GROUND-WATER RESOURCES OF THE CAPE LOOKOUT NATIONAL SEASHORE, NORTH CAROLINA

U. S. GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATIONS 78-52

PREPARED IN COOPERATION WITH THE
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16. Abstracts Fresh ground water in the Cape Lookout National Seashore occurs in the unconfined aquifer, an upper confined aquifer, and a lower confined aquifer. The unconfined aquifer beneath dunes on the barrier islands is estimated to yield up to 30 gallons per minute of freshwater to a horizontal well, but this aquifer is subject to periodic overwash by the ocean, thus temporarily contaminating the aquifer with saltwater.

The upper confined aquifer is about 90 to 150 feet deep, but is known to contain freshwater only in the Drum Inlet area. The potential yield of this aquifer where it is fresh is unknown because of the possibility of saltwater encroachment.

The lower confined aquifer (150 to 550 feet deep) contains freshwater southeast of Drum Inlet; potential yield is estimated to be up to 500 gallons per minute per well. The estimated yields from all aquifers depend on the position of the saltwater interface at any given site.

Maps of the Seashore are presented to show areas where freshwater may occur in the unconfined aquifer; each map is accompanied by a description of the availability of freshwater.

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USE OF INTERNATIONAL SYSTEM UNITS

The following table gives the factors used to convert U.S. customary units to metric or International System (SI).

Multiply customary units	by	to obtain SI units
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons (gal)	.0038	cubic meters (m^3)
gallons per minute (gal/min)	.0631	liters per second (L/s)
gallons per day (gal/d)	.0038	cubic meters per day (m^3/d)

COVER PHOTOGRAPH: Oblique areal view of the diamond-patterned Cape Lookout lighthouse and lighthouse keeper's residence. Built in 1859, the lighthouse is still in service and is operated by the U.S. Coast Guard. The view is looking toward the southeast from Lookout Bight. Photograph by Joel Arrington, North Carolina Division of Travel and Tourism, September 1973.

GROUND-WATER RESOURCES OF THE CAPE LOOKOUT
NATIONAL SEASHORE, NORTH CAROLINA

By M. D. Winner, Jr.

ABSTRACT

Fresh ground water in the Cape Lookout National Seashore occurs in an unconfined sand aquifer, an upper confined aquifer, and a lower confined aquifer. The unconfined aquifer in areas occupied by dunes will yield as much as 30 gallons per minute of freshwater to a horizontal well. In other parts of the Seashore this aquifer is subject to periodic overwash from the ocean, thus temporarily contaminating the aquifer with saltwater. Some dunes on Shackleford Banks and at Cape Lookout are high enough to offer some protection from overwash to the unconfined aquifer.

The upper confined aquifer occurs between depths of about 90 to 150 feet, but is known to contain freshwater only in the Drum Inlet area and at Harkers Island. The potential yield of this aquifer is unknown, but probably does not exceed 10 to 15 gallons per minute.

The lower confined aquifer occurs between depths of 150 and 550 feet and contains freshwater southeast of Drum Inlet. Potential yield is estimated to be as much as 500 gallons per minute per well. The estimated freshwater yield from all aquifers depends on the position of the saltwater interface at any site.

Water samples from wells in the Seashore generally meet drinking-water standards set by the U.S. Environmental Protection Agency, although some samples contained excess concentrations of chloride, iron, and manganese. Bacterial pollution has been reported to be a problem in some wells in the Seashore.

Maps of the Seashore show areas where freshwater may occur in the unconfined aquifer; each map is accompanied by a description of the availability of freshwater.

INTRODUCTION

The Cape Lookout National Seashore is on a narrow chain of barrier islands along the coast of North Carolina. These islands comprise a 58-mi section of the Outer Banks from Ocracoke Inlet to Beaufort Inlet (fig. 1). The total area of the Seashore is approximately 25 mi^2 and includes, from north to south, Portsmouth Island, the Core Banks, and Shackleford Banks. Island widths in this section of the Outer Banks typically average about 2,000 ft, ranging from slightly more than 500 ft in several places to nearly 2 mi on Portsmouth Island. Altitudes range from sea level to a maximum of about 30 ft on sand dunes on Shackleford Banks. On the Core Banks and Portsmouth Island, altitudes are generally less than 10 ft.

The National Park Service (NPS), which is responsible for the management of the Seashore, is faced with the task of developing it for public recreational use while at the same time maintaining as much of the unspoiled nature of the Seashore habitat as possible. A critical factor, which is directly related to the type and extent of visitor-use facilities that are developed, is the availability of freshwater. The major problem is finding freshwater supplies in an area surrounded by saltwater and underlain by aquifers that contain both freshwater and saltwater. The purpose of this report is to show where favorable conditions exist for the development of fresh ground water supplies in the Seashore, so that the Park Service can determine where to place facilities requiring water supplies.

The emphasis of this investigation was placed on evaluating well-location sites in terms of topographic and geologic conditions as generally described by Winner (1975) for the barrier islands of the Cape Hatteras National Seashore, which are adjacent to and north of the Cape Lookout National Seashore. The occurrence of fresh ground water in an offshore barrier island setting is briefly reviewed in a following section. This report is intended to be used for general planning purposes and the final choice of well locations should be made in the field by qualified persons having access to site-specific data from test wells.

The most favorable areas for the development of ground water in the Seashore are depicted on a series of maps along with the locations of wells for which data have been collected. Each map covers approximately a 3- to 4-mi section of the Seashore at a scale of 1:24,000, and is accompanied by a description of the availability of ground water in that section.

Topographic data used in interpretating ground-water conditions were obtained from topographic maps of the U.S. Geological Survey

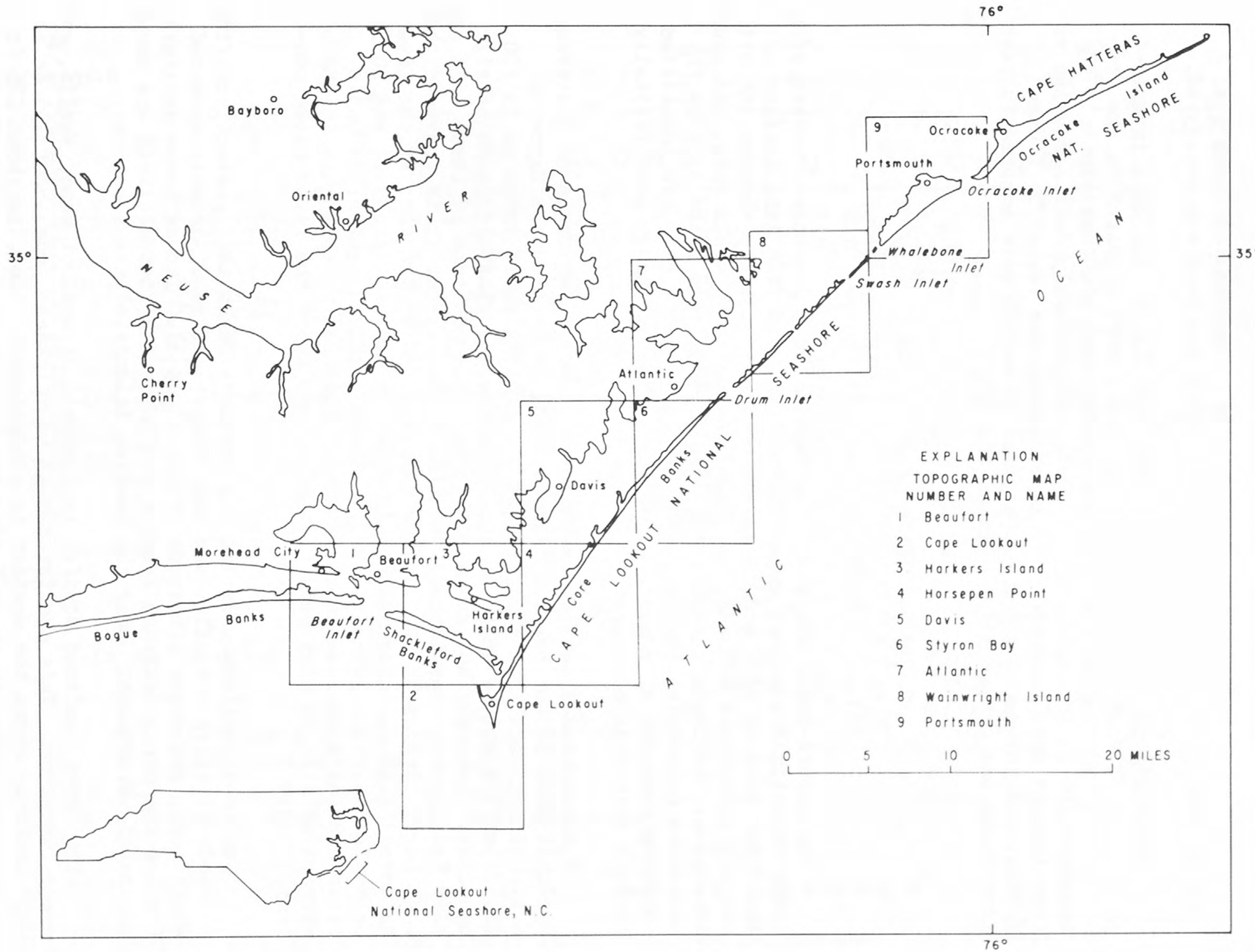

Figure 1.--Location of the Cape Lookout National Seashore and index to topographic maps of the area.

published at a scale of 1:24,000 (fig. 1). Portions of these quadrangles were used as the base maps on which the data are presented.

Hydrologic data are from field data collected for this investigation and from an earlier administrative report prepared by the Geological Survey that outlines the general hydrologic conditions in the Seashore (O. B. Lloyd, written commun. 1967). Early data for wells at Cape Lookout were obtained from a reconnaissance report by LeGrand (1960), and the geologic sections (figs. 2 and 3) were adapted in part from Brown and others (1972, pl. 26 and 50).

GROUND-WATER RESOURCES

Geohydrologic Setting

The ground-water system in the Cape Lookout Seashore consists of a sandy unconfined aquifer, which extends downward from land surface to the first beds of silt and clay, and confined aquifers beneath the silt and clay, composed of sand, partially consolidated shell beds, and sandy limestone. Geologic sections A-A' and A'-A" (figs. 2 and 3) show the sediments underlying the Seashore. The individual beds are identified as being composed of a dominant sediment type, although they typically contain thin beds of the other materials.

The unconfined aquifer is composed of surficial sands of Quaternary age that make up the barrier islands, and, as in the Cape Hatteras National Seashore, the thickness of the aquifer could range up to 100 ft, depending on the depth to locally occurring confining beds of silt and clay. Data are not available to show the position of these silt and clay beds in the Cape Lookout National Seashore, but it is presumed that they occur here as in the similar depositional environment at the Cape Hatteras Seashore, where such beds occur at depths between 10 and 50 ft below land surface (Winner, 1975). The unconfined aquifer shown in figures 2 and 3 represents the maximum thickness of this unit in the absence of silt or clay beds that may occur above the first known confining bed.

Confined aquifers underlie the Seashore below the uppermost confining beds of clays and silt, and are composed of sand, loosely cemented shell beds, and sandy limestone (figs. 2 and 3). Two of these aquifers (called the upper confined aquifer and lower confined aquifer) are known to contain freshwater under the barrier islands of the Seashore.

The upper confined aquifer is composed of beds of sand, shells, and sandy limestone. This aquifer ranges in thickness from about 125 ft at Cape Lookout, where the aquifer is predominantly sand, to about 275 ft at Ocracoke, where it is predominantly a sandy limestone.

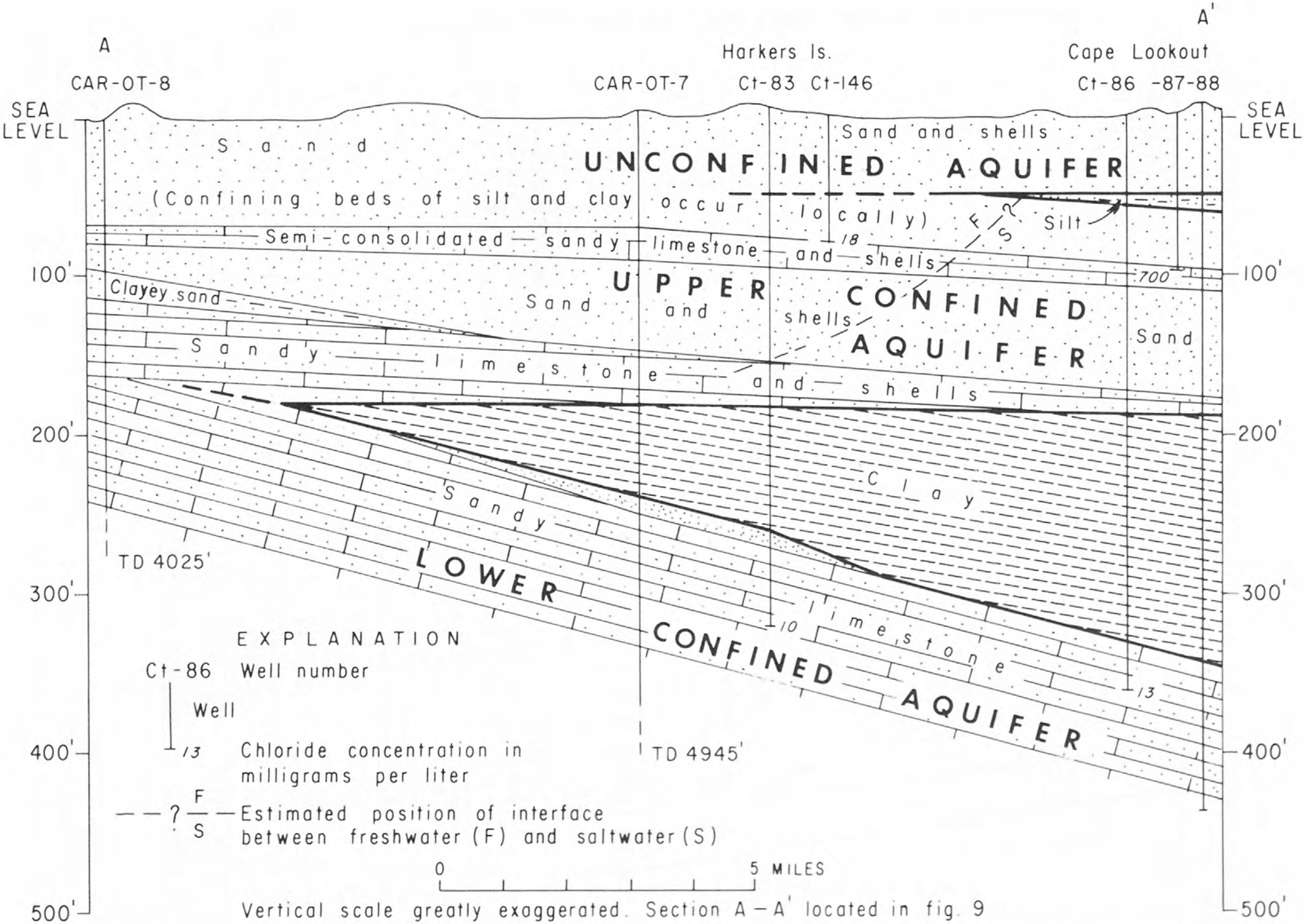

Figure 2.--Hydrogeologic section from 5 miles northwest of Morehead City to Cape Lookout.

