GROUND-WATER CONDITIONS AND WATER-SUPPLY ALTERNATIVES IN THE WACCAMAW CAPACITY USE AREA SOUTH CAROLINA

by

A. Michel Pelletier

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ABSTRACT

The present public water supply for the Waccamaw Capacity Use Area is developed almost entirely from aquifers in the Black Creek Formation. Water use is expected to increase by 140 percent by the year 2000, and there is concern about the adequacy of the present source to meet that need. Also, there are concerns about the quality of the water, specifically the sodium, fluoride, and chloride content.

These concerns have led to a search for alternate or supplementary supplies, ranging from the expansion of the existing ground water system to abandoning that system for a surface water supply. Several options are available, the most promising of which are a westward expansion of the ground-water well system and the tapping of the Atlantic Intracoastal Waterway. The possibility exists for storing some of the treated surface water, during off-season months, in the Black Creek aquifers and using the stored water for peak-load management during the critical summer months of June, July, and August.

INTRODUCTION

Study Area

The Waccamaw Capacity Use Area is in the extreme eastern part of South Carolina. It comprises Horry and Georgetown Counties and a portion of Marion County (Fig. 1). The region is largely rural, with a strong agricultural economy. However, along the coast, especially the strip in Horry County between the Intracoastal Waterway and the Atlantic Ocean called the Grand Strand, the economy is supported primarily by summer tourism and a growing retirement population. In the city of Georgetown, a steel mill, a paper mill, and a working seaport provide substantial support to the economy. Commercial fishermen and shrimpers operate out of facilities located in Georgetown, Murrells Inlet, and Little River. Recent developments in aquaculture have led to the reuse of several abandoned rice fields along the Santee River to raise shrimp and crayfish for local and national markets.

The Grand Strand is more highly urbanized than the remainder of the two-county area, with major population fluctuations between summer and winter, owing to the summer vacationers. The demand for water along the beaches fluctuates in direct response to the changing population. The remaining area in the two counties has a more uniform annual demand for water.

The municipal population of the two-county area obtains almost all of its drinking-water supply from wells completed in the Black Creek Formation. The one exception is Georgetown, which has obtained its water by canal from the Pee Dee River since 1974. Other significant uses of ground water include rural households and small commercial interests, including golf courses, concrete plants, car washes, and swimming pools. Surface water supplies, from streams, ponds, and the Atlantic Intracoastal Waterway (AICW), are used for cooling the two local steam-electric generating stations, for industrial processing in Georgetown, and for golf course irrigation.

Capacity Use Designation

In 1972, the Horry County Legislative Delegation, in conjunction with the Georgetown County Board of Commissioners, requested that the South Carolina Water Resources Commission (SCWRC) conduct a ground-water resource evaluation of the two counties under the authority of the Ground-Water Use Act of 1969. The act gives the commission authority to . . . "declare and delineate . . . capacity use areas of the State where it finds that the use of ground water requires coordination and limited regulation for the protection of the interest and rights of residents or property owners of such area, or of the public interest."

SCWRC initiated an investigation in 1973, in cooperation with the United States Geological Survey (USGS). A report of the findings was published by SCWRC, (Zack, 1977). A second report by SCWRC (Spigner, Stevens, and Moser, 1977) was prepared to address designation of the proposed capacity use area and the

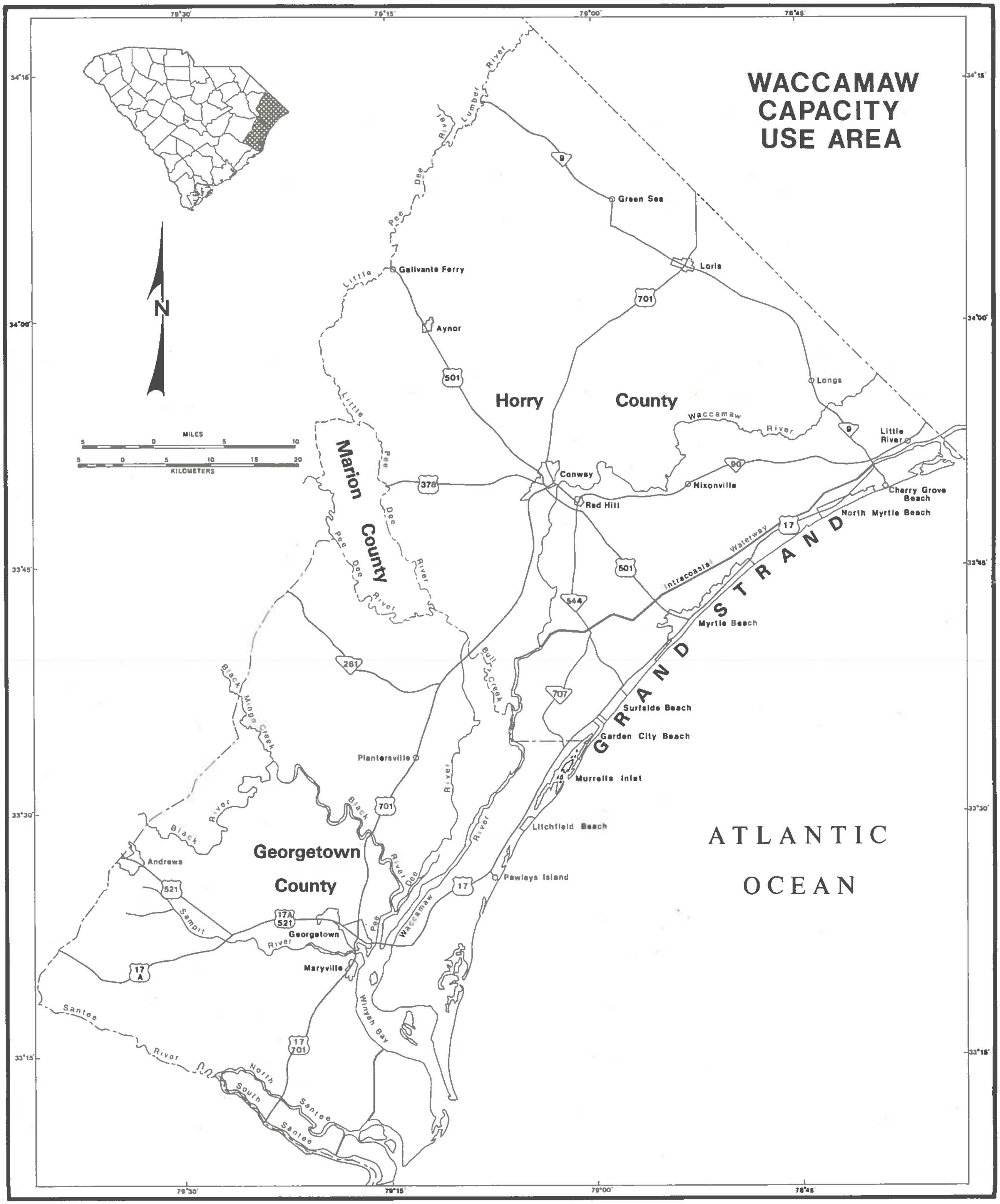

Figure 1: Location of the Waccamaw Capacity Use Area in South Carolina.

need to coordinate the withdrawals from the aquifer. Capacity use regulations were proposed by SCWRC in 1978 and were approved by the State Legislature in 1979.

Purpose and Scope of the Report

This report updates the reports by Zack (1977) and Spigner and others (1977) to reflect the ground-water conditions as of 1982. New data, from wells drilled in the interim and from continuous monitoring of water levels and water quality, are presented for use by the general public, government officials making water policy decisions, and ground-water users and developers making day-to-day decisions concerning the drilling, maintaining, and rehabilitating of wells in the area. In addition to updating the data base, this report describes several alternative sources for future public water supplies. These alternatives include surface-water and ground-water resources.

Well-Numbering System

SCWRC uses a grid system, based on the latitude and longitude coordinates of wells, to assign identification numbers. For this purpose, the State has been divided into major grid blocks, each measuring 5 minutes of latitude by 5 minutes of longitude. These blocks are identified by a number followed by a capital letter and are labeled from east to west and north to south. Each of these major grid blocks has been divided into 25 minor blocks, each being 1 minute square, which have been labeled with the lower-case letters from a to y. Within each minor block, the wells are numbered consecutively in the order they are inventoried. For example, the well with the number 9M-pl was the first well to be located in the minor block "p" of the major block 9M.

Figure 2 shows the location of wells referenced in the text and those used to construct the hydrogeologic section and potentiometric maps. Well numbers are included for ease of reference.

HYDROGEOLOGIC FRAMEWORK

Formations

There are four principal geologic formations overlying the crystalline bedrock in the Waccamaw Capacity Use Area. These formations provide a convenient framework for describing the ground-water conditions in the area. Each formation, or group of formations, has water-quality or water-bearing characteristics that distinguish it from the others.

Crystalline Bedrock

The crystalline bedrock is a complex of dense igneous and metamorphic rocks such as basalt, granite, schist, and gneiss. These rocks generally are very hard and have been fractured. The top of the bedrock complex lies at a depth of approximately 1,350 ft (feet) at Little River and 1,900 ft at Georgetown. The cause of this 550-ft difference in depth to bedrock is the Cape Fear Arch, a regional structure of elevated bedrock which reaches its apex just north of the North Carolina-South Carolina line. The study area is on the southern limb of this arch. Seven holes have been drilled to the bedrock, primarily to evaluate the water-supply potential of the deep sediments. Only the test well at Brittons Neck (10Q-p2) penetrated part of the bedrock complex, this to obtain lithologic data. Because of low well yields, poor water quality, and excessive drilling depths, no supply wells have been developed in this unit.

Middendorf Formation

The Middendorf Formation is Late Cretaceous in age and was probably deposited in a deltaic or fluvial environment. It is composed of multicolored clay (white, red, yellow, orange, brown, and purple) and white to gray, coarse sand and gravel. The formation is approximately 900 ft deep at Little River in the north end of the study area and 1,100 ft at Georgetown in the south, with thicknesses of 450 and 800 ft, respectively. It is a major water source in many parts of the State, but it contains salty water in most of the study area.

Black Creek Formation

The Black Creek Formation overlies the Middendorf Formation and is also of Late Cretaceous age. It consists of dark-gray to light-gray fine-grained sand and clay, suggesting an estuarine or near-shore marine depositional environment. Numerous layers of hard, cemented, calcareous sandstone occur in the formation, especially in the upper half. At Little River, this unit is 720 ft thick, between the depths of 180 and 900 ft. At Georgetown it is 620 ft thick, between the depths of 480 and 1,100 ft. The aquifers in this formation are the principal source of water for wells in the Waccamaw Area.

Peedee Formation

The Peedee Formation is the uppermost Cretaceous formation in the State. It was deposited in an open-shelf environment, and it is composed of thin, alternating beds of fine sand and clay with some beds of loose shell and coarse sand. The aquifers in this formation are not utilized for large municipal wells, owing to poor water quality and limited well yields, as contrasted with the aquifers in the Black Creek Formation. This formation is only 100 ft thick at Little River, extending from 80 to 180 ft in depth, and is 280 ft thick at Georgetown, between the depths of 200 and 480 ft.

Shallow Deposits

The shallow deposits consist of undifferentiated near-surface clay, sand, limestone, and shell of Tertiary and Quaternary age. Some of the shell beds have been mined for roadbed and fill material. The Santee Limestone is

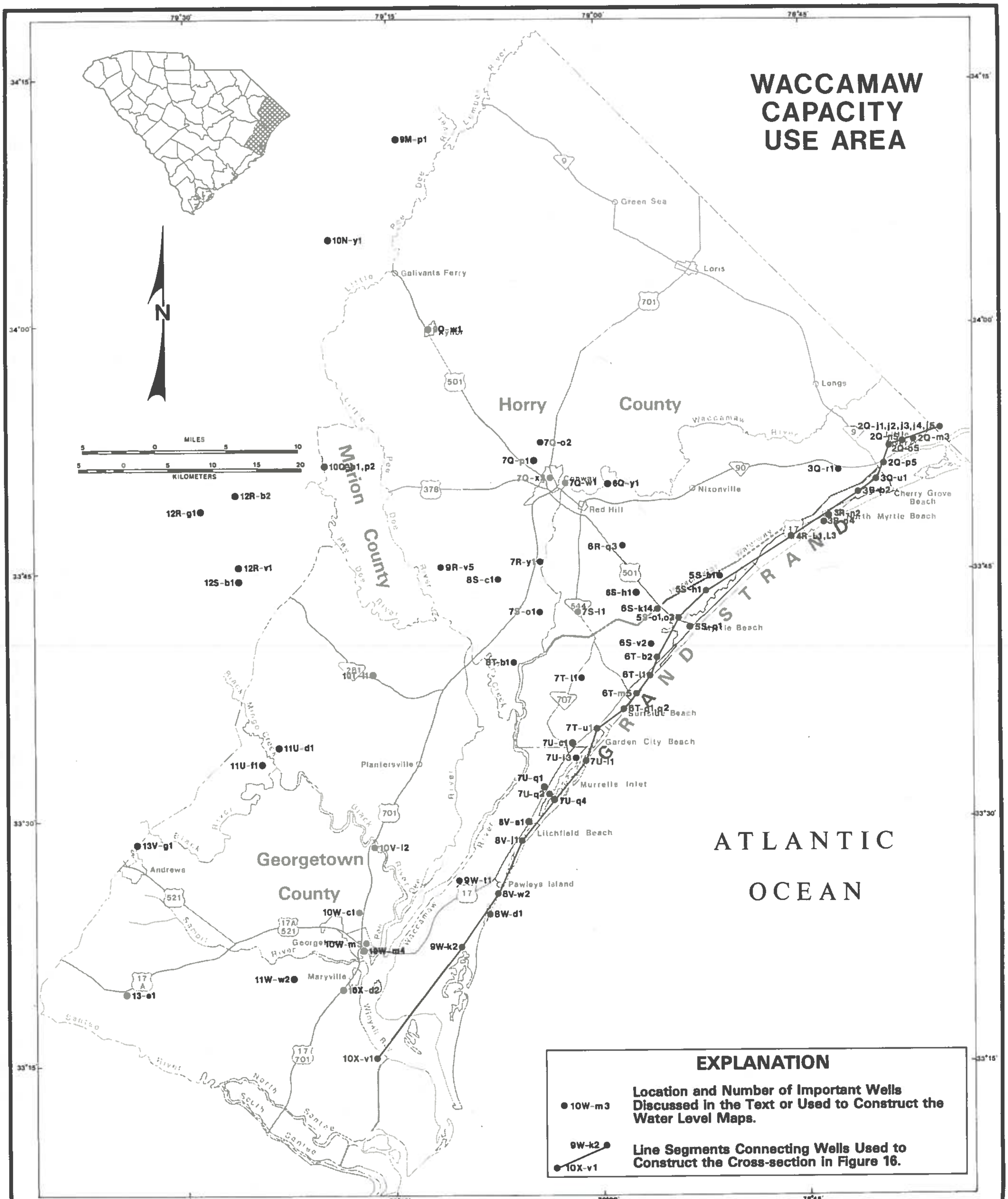

Figure 2: Locations of wells referenced in the text and used in the hydrogeologic section and potentiometric maps.

mined for crushed-stone aggregate in the extreme southwest corner of Georgetown County. These deposits extend from the land surface down to 80 ft at Little River and to 200 ft at Georgetown. Many residences and commercial establishments obtain water from wells in the aquifers within these deposits.

Defining the Framework

The geologic framework of an area reflects the manner in which the various formations are related to one another and how they are distributed over a given area. In defining this framework, a hydrogeologist uses many tools and techniques. The best tool is a test well drilled specifically for research purposes. A great deal of information can be obtained from continuous-core samples of the material penetrated, geophysical logs, water-quality samples, and pumping tests. Because test wells are expensive, they are not often constructed; however, the information obtained usually justifies their cost. More commonly, a hydrogeologist obtains data from well owners, well drillers, or public records. Information on existing wells and on wells under construction is helpful in defining the subsurface relationships among the various formations, even though some detail is lacking and the location is random, compared to a planned test well. Water-quality and well-performance data are, of course, valuable items of information that are often available for existing wells.

