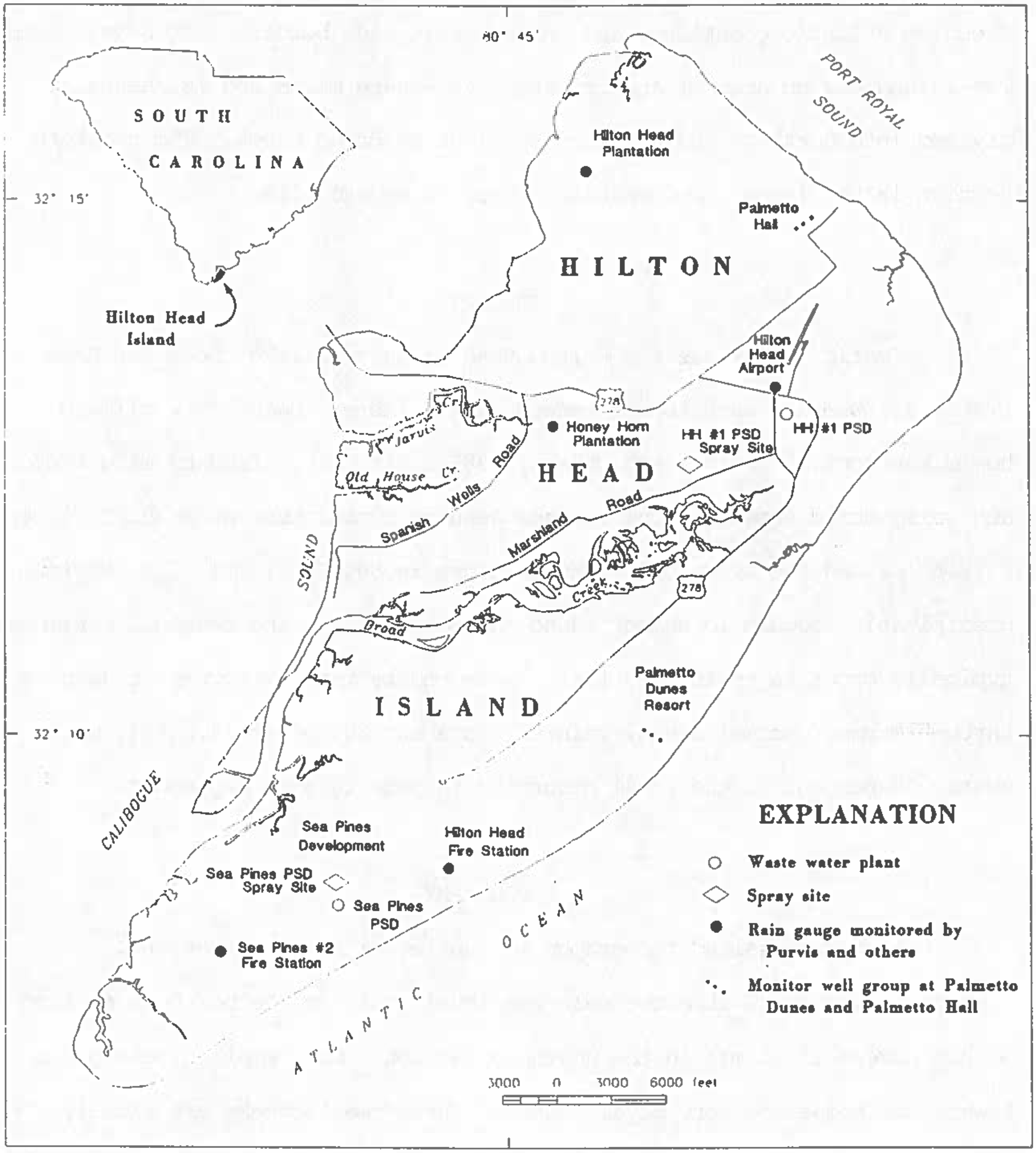

Figure 1. Map of Hilton Head Island.

borders Calibogue Sound, the intermediate-length side is the northeast trending Atlantic coastline, and the shortest side borders Port Royal Sound. The island has an area of approximately 45 square miles and is naturally divided into northern and southern sections by Broad Creek. The northern section is the larger, encompassing about 24 square miles.

CLIMATE

Climatic conditions for Hilton Head Island are like those for Beaufort (Table 1), where a much longer record is available. Beaufort's climate is humid subtropical (Purvis and others, 1987). It is typified by mild winters and warm, humid summers. The average January temperature at Beaufort is 49.1° F (9.5° C) and the average July temperature is 80.8° F (27.1° C). Maximum precipitation occurs in summer (June through August), and seasonal minimums typically occur in spring and fall. A secondary maximum occurs in January through March. Normal annual rainfall is about 50 inches (4.2 ft), with nearly 50 percent of the total occurring in June through September.

TOPOGRAPHY

Hilton Head Island topography is subtle, with low elevations. Elevations exceed 20 ft above mean sea level (msl) in the northern section but do not exceed 15 ft msl in the southern section. Many small creeks drain toward Calibogue and Port Royal Sounds. These small creeks are tidally affected where elevations are below about 5 ft msl. As example, the northern

Table 1. Climatic data for Beaufort and Hilton Head Island

	Beaufort (1985)		Hilton Head (1985)		Beaufort average	
Month	Temp	Precp	Temp	Precp	Temp	Precp
January	48.8	2.35	48.8	2.22	49.1	3.36
February	56.9	4.97	57.3	4.50	51.3	3.14
March	59.4	3.22		4.39	57.8	4.28
April	66.1	0.82	80.2	0.56	65.7	2.69
May	73.8	1.89		0.26	73.0	4.83
June	81.1	3.16	81.5	7.1	78.1	5.64
July	85.0	5.75		1.97	80.8	7.14
August	80.3	11.47	82.0	11.55	80.4	6.61
September	78.3	5.07	78.8	1.94	76.0	5.08
October	69.9	2.62	71.5	0.93	67.0	2.38
November	64.3	4.22	63.5	5.47	58.1	2.11
December	53.2	5.33	52.8	4.77	51.2	2.90
Annual	68.1	50.9		45.7	65.7	50.2

part of the island can be divided into 27 such small basins. The largest of Hilton Head's tidal creeks is Broad Creek. It drains approximately 6 mi^2 (square miles) of island high ground. Several smaller tidal creeks, including Jarvis Creek, Old House Creek, and Park Creek, are aligned parallel to dune crests and generally flow in either a southwestward or northeastward direction.

Freshwater wetlands form in swales without surface drainage. These were probably more prevalent before drainage canals were constructed. Drainage canals are intensively developed in the Palmetto Dunes and Sea Pines areas. In a hydrological sense, these canals are important because they alter flow to effect rapid drainage and therefore reduce the volume of water stored in the shallow aquifer.

ANALYSIS OF DATA

Existing Hilton Head Reports

Hardee (1981) reported water-table elevations for the Sea Pines

Plantation area; she included data from a cluster of three wells (her numbers 53, 54, 55) screened at depths 25 to 30, 35 to 40, and 15 to 20 ft, respectively. Data show a downward flow potential. The water level difference between the interval 25 - 30 ft and the interval 35 - 40 was 1.63 ft in May of 1980 and 5.54 ft in August 1980.

The reported water level for the lowermost unit of the shallow system for August and October is below sea level. It is interpreted as having been affected by drawdown of the upper Floridan. Semidiurnal, tide-induced water level fluctuations can occur in shallow-aquifer wells located 1,000 to 1,500 ft from tidal bodies. As example, water levels in well 27KK-e6 (located near the Salty Faire Gate to Hilton Head Plantation, approximately 1,000 ft from Skull Creek) show a distinct tidal response (Fig. 2) of about 0.4 ft amplitude. Well 27KK-e6 is completed from 36 to 56 ft below land surface and thus is comparable in depth to Hardee's well 54. The assumption that Hardee's measure was at the low point of the tidal cycle does not affect the conclusion that the shallow aquifer is probably coupled to the underlying upper Floridan aquifer. Adding 0.4 ft to the measured water levels raises the water levels to -2.4 and -2.6 ft msl, respectively.

Table 2 shows the calculated vertical gradient between the upper interval (15 - 20 ft) and middle interval (25 - 30 ft), and between the middle interval and lower interval (35 to 40 ft). Examination of these gradients show that the gradient for interval 1 to interval 2 remained about the same throughout the summer season of 1980 while the gradient from interval 2 to interval 3 increased by a factor of 10. This suggests that the upper unit of the shallow aquifer (composed of approximately 30 ft of fine sand) is separated from the lower unit by a less permeable unit. Data (Hardee,

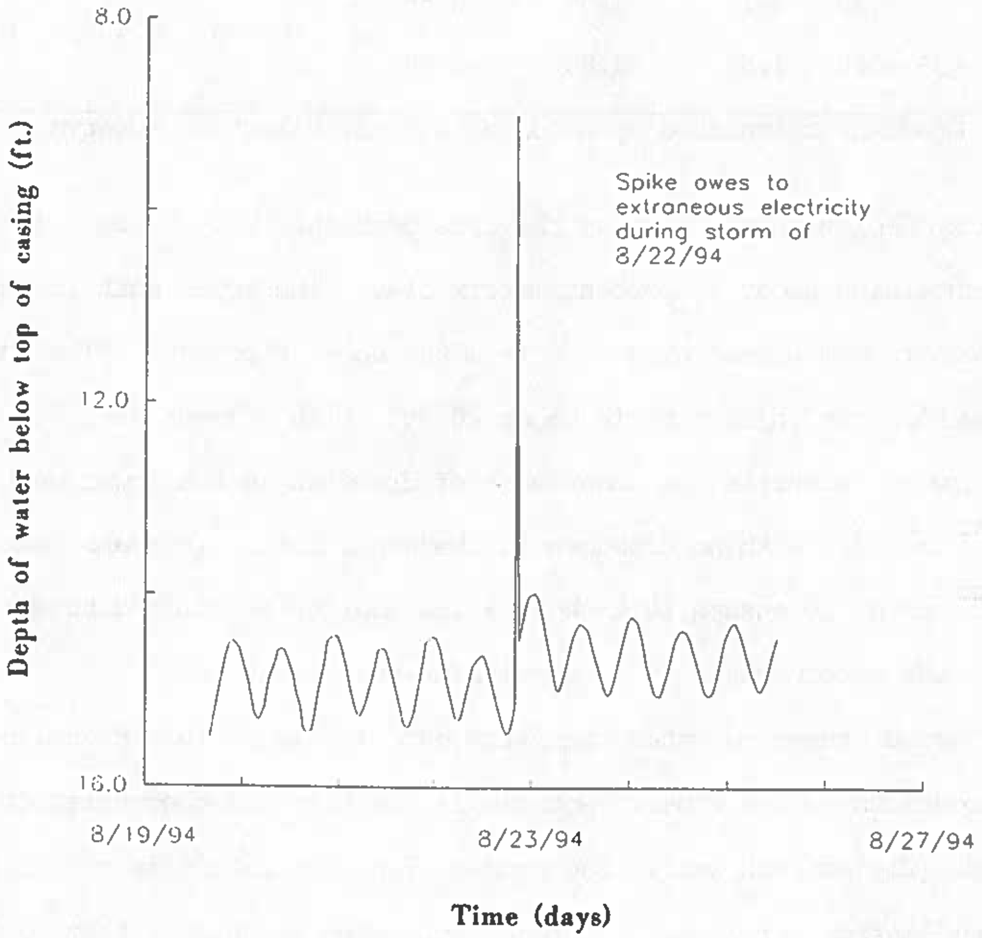

Figure 2. Tidal fluctuation in well 27KK-e6.

Table 2. Water-level measurements and estima ted vertical gradient at Sea Pines Plantation well cluster (Hardee, 1981)

Well No.	Screened interval (feet)	Water level elevation (feet msl)			Vertical gradient		
		5/14/80	8/6/80	10/13/80	5/14/80	8/6/80	10/13/80
55	15 - 20	3.19	2.64	2.84	0.017	0.105	0.028
53	25 - 30	2.12	1.59	2.56	0.056	0.439	0.554
54	35 - 40	1.56	-2.80	-2.98			

Note: Gradient calculated by assuming a 10-ft effective interval.

Appendix "Geologic Data") shows the less permeable unit to be a 1 - 2 ft shell hash containing about 10 percent matrix clay. The lower unit is separated by the Hawthorn Group confining zone from the upper Floridan. The thickness of the Hawthorn confining zone is about 40 ft. With present data, it is not clear how to reconcile the occurrence of drawdown in the lower unit of the shallow aquifer, with no drawdown in the upper unit. It seems reasonable, from the data, to assume that the shallow aquifer is limited to water-bearing sand in the uppermost 30 ft of section at this location.

Hardee presented water chemistry data (Table 3) for 18 shallow wells at four locations on Sea Pines. Notable is the elevated concentration of chloride (Cl) at each well. Background Cl concentration is probably about 4 mg/L (milligrams per liter). Hardee attributed the higher than background Cl concentration to contamination by seepage from wastewater disposal. A comparison of May and October 1980 data shows that at 12 of 16 sample locations the Cl increased in concentration (see Fig. 3). The seasonal increase in Cl is likely to be the result of salt concentration by evaporation from the water table. A concentration factor, defined as concentration for August or October, divided by concentration for May shows the greatest

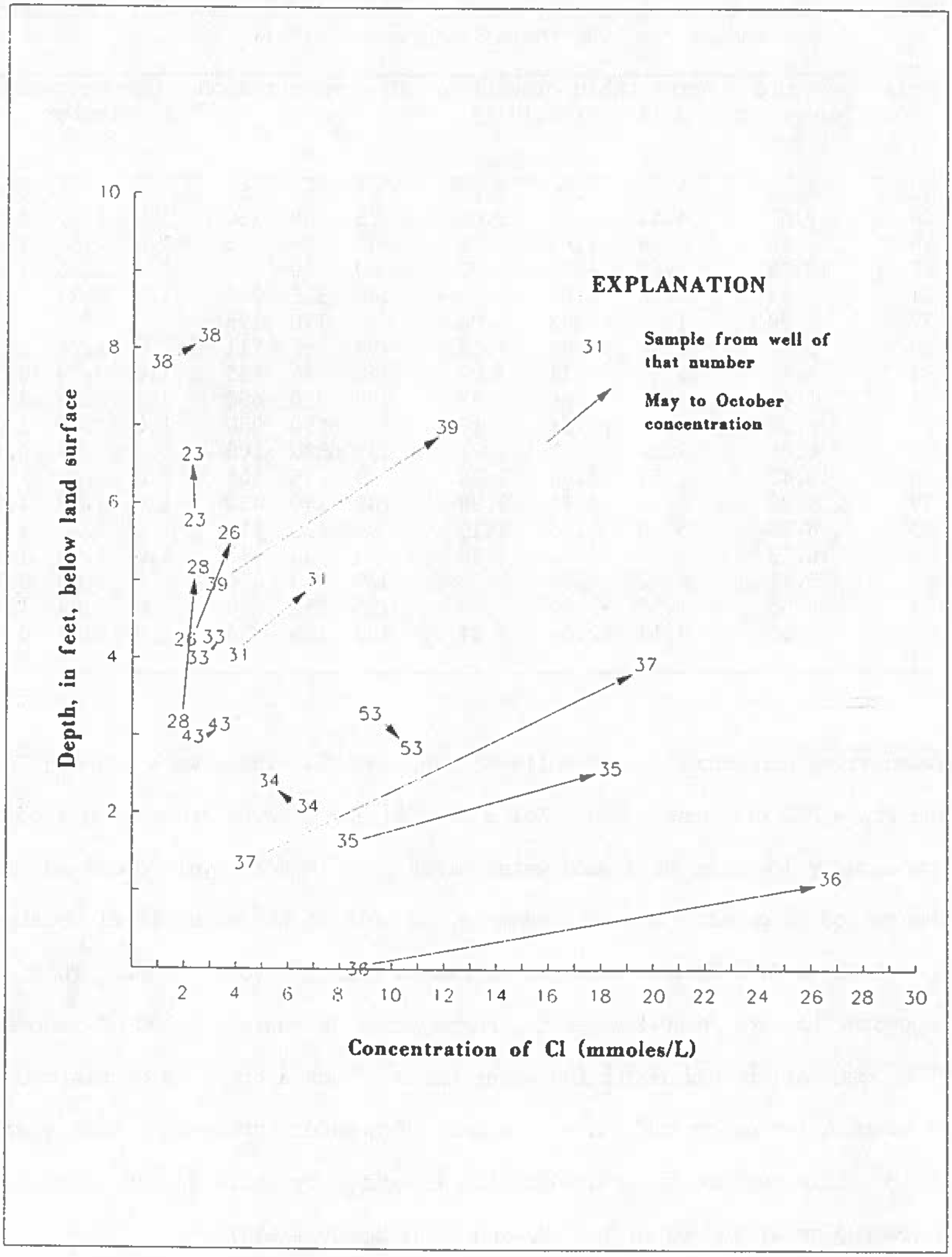

Figure 3. Chloride concentration (for May and October 1980) at various depths at Sea Pines.

Table 3. Water-table elevation, concentration of chloride, and concentration factor for 1980 (data from Hardee, 1981)

Well No.	Ground elevation (feet)	Water table elevation 5/14	8/06	10/13	Cl concentration (mg/L)			Concentration factor		
23	8.84	3.06	2.50	2.23	85	65	80	1.0	0.76	0.94
26	8.67	4.43	3.77	3.06	75	80	130	1.0	1.07	1.73
28	9.90	6.78	5.61	4.74	65	55	95	1.0	0.84	1.46
30	10.78	6.62	4.84	4.22	50	60		1.0	1.20	
31	7.34	3.30	2.85	2.33	145	325	250	1.0	2.24	1.72
32	4.99	1.28	0.83	0.94		170	195			
33	5.36	1.28	0.93	1.12	95	115	111	1.0	1.21	1.17
34	5.45	3.37	3.14	3.02	240	95	185	1.0	0.39	0.77
35	6.46	4.82	4.66	3.87	295	290	650	1.0	0.99	2.20
36	6.35	6.36	5.31	5.16	310	8500	950	1.0	27.42	3.06
37	8.85	7.49	6.39	4.91	155	6500	700	1.0	41.94	4.52
38	10.45	2.63	2.65	2.30	39	55	105	1.0	1.41	2.69
39	9.38	4.40	3.11	2.39	105	140	430	1.0	1.33	4.09
43	8.23	5.19	5.48	5.15	85	110	115	1.0	1.29	1.35
52	16.13		4.21	3.29	30	30	43	1.0	1.00	1.43
53	5.41	2.12	1.59	2.56	325	320	310	1.0	0.98	0.85
54	5.55	1.56	-2.80	-2.98	325	355	380	1.0	1.09	1.17
55	5.51	3.19	2.64	2.84	200	135	155	1.0	0.68	0.78

evaporative concentration at wells 35, 36, and 37. These were adjacent to the Sea Pines PSD effluent ponds. Wells 35, 36, and 37 were located in a topographically low area of ground water discharge. Water levels declined during the period of observation; for example, at well 35 the water level declined from 4.82 to 3.87 ft msl while Cl increased from 295 to 600 mg/L. This suggests that for ground water discharge areas there is a trend of increasing Cl concentration with declining water table. Such a trend is consistent with an evaporative concentration mechanism. Of greater interest to this study is the possible evaporative concentration indicated by wells 23, 26, and 28 (an unsewered area) and wells 38, 39, and 52 (a spray field).

Wells 23, 26, and 28 were screened from 4.5 ft to 7 ft below land surface (Hardee, 1981, Appendix "Drill Logs"). Chloride concentration increased from May to August at well 26 but decreased at wells 23 and 28. Chloride concentration increased from August to October at each of the wells. These changes suggest: 1) summer season rainfall for 1980 was sufficient to recharge the shallow aquifer, causing dilution of effluent by recharge water; and 2) late summer and early autumn rainfall was insufficient to dilute effluent, thereby allowing the mechanism of evapotranspiration to capture water from the water table at depths of nearly 6 ft (see, in particular, sample 26). The chloride concentration of treated wastewater is approximately 110 mg/L. Concentration of one sample, that of October from well 26, is at approximately this level. If the background concentration of Cl is assumed as 20 mg/L or less, these data suggest that the samples show effects of mixing of recharge water and water in storage continuously with evaporative concentration. The Cl in shallow ground water at depths of 4.5 ft to 7 ft can possibly be concentrated by a factor of 1.5 to 1.7.

Wells 38, 39, and 52 were located at the Sea Pines wastewater spray field. The site is a topographically higher area where water flow is driven by a larger gradient. Chloride accumulates by a factor of 1.4 from August to October in water from well 52. The initial concentration was low (30 mg/L) and water from well 52 may represent the local background condition. Well 52 was located on a dune ridge where depth to the water table is comparatively deep (11 ft) and little evaporative loss from the water table is possible. The Cl concentration factors at wells 38 and 39 are larger (2.69 and 4.09 times, respectively). At well 38 the concentration increased from 39 to 105 mg/L, while at well 39 chloride increased from 105 to 430 mg/L. In each instance, depth to water is likely a controlling variable in both starting concentration and concentration factor. At well 38 the depth to water declined from 7.8 to 8.2 ft, while at well 39 the depth to water declined from 4.98 to 6.99 ft. The greater concentration factor is in agreement with the shallower starting and ending water levels in well 39. The implications from these data are that wastewater applied by spraying can be concentrated in the soil zone by 1.4 times; water sprayed on a site with comparatively shallow water table by perhaps 4 times.

Hardee also presented Cl data for well 54 (see Table 3). The Cl concentration was, for the three times sampled, greater than 300 mg/L. The reason for these concentrations is not known. It may be downward transport of Cl as leakage from the wastewater storage ponds. The site, however, is in what was once a dune swale where the elevation is at 6 ft msl. Occasional salty water inundation, by storm flooding or wind-driven high tides, with subsequent downward transport of Cl, might also account for the observed concentration. Downward transport requires a downward gradient between the surface and depth 40 ft. A downward predevelopment gradient is not likely. The maximum age of the water in the 35 - 40 ft interval therefore is constrained to be no older than the length of time that a downward gradient has existed. This is about 50 years. This finding is in reasonable agreement with the observation of gradients suggesting coupling of the lower section of the shallow aquifer with the underlying upper Floridan aquifer.