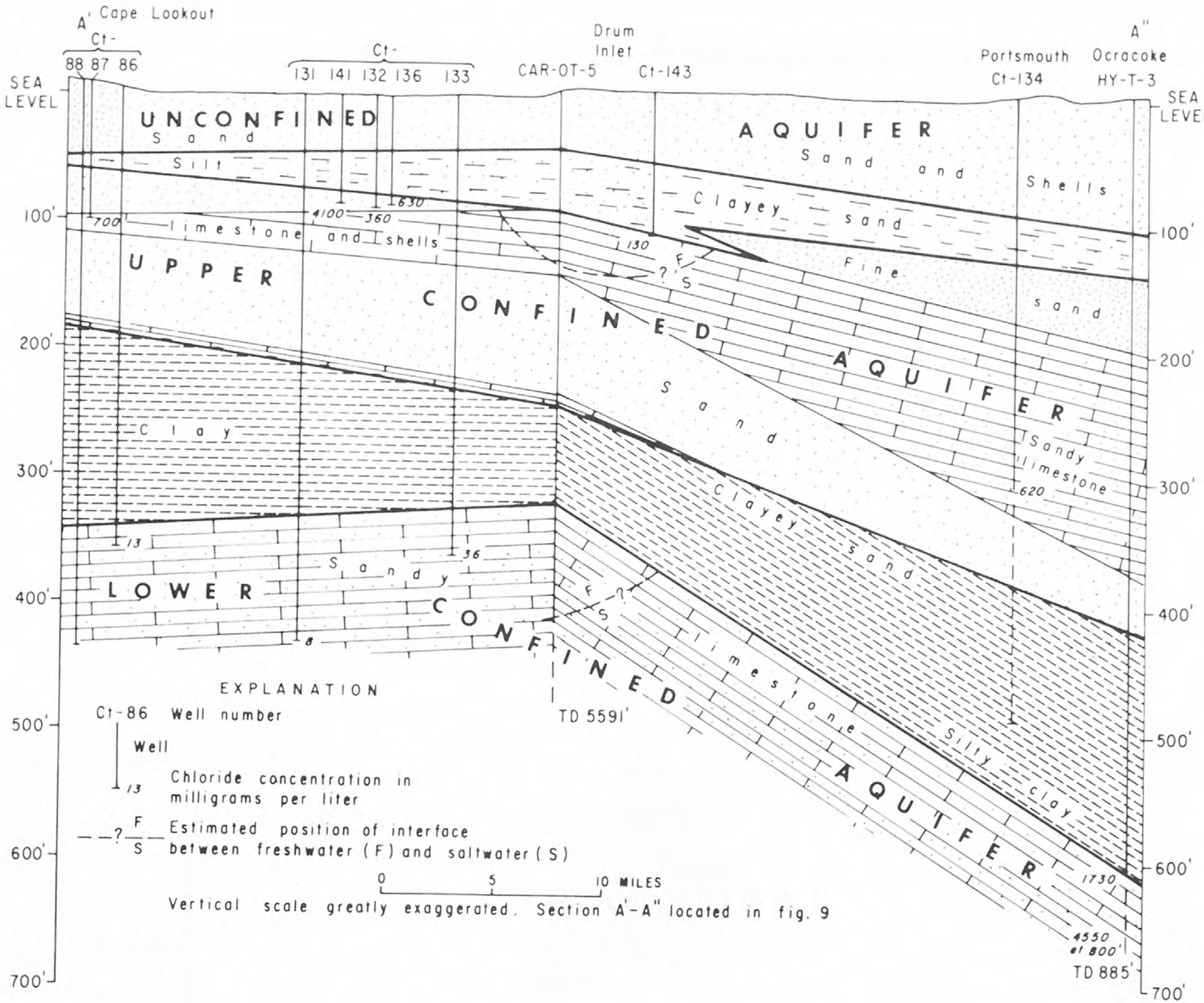

Figure 3.--Hydrogeologic section from Cape Lookout to Ocracoke.

The top of the aquifer, which is confined by beds of silt and clayey sand, ranges in depth from about 60 ft below sea level at Cape Lookout to about 135 ft below at Ocracoke. Most of the upper confined aquifer correlates with the Yorktown Formation of early Pliocene age. Some of the sand and shell beds overlying the uppermost limestone beds of this aquifer may be of Quaternary age (Mixon and Pilkey, 1976).

The lower confined aquifer is described by Mixon and Pilkey (1976) as a massive (over 200 ft thick), medium- to coarse-grained limestone of Oligocene age, ranging in depth along the Seashore from about 340 ft below sea level at Cape Lookout to over 600 ft at Ocracoke (fig. 3). The beds of clay, silty clay, and clayey sand that overlie and confine the lower confined aquifer correlate with the Pungo River Formation of early and middle Miocene age.

Freshwater-Saltwater Relations

Rainfall is responsible for the occurrence and maintenance of the fresh ground water in the unconfined aquifer, and virtually all rain seeps into the aquifer with little or no surface runoff. The movement of fresh ground water through the aquifer is downward and away from the central part of the islands toward discharge points in the ocean and the sound. Figure 4 is an idealized sketch of a typical cross-section of the Core Banks showing the physical features and the occurrence of ground water and its movement within the unconfined aquifer beneath the islands.

Fresh ground water in the unconfined aquifer beneath the islands can be visualized as a lens-shaped mass floating in and above denser saltwater. The size of the freshwater lens is constantly changing because of varying rates of recharge (rainfall) and discharge (movement from the system). Although the salinity of the water usually increases gradually with depth, the demarcation, or interface, between fresh and saltwater is commonly defined as the place where water contains more than 250 mg/L (milligrams per liter) chloride.

The size of the freshwater lens in an aquifer is governed in theory by the Ghyben-Herzberg relationship, which states, in effect, that for every foot of freshwater head above sea level the base of the lens will extend 40 ft below sea level. On the Outer Banks, however, other factors limit the full development of a freshwater lens. They are: (1) presence of confining beds, (2) the effects of diurnal tides, and (3) periodic storm overwash.

For most of the Cape Lookout National Seashore, periodic storm overwash is a major limiting factor in the development of water supplies from the unconfined aquifer. The low, natural dunes that are generally

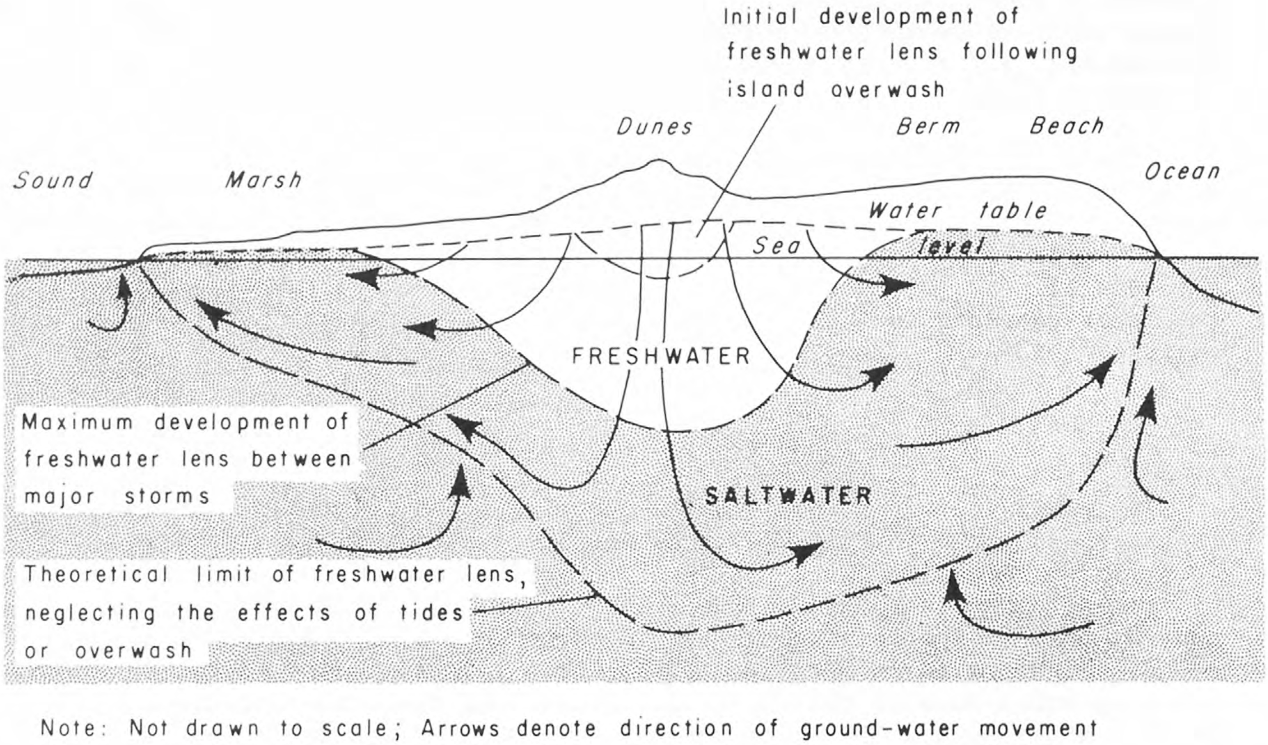

Figure 4.--Occurrence and movement of ground water and the development of a freshwater lens beneath a sandy barrier island.

between 5 and 8 ft above mean sea level are often topped by overwash generated by hurricanes and storms from the northeast. Ho and Tracey (1975) have shown that storm tides at Cape Lookout reach heights of 5 ft and 8 ft above mean sea level on the average once in 6 and 30 years, respectively (fig. 5). Consequently, saltwater periodically inundates the area in which the unconfined aquifer contains freshwater. Weeks or months are required for the saltwater to be flushed from the aquifer and for the freshwater lens to be restored, depending on the amount of saltwater that infiltrates into the aquifer and the amount of freshwater recharge that occurs later.

Some of the larger dune masses on Shackleford Banks and at Cape Lookout have altitudes exceeding 10 ft. These dunes are not likely to be topped by saltwater overwash, except by storm tides that have a recurrence interval greater than 100 years (fig. 5), and thus, would usually protect the underlying freshwater lens.