Figure 3 illustrates the information that can be provided by an existing well. The electric log on the right gives a reading of the electrical resistivity of the formations, as a function of depth. This type of log must be made during the early stages of well construction, prior to the installation of casing or screen. Sand containing freshwater is more resistive than clay and causes the log trace to deflect to the right. Clay layers, being more conductive, cause the trace to deflect to the left. The driller's log is a record of the types of rocks penetrated, and is obtained by an examination of the drill cuttings. The driller's log and electric log can be combined into a lithologic log, which provides an interpretive, visual representation of the formations. The well sketch shows the locations of the nine screens in a completed well at Myrtle Beach (well 5S-hl). Each screen has been placed opposite a sand deflection on the electric log where the driller's log confirmed the presence of sandy material.

Water samples from wells with multiple screens provide only an "average" water quality from the entire screened section, as opposed to discrete samples from a test well. With special equipment, it is possible to collect discrete samples from each zone in a multiple-screened well; however, this is not often done because of additional expense and inconvenience.

If fairly complete and accurate data are available from a number of wells in an area, correlations can be made to detect changes in thickness, depth, and composition of the formations. A structure map in Figure 4 shows the altitude of the top of the Black Creek Formation. The surface dips southerly and has a pronounced "valley" running southwestward from just west of Georgetown to Conway. This map was constructed by using information from approximately 100 wells and correlating the data across the two counties.

HYDROLOGIC CONDITIONS

Climate

The climate of Georgetown and Horry Counties is temperate, with rainfall throughout the year. During the summer, when invasions of continental air become infrequent, maritime tropical air persists for extended periods. Precipitation during the warmer half of the year, outside of tropical disturbances, is mostly of a showery nature. During the colder half of the year, precipitation is frequently of a steady nature associated with the passage of weather systems across the area.

An average winter day has an early morning temperature a few degrees above freezing and an afternoon maximum in the high 50's (Fahrenheit). Bright sunshine occurs during about 60 percent of the daylight hours. Less than half the days have a minimum temperature of freezing or below, and once in every two years, on the average, the temperature dips below 15 degrees. The winter rainfall total is 10 to 12 inches. One day in five will have at least 0.1 inch of rain. Snowfall is infrequent, but a trace or more occurs during most winters.

Spring is the most changeable season of the year. The temperature varies from an occasional cold snap in March to generally warm and pleasant in May. A typical day in March has a minimum temperature in the low 40's and a maximum in the mid 60's. In April these figures are 10 degrees higher, and by May the average afternoon high temperature reaches 80 degrees. March and May are the wettest non-summer months, with more than 4 inches of rainfall each.

Warm weather usually lasts from sometime in May into the first half of September. During midsummer, daily temperatures range from 70 to 90 degrees and 30 percent of the days have highs of 90 or more. One-fourth of the annual rainfall total is recorded in July and August. Rain falls, on the average, about one out of three days, with 1 inch or more occurring twice a month.

Fall is the driest period of the year, and many think the most pleasant. During October and November the days are warm and the nights are cool. Rainfall reaches an annual minimum during late October with a monthly total of 2½ to 3 inches. An occasional cold front passes in October, and their passages become more numerous in November as the winter regime takes over. However, cyclone activity is infrequent, and the weather fronts usually result in four to five days of freezing weather in November.

Both counties have experienced tornadoes, although the frequency has been greater in Horry County than in Georgetown County. A possible explanation is that the

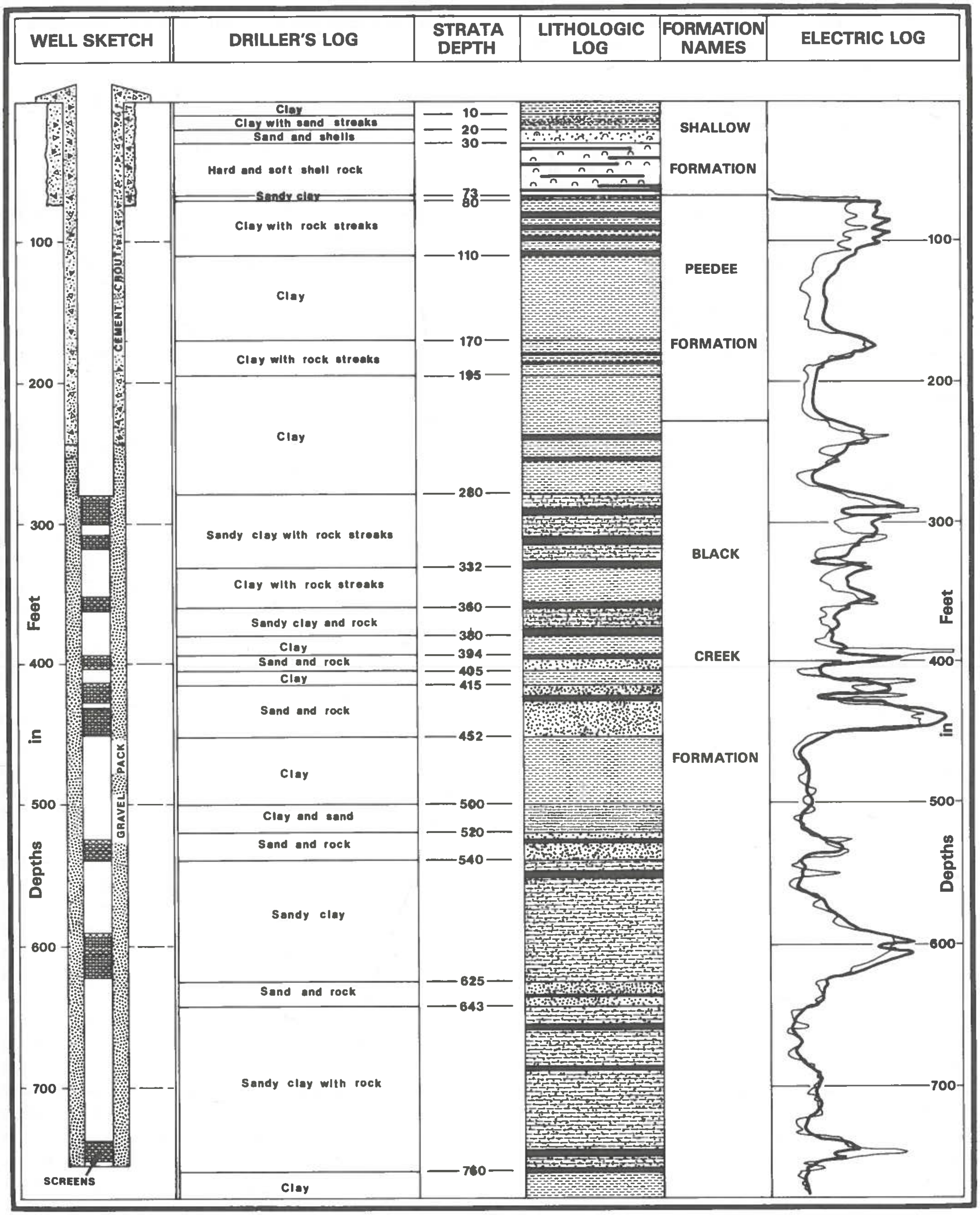

Figure 3: Composite log of well 5S-hl, showing the relationships among well construction, aquifer lithology, and electric log.

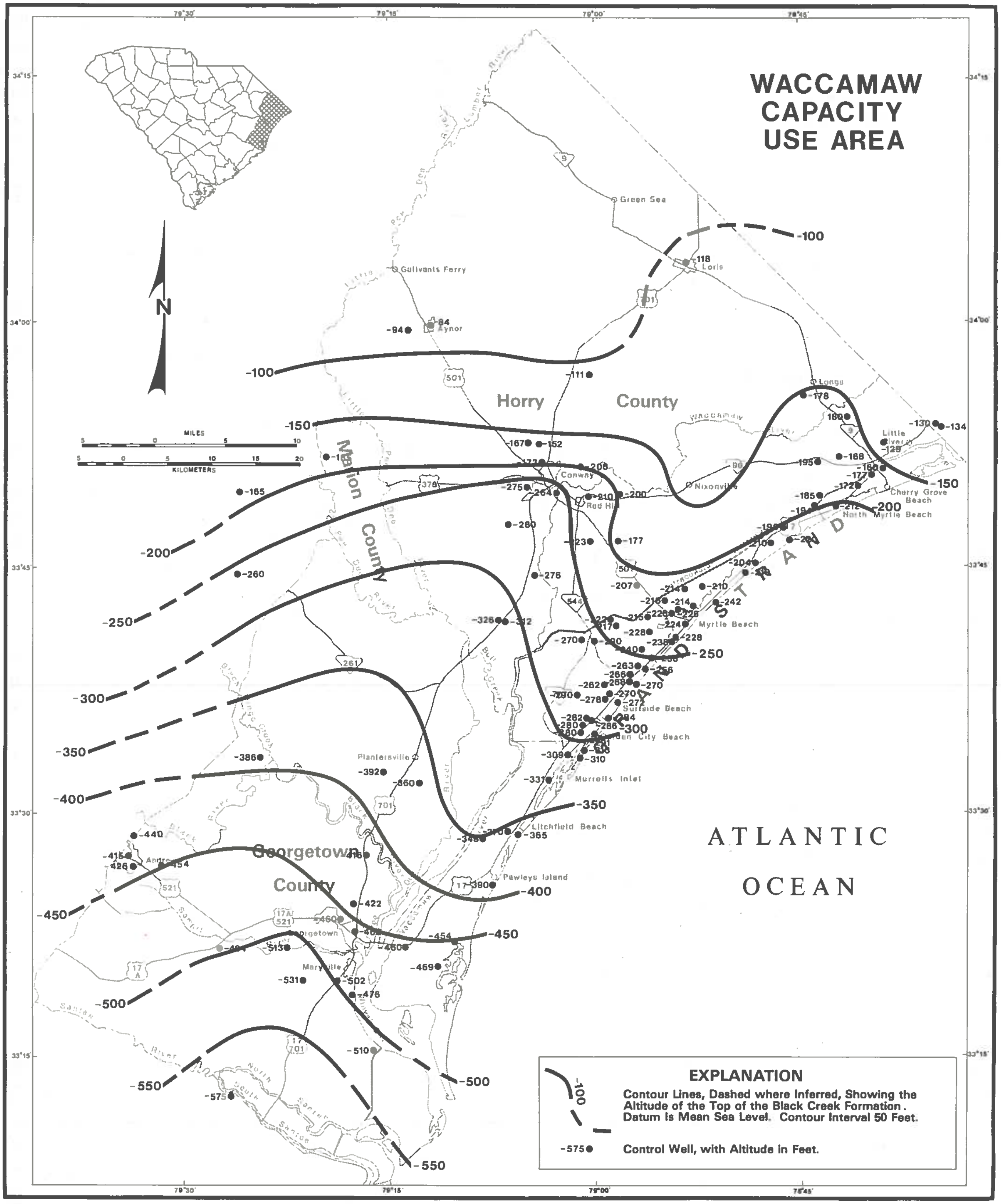

Figure 4: Structure contours on the top of the Black Creek Formation.

shape of the coastline increases the vulnerability of Horry County to tornadoes associated with the passage of hurricanes.

The area is affected by the fringe effects of passing hurricanes or tropical storms nearly every year. However, only two major hurricanes have struck the counties since 1912, the latest being Hurricane Hazel in 1954. Other hurricanes and tropical storms have come near enough to cause heavy rain, moderately strong winds, and minor damage. Winter and spring storms, intensifying as they move northeastward off the South Carolina coast, sometimes cause significant beach erosion and other damage along the coast.

Monthly temperature and precipitation averages are listed in Table 1, and precipitation normals and extremes for the Conway and Georgetown weather stations are plotted on Figure 5.

Surface Water

Because of the flatness of the terrain in the two counties, there are no natural lakes or sites suitable for large water-supply reservoirs. Because of this, if a surface-water supply is to be developed it must be obtained from the local streams without a reservoir structure. There are four principal water bodies that could provide future water supplies. These are the Atlantic Intracoastal Waterway (AICW) and the Pee Dee, Little Pee Dee, and Waccamaw Rivers. The Black, Sampit, and Santee Rivers in Georgetown County currently have insufficient flows to support a large-scale treatment plant. After the Santee-Cooper rediversion project is completed, the Santee River may provide a significant water supply.

The water bodies in the region largely conform to the Federal water quality standard of being fishable and swimmable, with only local degradation of water quality that usually occurs during the summer months. The most common water quality problems experienced are: reduced dissolved oxygen and low pH, resulting from the decomposition of organic matter in the extensive swamps adjacent to the rivers; elevated levels of fecal coliform bacteria from municipal and industrial wastewater discharges; and high nutrient and sediment loads for non-point sources such as agriculture.

The stream-flow analyses in the following sections are taken from the State Water Assessment (SCWRC, 1983) and are based on data generated by the USGS stream-gaging program. These stream gages, however, are generally located well upstream of potential drinking-water withdrawal points, and the data may not accurately reflect the conditions farther downstream. Three reports (Johnson, 1970; Johnson, 1977; and Carswell and Johnson, in press) provide documentation of conditions in the AICW.

Pee Dee River

The Pee Dee River originates in North Carolina and empties into Winyah Bay in Georgetown County. It serves as the boundary between Marion and Georgetown Counties and as a portion of the Horry-Georgetown County line. A stream gage located near the town of Pee Dee, in Marion county, has been operating since October 1938. During this period the average flow has been 9,850 cfs (cubic feet per second), which is 6,370 mgd (million gallons per day), and the 7Q10 (the lowest average flow expected during seven consecutive days once in 10 years) was 1,500 cfs (970 mgd). The minimum flow of record was 700 cfs (450 mgd) in September 1954.

Little Pee Dee River

The Little Pee Dee River originates in North Carolina, flows through Dillon County, and forms the greater part of the Horry-Marion County line. The average daily streamflow at the gage near Galivants Ferry is 3,240 cfs (2,100 mgd), the 7Q10 is 315 cfs (200 mgd), and the minimum flow of record was 155 cfs (100 mgd) in October 1954.

Waccamaw River

The Waccamaw River has its source and half of its drainage area in North Carolina. It flows through the

TABLE 1. Average temperature and precipitation data from the Conway and Georgetown weather stations.