Speiran and Belval (1985) reported water level, effluent spray rate, and water chemistry data for a site in the northern portion of Hilton Head Island. The data are illustrative of factors affecting ground water flow on a dune system. Further, they are illustrative of the scale of processes affecting flow and transport on Hilton Head Island. The site studied was approximately

21.8 acres; 14 acres were outfitted with spray heads and 7.8 acres were reserved. Speiran used 25 monitor wells, or about one well every 0.9 acre. Monitoring at this scale allows a sufficient density of wells to demonstrate that shallow ground-water flow will mimic the local topography (Figure 4a, and b). Site topographic elevations range from 15.6 ft down to 8.7 ft (elevation change of 6.9 ft). October 1982 water levels ranged from a high of 9.72 (where land surface was at 15.6 ft) to a low of 6.86 (where land surface was at 8.7 ft), for a total relief of 2.86 ft.

Hydraulic gradient is the change in water level divided by the length of flow path. It can have both horizontal and vertical components. Horizontal hydraulic gradients can be estimated by application of the Dupuit-Forchheimer assumptions with triangulation of adjacent water levels. Representative gradients from October 1982 ranged from 0.018 to 0.026. Vertical gradient can also be estimated. From level 6 ft to level 10 ft (for nest A, October 1982, see Table 4) a value of 0.003 is calculated. The usefulness of a calculation such as the previous one is tempered by the precision of the measure. The expected error is plus/minus one-half of the measurement interval; in this case plus/minus one-half of 0.01 ft, or 0.005 ft. Vertical gradient, therefore, can be from 0.001 to 0.005. In any case, vertical gradient for the upper 25 ft of the shallow section at this site is about one-tenth the horizontal gradient. Water level data show that various levels of the shallow aquifer are well connected in the hydraulic sense; water levels at all monitored horizons for nest A and nest E generally rise and fall together (Table 4).

Chloride is chemically conservative, and it can therefore serve the role of a tracer of the direction and rate of ground-water flow. Table 5

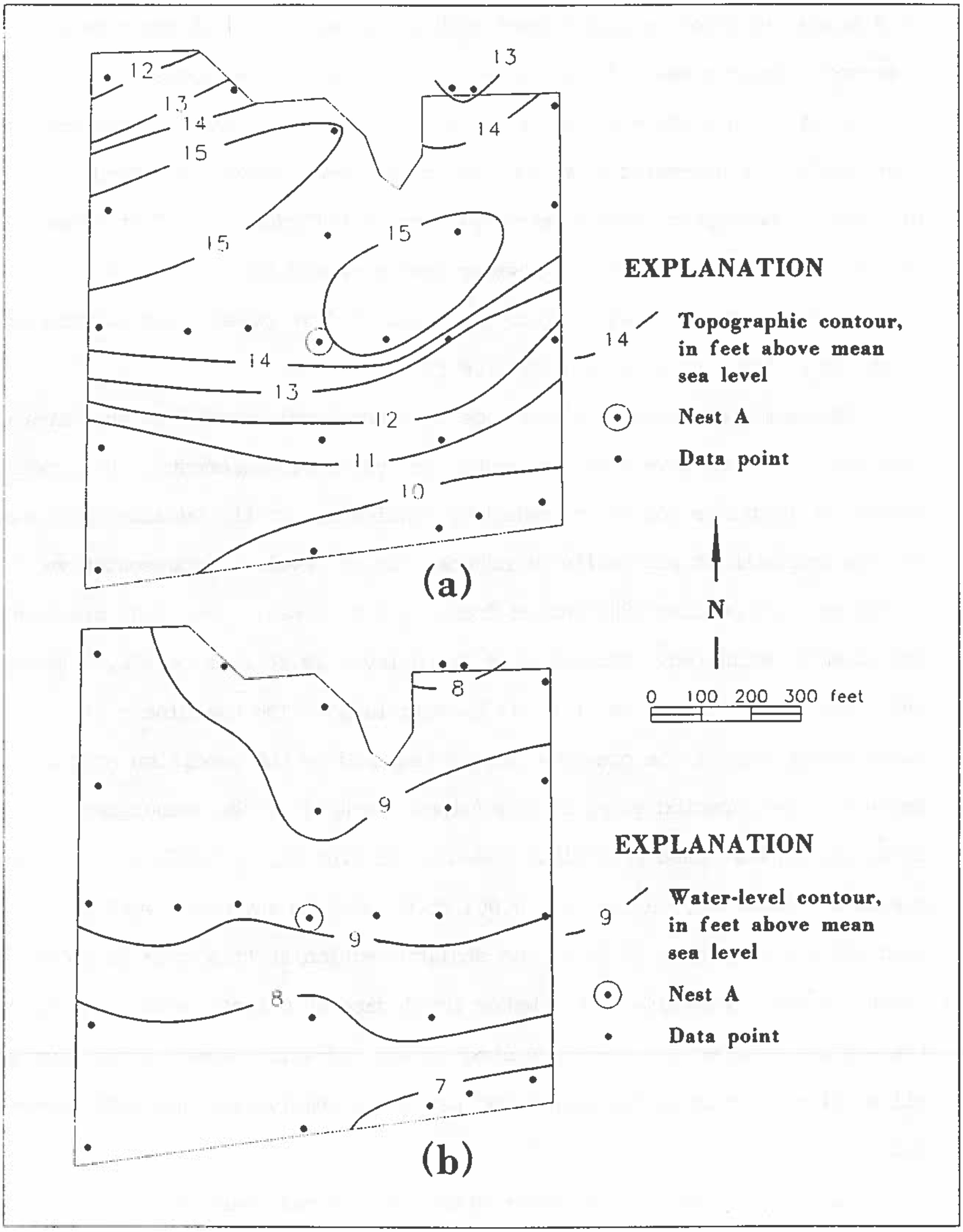

Figure 4. Topographic and water-level contour maps for October 26, 1982, at wastewater spray site.

Table 4. Water level data for well nests A and E

Date	Water level, in feet msl								
	A6	A10	A15	A20	A30	E5	E10	E15	E25
May 5, 1982	9.45	9.47	9.60	9.44	9.67		9.18	9.18	9.13
Sept 8, 1982	9.40	9.36	9.41	9.40	9.61				
Oct 26, 1982	9.23	9.22	9.23	9.21	9.16		9.06	8.75	8.90
Jan 26, 1983	12.16	12.17	12.16	12.23	12.31		8.87	8.86	8.78
March 1, 1983	11.88	11.83	11.82	11.90	11.61				
April 6, 1983						10.56	10.59	10.56	10.52
July 27, 1983	10.46	10.46	10.47	10.52	10.49		8.22	8.21	8.17
Aug 3, 1983	10.77	10.76	10.94	10.80	10.62		8.04	8.01	7.98
Aug 10, 1983	11.33	11.36	11.38	11.38	11.33		7.81	7.72	7.68
Aug 17, 1983	10.25	10.24	10.28	10.28	10.23		7.57	7.55	7.52
Aug 24, 1983	9.61	9.62	9.64	9.64	9.60		7.33	7.33	7.27
Aug 30, 1983	9.47	9.33	9.31	9.30	9.38		7.21	7.28	7.14
Sept 7, 1983	9.78	9.77	9.80	9.80	9.79		8.13	8.12	8.10
Oct 18, 1983	9.83	9.84	9.74	9.81	9.79		7.26	7.24	7.20
Nov 8, 1983	9.31	9.31	9.32	9.29	9.28				

Table 5. Chloride concentration in wells in nest A at wastewater spraying site

Date	Chloride concentration, (mg/L)				
	A6	A10	A15	A20	A30
Sept 9, 1982	4.1	17	8.8	11	15
Oct 27, 1982	3.9	17	9.6	14	20
April 5, 1983	110	27	26	13	19
April 27, 1983	110	25	23	15	
July 26, 1983	19	43	48		18
Aug 03, 1983	25	41	41		17
Aug 10, 1983	26	36	40	14	17
Aug 17, 1983				14	18
Aug 23, 1983	24	28	53	14	17
Aug 30, 1983	19	26	57	15	17
Sept 7, 1983	21	23	59	15	17
Dec 20, 1993	180	21	46	30	18
Jan 23, 1984	160	21	42		18

summarizes Cl data for nest A. The Cl concentration of the wastewater was about 110 mg/L (Speiran and Belval, 1985, Table 3). Aquifer background Cl concentration was reported as about 4 mg/L (Speiran and Belval, 1985, Table 3). The general trend is increasing concentration at increasing depth as a function of the passage of time. This trend can be used to constrain the minimum vertical transport time for the site. During January 1983, 10.8 inches of effluent was applied. A change in Cl concentration from backgroundwas measured for the first time at depth 15 ft on April 26, 1983; Cl was found at a concentration of 26 mg/L. The minimum vertical distance for transport is 9 ft, thus the Cl front traveled about 9 ft in 4 months, for an estimated minimum rate of 0.08 ft/day.

Concentration is affected by rainfall and evapotranspiration and the mixing of sprayed wastewater and ambient aquifer water; generally rainfall and mixing dilute the concentration. Chloride was recorded at concentration 110 mg/L on April 5 and 27, 1983. Spraying of 6.45 inches of wastewater preceded these samples. During the same period, about 5 inches of rainfall was recorded (unpublished SCDNR data). The concentration of Cl in rainfall is probably about the same as that of the most shallow ground water, noted previously as 4 mg/L. The Cl concentration of a mixture of wastewater and the assumed precipitation is 70 mg/L. During April, water is evapotranspired from the soil zone. The long-term average pan evaporation at Savannah is 8.5 inches (written communiation, SCDNR-WRD, Climatology Section). The long-term evapotranspiration from soil is variously estimated as 0.7 to 0.8 pan evaporation or 5.9 to 6.8 inches. Thus, the measured concentration of 110 mg/L, rather than being 100 percent wastewater, is more likely a mixture of effluent and rainfall affected by evaporation. The result is that Cl is concentrated in the shallow ground water by a factor of 1.57.

During the period April 27 - July 26, 8.4 inches of wastewater was sprayed on the site. During the same period 7.4 inches of rainfall fell on the site (unpublished data for rain gage 384169). The concentration of Cl, assuming complete mixing and no evaporative concentration of water for the 3-month period, would be about 60 mg/L. The measured Cl concentration in well A6 on July 26 was 19 mg/L. Rainfall from July 1 to July 26 totaled 5.0 inches, while wastewater application totaled only 0.5 inch. The anticipated concentration of the mixture, considering only July moisture (about 8 percent wastewater), is 14 mg/L. Thus, rainfall and wastewater mixing could account for the observed concentration on a time scale of about 25 days. However, average July pan evaporation is about 9 inches at Savannah and the probable soil zone evaporation is between 6 and 7 inches. The available moisture, therefore, would possibly have been consumed by soil-zone evaporation. July rainfall included three storms that dropped more than 0.1 inch of rain (SCDNR unpublished data). About 2 inches of rain fell on July 5 and July 6 and 3 inches on July 23. The likely reason for the low Cl reading is the small July application rate and the flushing effect of the rainfall. The rains of July 5 and 6 possibly flushed the accumulated salts from May and June dry weather. The rainfall of July 23 added a spike of freshwater to the water table. With this reasoning, the time scale of the soil zone processes affecting Cl transport is less than 14 days.

Rainfall during August totaled 2.6 inches, while wastewater application totaled 9.9 inches. The anticipated concentration of the mixture (77 percent wastewater, 23 percent rainfall) is about 86 mg/L. Data however, show shallow ground water Cl concentration closer to 25 mg/L (Table 5). A dilution factor can be calculated and used to estimate just what rainfall amount would be necessary to achieve observed results. The observed concentration of 25 mg/L Cl would have to be a mixture of 20 percent wastewater and 80 percent rainfall. The necessary rainfall would be 42 inches, which is physically unreasonable. The volume change cannot be accounted for entirely by deeper transport. The downward gradient remained small, 0.01 ft between the water levels in wells A6 and A10 (see Table 4). The most likely explanation for why Cl is not detected is that it is stored in soil-zone water that is nearly motionless. The total input of effluent (at 0.71 inch per week) and rainfall is insufficient to supply a flow that recharges the water table when rainfall is scarce. More importantly, Cl will be flushed from the soil whenever recharge water reaches the water table. The reported Cl concentration for the following December was 180 mg/L.

The climatology staff of the South Carolina Water Resources Commission (now the SCDNR-WRD) showed the variability in summer season precipitation spatially and in intensity. They established five rain gages on Hilton Head Island (see Fig. 1). Annual rainfall in 1986 ranged from 41.02 inches at the Hilton Head Airport to 59.07 inches at the Sea Pines Fire Station Number 2. These two stations are about 5 miles apart. The principal difference in measured precipitation between the sites results from differences in summer season precipitation: Sea Pines Fire Station Number 2 recorded 7.00 and 8.70 inches in June and August while Hilton Head Airport recorded 3.50 and 3.40 inches. Pan-evaporation measurements at Savannah, Georgia, for the same period were 8.52 and 7.51 inches, respectively; there was, by water balance calculation, a net deficit of water for June and net surplus of water for August at Sea Pines Fire Station Number 2 (-1.52 and +1.21 inches). There was net deficit (-5.02 and -4.11 inches, respectively) at the Airport. Their observations suggest that management of the shallow aquifer as an irrigation source, if coupled to precipitation measurement, will have to be undertaken at a scale less than island-wide in area.

Westinghouse Environmental recorded several observations useful in understanding the hydrology of the shallow aquifer. Their data (Table 6) show that water levels in the deeper sand aquifer are at lower elevations than water levels in the uppermost sand. Further, the deeper aquifer at Palmetto Headlands shows a higher potential than the deeper aquifer at Palmetto Dunes; water level at Palmetto Dunes in the lowermost aquifer is at a level nearly equal to sea level. This suggests that the lowermost section of the shallow aquifer at Palmetto Dunes is hydraulically connected to the underlying upper Floridan aquifer at this site.

Water from well AH-2 at Palmetto Dunes is reported brackish. The concentration of Cl when sampled was 530 mg/L. Chloride concentrations in wells AH-1 and AH-3 were higher than expected, being 90 and 130 mg/L, respectively. Westinghouse Environmental attributes the Cl in the shallow aquifer to possible leakage of brackish water from the adjacent drainage canal.

The reported transmissivity for AH-1 is approximately 1,200 ft^2/day. The sand producing the water has an estimated thickness of 19 ft; calculated hydraulic conductivity therefore is 64 ft per day. A sand unit of this conductivity cropping out in a nearby saltwater body, coupled with water levels nearly at sea level, can possibly be contaminated by naturally existing seawater intrusion.

Table 6. Water levels at Arthur Hills Golf Course and Palmetto Headlands test well sites

Well	Elevation LSD	Height of MP above LSD	Elevation of MP[1]	Measured depth to water	Water level	Screened interval
AH-1	8	1.5	10	10.75	0.	50 - 60
AH-2	10.6	2.6	13.17	13.40	-0.23	55 - 65
AH-3	10	2.0	12	15.41	-3	61 - 65
AH-4	9	1.0	10	3.26	7	18 - 28
AH-5	7.7	3.3	11.04	12.12	-1.08	51.5 -60.5
PH-1	14	3.6	18	14.87	3	42 - 52
PH-2	13	3.45	16	12.47	4	52 - 62
PH-3	14	3.4	17	4.92	12	12 - 22
PH-4	14	2.7	17	13.82	3	43 - 53

[1] Elevation of MP for wells AH-2 and AH-5 determined by leveling; remainder estimated from topographic map. All measurements are in feet.

Studies of Similar Hydrologic Environments

Wolaver and Williams (1986) studied the water chemistry of runoff from a 1,000-acre coastal watershed in Georgetown County, S.C. From their data, one can conclude that pH, molar concentration of Ca, and molar concentration of alkalinity inversely correlate with stream discharge. This implies a short residence time for water in the watershed. Storm events result in the highest discharges, and the maximum flow following rainfall was about 45,000 m^3/day (18 cfs). On average, the 1,000-acre watershed yielded a flow rate of about 5,000 m^3/day (2 cfs). Streamflow has a seasonal distribution related to seasonal difference in rain and ET. December, January, and February flows are in the range of 10,000 m^3/day (4 cfs), and May - August flows are too small to plot at their scale (except for days following storms). Runoff of 2 cfs averages 0.004 ft/day per ft^2 of land area. This is 1.4 ft/year. Four cfs during the December - February period is a flow averaging 0.08 ft/day per ft^2 of area, or 7.5 inches during that period. It is perhaps noteworthy that this value is approximately the average rainfall rate for the wet season.

Otvos (1984), working on Santa Rosa Island, Florida, determined that sealevel was at -22.5 m, or 74 ft below its present level, some 9.5 thousand years ago. He references that this is in good agreement with Delaware shore lines for the same era. It should be noted that this is approximately the elevation of the top of the Hawthorn Formation beneath Hilton Head Island.

GEOLOGY

Background

Sediments of Pleistocene and Holocene ages compose Hilton Head Island. McCarten and others (1990, p. A6) dated the age of the section forming the northern part of the Island as Pleistocene with an age of about 100,000 years before the present. The beach ridges commonly forming the eastern part of the Island (Fig. 5) and the shoreline deposits associated with Broad Creek are dated as about 7,000 years (McCarten and others, 1984; May, 1984). McCarten and others related these ages to times of glacial melting and higher sea level. The sediments forming Hilton Head Island rest on top of a 3,500-ft sequence of sediments (Hughes and others, 1988).

McCarten and others (1990) described a Pleistocene - Holocene stratigraphy encompassing seven lithostratigrahic units. These units are derived from analogy with the barrier island processes observable today. Each unit is categorized as being composed of beach deposits, backbarrier deposits, and shelf deposits, designated Q_b, Q_1l, and Q_o, respectively. The age of each deposit is designated by a number. To illustrate, Holocene beach deposits of 7,000 years (time unit 1) are designated by Q_{1b}. Likewise, beach deposits from 100,000 years past (time unit 2) are designed Q_{2b}. The defining elements of their lithostratigraphic units are: 1) vertical and lateral succession of depositional types (lithofacies) within a lithostratigraphic unit; 2) elevation with respect to present-day sea level; 3) sedimentary texture (grain size, grain shape, and sorting); 4) sedimentary structure (bedding, cross lamination, mineral laminae); 5) shape of deposit; and 6) presence or absence of fossils.

The lateral succession of units is: 1) shelf, 2) beach, and 3) backbarrier. Preserved beach is the topographically highest deposit. Dune ridges associated with beaches formed during the last 7,000 years are at about 12 ft above present day mean sea level. Those from 100,000 years ago are higher, to about 20 ft on Hilton Head Island. Backbarrier is the next topographically higher unit. The maximum elevation for the deposits from 7,000 years is about 6 ft. For the late Pleistocene barrier deposits the maximum elevation is about 16 ft. Shelf is always less than sea level at time of deposition; modern shelf is from about -15 to perhaps -50 ft below present mean sea level. Shelf from 100,000 years occurs from about -3 ft msl to -40 ft msl.

The unit Q_{2b} consists of well-sorted, fine- to medium-grained quartz sand. Topographically it is found at elevations upward to 24 ft. The top 7 ft of Q2b is humate-rich massive sand. Below 7 ft the unit is a sand containingheavy mineral laminations with festoon cross-bedding. Festoon cross-bedding is a repeating sequence of concave upward bowl-like structures composed of fine-sand ripples filled with mud and which are subsequently planed to a level surface. Typical colors are light tan to pale orange (Munsell Rock-Color Chart, shades of hue 10YR and 7).

Unit Q_{2o} consists of shelly, gray, fine- to medium-grained quartz sand with a mud matrix and thin clay layers. Typical colors are blue gray to green gray (Rock-color chart hues 5B - 5GY). Unit Q_{2o} in some places contains fossil foraminifers (see comment by McCarten and others, 1990, p. F2).

Unit Q_{21} consists of muddy quartz sand with clay, shell, and sand layers. Typical colors are gray to yellow to bright orange (Rock-color chart hues N/3 and higher to 5Y). A unit of age 200,000 years, designated Q_3 is similar in lithology. It has been mapped according to stratigraphic position and fossil assemblge. Unit Q_{3o} possibly occurs in the subsurface of Hilton Head Island. It is described (McCarten and others, p. A14) as a "muddy, fine-grained quartz sand". The sand contains locally mud lenses (USGS, Map I-1472, Table 3). Typical colors for Q_{3o} sand are tan to yellow (Rock-color chart hues 5Y), and mud gray, yellow, and orange (Rock-color chart hues 5YR).

Shallow-Section Geology

Core descriptions, grain-size analyses, sediment colors, and occurrence of fossil foraminifers for nine test holes are tabulated in Appendices I and II. Moment analyses of the core data are included in Appendix III. No one type of data is sufficient to define a lithostratigraphic unit in the subsurface of Hilton Head Island. Together, these data and the mapping criteria allow a description of geology at the lateral scale of nine holes in a 24-mi^2 area. Core sample standard deviation is derived from the measure of sample variance, which physically is a measure of the dispersion of the sample from the mean, that is, a measure of the sorting or lack thereof. Table 7 lists the ranges of standard deviation and the corresponding description of sorting (Blatt and others, 1976). Deposits Q_{2b} are, by definition, well sorted; mapping units Q_{2o} and Q_{21} are more variable, and are not well sorted, thus moment analyses with standard deviations of 0.5 or less are presumed to be beach deposits.