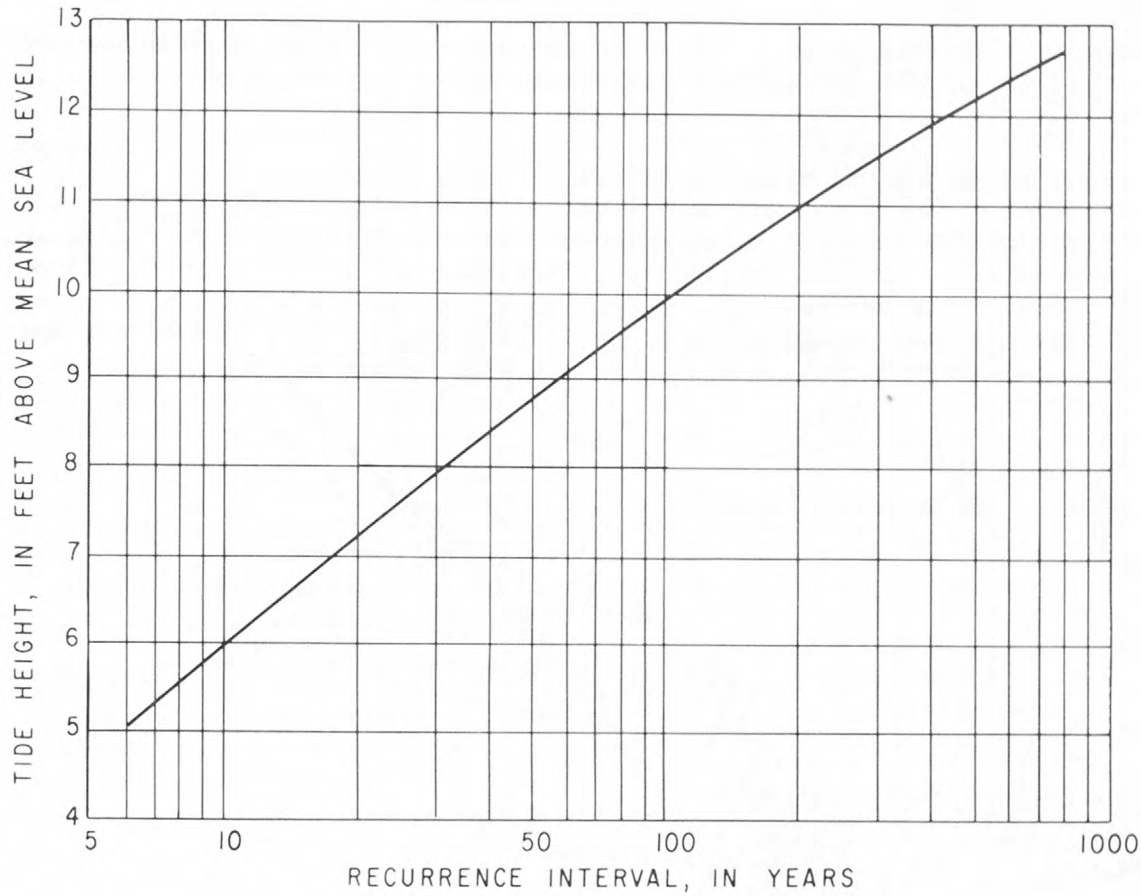

Figure 5.--Frequency of total tide heights at Cape Lookout (after Ho and Tracey, 1975).

The freshwater-saltwater relation in the confined aquifers underlying the seashore is different from that in the unconfined aquifer because the source of the freshwater in the confined aquifers is rain infiltrating the aquifers in their outcrop areas on the mainland to the west. After infiltrating, water moves laterally and downdip (toward the coast), becomes confined, and slowly discharges upward through overlying sediments to the ocean and sound. In this manner, freshwater may replace saltwater in the aquifer for some distance under the ocean or sound.

Freshwater in the upper confined aquifer beneath the Seashore is known to occur only northeast of Cape Lookout near Drum Inlet and in the vicinity of Harkers Island (fig. 6). Near Drum Inlet, water from well Ct-143 (fig. 3) that taps the upper confined aquifer contains a chloride concentration of about 130 mg/L. Neither the horizontal nor vertical extent of the freshwater lens in this area is known. Several wells

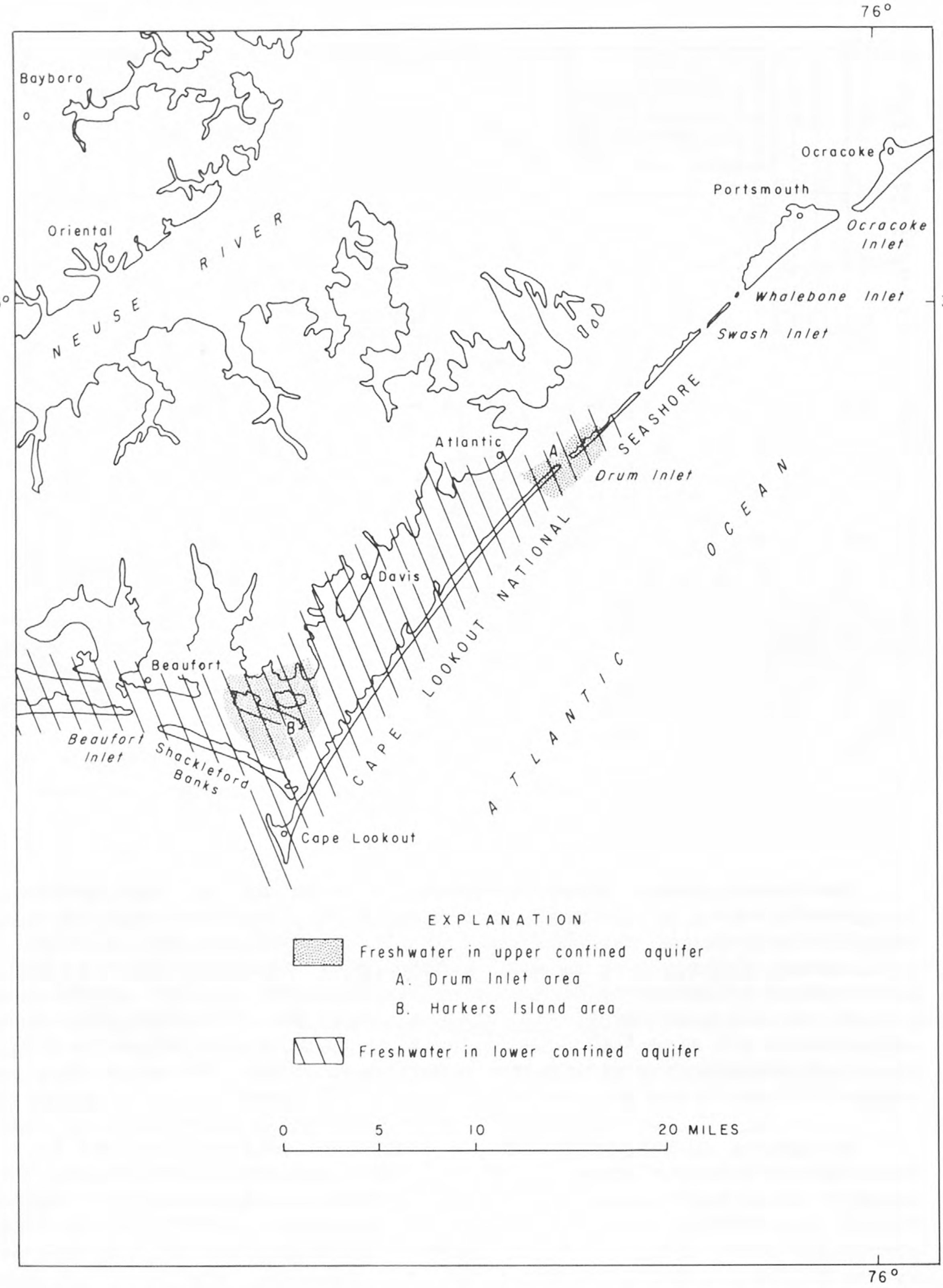

Figure 6.--Occurrence of freshwater in the upper confined aquifer and the lower confined aquifer beneath the Cape Lookout National Seashore.

between Drum Inlet and Cape Lookout are open to this aquifer, but produce salty water with chloride concentrations ranging between 600 and 4,000 mg/L.

The presence of freshwater in the upper confined aquifer at Drum Inlet may be due to (1) upward leakage of freshwater from the lower confined aquifer, (2) freshwater recharge to the upper confined aquifer on the mainland, or (3) a combination of the two effects. The difference in head between the upper confined aquifer and the lower confined aquifer supports the upward leakage hypothesis, as the head in the lower confined aquifer is higher than the head in the upper confined aquifer (fig. 7).

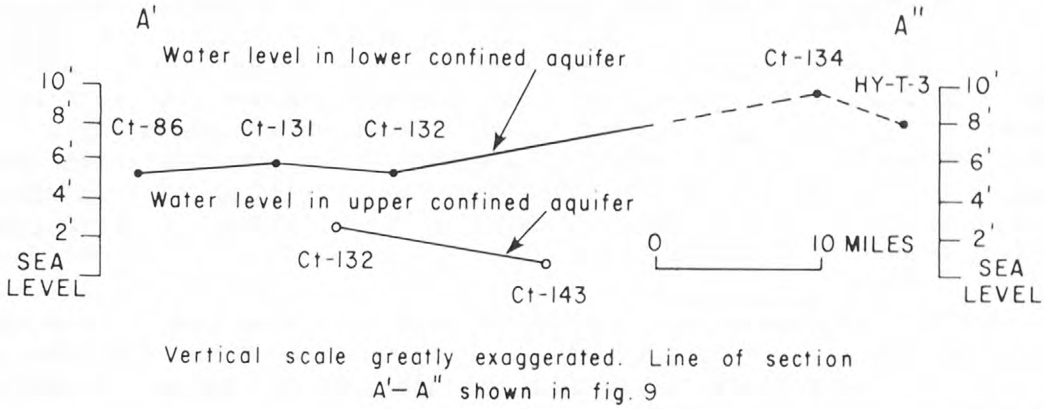

Figure 7.--Water-level profiles in the upper confined aquifer and lower confined aquifer from Cape Lookout to Ocracoke.

The wells on the Core Banks that tap the lower confined aquifer aquifer produce freshwater in the area shown in figure 6. Neither the depth to saltwater nor the northeastern extent of freshwater in the lower confined aquifer are definitely known; however, it is likely that a saltwater-freshwater interface is present northeast of Drum Inlet, based on test-well results at Ocracoke where chloride concentrations ranged from 1,730 to 4,550 mg/L in well HY-T-3 (fig. 3). The position of the interface seaward of the Seashore is unknown.

Well Yields

Unconfined Aquifer.--In the Cape Lookout Seashore the presence of saltwater in the unconfined aquifer at shallow depths is the major factor affecting well yields and the withdrawal of water from the freshwater lens. Any lowering of the water table, either naturally or by pumping a well, will cause a large rise of the saltwater-freshwater interface (as predicted by the Ghyben-Herzberg principle), and, in the case of a pumping well, will likely cause saltwater to move toward the well. Therefore, lowering of the water table, rather than yield, is the key to the withdrawal of freshwater from the unconfined aquifer in the Seashore where the freshwater lens is thin. To avoid saltwater encroachment it is necessary to limit drawdowns.

A practical method for minimizing drawdown is through the use of a horizontal collector (or well) to recover freshwater at or near the top of the lens. When a horizontal well is pumped, the drawdown is spread over a large area, rather than being concentrated at a point, as in a vertical well.

Winner (1975) describes how horizontal wells may be used in the unconfined aquifer in the Cape Hatteras Seashore to minimize saltwater encroachment. This also has direct application to similar conditions in the Cape Lookout Seashore. For example, in those areas of the Cape Lookout Seashore that are subject to overwash and where the depth to saltwater is 5 to 15 ft below sea level, the potential yield for a period of 100 days from a 2-inch diameter 100-foot long horizontal well is estimated to range from 2,000 to 25,000 gal/d (1.4 to 17.4 gal/min) (Winner, 1975). For other depths to saltwater, other yields from such a system may also be estimated.

Shorter versions of the horizontal well have been used on the Core Banks. One well (Ct-135, near Shingle Point) is constructed of two sand points connected to a tee and placed horizontally in a trench about 1 ft below the water table (fig. 8). The screens were covered with crushed shell before the trench was filled. The well, which is connected to a gasoline-powered centrifugal pump, is estimated to yield about 5 to 10 gal/min. Although the depth to saltwater is unknown, the owner reported that the water pumped is usually fresh, except after storm overwash when it becomes salty. A period of two or three months is required before the water from the well is fresh enough to drink again. It is not known how long the well would produce freshwater at the estimated pumping rate, but a sample of water taken from the well after withdrawing about 100 gal contained a chloride concentration of about 20 mg/L. The notable point of these observations is that a significant lens of freshwater has formed in the unconfined aquifer at well Ct-135, which is located about 500 ft from the ocean, where dune heights are about 5 to 6 ft above sea level, and where overwash is expected to occur about every 6 years (fig. 5).

Some areas at Cape Lookout and on the Shackleford Banks have extensive dunes with altitudes up to about 20 and 30 ft above sea level respectively. These dunes protect the underlying freshwater lenses in the unconfined aquifer from overwash during all but the largest storms, so that the lenses have long periods between overwash contamination. These dune masses in the Cape Lookout Seashore are similar in altitude

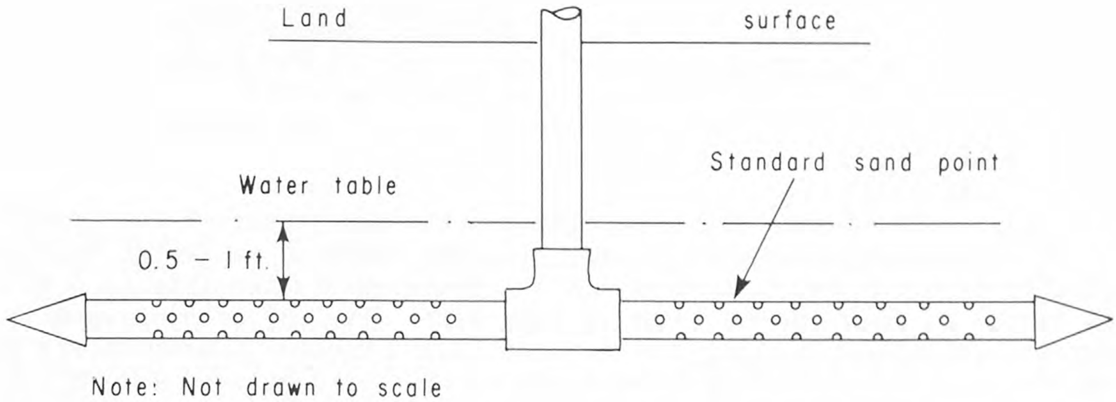

Figure 8.--Construction sketch of a horizontal well (Ct-135) on the Core Banks.

and general size to a dune mass on Bodie Island in the Cape Hatteras Seashore where the Park Service has installed a water-supply system. It is likely that the freshwater lenses under the larger dunes on the Shackleford Banks and at Cape Lookout are comparable in size to the one on Bodie Island (Winner, 1975, pl. 1, section A-A').

