

**GROUND-WATER CONDITIONS  
IN THE LADIES AND ST. HELENA ISLANDS AREA  
SOUTH CAROLINA**

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**STATE OF SOUTH CAROLINA**



**WATER RESOURCES COMMISSION  
REPORT NUMBER 147  
1985**

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SOUTH CAROLINA**

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by  
**Jeffrey A. Hassen**

A Study Sponsored By The  
South Carolina Coastal Council

**STATE OF SOUTH CAROLINA**



**WATER RESOURCES COMMISSION  
REPORT NUMBER 147  
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OF  
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# GROUND-WATER CONDITIONS IN THE LADIES AND ST. HELENA ISLANDS AREA SOUTH CAROLINA

by  
Jeffrey A. Hassen

## ABSTRACT

The Ladies and St. Helena Islands study area is composed of approximately 175 square miles in the southeast corner of South Carolina. The surface area is flat, consisting of several islands interconnected by saltwater estuaries and marshland. The majority of the 10,303 inhabitants live on the two largest islands, Ladies and St. Helena.

Ground-water supplies are available from several underlying formations, including the Middendorf, Black Creek, Peedee, Black Mingo, Santee, and shallow deposits. However, the best potential source of ground water in the area is the upper Floridan aquifer, encompassing the Santee Limestone. It is composed of limestone of Eocene age which underlies the entire study area at depths ranging from 30 to 120 feet below the surface and is at least 25 feet thick.

The principal recharge areas for the upper Floridan aquifer in this area are located in the northwestern portion of the study area, in northern Ladies Island, and in the central part of St. Helena Island. This recharge is the direct result of rainfall entering the aquifer through a shallower aquifer in areas where the overlying confining unit is thin or absent and, possibly to some extent, through sinkholes. Water levels in these areas are as high as 19 feet above sea level, producing a hydraulic gradient of as much as 15 feet per mile locally. Movement occurs radially away from island masses towards local rivers, estuaries, and the Atlantic Ocean.

Seasonal water-level fluctuations are observed in areas of heavier warm-weather pumping for crop and golf-course irrigation. Continual fluctuation in wells affected by tidal oscillations accounts for 0.23 to 4.51 feet of daily change in static water levels.

The chemical quality of water in the upper Floridan aquifer is generally good. Chloride, dissolved solids, and hardness concentrations nearest to recharge areas are well below the U.S. Environmental Protection Agency recom-

mended maximums for drinking water. These concentrations increase towards areas of lower potentiometric head, making the water unfavorable for domestic and, in some cases, irrigational use. Iron and hydrogen sulfide concentrations are locally high in several places.

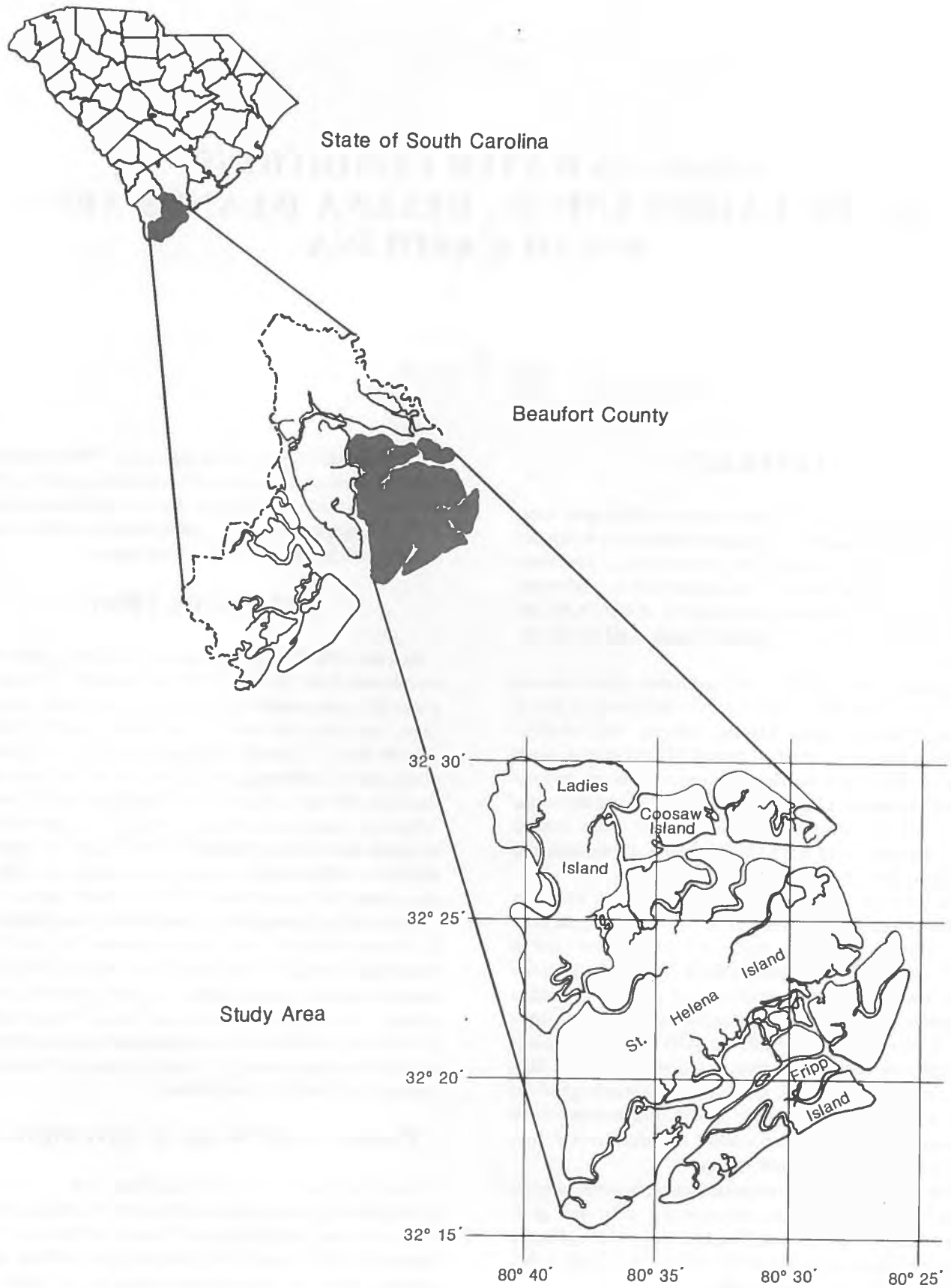
## INTRODUCTION

In 1983, 489.93 million gallons of ground water were withdrawn from the upper Floridan aquifer to meet the water demands made by domestic, commercial, agricultural, and industrial users in the Ladies and St. Helena Islands area. A rapidly increasing number of developments and a projected population increase of 90 percent through 1990 are certain to boost the demand for water. Although there is a sufficient amount of ground water to meet the expected demand, care must be taken in regulating withdrawals so as to insure minimal effect on the quality and availability of the ground water.

The study of ground-water conditions in the Ladies and St. Helena Islands area was sponsored by the South Carolina Coastal Council and was designed to acquire management-level information for Ladies and St. Helena Islands. This report concludes the first of a three-phase accelerated ground-water management program proposed to evaluate Ladies and St. Helena Islands, Port Royal Island, and Hilton Head Island.

## Purpose and Scope of Investigation

The purpose of this investigation was to evaluate ground-water conditions of Ladies and St. Helena Islands through close examination of water levels and water quality of the upper Floridan aquifer, which is the primary source of ground-water supplies. To achieve the project objective, the existing water-level monitoring system, which consisted of 40 wells, was increased to 110 wells. This allowed the construction of a potentiometric map accurate to within 1 foot. The map aided in the



**Figure 1.** Location of Ladies and St. Helena Islands area.

evaluation of local recharge conditions and in identification of areas of potential saltwater encroachment.

In addition to the development of an adequate water-level data base, 73 ground-water samples were analyzed to assess the distribution of the principal chemical constituents and properties, namely chloride, sulfide, iron, total dissolved solids, and hardness. Maps were constructed to illustrate the extent of contamination and to aid future investigations.

Information from this study will be the basis of a conceptual model to be used in managing ground-water development in the Low Country Capacity Use Area. The conceptual model will be used in determining how much water can be pumped from the upper Floridan aquifer without adversely affecting the resource.

## Location of Study Area

The study area, located in the southern corner of South Carolina, consists mainly of Ladies and St. Helena Islands in Beaufort County (Fig. 1). The area is bordered to the west and north by the Beaufort and Coosaw Rivers, respectively. It is also bordered on the northeast and southwest by the St. Helena and Port Royal Sounds and to the southeast by the Atlantic Ocean.

Included in the study area are approximately 175 square miles, half of which are streams and marshland. The 1984 population is 10,303 (Beaufort County Joint Planning Commission, 1984), located mostly in rural surroundings.

## Climate

The prevailing climate for the area is temperate to subtropical, marked by hot, humid summers and mild springs, winters, and falls. Average annual temperature is 65 degrees Fahrenheit, with relative humidity averaging 50 percent in spring and fall and 63 percent in August and September.

Average annual rainfall is 50 inches, with summer accounting for 39 percent of the annual total, followed by 21 percent in fall, 18 percent in winter, and 22 percent in spring.

These climatic conditions contribute to a long growing season, averaging 255 days a year. The normal date for the first fall freeze is around November 20 and the last spring freeze is around March 10.

Spring is the season of rapidly changing weather, from windy and cold in March to warm and pleasant in May. This is also the period when tornado and severe local storm warnings and alerts are most frequently issued.

An increase in hurricane activity is common during late summer months and reaches greatest frequency in September. Nearby tropical storms possess heavy rains and winds of gale to hurricane force. (South Carolina State Climatological Data).

## Data Collection and Analysis

An observation-well network of 110 wells, open only to the upper 10 to 20 feet of the upper Floridan aquifer,

was established to monitor water levels in the area (Table 1). Inventorying of wells was done with cooperation from local well drillers and the general public. Water-level data were collected over a 3-day period during a time of low pumpage, to assure minimal effects of short-term recharge to and discharge from the aquifer.

In order to construct a potentiometric map of 1-foot accuracy, precise leveling of all observation wells was needed. Therefore a surveying firm was contracted to conduct second-order leveling ( $\pm 1 \frac{1}{4}$  inches per 3 miles) in compliance with South Carolina Geodetic Survey specifications.

Several of the wells used for observation of water levels were affected by the tide. It was necessary to determine the magnitude of this effect in order to obtain representative water-level measurements. Thirteen wells subject to varied tidal influence were equipped with automatic digital recorders to monitor the water-level fluctuations. Data from the recorders later were used to construct graphs of tidal efficiency and lag time which made it possible to estimate tidal effects in unmonitored wells. Results of this work are discussed further in this report.

Seventy-three water samples were collected from a network of wells throughout the study area to obtain information about chemical characteristics and trends of the ground water. Additional information was obtained from the South Carolina Water Resources Commission (SCWRC) files in the Beaufort regional office. The collection of samples for "complete" analysis, as well as field determinations of specific conductance and temperature, was done in accordance with standard field methods. Detailed chemical analyses were made in the South Carolina Water Resources Commission laboratory.

## Previous Investigations

No previous reports have been devoted to the ground-water conditions of Ladies and St. Helena Islands. However, several regional reports include data from wells located on the islands. Cooke (1936) published data from three wells on St. Helena Island, which included well depths, stratigraphy, and water levels. Mundorff (1944), in the first report to include geology and ground water of the Low Country, theorized about possible breaches in the confining unit below the Beaufort River and Battery Creek. The report also referred to high chloride values from a well near Chowan Creek. Mundorff also recorded water levels from three wells on St. Helena Island that were used in constructing the first potentiometric map of the Santee Limestone to include Ladies and St. Helena Islands. Siple (1960) described the geology and ground-water conditions of the Beaufort area, and his tabulated well data included 15 wells located on Ladies and St. Helena Islands. Siple also documented evidence of breaches in the confining unit along the Beaufort River and Battery Creek, which was later confirmed in seismic profiles obtained for the Port Royal Sound Environmental Study (SCWRC, 1972). A potentiometric map by Siple in 1959 illustrated Ladies and St. Helena Islands positioned between the 0- and 5-foot contours and suggested



## Acknowledgements

a hydraulic gradient that dipped toward St. Helena and Parris Islands. Siple suggested the drilling of test wells on Ladies and St. Helena Islands to identify physical characteristics in the upper Floridan aquifer and monitor the rate of saltwater movement. Hayes (1979) published a detailed report of the ground-water resources in the Low Country, which included water-level data from 26 wells and chloride data from approximately 70 wells in the Ladies and St. Helena Islands area. He also evaluated the Ladies and St. Helena Islands study area with respect to hydraulic parameters, recharge, discharge, and potential problems caused by a leaky or absent confining unit, referencing Brickyard Point, Battery Creek, and the Beaufort River as problem areas. Hayes constructed the first structure contour map for the top of the Santee Limestone in the Low Country, including details of the Ladies and St. Helena Islands area. Sanders and Spigner (1983) completed an investigation of the ground-water resources of Datha Island, which is in the Ladies and St. Helena Islands study area. That investigation provided conclusions concerning the availability of ground water for irrigation and recommendations for developing ground-water resources on Datha Island. The report included well data and water quality data from 28 test wells and pumping test data from 12 wells located in the upper Floridan aquifer and shallow sand formations.

Other regional ground-water studies having a general bearing on the study area were published by Warren (1955), Siple (1956), Hazen and Sawyer (1956), Barber and Associates (1960), Springfield (1966), Siple (1969), Back, Hanshaw, and Rubin (1970), and Spigner and Ransom (1979).

## Well-Numbering System

The South Carolina Water Resources Commission well-numbering system is derived from a statewide latitudinal-longitudinal grid system. Each grid is composed of 5 minutes of latitude and longitude. Five-minute grids are divided into 1-minute latitudinal and longitudinal grids. As wells are inventoried, they are assigned a four-part well number which consists of a number, capital letter or letters, a small letter, and a number (e.g., 26HH-g6). The first number and the capital letters refer to location of the 5-minute latitude-longitude grid; the small letter refers to location of the 1-minute latitude-longitude grid; and the last number refers to a particular well within a 1-minute grid and the order in which it was inventoried. The well grid system and location of selected wells for the study area are shown in Figure 2.

A secondary well-numbering system used to cross-reference well locations consists of a county prefix and number. For example, well number BFT-564 refers to the five hundred and sixty-fourth well inventoried in Beaufort County. The county numbers appear in Table 1.

The author gratefully acknowledges the cooperation of residents in the study area for permitting access to their property and thus making it possible to measure water levels, collect water samples, and make geophysical logs.

Appreciation is extended to the Breland, Horry, and Pinckney well-drilling companies for providing information on recently constructed wells.

The author wishes to express his appreciation to Randy Nesmith of the South Carolina Department of Health and Environmental Control (SCDHEC), Ground Water Division, for providing drillers logs, water-level data, and water-quality data for several shallow wells. Appreciation is also extended to Albert Benschhoff, of the Beaufort County Joint Planning Commission, for providing population and projected growth trends for the study area.

The cooperation of Ferrell Prosser of the South Carolina Geodetic Survey and the private services of Rod Spann in surveying the elevations of several monitoring wells is greatly appreciated.

Special appreciation is extended to the South Carolina Coastal Council (SCCC) for financial support, which made this investigation possible.

## GEOLOGIC SETTING

Ground-water supplies in the study area, in all but a few places, are obtained entirely from wells drilled into the upper 10 to 20 feet of the Floridan aquifer. Therefore, most of this report is focused on the discussion of hydrogeology of the upper Floridan aquifer. Ground water from other formations, however, is of interest and may become of great importance in the future. In order not to exclude these formations, a brief summary of lithology and present utilization is included in this section.

### Upper Cretaceous Series

#### Middendorf Formation

The Middendorf Formation represents the oldest stratigraphic unit in the Cretaceous System. It consists of light-gray, white or buff-colored arkosic sand and interbedded gravel with white, pink, brown, or purple clay. Sedimentary structures include iron-oxide concretions, cross bedding, and graded bedding. In the study area it consists of green or maroon clay, and greenish-gray silt and sandstone with light-gray, fine- to coarse-grained sand (Siple, 1960, p.15). The top of the formation occurs at about 2,670 feet below land surface, and the unit has a total thickness of more than 800 feet (McLean, 1960).

The only existing well open to the Middendorf in the study area is located on Fripp Island (24JJ-c2). The well was drilled to 3,168 feet in an attempt to obtain better water for commercial irrigation than could be supplied by the Floridan aquifer in this particular area. Water from this well was found to contain high concentrations of fluoride (8.5 mg/L), dissolved solids (1,698 mg/L), and

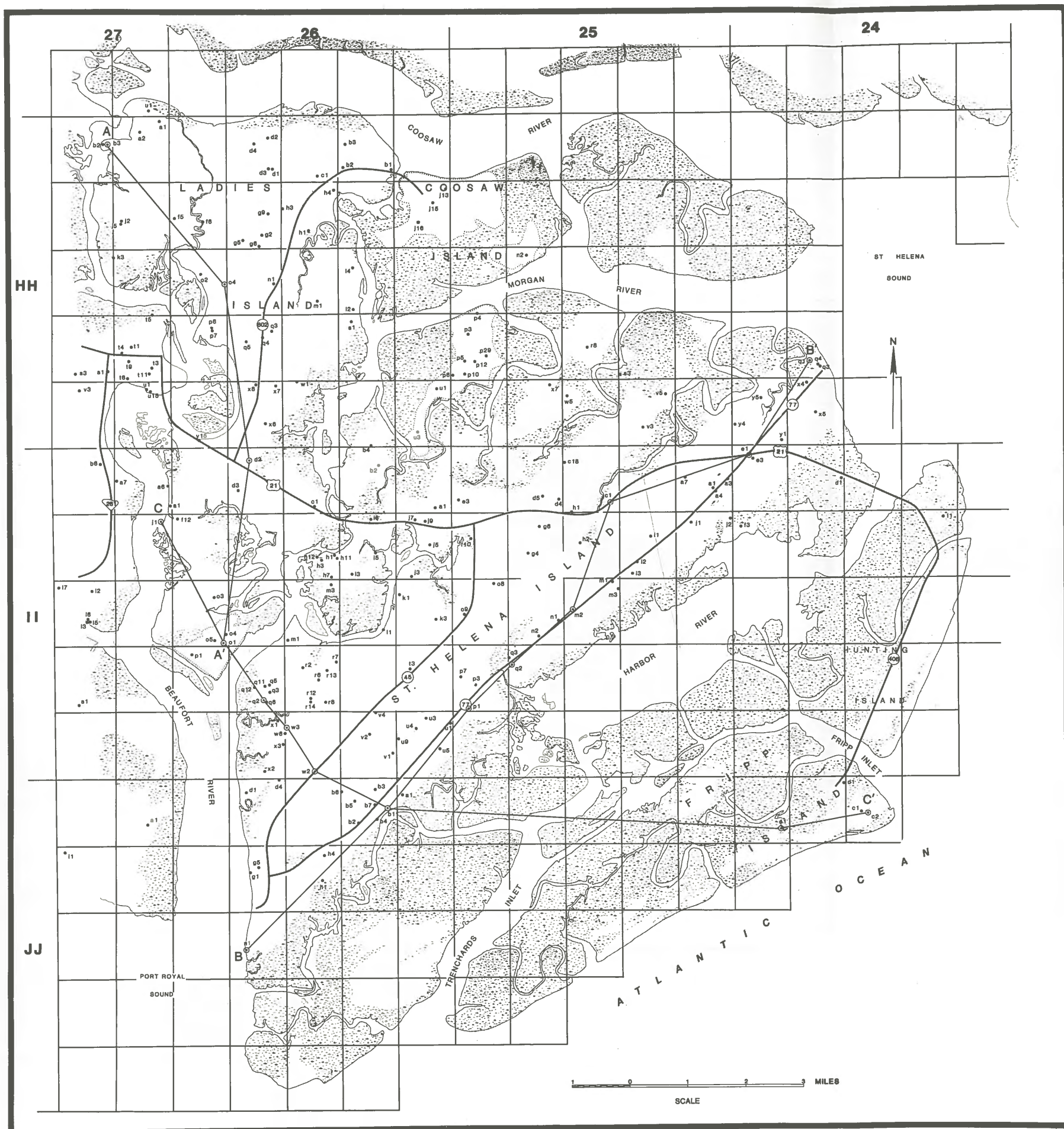


Figure 2. Location of selected wells and hydrogeologic section lines.



sodium (580 mg/L). Although these concentrations are acceptable for irrigation, water from the well was found unsatisfactory because of excessive boron (6.4 mg/L). Presently, the mixing of water from the well with another source to make it usable is being considered.

Other wells open to the Middendorf in Beaufort County are on Parris Island (27JJ-cl and 27II-s2) and Hilton Head Island (27KK-dl). Water from these wells is comparable in quality and yield, with artesian flows of 75 gallons per minute and shut-in pressures of 50 to 60 pounds per square inch at ground level, which translate to static water levels 120 to 150 feet above sea level.

In summary, water from the Middendorf Formation in the study area contains high concentrations of some chemical constituents. Utilization of the source requires mixing with better water to meet drinking-water and irrigation standards.

### **Black Creek Formation**

In the study area the upper portion of the Black Creek Formation consists of blue-gray to black shale and marl which in some areas contain shell beds. The lower unit consists of gray to white, glauconitic, phosphatic, and micaceous quartz sand interbedded with dark-gray to black thinly laminated clay containing variable amounts of pyrite and marcasite (Siple, 1960). In the Beaufort area, identification of the top of the Black Creek is rather difficult. McLean (1960), on the basis of foraminiferal data, and Siple (1960), through examination of electric logs, determined the top of the Black Creek to be at 1,625-1,645 feet below land surface in well 27JJ-cl at Parris Island. McLean (1960) also determined the formation to be about 700 feet thick.