Temperature (°F)

Station		J	F	M	A	M	J	J	A	S	O	N	D	Annual
Conway	Max.	56.9	59.5	67.1	76.1	83.0	87.8	90.5	89.8	84.9	76.3	67.8	59.4	74.9
	Min.	33.7	35.1	42.6	51.0	59.4	66.2	70.2	69.7	64.8	52.5	42.1	35.4	51.9
	Mean	45.3	47.3	54.9	63.6	71.2	77.0	80.4	79.8	74.9	64.4	55.0	47.4	63.4
Georgetown	Max.	57.8	60.0	66.7	74.9	81.7	86.6	89.2	89.0	84.5	76.5	68.4	60.6	74.7
	Min.	36.6	37.7	45.0	53.3	62.0	68.3	71.7	71.2	66.7	55.2	45.5	38.3	54.3
	Mean	47.2	48.9	55.9	64.1	71.8	77.5	80.5	80.1	75.5	65.9	57.0	49.4	64.5
Precipitation (inches)														
Conway		3.76	3.53	4.27	2.96	4.59	5.62	6.15	5.69	5.76	3.08	2.41	3.27	51.09
Georgetown		3.60	3.40	4.23	2.24	4.19	5.11	6.82	6.14	5.90	3.71	2.52	3.35	51.21

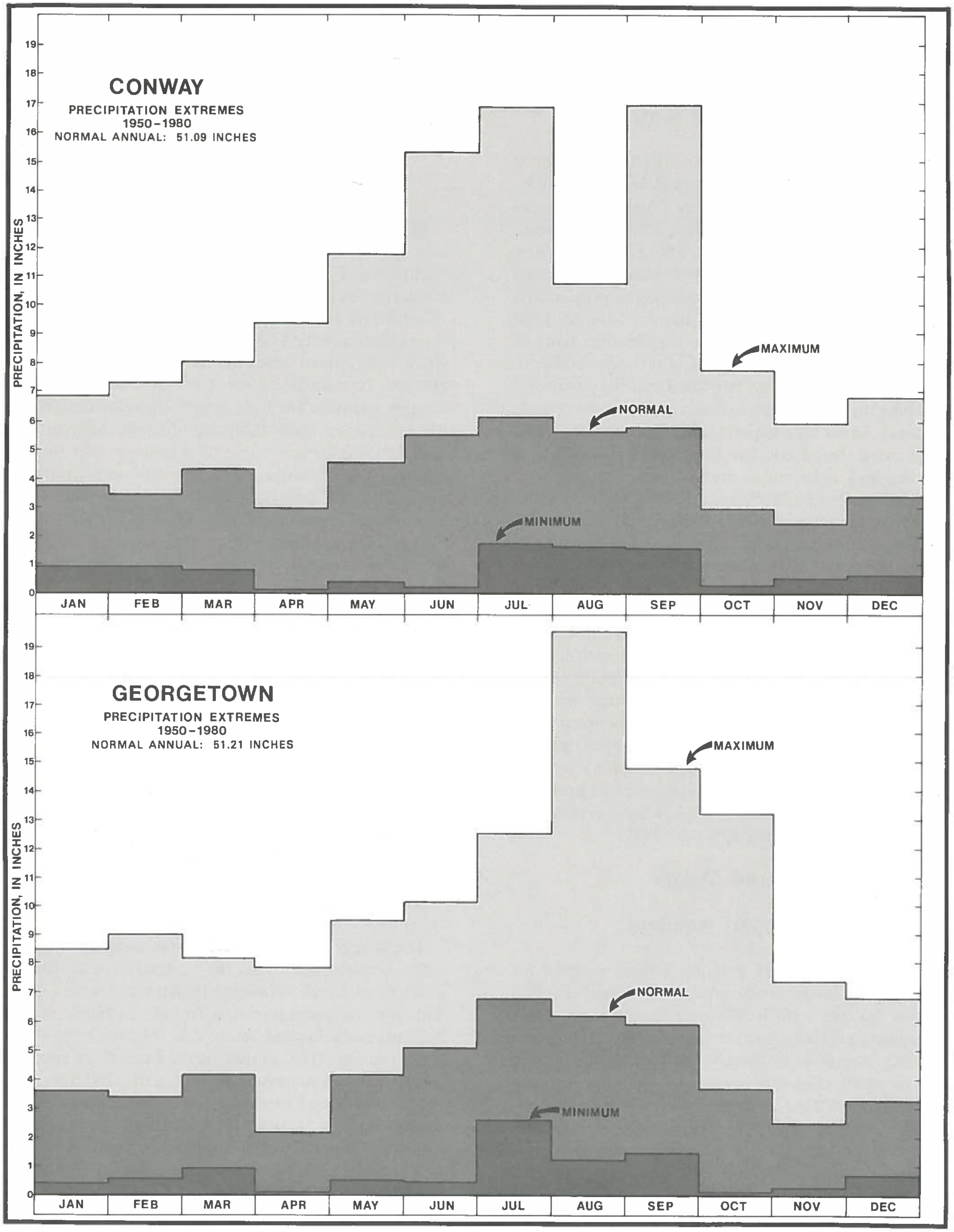

Figure 5: Monthly precipitation normals and extremes for the Conway and Georgetown weather stations during the period 1950-1980.

coastal portion of Horry County, past Conway, and empties into Winyah Bay. The average flow for the river is 1,220 cfs (790 mgd), the 7Q10 is 6.8 cfs (4.4 mgd), and the minimum flow of record was 1 cfs (0.65 mgd) in October 1954 at the gage near Longs.

Atlantic Intracoastal Waterway

The Atlantic Intracoastal Waterway (AICW), a series of linked natural, manmade, and man-improved waterways, was constructed by the Army Corps of Engineers to facilitate water-borne commerce along the Eastern Seaboard. The AICW extends from Florida to New Jersey as a continuously navigable channel. The section just to the west of the Grand Strand is the only stretch that contains freshwater. Gaging stations have not been installed on the AICW long enough to develop many of the flow statistics available on the other water bodies in the area, but the USGS has estimated that the northward 7Q10 past the city of Myrtle Beach is just under 300 cfs (194 mgd), based on comparison with flows in the Waccamaw, Pee Dee, Little Pee Dee, and Lynches Rivers (Carswell and Johnson, in press).

According to the USGS, the AICW is strongly influenced by tidal effects, and experiences a reciprocating flow with each tidal cycle. Under observed conditions, seawater entering from the north at Little River Inlet was able to penetrate to a point near Briarcliffe Acres (Carswell and Johnson, in press). Saltwater has also been observed to enter the AICW from the south at Winyah Bay. The predicted location of the saltwater interface during the 7Q10 low-flow conditions, is approximately 33 miles upstream from the mouth of the estuary near the place where the Horry-Georgetown County line departs from the Waccamaw River and trends due east toward the Atlantic Ocean (Johnson, 1970). In addition to the saltwater intrusion, the waterway experiences problems with depressed dissolved-oxygen levels and elevated fecal coliform bacteria counts (SCWRC, 1983).

Ground Water

Middendorf Aquifers

Only five Middendorf wells have been sampled for water quality in the study area. These analyses, plus analyses for two wells in Florence County and one in Williamsburg County, are shown in Table 2. The water from this formation in Florence County generally is of good to excellent quality, except for its high iron content. The 750-ft zone at Brittons Neck (10Q-p2) meets the EPA standards, except for fluoride, but with increasing depth the water becomes highly mineralized. At Calabash, Georgetown, and Esterville Plantation the water from the entire thickness of the formation is highly mineralized and is not suitable for public water supplies.

The yields from this aquifer are not well known in the study area because of the lack of adequate pumping tests. In the city of Florence, in Florence County, yields up to 2,000 gpm are reported. A well at Johnsonville (12R-b2) in Florence County, and another at Hemingway (12S-b1), in Williamsburg County, are screened in the zone analogous to the 750-ft zone in the Brittons Neck test well (10Q-p2) and are each reported to yield 700 gpm. Preliminary pumping-test data from the Brittons Neck test well indicate that the zones below the 750-ft level may not be permeable enough to yield significant amounts of water to wells.

Black Creek Aquifers

Most large-capacity public supply wells in the study area draw their water from aquifers in the Black Creek Formation. The water is soft, has an alkaline pH, and is suitable for most uses (Table 2). (Specific water quality problems are discussed in a later section). Figure 6 shows the water level trends (hydrographs) of four Black Creek wells plotted beside the cumulative departures from normal for rainfall at the Conway and Georgetown weather stations. The hydrographs of wells completed in unconfined, or water-table, aquifers would mimic the cumulative departure curve to the degree that they are connected to the atmosphere. It can be seen from these plots that the four hydrographs do not mimic the cumulative departures in detail. Well 10W-cl, in Georgetown, exhibited a mimicking response during October through December 1975, November 1976, September 1977, December 1978, and July and August 1979. However, during April 1976, March and December 1980, and July and November 1981 the water level and the cumulative departure responses were not similar. The hydrographs of wells 6S-v2 and 3Q-r1 exhibit large fluctuations that would mask any correlation. The plot for 7Q-x2 is a steadily declining straight line, showing a generalized correlation from 1977 to 1981, but exhibiting no correlation in detail with the departure plot. As a result of these inconsistent and conflicting relationships, no conclusive interpretation can be made from the analysis, and the degree of confinement has been established by other means, such as long-term pumping tests, measurements of water levels, chemical analysis of water samples, and lithogic descriptions showing the existence of extensive confining beds.

The supply source for most large-capacity wells is a water-bearing zone called the "principal sand aquifer" in the Black Creek Formation (Spigner and others, 1977). This zone ranges in thickness from 60 to 100 ft, with its base generally located 180 to 220 ft beneath the top of the formation. The altitude of the base of the principal sand can be approximated by subtracting 200 ft from the values shown on Figure 4. For example, two wells were drilled south of Murrells Inlet, where the altitude of the top of the Black Creek Formation on Figure 4 is −350 ft. The approximate location of the principal sand aquifer would be between the altitudes of −470 and −550 ft. The first well (8V-a1) was screened from 507 to 557 ft (between the altitudes of −492 and −542 ft), and produced 208 gpm with 47 ft of drawdown. The second well (7U-q4) was screened from 397 to 412 ft (between the altitudes of −387 and −402 ft) and produced 15 gpm

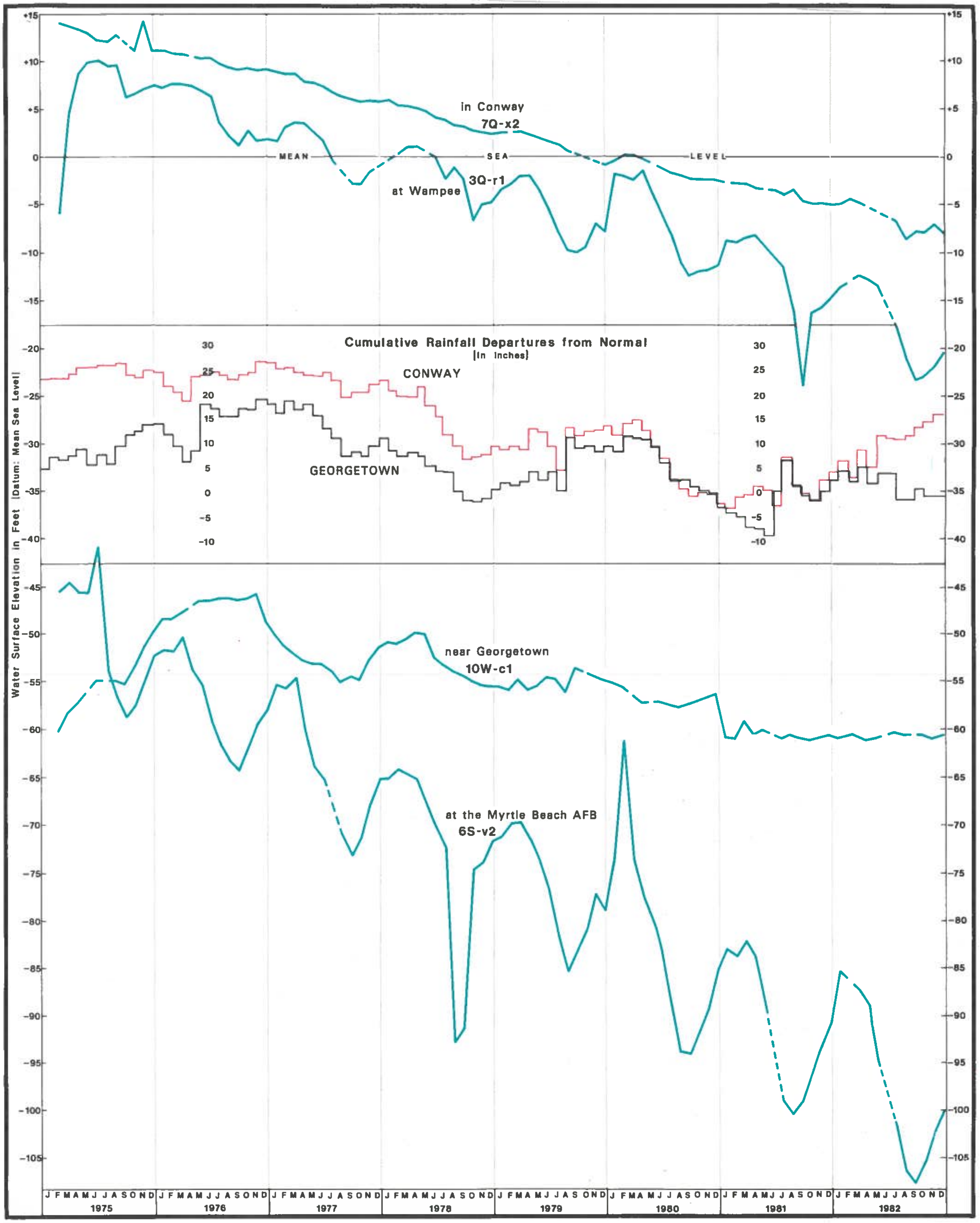

Figure 6: Comparison of the hydrographs of four wells in the Black Creek Formation with the cumulative rainfall departures at Conway and Georgetown, 1975-1982.

Table 2. Selected water quality data, by formation. (Concentrations are for dissolved constituents, expressed in milligrams

Well No.	Location	Sampled depth (ft)	Date sampled	Analyst	pH (units)	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$) Total	Hardness (as $CaCO_3$) Non-carbonate	Dissolved solids
	MIDDENDORF FORMATION								
2Q-j6	Calabash, N.C.	810-820	12-06-73	USGS	9.3	514	93	0	4320
2Q-j2	Calabash, N.C.	1042-1052	12-06-73	USGS	8.2	549	220	0	6560
10Q-p2	Brittons Neck	748-768	4-24-82	USGS	8.1	—	—	—	450
	Do	811-831	4-19-82	USGS	7.6	—	—	—	1540
	Do	1010-1030	4-09-82	USGS	7.5	—	—	—	1700
	Do	1120-1140	4-01-82	USGS	8.0	—	—	—	3470
10W-m4	Georgetown	?-1344	1-23-69	USGS	8.1	1020	28	0	2180
10X-v1	Esterville Plantation	1270-1295	7-06-76	USGS	9.4	1010	30	0	2460
12R-b2	Johnsonville	789-870	4-16-68	Comm.	8.5	253	7	—	360
12S-b1	Hemingway	826-884	10-12-70	USGS	8.8	—	6	0	401
16M-41	Florence	303-706	10-16-75	Comm.	6.4	—	20	—	—
	Note: Johnsonville and Florence are in Florence County, Hemingway in Williamsburg County.								
	BLACK CREEK FORMATION								
2Q-j5	Calabash, N.C.	338-348	5-24-73	USGS	8.2	423	56	0	1760
2Q-j4	Calabash, N.C.	496-506	12-06-73	USGS	8.0	546	50	0	1570
5S-h1	Myrtle Beach	280-750	3-08-83	SCWRC	8.2	515	13.7	—	773
6S-h1	Forestbrook	365-675	4-11-83	SCWRC	8.3	487	10.8	—	608
6T-q2	Surfside Beach	419-616	4-05-83	SCWRC	8.6	485	11.2	—	519
7Q-p1	Conway	612-728	9-13-83	SCWRC	8.3	395	9.6	—	691
90-wl	Aynor	300-350	11-21-77	USGS	8.8	480	13	0	629
9W-k1	DeBordieu Colony	544-640	9-13-83	SCWRC	8.5	499	11.6	—	694
10Q-p1	Brittons Neck	345-355	5-02-82	USGS	8.7	—	—	—	313
10Q-p2	Brittons Neck	517-537	4-30-82	USGS	8.6	—	—	—	496
10X-d2	Georgetown	612-800	9-13-83	SCWRC	8.6	414	9.0	—	621
13V-g1	Andrews	552-760	4-19-77	USGS	8.5	350	15	0	422
9M-p1	Mullins	194-334	8-06-79	Comm.	7.3	82	14	—	148
11M-y1	Marion	190-735	3-12-84	SCWRC	7.8	118	34	—	283
12R-g1	Johnsonville	292-386	4-12-77	USGS	9.0	220	10	0	277
12R-v1	Hemingway	310-495	3-26-59	USGS	9.1	—	10	—	277
10N-y1	Rains	230-290	3-12-84	SCWRC	8.1	438	49	—	697
	Note: Marion, Mullins and Rains are in Marion County.								
	PEEDEE AND SHALLOW FORMATIONS								
3R-n2	North Myrtle Beach	33-38	8-02-78	SCWRC	6.9	158	160	—	—
4R-l3	Myrtle Beach	84-94	2-22-78	USGS	9.6	210	230	18	293
6Q-y1	Conway	40-45	7-26-78	SCWRC	8.0	192	176	—	—
7U-c1	Murrells Inlet	35-45	12-01-83	SCWRC	7.1	198	165	—	248
10T-i1	NW Georgetown Co.	17-22	9-20-78	SCWRC	6.3	63	16	—	—
11W-w2	West of Georgetown	79-84	10-04-78	SCWRC	6.2	164	190	—	—
13X-e1	South of Andrews	49-52	9-29-78	SCWRC	6.3	155	156	—	—
	Maximum Contaminant Levels, as established by EPA				6.5-8.5**				500**

* primary standard; ** secondary standard; Analyst: SCWRC, South Carolina Water Resources Commission;

per liter except where indicated otherwise.)