The maximum well yield at Bodie Island was estimated to be 100,000 gal/day (69 gal/min), but this estimate was based on the presence of local confining beds that retard upward movement of saltwater toward pumping wells. In the absence of data showing confining beds or the depth to saltwater beneath the dunes on Shackleford Banks or at Cape Lookout, it is advisable not to expect this large a yield from a shallow well in these areas.

Upper Confined Aquifer.--Little is known about the yield of wells open to the upper confined aquifer, either on the mainland or on the Seashore. Well Ct-143 is intermittently pumped at a rate of between 5 and 10 gal/min and well Ct-146 was pumped at 5 gal/min, but these yields are not representative of the maximum yields possible from similar sand and limestone aquifers elsewhere in the area (LeGrand, 1960). The relatively high chloride concentration in water from well Ct-143 (130 mg/L), however, suggests that a freshwater-saltwater interface in the aquifer is nearby, and that sustained pumping rates of 5 to 10 gal/min or more from Ct-143 could induce saltwater encroachment. Additional data are needed to estimate optimum sustained yields from wells in the upper confined aquifer in the Drum Inlet area.

Lower Confined Aquifer.--Yields of wells tapping the lower confined aquifer have been reported to be as much as 750 gal/min (LeGrand, 1960). The towns of Beaufort and Morehead City pump from this aquifer and have wells that yield 430 and 550 gal/min, respectively; well Ct-88 at Cape Lookout reportedly was pumped at a rate of 180 gal/min. It is likely that properly constructed and developed wells in the lower confined aquifer could produce 500 gal/min, or more, throughout the Seashore area.

The wells on the Core Banks that tap the upper part of the lower confined aquifer produce freshwater, but the depth to saltwater in this aquifer is not known. Although the freshwater-saltwater interface is estimated to be in the vicinity of Drum Inlet (fig. 3), the seaward extent of freshwater along the Seashore is not known. Consequently, the optimum well yield for the lower confined aquifer cannot be determined without additional data.

Water Quality

Chemical analyses of samples of ground water from the aquifers beneath the Cape Lookout Seashore are presented in tables 1 and 2. Table 1 lists chemical constituents and physical properties of water samples collected in June 1977 and analyzed by the U.S. Geological Survey laboratory in Atlanta, Georgia. Earlier analyses that are available for each well are also tabulated for comparison, although not all of the listed constituents or properties were analyzed in each case.

The maximum limit for each parameter for public water supplies, as recommended by the National Academy of Sciences and National Academy of Engineering (1973)--where established--is also listed in table 1 as a guide to the general water quality. Where a constituent in a given analysis equals or exceeds the recommended limit, it is underlined.

Table 2 is a list of analyses where only a few constituents were determined, primarily to serve as an indication of the presence of saltwater. Locations of the wells in tables 1 and 2 are shown in figures 10-26, except for wells HY-T-3, Ct-83, and Ct-146 which are shown in figure 9.

None of the water samples indicated any evidence of man-made chemical pollution of the ground water as might be indicated by trace elements such as lead or mercury, or by nitrogen compounds. The constituents that most commonly exceed the recommended limits are chloride, iron, and manganese. Excessive chloride in the area is indicative of the presence of saltwater; excessive iron and manganese occur naturally in some ground water, and may also be dissolved from well casings or pumping equipment. A few samples showed excessive fluoride and sulfate, but these constituents probably appear in conjunction with saltwater in the respective samples.

Table 1.--Constituents and properties of ground water in the Cape Lookout National Seashore and vicinity

Constituent or property		Maximum recommended limit (NAS and NAE, 1973)	Ct-83 (analysis, USGS)	Ct-86 (analysis, USGS)	Ct-86 (analysis, N.C. Div. Health)	Ct-86 (analysis, USGS)
Alk,tot (as $CaCO_3$)	mg/L					405
Aluminum dissolved	ug/L	-		100		20
Arsenic,dissolved	ug/L	100			<10	5
Barium,dissolved	ug/L	1,000				0
Bicarbonate	mg/L	-	458	475		470
Cadmium,dissolved	ug/L	10			<10	0
Calcium,dissolved	mg/L	-		27	28.8	27
Carbonate	mg/L	-		0		0
Chloride,dissolved	mg/L	250	10	13	12	15
Chromium,hexavalent	ug/L	50			<50	0
Color (Pt-Co units)		75		20	60	23
Cyanide	mg/L	.2				.01
Fluoride,dissolved	mg/L	1/ 1.6		.8	.81	.7
Hardness, noncarb	mg/L	-		0		0
Hardness,total	mg/L	-	285	141	140	130
Iron,dissolved	ug/L	300		5,400	6,750	910
Lead,dissolved	ug/L	50			<50	0
Magnesium,dissolved	mg/L	-		18	16.8	16
Manganese,dissolved	ug/L	50		50	50	30
Mercury,dissolved	ug/L	2				.0
Nitrogen NO_2 as N	mg/L	1				.00
NO_2+NO_3 as N	mg/L	(2)		3/ .3		.00
pH,field		-				7.2
pH,lab		-	7.1	8.0	8.2	8.0
Potassium,dissolved	mg/L	-		7.3		6.4
Residue,dis 180°C	mg/L	-		441		485
SAR		-				5.3
Silica,dissolved	mg/L	-		14	23	40
Sodium,dissolved	mg/L	-		124		140
Sodium percent		-				68
Sp. conductance,lab	mmhos	-	699	685		746
Sulfate,dissolved	mg/L	250	1	.2		3.1
Water temp (Deg C)		-				20.0
Well depth (feet)		-	315	364	364	364
Collection date			10-8-52	11-29-66	4-20-77	6-16-77
Aquifer			lower confined	lower confined	lower confined	lower confined

1/ Value differs in different areas. The indicated value applies to the Cape Lookout area

2/ 10 mg/L for NO_3 as N

3/ NO_3 only

Table 1.--Constituents and properties of ground water in the Cape Lookout National Seashore and vicinity--Continued

Constituent or property		Ct-87 (analysis, USGS)	Ct-129 (analysis, USGS)	Ct-130 (analysis, USGS)	Ct-131 (analysis, USGS)	Ct-131 (analysis, USGS)
Alk,tot (as $CaCO_3$)	mg/L					360
Aluminum dissolved	ug/L		0	300	100	20
Arsenic,dissolved	ug/L					3
Barium,dissolved	ug/L					0
Bicarbonate	mg/L	438	119	126	435	440
Cadmium,dissolved	ug/L					0
Calcium,dissolved	mg/L	44	38	148	37	46
Carbonate	mg/L	0	0	0	0	0
Chloride,dissolved	mg/L	695	11	670	7.8	8.4
Chromium,hexavalent	ug/L					0
Color (Pt-Co units)		20	3	5	15	10
Cyanide	mg/L					.00
Fluoride,dissolved	mg/L	.8	.2	.2	.5	.5
Hardness, noncarb	mg/L	12	13	428	0	0
Hardness,total	mg/L	371	110	532	198	220
Iron,dissolved	ug/L	106,000	50	6,500	0	20
Lead,dissolved	ug/L					2
Magnesium,dissolved	mg/L	63	4.2	39	26	25
Manganese,dissolved	ug/L	880	10	30	10	10
Mercury,dissolved	ug/L					.3
Nitrogen NO_2 as N	mg/L					.00
NO_2+NO_3 as N	mg/L	[3] .8	[3] 1.7	[3] .7	[3] .3	.01
pH,field						7.3
pH,lab		7.6	7.9	7.4	7.6	7.7
Potassium,dissolved	mg/L	25	.8	4.3	12	11
Residue,dis 180°C	mg/L	1,670	140	1,480	457	446
SAR						2.5
Silica,dissolved	mg/L	31	3.8	4.3	35	40
Sodium,dissolved	mg/L	465	8.2	252	80	85
Sodium percent						44
Sp. conductance,lab	mmhos	2,820	236	2,290	685	726
Sulfate,dissolved	mg/L	114	9.6	44	23	21
Water temp (Deg C)						20.0
Well depth (feet)		98	15	5	430	430
Collection date		11-29-66	11-29-66	11-29-66	11-29-66	6-16-77
Aquifer		upper confined(?)	un-confined	un-confined	lower confined	lower confined

[3] NO_3 only

Table 1.--Constituents and properties of ground water in the Cape Lookout National Seashore and vicinity--Continued

Constituent or property		Ct-132 (analysis, USGS)	Ct-132 (analysis, N.C. Div. Health)	Ct-132 (analysis, N.C. Div. Health)	Ct-133 (analysis, USGS)	Ct-133 (analysis, USGS)
Alk, tot (as $CaCO_3$)	mg/L		440	405		360
Aluminum dissolved	ug/L	100			100	20
Arsenic, dissolved	ug/L		<10	<10		1
Barium, dissolved	ug/L					0
Bicarbonate	mg/L	528			427	440
Cadmium, dissolved	ug/L		<10	<10		0
Calcium, dissolved	mg/L	96	108	148	53	52
Carbonate	mg/L	0			0	0
Chloride, dissolved	mg/L	342	355	630	36	44
Chromium, hexavalent	ug/L		<50	<50		0
Color (Pt-Co units)		25	28	32	15	10
Cyanide	mg/L					.00
Fluoride, dissolved	mg/L	.3	.26	.23	.6	.5
Hardness, noncarb	mg/L	0			0	0
Hardness, total	mg/L	322	336	439	236	230
Iron, dissolved	ug/L	1,700	1,180	8,900	60	60
Lead, dissolved	ug/L		<50	<50		0
Magnesium, dissolved	mg/L	20	16.5	14.8	25	24
Manganese, dissolved	ug/L	110	100	420	10	10
Mercury, dissolved	ug/L					.2
Nitrogen NO_2 as N	mg/L					.00
NO_2+NO_3 as N	mg/L	3/ .7			3/ .2	.04
pH, field						7.3
pH, lab		7.5	7.9	7.8	7.6	7.5
Potassium, dissolved	mg/L	22	18	19.0	15	14
Residue, dis 180°C	mg/L	1,060			474	495
SAR						2.7
Silica, dissolved	mg/L	41		32	33	38
Sodium, dissolved	mg/L	258	290	375	78	95
Sodium percent						46
Sp. conduct	1,760			733	800	
Sulfate, dissolved	mg/L	.8			17	13
Water temp (Deg C)						20.0
Well depth (feet)		91	91	91	366	366
Collection date		11-29-66	11-22-76	3-25-77	11-29-66	6-17-77
Aquifer		upper confined	upper confined	upper confined	lower confined	lower confined

3/ NO_3 only

Table 1.--Constituents and properties of ground water in the Cape Lookout National Seashore and vicinity--Continued

Constituent or property		Ct-134 (analysis, USGS)	Ct-134 (analysis, USGS)	Ct-135 (analysis, USGS)	Ct-136 (analysis, private lab)	Ct-136 (analysis, N.C. Div. Health)
Alk,tot (as $CaCO_3$)	mg/L		480	80		435
Aluminum dissolved	ug/L	0	40	20		
Arsenic,dissolved	ug/L		2	1	10	<10
Barium,dissolved	ug/L		100	0	<30	
Bicarbonate	mg/L	578	580	97		
Cadmium,dissolved	ug/L		0	0	<2	<10
Calcium,dissolved	mg/L	26	26	24		100
Carbonate	mg/L	0	0	0		
Chloride,dissolved	mg/L	620	630	20	605	349
Chromium,hexavalent	ug/L		0	0	<8	<50
Color (Pt-Co units)		5	10	3		25
Cyanide	mg/L		.00	.00	<.03	
Fluoride,dissolved	mg/L	1.8	1.4	.2		.26
Hardness, noncarb	mg/L	0	0	22		
Hardness,total	mg/L	306	300	100		315
Iron,dissolved	ug/L	240	10	10	290	2,250
Lead,dissolved	ug/L		0	2	<25	<50
Magnesium,dissolved	mg/L	59	58	10		15.8
Manganese,dissolved	ug/L	0	0	10	43	140
Mercury,dissolved	ug/L		.1	.0	<1	
Nitrogen NO_2 as N	mg/L		.00	.00	1	
NO_2+NO_3 as N	mg/L		.00	.87	[3] .1	
pH,field			7.3	7.1		
pH,lab		7.9	8.1	8.1		8.0
Potassium,dissolved	mg/L	29	29	2.2		17
Residue,dis 180°C	mg/L	1,860	1,910	152	1,478	
SAR			15	.4		
Silica,dissolved	mg/L	31	31	2.8		17
Sodium,dissolved	mg/L	560	600	10		260
Sodium percent			79	17		
Sp. conductance,lab	mmhos	3,100	3,210	256		
Sulfate,dissolved	mg/L	249	240	6.1	18	
Water temp (Deg C)			20.5	22.0		
Well depth (feet)		490 (?)	490 (?)	5	89	89
Collection date		April 1960	6-22-77	6-16-77	7-21-76	3-25-77
Aquifer		lower confined	lower confined	un- confined	upper confined	upper confined

[3] NO_3 only

Table 1.--Constituents and properties of ground water in the Cape Lookout National Seashore and vicinity--Continued