The Black Creek Formation is penetrated by one well in the study area (24JJ-c2 on Fripp Island) and only three other wells in the entire county (27JJ-cl, 27II-s2, and 27KK-dl). Hayes (1979) indicated production rates of approximately 70 gpm for each of two screenings in well 24JJ-c2. Very little water-quality data exist in the study area for the Black Creek Formation. However, a water sample taken during the drilling of well 24JJ-c2 indicated a chloride concentration of 1,100 mg/L (Hayes, 1979, p. 25). Suspicion of high chloride values, as well as excessive concentrations of fluoride and other mineral constituents, label the Black Creek Formation an unlikely source of water supplies for the area.

### **Peedee Formation**

The Peedee Formation is the youngest Cretaceous deposit in the study area. It consists of dark-gray clay, thin layers of fine- to medium-grained sand, and lenses of shelly, argillaceous limestone and calcareous, arenaceous siltstone (Spigner and Ransom, 1979, p. 35). The top of the Peedee Formation occurs at approximately 1,300 feet below the surface in the study area, and the unit ranges in thickness from 300 to 500 feet (McLean 1960).

At present, no wells in the study area are open exclusively to the Peedee Formation. Knowledge of thin-bedded, fine-grained sand and clay lenses indicates that

the formation would not be conducive to development of high well yields. Spigner and Ransom (1979) indicated that although water-quality data are sparse, water from the Peedee is believed to contain highly mineralized water useful only for industrial and non-consumptive municipal purposes.

## **Eocene Series**

### **Black Mingo Formation**

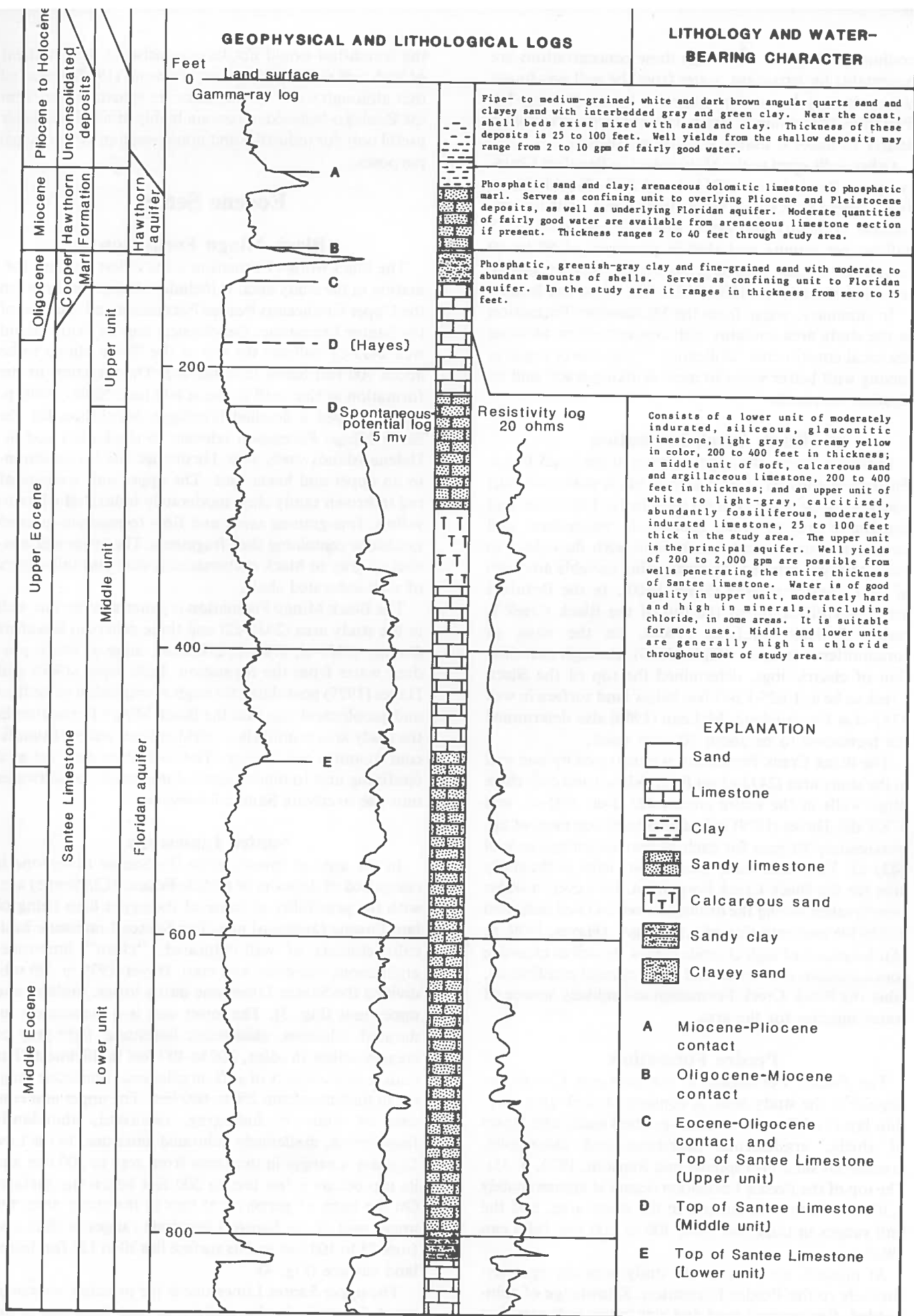
The Black Mingo Formation is the oldest Tertiary formation in the study area. It includes all deposits between the Upper Cretaceous Peedee Formation and the base of the Santee Limestone. Geophysical logs of Fripp Island well 24JJ-c2 indicate the top of the Black Mingo to be about 900 feet below land surface. The thickness of the formation at that well is about 600 feet. Siple (1960, p. 18) developed a detailed lithologic description for the Black Mingo Formation relevant to the Ladies and St. Helena Islands study area. He divided the formation into an upper and lower unit. The upper unit consists of red to brown sandy clay; moderately indurated white to yellow, fine-grained sand; and fine- to medium-grained sandstone containing shell fragments. The lower unit consists of gray to black carbonaceous clay and thin layers of well-indurated shale.

The Black Mingo Formation is penetrated by one well in the study area (24JJ-c2) and three others in Beaufort County (27JJ-cl, 27II-s2, 27KK-dl), none of which produce water from the formation. Both Siple (1960) and Hayes (1979) postulated through examination of drillers and geophysical logs that the Black Mingo Formation in the study area is unlikely to yield ground water of significant quantity and quality. The formation may act as a confining unit to inhibit upward movement of saltwater into the overlying Santee Limestone.

### **Santee Limestone**

In the area of investigation the Santee Limestone is composed of deposits of middle Eocene (Claiborne) age, with the possibility of some of the upper beds being of late Eocene (Jackson) age. The Santee Limestone basically consists of well-indurated, "clean" limestone, argillaceous limestone, and marl. Hayes (1979, p. 28) subdivided the Santee Limestone into a lower, middle, and upper unit (Fig. 3). The lower unit is a moderately indurated, siliceous, glauconitic limestone, light-gray or creamy yellow in color, 200 to 400 feet in thickness. The middle unit consists of soft, argillaceous limestone ranging in thickness from 200 to 600 feet. The upper unit consists of white to light-gray, calcitized, abundantly fossiliferous, moderately indurated limestone. In the Low Country it ranges in thickness from zero to 200 feet and its top occurs a few feet to 200 feet below the surface. On the basis of geophysical logs in the study area, the upper unit of the Santee Limestone ranges in thickness from 25 to 100 feet and its surface lies 30 to 120 feet below land surface (Fig. 4).

The upper Santee Limestone is the principal source of water for wells in the study area and therefore is the



**Figure 3.** Generalized post-Cretaceous geologic section showing lithology and water-bearing characteristics of the Santee Limestone. (Modified from Hayes, 1979)

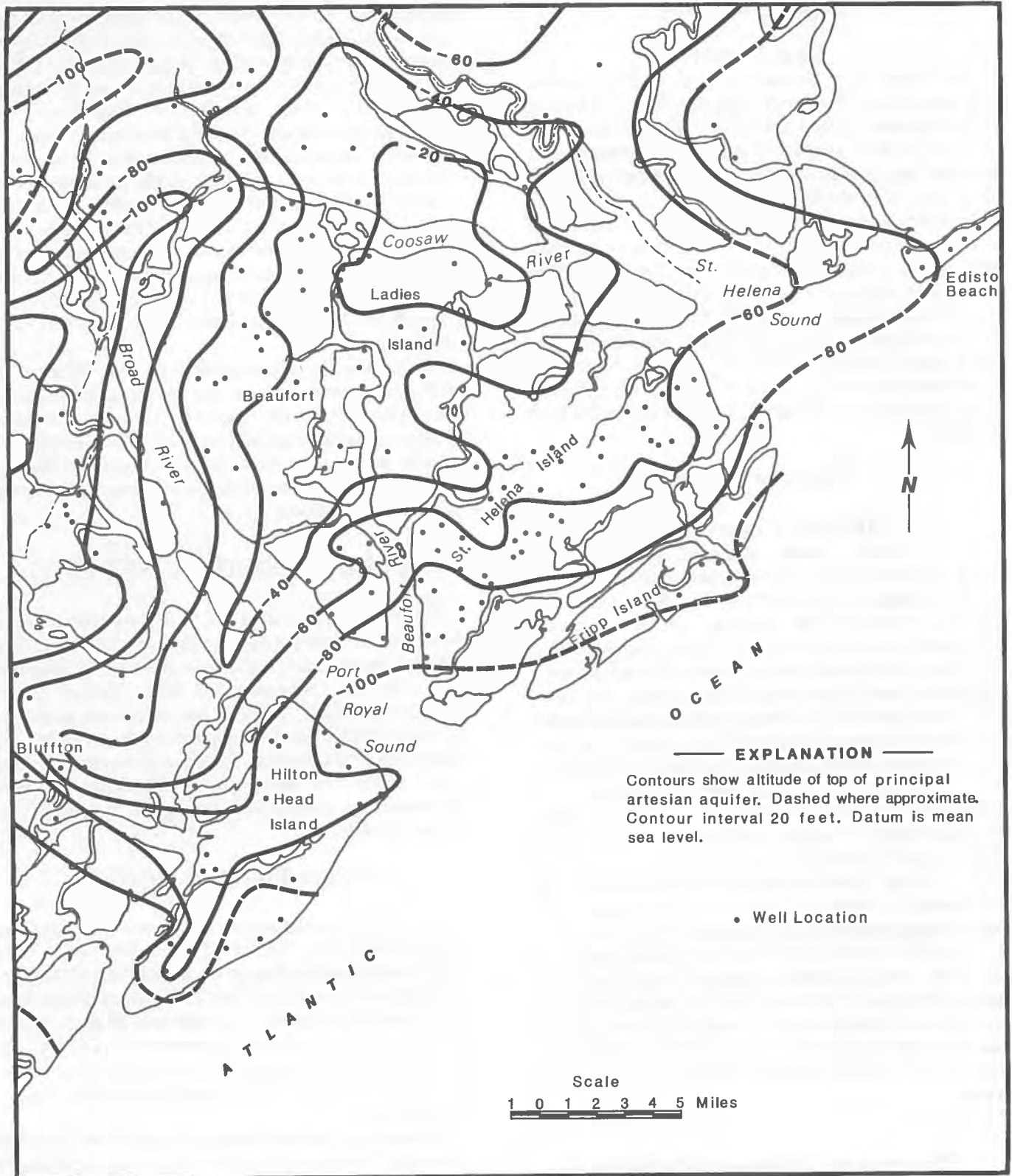


Figure 4. Structure-contour map of the top of the Santee Limestone. (Modified from Hayes, 1979)

primary concern of this investigation. It is the principal formational unit composing the Floridan aquifer. The water-bearing characteristics and water quality will be discussed in detail in the following sections.

## Oligocene Series

### Cooper Marl

The Cooper Marl, on the basis of fossil identification, was assigned by Cooke and MacNeil (1952, p. 27) to the early Oligocene. In the Ladies and St. Helena Islands area the Cooper Marl consists of phosphatic, greenish-gray clay and fine-grained sand with a moderate to very abundant amount of shells.

In several areas of South Carolina the Cooper Marl contains sections of argillaceous to clean limestone which may yield large amounts of good water. The Cooper Marl in this area serves as a confining unit to the underlying upper Floridan aquifer, retarding the movement of contaminants into the aquifer. The thickness of the Cooper Marl ranges from zero to 15 feet, reflecting the amount of erosion prior to deposition of the Hawthorn Formation. The top of the deposit is 20 to 120 feet below land surface.

## Miocene Series

### Hawthorn Formation

The Hawthorn Formation consists of deposits Miocene in age, which appear to be locally discontinuous and varying in lithologic features across most of coastal South Carolina. Cooke (1936) described the Hawthorn as phosphatic sand and clay and arenaceous dolomitic limestone. In the study area it consists of sandy, clayey, phosphatic marl. Cooke (1936), Siple (1960), and Hayes (1979) indicated that the Hawthorn Formation is eroded completely in coastal Beaufort County except for scattered locations. When present in the study area, it serves as a confining unit to the overlying Pliocene and Pleistocene deposits, as well as to the underlying upper Floridan aquifer. Sanders and Spigner (1983, p. 26) reported the Hawthorn Formation in all test wells drilled into the upper Floridan aquifer on Datha Island, encountering it 38 to 58 feet below the surface and penetrating a thickness ranging from 2 to 8 feet.

Potential of the Hawthorn Formation as an aquifer in the study area is doubtful, owing to its thinness and general lithology. Therefore, little is known about its water-bearing characteristics. In areas of Jasper, Hampton, and Colleton Counties, Hayes (1979, p. 30) reported yields of 50 to 200 gallons per minute of fairly good water.

## Pliocene to Holocene Deposits

Pliocene to Holocene deposits are described as containing fine- to medium-grained, white and dark brown angular quartz sand and clayey sand with interbedded

gray and green clay. Some areas near the coast contain shell lenses intermixed with sand and clay (Siple, 1960). Thickness of the Pliocene-Holocene deposits ranges from 25 feet inland to 100 feet along the coast. In some areas, such as east-central Ladies Island, lithologic samples collected from a test well (26HH-ml) revealed 42 feet of fine- to medium-grained sand before encountering 20 feet of clayey sand confining unit at 43 feet below the surface.

The shallow deposits of the Ladies and St. Helena Islands area consist of Pliocene, Pleistocene, and Holocene age deposits. Detailed lithologic descriptions of these shallow deposits were compiled by the South Carolina Department of Health and Environmental Control (SCDHEC) at more than 150 shallow (10-20 feet) wells located in the study area and throughout Beaufort County. These shallow deposits are also described by Siple (1960) and Sanders and Spigner (1983). Hydrogeologic sections A-A', B-B', and C-C' (Figs. 5, 6, and 7) show the depth and thickness of these deposits in the study area.

Water-bearing characteristics of the Pliocene to Holocene deposits are not well known across the study area. However, recent reports by Glowacz and others (1980) and Sanders and Spigner (1983) have described the aquifer potential of these deposits. Results of their investigations are discussed in the Hydrogeologic Setting section of this report.

## HYDROGEOLOGIC SETTING

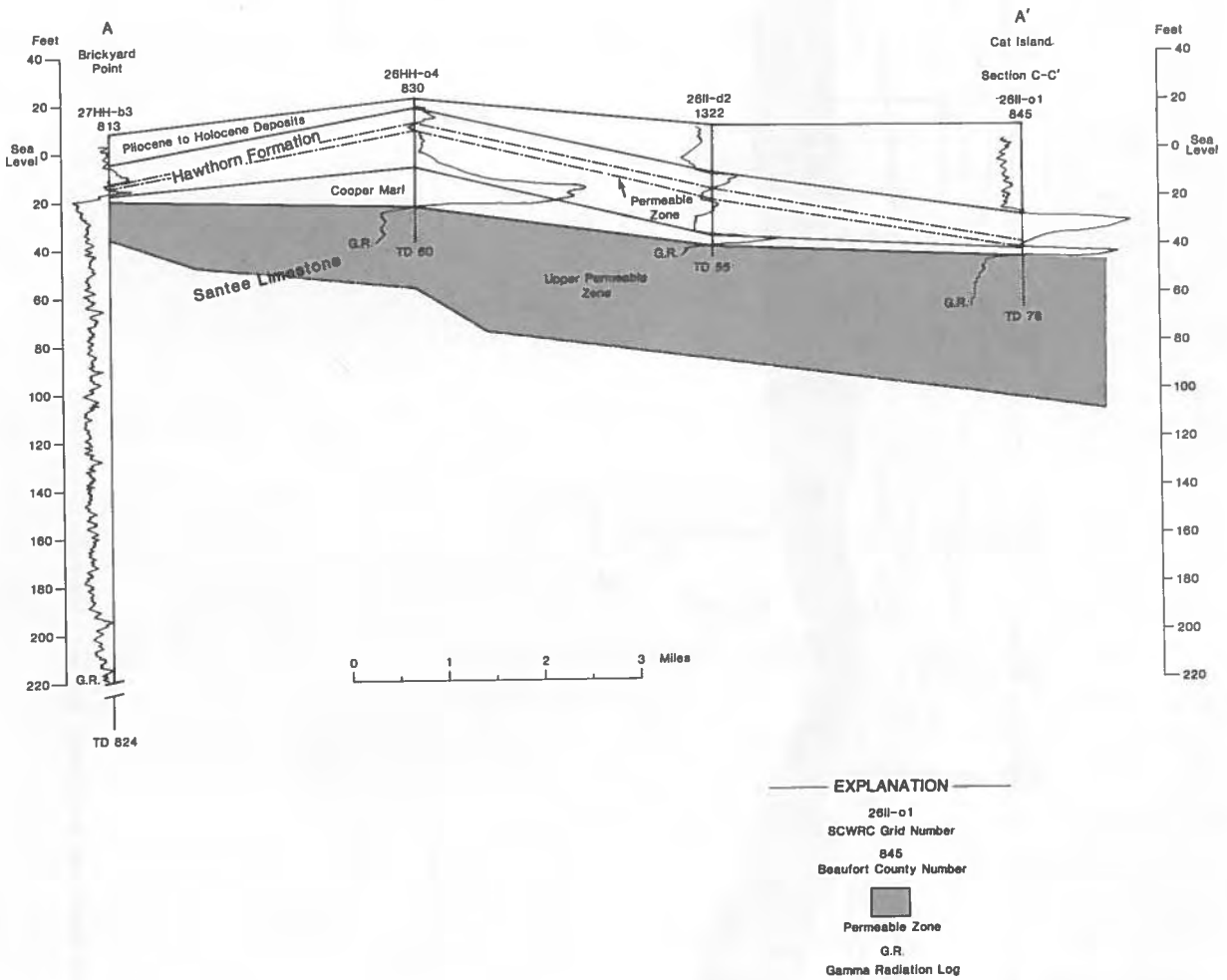
Ground water on Ladies and St. Helena Islands occurs in Cretaceous and younger formations. However, little emphasis in this report is placed on the water-bearing properties of the Cretaceous and lower Tertiary (Black Mingo) formations, owing to their minor role as sources of water supply. Vitally important are the water-bearing properties of the Floridan aquifer and shallower formations which are discussed in the following text. Hydrogeologic-section lines for figures 5, 6, and 7 are shown in figure 2.

### Upper Floridan Aquifer

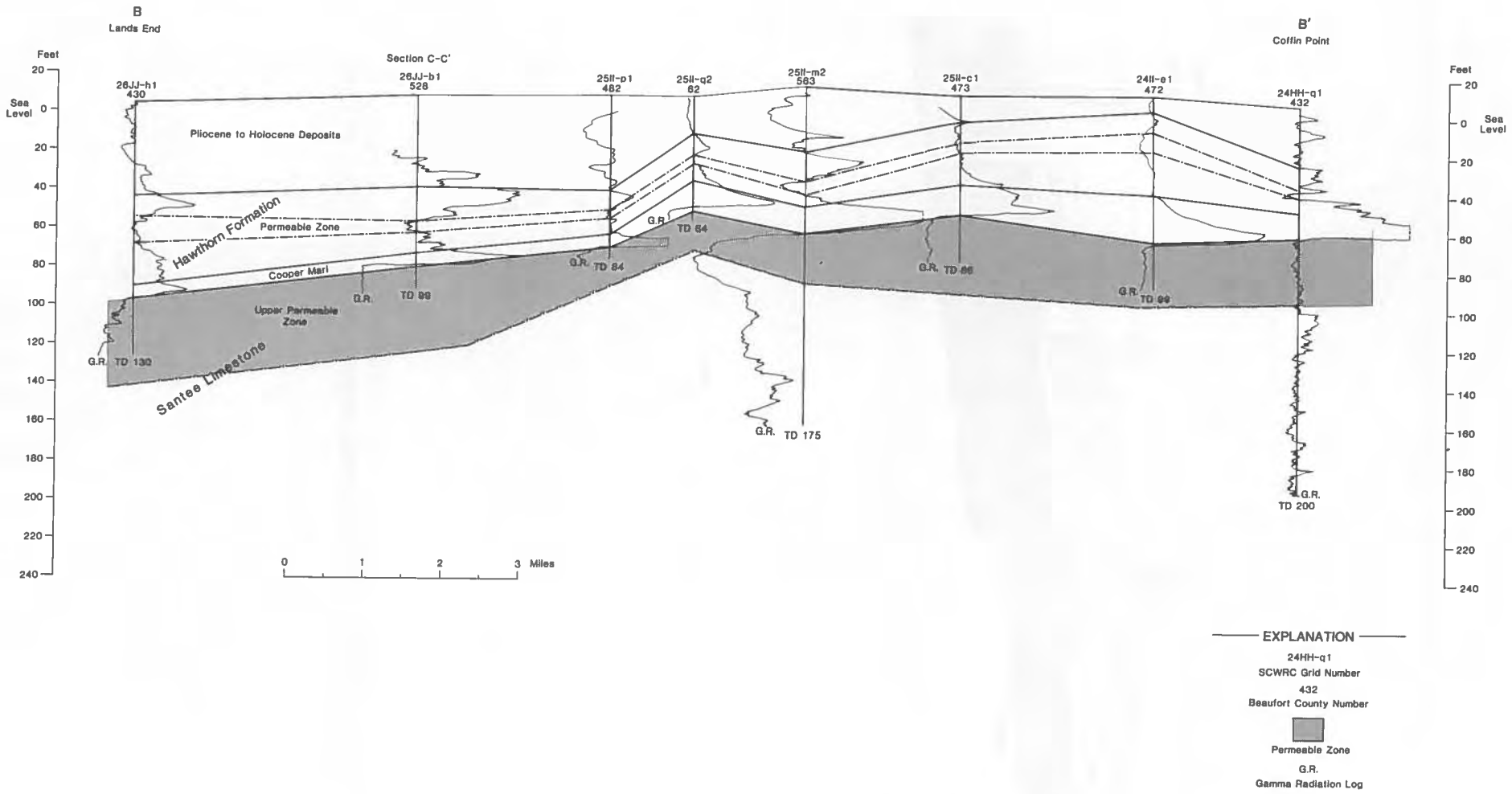
The upper Floridan aquifer underlies all of Ladies and St. Helena Islands. The top of the aquifer ranges from 30 feet below land surface at Brickyard Point (27HH-b3) to 120 feet at Fripp Island (24JJ-c2). The aquifer thickens from west to east across the study area (Figs. 5, 6, and 7). Water from this aquifer generally occurs under confined conditions but is present under unconfined conditions in areas where the confining unit is leaky, thin, or breached.