Iron (Fe) (ug/L)	Manganese (Mn) (ug/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Silica (SiO_2)
100	43	14	14	1600	40	102	420	18	2300	0.9	1.0	0.6
180	86	32	33	2500	33	0	669	12	3600	.9	—	4.9
120	10	1.7	.4	180	2.2	0	380	13	57	2.7	< .10	—
2200	89	12	3.4	580	6.1	0	819	118	359	.6	< .10	—
5500	91	9.9	2.6	480	6.6	0	886	124	373	.6	< .10	—
1600	400	42	12	1000	12	0	428	525	1300	6.7	< .01	—
530(t)	0	9.4	1.2	855	8.2	0	1240	9.8	645	3.8	.20	15
200	0	6.4	3.4	980	10	0	1230	6.0	830	—	—	15
170	0	2.8	0	—	—	—	—	10	33	1.5	—	—
0	—	2.4	0	151	2.7	0	350	5.2	31	2.0	.5	.8
1600	30	6.0	14	22	—	—	—	18	8.0	—	—	19
t, total												
10	10	10	7.5	690	26	0	516	30	720	1.6	—	13
100	29	9.6	6.3	600	52	0	666	5.2	550	2.8	—	16
21	0	3.4	1.1	308	5.6	—	—	7.0	115	4.8	—	13.7
29	0	2.66	.94	345	6.9	—	—	7.5	71	4.4	—	21.4
8	0	1.9	.78	300	7.3	—	—	7.2	27	4.3	—	23.3
29	6	2.83	.58	238	3.34	—	—	6.9	111	2.33	—	12.1
20	0	3.1	1.3	260	12	0	590	1.5	39	4.3	—	17
27	0	3.17	.86	260	6.99	—	—	3.4	71	1.36	—	14.3
11	1	1.4	.2	120	4.1	21.8	287	6.2	5.3	1.2	< .10	—
44	2	2.3	.5	190	3.7	11.9	485	.2	36	4.7	< .10	—
24	3	2.84	.45	238	6.95	—	—	6.4	89	1.19	—	14.9
150	0	5.3	.4	160	5.1	13	400	9.4	14	1.7	—	16
130	20	3.16	1.53	33.6		0	100	1.2	3	.42	.05	44.8
109	8	10.5	1.7	66	2.84	—	—	13.9	12	.65	—	35.8
30	0	2.0	1.3	95	4.9	14	240	8.1	5.3	1.7	—	26
70	10	2.8	.5	101	4.2	29	205	4.2	4.5	1.6	.3	24
0	14	12.0	3.0	207	10.6	—	—	8.8	67	1.7	—	28
1150	16	59.0	2.45	26.4	1.20	—	—	11.8	30	.11	.02	—
330	10	89	2.1	19	.9	0	260	15	32	.1	—	6.5
1580	96	54.2	4.45	13.1	2.27	—	—	5.3	9.9	.13	0	18.6
2310	23	58.8	2.75	13.1	1.07	—	—	20.5	17	.08	—	10.1
2810	11	24.0	.51	4.8	.95	—	—	1.7	23	0	.03	9.6
850	90	50.5	2.1	9.2	3.4	—	—	4.3	12	0	.08	20.9
970	55	46.2	2.1	7.5	1.2	—	—	2.3	7.4	.14	.14	46.3
300**	50**							250**	250**	1.6*	10*	

USGS, U.S. Geological Survey; Comm., Commercial Laboratory with 390 ft of drawdown. The first well was able to develop water efficiently from the principal sand, but the second was not deep enough to tap it and was unable to produce a significant yield. Well 5S-h1, in Figure 3, illustrates the typical construction of large-capacity wells. There are nine screen locations, only three of which are opposite the principal sand aquifer located between the depths of 394 and 452 ft.

Water Use

The water use map (Fig. 7) illustrates how the pumpage from the aquifers in the Black Creek Formation was distributed across the two counties. The map shows the amount of water pumped from aquifers in the Black Creek Formation during 1982 within each 1-minute grid of latitude and longitude. Water use was concentrated in a Y-shaped area extending from Conway to Myrtle Beach and from Little River to Garden City. The balance of the water use was dispersed more or less uniformly.

Water use reports are collected as part of the Capacity Use Program. Since September 1981, all holders of Class A water use permits have submitted monthly water use reports, on a quarterly basis, for all of their ground-water withdrawals.

TABLE 3. Annual water use, in millions of gallons, from the Black Creek Formation.

Year	Horry County	Georgetown County	Total
1974[1]	2,780	960	3,740
1982	5,950	1,080	7,020
2000	15,500[2]	1,500	17,000

Source: [1]Zack, 1977
[2]CH2M Hill, 1984b

TABLE 4. Water demand, in millions of gallons per day, from the Black Creek Formation.

Year		Horry County	Georgetown County	Total
1974[1]	Average	7.6	2.6	10.2
	Peak	12.7	4.4	17.1
1982	Average	16.3	3.0	19.3
	Peak	27.2	5.0	32.2
2000	Average	40[2]	4.0[3]	45
	Peak	72[2]	7.0[3]	80

Source: [1]Zack, 1977
[2]CH2M Hill, 1984b
[3]Extrapolation of 1974 and 1982 data

Note: The water use figures (Table 3) represent the quantity of water withdrawn during the year. The peak water demand figures (Table 4), on the other hand, show the rate at which water must be available for supply during short periods of higher water use. The aquifer, wells, pumps, and piping must have sufficient capacity to deliver the higher volumes reflected by the demand figures, not the annual water use figures.

The data in Table 3 indicate that between 1974 and 1982 the ground-water use in Horry County increased by 114 percent, while the use in Georgetown County increased only 12.5 percent. By the year 2000, projected usage will increase by 160 percent and 39 percent, in Horry and Georgetown Counties, respectively, over their reported pumpage in 1982. Table 4 shows the average daily demand (total pumpage from Table 3 divided by 365), as well as the estimated daily peak demand for the two counties. The peak demand shows the estimated stress the aquifer will be put under in the worst-case situation during the peak of the tourist season. It can be seen that by the year 2000 the average and peak demands will be more than twice the present figures.

The Georgetown County Industrial Development Commission is currently encouraging the development of an additional 30-mgd raw-water capacity in the county to attract new industrial prospects. If part of this increase were obtained from the Black Creek Formation, the projections in Table 3 and 4 for Georgetown County could be much too low.

Water Levels

Water levels have been measured on a monthly basis in a number of wells since 1975. The data from these measurements were used to construct hydrographs (Fig. 6) and potentiometric (water level contour) maps (Figs. 9-14). Historical data record that some Black Creek wells in Horry and Georgetown Counties flowed at the surface as recently as the late 1950's. Wells in the cities of Georgetown and Myrtle Beach, however, have lower levels resulting from local pumping.

When local water-use information is compared with the hydrographs of two wells near Myrtle Beach (5S-b1 and 6S-v2), an interesting pattern becomes apparent (Fig. 8). There appears to be a 1- to 2-month lag between the minimum water use and highest water level and between the maximum water use and the corresponding lowest water level. This lag time probably is explained by the fact that these wells are about 4 miles from the center of the Myrtle Beach cone of depression, and the water continues to flow toward the cone for some time after pumpage is reduced in the fall and winter months.

Figures 9, 10, 11, and 12 depict the potentiometric surface of the aquifers in the Black Creek Formation in March and September of both 1975 and 1982. Two cones of depression form the main features on the maps. The first, and largest, is centered at Myrtle Beach and encompasses Little River, Conway, and Murrells Inlet; the second is centered at Georgetown and is largely unmapped in areal extent, owing to insufficient data.

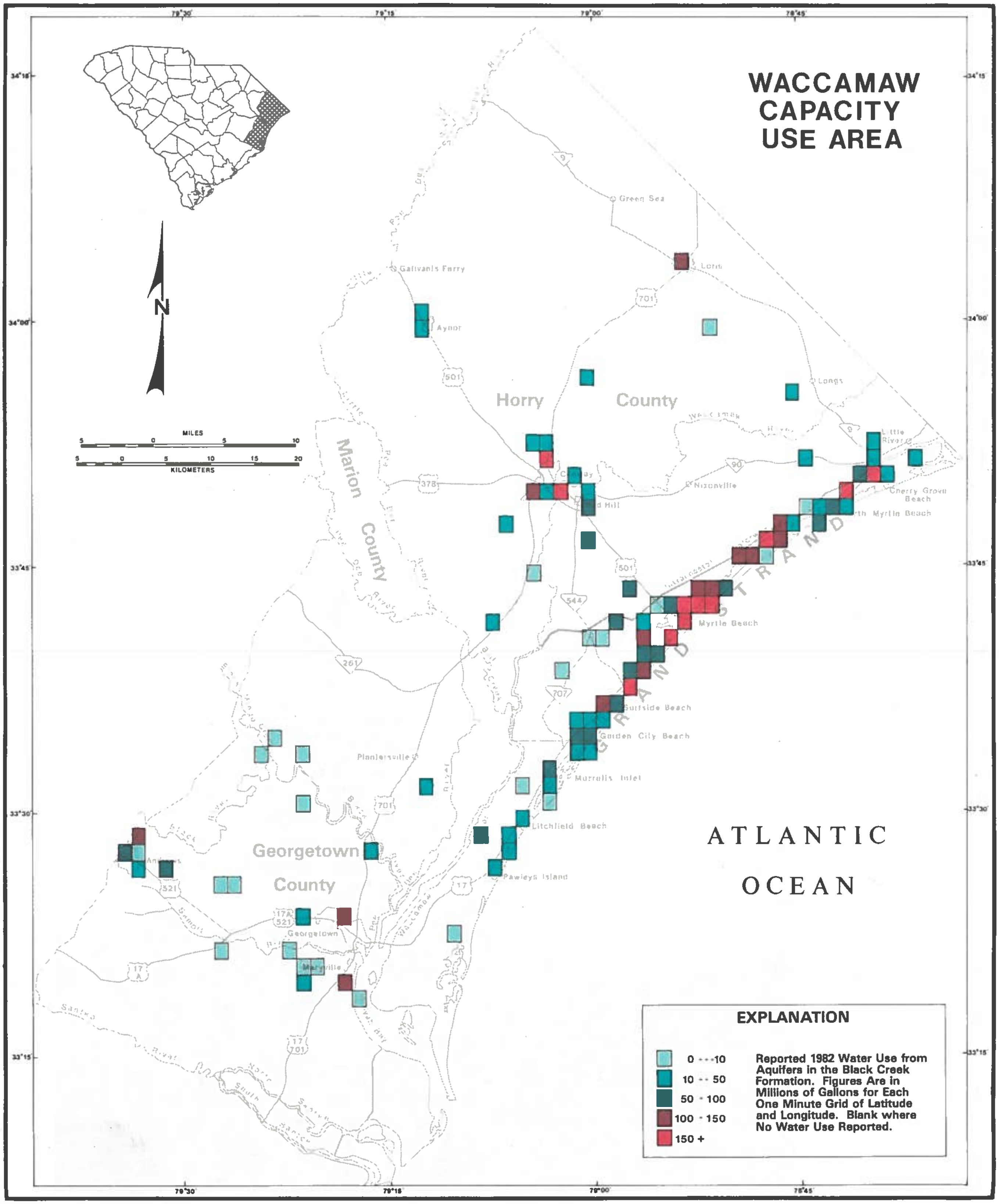

Figure 7: Areal distribution and intensity of reported water use from aquifers in the Black Creek Formation in 1982.

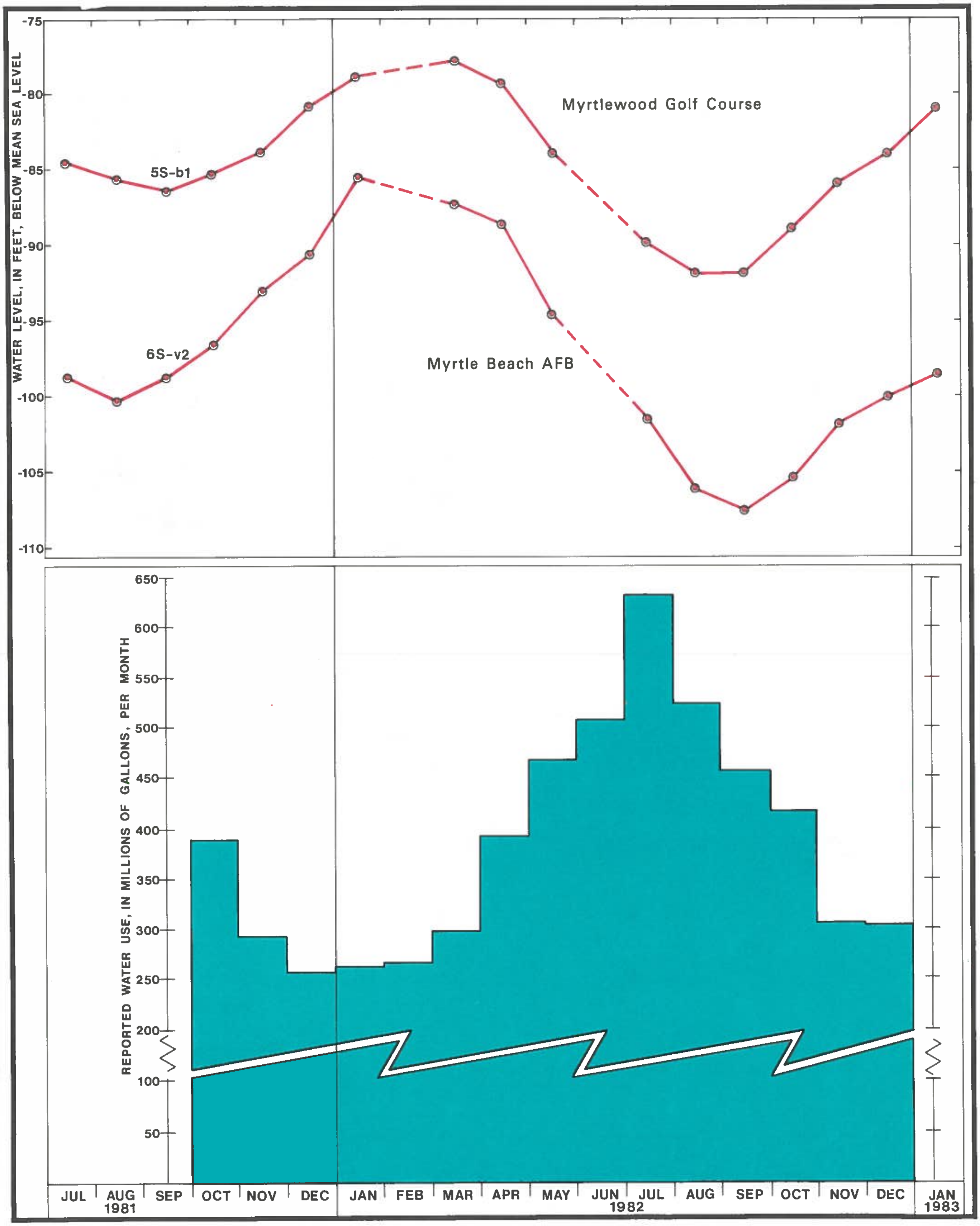

Figure 8: Comparison of hydrographs of two wells with reported water use within 12 miles of these wells.