The surficial geology of Hilton Head Island is shown on Figure 5. Four

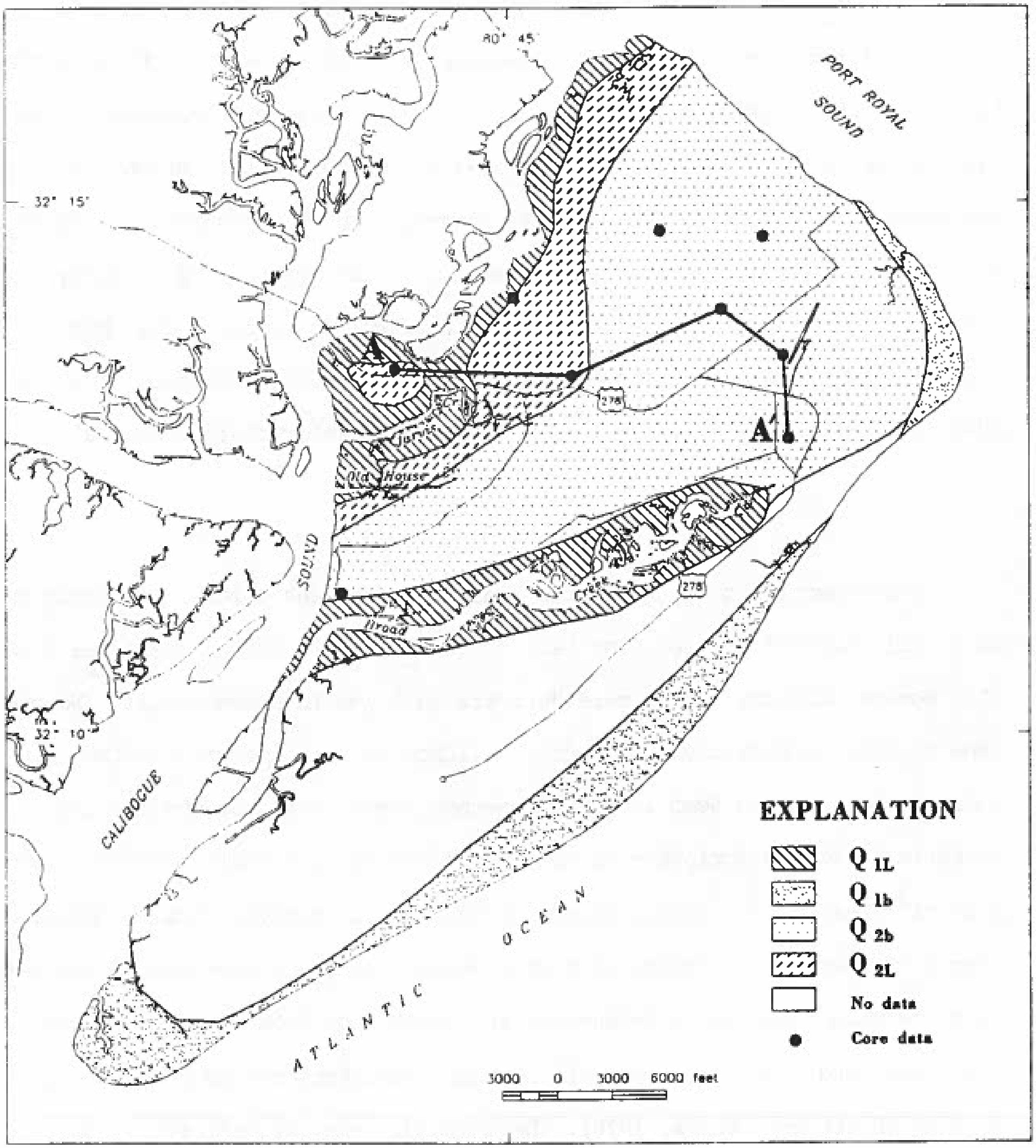

Figure 5. Surficial geologic map of Hilton Head Island.

Table 7. Sorting based on measured standard deviation (from Blatt and others, 1972, p. 60)

Standard deviation	Description
0.0 - 0.35	very well sorted
0.35 - 0.50	well sorted
0.50 - 0.70	moderately well sorted
0.71 - 1.00	moderately sorted
1.00 - 2.00	poorly sorted
2.00 - 4.00	very poorly sorted
4.00 -	extremely poorly sorted

lithostratigraphic units are drawn. Contact boundaries are as follows: the boundary between Q_{1b} and Q_{2b} is adapted from Figure 1 of May (1984, p. 5). The boundary between Q_{2b} and Q_{2l} is drawn along the bearing N30E, which is the approximate strike of the westernmost dune ridges. Unit Q_{1l} is restricted to the shores of Broad Creek and the tidal creeks draining into Calibogue Sound.

Elevation of each unit is included in the interpretation. Q_{1b} ranges from sea level to about 12 ft along the contact with unit Q_{2b}. The contact of unit Q_{2b} with unit Q_{2l} is drawn where the elevation is about 16 ft msl. The area shown as unit Q_{1l} is not intended to include land above 9 ft msl.

Figure 6 shows a section constructed with drill-hole data from five of nine test holes. The section assumes the plane of Q_2 beveling to be at approximately -35 ft msl. Rocks below -35 ft have variable descriptive characteristics. They are typically like mapping unit Q_{3o}, and the section is drawn that way. As the elevation of the plane of beveling is unclear, this is by no means the only interpretation.

McCarten and others (1984, sheet 2, test hole 79) mapped the contact of Tertiary-Pleistocene (T_m-Q_{2L}) sediments at -63 ft msl on Jenkins Island. Their test hole 79 was about 2,000 ft from SCDNR-WRD test hole 28KK-i11. Test

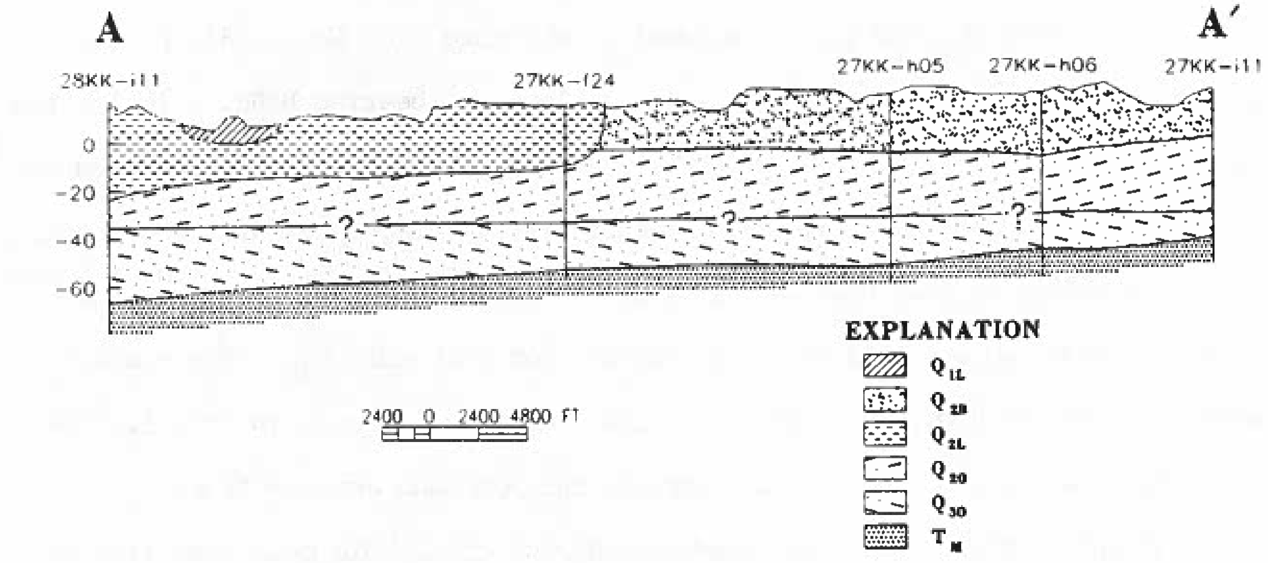

Figure 6. Geologic section of surficial geology.

hole 28KK-i11 bottomed at about -62 ft msl and the contact T_m-Q_2 was not encountered. The T_m-Q_2 plane of beveling was mapped as -33 ft msl on St. Helena Island, 12 miles northwest of test boring 28KK-i11 (McCarten and others, 1984, sheet 2, drill holes 10 and 11). This 30 ft difference in the base level of the shallow section north of Port Royal and south of Port Royal Sound presents a quandry. The strike (axis) of the preserved dune ridges associated with unit Q_{2b} on Hilton Head and St Helena islands is approximately N30E. The strike of the dunes of unit Q_{1b} on Hilton Head Island and nearby Prichards Island is about N45E, thus the sea of Q_2 time perhaps locally eroded the ancestral coast from a more easterly direction. Test holes 10 and 11 are approximately along strike from test hole 27KK-h5 assuming a N30E strike for the late-Pleistocene coastline. The contact T_m-Q_2 was recovered from core at 27KK-h5 at about -58 ft msl.

Sea level was about 300 ft lower than present some 150,000 years ago (Meisler and others, 1984). It was 74 ft lower about 9,500 years ago (Otvos, 1982). Rivers approaching the ancestral coast at Hilton Head Island would probably have had some tendency to meander. The removal of a 30-ft section of pre-Q_2 sediments on Jenkins Island is possibly a result of stream erosion by ancestral Skull Creek during any of the glacial eras preceding Q_2. Erosion by ancestral Skull Creek will not explain the topographically lower contact at test hole 27KK-h5 unless the more northern area of the Island was also eroded by pre-Q_2 aged streams. The modern location of Port Royal Sound suggests this to be plausible.

The Tm-Q contact at test hole 28KK-v5 was found to be at elevation -35 ft msl. This interpretation is based on lithology, rock color, and occurrence of fossil foraminifers (Appendix II). This topographic level is consistent with the finding on St. Helena Island. This finding, however, will not uniquely date the age of the post-Hawthorn time erosion on Hilton Head Island. There are five marine terraces along southern South Carolina, constructed during times of higher sea level, that are older than unit Q_2. Any combination of the events of construction, subsequent erosion, and limited preservation could have produced the the post-Hawthorn Group surface. Other geological processes can also account for a 30-ft difference in elevation of base level. These include differential long-term consolidation of the entire sedimentary section and/or a combination of consolidation and faulting. The writer knows of no data suggesting consolidation or Pleistocene-age faulting in the area.

Shallow-Aquifer Base

The rocks immediately underlying the Pleistocene section, physically delimiting the base of the shallow system, are of the Hawthorn Group. Eight of the nine test holes drilled in 1989 at least partly penetrated Hawthorn Group sediments. In these holes the base of the shallow system is marked by a lithologic and color change in sediments; typically the color changes from blue (Munsell color chart hues 5B) to a shade of olive-gray (Munsell color chart hues 10Y). According to Hughes and others, (1988, figure 7, p. 14) the Hawthorn Group is found at about 40 ft below sea level on the north end of the island and dips to about 70 ft msl at Sea Pines. More recent data (Table 9) show a different surface locally (Figure 7). The maximum elevation at the top of the Hawthorn Group is at 28KK-v5 where the Hawthorn was recovered at elevation -34 ft. The minimum elevation is at 27KK-c3 where the top of the Hawthorn Group is at -67 ft. The writer has interpreted the surface as a

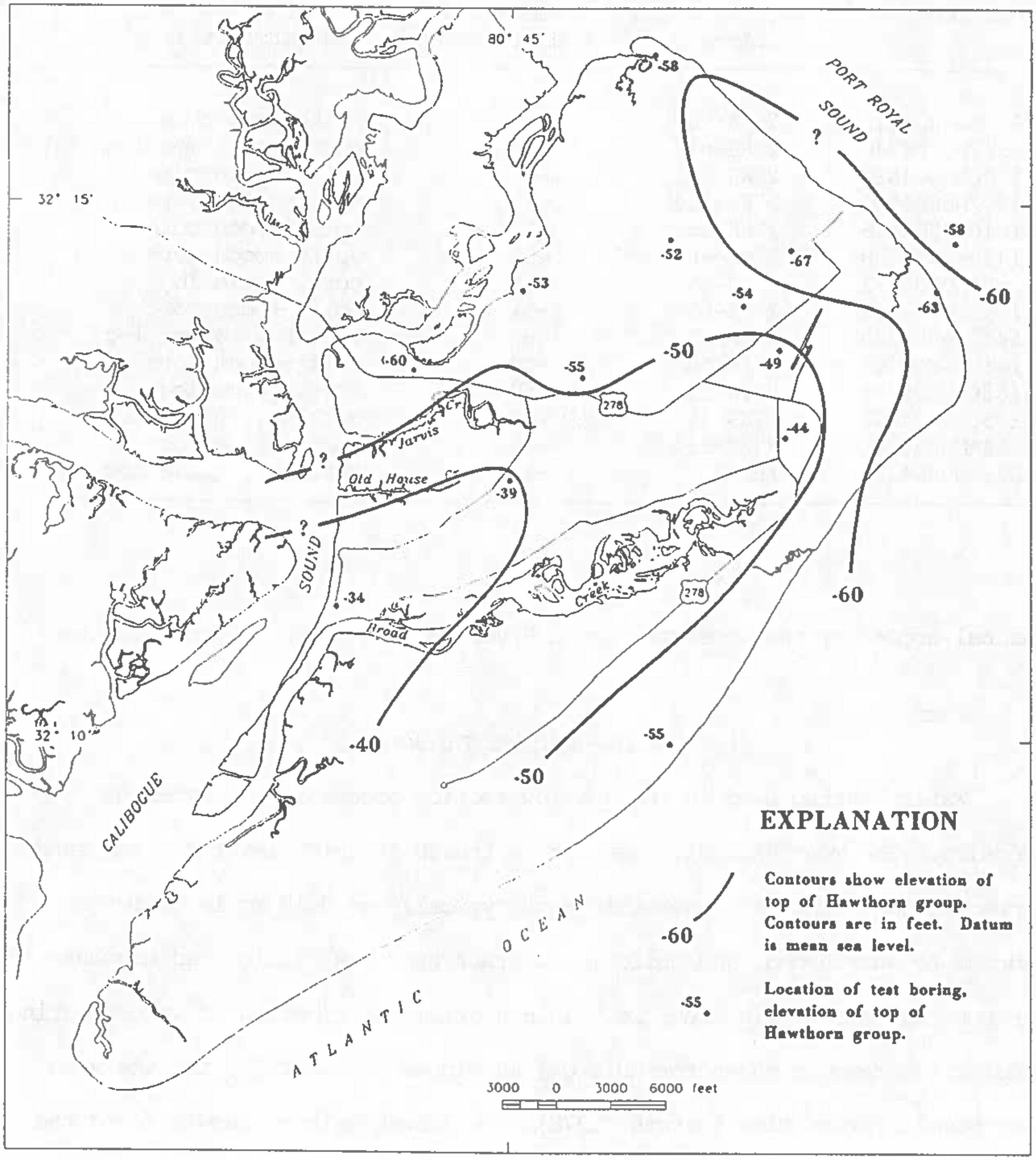

Figure 7. Structure map of underlying Hawthorn Group.

Table 8. Data used to construct contours on top of the Hawthorn Group

Location	Well or boring number	Elevation top of Hawthorn	Method of determination
321306N0804612	28KK-v5	-34	split-spoon core
321212N0804346	27KK-n17	-39	cuttings, gamma log
321306N0804612	28KK-i11	<-60	split-spoon core
321302N0804410	27KK-f24	-55	split-spoon core
321410N0804445	27KK-e6	-53	split-spoon core
321430N0804328	27KK-d6	-52	split-spoon core
321603N0804322	27JJ-q9	-58	core, gamma log
321310N0804205	27KK-h5	-54	split-spoon core
321412N0804220	27KK-c3	-67	cuttings, gamma log
321610N0804205	27KK-h6	-49	split-spoon core
321636N0804242	27JJ-r1	-58	core, gamma log
321358N0804038	27KK-j5	-63	cuttings, gamma log
321244N0804201	27KK-i11	-44	split-spoon core
320939N0804335	AH2	-55	cuttings, gamma log

channel eroded by the ancestral Broad River and has drawn it accordingly.

Shallow-Aquifer Thickness

Water-bearing sand in the shallow section occurs in two types of deposits. The most extensive deposit is the 30-ft thick layer of fine sand mapped as Q_{2b}. The data show this sand typically as 0.15 mm in diameter, rounded to subrounded, and uniform. Coarser sand was not located anywhere in the section, and shells are rare. This spatial distribution of water-bearing sand is the same as shown for unit Q_{2b} on Figure 5. Unit Q_{1b} is likely to have similar properties (Barwis, 1978). On Kiawah Island, Barwis found the section to be only about 20 ft thick, and its thickness on Hilton Head Island remains uncertain.

A second aquifer is located in the unit mapped as Q_{2o}. Data show unit

Q_{2o} as variable in thickness. Sand beds are thin, and the sand is fine grained. Coarser sand, typically 0.20 mm and locally to 0.35 mm, is found throughout unit Q_{2o}. Sorting is moderate to poor, and the sand typically has thin interbeds of clay. In addition, sand beds themselves typically display matrix clay. Sufficient data to draw the distribution of water-bearing sand in unit Q_{2o} are not available.

WATER CHEMISTRY

Water chemistry data from five shallow wells drilled by The South Carolina Water Resource Commission (SCWRC) in 1989, plus water chemistry data from nest A of Speiran and Belval (1985, Table 3) are available. Data for the SCWRC wells including number of screens, screen lengths, and depths are included in Appendix I. Four of the five SCWRC wells are screened in more than one layer. Analyses from multiscreened wells are difficult to interpret because the samples are mixtures of unknown amounts. The analyses are, however, instructive of the water chemistry that can be expected if wells are drilled and developed, and some interpretation of data is therefore warranted.

Vertical Profile

Data from well nest A, drilled by Speiran and Belval (1985), are used to examine the chemical evolution of the water in a vertical profile to depth 30 ft. The dune ridge setting is common to a large portion of Hilton Head Island. Analysis of the data for the five wells follows. Data for nest A (Table 11) are plotted on a trilinear diagram (Fig. 8). Shown also are reaction paths, starting with a hypothetical rainfall water. The hypothetical rainfall is constructed by assuming the ionic concentration to be a dilute

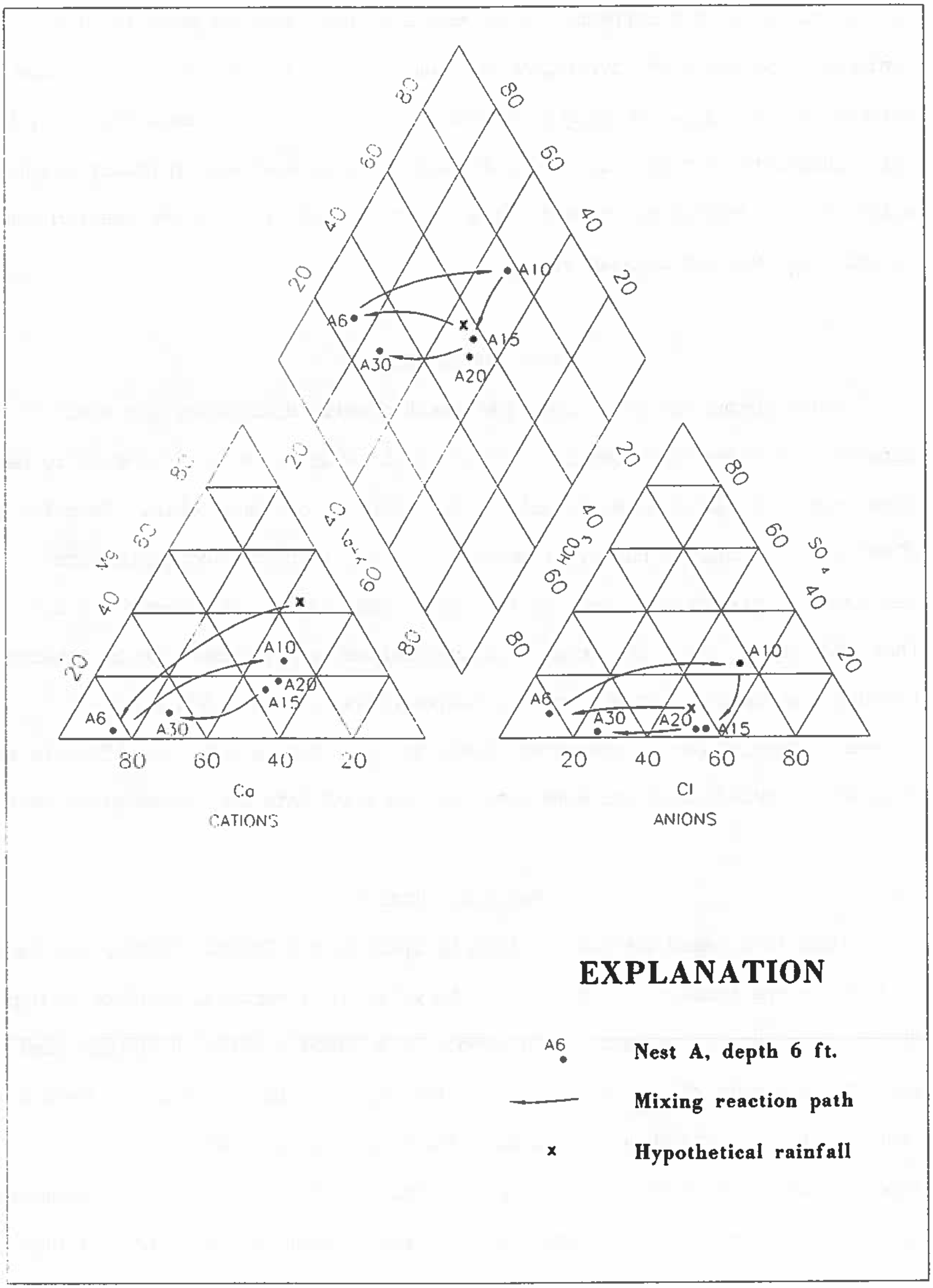

Figure 8. Trilinear diagram of water from A6, A10, A15, A20, A30.

Table 9. Water chemistry for nest A, Speiran and Belval (1985)

Well	Cations (mg/L)					Anions (mg/L)		
	pH	Ca	Na	K	Mg	Cl	SO_4	Alk[1]
A6	6.2	20	3.5	<0.1	0.47	4.1	5.0	48.58
A10	5.8	4.5	10	<0.1	2.8	17	10	10.16
A15	5.8	3.1	5.0	<0.1	0.79	8.8	<1.0	9.33
A20	5.8	3.8	7.0	0.5	1.3	11	1.0	14.07
A30	5.8	22	9.4	0.5	2.0	15	1.0	61.62
Rainfall[2]	5.2	0.02	0.53	0.01	0.12	0.62	0.06	

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[1] Derived by calculation of ionic balance

[2] Equilibrium with CO_2

Table 10. Water chemistry data from Hilton Head Island, June 20 and August 30, 1990, respectively

Well	Chemial constituent (mg/L)								
	pH[1]	Ca	Na	K	Mg	Fe	Alk[2]	SO_4	Cl	SiO_4
27KK-e6	7.69	47.2	10.9	1.2	2.8	0.079	145.0	0.79	19.43	3.48
27KK-h6	6.38	10.6	4.8	0.52	1.56	0.695	39.0	3.06	5.45	8.22
27KK-f24	5.80	7.6	11.8	0.41	5.12	1.66	19.0	34.2	23.7	4.81
27KK-i11	5.02	4.4	26.9	4.7	0.67	0.499	29.0	31.26	17.98	
27KK-c3	5.76	1.6	6.8	1.2	1.73	1.020	7.0	3.41	15.94	0.83
27KK-e6	7.77	40.6	10.9	1.1	2.47	0.011	141.0	0.73	18.47	3.1
27KK-h6	7.11	12.08	3.4	0.67	1.90	2.563	32.0	3.69	5.39	0.8
27KK-f24	4.79	26.3	17.7	1.1	14.03	8.586	2.0	137.2	32.2	0.86
27KK-i11	5.93	7.2	16.2	4.1	1.68	2.936	12.0	16.68	12.82	3.19
27KK-c3	4.10	1.26	5.3	0.18	1.82	0.203	1.5	13.47	13.47	0.57

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[1] pH is a field measurement except for well 27KK-c3. Field notes record that the meter did not stabilize for samples 27KK-i11 (5.02). Further notes document the measurement for 27KK-c3 (4.10) as a laboratory measurement made approximately 3 hours after sampling. pH was 6.44 and 5.76, respectively, after long-term storage.