Although the Santee Limestone ranges from 770 to 870 feet in thickness across the study area, the most permeable zone lies in the upper 25 to 100 feet. In much of the area only the top 10 to 20 feet yield large amounts of fresh water. For this reason, several hundred domestic, irrigation, and public supply wells tap this zone.

Well yields in the study area depend substantially on



**Figure 5.** Hydrogeologic section of post-Cretaceous formations from Brickyard Point to Cat Island.



**Figure 6.** Hydrogeologic section of post-Cretaceous formations from Land's End to Coffin Point.



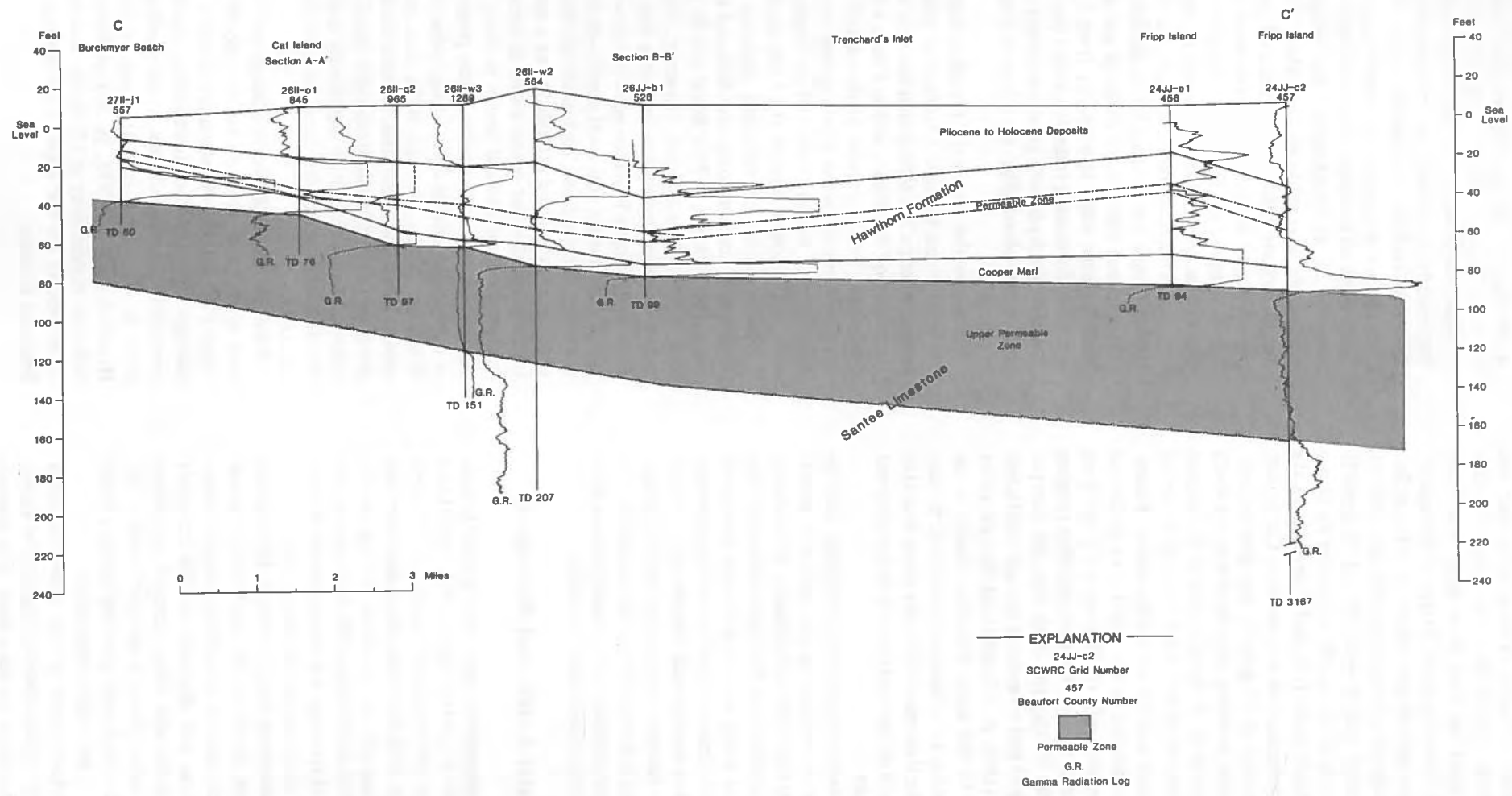


Figure 7. Hydrogeologic section of post-Cretaceous formations from Burckmyer Beach to Fripp Island.

the hydraulic properties of the aquifer, size (diameter) of the well, length of well open to the aquifer, and type of pump used. Wells drilled into the upper Floridan aquifer currently yield less than 50 to more than 1,200 gpm of fresh water from the upper 20 feet of the aquifer.

Specific capacities (gallons per minute of yield per foot of water-level drawdown) of two wells (25II-m2, 26II-w2) located on St. Helena Island were 20 and 17 gpm/ft. Values for three wells (24JJ-cl, -dl, -el) tested by Hayes (1979) on Fripp Island were 7, 5, and 3 gpm/ft. In the present study one pumping test was made on Cat Island, and a specific capacity of 19 gpm/ft was determined.

The first controlled pumping tests known in the study area were conducted by D. P. Sanders and B. C. Spigner in a recent investigation of the water-bearing potential of the upper Floridan aquifer on Datha Island. Pumping tests were concentrated in the upper 5 to 10 feet of the aquifer in three test wells (25HH-p6, -p12, -p17) on the island. These tests indicated transmissivities ranging from 2,300 to 4,700 ft<sup>2</sup>/day (or cubic feet per day per foot of aquifer width) and an average storage coefficient of 0.00007. Hayes (1979, p. 34) published the only other pumping-test data for the upper Floridan aquifer in the study area, calculating a transmissivity of 4,000 ft<sup>2</sup>/day for Fripp Island. The transmissivity of the upper Floridan aquifer in other parts of the study area is believed to not exceed 6,000 ft<sup>2</sup>/day.

Properly conducted pumping tests contribute vital information for use in evaluating an aquifer's water-producing potential and well performance. It is evident upon review of available data that information of this type is lacking in the study area. Conducting a series of pumping tests would further define hydraulic properties of the upper Floridan aquifer and identify areas where: (1) the potential for saltwater contamination is possible, (2) the confining unit is leaky, (3) aquifer transmissivities are low, and (4) high-capacity wells would be more likely to increase the rate of saltwater upconing.

## Ground-Water Levels and Movement

Prior to this investigation of the Ladies and St. Helena Islands area, Mundorff (1944), Siple (1960), and Hayes (1979) described the potentiometric surface of the area as ranging from sea level to 5 feet above sea level and consisting of a relatively low gradient sloping to the southeast. Siple (1960) and Hayes (1979) believed that the most significant local recharge was located at the Marine Corps Air Station northwest of the study area.

Figure 8, a potentiometric map for March 1984, shows a somewhat different situation. The addition of several monitoring wells has made it possible to identify areas of significant recharge and discharge within the study area. Water levels in the area range from 18 feet above mean sea level on Ladies Island to sea level south of St. Helena Island, with a hydraulic gradient ranging from 15 ft per mile to 1 ft per mile, respectively.

One principal recharge area of the upper Floridan aquifer is marked by a potentiometric high in the vicinity of Royal Pines Estates on Ladies Island. The absence

or thinness of the confining unit, in combination with a structural high, permits rainfall to enter the upper Floridan aquifer through a shallow aquifer.

Minor surface depressions in scattered localities mark the underlying presence of collapse features in the confining material that overlies the soluble Floridan aquifer. The surface expression of these features is a circular depression with a depth of 4 to 8 feet. They have been referred to as "sinkholes" by several previous investigators. It is probable that where the confining unit has undergone collapse, as described above, downward percolation of water to the aquifer is enhanced. However, any recharge to the limestone through this mechanism is likely to be minor when compared to the total recharge. An in-depth discussion of sinkholes in the Southeastern United States was written by Stringfield (1966 p. 82).

Additional amounts of recharge occur on St. Helena Island, where water levels range from 3 to 7 feet above sea level, decreasing radially toward the island margins. The steepest hydraulic gradient occurs in the southern part of the island (Fig. 8), where it is approximately 7 ft per mile.

Recharge also enters the Floridan aquifer at many of the smaller sea islands. Evidence of this is seen at Cat Island, where a 2-ft MSL potentiometric high occurs near the center of the island, and at Coosaw Island, where a freshwater lens is present in the central portion of the island. Similarly, water levels appear to be highest near the center of Datha Island, where freshwater is present only in the upper 5 to 15 ft of the aquifer.

The potential for saltwater recharge exists through breaches in the confining unit believed to be present in the Atlantic Ocean, in Port Royal and St. Helena Sounds, and in several local rivers. However, the occurrence of this phenomenon requires lowering the potentiometric head in the upper Floridan aquifer below that which exists in the Sounds and local rivers—in effect, reversing the hydraulic gradient. Such reversals may occur during periods of prolonged drought or as a result of concentrated ground-water withdrawals at island margins.

Movement of ground water is from areas of high potentiometric head to areas of low potentiometric head in a pattern radiating from topographic highs. Artificial discharge occurs through wells that pump from the aquifer throughout the area. Natural discharge occurs in places where sufficient freshwater head exists to force water upward through an imperfectly confining unit and into the shallow aquifer, from which it drains into local estuaries.

Rates of recharge and discharge are not only a product of hydraulic gradient but are also affected by fluid-density boundaries (freshwater-saltwater interface) and changes in aquifer characteristics, such as porosity, permeability, and thickness. Little investigation has been done in regard to the latter two in the study area. However, Hayes (1979, p. 55) published an average hydraulic conductivity of 175 ft/day and average porosity of 30 percent for the upper Floridan aquifer in eastern Beaufort County.



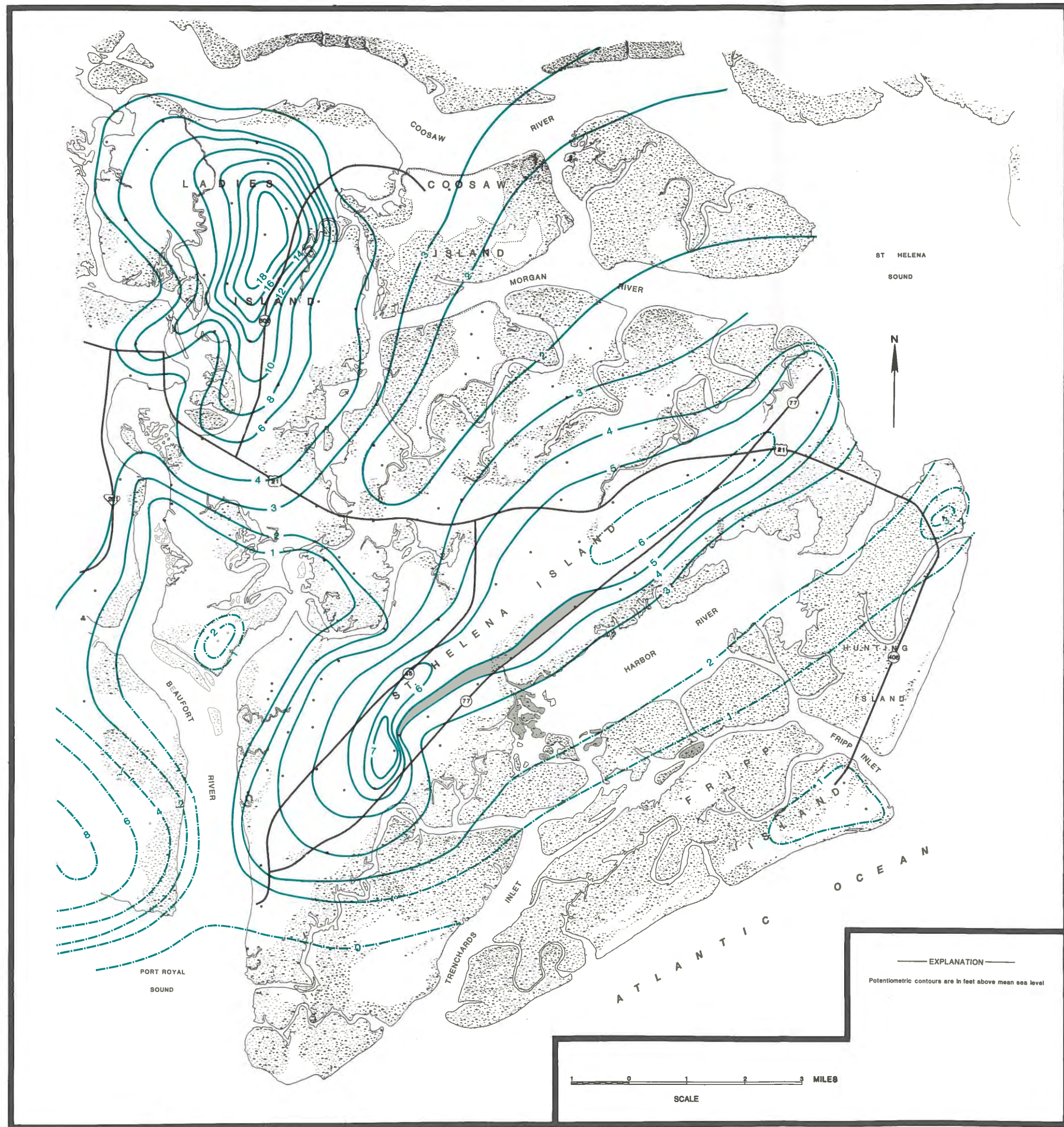


Figure 8. Potentiometric surface for the upper Floridan aquifer.



## Causes of Water Level Fluctuations

Water levels in an artesian system fluctuate with respect to a number of factors that include: pumping, recharge, changes in barometric pressure, tidal oscillations, and other minor factors. Several of these factors involve an indirect effect through a loading phenomenon applied on the aquifer, and others are the direct result of recharge to or discharge from the aquifer.

The most notable water-level change in the study area is brought about by the pumping of wells. The effects of this fluctuation are greatest on St. Helena Island where numerous high-capacity irrigation wells are pumped seasonally for crop irrigation. The magnitude of this fluctuation is highly dependent on duration of pumping, rate of pumping, permeability of the aquifer, and the distance from other pumping wells.

An automatic digital water-level recorder was installed on well 26II-w2, located in the area of high seasonal pumpage on St. Helena Island. In the data from this recorder (Fig. 9), there does not appear to be a direct relationship between precipitation and water levels except for periods of peak rainfall. It is likely that many of the fluctuations appearing on the hydrograph reflect periods of peak pumping in the vicinity of the recorder. However, a shortage of pumping records in the area prior to 1982 and lack of daily water-level data in the 1982-83 period makes further illustration of this fact not possible.

When barometric pressure increases in the vicinity of a well, the positive differential of pressure passing directly into the well over that entering the well through the aquifer causes the column of water in the well, or water level to be depressed (Fig. 10). Because this effect is seldom greater than 0.5 foot, which is negligible compared to pumping and tidal fluctuations, no attempt was made to compensate for these changes by monitoring barometric pressure and correcting water levels accordingly.

The most pronounced cyclic water-level fluctuation in the study area occurs as a result of tidal oscillations. There are two situations in which tidal stresses may act on an aquifer: (1) an aquifer is in direct hydraulic contact with a tidal body, and (2) the incoming tide applies a vertical loading stress on the aquifer through overlying beds. Both types of stress cause a pressure differential in the aquifer, raising the water level in a well with an incoming tide and lowering the water level with a retreating tide.

Tide gages were installed on 13 wells measuring water-level fluctuations with respect to known tide ranges. Tidal efficiencies (the ratio of water-level fluctuation in a well to a corresponding tidal oscillation) ranged from less than 3 percent for wells more than 8,800 feet from a tidal body to more than 62 percent for wells less than 100 feet from a tidal body (Table 2). Tidal response time (lag time) observed in wells trailed the effective tidal body times by 26 to 193 minutes, increasing with distance from the tidal body. Tide-induced water-level fluctuations in monitoring wells ranged from 0.20 to 4.51 feet with average tidal oscillations of 6.5 feet.

Because of the accuracy needed to construct a detailed

potentiometric map of 1-foot water-level variations, it was necessary to correct for tidal effects with respect to mean sea level. Therefore, graphs illustrating average tidal efficiency, lag time, and fluctuation of water level in 13 monitoring wells were constructed to correct water levels in wells unmonitored by tide gages (Figs. 11A-B, 12A-B). In determining tidal efficiencies and fluctuations in water levels, it was necessary to distinguish between wells affected by tidal bodies of considerable volume and wells affected by tidal bodies that are shallower and of smaller surface area. Effective tidal bodies of considerably larger volume impose a much greater force on the aquifer than a smaller tidal body the same distance from a monitoring well (Figs. 11A-B). In calculating lag time for unmonitored wells, graphs of water-level response to rising and falling tides were constructed. Lag time during rising tide ranged from 7 to 64 minutes less than falling-tide lag times in the same wells (Figs. 12A-B). This difference exists because the rate at which water rises in a tightly cased well is a product of an applied force on the aquifer, permeability of the aquifer, and distance from the effective tidal body. During falling tide the force applied by an additional volume of water is removed and the only factors controlling lowering of the water level in a well are rebounding of the aquifer, distance from the effective tidal body, and permeability; consequently, lag times are much longer.

Tidal corrections were made for all monitoring wells displaying water-level fluctuations of 0.5 foot or greater. After calculating tidal efficiency and lag response from graphs shown in figures 11A-B, 12A-B, static water levels were corrected by modifying a graphical method for determining tide height that was suggested by the National Oceanic and Atmospheric Administration (NOAA), NOAA tide tables (1984, p. 238). A simple cosine curve simulating a normal tide cycle was constructed for each day of water-level measurements by using predicted NOAA tide heights (Fig. 13). With this graph, the time of day in which a measurement was taken minus the lag time is projected vertically to the tide curve, and the difference in height from the curve to an assumed mean sea level (half the tide cycle) is determined to be the change in feet of the surface water level ( $\Delta T_s$ ). The difference in water level above or below sea level is then multiplied by a well efficiency (E) to determine the variance from the static water level in a well ( $\Delta T_w$ ). This variance is then added or subtracted from the measured static water level ( $M_{swl}$ ) (subtracted if variance is above assumed mean sea level or added if below assumed mean sea level) to achieve a corrected static water level ( $C_{swl}$ ).