In comparing the two cones among the four maps, it can be seen that the cone around Georgetown has not changed appreciably, in depth or areal extent, in the 7 years between maps. The cone around Myrtle Beach, however, has deepened by approximately 80 ft and has expanded laterally by at least 5 miles. The different responses in the two cones are caused by differences in local water-use patterns. As shown in Tables 3 and 4, the increase in ground-water use in Horry County was much larger than that in Georgetown County. In addition, a large part of the increase in Horry County has occurred within the cone of depression centered at Myrtle Beach, whereas the increase in Georgetown County was spread over a larger area.

A map of the average annual rates of decline over the period of record for all of the observation wells (Fig. 13) shows that the contour lines on this map mimic the potentiometric contours, and that the observed rates of decline range from almost zero at Georgetown to almost 10 ft per year at Myrtle Beach. With the center of the cone of depression beneath Myrtle Beach at an altitude of −160 ft, and the water levels dropping at a rate of 9.5 ft per year, the water levels will reach the top of the Black Creek Formation (−240 ft) in 8 or 10 years and will reach the top of some well screens (approximately −300 ft) in another 5 to 10 years. Figure 14 shows the estimated potentiometric surface for the year 2000, provided that current water-use and water-level patterns continue. A considerable area (dark shading) will be dewatered, with a potential for aquifer compaction, reduced transmissivity, and air entrainment. An even larger area (light shading) will undergo some degree of dewatering during pumping cycles, with less severe effects than in the central zone. (It was assumed that an average pumping level in a well would be 100 ft below the static water level). These depressed water levels would also increase the potential for saltwater movement into the aquifer.

A nomogram has been constructed to aid in the prediction of increased pumping costs as water levels continue to decline (Fig. 15). Several assumptions were made in order to draw this nomogram:

— an electrical cost of 5.29 cents per kilowatt-hour,
— a pump efficiency of 75 percent, and
— a motor efficiency of 85 percent.

To use the diagram, determine the location of interest on Figure 13 and estimate the local rate of decline. Place a straightedge between the rate of decline on the left of Figure 15 and the pumping rate of the well on the right. Read the increase in pumping costs in the center. For example, to calculate the annual increase for a 500-gpm well in the Briarcliffe Acres section, between Myrtle Beach and North Myrtle Beach, it is first determined from Figure 13 that the rate of decline in that area is 7 ft per year. On Figure 15, connect the 7 ft per year, on the left, with the 500 gpm on the right, and read 5.5 cents per hour increase in hourly pumping costs in the center, as shown. If this well were to pump 16 hours per day and 5 days per week for a year, the increased pumping cost would be approximately 230 dollars above the previous year's cost.

Water Quality

As mentioned earlier, the Black Creek aquifers presently provide most of the water supply in the area. The water is of a sodium bicarbonate type, those constituents being the two predominant ions in solution; it is soft, low in iron, and alkaline. There are several objectionable water quality characteristics, however, that will be important in deciding the future status of the aquifer. These characteristics are the high chloride, fluoride, sodium, and total dissolved solids and, to a lesser degree, the taste. Another problem, although it is a local one, is turbidity (cloudy water), which has been reported in several wells.

Chloride. Some parts of the Black Creek Formation contain chloride levels in excess of the recommended limit of 250 mg/L. The major problem occurs in a triangular area from Loris to North Myrtle Beach to the North Carolina line. In this area, excessive chloride levels occur in all, or most, of the aquifer system (Fig. 16). The probable source of this chloride is the original seawater in which the Black Creek sediments were deposited. The saltwater has not been flushed out of these sediments because the Cape Fear Arch has deflected the fresher ground-water flow around them (Zack, 1977).

Another chloride problem may occur in the future, owing to the potential for saltwater intrusion or encroachment. The intrusion of seawater into coastal aquifers occurs when the water levels are lowered substantially in close proximity to the ocean or other body of saltwater. The lowered water levels reverse the usual prepumping seaward flow of ground water and cause the water to flow toward the wells from the ocean side. To date, no such movement of saltwater has been detected, but it is probably occurring in the portion of the aquifer beneath the Atlantic Ocean, and it may be occurring at a very slow rate beneath North Myrtle Beach as well.

Fluoride. For the purpose of preventing dental fluorosis (tooth mottling) the U.S. Environmental Protection Agency (EPA) has established a limit of 1.6 mg/L for the fluoride concentration in public water supplies in this area. The water from nearly every Black Creek well in the area has a fluoride level between 2.0 and 5.0 mg/L, with one sample from a well at the Myrtle Beach Air Force Base (6T-b2) having been mesured as high as 7.0 mg/L and several wells in Georgetown County having levels of less than 1.0. The source of this fluoride, according to Zack (1980), appears to be the fluorapatite in fossilized shark teeth, known to be abundant in the Black Creek Formation. Through a series of chemical exchanges, the fluorapatite in the teeth becomes hydroxylapatite while releasing fluoride ions to the water.

EPA, at the request of the South Carolina Department of Health and Environmental Control and agencies from 16 other states, is presently reviewing their interim standards for fluoride. No decision has been made on whether to relax the current limit, reaffirm it, or establish primary as well as secondary standards. The available technology to remove the fluoride is very costly.

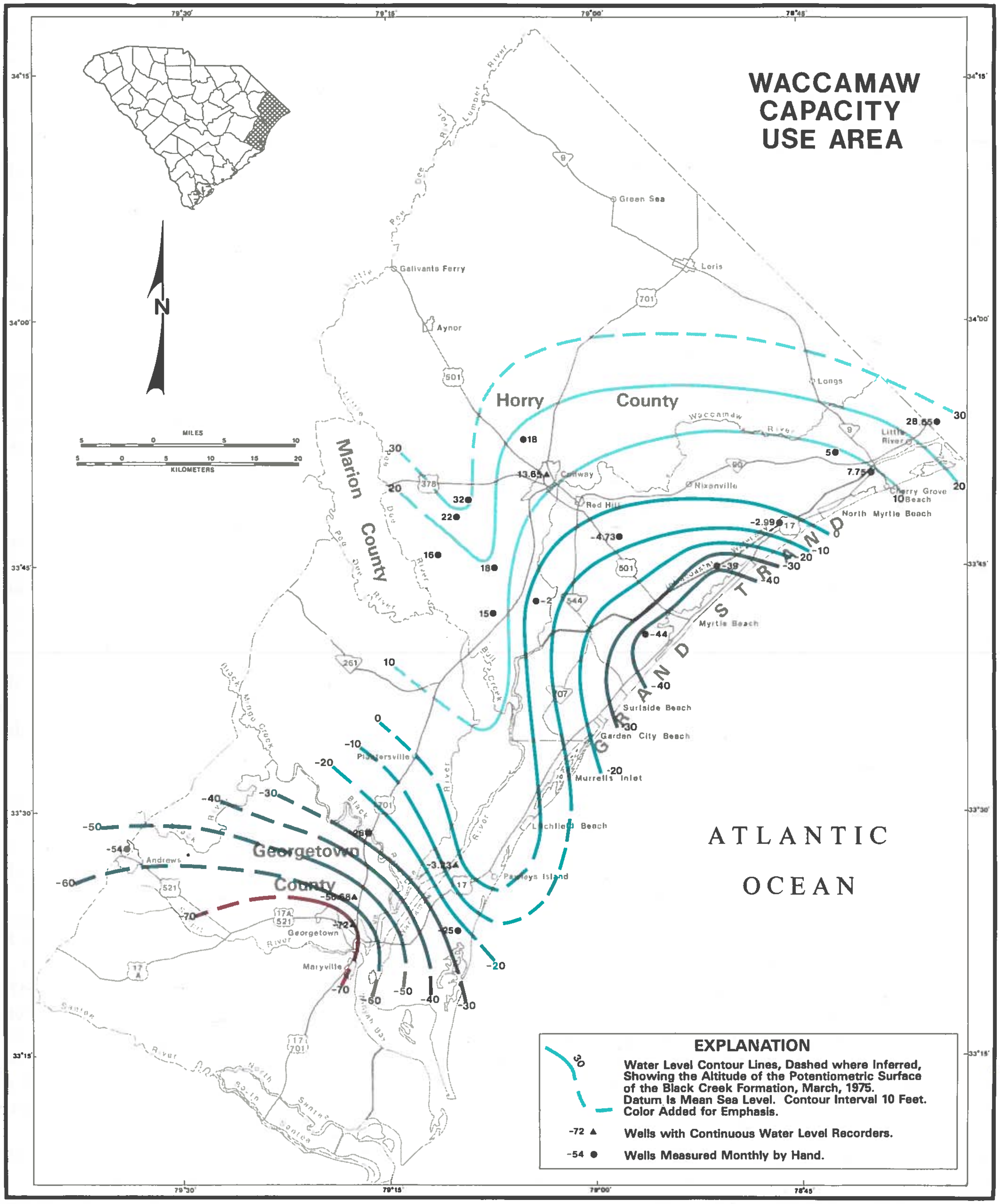

Figure 9: Potentiometric contours for the Black Creek Formation, March 1975.

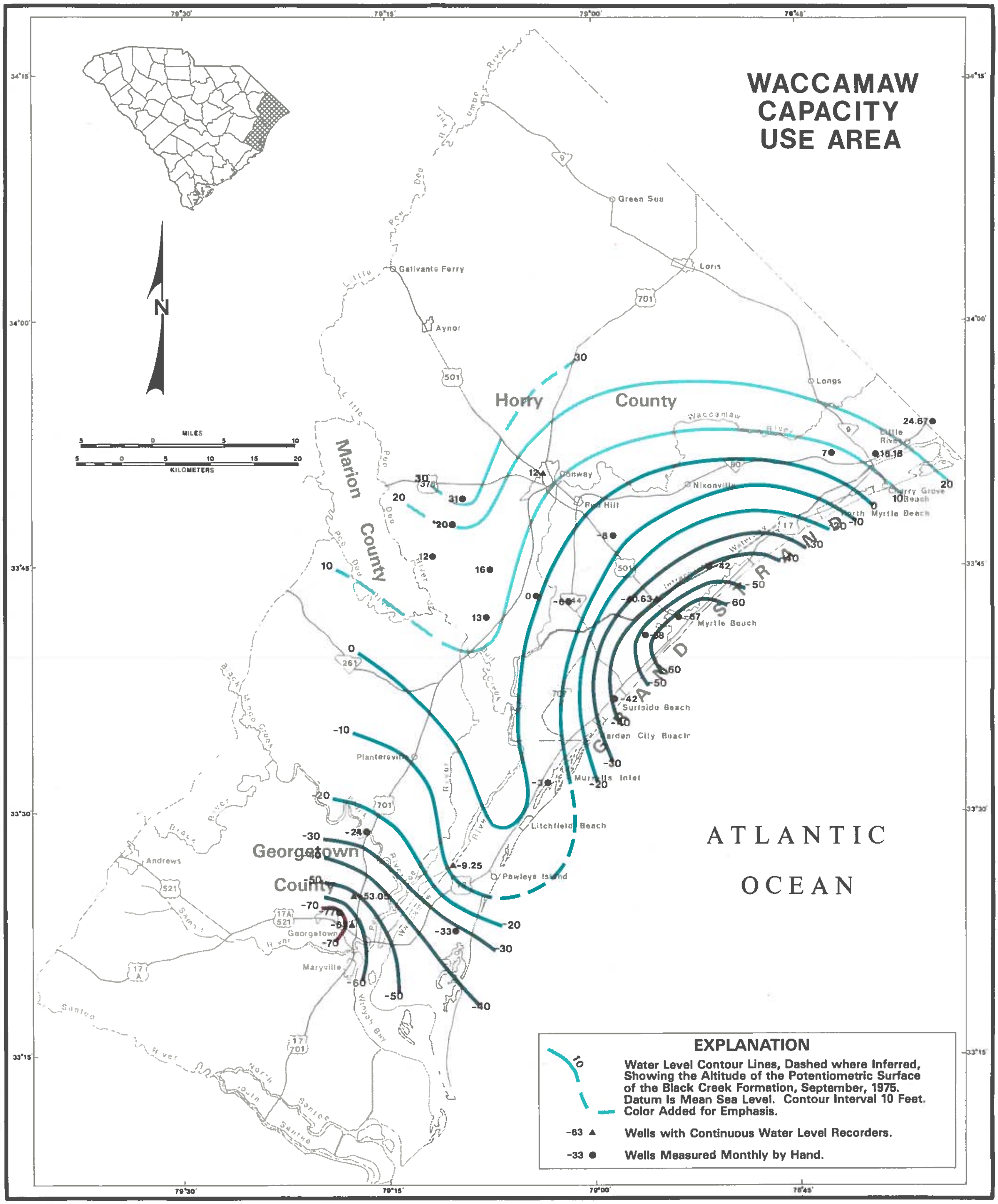

Figure 10: Potentiometric contours for the Black Creek Formation, September 1975.

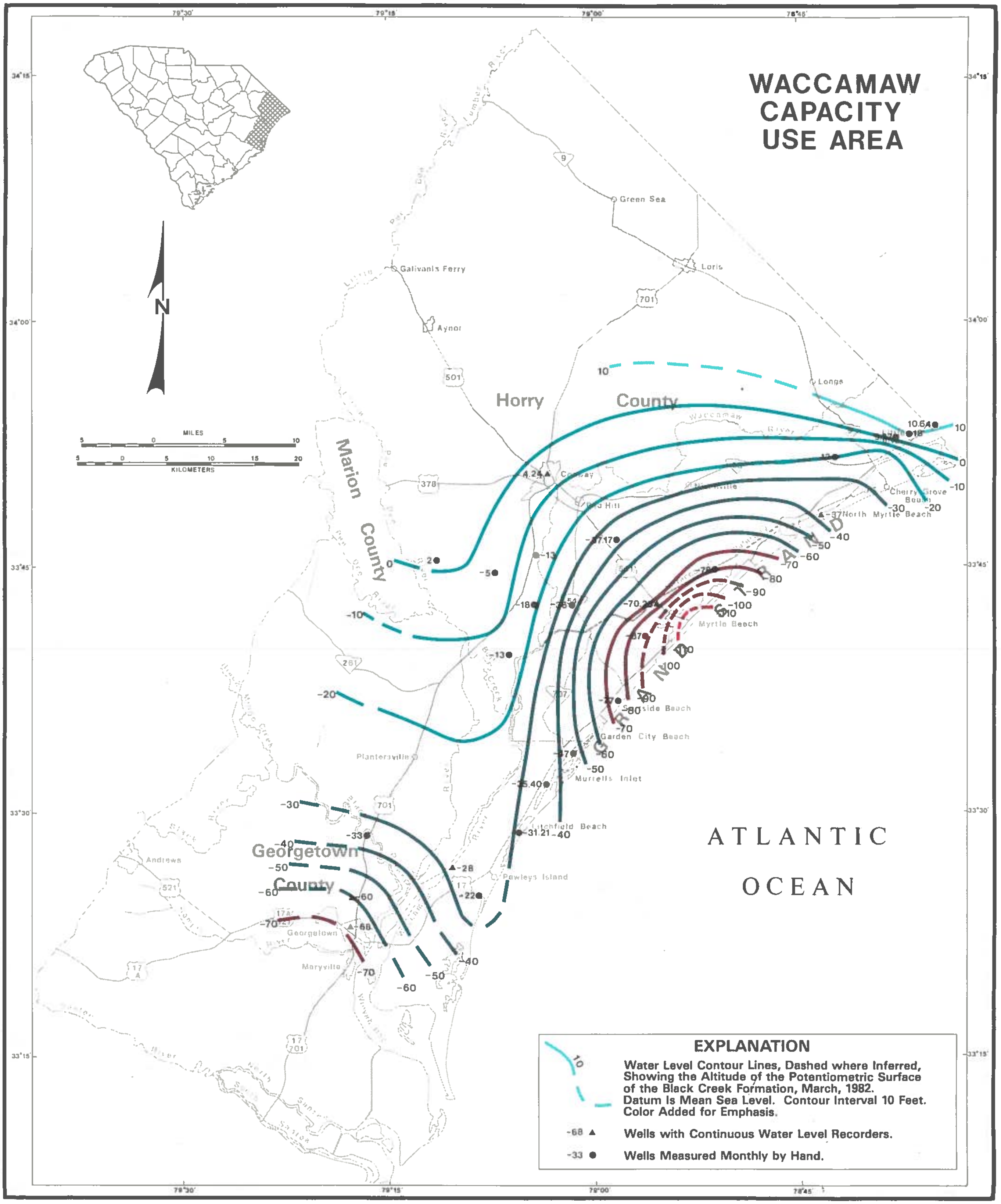

Figure 11: Potentiometric contours for the Black Creek Formation, March 1982.