Constituent or property		Ct-136 (analysis, USGS)	Ct-137 (analysis, USGS)	Ct-141 (analysis, private lab)	Ct-141 (analysis, N.C. Div. Health)	Ct-141 (analysis, N.C. Div. Health)
Alk,tot (as $CaCO_3$)	mg/L	380	120		350	345
Aluminum dissolved	ug/L	20	60			
Arsenic,dissolved	ug/L	3	5	<2	<10	<10
Barium,dissolved	ug/L	0	100	<30		
Bicarbonate	mg/L	460	150			
Cadmium,dissolved	ug/L	0	0	<2	<10	<10
Calcium,dissolved	mg/L	140	49		370	370
Carbonate	mg/L	0	0			
Chloride,dissolved	mg/L	630	13	4,174	4,000	4,150
Chromium,hexavalent	ug/L	0	0	28	<50	<50
Color (Pt-Co units)		30	5		15	14
Cyanide	mg/L	.00	.01	<.03		
Fluoride,dissolved	mg/L	.2	.1	<.1	.23	.23
Hardness, noncarb	mg/L	42	8			
Hardness,total	mg/L	420	130		1,910	1,941
Iron,dissolved	ug/L	2,200	350	90	130	160
Lead,dissolved	ug/L	2	0	<25	<50	<50
Magnesium,dissolved	mg/L	17	2.0		240	248
Manganese,dissolved	ug/L	270	0	71	80	80
Mercury,dissolved	ug/L	.0	.0	<1		
Nitrogen NO_2 as N	mg/L	.00	.00	<.001		
NO_2+NO_3 as N	mg/L	.00	.04	3/ .02		
pH,field		7.1	6.9			
pH,lab		7.7	8.1		7.6	8.1
Potassium,dissolved	mg/L	18	1.1		84	
Residue,dis 180°C	mg/L	1,550	182	8,126		
SAR		8.7	.5			
Silica,dissolved	mg/L	44	6.9			
Sodium,dissolved	mg/L	410	12		1,890	
Sodium percent		67	17			
Sp. conductance,lab	mmhos	2,520	269			
Sulfate,dissolved	mg/L	14	5.7	232		
Water temp (Deg C)		20.0	21.0			
Well depth (feet)		89	7	90	90	90
Collection date		6-16-77	6-20-77	7-21-76	11-22-76	4-20-77
Aquifer		upper confined	un-confined	upper confined	upper confined	upper confined

3/ NO_3 only

Table 1.--Constituents and properties of ground water in the Cape Lookout National Seashore and vicinity--Continued

Constituent or property		Ct-143 (analysis, private lab)	Ct-143 (analysis, N.C. Div. Health)	Ct-143 (analysis, USGS)	Ct-146 (analysis, USGS)	Hy-T-3 (analysis, USGS)	Hy-T-3 (analysis, USGS)
Alk,tot (as $CaCO_3$)	mg/L		415	390	210		
Aluminum dissolved	ug/L			50	300	300	500
Arsenic,dissolved	ug/L	<8	<10	2			
Barium,dissolved	ug/L	<30		100			
Bicarbonate	mg/L			480	256	586	456
Cadmium,dissolved	ug/L	<2	<10	0			
Calcium,dissolved	mg/L		154	160	47	37	128
Carbonate	mg/L			0	0	0	0
Chloride,dissolved	mg/L	135	127	130	18	1,730	4,550
Chromium,hexavalent	ug/L	<8	<50	0			
Color (Pt-Co units)			26	20	25	5	5
Cyanide	mg/L	<.03		.01			
Fluoride,dissolved	mg/L	<.1	.16	.2	.2	2.0	.1
Hardness, noncarb	mg/L			76	0	78	1,290
Hardness,total	mg/L		457	470	195	588	1,660
Iron,dissolved	ug/L	<10	70	90	1,000	3,600	2,500
Lead,dissolved	ug/L	<25	<50	0			
Magnesium,dissolved	mg/L		17.5	17	19	113	326
Manganese,dissolved	ug/L	<8	30	20	70	0	0
Mercury,dissolved	ug/L	<1		.0			
Nitrogen NO_2 as N	mg/L	.002		.00			
NO_2+NO_3 as N	mg/L	3/ .03		.02	3/ .4		
pH,field				6.9			
pH,lab			7.8	7.8	7.7	7.8	8.0
Potassium,dissolved	mg/L			7.0	3.7	58	110
Residue,dis 180°C	mg/L	550		661	286	3,890	8,660
SAR				1.2			
Silica,dissolved	mg/L			47	42	29	19
Sodium,dissolved	mg/L			60	17	1,220	2,380
Sodium percent				21			
Sp. conductance,lab	mmhos			1,110	426	6,500	13,200
Sulfate,dissolved	mg/L	2.8		3.1	1.4	372	401
Water temp (Deg C)				21.0			
Well depth (feet)		111	111	111	71	600	800
Collection date		7-21-76	4-22-77	6-21-77	11-30-66	April 1960	April 1960
Aquifer		upper confined	upper confined	upper confined	upper confined	lower confined	lower confined

3/ NO_3 only

Table 2.--Selected constituents and physical properties of ground water in the Cape Lookout National Seashore

(Analyses by U.S. Geological Survey)

Parameter	Ct-132	Ct-138	Ct-139	Ct-140	Ct-141	Ct-142	Ct-144	Ct-145
Well depth (ft)	a91	b5	b5	b10	a90	b6	b8	b3
Calcium (mg/L)	99	78	71	44	370	47	37	4.8
Magnesium (mg/L)	17	12	51	3.2	260	7.6	11	4.1
Total Hardness (mg/L)	320	240	390	120	2,000	150	140	29
Chloride (mg/L)	360	170	470	19	4,100	22	68	58
Specific conductance (mmhos)	1,800	543	1,890	330	11,600	346	543	350
Date of collection	6-17-77	6-20-77	6-20-77	6-17-77	6-17-77	6-17-77	6-22-77	6-22-77

a Upper confined aquifer
b Unconfined aquifer

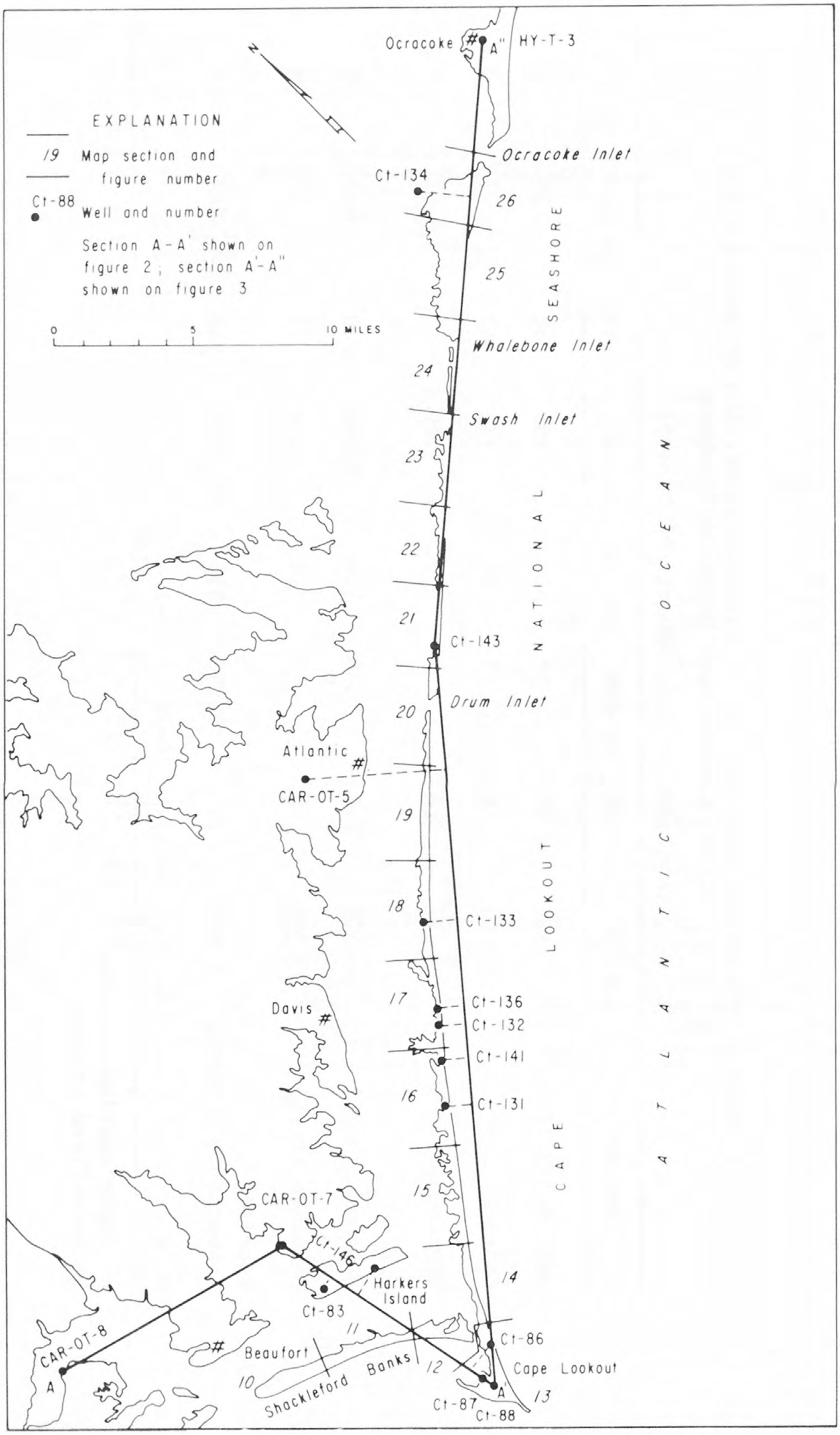

Figure 9.--Location of map and geologic sections along the Cape Lookout National Seashore.

Bacterial pollution has been reported to be a frequent water-quality problem in wells in the Seashore. Water samples from several wells that were collected by the Park Service and analyzed by the North Carolina State Board of Health have contained coliform bacteria in excess of 16 per 100 milliliters of sample. Sources of bacteria can be either external to the well, or from within the well and distribution system. Shallow wells in the unconfined aquifer are specially susceptible to pollution sources outside the well. At some campsites the discharge ends of sewage pipes are at the ground surface only a few feet from water-supply wells. Sewage thus discharged is likely to be drawn back to the well during pumping without benefit of sufficient filtration. Waste from fish-cleaning sinks observed at one well site could likewise contribute to bacterial pollution, both from seepage through the ground and from seepage down improperly grouted well casings.

Bacteria may enter a well system through improperly sealed pumps and leaky distribution lines, surface-water drainage into the well, and improperly sealed storage tanks. Most of the "home-built" water-storage facilities at campsites in the Seashore are not adequately protected from potential sources of pollution such as birds, wind-blown dust, and insects.

Unconfined Aquifer.--Where ground water in the unconfined aquifer is fresh, it is generally of good quality. It has generally less than 120 mg/L total hardness and usually has less than 200 mg/L dissolved solids. (See Ct-135 and Ct-137 in table 1.) Iron may exceed the recommended limit in localized areas, but may also be added to the ground water from contact with well casing, pump parts, pipes, or storage tanks.

Ground water from wells located in marsh areas, located in dunes surrounding marshes, or penetrating buried marsh deposits may be highly colored. Water from wells Ct-144 and Ct-145 on Portsmouth Island had a yellow and dark brown color, respectively. Areas where ground water from the unconfined aquifer may be colored are shown on figures 10-26.

Upper Confined Aquifer.--Fresh ground water in the upper confined aquifer may have more than 200 mg/L total hardness and may contain excessive iron and manganese. Analyses of water from wells Ct-143 and Ct-146 (table 1) are the only examples of freshwater from this aquifer in the Seashore area.

Well Ct-87 at Cape Lookout (fig. 2) was reported to have been drilled to over 400 ft in depth, but was sounded to 98 ft. It is not definitely known whether the water analysis (table 1) typifies the upper confined aquifer, or is a mixture of waters from different aquifers. Similarly, well Ct-134 near Portsmouth (fig. 3) was reported to be about 490 ft deep, but was sounded to slightly over 300 ft. Water from this well may be a mixture from more than one aquifer, as the casing (or open hole?) may have collapsed.

Lower Confined Aquifer.--Analyses of water from wells Ct-83, Ct-86, Ct-131, and Ct-133 (table 1) typify the quality of freshwater in this aquifer in the Seashore. Like that in the upper confined aquifer, the ground water generally has a total hardness greater than 200 mg/L and may contain excessive amounts of iron and manganese locally. Analyses of water from test well Hy-T-3 shows that the lower confined aquifer contains saltwater at Ocracoke.

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DESCRIPTION OF MAP SECTIONS

The following descriptions summarize the availability of ground water throughout the Cape Lookout National Seashore beginning with the Shackleford Banks at Beaufort Inlet and extending to Portsmouth Island at Ocracoke Inlet (fig. 9). Each map section is described in terms of general physical characteristics and facilities such as camps or residences. Known sources of water supply for these facilities are also described, and, finally, the potential for ground-water development is reviewed for each of the aquifers. Areas where freshwater lenses may occur in the unconfined aquifer are shown on each map section and are described below in the explanation for figures 10-26. The delineation of these areas is based on the recurrence of the 6-year and 100-year total tide height as shown in figure 5. The areal distribution of freshwater in the upper confined and lower confined aquifers is shown in figure 6.