## Shallow Aquifer

Ground water in the shallow aquifer occurs under unconfined conditions, allowing rapid rates of recharge by local rainfall. Water levels in these deposits respond frequently to changes in the rates of rainfall, evaporation, and transpiration. Glowacz and others (1980), in a report written for SCDHEC, found that water levels in shallow wells ranged from zero to 10 feet below land surface,

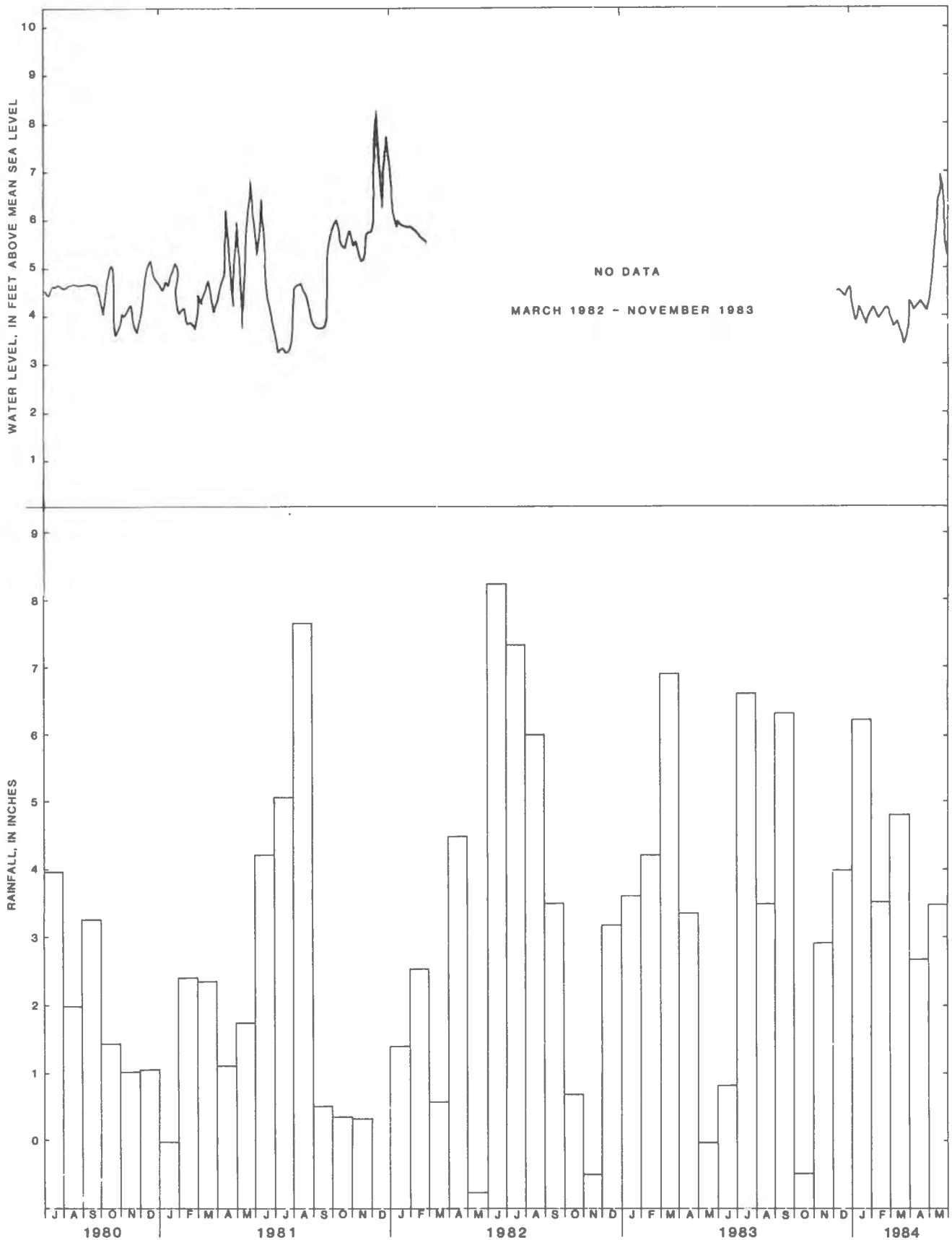
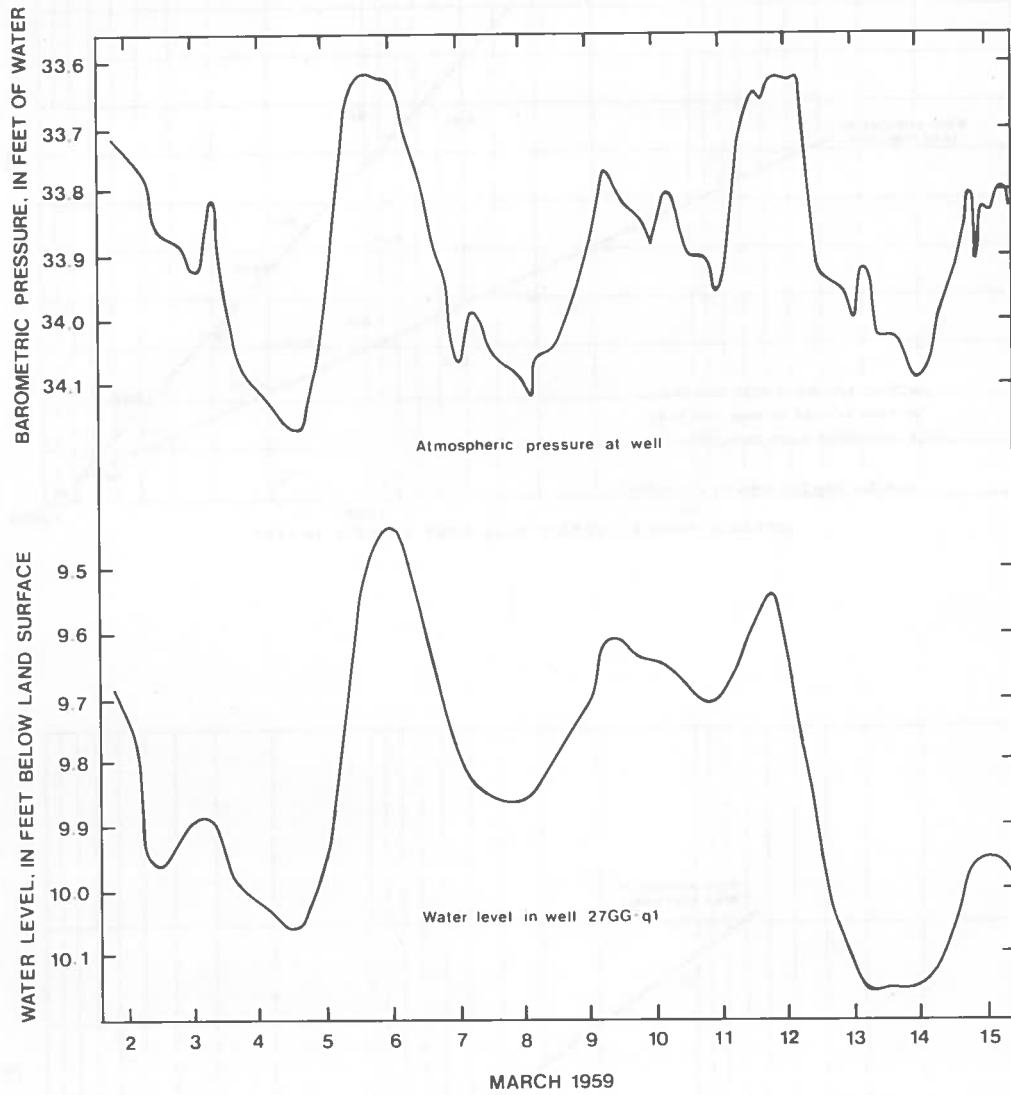
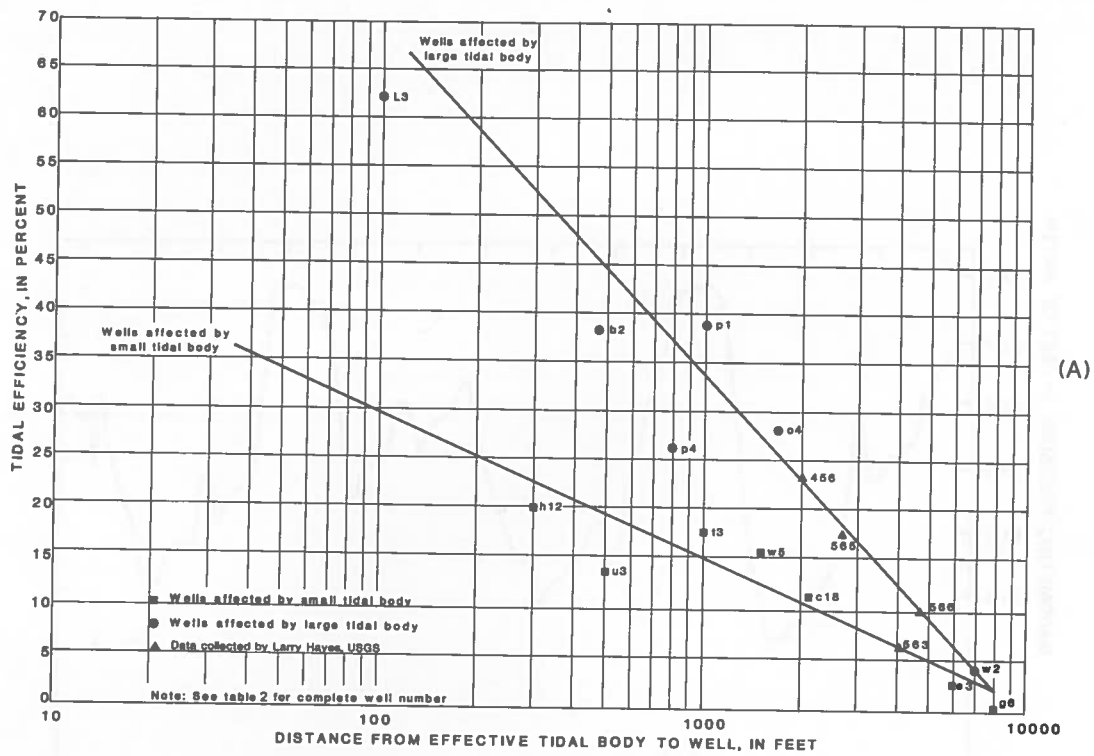


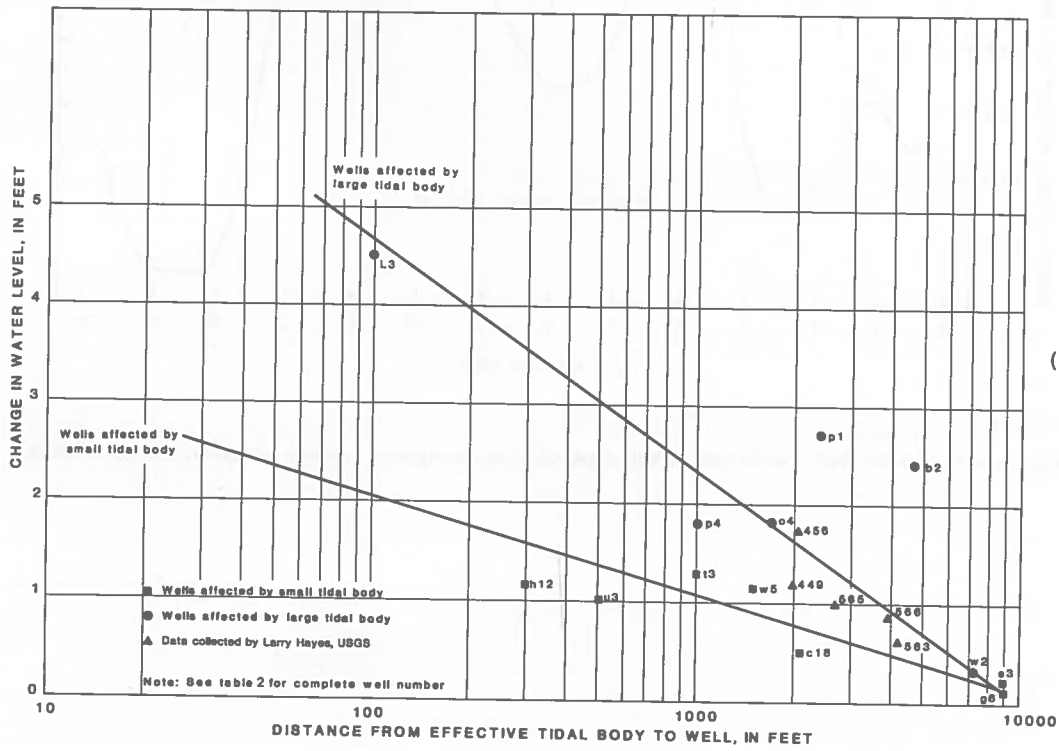
Figure 9. Hydrograph of water levels in well 2611-w2, which taps the upper Floridan aquifer, and monthly rainfall at Beaufort, S.C.



**Figure 10.** Comparison of water-level fluctuations in well 27GG-q1 with atmospheric pressure changes (after Siple, 1960).



(A)



(B)

Figure 11A-B. (A) Relationship between tidal efficiency and distance from effective tidal body. (B) Relationship between distance and change in water level.

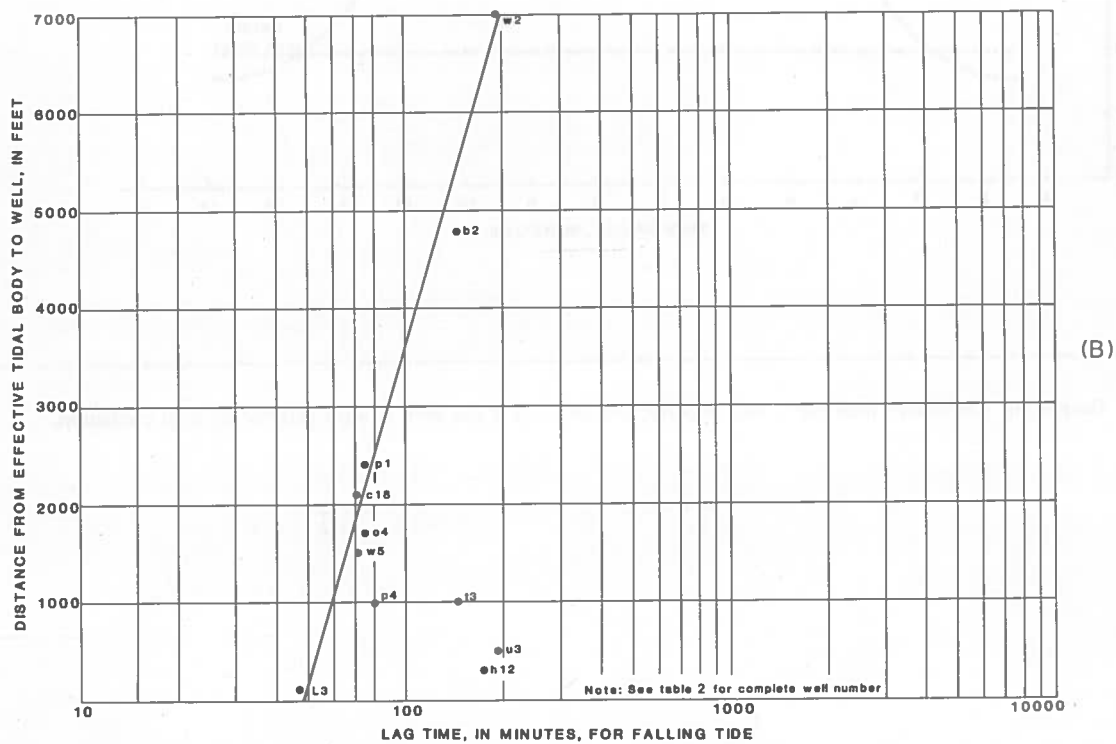
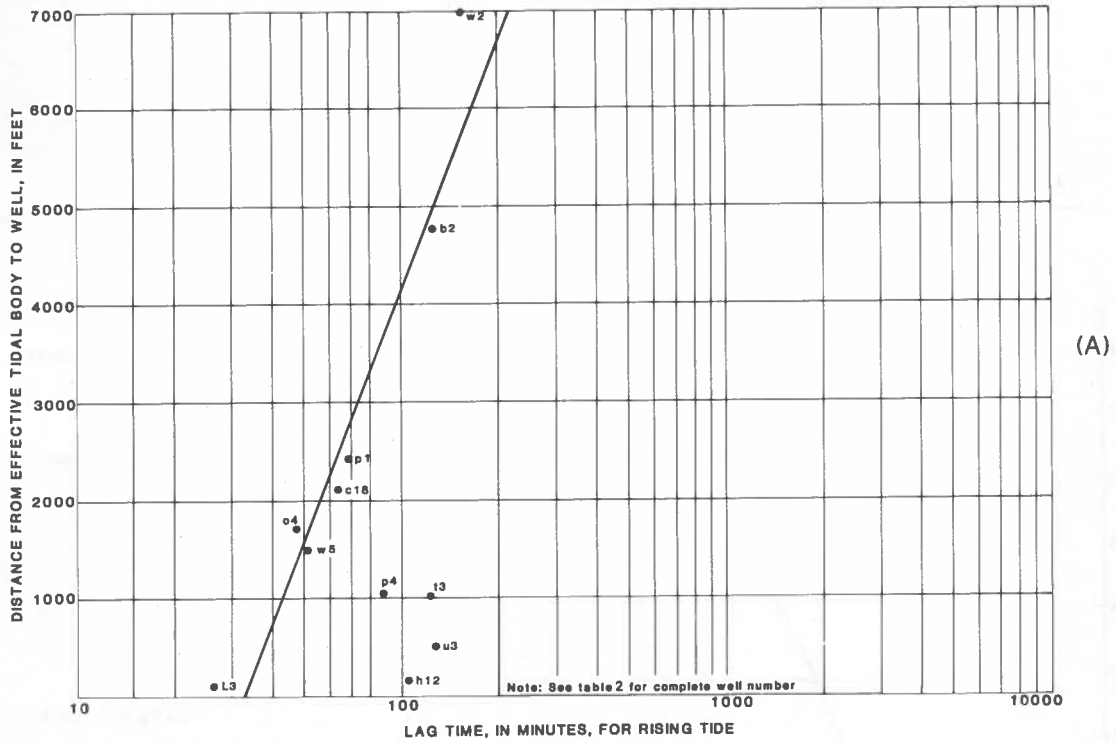
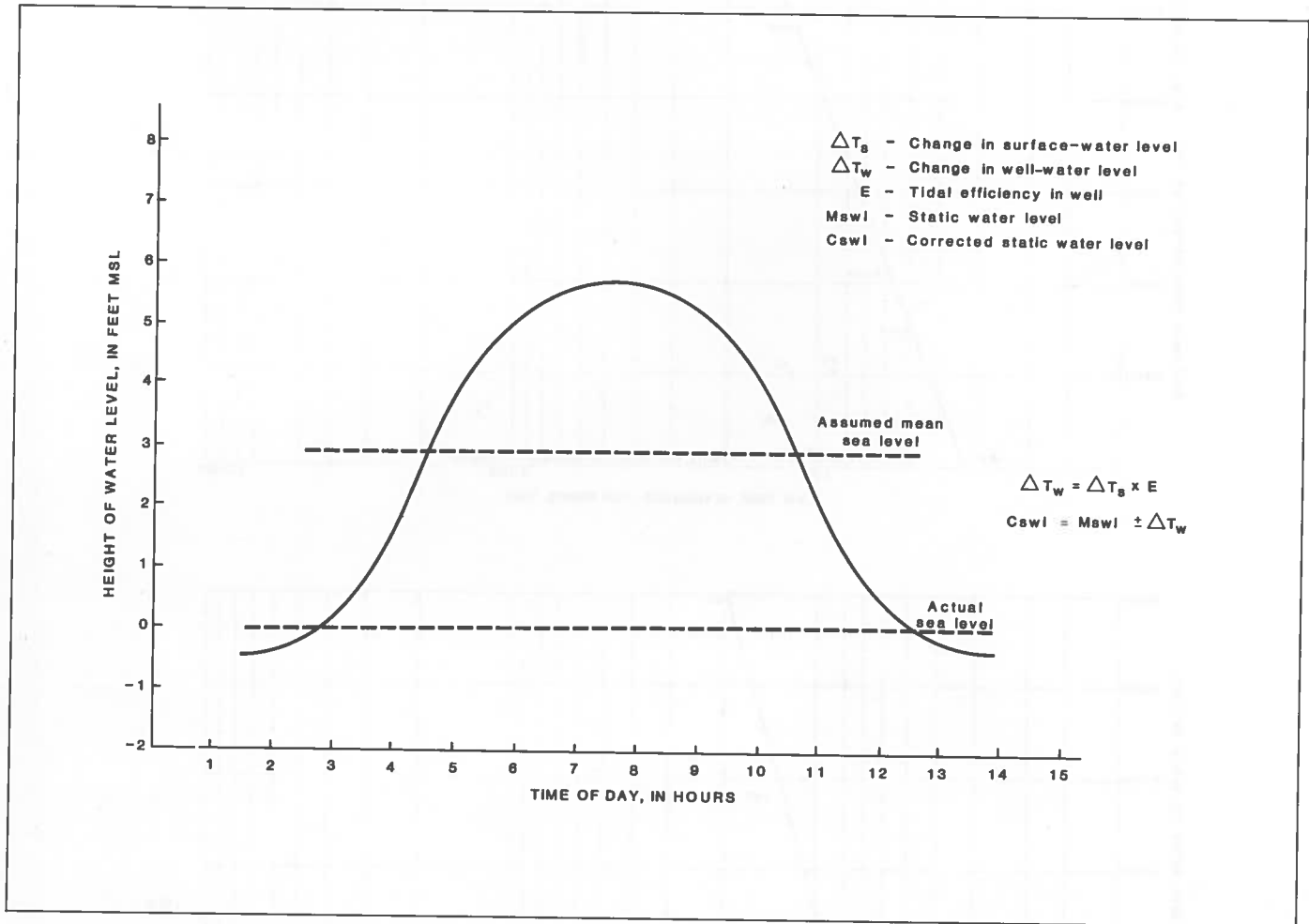


Figure 12A-B. Relationship between distance from effective tidal body and lag time for tidal response in selected observation wells (A) rising tide, (B) falling tide.





**Figure 13.** Graphically constructed tidal curve used in correction for static water level in wells affected by tidal oscillation.