[2] Alkalinity, as listed, is a laboratory measurement.

solution derived from seawater. Chloride is assumed at a concentration of 0.62 mg/L (Drever, 1982, p.4), and the other constituents are in balance. If data from well A6 are momentarily not considered, the cation composition of the water from nest A evolve from a solution dominated by Na and Mg (A10, A15, A20) to a solution dominated by Ca (A30). The cation composition of the hypothetical rainfall and the cation evolution path of the nest A water are in good agreement in the sense that evaporated seawater should contain a higher concentration of Mg and Na than of Ca. The path shows concentration of Ca increasing with well depth.

Anion composition shows a similar evolutionary path. The water evolves from a Cl and SO_4 water (sample A10) with 55 percent Cl and 24 SO_4 to a HCO_3 and Cl solution (A15) with 55 percent Cl and 44 percent HCO_3, and finally to a HCO_3 water (A30). Water from well A6 does not fall on this evolutionary pathway; the key difference is in the concentrations of alkalinity and SO_4.

Alkalinity concentration is highest at depths 6 and 30 ft (Fig. 9). It decreases from 6 ft to its minimum value at 15 ft. High alkalinity concentration would be expected at the water table, owing to the decay of organic matter by soil-zone bacteria. Decay is a respiration process, and so long as O_2 is available, CO_2 is liberated; one possible reaction (Freeze and Cherry, 1979, p. 117) is:

$$\text{Organic matter} + O_{2(g)} = CO_2 + H_2O.$$

where organic matter is represented by CH_2O. The increase in carbon dioxide in solution forms a weak acid in water which at greater depths (30 ft) probably dissolves shell matter ($CaCO_3$) thereby increasing alkalinity and pH. One set of possible reactions (Drever, 1979, p. 35, 36, 55) is:

$$CO_{2(g)} + H_2O = H_2CO_3$$

$$H_2CO_3 = H^+ + HCO_3^-$$

$$CaCO_3 + H_2O + 2H^+ + CO_3 = Ca_{+2} + 2HCO_3 + H_2O.$$

This reaction consumes H^+, which is in agreement with the reported rise in pH.

Sulfate concentration increases from 5 to 10 mg/L from A6 to A10, then it decreases to nearly zero by A15 ft (Fig. 9). This is interpreted to mean SO_4 is reduced to the sulfide form during anaerobic reduction of orgnic matter. One possible reaction (Drever, 1982, p. 281) is:

$$CH_2O + 2SO_4 + 2H_2O = H_2S + 2HCO_3.$$

The concentrations of Cl for wells A6, A15, A20, and A30 fall on a straight line (Fig. 10). Further, the log equivalent-weights of Na and Cl plot on a straight line parallel in slope to an evaporation line, assuming A6 as the starting value. The Cl value from well A10, not falling on the well A6 to A30 line, probably shows the effect of evaporation and subsequent soil-zone flushing. Water flow and consequent Cl transport are dependent on the hydraulic conductivity of the soil and the head. Hydraulic conductivity is, in turn, affected by the amount of water in the soil (Freeze and Cherry, 1979, p. 42). As the soil dries from evapotranspiration, the hydraulic conductivity decreases. Chloride accumulates in the practically immobile soil water during the evaporation process. When the soil is again wetted, the accumulated Cl is flushed, causing the concentration of Cl at the water table to increase. That the most dilute water is at A15 is interpreted to indicate that complete mixing of water does not take place by depth 15 ft, that is, the water travels as a discrete slug by the mechanism sometimes noted as piston flow. The more dilute water is likely to be cool season recharge water. Assuming that it dates from the previous month of March implies that the water travels downward about 10 ft in 6 months for an average vertical velocity of 0.06 ft/day.

Calcium and CO_3 can be precipitated as calcite ($CaCO_3$) in pore space if the evaporative concentration exceeds 2 (Drever, 1982, p. 202). The solution

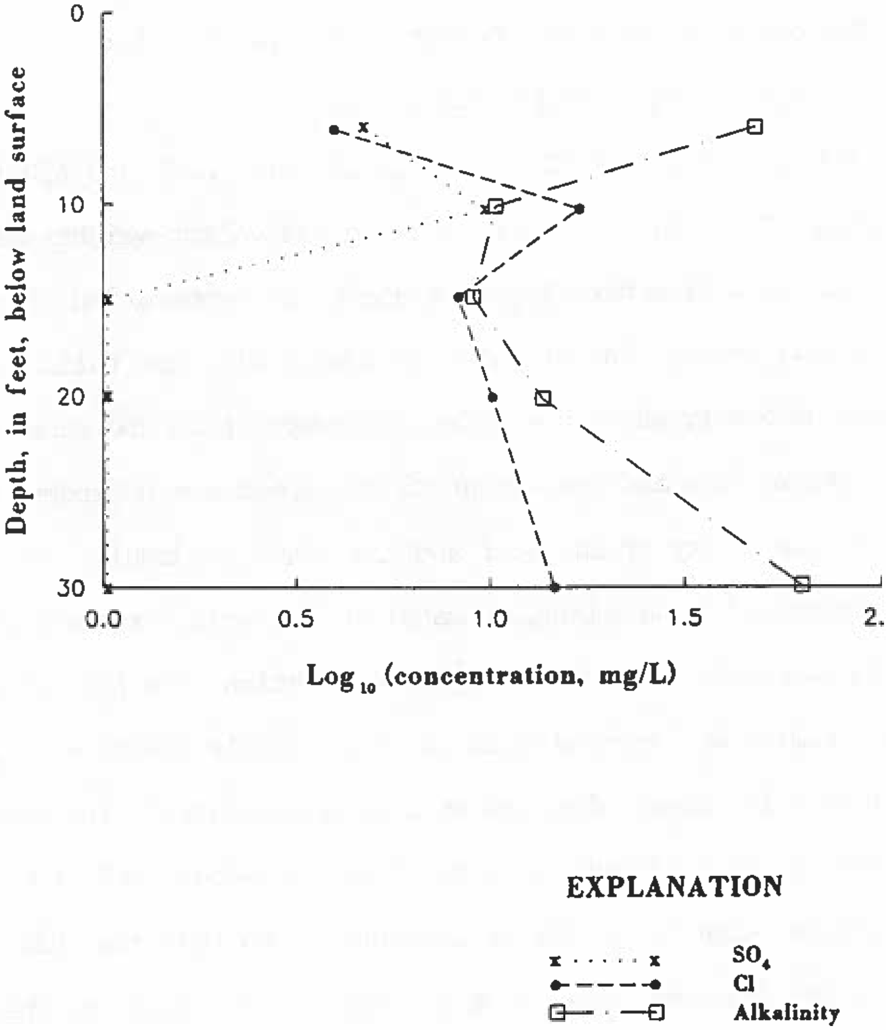

Figure 9. Chloride, sulfate, and alkalinity at various depths for nest A.

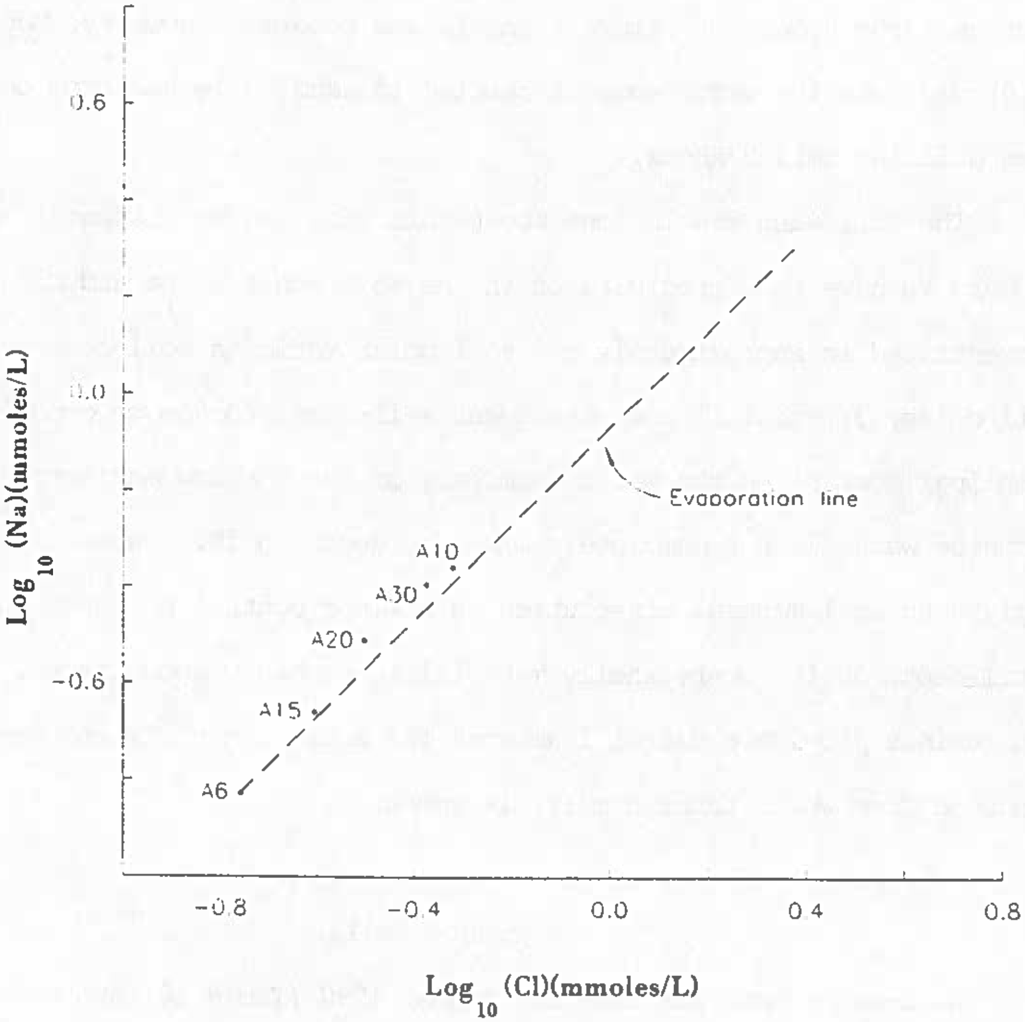

Figure 10. Concentration of sodium compared to concentration of chloride for nest A.

concentration as derived from Cl data is about 4. The higher concentration of Ca and alkalinity at A6 could be the result of rainfall dissolving calcite that had precipitated at or above the water table. A buildup of calcite in Hilton Head Island soils is likely to be an ephemeral occurrence owing to the average large amount of rainfall the Island receives; however, May (1984, p.10) did note the occurrence of calcite in sand collected from depth 5 ft when drilling well 27KK-c2.

The following conclusions about this site can be listed: 1) calcite appears to have been precipitated in the soil zone; 2) Na and Cl are concentrated in approximately a 1 to 1 molar ratio in soil-zone water as the soil dries; 3) rainfall and subsequent soil-zone storage of constituents exert principal control on the water chemistry of the shallow aquifer; and 4) recharge water is not completely mixed by depth 15 ft. These conclusions imply that soil mineral dissolution is a minor control on water chemistry until depth 30 ft, where shelly material is probably encountered. These conclusions provide a useful framework for examining the mixed samples produced from wells tapping multiple zones.

Shallow Wells

Well-water data for June and August 1990 (Table 10) are plotted on the trilinear diagram in Figures 11 and 12. On both diagrams the data are widely scattered. Two types of water, those from 27KK-e6 and -h6, plot similarly to well A30. Water from -e6 is mildly alkaline and is low in SO_4 and dissolved Fe, suggesting that the water might be from a chemically reducing environment. The molar ratio Na/Cl is 0.88 which is close to that of seawater, indicating the composition of the water to be initially controlled by the composition of the recharge water. The concentration of Ca and alkalinity indicate that the water probably has dissolved shells composed of $CaCO_3$ that occur in the section. The water is slightly super-saturated with respect to calcite (Table 11).

Water from 27KK-h6 is a mixture of water from two screens. On the trilinear diagram, the cation composition plots in the cation field for water that contains dissolved calcite. The anion composition plots in the field for a water rich in alkalinity. This is similar to water that is dissolving shell matter or is affected by evaporation. The pH of the sample from June is mildly acidic (6.38). Calculated total dissolved solids concentration is comparatively low (74 versus 227 for water from 27KK-e6). The concentrations of Na and Cl plot near the theoretical evaporation line (Fig. 13). The evaporative concentration factor is less than 2 and, in fact, the water is undersaturated with respect to $CaCO_3$ (Table 11). The concentration of SO_4 is comparatively low relative to the evaporated water (Fig. 14) from well A6.

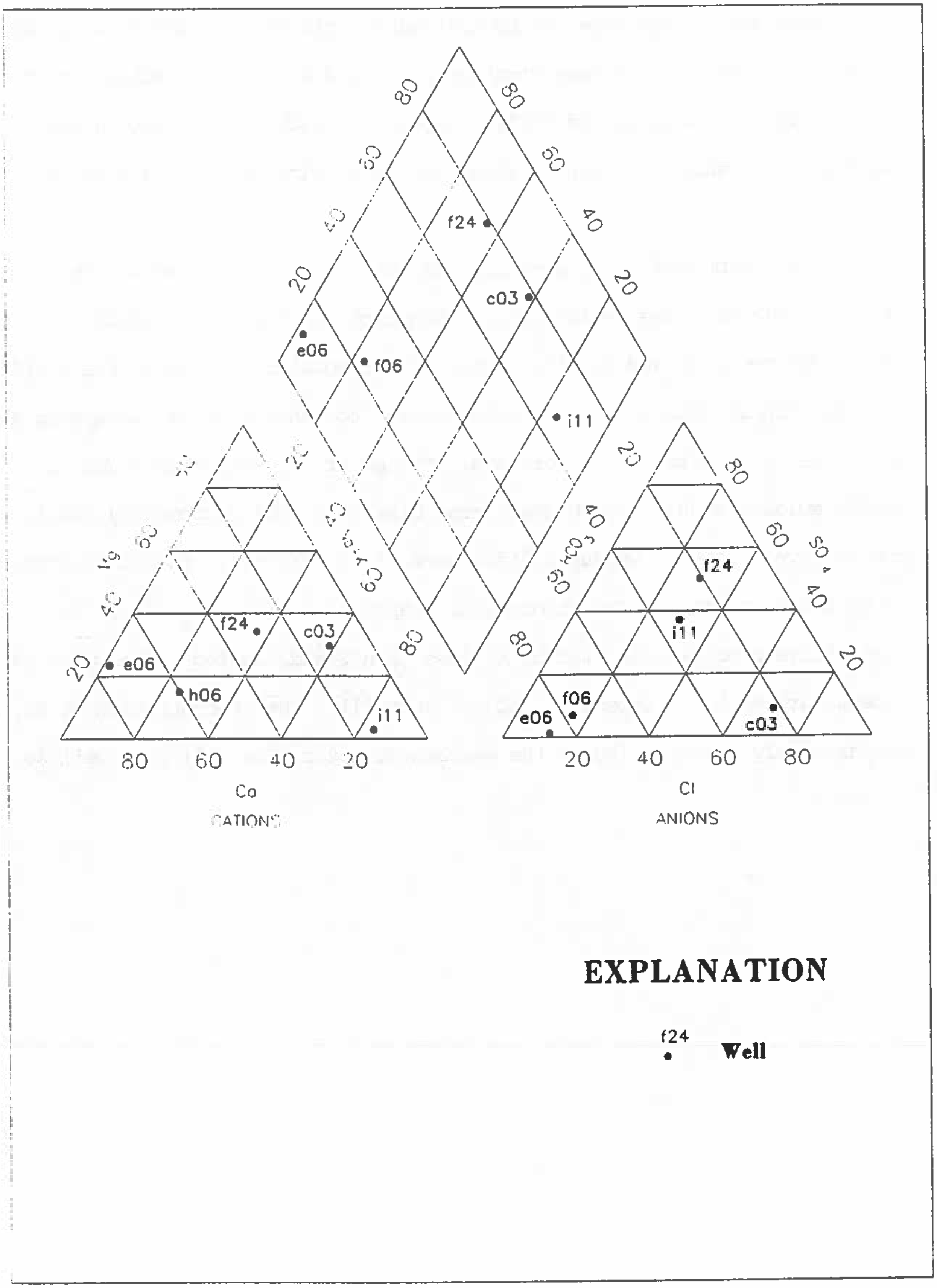

Figure 11. Trilinear diagram of water from shallow wells, June 1990.

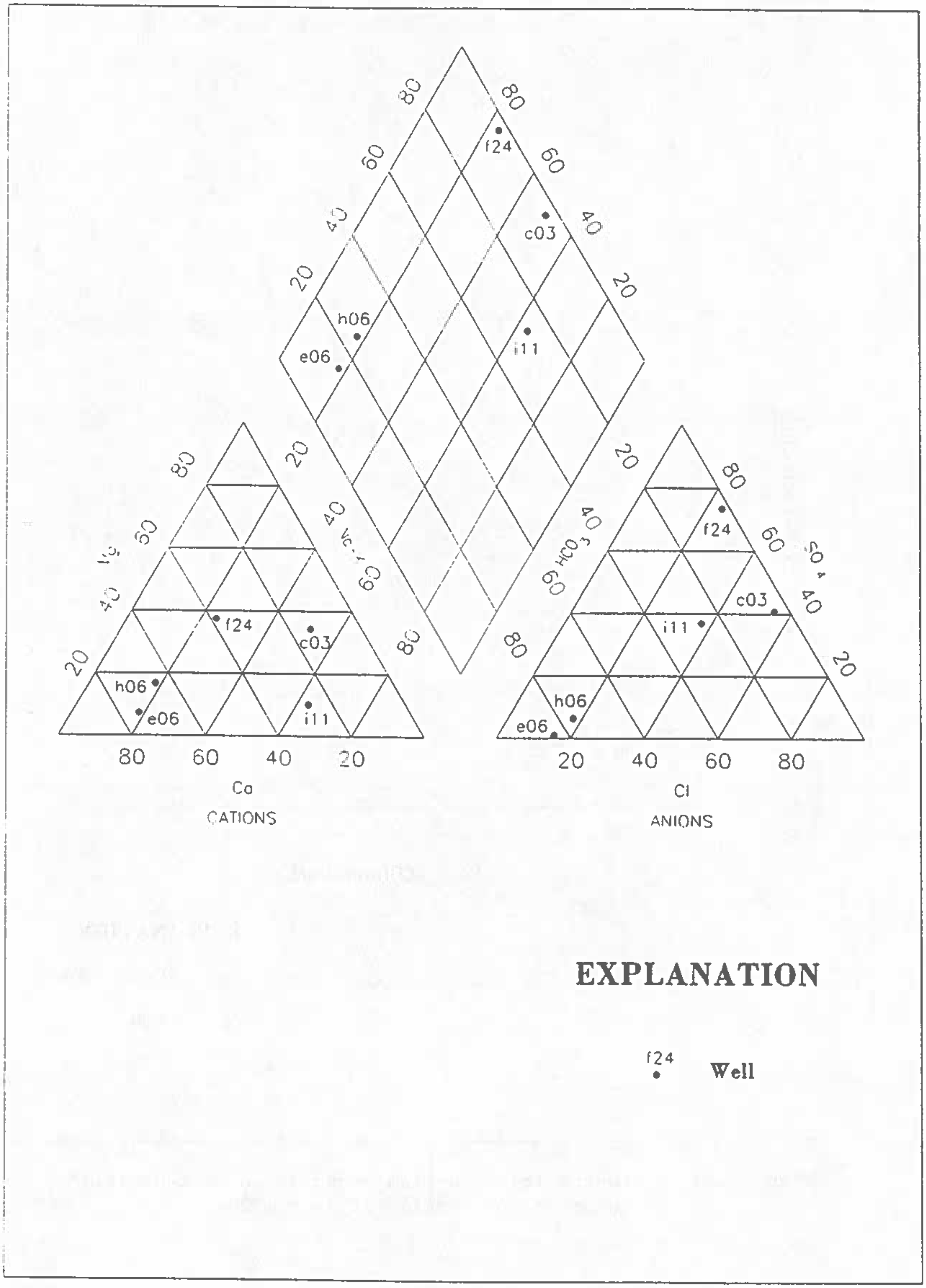

Figure 12. Trilinear diagram fo water from shallow wells, August 1990.