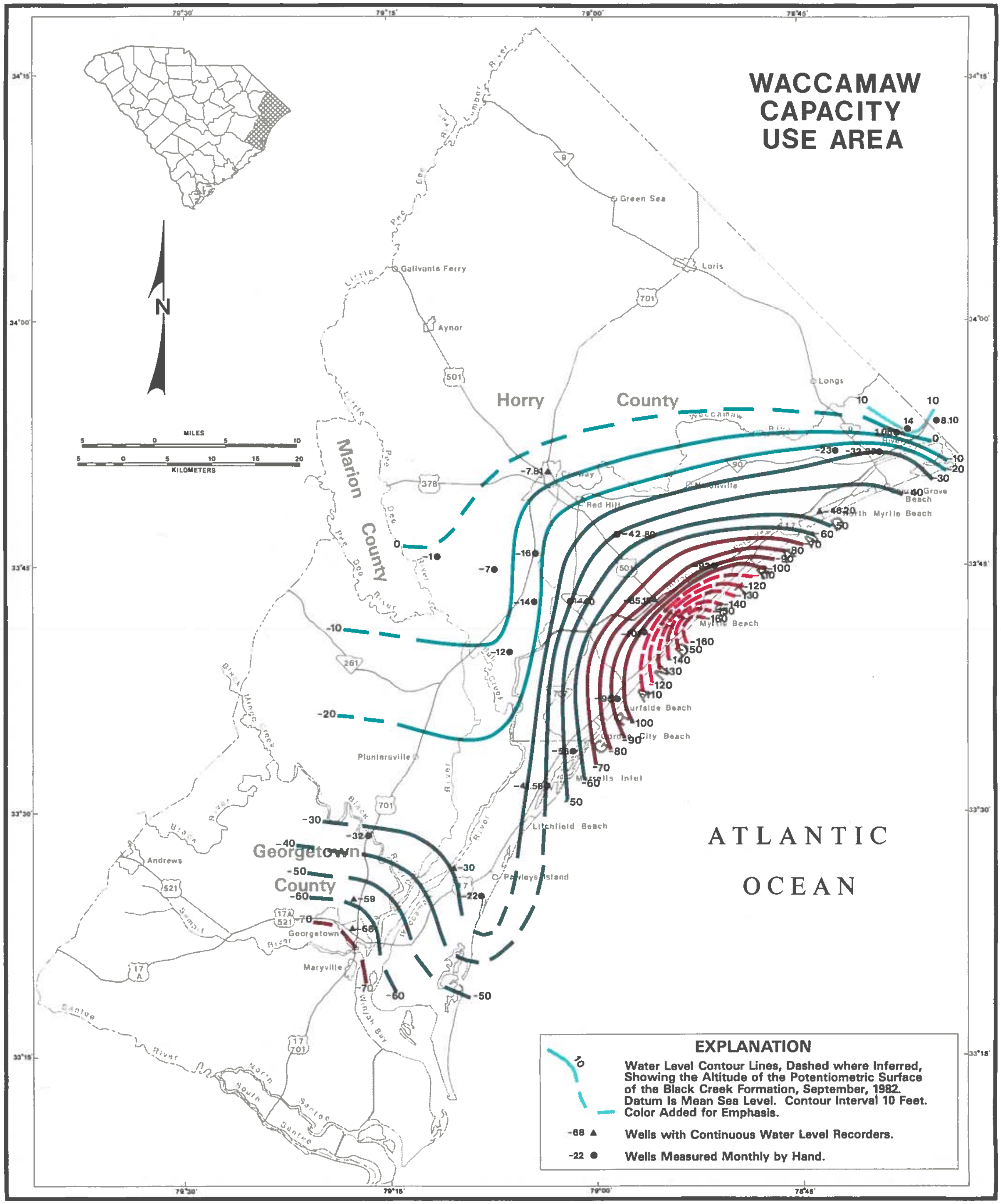

Figure 12: Potentiometric contours for the Black Creek Formation, September 1982.

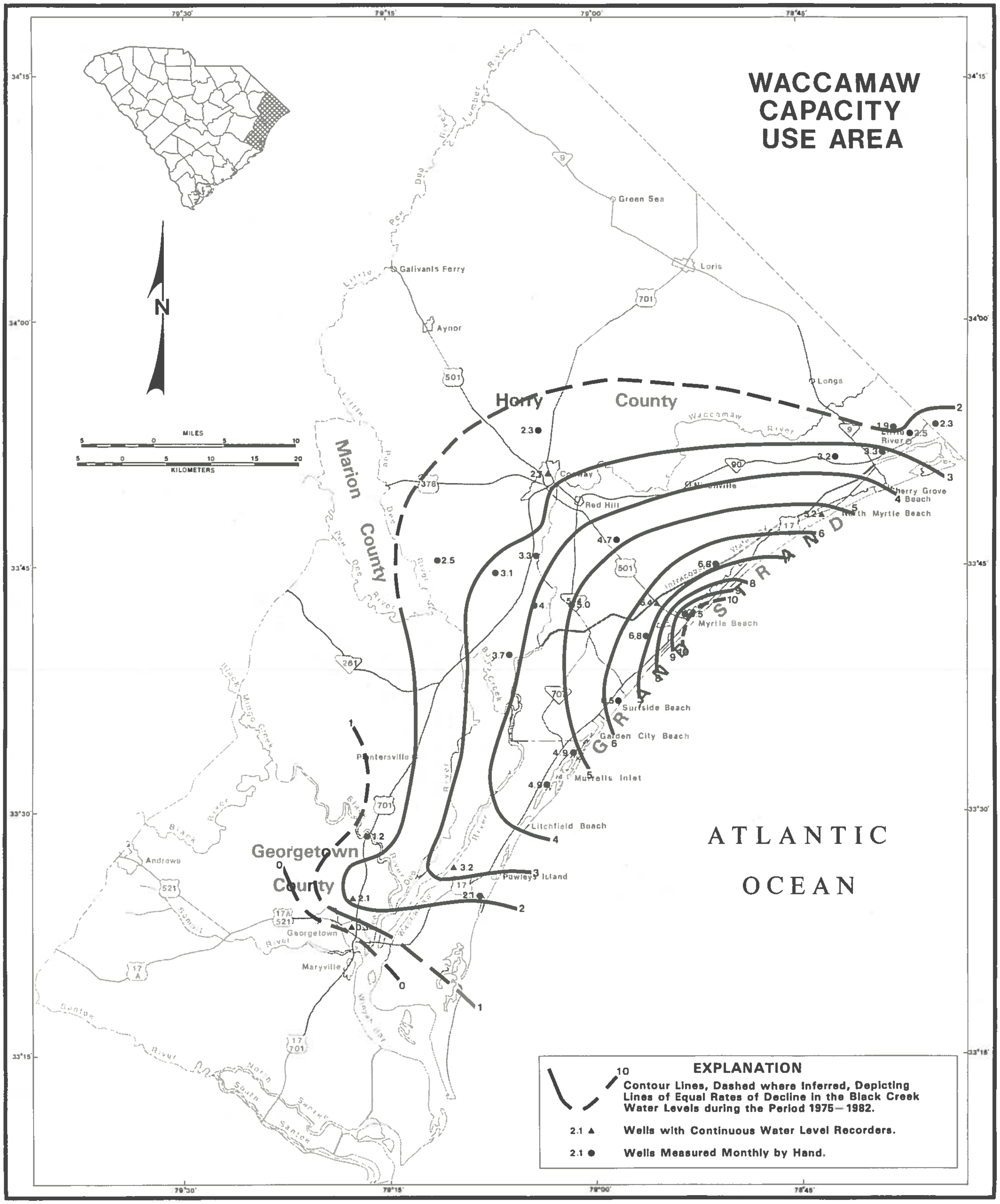

Figure 13: Contours showing rates of decline, in feet per year, of water levels in the Black Creek Formation, 1975-1982.

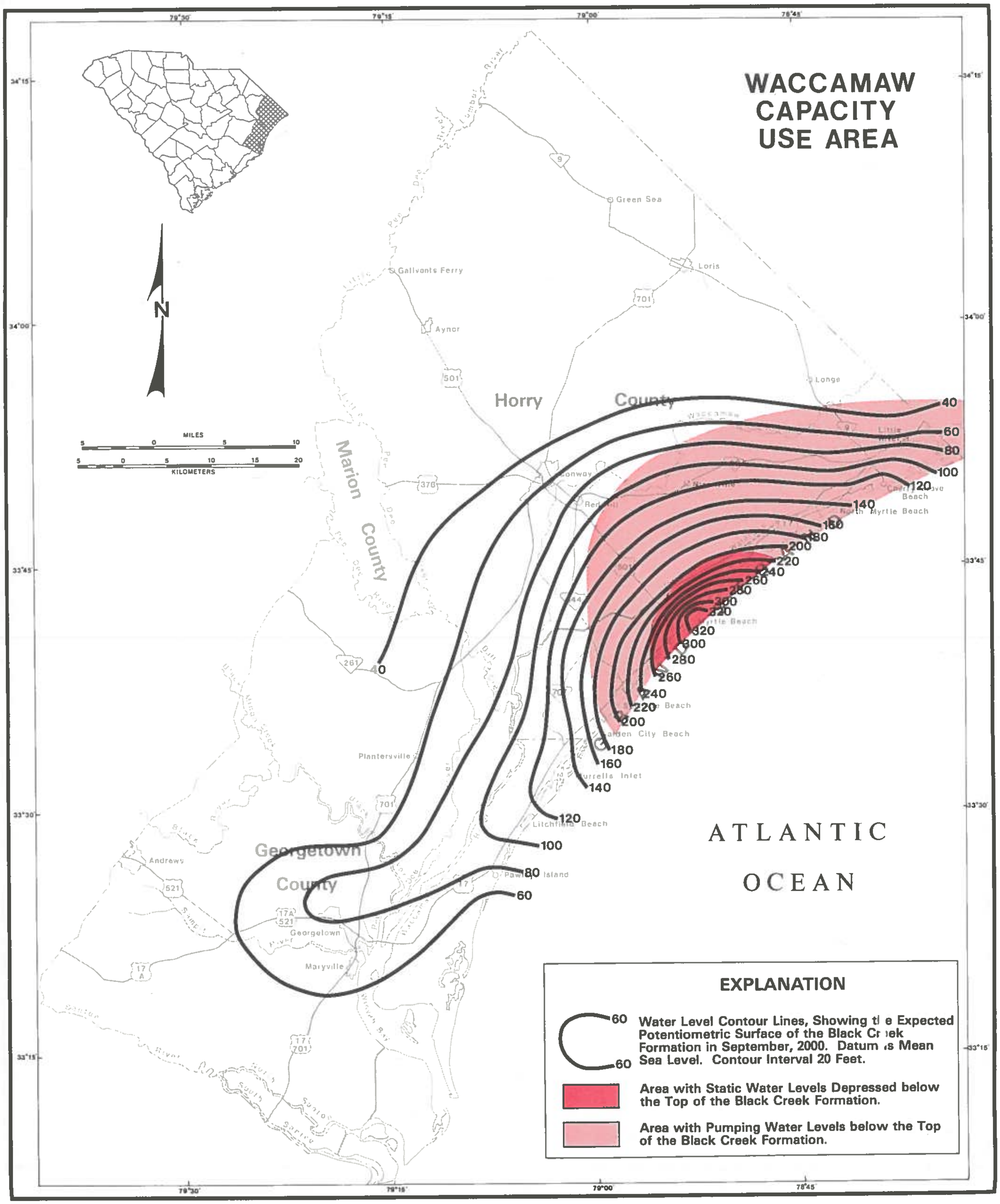

Figure 14: Projected potentiometric contours for the Black Creek Formation, September 2000.

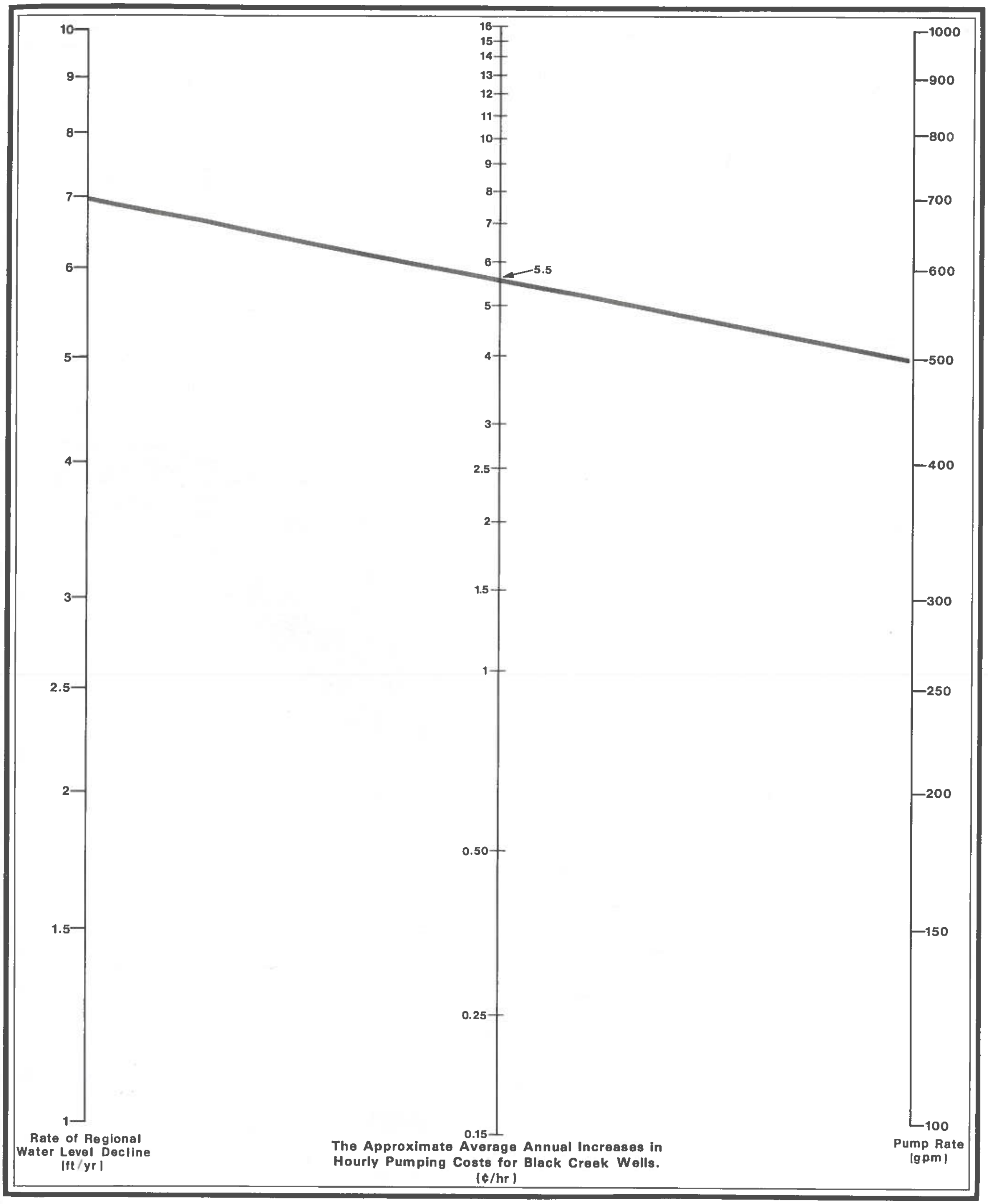

Figure 15: Nomogram used to calculate increased pumping costs caused by regional water level declines in the Black Creek Formation.