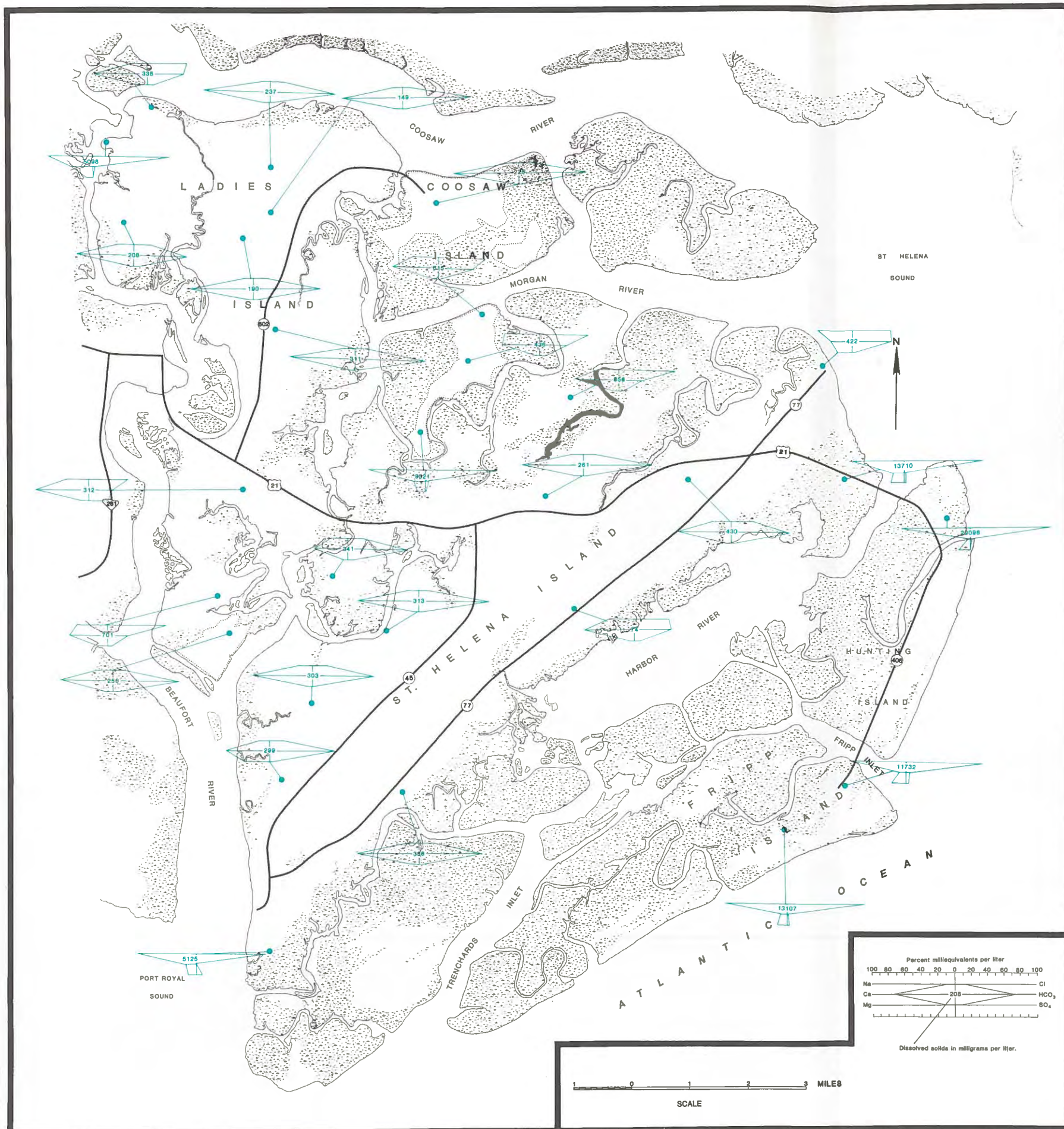


Figure 14. Areal distribution of ground-water types, as shown by modified Stiff diagrams.





Figure-15. Areal distribution of chloride in the upper Floridan aquifer.



averaging 3 feet in the study area. Water levels in shallow wells are directly related to topography and the presence of underlying confining units. Water levels farthest below the surface occur in areas of high elevation and in areas distant from bodies of surface water.

Water-bearing characteristics of the shallow deposits are generally unknown in the study area. Glowacz and others (1980) published information from five monitoring wells on St. Helena Island and one well on Ladies Island. Transmissivity in the shallow aquifer ranged from 1,300 ft<sup>2</sup>/day in coarse sand to much less in finer sand and clay. Sanders and Spigner (1983) calculated a storage coefficient of 0.20 for wells in the same deposits on Datha Island and estimated possible yields of 4 to 10 gpm/ft from fairly permeable sands. Glowacz and others (1980, p. 30) reported water quality from six wells in the study area that were screened at depths ranging from 3 to 20 feet below the surface. These results reflected water of acceptable quality for domestic and agricultural use, with the exception of wells located near the coast or saltwater estuaries.

## GROUND-WATER QUALITY

Rainfall that recharges the aquifer in the study area is only slightly mineralized. As ground water, it moves through various underlying deposits, dissolving mineral constituents from the surrounding material. The amount and kind of minerals in the water depend upon the composition and solubility of the surrounding material, the chemical composition of the water, and the length of time the water has been in contact with surrounding material. Therefore, the amount of dissolved minerals in ground water in recharge areas is relatively small; it increases with depth and distance from the point of origin.

Table 3 lists chemical analyses from selected wells in the Ladies and St. Helena Islands study area. These analyses were made by the South Carolina Water Resources Commission's laboratory, where uniform analytical procedures were followed. Properties such as specific conductance, temperature, pH, and alkalinity, change with time after a ground-water sample has been taken and should be measured at the time of sampling. However, only specific conductance and temperature were measured at the well head; pH and alkalinity were calculated after several days of storage. The locations and construction of wells from which samples were taken are included in Table 1.

Ground water in the study area generally comprises three types: (1) calcium bicarbonate, (2) calcium bicarbonate with the admixture of sodium and chloride, and (3) sodium chloride. Figure 14 shows the distribution of typical ground-water composition. Each analysis is represented by an amended Stiff diagram showing the percentage of total anions and cations, in milliequivalents per liter, plotted on a horizontal axis. The total dissolved solids (in milligrams per liter) appear in the center of each diagram.

Diagrams that represent analyses from wells 26HH-g5,

26II-r4, and 25II-a7 are typical of water from the upper Floridan aquifer. They are characterized by high percentages of calcium and bicarbonate with minor amounts of sodium, chloride, magnesium, and sulfate. Water of this type exists in areas of locally high potentiometric head, reflecting rapid dissolution of calcium carbonate from the surrounding limestone.

Samples 26II-d3, 25HH-p4, and 24HH-q4 represent water from the upper Floridan aquifer in which saltwater contamination is present. Chloride values of 50 to 144 mg/L in these samples are typical of water containing admixtures of saltwater. Water of this nature is of a transitional type and exists in zones where hydraulic gradients are low and minor amounts of recharge occur.

Stiff diagrams of samples taken from wells 24JJ-el, 26HH-u3, and 26JJ-nl illustrate patterns of predominantly sodium chloride water. This type of water exists in areas of extensive saltwater contamination occurring mainly near areas bordering saltwater bodies.

Upon review of the areal distribution of water types, a distinctive pattern can be recognized. Calcium bicarbonate water exists on Ladies and St. Helena Islands, along with the interior of smaller islands, corresponding to areas of local recharge. Transitional water occurs along island margins paralleling areas of relatively low hydraulic gradient, and sodium chloride water is prevalent in areas near saltwater bodies, as well as in areas where the confining unit is leaky or absent. In general, water-quality conditions deteriorate from areas of recharge to points of discharge.

Ground water in the Ladies and St. Helena Islands study area is generally of good chemical quality. Mineral constituents are usually within the limits established by the U.S. Environmental Protection Agency (USEPA), although in several wells iron and chloride exceed the recommended limits of 0.3 mg/L and 250 mg/L, respectively. The source, effect, and treatment of these and other major chemical constituents are shown in Table 4.

## Chloride

Chloride concentrations that have been measured range from 7.0 to 13,200 mg/L, in several wells far exceeding the recommended USEPA limits of 250 mg/L for drinking water. The tidal water bodies that surround the study area are, in general, the major source of saline water entering the aquifer. Figure 15 is a map of the study area showing chloride distribution in the upper 20 feet of the upper Floridan aquifer.

The distribution of chloride can best be explained through comparison of figures 8 and 15. The chloride content of the water is lowest near areas of recharge and progressively higher towards areas of discharge. Higher chloride values are due to lower hydraulic head that results in less flushing of the aquifer. Figure 16 further illustrates this point by showing chloride data from well 25HH-p4 located in a discharge area. It shows a relatively small amount of freshwater existing above saltwater, interconnected by a zone of transition marked by a sharp increase in chloride values with depth.

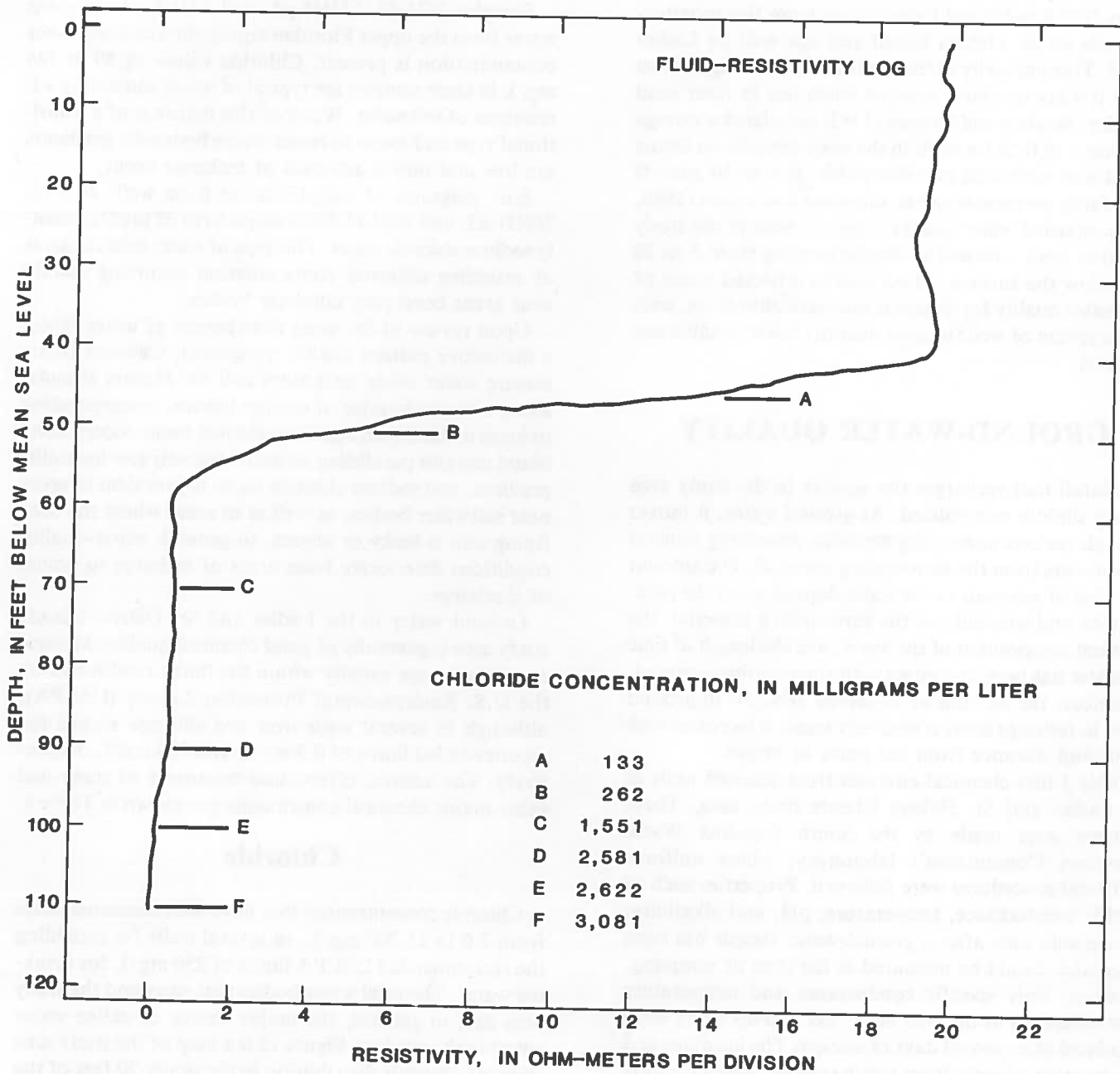


Figure 16. Relation between chloride concentration and depth in well 25HH-p4.

Through further examination of figure 15, areas of locally high chloride values can be observed. One of these areas is in the northwest corner of Ladies Island along Brickyard Creek. A water sample from well 27HH-b2 showed a chloride value of 2,524 mg/L. This area was identified by Hayes (1979) and others as one in which saltwater intrusion has occurred through a breach in the confining unit overlying the upper Floridan aquifer beneath Brickyard Creek. Similar problems were identified during the Port Royal Sound Environmental Study conducted by the South Carolina Water Resources Commission (1972). Seismic studies revealed areas of the Beaufort River where the confining unit is thin or breached due to dredging and natural erosional processes. It is probable that additional undiscovered localities of thin or absent confining unit exist beneath other tidal water bodies, as well as on the land surface in the study area.

The lack of a sufficient confining unit and hydraulic head greatly increases the potential for saltwater intrusion along island margins. This problem is of prime concern on smaller islands in the study area where a lack of sufficient local recharge, along with continued high-capacity pumping, could cause an intrusion of saltwater into the aquifer. Instances of recent saltwater intrusion have been reported at Beaufort, Port Royal, and Parris Island, immediately west of the study area, and at the southwestern margin of St. Helena Island.

Chloride contamination by means of saltwater intrusion can also occur along the margins of Ladies and St. Helena Islands and on many of the smaller islands. Upconing may take place wherever saltwater occurs at the base of the upper Floridan aquifer and large withdrawals are made from the overlying freshwater-bearing section. As the withdrawals are made, the saltwater migrates upward and eventually enters the well bore. An example of this problem is shown in the results of a pumping test conducted on well 26II-pl, in which chloride levels were monitored for 25 hours of continuous pumping (Fig. 17). The graph shows an increasing concentration of chloride throughout the test, typical of saltwater upconing.

## Iron

Iron occurs in varying concentrations in water from the upper Floridan aquifer throughout the Ladies and St. Helena Islands area. As indicated in Table 3, dissolved-iron concentrations ranged from 0.004 to 14 mg/L, frequently exceeding the 0.3 mg/L maximum recommended by the USEPA for drinking water. The effects of and treatment for iron exceeding this limit are included in Table 4.

Iron compounds are present in most geologic formations, occurring in ground water as ferrous iron until pumped from a well and oxidized upon contact with atmospheric oxygen to produce ferric iron. Ferric hydroxide later precipitates from ferric iron to produce a rust-colored deposit on laundry and fixtures.

The principal chemical factors that control iron solubility in ground water are pH and the oxidation-

reduction potential (Eh). For a detailed description of these factors, the reader is referred to Hem (1970, p. 114-126).

Figure 18 is a map showing the distribution of iron in the Ladies and St. Helena Islands study area. The areal distribution of iron concentrations displays a sporadic arrangement of high and low values. It is probable that increased iron values in recharge areas are due to rainfall taking into solution a relatively large amount of iron from the shallow aquifer, and precipitating it in the Floridan aquifer. However, locally high iron values also may reflect a combination of other sources such as vertical leakage caused by thinning of the confining unit, improper well construction, increased precipitation of iron along well borings, contamination from old well casings, and proximity to marshlands.

## Hydrogen Sulfide

Hydrogen sulfide (H<sub>2</sub>S) is a gaseous compound having a characteristic odor of rotten eggs. Black and Brown (1951, p. 15) discussed two possible sources of hydrogen sulfide in ground water: (1) the reduction of sulfate to sulfides by organic material under anaerobic conditions in the aquifer, resulting in the yield of H<sub>2</sub>S, and (2) the anaerobic reduction of organic material with which ground water comes in contact.

The presence of hydrogen sulfide in ground water does not present a health hazard, but it can impart an unpleasant taste and odor to the water. This odor is distinctive and can be detected in water containing a few tenths of a milligram per liter of sulfide (Hem, 1970, p. 170). Hydrogen sulfide possesses corrosive properties affecting plumbing and fixtures. Bent (1984, p. 28) discusses methods of treating hydrogen sulfide problems, suggesting chlorination, oxidation by aeration, manganese-green sand filtration, or activated-carbon absorption.

Special sampling and analytical methods are needed to determine the amount of hydrogen sulfide in ground water. For this reason, hydrogen sulfide was not evaluated. However, samples were taken to determine the concentration of sulfide which reflects hydrogen sulfide levels. Sulfide concentrations in the study area ranged from 0 to 17 mg/L (Table 3). The areal distribution of sulfide (Fig. 19) demonstrates no particular pattern in the study area. However, the random presence of sulfide in wells may be due to ground water coming in contact with anaerobically reduced organic material before entering the aquifer. Furthermore, it is likely that the presence of sulfide in wells bordering marshland is due to anaerobically reduced sulfate that is associated with the presence of saltwater in the same areas.

## Dissolved Solids

In ground water, the total concentration of dissolved solids is highly dependent on the concentration of inorganic salts, small amounts of organic matter, and dissolved gases (Sawyer and Carty, 1967).

Dissolved solids in samples from the study area ranged

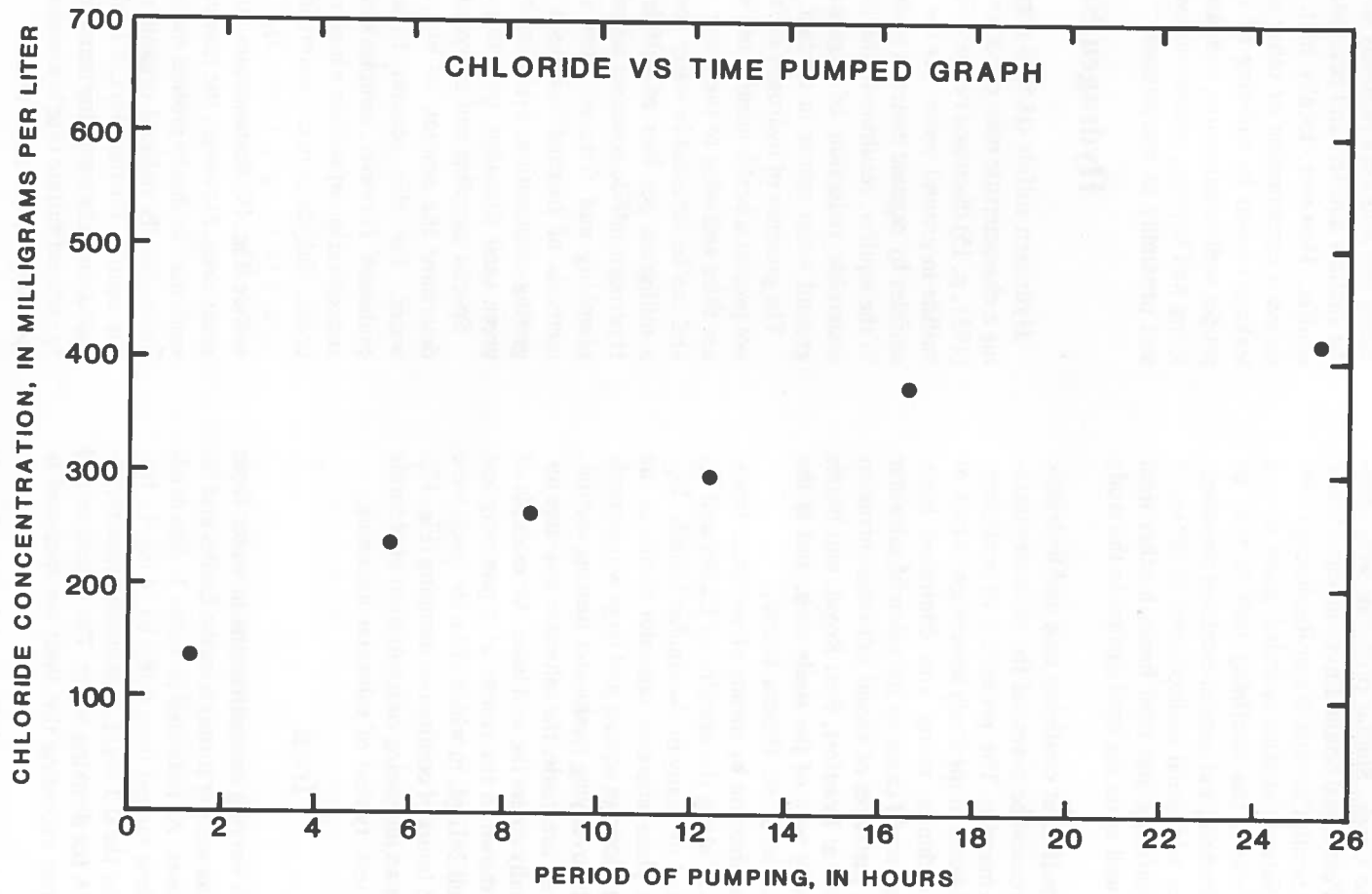


Figure 17. Chloride increase with pumping in well 26II-p1.





Figure 18. Areal distribution of iron in the upper Floridan aquifer.