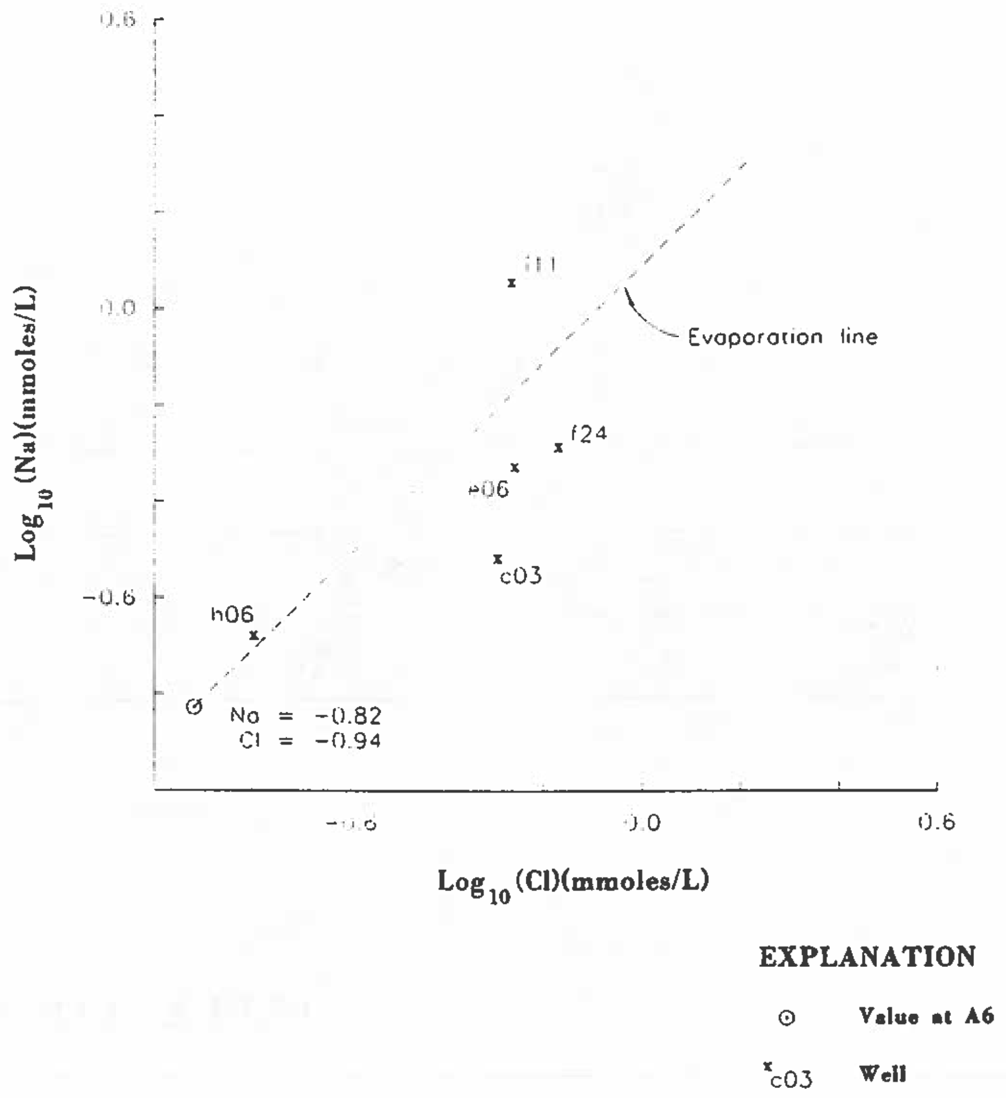

Figure 13. Concentration of sodium compared to concentration of chloride for samples of June 1990.

The concentration of Fe is, however, relatively high (0.6 mg/L). This is interpreted as indicating that dissolved oxygen in the infiltrating water has been consumed, creating an environment favorable for iron transport. According to equilibrium calculations, hematite and goethite are supersaturated (Table 11). These minerals contain iron in the Fe^{+3} state. The idea that these minerals are being simultaneously reduced and precipitating is not logical. More work is necessary to adquately explain these observations.

Water from well 27KK-c3 is a mixture of water from three screens. On the trilinear diagram it plots in the cation field as Na-type water. Notably, the water has Mg composing approximately 30 percent of its dissolved cations. It plots as a Cl-type water in the anion field. The pH is acidic, and the water is poorly buffered; the solution is chemically close to the solution making up the hypothetical rainfall. This observation and the poor buffering capacity suggest that the water is primarily from the uppermost screen.

Sodium and Cl do not fall on the nest A evaporation line (Fig. 13). Neither SO_4 nor Cl fall on a similarly constructed evaporation line (Fig. 14). The concentration of SO_4 is low, likely owing to reduction. The solution is much undersaturated with respect to calcite (Table 11). These observations probably owe to the effect of mixing of waters assummed to be composed of a shallow zone affected by evaporation and a deeper zone characterized by low Fe and SO_4 concentration. Sodium concentration is possibly affected by exchange reactions but insufficent data to reasonably postulate whether it would be exchange in the lower zone or the upper zone are not available. More importantly, explanations do not adequately explain the observed low pH and low alkalinity.

Water from well 27KK-f24 is produced from two screens. On the trilinear diagram the water falls in the SO_4 anion field. The cation field is similar to the hypothetical rainfall in that it displays no cationic dominance. The water is mildly acidic to acidic (pH 5.8 and 4.8, respectively). It is low in total dissolved solids. Water from well -f24 is poorly buffered (alkalinity 19 and 7 mg/L, respectively), and this is reflected by the low pH values. The plot of Na versus Cl falls close to the hypothetical rainfall evaporation line. An evaporative concentration factor greater than 5 is possible, assuming that the hypothetical rainfall Cl of 4 mg/L is reasonable. This suggests that the water chemistry of the cations are controlled by atmospheric input.

The water is comparatively high in dissolved Fe^{+2} and $S0_4$ as evidenced by calculated chemical activities of 10^{-5}, and 10^{-4} moles/kilogram of solution respectively. For measured pH and assuming the pE (oxidation - reduction potential) is less than 0, sulfur as SO_4 and iron as Fe^{+2} can occur only in a narrow set of conditions (Fig. 15). This perhaps implies that either the reduction reactions have not had time to go to completion or the water is buffered with respect to SO_4 reduction. The observed conditions possibly are described by the a reaction of anaerobic decay of organic matter. A possible reaction is:

$$CH_2O + Fe_2O_3 + H^+ = 2Fe^{+2} + HCO_3^{-1} + H_2O + 2e^-$$

where CH_20 represents organic matter and Fe_2O_3 is hematite. This reaction is bacterially mediated. Sources of the necessary carbon include organic matter in the soil zone and unit Q_{21} sediments.

Water from 27KK-i11 is produced from two screens. On the trilinear diagram the cation field is predominantly a Na water. The diagram shows that

Table 11. Logarithm of saturation indices for selected minerals in the samples of June 1990

	27KK-e6	27KK-h6	27KK-f24	27KK-c3	27KK-i11
Calcite	0.20	-2.25	-3.33	-4.41	-4.16
Gypsum	-3.73	-3.64	-2.79	-4.37	-3.05
Hematite	12.13	6.27	3.47	2.91	-2.26
Goethite	3.58	0.64	-0.75	-1.03	-3.62

NOTE: Logarithm saturation index equal to zero indicates saturation, greater than zero supersaturation and possible precipitation, less than zero undersaturation and dissolution.

the water has no dominant anion. The pH is acidic and the water is only moderately buffered. The water falls above the evaporation line and the molar ratio Na/Cl is 2.3. This ratio indicates a process operating that adds Na to the water at a rate greater than Cl is added. The evaporation factor is greater than 5, but the water is undersaturated with respect to calcite. Calcium activity is too low to achieve calcium carbonate saturation in this solution. Whether this results because the water is a mixture of water from two separate aquifers or because of other unmeasured factors cannot be determined. Sulfate is plentiful, as is Fe^{+2}. The water chemistry may be indicative of holdover contamination from the former Hilton Head No. 1 PSD ponds.

AQUIFER HYDRAULICS

Few data on hydraulic conductivity of the Hilton Head Island shallow aquifer are available. The writer located aquifer test data from Arthur Hills and Palmetto Headlands wells (discussed previously) and wells 27KK-e6 and 27KK-n17 (SCDNR-WRD unpublished data). The tests from Arthur Hills, Palmetto

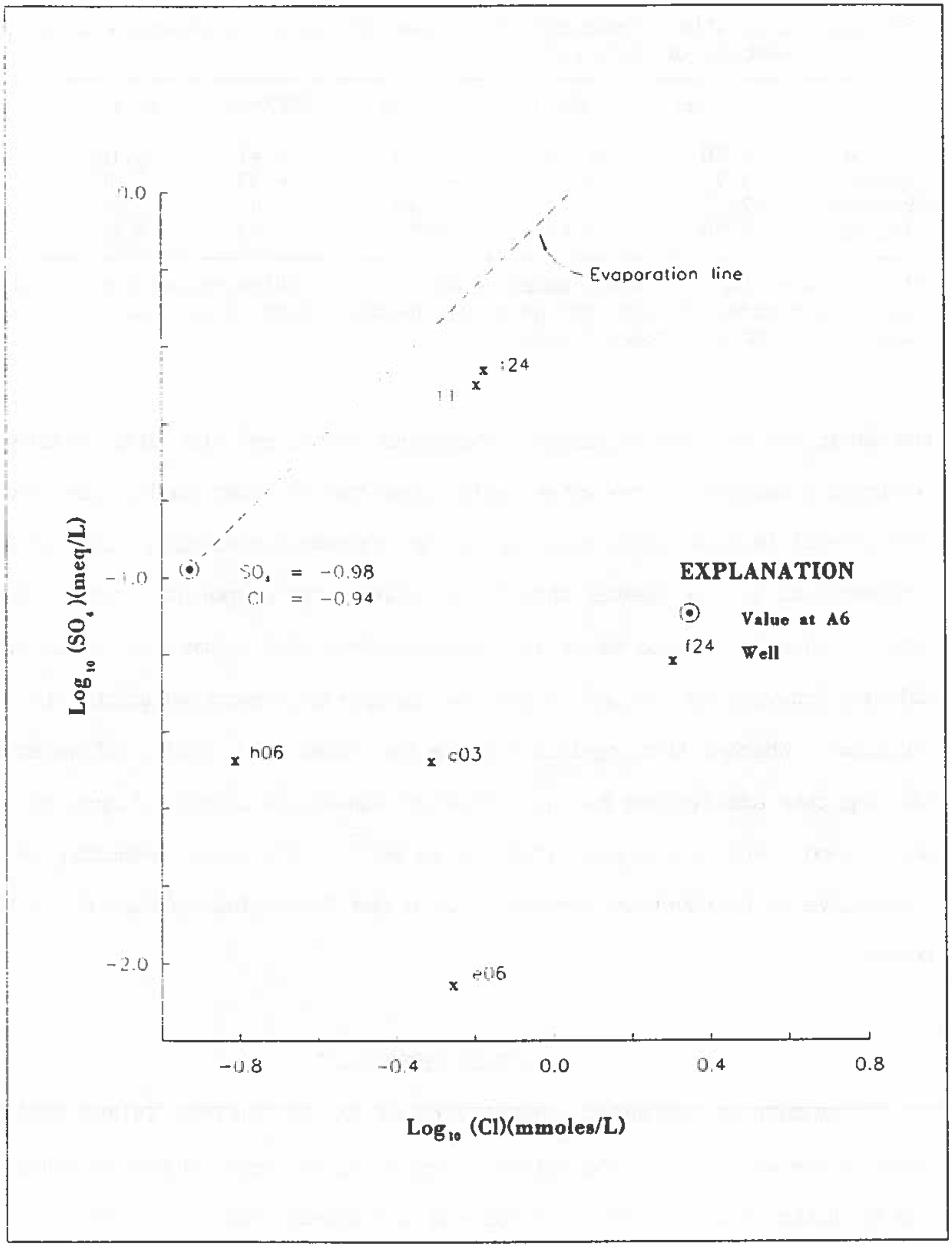

Figure 14. Concentration of sulfate compared to concentration of iron for samples of June 1990.

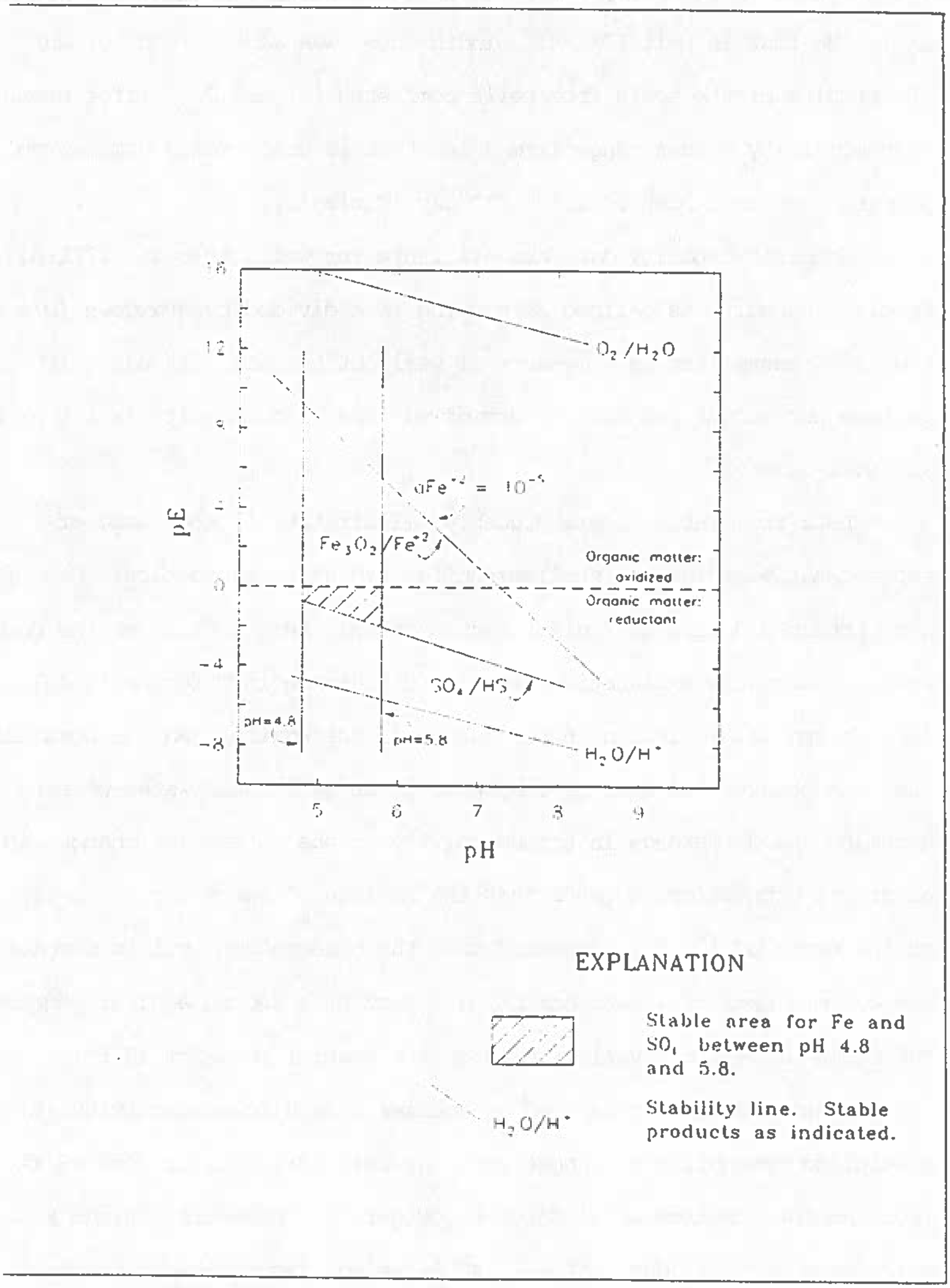

Figure 15. Stability diagram for system $H_2O-Fe-SO_4$.

Dunes, and 27KK-e6 (Salty Faire Gate) were made in sand within mapping unit Q_{2o}. The test in well 27KK-n17 (Indigo Run) was made in sand of unit Q[illegible]. The results of the tests from wells completed in unit Q_{2o} differ greatly. Transmissivity values range from a low that is practically unmeasurable by pumping test to a high of 1,200 ft^2/day (Table 12).

Specific-capacity data are available for wells AH-5 and 27KK-n17. Specific capacity is defined as pumping rate divided by drawdown (Q/s at time equals 24 hours) and is a measure of well performance. It has units of gallons per minute per foot of drawdown. Specific capacity is 1.5 at 27KK-n17 and 0.72 at AH-5.

Data from Table 12 are probably illustrative of the range of representative values of shallow-aquifer hydraulic parameters. Data for AH-1 were obtained during an aquifer test with well AH-5 serving as the pumping well. Reasonable explanations for the difference in T for wells AH1 and AH5 include spatial variation in the makeup of the aquifer and the possibility that the observation well is completed in an additional water-bearing sand. Assuming the difference in transmissivity is due to spatial changes in the aquifer's properties suggests that the horizontal scale for transmissivity is on the order of 100 ft. Assuming that the observation well is completed in one or more beds of a sand composing a part of a second aquifer suggests that the scale of vertical variation is on the spatial scale of 10 ft.

Transmissivity is defined as aquifer hydraulic conductivity (K) multiplied by aquifer thickness (b). At well AH-1 b is at most 19 ft (Westinghouse Environmental Services, Figure 4) therefore minimum K is calculated as 60 ft/day. At well AH-5 the aquifer thickness is about 12 ft, and calculated K is 25 ft/day. At both wells the producing interval is described (Westinghouse Environmental Services, Appendix IV) as a sand of fine to medium grain size and with more than 5 percent matrix silt/clay. It seems reasonable to conclude that field-scale observation of aquifer materials will be insufficient to estimate well performance.

Analysis of the pumping test at well 27KK-n17 yielded varied numbers. Analysis by the Cooper-Jacob approximation yielded a T value of 1,000 ft^2/day. If interpreted as water table, analysis by the Neuman method yields an effective T of 130 ft2/day.

CONCLUSIONS

1) The shallow-aquifer system on Hilton Head Island is composed of five mapping units: Q_{1b}, Q_{1l}, Q_{2b}, Q_{2o}, and Q_{2l}. Presently, data exist to describe three of these units; Q_{2b}, Q_{2l}, and Q_{2o}. Units Q_{1b} and Q_{1l} date from about 7,000 years ago. Unit Q_{1b} is the deposit of beach ridge sand along the eastern margin of the Island. Unit Q1l consists of scattered deposits of fine-grained marsh mud associated with flooding of existing channels. Unit Q_{2b} is comprised of fine beach sand of 0.15-mm diameter. It is well sorted and rounded to subrounded. The deposit is approximately 30 ft thick. Unit Q_{2l} is a muddy fine sand with thin clay beds found along the western third of the northern section of the Island. It is similar to present-day marsh deposits formed leeward of the beach complex. Unit Q_{2o} is fine sand with broken shells, matrix mud. Where present the sand beds are thin.

2) An aquifer is formed by unit Q_{2b}. A second aquifer occurs in the thin, comaparatively well-sorted sand distributed within unit Q_{2o}. This aquifer is not likely to be as continuous as the aquifer in unit Q_{2b}; it is variable in both lateral and vertical sequence. Data show that the unit will

Table 12. Summary of hydraulics data from Hilton Head Island

Location	Transmissivity (ft^2/day)	Hydraulic conductivity (ft/day)	Storage coefficient
27KK-e6	80	4	---
AH-1	1,200	65	0.0002
AH-5	200	25	.0002
PH-1	> 0		---
27KK-n17	130	20	---

Value of 600 is T by slug test, method of P,B, and Cooper.

produce water in the area of Palmetto Dunes but not in the vicinity of Palmetto Headlands.

3) The water-table surface of the shallow aquifer in unit Q_{2b} will a subdued copy of the local topography. This implies that topographic changes to land surface probably have affected the direction and rate of ground-water flow.

4) Shallow-aquifer water-level monitoring will have to be designed in terms of statistically suitable locations. The concept of an island-wide water-level surface for the shallow aquifer does not apply, owing to the number of small drainage basins. Speiran showed that a well density of about 1 per acre would be necessary to draw such a surface. Rainfall also is thought to vary areally. Purvis and others showed, with data from five rain gages, that summer season rainfall is widely variable. Thus the rainfall is most variable during the season of maximum demand for the water.

5) Shallow-aquifer water chemistry is controlled principally by atmospheric input and, during warm weather, by subsequent evaporation processes. Two water-rock reactions possibly affecting shallow-aquifer water

chemistry are dissolution of iron sulfide minerals and dissolution of calcite in shell matter. This last reaction occurs pricipally at depths of 30 ft and greater. Wastewater adds an additional dissolved-solids load to the aquifer. Because of this, wastewater may have an application threshold. Speiran showed that rates of 0.71 inch per week were insufficient to avoid buildup of solids in the soil zone. Data from Hardee show that Cl is concentrated by evaporation where the water table is less than 6 ft. Concentration of solids can limit the use of wastewater for irrigation of some ornamental plants. Deep transport of wastewater is not desirable.

6) Shallow-aquifer ground water will probably be iron-rich, owing to the chemically reducing conditions of the aquifer environment. The water's utility for irrigation could be limited, owing to iron's affinity to precipitate on surfaces when in contact with oxygen. The practical result is the clogging of openings of well screens and sprinkler heads and discoloration of surfaces sprayed by the water. Sampling for dissolved iron is a part of the shallow-aquifer study at Hilton Head Island.

7) Shallow aquifer water levels are at their lowest levels during the meteorological summer when water is most needed. Wells draw down the water table when pumped, thus the season of greatest demand can also be the season of least water in storage.

8) The hydrological base of the shallow system requires definition. Water levels in wells completed in units at the base of the shallow system are all at or near sea level. Further, data suggest that at Sea Pines and at the Palmetto Dunes Resort the water levels in wells screened in mapping unit Q_{2o} are affected by upper Floridan pumping.

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APPENDIX I. CORE DESCRIPTIONS

Test hole number, latitude and longitude, geographic location, number and depth of screens, and lithological and color description of core data. Color descriptions are determined from standard colors of the Munsell Color Chart (Geological Society of America, 1980). Cored intervals are 5 to 7 feet, 10 to 12 ft, etc. Method was split-spoon sampling.

28KK-i11, 321306N804612, Jenkins Island, test hole, no screens

0 - 5 drilled

5 - 7 14 inches recovered; clay with sand lenses, sand 3.0 to 2.5 phi, very clayey, moderately well sorted, 1 to 2 % heavies; clay sandy 2%, appears to be rooted, sand lenses appear to be sand filled burrows, iron staining around rootlets; Color: yellowish gray, 5Y 7/2.

7 - 10 drilled

10 - 12 7 inches recovered, sand, 3.0 to 2.5 phi, 1 to 2 % clay, less than 1% heavy minerals, 1% muscovite, moderately-well sorted, subrounded grains; toward bottom of core some clay lenses suggesting cross bedding; Color: yellowish gray, 5Y 8/1.

12 - 15 drilled

15 - 17 9 inches core recovered; sand, 3.0 to 2.5 phi, 1% heavies, concentrated along base of cross-beds, trace muscovite, 1% or less clay; well sorted, subrounded to subangular, cross-beds some grains iron stained; color: yellowish-gray, 5Y 7/2.

22 - 25 drilled

25 - 27 22.5 inches core recovered; upper 5.5 inches clay-sand, 3.0 to 2.5 phi, 40 to 50 % clay; Color: light bluish gray, 5B 7/1; 5 inches, sand w/ 10 % clay, sand 3.0 to 2.5 phi, color: dark yellowish orange; 10YR 6/6; 9 inches, sand with 15 to 20 % clay, 3.0 to 2.5 phi, iron stained, 1 % or less shell fragments, trace of muscovite, less than 1% heavies, clay in matrix not laminated; color: 10YR 6/6; bottom 3 inches, sand, 3.0 to 2.5 phi, trace muscovite, 3 to 5 % clay, sand subangular, moderately-well sorted, color: 10YR 7/4.