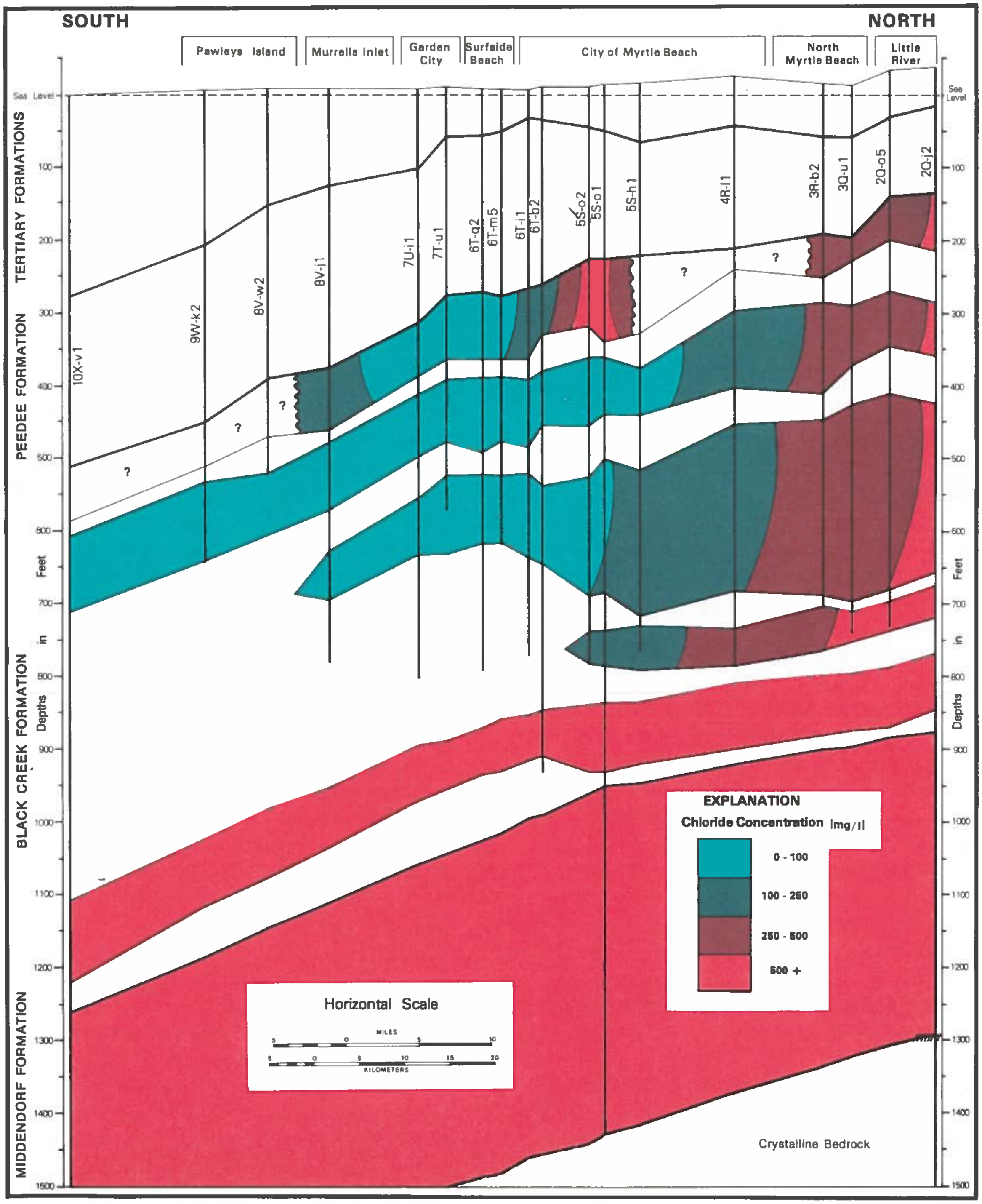

Figure 16: Hydrogeologic section from Esterville Plantation to Little River, showing the geologic structure and the chloride content of water in the Black Creek Formation.

Sodium. At present, there is no EPA limit for sodium. However, for heart patients and those who have high blood pressure and kidney disease, there is concern about the sodium content of the water. Sodium levels in water systems have been measured at approximately 700 mg/L near the North Carolina line, diminishing to 250-300 mg/L at the Horry-Georgetown County line and to 150-200 mg/L at the western boundary of Georgetown County. For people on a sodium-restricted diet, these levels necessitate the use of bottled water or the purchase of a home water-purification system.

The American Heart Association has recommended to EPA that a limit of 20 mg/L be adopted as the standard, in order to protect the heart and kidney patients on low-sodium diets (Calabrese and others, 1980). If this is found by EPA to be an acceptable limit, it will provide an additional thrust to seeking an alternate water supply for the local communities.

Dissolved Solids. The EPA list of secondary water quality standards indicates a limit of 500 mg/L for total dissolved solids. The drinking water obtained from the Black Creek aquifers along the coast near the North Carolina line contains more than 1,500 mg/L of dissolved solids. The content decreases to approximately 600 mg/L at the Horry-Georgetown line and to 400 mg/L in some parts of Georgetown County. This is mainly an aesthetic standard, having limited health-related implications, but water having high solids often has a cloudy appearance and leaves spots on dishes, glassware, sinks, countertops, and cars when they are washed and allowed to air dry.

Taste. There is, of course, no "limit" as to how a water supply tastes. Long-time residents of an area, haveing grown accustomed to the way that the water tastes, generally have no complaints. It is the people moving into the area that notice the taste and remark about it. The large volume of bottled water sold in Horry and Georgetown Counties, and the number of home water-treatment systems installed, are two indications of public concern for the taste of the water, as well as the health-related problems already discussed. Taste is, to be sure, a small matter but one that is certain to be mentioned in any discussion of the present, or any future, water supply.

Turbidity. Several Black Creek wells have initially produced water with excessive turbidity caused by a form of calcium carbonate (aragonite) in suspension. The problem has been found throughout the study area, even though it follows no obvious pattern. For example, a cloudy-water well (5S-i8) was drilled only 50 ft from an existing clear-water well (5S-i3). The cloudiness has been found to dissipate with time and pumping. Several wells have been successfully treated with a timer, which automatically cycles the pump to waste for short periods.

The facts that the problem follows no apparent geographic pattern, that the cloudiness eventually clears up, and that the water in the Black Creek aquifers contains relatively little calcium (Table 2), suggest that the problem may be caused by an agent introduced during the drilling or construction stages of the well. More study is needed to document the occurrence and causes of this phenomenon, so that it may be avoided in the future.

Water Availability

The Black Creek Formation contains the most productive and areally extensive aquifers in the study area. It produces large volumes of potable water at reasonable cost. Well yields are as high as 1,000 gpm just south of Myrtle Beach, but they more commonly fall into the 300- to 700-gpm range. Farther south, near Georgetown, wells tend to produce less, and a 200- to 250-gpm yield would be considered excellent. The aquifer occurs at greater depth there, and its water quality improves, but its ability to transmit water decreases.

Wells at Red Hill (11U-f1) and Rose Hill (11U-d1) in Georgetown County are completed opposite deeper aquifers in the Black Creek Formation than other local wells (880-990 and 770-918 ft, respectively). They have reported specific capacities of 15 and 9 gpm per ft of drawdown, which are significantly higher than nearby wells and may indicate the existence of a very productive zone not previously explored.

The transmissivity values of the Black Creek aquifers, calculated from 70 pumping tests, are represented in figure 17. The results have been segregated into five geographical areas for the purpose of comparison. The diagram indicates that the aquifer is generally more transmissive in the northern and western (inland) portions of the two counties. This supports the observation of lower well yields in the southern section of the study area, which may in part be attributable to the larger portion of the aquifer which is occupied by clay beds (Fig. 16).

The theoretical yield shown at the bottom of figure 17 was calulated for a 75-percent efficient, 12-inch well having 100 feet of drawdown after 24 hours of pumping from an aquifer having the indicated transmissivity. The calculations used the Theis equations (Theis, 1935) for drawdown and yield.

Peedee and Shallow Aquifers

The Peedee and shallow aquifers lie above the Black Creek Formation and are important sources of water for the region. Wells completed in them probably number in the thousands. The wells usually are less than 200 ft deep and produce 60-100 gpm where maximum yields are sought. Some wells produce as much as 600 gpm. There appears to be considerable variability in the lithologic composition of these aquifers, and detailed investigations may identify areas of highest transmissivity, where consistently high well yields could be obtained.

Water-level data indicate that the Peedee and shallower formations contain two aquifer systems which are not necessarily divided at the formational boundary. The shallower of the two systems occurs under water-table, and locally artesian, conditions. It comprises all of the Tertiary and younger deposits and may locally include

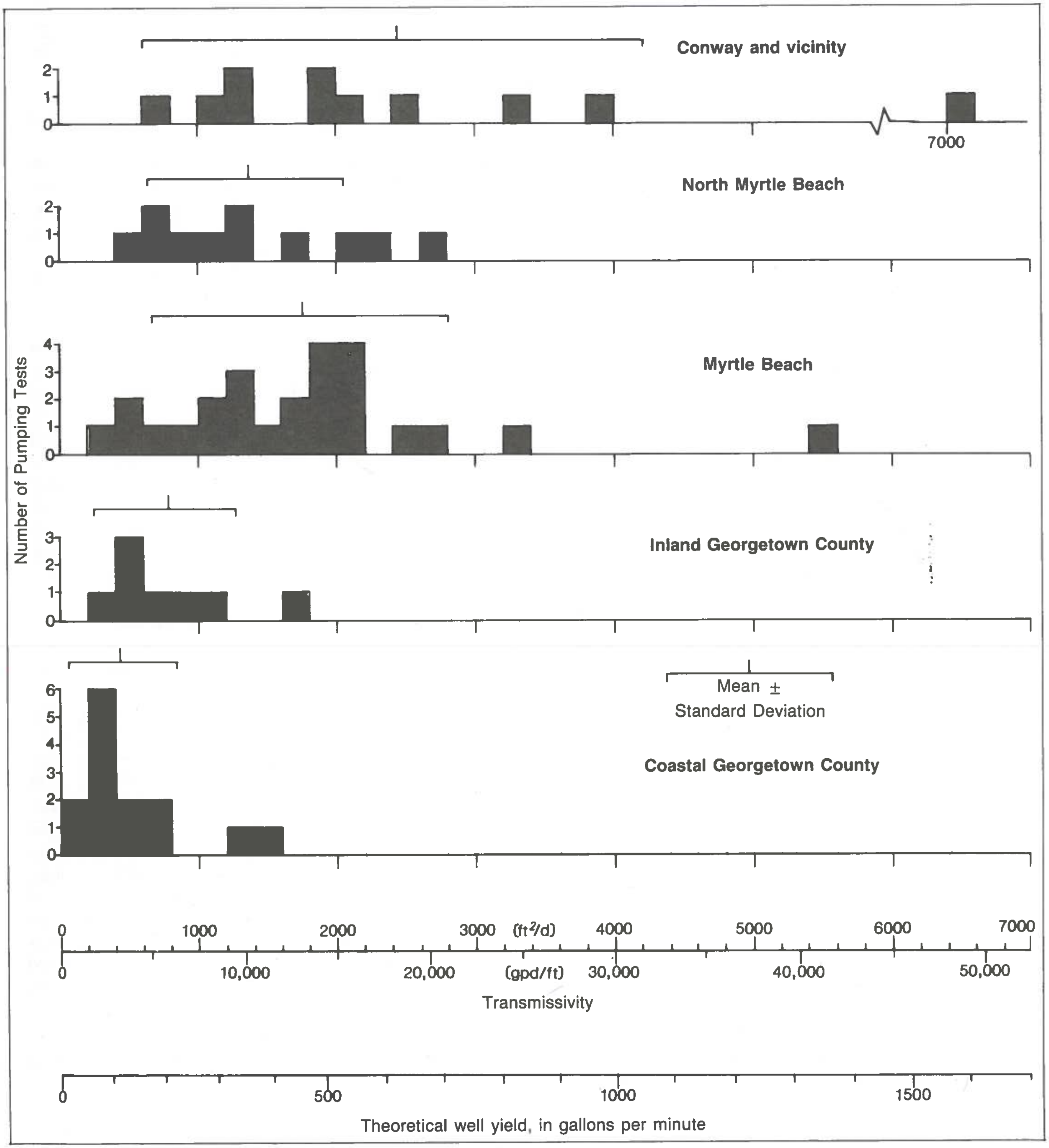

Figure 17: Range and variation in transmissivity, as indicated by pumping tests in the Waccamaw Capacity Use Area.

the upper parts of the Peedee Formation. The water levels tend to reflect the topography and drainage patterns, except where artesian conditions occur. The deeper of the two aquifer systems lies just above the Peedee-Black Creek contact. The water occurs under artesian conditions and the water levels appear to be dropping, but at slower rates than in the Black Creek aquifers. This may indicate that this lower unit is actually a part of a larger aquifer system that includes the Black Creek Formation. Further study is needed to define these aquifers and to perhaps redraw the aquifer and formation boundaries.

Streamflow data for the area indicate that the average volume of water being added to the streams during rain-free periods ranges from near zero to 1.6 cubic feet per second per square mile, or 0 to 1.0 million gallons per day per square mile (mgd/mi²). This range brackets the USGS estimate of 0.6 mgd/mi², which was based on rainfall and evaporation data (W. Lichtler, USGS, oral comm.). This water is derived principally from ground-water storage in the shallow water-table aquifer, which is recharged by local rainfall.

Practically speaking, only a fraction of this volume would be available to wells. The recoverable percentage would depend on a number of factors, including thickness and permeability of the aquifer, spacing of wells, available drawdown, and threat of saltwater intrusion. If 25 percent of the total recharge volume is used to estimate the amount available to wells, then the area from the North Carolina line to Pawleys Island and 4 miles inland (200 mi²) would theoretically yield 30 mgd on a continuing basis (0.6 mgd/mi² $\times$ 0.25 $\times$ 200 mi²). This is a sufficient volume to have supplied the entire capacity use area in 1982, with some to spare (Tables 3 and 4).

The water quality in these formations is highly variable, ranging from very poor to excellent. Local problems have been experienced with elevated levels of iron, hardness, hydrogen sulfide, and color. Otherwise, the water is low in sodium, fluoride, and dissolved solids. Problems with chloride levels have been found to exist along the coastal margin of the area in the shallower deposits. Many of these water quality problems are localized with no apparent pattern to their occurrence. More study would be required to define and map the various water quality zones and to target areas of better quality for possible public supply wells.