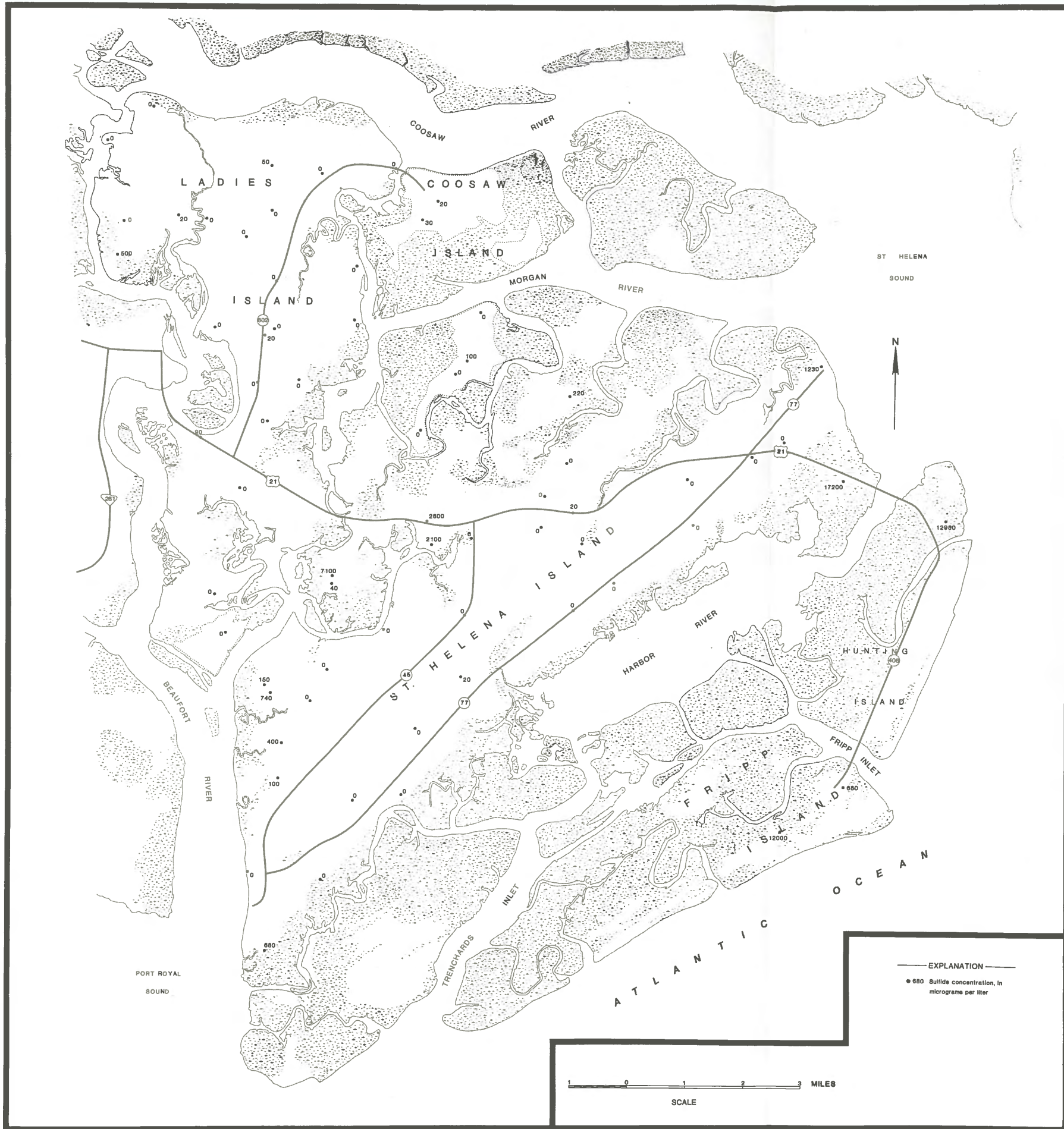


Figure 19. Areal distribution of sulfide in the upper Floridan aquifer.



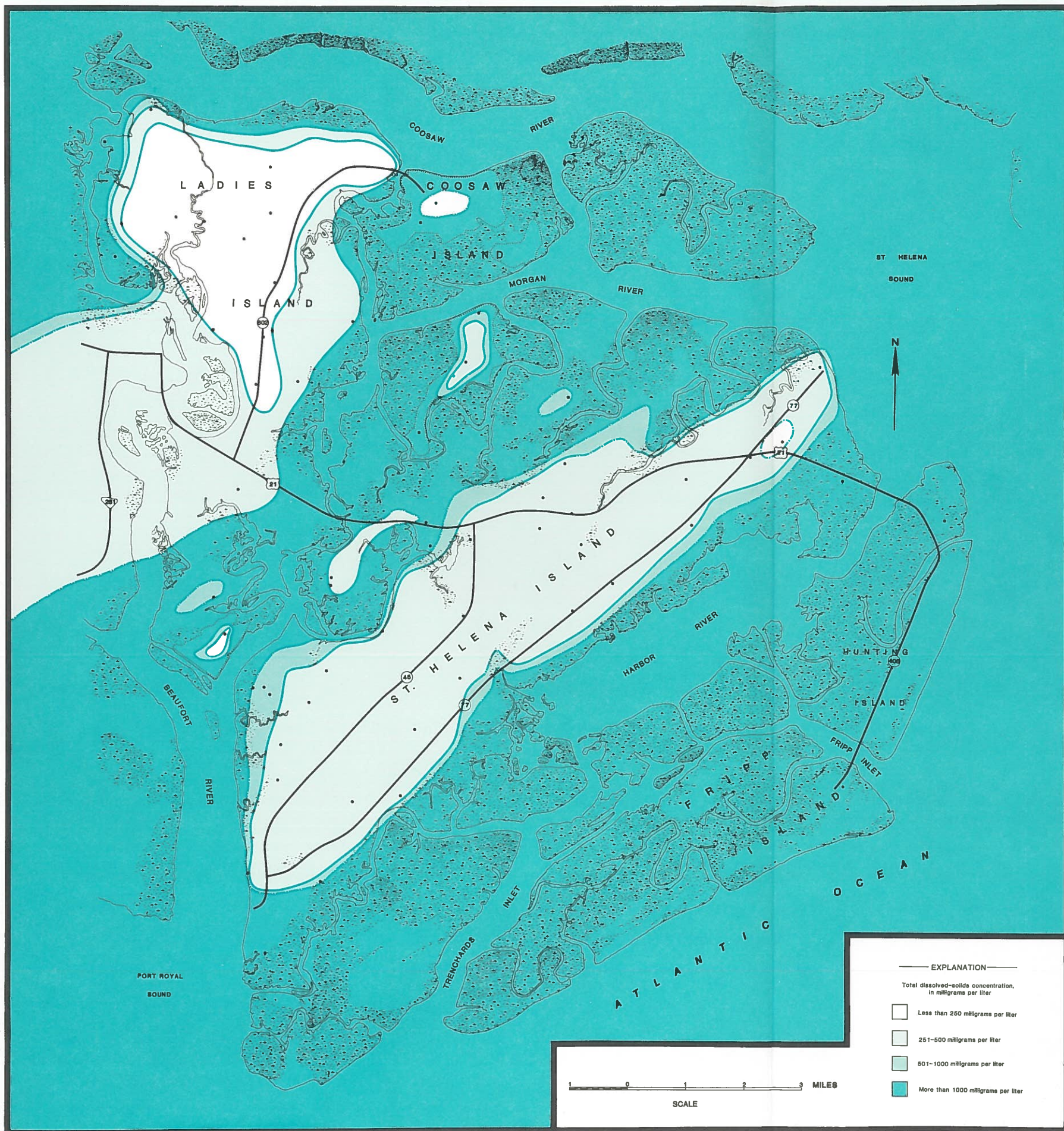


Figure 20. Areal distribution of dissolved solids in the upper Floridan aquifer.



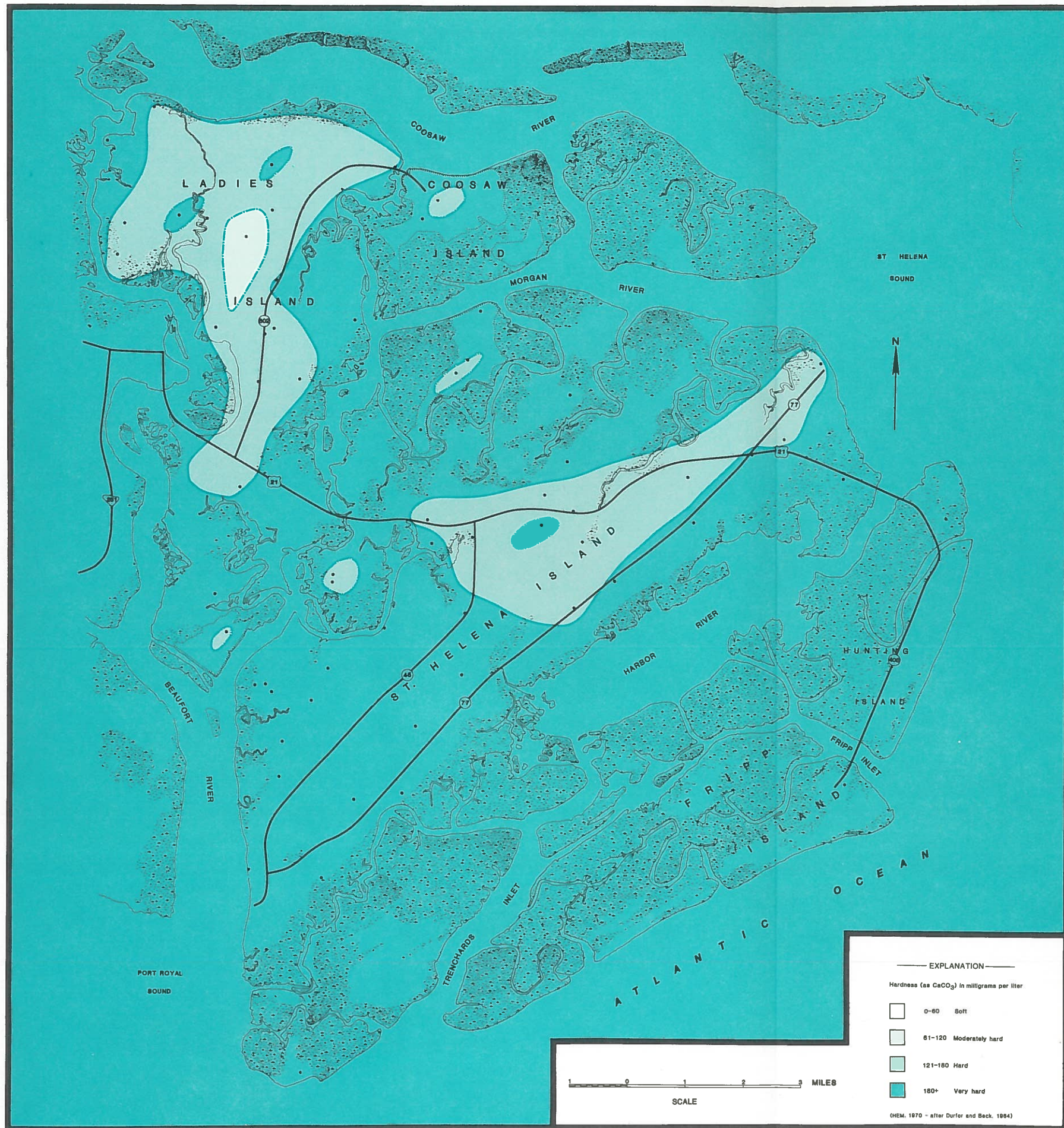


Figure 21. Areal distribution of hardness in the upper Floridan aquifer.



from 57 to 29,000 mg/L, with relatively high chloride concentrations accounting for the highest values (Fig. 20). For wells in which chloride levels did not exceed 250 mg/L, dissolved solids ranged from 57 to 852 mg/L. Ground water normally contains between 20 and 1,000 mg/L of dissolved solids. However, the recommended limit set by the USEPA for drinking water is 500 mg/L. Water containing higher concentrations of dissolved solids may have excessive amounts of chloride, causing accelerated corrosion of plumbing as well as destruction of many types of plant life.

## Hardness

There are two types of hardness in ground water; (1) carbonate hardness caused by calcium and magnesium bicarbonates and (2) noncarbonate hardness caused by dissolved metals, sulfates, chlorides, and nitrates of calcium and magnesium.

A generalized map showing the distribution of hardness (as  $\text{CaCO}_3$ ) in the study area is shown in Figure 21. Hardness values ranged from 57 to 3,860 mg/L in samples from across the study area as shown in Table 3, with all but one well (2511-m3) exceeding 60 mg/L. Water of this quality is considered hard, causing interference with the lathering action of soap and also forming a scaly precipitate on plumbing fixtures, boilers, and utensils when water is heated. Hardness exceeding 60 mg/L is common in the study area, owing to the presence of a limestone aquifer. According to Hem (1970, p. 225), hardness values of 200 mg/L or more from a limestone aquifer are common.

Most of the hardness in the study area is considered to be carbonate hardness and can be treated by the addition of soda-ash or lime-soda or removed by heating. Noncarbonate hardness is much more difficult to treat, but it can be reduced by the use of ion-exchange filters.

## WELL CONSTRUCTION

Wells that obtain water from the upper Floridan aquifer are usually constructed by cable tool or rotary drilling methods. A well is drilled through the overlying deposits until reaching the top of the upper permeable zone of the aquifer. The well is then drilled a few feet deeper to insure entry of the water-yielding zone and cased from the surface to this point. After installation of the casing, drilling is then continued through the casing, producing an open hole sufficient to yield an ample supply of water.

Another procedure commonly incorporated in well drilling is well grouting. It consists of filling the annular space between the drilled hole and the well casing with an impervious material (neat cement). The purposes of grouting are: (1) to protect the aquifer or aquifers against the mixing of water from other aquifers and thereby to preserve water quality and hydraulic response of the producing zone(s), and (2) to protect the well against contamination from surface water or a subsurface zone (USEPA). Figure 22 is a diagram illustrating proper well

and grouting construction. For additional information concerning well-construction practices, the reader is referred to the USEPA manual for water-well construction.

Improperly cased or grouted wells can contribute to contamination of the aquifer by acting as a hydraulic connection between the aquifer and other permeable zones, causing vertical movement of pollutants into the aquifer. In the study area the greatest danger resulting from this movement is the contamination of the freshwater zone by water containing high concentrations of chloride.

Proper well-construction practice not only guards against saltwater contamination but also the contamination by bacterial organisms. These bacterial organisms can enter a well in two ways: (1) subsurface or surface contamination that occurs along the exterior of casing walls in improperly constructed wells; or (2) surface contamination through improperly sealed or capped wells.

Improperly constructed wells have been cited as the cause of several cases of ground-water contamination in Beaufort County. Mundorff (1944), Siple (1956), Hayes (1979), and Spigner and Ransom (1979) made reference to many of these problems, suggesting that they pose a serious threat to ground-water quality. They also recommended that new wells be grouted into the upper permeable zone and that abandoned wells be properly plugged to avoid further contamination.

## WATER USE

In 1983, approximately 749 million gallons of water were withdrawn to serve the Ladies and St. Helena Islands study area. Ground water accounted for 65 percent of the withdrawal, and the remaining 35 percent was supplied by surface water from the Savannah River.

In 1982, the South Carolina Water Resources Commission (SCWRC) initiated the reporting of ground water use in declared capacity-use areas of South Carolina. In these areas, any water user possessing a Class A well (a well or combination of wells that pumps 0.1 mgd or more) is required to submit quarterly reports of total pumpage. Figure 23 is a map showing the location of Class A wells, as well as total pumpage for 1983. These areas of high-capacity wells represent, in most cases, localities of seasonal pumpage for crop and golf-course irrigation.

Figure 24 depicts ground-water uses for 1983. Self-supplied domestic use was calculated by multiplying the population not served by a municipality or water district by a per capita use of 60 gallons per day. Surface water accounted for approximately 193.6 million gallons of domestic water supply in 1983.

Withdrawals of ground water for commercial use (including golf-course irrigation) were approximately 174.3 million gallons for 1983. Virtually all commercial ground-water use was withdrawn for golf-course irrigation, with only minor amounts used for a variety of other commercial needs.

Surface water supplied 65.3 million gallons of water for commercial use, most of which included nonirrigational application.

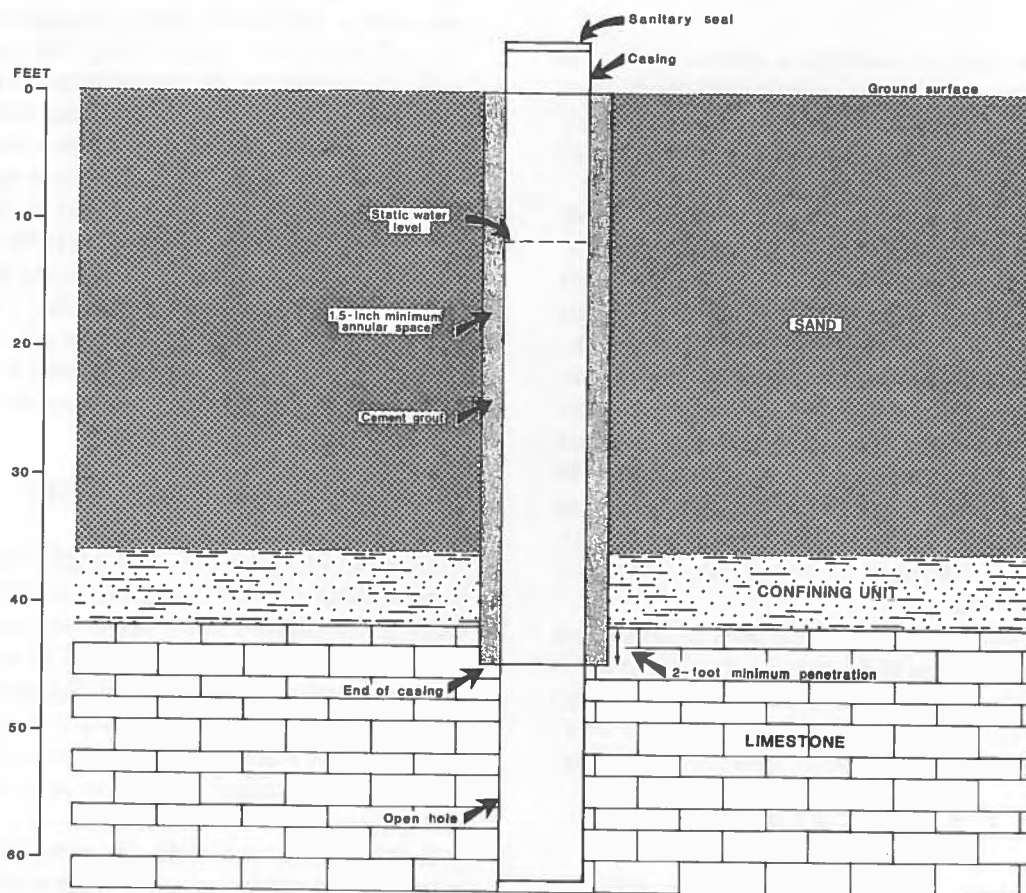


Figure 22. Construction of open-hole well tapping the upper Floridan aquifer.