27 - 30 drilled

30 - 32 24 inches core recovery; sand, 95% 3.0 to 2.5 phi, 5% 0.5 to 0.0 phi, coarsening downward, upper 7 inches 8 to 10 % clay, bottom 5 to 8 % clay, content decreasing downward to 5 % clay, 1 to 2 % heavies, sand cross-bedded, poorly to moderately sorted, sand subangular to angular, bed sets 1 to 3 inches thick. color: dark yellowish orange (10YR 7/4).

32 - 35 drilled

35 - 37 24 inches core recovery; upper 14.5 inches, sand, interbeddded, very clayey, 90% 2.5 to 2.0 phi, 10 % 3.0 to 2.5 phi, moderately sorted, subangular grains, 10 to 15 % clay, matrix clay, with burrows filled with fine sand. Color: grayish orange (10YR 7/4); 14.5 to 19.5, sand fining downward to clayey-sand, 80 to 85 % 3.0 to 2.5 phi, 20 to 25 % matrix clay; bottom 3 inches, sand, trace muscovite, sand 3.0 to 2.5 phi, well sorted, 3 to 4 % clay, fining downward to 15 to 20 % matrix clay; Color: grayish-orange (10 YR 7/4) to dark yellowish-orange, 10 YR 6/6.

37 - 40 drilled

40 - 42 22 inches core recovery; sand to clayey-sand, fining downward; upper 8 inches sand 90% 2.5 to 2.0 phi, 10 % 3.5 to 3.0 phi, moderately well sorted, subangular grains. Bottom 14 inches, clayey-sand, 80 % 3.0 to 2.5 phi, 20 % 3.5 to 3.0 phi, 10 to 15 % matrix clay, trace to 1 % muscovite, sand/ clay lenses; Color: medium bluish gray, 5B 5/1.

42 - 45 drilled

45 - 47 23 inches core recovery; 21 inches, clayey-sand, bottom 2 inches, clay. Sand 80 % 3.0 to 2.5 phi, 20 % 3.5 to 3.0 phi, 40 % matrix clay, some lenses of sand -- lenticular bedding, slightly micaceous; Color: medium bluish gray, 5B 5/1.

47 - 50 drilled

50 - 52 24 inches recovered; Upper 12 inches very sandy clay, coarsening downward over 11 inches interval to sand, 60 % 1.0 to 0.5 phi, 40 % 0.5 to 0.0 phi, moderately sorted, subrounded, 3 % heavy minerals, 1 % phosphate pellets, 10 % shell fragments, 1 to 2 % clay (as matrix), gradational contact with sandy clay and sand; Color: dark bluish gray, 5B 7/4.

52 - 55 drilled

55 - 57 22.5 inches recovered; upper 12 inches sandy clay, 60 % clay, 40 % sand. Bottom 9 inches sand, 1.5 to 1.0 phi, fining downward to 2.0 to 2.5 phi. Bottom 1.5 inches, clay sand, 6 to 10 % clay. Upper sand is moderately sorted, subangular to subrounded, 2 % phosphate, 1 % heavy minerals, trace shell fragments, 1 % or less clay in the uppermost 8.5 inches of core; Color: sandy clay is dark gray (N3), sand islight bluish gray, 5B 7/1.

57 - 60 drilled

60 - 62 2 inches recovered; sand, 2.0 to 1.5 phi,10 % 3.0 to 3.5 phi, poorly sorted, 1 % glauconite, 1 % heavy minerals, 1 % phosphate, less than 1 % clay, subrounded to subangular; Color: light-bluish gray, (5B 7/1).

62 - 65 drilled

65 - 67 6 inches recovered; sand, 3.0 to 2.5 phi, 5 % 2.5 to 2.0 phi, moderately well sorted, 3 % heavy minerals, 3 % shell fragments, trace phosphate, about 1 % matrix clay. Color: light bluish-gray, 5B 7/1.

67 - 70 drilled

70 - 72 16 inches recovered; upper 4 inches sandy clay with abundant phosphatic shell fragments, also phosphate pellets. Color: light bluish-gray (5B 7/1); bottom 11 inches sand, 80% 2.5 to 2.0 phi, 20 % 3.0 to 2.5 phi, fining downward with increase in clay, 3.0 to 2.5 phi, 3 to 4 % matrix clay. Upper part of sand 1 % or less clay, shell hash along bedding planes. Color: light bluish-gray, 5B 7/1.

72 - 75 drilled

75 - 77 21 inches core recovery. Upper 12 inches sand, 2.0 to 2.5 phi, 2 % phosphate, 2 % heavy minerals, 1 % or less clay. Middle 7 inches, sand, 80 % 0.0 to -0.5 phi, 20 % 0.0 to 0.5 phi, 5 to 6 % phosphate, 3 to 4 % calcareous shell fragments, 2 to 3 % clay, poorly sorted, subangular. Bottom 2 inches. Sand, 2.0 to 2.5 phi, well sorted, 3 % matrix clay, 3 % heavy minerals. Color light bluish-gray, 5B 7/1.

27KK-h06, 321610N0804205, Hilton Head Airport, Well, 2 screens 20 to 30 ft, and 42 to 52 ft.

0 to 5 drilled

5 to 7 12 inches recovered; upper 6 " sand: 3.0 to 2.5 phi, well sorted, rounded to subrounded, 2 % heavy minerals, 3 to 4 % organics, 2 % clay, color: moderate. yellowish brown 10 YR 4/2; bottom/ 6" sand: 2.5 to 2.0 phi, well sorted, subrounded, 3 to 4 % heavy minerals, 1 % or less clay, some iron staining; Color: yellowish gray, 5 Y 7/2.

5 to 10 drilled

10 to 12 6 inches recoverd; sand, 1 % 2.0 to 1.5 phi, 60 % 2.5 to 2.0 phi, 38 % 3.0 to 2.5 phi moderate. sorted, subrounded, 1 % heavy minerals 2 % phosphate lt. brown mineral, 97 % qtz, trace of mica; Color: yellowish gray, 5Y 7/2. (Mixed in some Bentonite)

10 to 15 drilled

15 to 17 24 inches recovered; sand 8 % 2.0 to 2.5 phi, 20 % 2.5 to 3.0 phi, moderate. well sorted, subrounded 2 % phosphate lt. mineral, 1 % heavy mineral, 91 % qtz, 1 % clay, cross-bedding, possible low angle heavy minerals concentration along bed planes; Color: yellowish gray, 5Y 7/2.

15 to 20 drilled

20 to 22 14 inches recovered; sand fining downward, upper 4 inch 2.0 to 2.5 phi, 1 % heavies, trace of muscovite, trace of phosphate, 1 % 98 % qtz matrix clay, subrounded well sorted, bottom 10 inch sand, 3.0 to 2.5 phi, subangular well sorted, 99 % qtz, 1 % heavy mineral, 1 % matrix clay; Color: light olive gray, 5 Y G/1.

20 to 25 drilled

25 to 27 14 inches recovered; sand fining downward, upper 5 inches sand, 2.5 to 2.0 phi, subangular to subrounded, well sorted, 99 % quartz, 1 % heavy minerals, 2 % matrix clay; lower 9 inches, fining downward sand, 80 % 2.0 to 2.5 phi, 20 % 3.0 to 2.5 phi, subrounded grains, moderately-well sorted, 1 to 2 % heavy minerals, trace of muscovite; Color: yellowish gray, 5 Y 7/2.

25 to 30 drilled

30 to 32 6 inches recovered; sand, 3.0 to 2.5 phi, well sorted, 2 % matrix clay, subrounded to subangular, 98 % qtz, 2 % heavy minerals, trace of muscovite, s/ isolated zones of clayey sand, possible burrows; Color: very light gray (N8).

30 to 35 drilled

35 to 37 24 inches recovered; sandy clay, with sand lenses (lenticular beds) 5 to 6 % sand in the clay, base of sand lenses, shell fragments fossils (Olivia ssp) possible back barrier; Color: medium bluish gray 5 B 5/1. Note: shell assembly suggest higher energy environment.

35 to 40 drilled

40 to 42 24 inches recovered; upper 12 inches clay, with sand lenses, 2 to 3 % organics rooted, possible sand filled burrows; Color: medium bluish gray, 5 B 7/1; bottom 12 inches sand fining downward, top 2.0 to 1.5 to bottom 3.0 to 2.5 phi, 10 to 15 shell fragments, sand moderately sorted, subrounded, 1 to 2 % matrix clay. Note: possible channel lag above clay, abandoned fill below.

42 to 45 drilled

45 to 47 16 inches recovered; upper 4 inches sandy clayey shell lag, 40 % sand, 30 % clay, 30 % shell frag, mesh gastropods, Dinocardium (ssp) linguar shell frag, 4 inch shell, 70 % 2.0 to 1.5 phi, 20 % 2.5 to 2.0 phi, 10 % 3.0 to 2.5, 5 % shell frag, 1 % heavy minerals, 94 % qtz, 10 to 12 % clay, moderate to poorly sorted, subangular to subrounded grains, 1 inch clay 1 to 2 % sand, 7 inch sand as above interbedded w/ 1/2 to 1/4 inch clay lenses sand matrix clay 2 to 3 %; Color: medium bluish gray, 5 B 5/1.

47 to 50 drilled

50 to 52 24 inches recovered; upper 2 inch clay and shell frag; 50 % shell fragments (Dino cardini?), very large olive, gastropods marsh, bottom 14 inch clayey sand interbedded w/ shell hash, sand 2.5 to 2.0 phi course downward to 1.5 to 2.0 phi, btm 2 inch sand is 1.5 to 2.0 phi, w/ 40 % shell hash (fragments 1 % to 2 % phosphate grains, 2 to 3 % clay, upper sand, 4 to 5 % clay, 1 to 2 % heavy minerals; Color: medium bluish gray 5 B 5/1.

52 to 55 drilled 55 to 57 upper 4 inches peaty, sandy clay, 40 % shell fragments, 20 % sand, 20 % peat, 20 % clay; 2 inches shell lag, 2 inch sdy clay, w/ peat, btm 16 inch clay, rooted marsh; Color: medium dark gray. Note: vertical rooting, pieces of marsh peat?

57 to 60 drilled

60 to 62 24 inches recovered; 0 to 24 inches slightly sandy clay with thin lenses of sand, approximately 2 inches between sand lenses, trace of organics; shell lag approximately 6 inches from bottom of core; Color: medium dark gray, N4.

62 to 65 drilled

65 to 67 24 inches recovered; 0 to 24 inches clayey sand, sand 3.5 to 3.0 phi, 20 % clay, 60 % sand, trace of phosphate grains, sand content increases downward; Color: moderate olive brown, 5 Y 4/4. Note: contact Hawthorn Formation.

67 to 70 drilled

70 to 72 24 inches recovered; clayey sand, sand 3.0 to 2.5 phi, well sorted, 2 to 5 % phosphate grains, 6 to 8 % matrix clay, mottled texture, burrowed, bioturbation appears moderate to heavy; Color: grayish olive, 10 Y 4/2.

72 to 75 drilled

75 to 77 24 inches recovered; clayey sand, sand 60 % 3.0 to 2.5 phi, 40 % 2.5 to 2.0 phi, 6 to 8 % matrix clay, 4 % phosphate grains and shell fragments, 5 to 6 % shell fragments, $CaCO_3$, shark teeth, peatinacen is present; Color: grayish olive, 10 Y 4/2. Note: shelf deposit?

77 to 80 drilled

80 to 82 24 inches recovered; 0 to 24 inches clayey phosphatic sand, matrix clay increasing downward, sand 90 % 3.0 to 2.5 phi, 10 % 2.5 to 2.0 phi, trace 1.5 to 1.0 phi, moderately sorted, 5 to 6 % matrix clay increasing to 10 to 12 % of the base of the core, some stringers of light color phosphate sandstone, phosphate 3 to 4 %; Color: grayish olive, 10 Y 4/2.

Note: drilled 82 to 90 feet. Very hard drilling at approximately 85 ft.
Cored 90 to 92

90 to 9 ches recovered; sand 70 % 1.0 to 0.5 phi, 20 % 1.5 to 1.0 phi, 10 % 2. 5 phi, moderately sorted, subangular grains, some cross bedding, clay 1 2 to 3 % phosphatic, some hard zones, possibly calcareous; Color: ray, 5 Y 4/1.

92 to 9 ed

95 to 9 ches recovered; sand, 1.5 to 1.0 phi to 2.0 to 1.5 phi, moderat sorted, subrounded grains, trace of phosphate grains, upper 6 inches matrix clay decreasing downward to 1 to 2 %; Color: olive gray 5 Y 4/

27KK-f 2N0804410, Hilton Head Elementary School, Well, 2 screens, 15 to 25 50 ft.

0 - 5 ed

5 - 7 sand 2.5 to 2.0 phi, well sorted, subrounded, sand with clay lenses, and horizontal layers of what appears to be iron precipitant, 100 % quartz, 2 to 3 % clay and/or iron?), 1 to 2 % organics, color: moderate brown

7 - 1 ed

10 - 1 sand 60 % 2.5 to 2.0 phi, 40 % 3.0 to 2.5 phi, subrounded to subangular, moderately well sorted, 1 to 2 % heavy minerals with grains showing some taining, trace of muscovite, 1 % or less matrix clay, color: dusky yellow 5 Y 6/4.

12 - 1 ed

15 - 17 sand 70 % 3.0 to 2.5 phi, 30 % 3.5 to 3.0 phi, trace 2.0 to 1.5 phi, moderately sorted, subangular to subrounded, 3 to 4 % heavy minerals, trace of phosphate , muscovite, 1 to 2 % matrix clay with concentration increasing around fossil: ophiomorpha(?), iron nodules present, color: light olive green , 5Y 5/2.

17 - 2 ed

20 - 22 occuring as fining upward sequences, cross bedded, 80 % 3.0 to 2.5 phi .5 to 2.0 phi, 3 % at base of fining upward sequences, 0.5 to 0.0 phi eavy minerals, 6 - 10 % matrix clay toward bottom of core, clayey ard top of core, organics (which occur in lenses), color: light olive-gray 5 Y 5/2, note: trace of muscovite.

22 - 2 d

25 - 27 ches recovered; sand, 3.0 to 2.5 phi, well-sorted, subangular, 4 to 5 % heavy minerals, 2 % matrix clay, trace of muscovite, stained with iron precipatate, isolated zones maybe burrowed, color: olive gray 5 Y 4/1.

27 - 30 drilled

30 - 32 10 inches recovered; sand, interbedded with layers of mixed clay and organics, upper 2 inches of sand, then clay layers, clay layer very thin (flaser bedding), sand is 70 % 3.0 to 2.5 phi, 30 % 2.0 to 2.5 phi, moderately well-sorted, subangular grains, trace of heavy minerals, trace of muscovite, 1 to 2 % matrix clay, cross-bedded.

32 - 35 drilled

35 - 38 24 inches recovered; upper 6 inches, interbedded sand and clayey-sand, sand 3.0 to 2.5 phi, well-sorted, subrounded, 2.5 inches sand between clay parting or lense, middle 4 inches clayey-sand, 60 % sand, 40 % matrix clay; 0 inches, sand, 2.0 to 2.5 phi with trace 1.5 to 1.0 phi, sand interbedded with clay and organic plant material, salt marsh (?), sand is well-sorted, with 2 to 3 % matrix clay, lowermost 3 of 10 inches inches, sand with clay; bottom 5 inches sand, 90 % 2.5 to 2.0 phi, 5 % 3.0 to 2.5 phi, 5 % 2.0 to 1.5 phi, moderately sorted, subrounded, 5 % matrix clay, possible uppersalt marsh to tidal flat or channel in tidal marsh; color: medium-gray N5.

38 - 40 drilled

40 - 42 24 inches recovered; upper 6 inches interbedded sands, clay, and organics; sand, 2.5 to 2.0 phi, well sorted, subrounded, 6 to 7 % matrix clay, clay and organic layers (as partings), 1 to 1.5 inches; lower 16 inches, sand, 3.0 to 2.5 phi, well-sorted, subangular, 7 to 8 % matrix clay, bottom 4 inches, sand, 2.5 to 2.0 phi, well sorted, subangular, 1 to 2 % heavy minerals, trace muscovite, 3 to 4 % matrix clay, color: dark-bluish gray.

42 - 45 drilled

45 - 47 24 inches recovered; sand, 80 % 2.5 to 2.0 phi, 20 % 3.0 to 2.5 phi, moderately-well sorted, trace 1.5 to 1.0 phi, middle of core possible lag deposits of sand, size as above with 3 to 4 % -0.5 to -1.0 phi, to 2 % heavy minerals, 1 % muscovite, 1 to 2 % clay (or less); color: olive gray 5 Y 4/1.

47 - 50 drilled

50 - 52 23 inches recovered; upper 8 inches, sandy clay with sand lenses, lenticular bedding; bottom 15 inches, sand at contact with upper clay, some quartz pebbles, granular quartz grains, 1 % at clay bottom, sand, 90 % 2.0 to 1.5 phi, 8 % 2.5 to 2.0 phi, 2 % 1.0 to 0.5 phi, moderately sorted, subangular, 1 % heavy mineral, 1 % or less matrix clay, color: olive gray 5 Y 4/1.

52 - 55 drilled

55 - 57 upper 7 inches, sand, 3.0 to 3.5 phi, well sorted, subangular to subrounded, 1 % muscovite, trace of phosphate, 4 to 5 % clay, 4 inches clayey-sand, as above, 6 to 7 % clay s/ organics; middle 6 inches, sand as above, 10 to 12 % clay; bottom 4 inches sand, 2.5 to 2.0, well sorted, subrounded grains, 5 to 6 % clay, 1 % muscovite, 1 % heavies; color: olive gray 5 Y 4/1.

57 - 60 drilled

60 - 62 upper 3 inches clay with sand, sand 90 % 2.5 to 2.0 phi, 10 % 3.0 to 2.5 phi, moderately-well sorted, subangular, 5 to 6 % clay, clayey-sand is separated by 1 inches clay lenses, 3 inch of sand, 2.5 to 2.0 phi well sorted, subrounded, 2 % heavy minerals, 1 to 2 % matrix clay, 1 inch clay, slightly sandy w/ organics, btm 2 inch sand 3.0 to 2.5 phi well sorted 1 to 2 % matrix clay, subangular; color: medium bluish-gray, 5B 5/1.

62 - 65 drilled

65 - 67 23 inches recovered; upper 3 inches clayey-sand, 3.0 to 2.5 phi, 15 % matrix clay; 5.5 inches sandy clay with lenses of light olive brown (from Hawthorn), 4 inches sand, 1.5 to 1.0 phi to pebbles, phosphatic, 3 to 4 % phosphate grains, transgressive lag directly above Hawthorn; color: medium dark gray; Hawthorn contact: 10.5 inches clayey-sand, sand 3.0 to 2.5 phi, 8 to 10 matrix clay, well sorted, subangular grains, 3 % phosphate, color: moderate olive brown 5 Y 4/4.

67 - 70 drilled

70 - 72 15 upper 9 inches, clay with clayey-sand lenticular lenses, clayey-sand is Hawthorn; color: light olive brown, within the clay are pebble size quartz grains, 2 to 3 %; bottom 6 inches clayey-sand, sand, 3.0 to 2.5 phi, 15 % matrix clay, slightly phosphatic, color: light olive brown, Hawthorn.

Note: reamed hole to 75 ft, circulated, and collected samples. At depth 75 feet, clayey-sand, continue to drill and circulated at 80 ft, Hawthorn sand, very little matrix clay, sample collected.

27KK-h05, 321310N0804205, Palmetto Headlands, near Hilton Head Hospital, Well, 2screens, 20 to 30 ft, and 42 to 52 ft.

0 - 5 drilled

5 - 7 recovey not recorded. Core, sand, 3.0 to 2.5 phi, 1 % heavy minerals, 1 to 2 % mixture of clay and organics, sand is well sorted, subangular grains, mottled texture, soil zone, color: at top of grayish orange, 10 YR 7/4, color: grading downward to grayish brown, organics present, 5 YR 3/2, core not saturated.

7 - 10 drilled

10 - 12 sand, 60 % 3.0 to 2.5 phi, 40 % 2.5 to 2.0 phi, 1 to 6 % heavy minerals, highest concentration along bedding planes, sand well sorted, subangular grains, bed sets thin, 0.4 inch to 0.5 inches, (possible low-angle shore face). Color: very pale orange, 10 YR 8/2, core is saturated.

12 - 15 drilled

15 - 17 10 inches recovered; sand, 3.0 to 2.5 phi%, 2 % heavy minerals, 1 % light colored mineral (possibly phosphate (?)), 1 % or less matrix clay, sand is well sorted, subangular grains, Andrew (driller) thinks below sand is a clay layer, which was not recovered. Color: very pale orange, 10 YR 8/2.

17 - 20 drilled

20 - 22 19 inches recovered; upper 7 inches sand, 95 % 3.0 to 2.5 phi, 5 % 2.5 to 2.0 phi, 2 to 3 % heavy minerals, 1 % or less muscovite, 1 % or less matrix clay, sand moderately-well sorted, subrounded grains; Color: yellowish gray 5 Y 7/2, 4 inches sand, 3.0 to 2.5 phi, slightly finer than above, 4 to 5 % matrix clay, 1 % heavy minerals, sand well sorted, subangular grains, appears to be massive: color: dark yellowish brown 10 YR 4/2; bottom 8 inches sand as above, 3.0 to 2.5 phi, 5 to 7 % matrix clay; Color: light olive gray, 5 Y 6/1. Dark zone possible old paleosoil.

22 - 25 drilled

25 - 27 sand, 95 % 3.0 to 2.5 phi, 5 % 2.5 to 2.0 phi, 1 to 2 % heavy minerals, 3 to 4 % matrix clay, trace muscovite; sand, well sorted, subangular grains, no apparent bedding; Color: light olive gray 5 Y 6/1.

27 - 30 drilled

30 - 32 upper 5 inches sand, 3.0 to 2.5 phi, 1 to 2 % heavy minerals, trace of muscovite, 1 to 2 % matrix clay, sand is well sorted, subangular grains; bottom 12 inches sand, 3.0 to 2.5 phi, 2 to 3 % heavy minerals, trace of muscovite, 1 to 2 % matrix clay at top increasing to 10 to 12 % at base of core, possible cross-bedding, Color: upper 5 inches yellowish gray, 5 Y 8/1, bottom 12 inches, medium-bluish gray, 5 B 5/1.