WATER-SUPPLY ALTERNATIVES

Mounting concerns over declining water levels and high sodium and fluoride concentrations in water from the Black Creek Formation have generated interest in locating alternative water supplies, especially for the public supplies along the Grand Strand. If present trends continue, the center of the Myrtle Beach cone of depression will reach the top of the Black Creek Formation in 8 to 10 years. If this is allowed to occur, the aquifers will begin to be dewatered, their transmissivities will be reduced, and well yields will eventually decline to levels where it will no longer be economical to use the ground water resource.

Water Use Analysis

Engineers for the Grand Strand Water and Sewer Authority have estimated the peak daily water demand in the year 2000, for coastal Horry County, to be 72 mgd (CH2M Hill, 1984b). This would approximate an average daily demand of 40 to 45 million gallons (Table 4). To meet this demand, the combined water systems in the year 2000 must deliver more than twice what they delivered during 1982.

In Georgetown County, extrapolation of present trends indicates a continuing slight rise in water demand that is probably conservative. The actual water demand may be higher than indicated in Table 4, especially if the Georgetown County Industrial Development Commission is successful in attracting new water-intensive industries.

In order to be considered feasible, any proposed raw-water supply must be able to meet these projected needs with a margin of safety. It must also produce raw water of adequate quality to minimize treatment costs, and it must be reasonably close to the point of use, to reduce transmission costs.

Ten options are discussed below. Some will warrant further examination, while others are added for completeness. Several include continued reliance on the Black Creek aquifers or other ground water sources, others look toward a surface-water solution, and a third group considers possible joint use of surface- and ground-water supplies (conjunctive use).

Ground Water Options

Option 1: No Change from the Present

This would allow development to continue under the present water use patterns, where new wells are drilled in the vicinity of increased demands similar to the pattern of water use shown in Figure 7. If each new well in Horry County were able to pump 600 gpm, approximately 120 wells (70 new ones) would be needed to supply the projected peak demand in the year 2000. With average water demand expected to climb from 16 to 40 mgd, drawdowns in the center of the Myrtle Beach cone of depression will be approximately 320 ft, and a large area of the aquifer will be dewatered and removed from production (Fig. 14). Pumping levels will be deeper than 400 ft, and many, if not all, of the existing wells will probably be abandoned as a result of saltwater intrusion or excessively deep pump settings.

Option 1 is probably not a viable alternative for Horry County, nor for the Grand Strand in particular. Georgetown County, with its more diffuse water use patterns in all areas except the immediate coastline, may be able to continue with this option without major problems for a few years longer than Horry County.

Option 2: Freeze Ground-Water Pumping Rates

This option would place a limit on either the rate of ground-water withdrawal or the depth to which the water level in the wells will be allowed to drop in order to avoid dewatering the aquifer. Additional water will be required to keep pace with local development, and with a cap of this type on the withdrawals from the Black Creek Formation, other sources of supply must be found. These other sources may be either surface-water or alternative ground-water supplies, or a combination of the two.

Option 3: Develop the Peedee Formation and Shallow Aquifers

These aquifers have been studied less intensively than the Black Creek aquifers, but preliminary data indicate that they will not yield as much water to individual wells as the Black Creek. If an average well yield is assumed to be 100 gpm, then the average increased demand of 25 mgd by the year 2000 will require that approximately 260 new wells be drilled to supplement the current pumpage from aquifers in the Black Creek Formation. Estimates from streamflow and weather data indicate that there is a significant volume of water available from these aquifers, perhaps as much as 30 mgd in just the coastal margin of the area.

Water from the Peedee and shallow aquifers is low in sodium and fluoride, and it is in some ways superior to water from the Black Creek aquifers. In most of the study area, however, the water is hard and contains objectionable amounts of iron and hydrogen sulfide. This may prove to be a viable alternative, but more investigation must be undertaken to assess the potential long-term well yields of the aquifer and to document the areal variations in water quality.

Option 4: Develop Alternative Black Creek Well Fields

The coastal margins of the Black Creek aquifers have become severely stressed while the inner regions of the county have remained relatively undeveloped. An alternative inland well field might relieve some of the coastal stresses. Two principal areas may prove fruitful: 1) near the Town of Aynor, a 50-well field on 2-mile centers, and 2) along the Little Pee Dee River, a series of wells could be constructed to tap the alluvial riverbank deposits as well as the Black Creek and Middendorf aquifers (Fig. 18). For both alternatives, additional transmission costs will be incurred in transporting the water from the well field to the point of use at the beach.

Aynor Well Field

Figures 11, 12, and 13 show the town of Aynor to be on the outskirts of the Myrtle Beach cone of depression. If pumping from the existing wells on the Grand Strand were "frozen," and new ground water development took place in this area, the life of the Black Creek aquifers at the beach would be extended (Fig. 18). Indications are that the sodium and fluoride content of the water at Aynor is slightly lower than at the beach, even though the fluoride exceeds the limit set by EPA (Table 2). In addition, the Brittons Neck test well (10Q-p2) and the wells at Hemingway (12S-b1) and Johnsonville (12R-b2) suggest a possibility of developing a fresh-water supply from the aquifers in the Middendorf Formation, which contain only salty water along the coast.

At least one test well and one observation well in each aquifer would be needed to determine the suitability of the area from the standpoints of water quality and quantity. Each well pair should penetrate the entire thickness of the aquifer. These data can then be used to ascertain the capacity of the proposed well field to satisfy future water needs.

Galivants Ferry Well Field

Along the Little Pee Dee River, there may be sites suitable for shallow infiltration wells. These wells would withdraw water from the flood-plain deposits (generally sand and gravel), which are recharged by the river when ground-water levels are lowered sufficiently. The pumped water would be sodium and fluoride free and would be naturally filtered by the riverbed materials. Some infiltration wells at other locations in the State have experienced problems with high iron concentrations. If this occurred, an additional treatment step prior to distribution would be required. Each infiltration-well site may also be suitable for a 300- to 400-ft Black Creek well and a 700- to 800-ft Middendorf well. This triple siting would allow for treatment and onsite mixing prior to transmission of the water, to produce net low sodium, fluoride, and iron concentrations. Careful selection of sites for development along the river will be necessary, to exploit productive areas of the flood plain.

Surface-Water Options

Surface-water bodies, such as lakes and rivers, are generally more visible and more widely understood by the public than are ground-water aquifers. As a result, surface-water sources provide much of the nation's water, even in the presence of considerable ground-water resources. The local surface supplies are usually of a quality that can be treated by using standard techniques, and they are low in sodium and fluoride. There are basically four bodies of water available in Horry County. These are the Pee Dee, Little Pee Dee, and Waccamaw Rivers and the Atlantic Intracoastal Waterway. The Pee Dee canal already exists, to bring water to Georgetown, and probably no additional structures will be required by the year 2000. The canal reportedly can deliver 60 mgd. At present, the International Paper Company is using 30-35 mgd from the canal and the city of Georgetown has a 6-mgd treatment plant withdrawing water from it.

Option 5: Pee Dee River

Only a short stretch of the river borders Horry County, this near the Bucksport Community. The expected low flow of the combined Pee Dee and Little Pee Dee exceeds 1,160 mgd, which is 16 times the expected 72-mgd demand in the year 2000. This river may provide an excellent

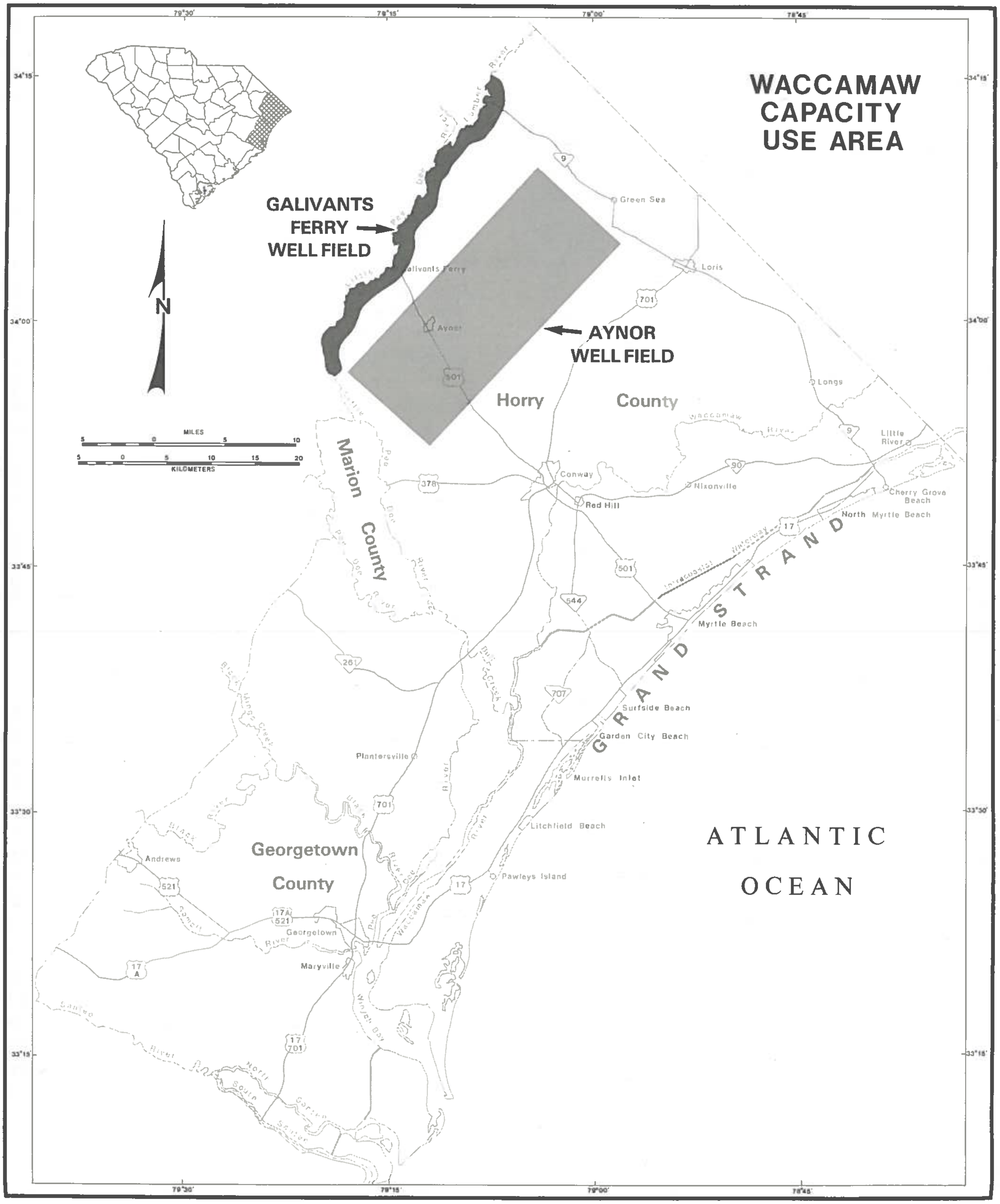

Figure 18: Potential well-field sites for supplemental water supply at the coast.

water supply, if needed; however, it is in the extreme southern portion of the county, and transporting the finished water may be expensive.

Option 6: Little Pee Dee River

The low flow of record for the river at Galivants Ferry is only 155 cfs (100 mgd), with an expected 10-year low flow of 315 cfs (200 mgd). This river may be able to provide the projected 72-mgd demand, but it may develop some navigation or wildlife problems during low-flow conditions. Reservoir storage may help, but with the low relief in the area a reservoir would require large land areas for innundation to create the necessary volume.

Option 7: Waccamaw River

The Waccamaw River has a highly variable discharge. The average flow is 1,200 cfs (775 mgd), but its expected low flow is only 6.8 cfs (4.4 mgd), and its record low flow was only 1 cfs (0.65 mgd). With storage, the Waccamaw may prove to be a valuable supplementary water supply, especially since the high rainfall season (Fig. 5) coincides fairly well with the high water-use season (Fig. 8). However, it will probably not be adequate as the sole source of the area's water.

Option 8: Atlantic Intracoastal Waterway

Preliminary investigations by USGS indicate that the AICW could provide up to 30 mgd of freshwater to the area. The estimated average low flow is 300 cfs (195 mgd) (Carswell and Johnson, 1984). It is not known what effects a withdrawal of 72 mgd would have on the saltwater-freshwater interface in the waterway, nor marine transportation and service facilities.

At present both the city of Myrtle Beach and the Grand Strand Water and Sewer Authority are actively pursuing investigations to test the feasibility of using the AICW to produce dependable supplies of freshwater. The investigations are encouraging, and residents may have a change in their water supply in the next few years.

Conjunctive Options

Many communities across the nation rely on conjunctive systems, the pairing of a ground-water source with a surface-water source, to provide their water needs. This approach may prove necessary in view of increasing demands on the water supply.

Option 9: Mixing with Low-Fluoride Water

One way to reduce the fluoride content of the ground water, and to expand the water-supply capacity at the same time, would be to mix low-fluoride surface water with high-fluoride ground water to dilute the fluoride to acceptable levels. Unfortunately, in order to monitor the mixing and to efficiently manage the system, it would require that the ground water be collected at one point, be mixed in a single operation, and then be distributed. The existing distribution system would have to be extensively altered in order to accomplish this.

Option 10: Aquifer Recharge and Recovery

Near Bradenton, Fla., the Suwannee Limestone aquifer, which contains marginally potable water, is being used to store treated drinking water during the off-season. This stored water is later pumped out during the high-demand season for purposes of peak-load management. This approach has proved to be not only technically feasible but definitely cost effective (CH2M Hill, 1984a).

If a surface-water plant were to become a reality in Horry County, and if the Black Creek aquifers were to prove receptive to injection water, there would be numerous benefits resulting from such a recharge/recovery operation, including:

1. Reduction in the size, or extension of the life, of the initial treatment plant.
2. Continued utilization of the investment in at least a portion of the existing wells as possible injection/recovery points.

At present, it is not known whether such an injection program is possible in this area, owing to uncertainties in the aquifer characteristics and to institutional policies. However, if a test program of this type were to be proved successful, it would improve the prospects for the Grand Strand's water supply for the near future, and it would place one more tool in the hands of the water managers of the area.

SUMMARY AND CONCLUSIONS

The Waccamaw Capacity Use Area, in the eastern corner of South Carolina, is experiencing rapid growth in its residential population, as well as in its summer tourist population. This growth has required a rapid expansion of the local water supply systems, which obtain their water from wells completed in aquifers of the Black Creek Formation of Late Cretaceous age. The peak water demand for the area increased by 88 percent, from 17.1 to 32.2 mgd, between 1974 and 1982, and it is expected to increase by another 140 percent by the year 2000, when it is projected to reach 80 mgd.

As a result of this continuing development, water levels in the aquifers of the Black Creek Formation are declining at rates as great as 9.5 feet per year. The area most impacted by these declines is coastal Horry County in the vicinity of Myrtle Beach. At the current rates of decline, the topmost Black Creek aquifers at Myrtle Beach will begin to be dewatered in 8 to 10 years.

The water in the Black Creek aquifers is very soft, alkaline, and low in iron. It contains high levels of fluoride and total dissolved solids, with local areas having high chloride concentrations. Sodium ranges from 160 to 690 mg/L, which far exceeds the level of 20 mg/L recommended by the American Heart Association for patients with kidney and heart conditions.

These water quality concerns, coupled with declining water levels in the aquifers, have caused the local water suppliers to search for alternative water supplies to supplement, or even replace, the water pumped from the Black Creek aquifers. The most promising of the available options are: development of shallower aquifers; construction of an inland Black Creek well field, away from the present pumping centers; and use of the Atlantic Intracoastal Water (AICW) or the Pee Dee River as a surface water supply. The two available conjunctive options are (1) mixing of low-fluoride surface water with the ground water prior to distribution, and (2) use of the aquifer for storage of excess treated surface water during off-peak seasons for later recovery and use during peak-demand periods.

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