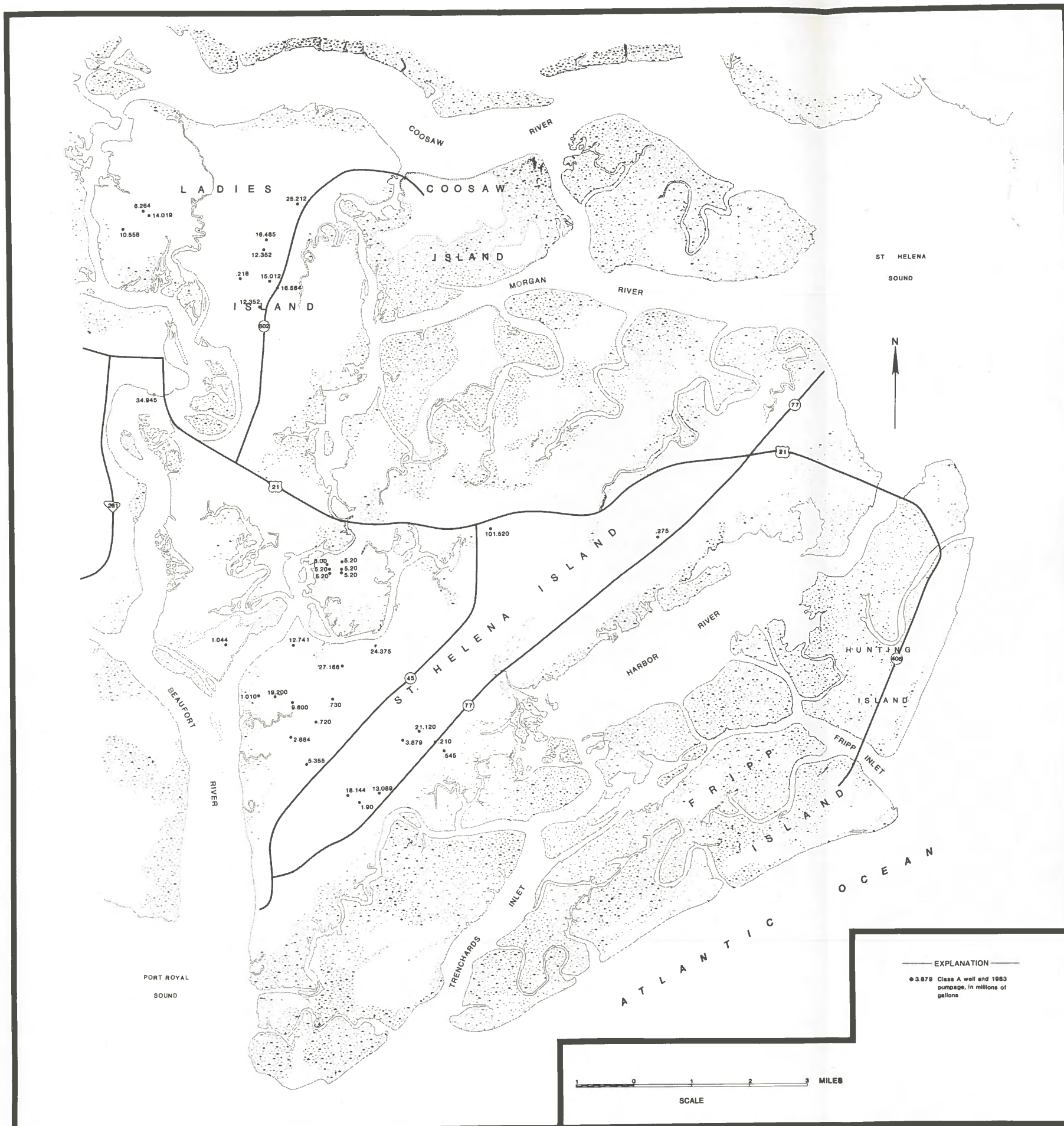
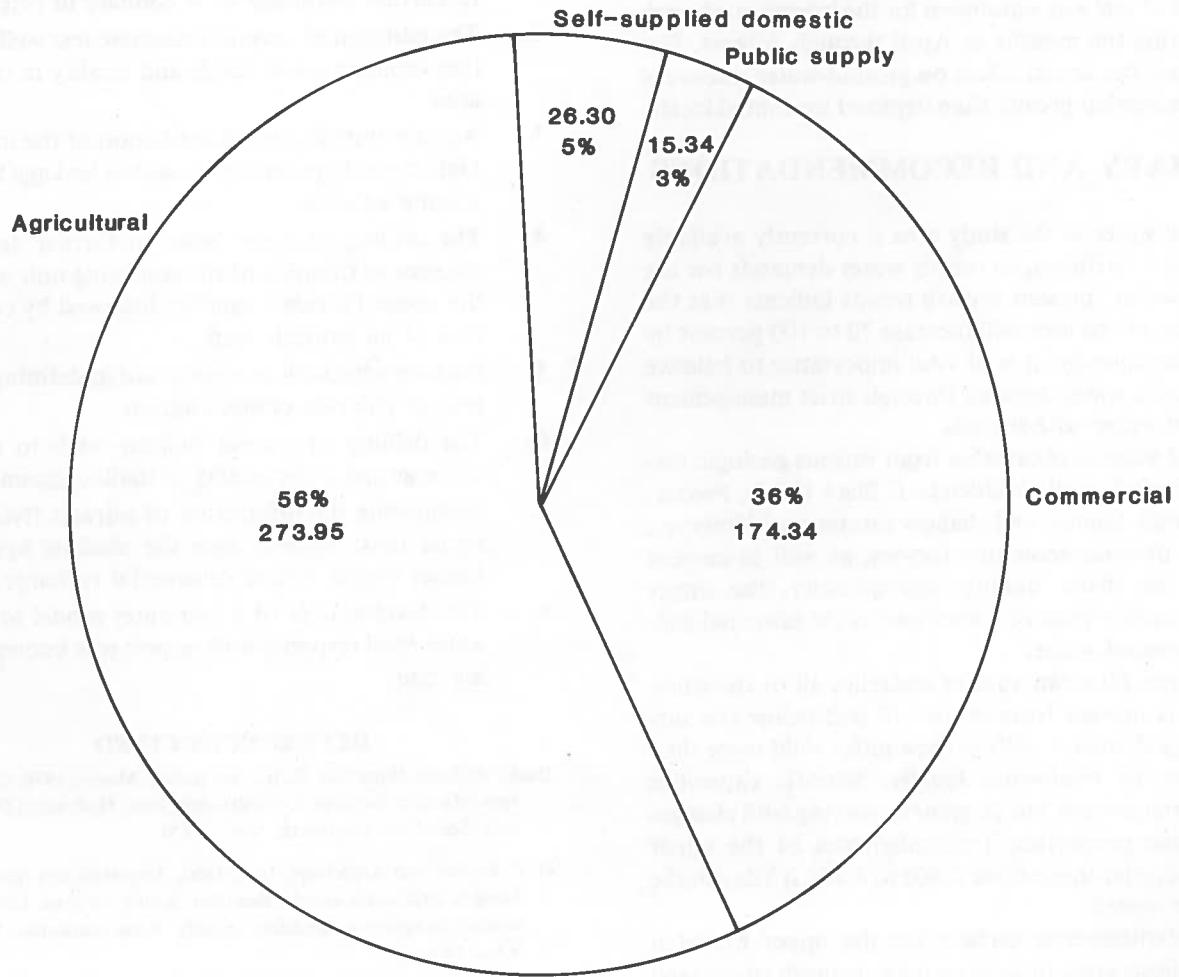


Figure 23. Location of Class A wells, with their pumpage for 1983.



Amounts are in millions of gallons for the year.

**Figure 24.** Use of ground water in the study area, by category, 1983.

Municipal suppliers and water districts used 15.3 million gallons of ground water for public supply (combined domestic and commercial use) during 1983. The majority of the public supply wells in the study area are used to supplement surface-water supplies. Therefore, they remain on standby except for periods of peak water withdrawal. Surface water was used to furnish 258.9 million gallons of water in 1983, serving as the primary source of public supply water.

Approximately 274 million gallons of ground water was used for agricultural purposes in 1983, representing the largest percentage of withdrawal use in the study area. Nearly all of this was withdrawn for the irrigation of truck crops during the months of April through August. For this reason, the actual effect on ground-water resources may be somewhat greater than depicted by annual totals.

## SUMMARY AND RECOMMENDATIONS

Ground water in the study area is currently available in quantities sufficient to supply water demands for the area. However, present growth trends indicate that the population of the area will increase 70 to 100 percent by 1990. Consequently, it is of vital importance to balance the increased water demand through strict management of ground-water withdrawals.

Ground water is obtainable from various geologic formations, including the Middendorf, Black Creek, Peedee, Black Mingo, Santee, and shallow formations. However, owing to obvious economic factors, as well as current demands on water quality and quantity, the upper Floridan aquifer (Santee Limestone) is the principal supplier of ground water.

The upper Floridan aquifer underlies all of the study area and is present from 30 to 120 feet below the surface. Large-diameter wells in the aquifer yield more than 1,200 gpm of freshwater locally. Specific capacities generally range from 3 to 20 gpm/ft, varying with changes in hydraulic properties. Transmissivities of the upper Floridan aquifer range from 2,300 to 4,700 ft<sup>2</sup>/day in the few places tested.

The potentiometric surface for the upper Floridan aquifer reflects areas of local recharge beneath island land masses followed by radial discharge towards areas of lower elevation. One principal recharge area identified on Ladies Island has a hydraulic gradient of 15 feet per mile at the center of the recharge mound. This recharge is controlled by the absence or thinning of the confining unit, in combination with a structural high which permits the infiltration of rainfall through a shallow aquifer into the upper Floridan aquifer.

Recharge also occurs at St. Helena Island and is reflected in an elongated potentiometric high that runs nearly the entire length of the island. The potentiometric head ranges between 7 and 0 ft MSL, and hydraulic gradients are approximately 1 to 4 feet per mile along the flanks of the recharge area.

Ground water from the upper Floridan aquifer is generally of good quality and is suitable for domestic, commercial, and agricultural uses. It is marked by low

dissolved-solid concentrations that increase down the hydraulic gradient, low chloride concentrations that increase near island margins and towards discharge areas, sporadically high concentrations of iron and hydrogen sulfide, and high hardness that also increases down the hydraulic gradient.

To further evaluate water from the upper Floridan aquifer and prepare for future demands on the resource, the following recommendations should be considered:

1. The implementation of age dating of water samples to determine whether chloride contamination is due to current pumpage or is connate in origin.
2. The addition of several limestone test wells to further monitor water levels and quality in the study area.
3. Aquifer tests to permit prediction of the impact of high-capacity pumping, as well as leakage from adjoining aquifers.
4. The drilling of auger holes to further define the absence or thinning of the confining unit overlying the upper Floridan aquifer, followed by construction of an isopach map.
5. Surface-resistivity surveys to aid in defining the extent of chloride contamination.
6. The drilling of several shallow wells to monitor recharge and water quality of shallow ground water.
7. Monitoring the infiltration of nitrates (NO<sub>3</sub>) from septic tank effluent into the shallow system on Ladies Island, where substantial recharge occurs.
8. The development of a computer model to predict water-level response with respect to a known pumping rate.

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Table 1. Selected well data

Column  
Well use—DOM: Domestic  
UNU: Unused  
OBS: Observation, water level and/or water quality  
IRR: Irrigation  
STB: Standby  
TEST: Test hole  
REC: Recreation  
PS: Public supply  
Elevation of meas. point—feet above mean sea level (\*Estimated)

Geophysical logs—G: Gamma-ray  
CAL: Caliper  
E: Electric  
SP: Spontaneous-potential  
T: Fluid-temperature  
FL-R: Fluid-resistivity  
N: Neutron  
C: Conductivity

WL well—well used for monitoring water level  
Chemical analysis—Well used for monitoring water quality (See Table 3)  
Sampling date—Water sample collection date

SCWRC Well No.	Beaufort		Elevation of meas. point	Total depth (ft)	Casing diam(in)	Casing depth(ft)	Geophysical logs	WL well	Chemical analysis	Sampling date
	County number	Well use								
24HH-q1	432	DOM		201	4		G			
24HH-q4	1604	DOM	15.84	105	4			X	X	3-5-84
24HH-x5	1542	UNU	13.79	133	2			X		
24HH-y1	506	DOM		75	2					
24II-d1	562	OBS	8.14	212	4	78	G,CAL,E,SP,T	X	X	5-29-84
24II-e1	472	DOM		99	2		G		X	4-29-84
24II-e3	412	UNU	10.23	91	6	72	FL-R,T,G,CAL	X		5-29-84
24II-f3	497	OBS	6.33	58	2		G,CAL.	X		
24II-i1	452	OBS	7.79	103	4	75	N,CAL,G,GG	X	X	4-29-84
24JJ-c1	449	UNU	7.21	150	12	96	G,C,CAL.	X		
24JJ-c2	457	IRR/STB		3168	24	2320	G,C,E,T,CAL		X	5-29-84
24JJ-d1	455	UNU	8.36	102	4	96	G,CAL.	X	X	4-29-84
24JJ-e1	456	UNU	7.69	102	4	72	G,CAL.	X	X	5-29-84
25HH-n2	1609	DOM	7.74	35	4			X		
25HH-p3	1457	TEST	14.30	55	4	44	G,E	X		
25HH-p4	1458	TEST	10.1*	39	4	100	G,CAL,FL-R,T	X	X	5-29-84
25HH-p5	1459	IRR	24.15	50	4	55	G,E	X	X	5-29-84
25HH-p6	1560	IRR		58	4	50			X	5-29-84
25HH-p10	1564	IRR	23.30	63	6	58		X		
25HH-r8	1538	UNU	14.96	60	3			X		
25HH-s3	1540	UNU	13.87	62	2			X		
25HH-v3	595	IRR/UNU	13.33	86	3			X		
25HH-v5	597	IRR/UNU	8.58	84	3			X		
25HH-w5	1537	IRR	8.85	80	4		G,CAL,SP,FL-R,T	X	X	2-10-84
25HH-x7	1535	IRR	7.50	83	4			X		
25II-a7	488	IRR	12.26	100	6	76		X	X	5-29-84
25II-c1	473	UNU	10.18	86	3		G	X		
25II-c18	1260	IRR	11.88	140	6	90	G	X	X	4-29-84
25II-d4	1252	UNU	21.47	86	4	70		X		
25II-d5	1253	IRR/UNU		90	2				X	2-10-84
25II-e3	1407	UNU	9.96	60	3			X		
25II-f10	1615	DOM		65	2				X	5-29-84
25II-g4	792	REC	19.5*	109	6	78	G,CAL.	X		

SCWRC Well No.	Beaufort County number	Well use	Elevation of meas. point	Total depth (ft)	Casing diam(in)	Casing depth(ft)	Geophysical logs	WL well	Chemical analysis	Sampling date
25II-g6	599	IRR/UNU		145	6		G,CAL,FL-R,SP		X	2-10-84
25II-h1	1595	DOM		50	2				X	2-10-84
25II-h2	1514	UNU	10.18	90	4		G	X	X	2-10-84
25II-i3	1550	UNU	10.86	82	2			X		
25II-j1	510	DOM		60	2.5				X	5-29-84
25II-m1	519	DOM		60	2				X	5-29-84
25II-m2	563	OBS	19.28	210	4	79	G,E,SP	X		
25II-m3	1549	UNU	8.50	43	2			X	X	4-29-84
25II-o8	1548	UNU	27.47	100	2			X		
25II-o9	1616	DOM		75	2				X	5-29-84
25II-p1	482	DOM		84	3		G			
25II-p3	1247	STB	9.52	80	2	40		X		
25II-p7	1421	IRR		104	6	90			X	2-10-84
25II-q2	62	UNU		74	3		G			
25II-q3	600	IRR	11.78	107	4			X		
26HH-b1	549	DOM		30	2.5				X	5-29-84
26HH-c1	1491	DOM		50	4				X	5-29-84
26HH-d2	782	DOM	22.53	90	4			X	X	2-10-84
26HH-d4	837	IRR/UNU	8.19	50	4			X		
26HH-f5	1603	DOM		43	4				X	3-5-84
26HH-f6	1619	DOM		70	2				X	5-29-84
26HH-g2	585	IRR	23.73	60	6			X		
26HH-g5	591	IRR/PS		60	2				X	5-29-84
26HH-g8	1489	REC	17.09	50	3			X		
26HH-g9	1598	DOM		63	4				X	4-29-84
26HH-h1	551	DOM	16.94	80	4			X		
26HH-h3	1599	DOM	22.54	63	4			X		
26HH-h4	1516	DOM	8.635	60	2			X		
26HH-j13	1463	UNU	14.79	50	2	30		X		
26HH-j15	1584	DOM		150	3				X	2-10-84
26HH-j16	1593	DOM		70	2				X	2-10-84
26HH-12	1498	DOM		45	3				X	2-10-84
26HH-14	1605	DOM	19.26	70	4.5			X		

SCWRC Well No.	Beaufort County number	Well use	Elevation of meas. point	Total depth (ft)	Casing diam(in)	Casing depth(ft)	Geophysical logs	WL well	Chemical analysis	Sampling date
26HH-m1	1466	OBS	18.07	70	4	50	G,CAL,FL-R	X		
26HH-n1	468	DOM		63	3		G		X	5-29-84
26HH-o2	1031	PS	20.12	60	4			X		
26HH-o4	830	IRR	22.13	60	6		G	X		
26HH-p6	1582	DOM		80	4				X	2-10-84
26HH-p7	1583	DOM	18.72	80	4			X		
26HH-q3	1270	DOM		69	2	50	G		X	2-10-84
26HH-q4	1580	DOM		50	2				X	2-10-84
26HH-q5	1600	DOM	23.42	65	4.5	58		X		
26HH-s1	1581	DOM		63	3				X	2-10-84
26HH-u3	1618	TEST	10.97	60	4	42		X	X	5-29-84
26HH-w1	1578	DOM		75	2				X	2-10-84
26HH-x6	1497	DOM/IRR	19.84	90	6			X	X	2-10-84
26HH-x7	1505	DOM/UNU	18.51	52	3			X		
26HH-x8	1579	DOM		100	2				X	2-10-84
26HH-y15	1488	DOM	16.89	80	3			X	X	2-10-84
26II-a1	1496	UNU	12.31	75	3			X		
26II-b2	1511	UNU	8.98	45	2			X		
26II-b4	1513	UNU	11.59	50	2			X		
26II-c1	1526	UNU	9.30	62	3			X		
26II-d2	1322	UNU		56	2		G			
26II-d3	1617	DOM		45	2				X	5-29-84
26II-h3	1400	IRR	8.49	60	3			X		
26II-h7	1404	UNU	10.85	60	3			X	X	4-29-84
26II-h11	1417	IRR	12.30	61	3			X		
26II-i3	1518	UNU	13.49	75	3			X		
26II-i5	1520	UNU	9.30	70	3			X		
26II-i6	1530	UNU	11.39	57	2			X		
26II-j5	1494	IRR		50	3				X	4-29-84
26II-j7	1527	UNU	11.49	49	3			X		
26II-j9	1614	DOM		70	2				X	5-29-84
26II-k3	1551	UNU	14.64	79	2			X		
26II-l1	470	IRR/DOM	10.45	62	6		G	X	X	4-29-84

SCWRC Well No.	Beaufort		Elevation of meas. point	Total depth (ft)	Casing diam(in)	Casing depth(ft)	Geophysical logs	WL well	Chemical analysis	Sampling date
	County number	Well use								
26II-m1	977	IRR	11.26	120	12			X		
26II-m3	1594	PS		100	2				X	2-10-84
26II-o3	1504	DOM	13.26	50	2			X	X	5-29-84
26II-o4	1610	IRR	14.57	66	6	56	G,CAL,FL-R,T	X	X	3-5-84
26II-o5	1633	IRR	8.42	75	6	56		X		
26II-pl	982	IRR		74	6	56	E,SP,G	X		
26II-q3	966	IRR	7.22	91	12		T,C,E,SP,CAL,G	X	X	4-29-84
26II-q5	971	IRR	9.00	84	6		G,CAL,T,C	X		
26II-q6	972	IRR	9.04	90	6			X		
26II-ql1	1587	IRR		113	6				X	4-29-84
26II-ql2	1612	PS		75	2				X	5-29-84
26II-r6	1292	IRR	11.04	125	6			X		
26II-r7	447	IRR	17.15	130	6	60		X		
26II-r12	1290	IRR	13.67	113	6			X		
26II-r13	1557	IRR		130	6		G,CAL,FL-R,SP		X	4-29-84
26II-r14	1613	IRR		70	3				X	5-29-84
26II-t3	1592	IRR	25.29	62	6			X		
26II-u3	535	IRR/STB	11.64	100	6			X		
26II-u4	970	IRR		159	12		G,CAL,T,C		X	4-29-84
26II-u5	976	IRR	7.87	110	12		G,CAL,T	X		
26II-u9	1234	IRR	8.35	110	12			X		
26II-v1	192	IRR	11.35	100	8	78		X		
26II-v4	1434	UNU		95	8			X		
26II-w2	564	OBS	19.63	207	4	84	E,G,CAL,SP,T,C	X		
26II-w3	1289	IRR	8.86	168	6		G,E	X		
26II-w6	1429	IRR	12.12	123	4	80		X		
26II-x2	1199	UNU	10.75	112	4	86	G,E,CAL	X		
26II-x3	1428	IRR		120	4	80			X	4-29-84
26JJ-a1	989	IRR		100	4				X	5-29-84
26JJ-b3	538	OBS/IRR	9.88	82	8			X		
26JJ-b5	969	IRR		105	12		CAL,T,C,G		X	4-29-84
26JJ-b6	1203	IRR	11.68	80	4			X		
26JJ-d1	791	DOM	10.96	102	4	70	G,CAL.	X		



SCWRC Well No.	Beaufort		Elevation of meas. point	Total depth (ft)	Casing diam(in)	Casing depth(ft)	Geophysical logs	WL well	Chemical analysis	Sampling date
	County number	Well use								
26JJ-d4	1288	IRR	10.12	135	6		G,E	X	X	4-29-84
26JJ-g1	534	DOM		110	1.5				X	4-29-84
26JJ-g5	1554	UNU	11.13	80	2			X		
26JJ-g6	1555	UNU	8.41	120	3			X		
26JJ-h1	530	DOM		190	2.5				X	4-29-84
26JJ-h4	1556	UNU	11.84	100	2			X		
26JJ-n1	430	OBS	7.77	430	4	104	G,T,CAL	X	X	4-20-84
27GG-u1	1043	IRR/DOM		99	2				X	2-10-84
27HH-a1	467	DOM	10.80	54	2		G	X		
27HH-b2	569	OBS	7.87	232	4	31	G,E,SP	X	X	5-29-84
27HH-b3	813	UNU		824	4		G,CAL,E,SP			
27HH-j2	1506	IRR/UNU	18.90	150	6			X		
27HH-j5	1509	IRR/UNU	12.10	48	6		G	X	X	5-29-84
27HH-k3	1455	IRR		200	6				X	5-29-84
27HH-r9	1545	PS		60	3				X	2-20-84
27HH-t1	801	OBS	12.96	88	4	64		X		
27HH-t6	28	PS	24.98	95	10		G,E,SP	X		
27HH-u1	559	OBS	10.18	62	3	43	G,CAL	X		
27II-a1	471	DOM	14.61	48	2		G,CAL	X		
27II-a6	1602	UNU	13.69	64	2.5			X		
27II-a7	1611	DOM	19.83	80	4	55		X		
27II-j1	557	OBS	9.12	50	2	42	G	X		
27II-12	496	PS	19.00	80	6			X		
27II-13	793	OBS	8.78	95	4		C,CAL,T,C	X		
27II-15	795	OBS	9.75	95	8		G,CAL,T,C,FL-R	X		
27II-16	800	OBS	10.00	100	4	100	G,CAL,E,SP,T,C	X		
27II-s1	566	OBS	15.06	232	4	84	E,SP,G	X		
27JJ-a1	565	OBS	17.83	209	4	89		X		
27JJ-i1	459	OBS	11.85	106	4		G,CAL	X		

**Table 2. Tidal efficiency and lag-time data**

Well No.	Date	Distance from ETB (ft)	Average tide range (ft)	ATE (percent)	Lag time RT (min)	Lag time FT (min)
26HH-u3	4/17 — 4/18/84	500	1.02	14.00	129	193
24II-e3	4/17 — 4/18/84	8800	.23	2.98	NA	NA
26II-w2	1/31/84	7200	.34	4.35	152	192
26II-o4	4/27/84	1700	1.82	28.70	47	75
25HH-p4	4/30 — 5/1/84	1000	1.82	26.76	89	81
26II-p1	5/2 — 5/3/84	2400	2.71	39.27	69	76
27HH-b2	5/3 — 5/7/84	4752	2.42	38.97	125	147
25HH-w5	5/1 — 5/2/84	1500	1.15	16.13	51	71
26II-h12	5/7 — 5/10/84	300	1.17	20.43	105	175
25II-c18	5/7/84	2100	.52	11.50	64	71
25II-g6	5/3 — 5/7/84	9000	.20	NA	NA	NA
27II-L3	6/1 — 6/3/84	100	4.51	62.12	26	47
27HH-t3	6/1 — 6/3/84	1000	1.30	18.00	122	148