32 - 35 drilled

35 - 37 21 inches recovered; upper 5 inches sand, 3.0 to 2.5 phi, 3 to 4 % heavy minerals, 1 % muscovite, 2 to 3 % matrix clay, sand moderately well sorted, subangular grains; middle 9 inches, sand 1.5 to 1.0 phi, fining to 3.0 to 2.5 phi, trace of phosphate, 2 % heavy minerals, trace of muscovite, 4 to 5 % matrix clay, burrowed at top, base cross-bedded; bottom 7 inches sand, 80 % 2.5 to 2.0 phi, 20 % 3.0 to 2.5 phi, 3 % heavy minerals, trace of muscovite, no phosphate, 6 to 8 % matrix clay; Color: olive gray 5 Y 4/1.

37 - 40 drilled

40 - 42 24 inches recovered; upper 15 inches sand, 60 % 2.5 to 2.0 phi, 40 % 3.0 to 2.5 phi, tr. 2.0 - 1.5 phi, 2 - 3 % heavy minerals, 1 % mustovite, 3 to 4 % matrix clay sand, moderate sorted, subangular grains; bottom 9 inches sand, 80 % 2.5 to 2.0 phi, 5 % 1.5 to 1.0 phi, 15 % 3.0 to 2.5 phi, moderately to poorly sorted, 1 % heavy minerals, trace phosphate, trace of muscovite, 5 to 6 % matrix clay; Color: olive gray, 5 Y 4/1.

42 - 45 drilled

45 - 47 24 inches recovered; entire core is sand with matrix clay, 80 % 3.0 to 2.5 phi, 15 % 2.5 to 2.0 phi, 5 % 2.0 to 1.5 phi, coarsening downward to 90 % 2.5 to 2.0 phi, 10 % 2.0 to 1.5 phi, top of core, 15 to 16 % matrix clay, decreasing downward to 5 to 10 % at base of core, sand poor to moderately sorted with sorting increasing for the good toward base of core, subangular grains, upper 6 to 7 inches burrowed with clay infilling, burrows at the basal 6 inches interbedded with sand or shell lag; Color: medium bluish gray, 5 B 5/1.

47 - 50 drilled

50 - 52 24 inches recovered; upper 6 inches sand fining downward, upper part of core sand, 80 % 2.5 to 2.5 phi, 20 % 3.0 to 2.5 phi, trace of sand, 2.0 to 1.5 phi, core fining downward to 3.0 phi to 2.5 phi, 2 to 3 % matrix clay, upper portion of core increasing to 3 to 4 % at the base of the core, upper section 6 inch 2 - 3 % phosphate, 1 - 2 % heavy mineral bottom 18 inches, phosphate 1 % 0 - less, 1 - 2 % heavy minerals, btm 7 inch sand interbedded with shell hash and mud lenses, Color: medium bluish-gray, 5 B 5/1.

52 - 55 drilled

55 - 57 24 inches recovered; upper 8 inches, mixed shell hash and sandy clay, 40 to 45 % shell fragments; bottom 9 inches, interbedded clay and sandy-clay, sand lenses of approximately 1 and 0.5 inches thickness, sand size 3.0 to 2.5 phi, mixed with shell fragments; bottom 8 inches micaeous clay, some sand; Color: medium bluish-gray, 5 B 5/1.

57 - 60 drilled

60 - 62 24 inches recovered; core is clay to sandy-clay; 19 inches very little sand, with some organic material mixed with clay; bottom 5 inches organics with some sand, interbedded with clay -- clay is miceous, no shell fragments present, Color: medium bluish-gray 5B 5/1.

62 - 65 drilled

65 - 67 24 inches recovered; core is clay interbedded with sand lenses, sand lenses are separated by approxmately 6 inches of clay, within the sand lenses are thin clay lenses and some shell fragments, sand is 3.0 to 2.5 phi; Color: medium bluish-gray 5B 5/1.

67 - 70 drilled

70 - 75 24 inches recovered; core is clayey-sand, sand 2.0 to 2.5 phi, 20 % matrix clay, probably Hawthorn(?); Color: moderate. olive brown 5Y 4/4.

72 - 75 drilled

75 - 77 core is very sandy clay, 40 to 50 % sand, sand 60 % 3.5 to 3.0 phi, 40 % 3.0 to 2.5 phi, phosphatic, 2 to 3 % phosphate grains, burrowed; Color: pale olive 10 Y 6/2, burrows filled with grayish olive fine sand, 10 Y 4/2.

77 illed

80 inches recovered; core is a clayey sand, 60 % sand, 40 % clay,
sa 2.5 phi, well sorted, subangular, 6 to 8 % phosphate, burrowed,
mo ure; Color: moderate olive brown to grayish olive.

82 lled

85 inches recovered; core is very sandy clay to very clayey, sand
w ds of phosphatic sand; phosphate grains, 50 to 60 % sand, 3.0 to
3 e sand layers ranging from 2.0 to 1.5 phi to 2.0 to 2.5 phi, some
sh nts, phosphate 3 to 4 %, up to 10 to 15 %, 5 layers that are 90 %
sh nts, partially dissolved, forming calcite cement entire core
s careous appears to be burrowed, color: dark greenish-gray, 5 GY
4, ate olive brown.

87 lled same as above.

1 ayey-sand, sand 1.5 to 1.0 phi, 12 to 15 % matrix clay, 6 to 8 %
ph 0 - 90 % quartz sand 10 - 20 % matrix clay, at base of core is
ha s-phosphatic sand; Color: dark greenish-gray, 5GY 4/1.

2 1412N0804220, Palmetto Headlands, Well was not cored, cuttings
cc ery 5 ft, 3 screens 8 to 18 ft, 35 to 45 ft, 76 to 86 ft.

peat.

10 90 % 3.0 to 2.5 phi, 10 % 3.5 to 3.0 phi, 1 % or less heavy
mi to 4 % organic (peat) 1 % matrix clay.

1 90 % 3.0 to 2.5 phi, 10 % 3.5 to 3.0 phi, 1 to 2 % heavy minerals,
1 matrix clay, some grains iron stained.

2 3.0 to 2.5 phi, 2 to 3 % heavy minerals, 1 % matrix clay, well
s ngular.

25 90 % 3.0 to 2.5 phi, 10 % 2.5 to 2.0 phi, 1 % heavy minerals, 3 to
4 lay, Color: light olive gray, 5 Y 5/2.

30 silty clay, Color: medium gray (N5).

35 silty clay, 2 to 3 % sand, some organics, Color: medium gray N5.

40 y-sand, sand 3.0 to 2.5 phi, 1 % heavy minerals, 10 to 12 % clay,
sa orted, subangular; ColoR: olive gray 5 Y 4/1.

45 sand. [illegible] % 3.0 - 2.5 phi, 20 % 2.5 - 2.0 phi, 15 - 18 % matrix
cl of phosphate, 1 % heavy minerals, med bluish gray.

50 5 % pebbles, 10 % 0.0 - 0.5 phi, 85 % 0.5 - 0.0 phi, moderate
so % or less matrix clay, subangular, 3 % phosphate.

55 - clayey sand, sand 90 % 3.0 to 2.5 phi, 10 % 2.5 - 2.0 phi, some coarse but only a trace, 15 to 20 % matrix clay, 5 to 8 % phosphate; Color: medium dark gray, N4.

60 - clayey sand, sand 3.5 to 3.0 phi, well sorted, subangular 2 to 3 % phosphate, 15 to 20 % matrix clay; Color: dark greenish-gray, 5 GY 4/1.

65 - sandy clay, 40 % sand, sand size 3.5 to 2.5 phi, 5 to 6 % phosphate, 60 % clay, medium bluish-gray, 5B 5/1.

70 - clayey sand, 70 % 2.5 to 2.0 phi, 20 % 3.0 to 2.5 phi, 10 % 2.0 to 1.0 phi, 3 to 4 % phosphate, 10 to 15 % matrix clay, sand, moderate to poorly sorted, subangular grains.

75 - sand, 80 % 0.0 to -0.5 phi, 10 % 0.5 to 1.0 phi, 10 % -0.5 to -1.0 phi, moderate to poorly sorted, subangular grains, 1 % or less matrix clay, 3 to 4 % phoshate; Color: light olive gray, 5 Y 6/1.

80 - clayey sand, sand 80 % 2.0 to 2.5 phi, 10 % 2.0 to 1.5 phi, 10 % 3.0 - 2.5 phi, poorly sorted, subangular grains, 2 % shell fragments, 2 % phosphate, 10 % matrix clay; Color: medium dark gray N4.

85 - clayey sand, sand 70 % 3.0 to 2.5 phi, 20 % 2.5 to 2.0 phi, 10 % 2.0 to 1.5 phi, trace of 1.0 - 0.5 phi, 3 % phosphate, 1 to 2 % shell fragments, 10 to 15 % matrix clay, sand poorly sorted, subangular grains.

90 - pebbly clayey sand, 30 % -0.5 to -1.0 phi, pebbles of quartz and phosphate, 60 % 2.5 to 2.0 phi, 10 % 2.0 to 1.5 phi, poorly sorted, subangular grains.

95 - sandy phosphatic clay, sand 10 to 15 % 1.5 to 1.0 phi, phosphate 2 to 3 %; Color: grayish-olive, 10 Y 4/2.

100 - clayey sand, 80 % 3.0 to 2.5 phi, 10 % 3.5 to 3.0 phi, 10 % 2.5 to 2.0 phi, trace 1.0 - 0.5 phi, 10 to 12 % matrix clay, 5 to 6 % phosphate, trace shell fragments, sand moderately sorted, subangular grains; Color: pale olive 10 Y 6/2.

27KK-i11, 321244N0804201, Hilton Head PSD #1 Treatment Plant, Well, 2 screens, 10 to 20 ft, and 42 to 52 ft.

0 - 5 drilled

5 - 7 18 inches recovered; 0.3 ft topsoil, dark brown, 0.3 fine sand, 2.5 to 3.0 phi, low % clay (2 % ?) 1.0 ft fine sand as above, dark brown, 5YR 3/4.

7 - 10 drilled

10 - 12 22 inches core recovered; entire core is sand, 2.0 to 1.5 phi, some matrix clay (1 to 2 %), well sorted, subrounded, 1 % heavy minerals, size 2.5 - 3.0 phi; Color: 10 YR 5/4.

12 - 15 drilled

15 - 17 22 inches core recovered, possible cross-bedding; from 0 to 4 inches, sand, 2.5 to 3.0 phi, well sorted, 1/2 inch heavy banding, burrowing, trace of coarser sand; 4 to 22 inches, sand, 2.5 to 3.0 phi, subrounded, well sorted, low % matrix clay, clay not sticky; Color: 5 Y 5/6.

17 - 20 drilled

20 - 22 22 inches recovered; core quite variable, 0 to 6 inches, fine sand, 3.5 to 3.0 phi, subrounded, slightly sticky; color: 10 Y 4/2; 6 to 7 inches, clay; Color: 5 Y 3/2; 7 to 12 inches, fine sand, 3.5 to 3.0 phi, sticky, subrounded, 2 % heavy minerals; Color: 10 Y 4/2; 12 to 14 inches, clay, Color: 5 Y 3/2; 14 to 18 inches, sand, as interval 7 to 12 inches, less heavies; 18 to 23 inches, clay; Color: 5 Y 3/2; Note: fine sand in core basket from 21 to 22 inches.

23 - 25 drilled

25 - 27 14 inches core recovered; core is sand, fine, 2.5 to 3.0 phi, micaeous; Color: 5GY 4/1; 7 % heavies, low clay, 5 % as matrix clay, subangular; clay layer at 6 inches is less than 1/4 inch thick.

27 - 30 drilled

30 - 32 23 inch recovered; 0 to 7 inches, sand, very fine, 3.0 to 3.5 phi, rounded, sticky, 1 to 2 % heavy minerals,; Color: 5 GY 4/1; 7 to 10 inches sand with shells (Olivia sp), sand 3.0 to 2.5 phi, high clay %; 10 to 23 inches, clayey-sand to clay with shells; Color: 5 GY 2/1

32 - 35 drilled

35 - 37 24 inches core recovered; 0 to 17 inches, clay, Color: 5GY 4/1, isolated sand beds (typically less than 1/10 inches); 17 to 23 inches, sand, 3.0 to 2.5 phi, sticky, 25 % clay (as matrix), heavies, 1 to 2 %, possible phosphate?; Color: 5 GY 4/1, 23 to 24 inches, as above with shells. Note: break at 17 inches is contact.

37 - 40 drilled

40 - 42 24 inches recovered; 0 to 4 inches, clay, Color: 5GY 2/1, texture: gritty, (better described as sandy-clay?); 4 to 6 inches, shell hash, shells broken, shells in sand, fine sand 3.5 to 3.0 phi, very sticky, Color: 5GY 4/1; 6 to 18 inches, clay, sand lenses (less than 1/10 foot thick at depth 10 and 13 inches), Color: 5 GY 2/1; 18 to 24 inches, clay with sandy clay lenses at 18 and 23 inches. Note: break at 18 inches, shells at 20 inches, Color: 5 GY 2/1.

42 - 45 drilled

45 - 47 24 inches recovered; 0 to 3 inches, shell hash, thick shells in clay, with sandy clay; Color: 5 GY 4/1. 3 to 24 inches, fine sand, 3.0 - 2.5 phi, very low % clay, 1 % heavies, no structure; Color: 5 GY 5/1.

47 - 50 drilled

50 - 52 14 inches recovered; 0 to 3 inches, shell hash, sandy-clay, gritty-very sticky; Color: 5 GY 4/1. 3 to 14 inches, fine sand, 2.5 to 2.0 phi, subrounded, some interworked subangular grains, shells including Olivia ssp, Color: 5 G 4/1. Notes: No sedimentary structure; 1 % heavy minerals, possibly some phosphate, size 3.5 phi.

52 - 55 drilled

55 - 57 19 inches recovered; 4 inches, sandy-clay, some shell hash, sand 3.5 to 3.0 phi, very sticky, Color: 5 GY 4/1. 4 to 11 inches, sandy-clay, few shells, Color: 5 G 4/1. 11 to 14 inches, clayey sand, sand 3.0 to 2.5 phi, Color: 5 GY 4/1 20 % matrix clay, 14 to 15 inches, clay, Color: 5 G 2/1. 16 to 19 inches, clayey-sand, sand 3.0 to 3.5 phi, with shells, broken reworked phosphate grains ?, 15 % matrix clay.

57 - 50 drilled

60 - 62 24 inches recovered; 0 to 3 inches, clayey-sand, with shells, quartz sand -0.5 to -1.0 phi, phosphate to 2 %, some heavies, color: 5 G 4/1. 3 to 24 inches, sandy-clay to clayey-sand, sand 3.5 t0 3.0 phi, fragments, Color: 5 Y 4/4. Note: 3 to 24 inches is Hawthorn.

62 - 65 drilled

65 - 67 24 inch recovered, 0 to 24 inches, clayey sand, sand subangular, 20 % or more matrix clay, sand 3.0 to 2.5 phi, quartz, phosphate, scattered qtz grains of size 1.0 phi +, Color: 5 Y 4/4. Note: core sticky, gritty, with scattered shell fragments.

Drilled to 75 ft. Note: cuttings: green clay, fine sand w/phospate, clay such that dispersed in mud, many shell fragments, Color: 5 Y 4/4.

27KK-e06, 321410N0804445, Salty Fare Village, Well, 1 screen 32 to 52 ft.

0 - 5 drilled

5 - 7 18 inches recovered, 0 to 18 inches, sand, 3.0 to 2.5 phi, well sorted, subrounded to subangular grains, 3 % heavy minerals, possible trace of phosphate, less than 1 % matrix clay, possible cross-bedding, bedsets greater than 8 inches; Color: yellowish gray 5 Y 7/2

7 - 10 drilled

10 - 12 24 inches recovered; clay, 3 to 4 % silt, trace of muscovite w/rooting and organics, rooting maybe recent; Color: medium bluish-gray, 5 B 5/1.

12 - 15 drilled

15 - 17 24 inches recovered; silty-clay, 3 to 4 % silt, trace of muscovite, some rooting, possible spartina marsh; Color: medium bluish gray 5 B 5/1.

17 - 20 drilled

20 - 22 9 inches recovered; 0 to 6 inches sandy-silty clay with 30 % shell fragments (oysters), 6 to 9 inches, silty clay, 3 to 4 % silt, no shell fragments; color: medium bluish-gray 5 B 5/1.

22 - 25 drilled

25 - 27 24 inches recovered; upper 2 inches sandy silty-clay; 2 to 7 inches, clayey, silty-sand, fine sand 3.5 to 3.0 phi, subangular grains, 10 to 15 % matrix clay, 10 % shell fragments; , 7 to 15 inches (8" section) interbedded clay and sand, lenticular bedding, sand 3.0 to 2.5 phi, moderately sorted, subangular grains, 3 to 6 % matrix clay, clay-silty, trace of mica; 15 to 22 inches (next 7") interbedded sand and clay, flaser bedded (?), sand 3.0 to 2.5 phi, well sorted, 1 to 2 % matrix clay, 1 to 2 % heavy minerals, some organics; 22 to 24 incnes, clay as above; color: medium bluish-gray 5 B 5/1.

27 - 30 drilled

30 - 32 16 inches recovered; upper 2 inches, shell & clay mixture, 60 % shell fragments (oysters), clay is silty, 2 to 5 inches, sand, 3.0 to 2.5 phi, moderately well sorted, 6 to 8 % matrix clay, subangular grains, 1 to 2 % heavy minerals, at base of section 1" of shell fragments in sand; 5 to 13 inches, sand, 3.0 to 2.5 phi, 10 to 15 % matrix clay, 3 % shell fragments, trace of phosphate, moderately sorted, subangular grains; 13 to 18 inches (following 3") sand, 3.0 to 2.5 phi, 3 to 5 % matrix clay, moderately well sorted, subangular grains, 1 to 2 % heavy minerals, 3 to 4 % shell fragments; Color: greenish-gray 5 G 6/1.

32 - 35 drilled

35 - 37 24 inches recovered; upper 5 inches sandy, silty-clay, 2 to 3 % sand, 1 to 2 % silt, sand content increasing downward, contains some organics, 5 to 15 inches, clayey sand, sand is 3.0 to 2.5 phi, 3 to 4 % matrix clay, 5 to 6 % shell fragments, 1 to 2 % phosphate, shell fragments (possibly Donax ssp.), moderately sorted, subangular grains; 15 to 21 inches (following 6") sand, 3.0 - 2.5 phi, 3 to 4 % matrix clay, 1 to 2 % heavy minerals, moderately well sorted, subangular grains; lower 4 inches 1 inch possible shell lag and 3 inches sandy, silty-clay; Color: medium bluish-gray, 5 B 5/1.

37 - 40 drilled

40 - 42 24 inches recovered, upper 14" clayey sand, 80% sand, 2.5 to 2.0 phi, 20% sand 1.5 to 2.0 phi, moderate to poorly sorted, subangular grains, 6 to 10% matrix clay, 8 to 10 % shell fragments; 14 to 23 inches, sand and shell hash, sand 95% 0.5 to 0.0 phi, 5% 3.0 to 2.5 phi, poorly sorted, subangular grains, 40 to 45% shell fragments; lower 1 inch sand interbedded with shell hash, sand 80 % 2.5 to 2.0 phi, 20 % 3.0 to 2.5 phi, 1 to 2 % matrix clay, 1 to 2 % heavy minerals, moderately well sorted, subangular grains, cross-bedded, tidal channel or washover deposit?; Color: light olive-gray, 5 Y 6/1.

42 - 45 drilled

45 - 47 24 inches recovered; upper 9 inches sand, 60 % 0.5 to 0.0 phi, 30 % 2.0 to 1.5 phi, 10 % 3.0 to 2.5 phi, poorly to moderately sorted, subangular grains, 6 to 8 % matrix clay, 15 to 20% shell fragments (hash), 1 to 2% phosphate; 9 to 19 inches silty, sandy-clay, with lenticular beds of sand (3.0 to 2.5 phi), sand, lower 5 inches, sand, 3.0 to 2.5 phi, moderately well-sorted, subangular grains, 1% or less heavy minerals, flaser bedded with clay drupes, clay drupes becoming more numerous toward bottom of core; Color: medium bluish-gray, 5B 5/1.

47 - 50 drilled

50 - 52 19 inches recovered; upper 14 inches sand, 10 % 0.0 to -0.5 phi, 40 % 0.5 to 0.0 phi, 30 % 1.0 to 0.5 phi, 20 % 1.5 to 1.0 phi, poor to moderately sorted, subangular grains, 3 to 4% phosphate, 2 to 3% shell fragments, 1% or less matrix clay; 14 to 16 inches, shell hash; 16 to 19 (lower 3") sand and shell interbedded, cross-bedded sand, 80% 2.5 to 2.0 phi, 10 % 1.5 - 1.0 phi, 10% 3.0 to 2.5 phi, 1% to 2% phosphate, 1% heavy mineral, 1% or less matrix clay, sand is moderately to poorly sorted, subangular grains; Color: light bluish-gray 5 B 7/1.

52 - 55 drilled

55 - 57 23 inches recovered; upper 2 inches sandy clay, with loose phosphate (as fragments?), and shell fragments; 2 to 8 inches, slightly clayey-sand, 95 % 2.5 to 2.0 phi, 5 % 0.5 to 0.0 phi, 3 to 4 % matrix clay, 10 to 15 % shell fragments, 2 to 3 % phosphate, sand is moderately to poorly sorted, subangular; 8 to 24 inches (17"), sand 1.5 to 1.0 phi, moderately well sorted, subangular grains, 2 to 3 % phosphate, sand cross bedded with shell fragments and phosphate on top of beds; Color: medium light gray (NG).

57 - 60 drilled

60 - 62 18 inches recovered; core is 18 inches sand, 80 % 2.0 to 1.5 phi, 10 % 1.5 to 1.0 phi, 10 % 2.5 to 2.0 phi, moderately sorted, subangular grains, less than 1 % matrix clay, 3 to 4 % phosphate, cross-bedded, trough bedsets, 1" to 0.75" with shell hash defining top of bedsets; Color: medium light gray, N6.

62 - 65 drilled

65 - 67 19 inches recovered; upper 11 inches sand, 60 % 2.5 to 2.0 phi, 35 % 3.0 to 2.5 phi, 5 % 0.0 to -0.5 phi, trace of quartz pebbles, moderately sorted, subrounded grains, 1 to 2 % matrix clay, 1 to 2 % phosphate, 1 to 2 % heavy minerals, cross-bedded, with phosphate and heavy minerals along contacts of bedsets; Color: medium gray, N5; 11 to 19 inches, sand, 80 % 2.0 to 2.5 phi, 20 % 2.0 to 1.5 phi, moderately well sorted, subangular to subrounded, 2 to 3% matrix clay, 1 to 2 % phosphate, cross-bedded with partially dissolved shell fragments defining the bedsets; Color: medium gray, N5.