EXPLANATION FOR FIGURES 10-26

Areas subject to rare inundations of saltwater (100-year recurrence interval); water-level range 3 to 8 ft above sea level; depth to saltwater estimated to be more than 25 ft below sea level; potential yield of vertical wells is dependent on depth to saltwater and presence of confining beds and is estimated to be 15 to 30 gal/min

Areas subject to rare inundations of saltwater, but adjacent to or surrounded by areas subject to frequent saltwater inundation (6-year recurrence interval); pumping effects in vertical wells may induce saltwater encroachment; use of horizontal wells is more satisfactory

Areas subject to frequent inundation by saltwater (6-year recurrence interval); weeks or months may be required to reestablish a significant lens of freshwater; water-level range 1 to 3 ft above sea level; depth to saltwater estimated to be less than 25 ft below sea level; potential yield 1 to 15 gal/min from horizontal wells

Areas where ground water may be highly colored due to marsh deposits

Area is subject to frequent inundation by saltwater; water level less than 1 ft above sea level, and saltwater occurs at shallow depths; not suitable for development of ground water in the unconfined aquifer

Ct-134
● Well and identification number

Contour interval 5 ft; datum is mean sea level

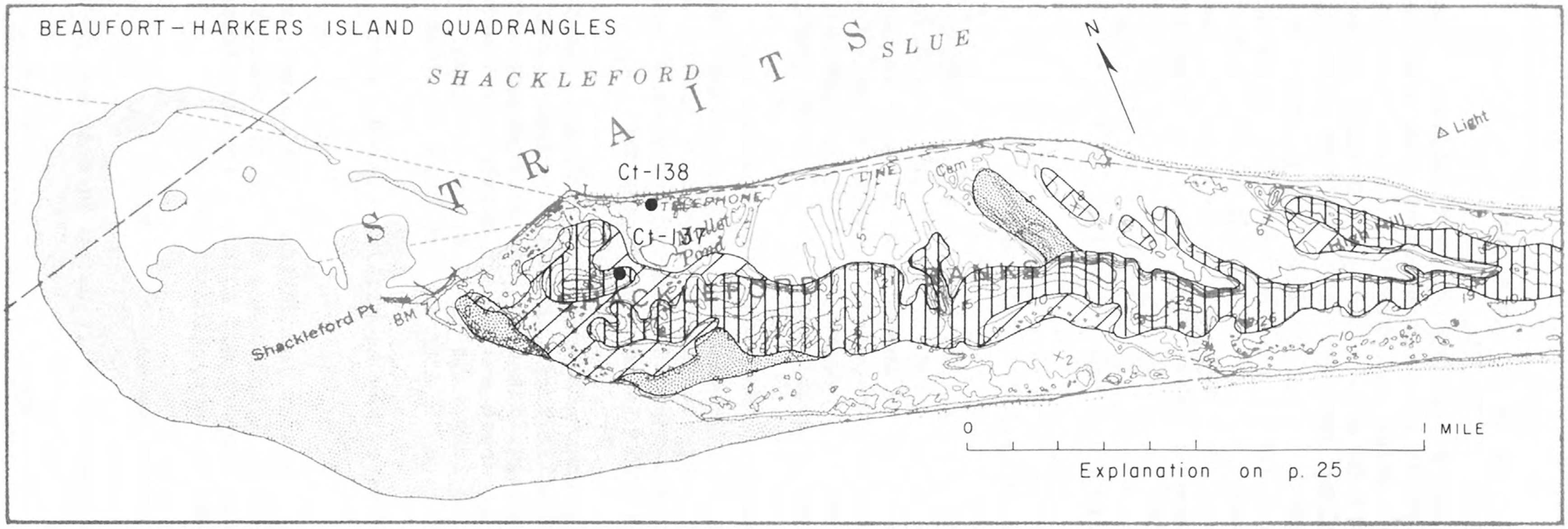

Figure 10.--Western part of Shackleford Banks.

Western part of Shackleford Banks.--This section of the Seashore, shown in figure 10, is the western third of the Shackleford Banks, and contains the largest dune area and remnants of maritime forest in the Seashore. The average altitude of the central dune mass is 10 to 15 ft above sea level, and individual dunes may reach 30 ft.

Several freshwater ponds along the sound side were originally small embayments that were closed off from the sound by bars. The freshwater in the ponds is maintained by rainfall and ground water discharge, but the ponds are subject to frequent inundations of saltwater during storms and are being filled by blowing sand and marsh vegetation.

Several private camps in this area use water from shallow wells that tap the unconfined aquifer. These wells are generally less than 10 ft deep. A description of the wells shown on figure 10 follows:

Well Ct-137 (344102076383801)1/--date drilled, June 1977; owner, NPS; aquifer, unconfined; depth, 7 ft; diameter, 1-1/4 in; yield, 10 gal/min; chloride concentration, 13 mg/L on June 20, 1977.

Well Ct-138 (344109076383001)--date drilled, unknown; owner, NPS; aquifer, unconfined; depth, 5 ft (est.); diameter, 1-1/4 in; yield, 5-10 gal/min (est.); chloride concentration, 170 mg/L on June 20, 1977.

This section of the Shackleford Banks offers many sites for the development of wells--both vertical or horizontal--in the unconfined aquifer, where high dunes offer good protection from storm overwash.

The extent of the upper confined aquifer under this section is not known, but the aquifer is likely to thin west of Cape Lookout and be less calcareous (Mixon and Pilkey, 1976). One or more test holes are required to define this aquifer and to determine if it contains freshwater under this part of Shackleford Banks.

The lower confined aquifer likely contains freshwater throughout this area, based on data at Fort Macon (east end of Bogue Banks, about one mile west of Shackleford Banks), Beaufort, and at Cape Lookout (LeGrand, 1960). The top of this aquifer is at about 225 to 250 ft below sea level in this section.

1/ Supplementary well identification number based on the latitude-longitude coordinates of the well.

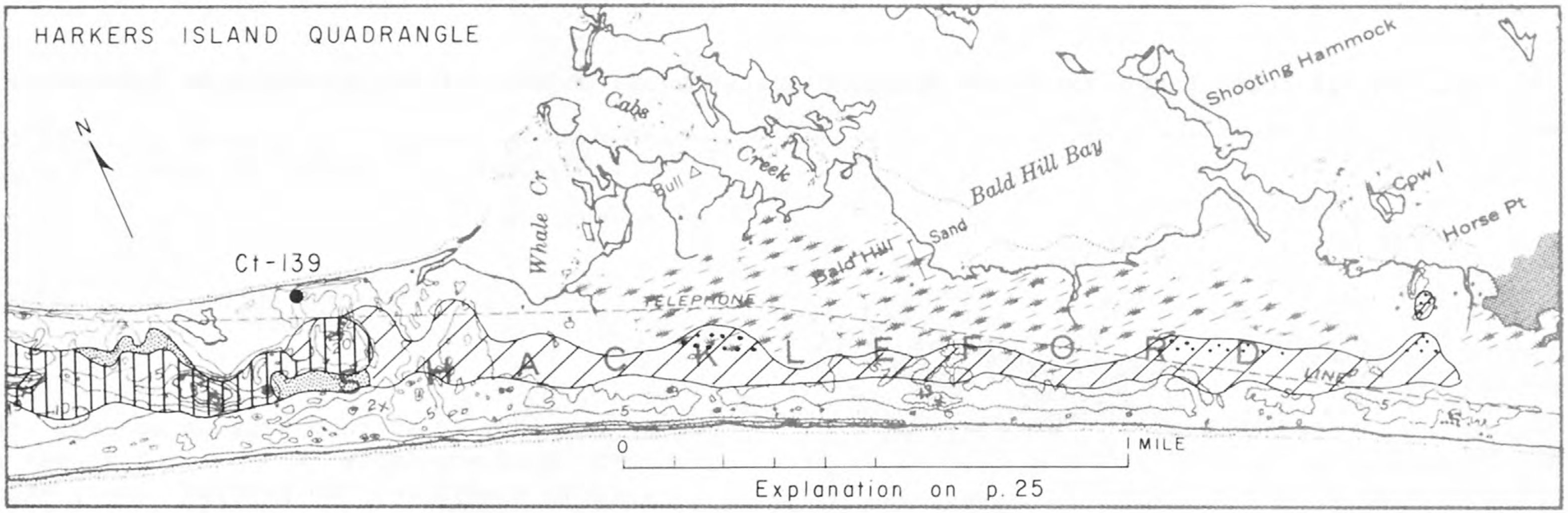

Figure 11.--Central part of Shackleford Banks.

Central part of Shackleford Banks.--The average altitude of the dune mass in this section is about 10 or 15 ft above sea level, but most of the higher dunes are small in areal extent and occur in isolated patches ranging up to an altitude of about 25 ft (fig. 11).

Development of water supplies for private camps is similar to that for the west end of the Banks. A typical shallow well, Ct-139, shown on figure 11 is described as follows:

Well Ct-139 (344023076361401)--date drilled, unknown; owner, Mildred Holland; aquifer, unconfined; depth, 5 ft (est.); diameter, 1-1/4 in; yield, 5-10 gal/min (est.); chloride concentration, 470 mg/L on June 20, 1977.

Vertical wells could be constructed in the unconfined aquifer in the high dunes of this section. Horizontal wells could be constructed in the low dunes scattered along the central part of the island but these areas are subject to storm overwash, perhaps once every 6 years (fig. 5).

Data are not available for the upper confined aquifer in this section.

The lower confined aquifer probably contains freshwater throughout this section as discussed previously, but the aquifer dips eastward and the top of the limestone may be as much as 300 ft below sea level.

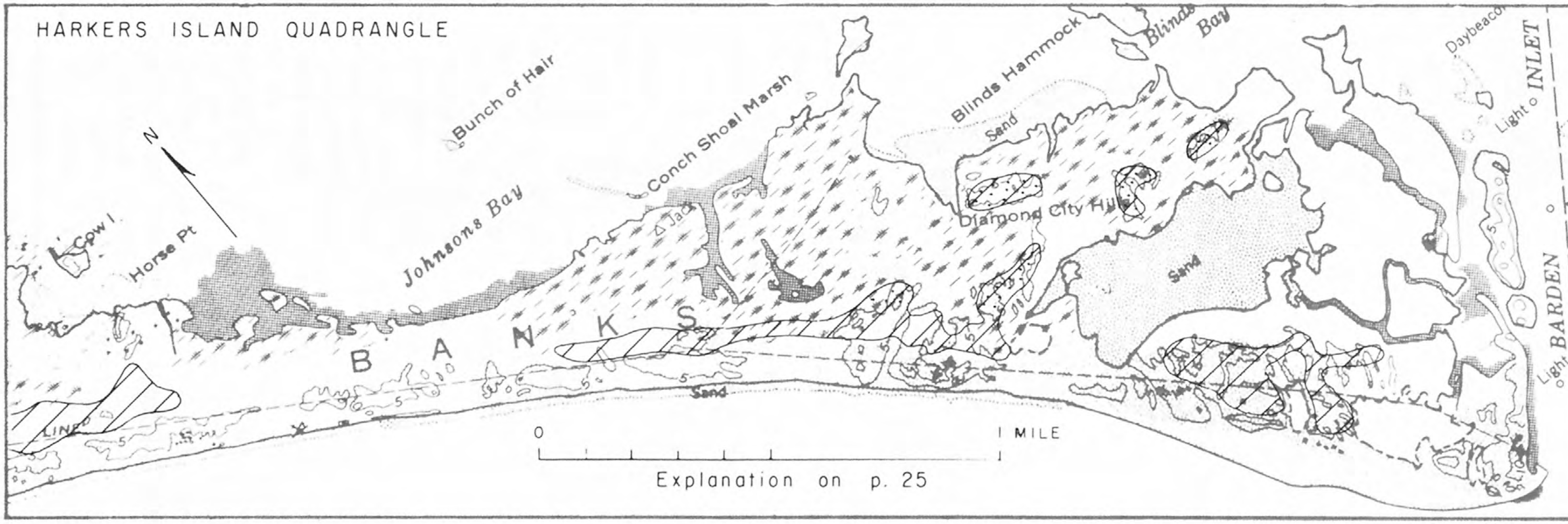

Figure 12.--Eastern part of Shackleford Banks.

<u>Eastern part of Shackleford Banks</u>.--Much of the eastern end of Shackleford Banks is subject to storm overwash (fig.12). Dunes are generally less than 10 ft above sea level and the freshwater lenses in the unconfined aquifer probably do not extend more than about 25 ft below land surface. Horizontal wells could be constructed in these dunes for a freshwater supply, but where the dunes are surrounded by marsh, ground water may be highly colored due to the presence of organic matter.

Water in the upper confined aquifer may be salty in this section of the Seashore, but the lower confined aquifer contains freshwater throughout the area (fig 6).