ETB — Effective tidal body  
 ATE — Average tidal efficiency  
 RT — Rising tide  
 FT — Falling tide

Table 3. Selected ground-water chemical analyses

SCWRC No.	Depth (feet)	Sampling Date	Alkalinity	Specific Conductance	pH (lab.)	Temperature °C (field)	Chloride (Cl)	Fluoride (F)	Hardness (as CaCO <sub>3</sub> )	Residue on evaporation	Sulfate (SO <sub>4</sub> )	Sulfide (S)
24HH-q4	105	02-21-84	142.0	460	7.90	19.0	80.3	1.52	137	422	6.2	1.23
24HH-y1	75	04-11-84	23.0	170	7.49	18.0	22.7	0.00	21	84	18.5	0.00
24II-d1	82	03-22-84	137.0	20000	6.73	20.0	6308.0	0.54	3863	13710	63.9	17.20
24II-e1	99	04-11-84	217.0	575	8.20	18.5	67.5	0.33	205	335	3.8	0.00
24II-i1	78	03-22-84	318.0	37000	9.04	20.0	13210.0	0.42	3808	29096	36.7	12.95
24JJ-c2	3168	04-11-84	595.0	2500	8.41	-	55.0	8.50	6	1698	0.0	0.00
24JJ-d1	98	03-22-84	220.0	16000	7.52	20.0	4839.0	0.71	2689	11732	170.0	0.68
24JJ-e1	75	04-11-84	85.6	19000	7.67	20.0	7373.0	0.68	860	13107	209.0	12.00
25HH-p4	45	04-11-84	193.0	750	8.08	14.5	144.0	0.22	287	615	4.8	0.00
25HH-p5	63	04-11-84	55.0	725	8.25	17.0	61.0	0.48	235	436	7.3	0.10
25HH-p6	52	04-11-84	111.0	400	8.24	16.0	39.0	0.19	135	270	40.8	0.00
25HH-w5	70	01-24-84	152.0	990	7.63	18.0	217.9	0.24	485	656	21.2	0.22
25II-a7	100	04-11-84	223.0	500	8.23	19.0	44.9	0.35	189	430	4.1	0.00
25II-c18	92	03-22-84	173.0	340	8.20	20.0	18.2	0.37	185	281	4.3	0.00
25II-d5	70	01-24-84	181.0	320	7.45	17.5	17.0	0.29	158	261	3.3	0.00
25II-f10	65	04-11-84	179.0	342	8.33	17.6	16.5	0.44	156	211	3.6	0.00
25II-g6	100	01-24-84	261.0	410	8.12	16.0	20.5	0.24	509	303	7.2	0.00
25II-h1	50	01-24-84	77.0	195	7.90	19.0	9.0	0.33	74	112	4.1	0.02
25II-h2	90	01-24-84	125.0	250	7.65	18.7	14.0	0.15	124	282	3.5	0.00
25II-j1	60	04-11-84	247.0	650	8.43	20.0	74.0	0.65	198	505	3.8	0.00
25II-m1	60	04-11-84	183.0	385	8.12	18.0	17.5	0.18	194	320	0.0	0.00
25II-m3	81	03-22-84	30.0	175	9.62	21.0	16.3	0.31	57	74	4.8	0.00
25II-o9	75	04-11-84	191.0	420	8.00	19.0	21.0	0.20	205	356	3.8	0.00
25II-p7	90	01-24-84	222.0	490	7.22	17.3	50.0	0.21	286	478	4.9	0.02
26HH-b1	30	04-11-84	142.0	370	8.04	19.0	39.5	0.17	140	204	5.4	0.00
26HH-c1	50	04-11-84	-	-	-	-	-	-	-	-	-	0.00
26HH-d2	90	01-11-84	155.0	295	7.60	17.3	16.8	0.21	196	237	4.0	0.50
26HH-f5	43	02-21-84	135.0	1040	7.31	18.5	378.7	0.20	350	1037	42.4	0.02
26HH-f6	70	04-11-84	131.0	390	8.38	17.0	59.0	0.12	133	340	8.3	0.00
26HH-g5	60	04-11-84	95.0	192	7.98	18.5	9.5	0.15	88	190	3.8	0.00
26HH-g9	65	03-22-84	135.0	260	8.30	19.0	7.5	0.18	142	149	3.7	0.00
26HH-j15	130	01-11-84	140.0	220	7.60	13.0	11.5	0.18	142	225	3.3	0.02
26HH-j16	70	01-24-84	112.0	2000	7.20	15.5	690.0	0.12	579	1495	57.8	0.03
26HH-12	45	01-11-84	-	275	-	15.0	-	-	-	-	-	0.00
26HH-n1	63	04-11-84	176.0	340	8.32	18.0	17.5	0.40	198	212	4.5	0.00
26HH-p6	80	01-11-84	136.0	255	8.00	18.3	12.0	0.10	143	236	-	0.00
26HH-q3	70	01-11-84	164.0	275	7.60	16.5	12.5	0.12	143	311	3.3	0.00

Concentrations are given in milligrams per liter, except for iron and manganese, which are given in micrograms per liter.

SCWRC No.	Calcium (Ca) total	Calcium (Ca) dissolved	Iron (Fe) total	Iron (Fe) dissolved	Magnesium (Mg) total	Magnesium (Mg) dissolved	Manganese (Mn) total	Manganese (Mn) dissolved	Potassium (K) total	Potassium (K) dissolved	Silica (SiO <sub>2</sub> ) dissolved	Sodium (Na) total	Sodium (Na) dissolved	Silicon (Si) dissolved
24HH-q4	32.2	29.7	69	38	13.75	13.66	5	0	14.06	11.19	45.56	60.1	58.8	21.30
24HH-y1	8.5	8.0	844	831	2.69	2.51	24	14	1.23	1.15	3.14	17.4	16.6	1.47
24II-d1	731.0	468.0	2380	428	495.00	490.00	91	38	154.00	136.00	86.63	3730.0	3540.0	40.50
24II-e1	82.3	79.6	429	203	6.90	6.80	17	7	2.62	2.57	54.89	36.5	33.9	25.66
24II-i1	21.6	18.7	25400	326	912.00	876.00	207	145	342.00	338.00	1.90	9580.0	9260.0	0.89
24JJ-r2	2.2	2.2	208	198	0.80	0.78	0	0	6.62	6.45	19.23	580.0	563.0	8.99
24JJ-d1	355.0	332.0	6630	560	438.00	431.00	76	54	124.00	120.00	47.25	3150.0	2810.0	22.09
24JJ-e1	344.5	333.1	61100	561	320.00	310.00	289	139	162.90	160.30	32.15	3820.0	3520.0	15.03
25HH-p4	115.0	66.8	1308	4	6.60	6.10	98	76	4.30	3.75	32.19	79.0	78.3	15.05
25HH-p5	94.1	41.7	811	23	5.90	2.37	74	21	22.95	22.75	34.54	102.4	96.3	16.15
25HH-p6	54.0	45.9	1388	109	2.46	2.30	32	16	9.25	8.39	17.22	37.2	36.3	8.05
25HH-w5	175.0	77.8	3970	27	11.72	8.15	87	36	7.50	6.50	29.30	136.0	135.0	13.70
25II-a7	75.5	73.3	522	499	5.50	5.50	47	36	2.58	2.47	37.86	28.7	28.3	17.70
25II-c18	65.5	58.3	2850	650	5.30	4.70	32	29	1.85	1.70	29.49	13.0	12.8	13.79
25II-d5	57.3	54.8	535	504	3.72	3.71	52	46	1.63	1.54	33.70	11.9	11.4	15.80
25II-f10	62.4	59.1	11	0	5.00	4.80	29	24	2.13	1.98	50.07	11.9	11.6	23.41
25II-g6	195.0	72.6	1140	250	5.46	4.20	80	48	3.72	3.34	33.50	14.0	13.3	15.70
25II-h1	27.2	26.3	278	241	1.50	1.47	16	13	0.55	0.52	8.00	5.8	5.7	3.80
25II-h2	46.4	43.4	197	91	2.02	2.01	24	18	1.55	1.47	10.20	9.4	9.3	4.80
25II-j1	79.4	71.5	377	333	11.70	11.20	16	8	6.81	6.76	54.93	44.5	43.3	25.68
25II-m1	77.6	74.2	32	18	11.60	11.40	31	30	1.29	1.21	27.29	18.0	15.0	12.76
25II-m3	20.6	18.5	20	12	1.40	1.30	0	0	1.28	1.27	21.81	11.7	10.0	10.20
25II-o9	82.0	64.2	2098	618	4.20	3.70	75	73	0.92	0.89	19.18	11.9	11.5	8.97
25II-p7	100.0	71.7	1320	375	8.85	8.07	75	54	1.45	1.32	23.30	23.3	23.1	10.90
26HH-b1	56.0	54.8	670	367	2.76	2.75	70	66	1.44	1.31	11.03	27.1	25.8	5.16
26HH-c1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26HH-d2	73.9	54.9	1047	761	3.00	2.70	47	45	0.63	0.59	10.40	9.4	9.3	4.80
26HH-f5	118.2	118.0	8720	7710	13.41	13.30	139	137	4.55	4.35	9.41	172.2	168.5	4.40
26HH-f6	53.2	51.2	484	384	4.28	4.18	52	50	1.56	1.36	10.37	34.3	32.7	4.85
26HH-g5	35.2	34.0	1081	898	1.77	1.73	54	50	0.55	0.43	10.82	5.5	5.3	5.06
26HH-g9	52.0	51.4	570	492	2.90	2.80	23	23	0.38	0.35	9.32	8.5	8.3	4.36
26HH-j15	52.5	49.9	405	277	2.70	2.60	28	25	1.05	1.04	10.10	7.3	7.3	4.70
26HH-j16	193.0	191.0	3340	1960	23.70	22.50	135	130	14.35	13.75	20.70	235.0	233.0	9.70
26HH-l2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26HH-n1	79.4	63.9	1276	792	3.80	3.40	117	116	0.57	0.51	16.15	8.4	8.1	7.55
26HH-p6	53.2	51.7	52	40	2.50	2.40	34	28	0.63	0.60	11.70	5.7	5.6	5.50
26HH-q3	53.2	51.4	308	294	2.50	2.40	32	29	0.75	0.70	15.20	7.4	7.2	7.10

SCWRC No.	Depth (feet)	Sampling Date	Alkalinity	Specific Conductance pH (lab.)	Temperature °C (field)	Chloride (Cl)	Fluoride (F)	Hardness (as CaCO <sub>3</sub> )	Residue on evaporation	Sulfate (SO <sub>4</sub> )	Sulfide (S)
26HH-q4	50	01-11-84	145.0	260 7.70	19.0	8.2	0.10	151	231	5.3	0.02
26HH-s1	63	01-11-84	190.0	318 7.70	17.5	13.9	0.10	206	325	3.3	0.00
26HH-u3	45	04-11-84	387.0	9800 7.75	13.0	4308.0	0.22	1126	9021	23.9	0.00
26HH-w1	70	01-11-84	176.0	277 7.70	19.0	12.0	0.13	180	282	3.1	0.00
26HH-x6	90	01-24-84	-	209 8.40	17.0	-	-	-	-	-	0.00
26HH-x8	100	01-11-84	140.0	250 7.60	18.0	11.5	0.16	139	227	3.3	0.00
26HH-y15	80	01-24-84	-	235 -	16.0	-	-	-	-	-	0.09
26II-d3	45	04-11-84	55.0	380 8.43	19.0	50.0	0.25	123	312	35.9	0.00
26II-h7	40	03-22-84	143.0	295 7.66	18.0	15.3	0.21	133	341	13.4	7.10
26II-j5	50	03-22-84	171.0	1650 7.68	20.5	395.0	0.35	339	1130	37.8	2.10
26II-j9	70	04-11-84	192.0	800 8.18	20.0	165.9	0.25	171	620	12.3	2.60
26II-l1	62	03-22-84	208.0	370 7.93	19.5	16.3	0.27	210	313	3.4	0.00
26II-m3	100	01-24-84	140.0	440 7.50	14.0	68.0	0.18	158	382	11.6	0.04
26II-o3	50	04-11-84	102.0	900 8.20	17.0	173.9	0.12	250	701	12.3	0.00
26II-o4	57	02-21-84	252.0	250 8.27	19.0	22.6	0.26	123	259	6.7	0.00
26II-o4	63	02-21-84	-	263 -	19.8	23.1	-	-	-	-	0.00
26II-o4	66	02-21-84	-	320 -	19.0	27.4	-	-	-	-	0.00
26II-o4	66	02-21-84	-	348 -	17.5	33.2	-	-	-	-	0.00
26II-q11	85	03-22-84	172.0	465 8.06	20.0	77.3	0.25	311	852	7.1	0.15
26II-q12	75	04-11-84	161.0	430 8.22	20.0	49.0	0.18	165	380	4.7	0.00
26II-q3	91	03-26-84	220.0	850 7.89	19.0	147.0	0.22	295	564	13.9	0.74
26II-r13	75	03-22-84	213.0	400 8.03	20.5	19.0	0.31	245	306	4.3	0.00
26II-r14	70	04-11-84	174.0	405 8.32	18.0	22.0	0.26	162	303	4.0	0.00
26II-u4	159	03-26-84	215.0	390 7.96	17.0	18.6	0.32	217	284	4.4	0.00
26II-x3	82	03-22-84	183.0	342 7.99	20.0	23.4	0.22	190	306	6.4	0.40
26JJ-a1	91	04-11-84	226.0	470 8.59	18.0	31.0	0.22	220	356	4.6	0.00
26JJ-b5	105	03-26-84	226.0	455 7.82	16.0	28.6	0.24	235	306	4.8	0.00
26JJ-d4	94	03-22-84	177.0	364 8.08	20.0	18.2	0.32	229	299	4.4	0.10
26JJ-g1	110	03-22-84	176.0	350 8.16	19.0	20.2	0.15	176	386	3.7	0.00
26JJ-h1	190	03-26-84	220.0	720 7.94	16.0	126.9	0.33	294	521	3.7	0.00
26JJ-n1	92	03-22-84	18.0	6200 8.20	21.0	2218.0	0.10	1030	5125	288.0	0.68
2766-u1	99	01-24-84	95.0	345 7.62	16.0	63.0	0.12	142	338	11.1	0.00
27HH-b2	40	04-11-84	140.0	6900 8.05	16.5	2524.0	0.11	1131	5098	16.3	0.00
27HH-j5	200	01-24-84	97.0	182 7.60	8.9	19.0	0.09	104	208	10.9	0.00
27HH-r9	60	01-11-84	114.0	600 7.60	11.0	122.0	0.14	246	490	3.1	0.00



SCWRC No.	Calcium (Ca) total	Calcium (Ca) dissolved	Iron (Fe) total	Iron (Fe) dissolved	Magnesium (Mg) total	Magnesium (Mg) dissolved	Manganese (Mn) total	Manganese (Mn) dissolved	Potassium (K) total	Potassium (K) dissolved	Silica (SiO <sub>2</sub> ) dissolved	Sodium (Na) total	Sodium (Na) dissolved	Silicon (Si) dissolved
26HH-q4	54.2	51.7	595	562	3.90	3.80	31	30	0.52	0.50	9.20	5.8	5.7	4.30
26HH-s1	78.2	69.7	75	73	2.60	2.50	22	19	1.64	1.55	29.50	10.3	10.2	13.80
26HH-u3	451.0	392.0	4680	411	197.00	184.00	393	336	80.80	80.80	54.30	2250.0	2190.0	25.40
26HH-w1	66.9	63.7	391	350	3.20	3.10	41	9	0.90	0.89	17.20	6.4	6.3	8.10
26HH-x6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26HH-x8	52.5	52.1	551	467	2.00	1.90	35	31	0.61	0.58	10.90	9.6	9.5	5.10
26HH-y15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26II-d3	49.4	48.2	53	36	3.05	3.02	40	38	1.10	1.05	15.72	24.5	22.6	7.35
26II-h7	47.7	44.5	36400	851	3.40	2.80	85	66	1.23	1.13	22.28	27.1	25.8	10.42
26II-j5	85.5	84.7	82	29	30.60	29.80	32	32	11.69	11.67	44.19	236.0	230.0	20.66
26II-j9	68.3	64.7	1875	859	15.20	14.10	68	65	9.10	8.32	55.87	90.1	86.8	26.12
26II-l1	75.3	72.8	1300	660	5.40	4.70	23	18	1.55	1.48	28.47	13.0	12.9	13.31
26II-m3	53.0	51.6	230	80	6.27	6.04	53	46	2.22	2.19	16.20	34.4	33.2	7.60
26II-o3	100.5	98.8	673	211	13.80	13.20	49	47	3.56	3.09	38.05	92.5	91.3	17.79
26II-o4	41.1	40.8	480	22	3.74	3.65	12	5	1.80	1.68	18.30	15.3	15.1	8.54
26II-o4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26II-o4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26II-o4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26II-q11	103.6	70.6	181	0	12.80	4.90	37	18	3.07	2.04	24.32	150.1	51.1	11.37
26II-q12	66.0	63.8	90	69	4.20	4.10	56	52	2.06	1.75	30.07	23.3	21.3	14.06
26II-q3	95.9	94.1	72	70	13.40	13.20	41	41	3.50	3.11	30.07	79.0	78.4	14.06
26II-r13	85.1	67.7	435	48	7.90	6.70	20	14	2.34	2.30	21.00	14.7	14.7	9.80
26II-r14	64.9	63.9	71	35	4.00	4.00	12	8	1.87	1.73	22.86	15.1	14.9	10.69
26II-u4	80.4	80.2	1240	1170	4.00	3.80	51	49	1.18	1.10	30.33	14.6	14.2	14.18
26II-x3	64.4	62.8	602	430	7.00	6.60	18	18	1.36	1.32	21.39	15.4	15.3	10.00
26JJ-a1	88.2	85.3	1976	1071	4.90	4.10	43	40	1.92	1.75	23.76	20.7	20.2	11.11
26JJ-b5	84.5	81.3	2390	1010	5.90	5.80	51	48	1.27	1.13	26.65	18.5	18.4	12.46
26JJ-d4	57.6	52.7	628	0	20.70	11.80	6	5	1.80	1.43	22.97	14.6	13.8	10.74
26JJ-g1	62.0	58.9	244	117	5.20	4.80	25	25	1.23	1.17	14.90	18.8	18.7	6.97
26JJ-h1	102.9	101.5	311	225	8.90	8.10	28	26	2.68	2.58	28.83	49.8	48.9	13.48
26JJ-n1	232.0	213.0	52500	252	109.50	103.90	391	46	27.30	26.70	1.47	1473.0	1452.0	0.69
2766-u1	43.1	35.5	63	59	5.45	5.44	20	19	1.30	1.25	12.60	14.4	13.8	5.90
27HH-b2	454.0	421.0	114700	14370	94.00	93.00	609	465	12.76	11.88	16.87	1080.0	1077.0	7.89
27HH-j5	38.2	34.4	103	22	1.97	1.95	9	4	3.19	3.09	2.30	11.4	11.2	1.10
27HH-r9	82.6	76.1	240	50	9.60	8.70	34	30	4.20	3.80	22.60	40.6	39.2	10.60

**Table 4. Source, effect, and treatment of selected constituents in ground water. Modified from Fairchild (1972)**

Constituent or property	Source and/or solubility	Effects	Treatment
Silica (SiO <sub>2</sub> )	Most abundant compound in earth's crust. Resistant to solution.	Causes scale in boilers and deposits on turbine blades.	Reverse osmosis or ion exchange.
Iron (Fe)	Very abundant element, readily precipitates as hydroxide.	Stains laundry and porcelain, bad taste.	Zeolite type ion-exchange water softeners, manganese-green sand, birm, or oxidation by aeration.
Manganese (Mn)	Less abundant than iron, present in lower concentrations.	Stains laundry and porcelain, bad taste	Same as for iron.
Calcium (Ca)	Dissolved from most rock, especially limestone and dolomite.	Causes hardness, forms boiler scale, helps maintain good soil structure and permeability.	Zeolite or other ion-exchange water-softener devices.
Magnesium (Mg)	Dissolved from rocks, industrial wastes.	Same as calcium	Same as calcium
Sodium (Na)	Dissolved from rocks, industrial wastes.	Injurious to soils and crops and certain physiological conditions in man.	Reverse osmosis or ion exchange.
Potassium (K)	Abundant, but not very soluble in rocks and soils.	Causes foaming in boilers	Zeolite or other ion-exchange water-softener devices.
Bicarbonate (HCO <sub>3</sub> ) Carbonate (CO <sub>3</sub> )	Abundant and soluble from limestone, dolomite, and soils.	Causes foaming in boilers and embrittlement of boiler steel.	Distillation
Sulfate (SO <sub>4</sub> )	Sedimentary rocks, mine water, and industrial wastes.	Excess: cathartic, taste	Activated charcoal filtration cartridges.
Chloride (Cl)	Rocks, soils, industrial wastes, sewage, brines, sea water.	Unpleasant taste, increases corrosiveness.	Ion exchange, reverse osmosis, or distillation.
Fluoride (F)	Not very abundant, sparingly soluble, seldom found in industrial wastes except as spillage, some in sewage.	Over 1.5 mg/L causes mottling of children's teeth, 0.88 to 1.5 mg/L aids in preventing tooth decay.	Reverse osmosis, distillation, activated alumina absorption, or activated charcoal in filtration cartridges.
Nitrate (NO <sub>3</sub> )	Rocks, soil, sewage, industrial wastes, normal decomposition, bacteria.	High value indicates pollution, causes methemoglobinemia in infants.	Reverse osmosis
Hardness as CaCO <sub>3</sub>		Excessive soap consumption, scale in pipes interferes in industrial processes. Below 60 mg/L — soft 60 to 120 mg/L — moderately hard 120-200 mg/L — hard over 200 mg/L — very hard	Same as calcium and magnesium.