67 - 70 drilled

70 - 72 24 inches recovered, upper 20 inches clayey sand, sand 3.0 to 2.5 phi, moderately well sorted, 8 to 10 % matrix clay, 1 % or less phosphate, 4 inches clayey calcareous sand, as above; Color: grayish olive, 10 Y 4/2. Note: Hawthorn Fm.

72 - 75 drilled

73 - 74 drilled limestone or other hard zone.

75 - 77 16 inches recovered; 2" phosphate pebbles and some silty sandy clay 14" sand, 90 % 1.0 - 0.5 phi, 10 % 1.5 - 1.0 phi, 3 % partially dissolved shell fragments, 2 - 3 % phosphate btm 6", 1 - 2 % calcareous mud, w/percentage increasing downward, btm 6" calcareous sand, consolidated in places s/ zones non-calcareous, grayish olive low permeable zones and calcareous zones with permeable zone color yellowish gray 5 Y 7/2.

77 - 80 drilled

80 - 82 20 inches recovered, entire core is sand, 90 % 2.5 to 2.0 phi, 10 % 2.0 to 1.5 phi, 1 % calcareous matrix clay, 2 % partially altered shell fragment, 1 to 2 % phosphate, sand moderately well sorted, subangular to subrounded, cross-beded, 0.25 to 0.50 inches bedsets, separated by calcareous zones along bedset contact; Color: light olive-gray, 5 Y 6/1 to medium gray, N5. (non-calcareous)

82 - 85 drilled

85 - 87 22 inches recovered, upper 14 inches calcareous sand, 90 % 3.0 to 2.5 phi, 10 % 2.5 to 2.0 phi, moderately well sorted, subangular grains, 2 to 3 % calcareous mud matrix, some zones consolidated, 1 to 2 % phosphate, 2 to 3 % partially altered shell fragments; lower 8 inches sand, 3.0 to 2.5 phi, well sorted, subangular, 1 to 2 % matrix clay, non clacareous, 1 to 2 % phosphate, 2 to 3 % shell fragments; Color: light olive gray, 5Y 6/1.

27KK-d06, 321430N0804328, Hilton Head Plantation test boring 2,
0 - 5 drilled

5 - 7 23 inches recovered, 0 to 23 inches, fine sand, 2.5 - 3.0 phi, subrounded, low % clay (less than 1 %?), slightly micaceous, few heavies, uniform grain size; Color: 5 YR 3/4 - 10 YR 4/2.

7 - 10 drilled

10 - 12 23 inches recovered; 0 to 23 inches, fine sand, 3.0 to 2.5 phi, cross-bedded, 4 to 4.5 inches bedsets, heavy mineral accumulation, subrounded, uniform; Color: 10 YR 4/2.

12 - 14 drilled

15 - 17 21 inches recovered; 0 to 13 inches, fine sand, 2.5 to 3.0 phi, not uniform, some sand about 3.5 phi, organics at 13", 1 % heavy minerals; 1 % or less clay; Color: 5 Y 5/2; 14 to 21 inches, fine sand, 2.5 to 2.0 phi, greater clay than above (5 %), 1 % heavy mineral accumulation, micaceous, moderately well sorted; Color: 5Y 5/2.

17 - 20 drilled

20 - 22 22 inches recovered; 0 to 22", fine sand, uniform (well sorted), 2.5 to 3.0 phi, micaceous, very fine, less than 1 % heavy minerals, burrowing at 12", Color: 5 GY 6/1.

22 - 25 drilled

25 - 27 24 inches recovered; 0 to 24 inches, fine sand, 2.5 to 3.0 phi, micaceous, subrounded to subangular, 2 % heavy minerals; Color: 5 GY 6/1.

27 - 30 drilled

30 - 32 23 inches recovered, core quite variable, 0 to 3 inches, fine sand, 3.0 to 2.5 phi, some organics; Color: 10 YR 5/2; 3 to 4 inches, fine sand, 3.0 to 2.5 phi; 4 to 5 inches, peat, rooted, woody; 5 to 11 inches, clay; Color: 10 YR 2/2, peat at 11 inches; 11 to 23 inches, fine sand with clayey sand, sand 2.0 to 2.5 phi, 10 % clay (matrix?); Color: 5 G 4/1.

32 - 35 drilled

35 - 37 24 inches recovered; 0 to 7 inches, shell hash, woody peat at top, coarse quartz, much clay; Color: 5 G 4/1; 7 to 24 inches clay, rooted; Color: 5 GY 2/1.

37 - 40 drilled

40 - 42 24 inches recovered; 0 to 9 inches, clay interbedded with fine sand, sand 3.0 to 2.5 phi, Color: 5 GY 4/1, fine sand is clayey (5 % matrix) some organics in clay. 9 to 24 inches, fine sand with interbedded clay (2 splits), shell hash at 19 inches, phosphate pebbles, sand size increasing downward from 2.5 phi to 1.5 phi; Color: 5 GY 6/1.

42 - 45 drilled

45 - 47 24 inches recovered; 0 to 11 inches, medium sand, 1.5 to 1.0 phi, shell hash, phosphate, subangular to subrounded, 2 % heavy minerals; Color: 5 GY 6/1; 11 to 20 inches, clay, some shells; Color: 5 Y 2/1; 20 to 24 inches, sandy clay, sand 3.0 phi, minor organics, micaceous (?); Color: 5 GY 2/1.

47 - 50 drilled

50 - 52 24 inches recovered; 0 to 12 inches sand interbedded with clay, core in three 4 inch sections, fine sand with phosphate, organics and fine shells, sand 2.0 - 1.5 phi; Color: 5 G 4/1; 12 to 24 inches sand with flaser beds, more shells, sand 1.5 to 1.0 phi, minor phosphate or heavy minerals, some organics; Color: 5 GY 4/1.

52 - 55 drilled

55 - 57 24 inches recovered; 0 to 3 inches, clay to sandy-clay; sand 3.5 to 3.0 phi; Color: 5 G 4/1; 3 to 8 inches, coarse quartz sand (lag deposit?), possible erosion surface, shells with greenish platy mineral (glaconite?), sand 10 % to -0.5 phi, 90 % 2.5 to 3.0 phi, poorly sorted; Color: 5 G 4/1; 8 to 13 inches, sandy clay, some phosphate, some shells; Color: 5 GY 4/1; 13 to 24 inches clay with organics, possibly rooted; Color 5 GY 2/1.

57 - 60 drilled

60 - 62 24 inches recovered; 0 to 18 clay; Color: 5 G 4/1; 18 to 24 inches, fine sand with shell hash sand 90 % 2.0 to 2.5 phi, Color: 5 G 6/1.

62 - 65 drilled

65 - 67 24 inches recovered; 0 to 14 inches, fine sand 3.0 to 2.5 phi, 10 % clay, uniform, 2 % dark minerals, few shells, lenticular bedding, possible glauconite; Color: 5 GY 6/1; 14 to 24 inches, clay to sandy-clay, very sticky, micaceous possible roots (?); Color: 5 GY 4/1.

67 - 70 drilled

70 - 72 24 inches recovered; 0 to 8 inches clay streak to fine sand containing reworked Hawthorn, sand 2.0 to 1.5 phi, greater than 80 % shell hash, phosphate pebbles; 8 to 24 inches, Hawthorn contact, very sticky quartz, some green mineral, clayey-sand, sand 2.5 to 3.0 phi, contains phosphate, micaceous.

72 - 75 drilled

75 - 77 24" recovered, 0 to 24 inches, very fine to clayey sand, sand greater than 90 % 3.5 to 3.0 phi, micaceous, possible burrowing from 21 to 23 inches; Color: 10 Y 4/2.

77 - 80 drilled

80 - 82 24 inches recovered; as above, fine clayey sand with sparse shells.

82 - 85 drilled

85 - 87 24 inches recovered; fine sand, micaceous, low % clay (perhaps 2 %), no structure, phosphate, sand 3.0 to 2.5 phi, clay % decreasing downward, subangular, moderately-well sorted; Color: 10 Y 4/2.

87 - 90 drilled

90 - 92 24 inches recovered; fine sand, micaceous, sand 2.5 to 2.0 phi, increasing amount of phosphate compared to above, subangular; Color: 10 Y 4/2.

92 - 95 drilled limestone at 94 ft, no core recovered.

28KK-ill, 321306N0804612, Spanish Wells Plantation, test hole

0 - 5 drilled

5 - 7 23 inches recovered; 0 to 23 inches sand, 3.0 to 2.5 phi, less than 1 % matrix clay, 1 to 2 % heavy minerals, sand is well sorted, subangular, cross-bedded, beds appear to be trough (dunes?), some mottling of soil zone; Color: moderate yellowish brown, 10 YR 5/4.

7 - 10 drilled

10 - 12 20 inches recovered; 0 to 20 inches sand, 3.0 to 2.5 phi, 1 % or less matrix clay, less than 1 % heavy minerals, sand is well sorted, subangular, appears to be massive, saturated; Color: moderate brown, 5 YR 4/4.

12 - 15 drilled

15 - 17 24 inches recovered; 24 inches sand, 90 % 3.0 to 2.5 phi, 10 % 2.5 to 2.0 phi, moderately well sorted, 1 % or less matrix clay, trace of heavy minerals, cross bedded, bed sets 5 to 7 inches, separated by a layer of organics or clayey sand, or both, organics appear to be land deposits; Color: moderate yellowish-brown, 10 YR 5/4.

17 - 20 drilled

20 - 22 23 inches recovered; 0 to 7 inches sand, 3.0 to 2.5 phi, 3 % matrix clay, 2 to 3 % heavy minerals, well sorted, subangular grains, 7 to 19 inches, sand interbedded with clay lenses, almost flaser bedding, sand 2.5 to 2.0 phi, moderately sorted, 2 to 3 % matrix clay, sand sequence fines downward to 3.0 to 2.5 phi, 3 % heavy minerals; 19 to 23 inches, clayey-sand (possible shell hash), possible washover deposit.

22 - 25 drilled

25 - 27 24" recovered; 0 to 2 inches, clayey sand and shell hash; 2 to 12 inches sand, 3.0 to 2.5 phi, 1 to 2 % matrix clay, 1 to 2 % heavy minerals, approximately 2 % shell hash; 12 to 18 inches (6 inches section) clayey sand, sand as above mixed with shell hash, predominate shell Donax ssp.; possible washover or lower shoreface deposit; 18 to 24 inches, sand, 3.0 to 2.5 phi, 1 to 2 % matrix clay, well sorted, subangular grains, 1 to 2 % heavy minerals, 4 to 6 % shell fragments, mostly Donax ssp; Color: medium bluish-gray, 5 B 5/1.

27 - 30 drilled

30 - 32 24" recovered; 0 to 3 inches, sandy to silty clay, organic rich rooted, (possible swamb deposit), 3 to 4 inches peat; 7 to 21 inches (17" section) sand, silty clay, rooted, organic rich, does not appear to be saltmarsh, swamp directly below cores; Note: losing water in mud pits; Color: medium bluish gray, 5 B 5/1.

32 - 35 drilled

35 - 37 24 inches recovered; 0 to 24 inches, silty clay, bottom 15 inches rooted with organics, sandy; bottom 1 inch sand occurring as lenses, 9 inches from top cored wood, possible large root?, clay slightly micaeous; Color: medium bluish gray, 5 B 5/1.

37 - 40 drilled

40 - 42 24" recovered; 0 to 19 inches sandy silty clay with trace of organics, interbedded with clayey sand; the clayey sand occurs as beds approximately 1 inch thick, and approximately 4 inches apart, clay is interbedded with some lenses of organics, 19 to 24 inches (5") clayey sand, 60 % sand is 3.0 to 2.5 phi, sand is well-sorted, subangular, 40 % matrix clay, trace of organic, trace of muscovite; Color: medium bluish gray; 5 B 5/1.

42 - 45 drilled

45 - 47 24" recovered; 0 to 24" clayey sand, upper 16" is clayey sand, 50 % 3.0 to 2.5 phi and 40 % 2.5 to 2.0 phi, moderately-well sorted, subangular grains, trace of organics, 10 to 15 % matrix clay; 8" clayey sand, 60 % 2.5 to 2.0 phi, 40 % 2.0 to 1.5 phi, moderately sorted, subangular grain, trace of pebbles, appears to be semiconsolidated; Color: medium bluish gray, 5 B 5/1.

47 - 50 drilled

50 - 52 24 inches recovered; 0 to 7 inches clayey sand, sand is 3.0 to 2.5 phi, moderately-well sorted, subangular, 8 to 10 % clay, burrowed, vertical burrows; 7 to 24 inches (17") clayey sand as above with 3 to 4 % shell fragments occurring as lenses; color change Color: grayish olive, 10 Y 4/2. Note: Hawthorn Fm.

52 - 55 drilled

55 - 57 24 inches recovered; 0 to 24 inches clayey sand, 3.0 to 2.5 phi, 8 to 10 % clay as matrix, 1 to 2 % phosphate, approximately 2 % shell fragments, some vertical burrows, rare, some shell lenses; Color: grayish olive, 10 Y 4/2.

57 - 60 drilled

60 - 62 24 inches recovered; 0 to 24 inches clayey-sand, 3.0 to 2.5 phi, subrounded grains, clay matrix, sparse shells, minor phosphate; Color: 10 Y 4/2.

62 - 65 drilled

65 - 67 24 inches recovery; 0 to 24 inches clayey-sand, fining downward, 3.0 to 2.5 phi at top, 3.5 to 3.0 phi at bottom, very minor phosphate; Color: 10 Y 4/2.

67 - 70 drilled

70 - 72 24 inches recovered; 0 to 24 inches, clayey-sand, sand 3.0 to 2.5 phi, matrix clay to 10 % (?), very sticky, sand is subrounded, very minor phosphate; Color: 10 Y 4/2.

72 - 75 drilled

75 - 77 24 inches recovered; 0 to 24 inches, clayey-sand, sand 3.0 to 2.5 phi, 10 % matrix clay, very minor mica, sticky, no structure; Color: 10 Y 4/2.

77 - 80 drilled

80 - 82 24 inches recovered; 0 to 24 inches clayey-sand, sand 3.0 to 2.5 phi, 8 % to 10 % matrix clay, 2 to 3 % phosphate grains, trace of shell fragments, shell fragments not phosphorized, core appears to be massive; Color: grayish olive, 10 Y 4/2.

82 - 85 drilled

85 - 87 24" recovered; 0 to 4 inches, clayey sand, sand 3.0 to 2.0 phi, moderately sorted, 8 to 10 % matrix clay, 4 % to 5 % phosphate, slightly calcareous; 4 to 7 inches(3") silty, sandy, phosphatic, soapy clay, 7 to 20 inches (13") clayey-sand, sand 3.0 to 2.5 phi, 8 to 10 % matrix clay, 4 to 5 % phosphate, zones that are calcareous; Color: grayish olive, 10 Y 4/2; 20 to 24 inches (4") sand, sand 60 % 2.0 to 1.5 phi, 40 % 1.5 to 1.0 phi, moderately sorted, 1 % or less matrix clay, 4 to 5 % phosphate, subangular grains; Color: medium light gray, N6.

85 - 90 drilled

90 - 92 cored, hard, none recovered, could not penetrate with split-spoon.

APPENDIX II. FORAMINIFERA IN TEST-HOLE CORES

hole number and depth of recovery of foraminifera in Hilton Head Island cores

28	27KK-e6	27KK-d6	27KK-h5	27KK-h6	27KK-i11	28KK-v5
15	35 - 37	50 - 52	35 - 37	50 - 52	35 - 37	40 - 42
55	85 - 87	55 - 57	85 - 87	65 - 67	60 - 62	50 - 52
		65 - 67		70 - 72		55 - 57
		70 - 72				60 - 62
		75 - 77				65 - 67
		80 - 82				70 - 72
						75 - 77

APPENDIX III. SIEVE ANALYSES

St of core 28KK-i11, Jenkins Island

Dep (ft,	Mean	Variance	Standard deviation
5 tc	3.6359	0.5810	0.7623
10 -	2.496	0.1937	0.4402
15 -	2.5194	0.1763	0.4199
20 -	3.0183	0.8940	0.9455
25 -	2.6028	0.8086	0.8992
30 -	1.3133	1.4035	1.1847
35 -	2.6563	0.8536	0.9239
40 -	2.9872	0.4461	0.6679
45 -	3.7385	0.5015	0.7981
50 -	2.0141	3.3330	1.8256
55 -	2.0338	2.4342	1.5602
60 -	2.3121	1.4995	1.2245
65 -	2.7002	0.8366	0.9147
70 -	2.5411	1.6133	1.2702
75 -	2.2238	1.6900	1.2999

Stat f core 27KK-h6, Hilton Head Airport

De (ft,	Mean	Variance	Standard deviation
5 to			
10 -	2.3723	0.1251	0.3537
15 -	2.2494	0.2680	0.5176
20 -	2.5262	0.2732	0.5227
25 -	2.6184	0.2436	0.4936
30 -	3.5056	1.8128	1.3463
35 -	4.0835	0.2273	0.4767
40 -			
45 -	2.3442	1.8538	1.3616
50 -	1.9942	1.2400	1.1136
55 -			
60 -	3.4897	1.0199	1.0099
65 -	3.5546	0.4887	0.6990
70 -	3.1155	0.7483	0.8651
75 -	2.5089	1.5600	1.2490
80 -	2.4673	1.4965	1.2233
85 -		no core collected	
90 -	1.7126	1.9369	1.3917
95 -	1.4019	1.1559	1.0751

Statistics of core 27KK-i11, Public Service District #1

Depth (ft. bls)	Mean	Variance	Standard deviation
5 to 7	2.4405	0.1373	0.3706
10 -12	2.3981	0.1438	0.3792
15 -17	2.6318	0.3017	0.5493
20 -22	3.0376	0.6557	0.8097
25 -27	2.5283	0.6261	0.7913
30 -32	2.8700	2.6348	1.6232
35 -37	3.2167	0.6407	0.8005
40 -42	3.7568	0.9501	0.9747
45 -47	2.5137	0.3414	0.5842
50 -52	1.5496	1.2932	1.1372
55 -57	2.3798	1.6125	1.2698
60 -62	3.0143	0.6087	0.7802
65 -67	2.6495	1.0435	1.0215

Statistics of core 27KK-h5, near Hilton head Hospital

Depth (ft, bls)	Mean	Variance	Standard deviation
5 to 7	2.4957	0.1182	0.3438
10 -12	2.4433	0.1063	0.3260
15 -17	2.2479	0.0988	0.3144
20 -22	2.7742	0.1850	0.4301
25 -27	2.2634	0.2441	0.4941
30 -32	2.6295	0.4295	0.6554
35 -37	2.2047	1.1627	1.0783
40 -42	2.3077	0.6632	0.8143
45 -47	2.6268	1.1556	1.0750
50 -52	2.6124	0.3697	0.6080
55 -57	2.6927	3.5932	1.8956
60 -62	4.0240	0.2858	0.5347
65 -67	3.7015	0.5905	0.7685
70 -72	3.0707	0.3799	0.6164
75 -77	3.2832	0.6733	0.8206
80 -82	2.9718	1.1525	1.0735
85 -87	2.9785	1.7239	1.3129
90 -92		no core taken	
95 -97		no core taken	
100-102	1.6486	1.9032	1.3796

Statistics of core 28KK-v5, Spanish Wells Plantation

Depth (ft, bls)	Mean	Variance	Standard deviation
5 to 7	2.6036	0.1900	0.4359
10 -12	2.6945	0.2834	0.5324
15 -17	2.7968	0.3308	0.5752
20 -22	2.4299	1.4048	1.1852
25 -27			
30 -32	4.1675	0.1170	0.3420
35 -37	4.1924	0.0928	0.3046
40 -42	3.8508	0.4127	0.6424
45 -47	2.1068	2.8692	1.6939
50 -52	3.1222	0.3912	0.6255
55 -57	3.0686	0.3213	0.5669
60 -62	3.1822	0.2878	0.5365
65 -67	3.1919	0.3538	0.5948
70 -72	3.2339	0.3903	0.6247
75 -77	3.4327	0.3865	0.6217

Statistics of core 27KK-f24, Hilton Head Elementary School

Depth (ft, bls)	mean	variance	standard deviation
5 to 7	2.79	0.35	0.59
10 -12	2.68	0.34	0.58
15 -17	2.83	0.71	0.84
20 -22	2.52	1.12	1.06
25 -27	2.78	0.41	0.64
30 -32	2.88	0.35	0.59
35 -37	2.56	1.06	1.03
40 -42	**		
45 -47	2.09	1.38	1.18
50 -52	3.06	0.71	0.84
55 -57	**		
60 -62	2.87	0.500	0.707
65 -67	1.9976	1.4611	1.2087
70 -72	2.51	1.05	1.02

Statistics of core 27KK-d6, Hilton Head Plantation

Depth (ft, bls)	Mean	Variance	Standard deviation
5 to 7	2.5934	0.2421	0.4920
10 -12	2.6838	0.2806	0.5297
15 -17	2.6558	0.3880	0.6229
20 -22	2.7005	0.4929	0.7021
25 -27	2.8489	0.2760	0.5234
30 -32	2.9937	0.9911	0.9955
35 -37	4.0123	0.3288	0.5734
40 -42	2.7887	0.7847	0.8856
45 -47	2.5059	1.7223	1.3124
50 -52	2.4303	1.0973	1.0476
55 -57	4.0256	0.5544	0.7446
60 -62	3.9419	0.8913	0.9441
65 -67	3.4559	0.7328	0.8560
70 -72	2.7193	1.3996	1.1830
75 -77	3.2022	0.4488	0.6699
80 -82	3.1320	0.5379	0.7333
85 -87	2.9896	0.7212	0.8492
90 -92	2.6491	1.5452	1.2431

Statistics of core, 27KK-e6 Salty Faire Village

Depth (ft, bls)	Mean	Variance	Standard deviation
5 to 7			
10 -12			
15 -17			
20 -22			
25 -27			
30 -32	2.5200	2.1400	1.4600
35 -37	2.2800	2.4600	1.5700
40 -42	1.6100	2.2100	1.4900
45 -47	2.0500	4.0500	2.0100
50 -52	1.0400	1.5800	1.2600
55 -57	1.4800	1.3600	1.1700
60 -62	1.3200	1.2600	1.1200
65 -67	1.4100	1.4200	1.1900
70 -72	3.1000	1.0000	1.0000
75 -77	1.2000	2.2500	1.5000
80 -82	1.6100	1.7600	1.3300
85 -87	2.3000	1.7000	1.3000
90 -92			