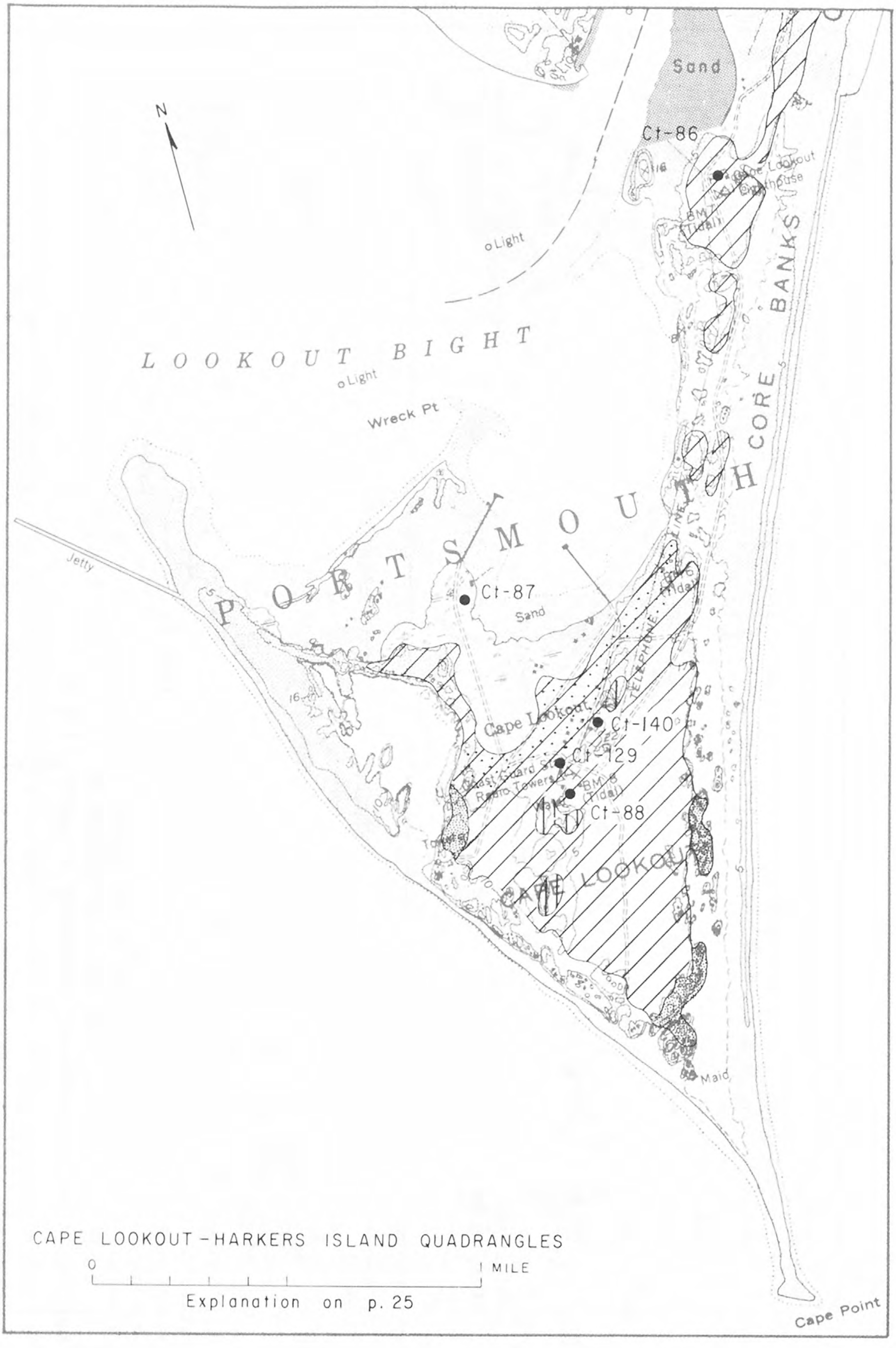

Figure 13.--Cape Lookout area.

Cape Lookout area.--The Cape Lookout Lighthouse is a major attraction to visitors to the Seashore, and the surrounding area is considered by the Park Service to be a candidate for a major visitor-use facility (fig. 13). A deep well (Ct-86) at the building formerly used as a residence for the lighthouse keeper might be used for a freshwater supply.

The U.S. Coast Guard maintains a station about a mile south of the lighthouse and draws its water supply from the unconfined aquifer. Several private residences and cottages in the area also tap the unconfined aquifer. During World War II the U.S. Army operated a coastal artillery battery at Cape Lookout. Water for this unit came from a deep well (Ct-88) in the lower confined aquifer, which reportedly was located near a water tower (shown on fig. 13) that has been torn down since the map was drawn. The exact location of the well is not known.

Well Ct-88, if located, might provide a suitable supply of freshwater, however, it should be thoroughly checked to see that the casing is intact. Such abandoned wells pose a contamination possibility to the lower confined aquifer if they are not plugged and sealed properly.

Descriptions of the wells shown on figure 13, are as follows:

Well Ct-86 (343723076312901)--date drilled, 1941 or earlier; owner, NPS; aquifer, lower confined; depth, 364 ft; diameter, 4 in; yield, unknown; chloride concentration, 15 mg/L on June 16, 1977.

Well Ct-87 (343638076322801)--date drilled, about 1941; owner, R. W. Baker; aquifer, upper confined; depth, 98 ft; diameter, 2 in; yield, 1 gal/min flow; chloride concentration, 695 mg/L on Nov. 29, 1966.

Well Ct-88 (343610076321801)--date drilled, July 10, 1942; owner, U.S. Army; aquifer, lower confined; depth, 435 ft; diameter, 8 in; yield, 180 gal/min; chloride concentration, unknown.

Well Ct-129 (343613076321801)--date drilled, 1965; owner, U.S. Coast Guard; aquifer, unconfined; depth, 15 ft; diameter, 1-1/4 in; yield, 15 gal/min; chloride concentration, 11 mg/L on Nov. 29, 1966.

Well Ct-140 (343617076321201)--date drilled, before 1970; owner, Mr. Setzer; aquifer, unconfined; depth, 10 ft; diameter, 1-1/4 in; yield, 5-10 gal/min (est.); chloride concentration, 19 mg/L on June 17, 1977.

Potential well yields from the unconfined aquifer could be as much as 30 gal/min under the highest dunes shown on figure 13, but these areas could be surrounded by saltwater overwash during large storms. The areal extent of these dunes is probably not sufficient to protect vertical wells from lateral saltwater encroachment. Horizontal wells in the areas subject to inundation could yield as much as 20 gal/min.

Water from the upper confined aquifer is probably salty in this section of the Seashore, as indicated by data from Ct-87. This well was reported to be 412 ft deep when drilled in 1941, but was sounded to 98 ft in 1966. There is a possibility that the hole has collapsed, or that casing corrosion has allowed saltwater to enter the well above the lower confined aquifer.

The lower confined aquifer is about 350 ft deep at Cape Lookout and likely contains freshwater throughout the area (Fig. 2). Yields up to 500 gal/min should be possible from wells. Well Ct-88, if relocated, might provide a suitable supply of fresh water; however, it should be thoroughly checked to see that the casing has not collapsed.

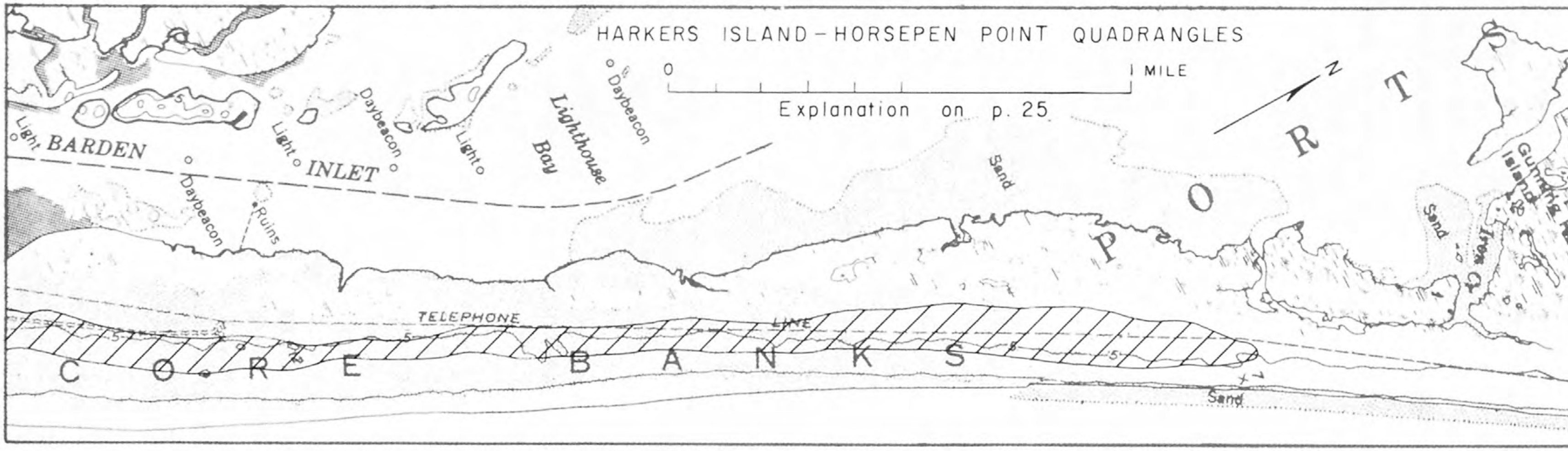

Figure 14.--Barden Inlet area.

Barden Inlet area.--The central dune mass along this section is typical of the Core Banks and is composed of low, featureless dunes that have been partly shaped by storm overwash, and generally is not much higher than about 5 ft in altitude (fig. 14).

Horizontal wells constructed in the unconfined aquifer in the center of the island could yield freshwater, but saltwater overwash would contaminate the aquifer until the freshwater lens was reestablished.

Although no data are available in this section, the upper confined aquifer, the top of which occurs about 70 ft below land surface, is believed to contain saltwater. However, wells completed in the lower confined aquifer at depths of about 350 ft will yield freshwater.

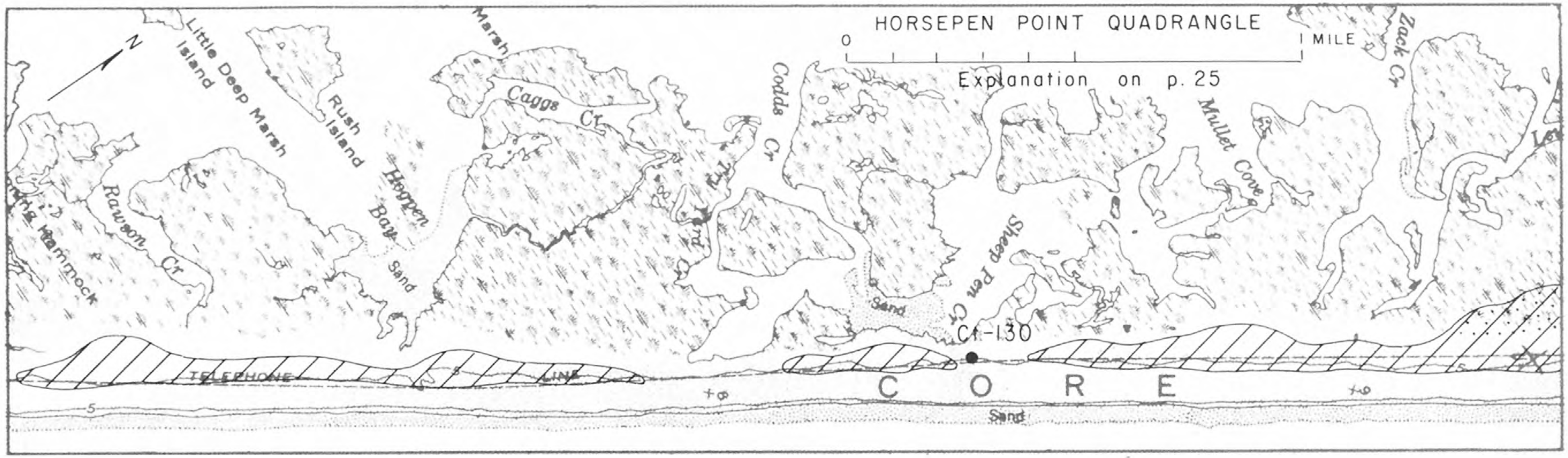

Figure 15.--Sheep Pen Creek area.

<u>Sheep Pen Creek area</u>.--Most of the Core Banks along this section is composed of marsh, narrow beach and dunes, and small marsh islands separated by shallow tidal creeks (fig. 15).A cluster of cabins known as Murphy Camp is near Sheep Pen Creek. Data for a shallow well (Ct-130) in this camp are as follows:

Well Ct-130 (344137076281501)--date drilled, unknown; owner, unknown; aquifer, unconfined; depth, 5 ft; diameter, 1-1/4in; yield, 3 gal/min; chloride concentration, 670 mg/L on Nov. 29, 1966.

Nearly all of this section is subject to overwash about once every 6 years, on the average (fig. 5). Horizontal wells constructed in the unconfined aquifer in the center of the dune mass would yield fresh-water, but the aquifer could become contaminated with saltwater following a storm. Freshwater under dunes adjacent to the marsh areas may be highly colored.

The suitability of the upper confined aquifer for a freshwater supply in the Sheep Pen Creek area is not known. It is likely to contain saltwater.

The lower confined aquifer is about 350 ft deep and contains freshwater throughout this section of the Core Banks.

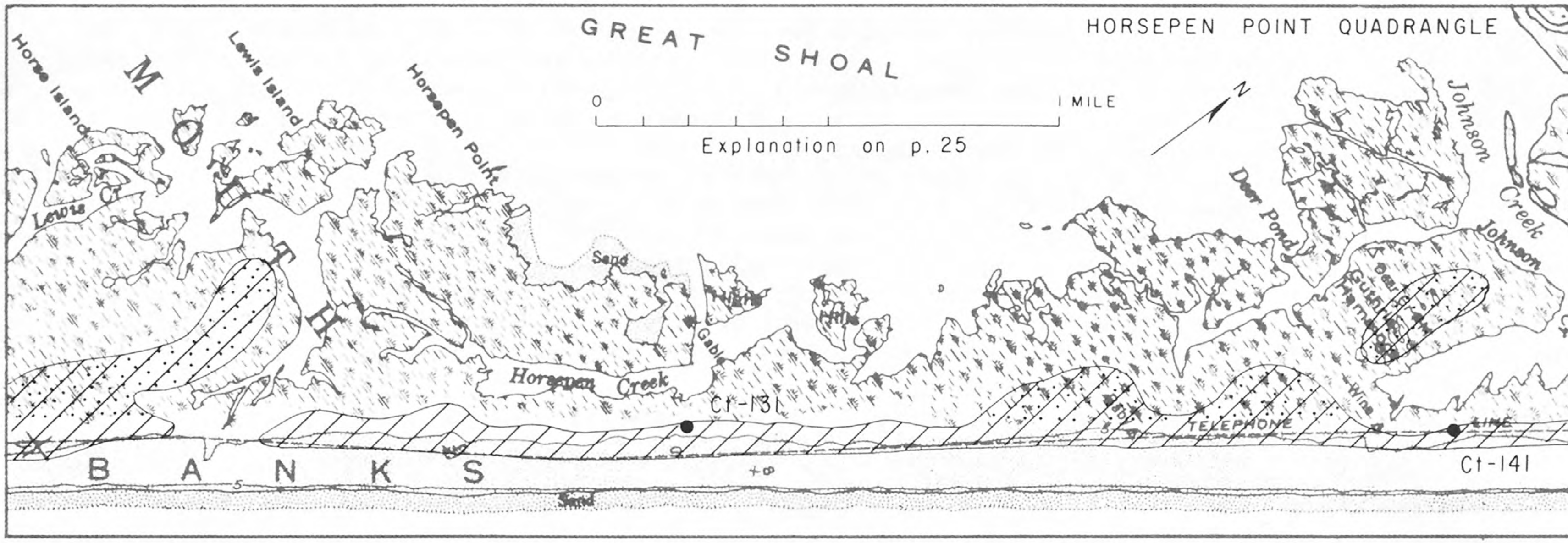

Figure 16.--Horsepen Creek area.

Horsepen Creek area.--This section includes the area between Lewis Creek and Johnson Creek (fig. 16), approximately 8 to 9 mi northeast of the Cape Lookout lighthouse. Fishing camp cabins are located along Horsepen Creek (Davis Camp) and at Johnson Creek (Alger Willis Camp). Wells at these sites are described as follows:

Well Ct-131 (344330076263901)--date drilled, 1963; owner, Earl Davis; aquifer, lower confined; depth, 430 ft; diameter, 2 in; yield, 5-10 gal/min flow (est.); chloride concentration, 8 mg/L on June 17, 1977.

Well Ct-141 (344440076253701)--date drilled, unknown; owner, Alger Willis; aquifer, upper confined; depth, 90 ft; diameter, 1-1/2 in; yield, 5-10 gal/min (est.); chloride concentration, 4,100 mg/L on June 17, 1977.

All of the barrier island in the Horsepen Creek area is subject to saltwater overwash, which would temporarily contaminate the freshwater lens in the unconfined aquifer beneath the central dune mass.

Ground water beneath the dunes bordering the marsh areas and under the small dunes of Guthrie Hammock (fig. 16) may be colored.

Water from the upper confined aquifer in this section contains excess chloride concentration (Ct-141) and cannot be used as a source of drinking water. Water in the lower confined aquifer, however, is fresh as seen by the analysis of water from well Ct-131 (table 1).

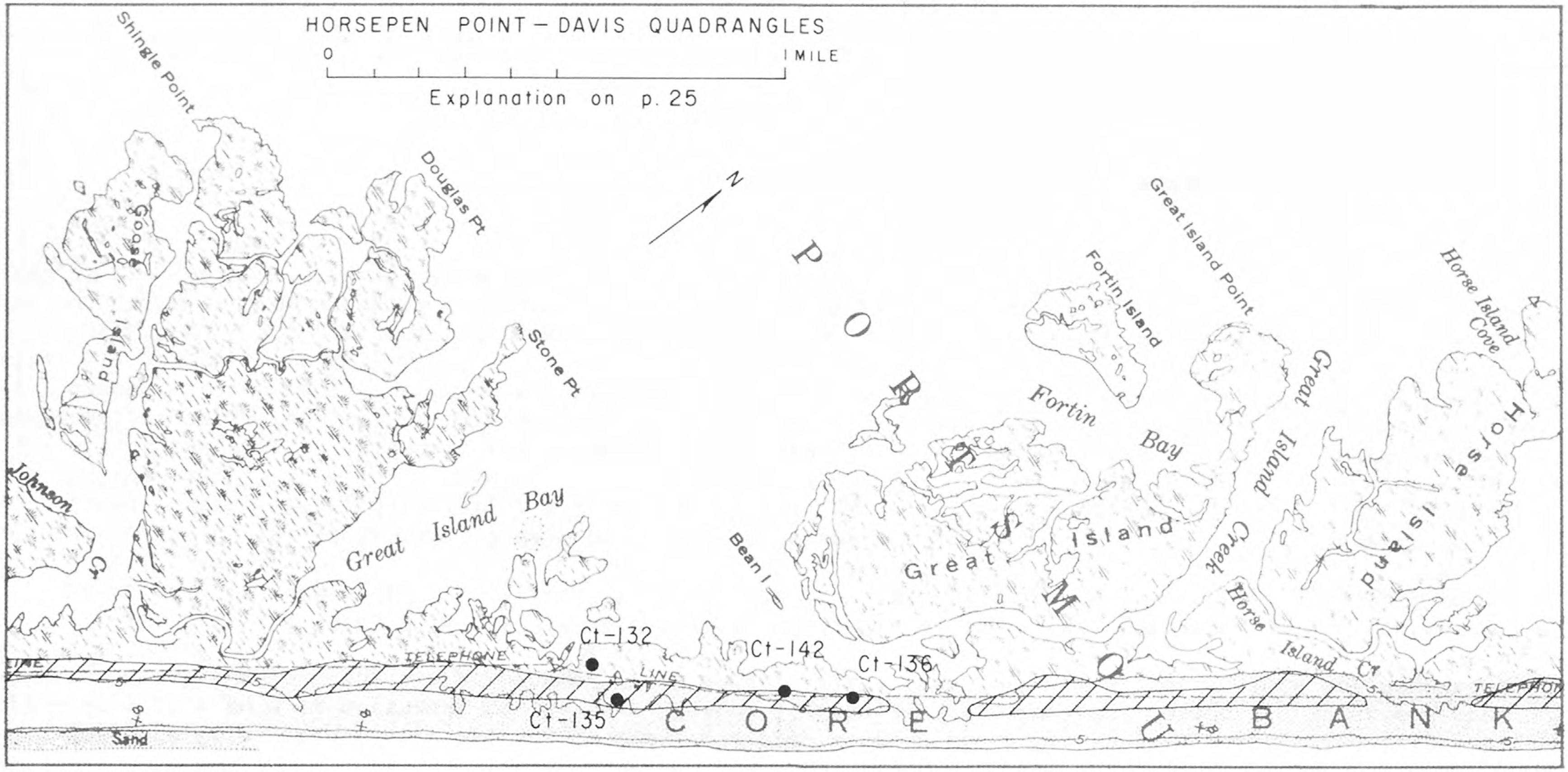

Figure 17.--Shingle Point area.

<u>Shingle Point area</u>.--This part of the Core Banks has been tentatively selected for development by the Park Service, and includes the area between Johnson Creek and Horse Island (fig. 17). Fishing camp activity centers about a cluster of cabins in the area between wells Ct-132 and Ct-136, known as Dixon Camp. The water supplies in this map section are described as follows:

Well Ct-132 (344559076242101)--date drilled, 1954; owner, Gary Hamilton; aquifer, upper confined; depth, 91 ft; diameter, 2 in; yield, 20 gal/min (est.); chloride concentration, 360 mg/L on June 17, 1977.

Well Ct-135 (344537076244101)--date constructed, about 1970; owner, Ray Hine; aquifer, unconfined; depth, 5 ft (horizontal collector well); 1-1/4 in; yield, 5-10 gal/min (est); chloride concentration, 20 mg/L on June 16, 1976.

Well Ct-136 (344559076242201)--date drilled, unknown; owner, Carlie Willis; aquifer, upper confined; depth, 89 ft; diameter, 1-1/2 in; yield, 5 gal/min (est.); chloride concentration, 630 mg/L on June 16, 1977.

Well Ct-142 (344552076242801)--date drilled, unknown; owner, Barber; aquifer, unconfined; depth 6 ft; diameter, 1-1/4 in; yield, 5 gal/min (est.); chloride concentration, 22 mg/L on June 17, 1977.

Well Ct-135 is an example of a horizontal well, and well Ct-142 is a vertical well, both of which produce freshwater from the unconfined aquifer in this section. Vertical wells that draw from the freshwater lens, however, are likely limited in sustained yield to 1 gal/min or less with a total daily pumpage not to exceed 100 to 500 gallons, in order to produce water with a chloride concentration less than 250 mg/L.

From the chloride values for Ct-132 and Ct-136 both of which are open to the upper confined aquifer, it is inferred that this aquifer contains saltwater in this area of the Core Banks.

Large quantities of freshwater are available from the lower confined aquifer at depths below about 350 to 400 ft, based upon the interpolation of data shown in figure 3.

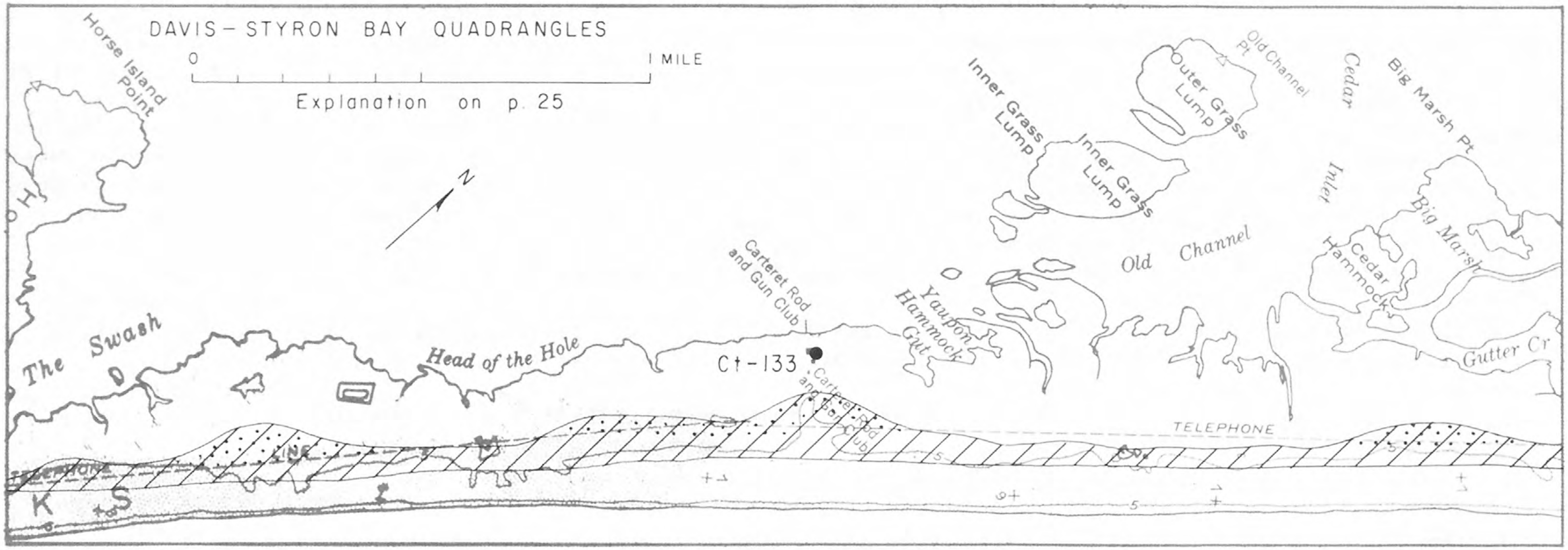

Figure 18.--Carteret Rod and Gun Club area.

Carteret Rod and Gun Club area.--This section of the barrier island extends from Horse Island to Gutter Creek (fig. 18). The low, overwashed dunes seaward of the sound-side marshes are typical of the Core Banks, and are less than 10 ft in altitude. The Carteret Rod and Gun Club camp is served by a deep well (Ct-133), which is described as follows:

Well Ct-133 (344814076223101)--date drilled, about 1900; owner, Carteret Rod and Gun Club; aquifer, lower confined; depth, 366 ft; diameter, 2-1/2 in; yield, 2 gal/min flow; chloride concentration, 44 mg/L on June 17, 1977.

Freshwater is available in the unconfined aquifer beneath the dunes along the central part of the island, but this area is vulnerable to storm overwash that could temporarily contaminate the freshwater lens. The use of horizontal wells would be the most practical means of tapping the freshwater supply in this aquifer. Freshwater under dunes adjacent to the marsh areas could be colored by organic matter.

There are no data for the upper confined aquifer in this area; the quality of water in this aquifer is unknown. As shown in figure 3, a freshwater-saltwater interface may be present in the upper confined aquifer in this general area, and test wells would be needed to determine the availability of freshwater in this aquifer.

Freshwater is available in the lower confined aquifer as shown by data from well Ct-133, but the significance of the higher chloride concentration in water from well Ct-133 (44 mg/L versus 8 mg/L in well Ct-131 in this area is not completely understood.

One interpretation of the higher chloride value is that this part of the aquifer is near the freshwater-saltwater interface in the lower confined aquifer. Another interpretation is that withdrawals from Ct-133 since 1900 have caused an increase in the chloride concentration of the water around the well. A water sample collected in 1966 had a chloride concentration of 36 mg/L (table 1).

Whichever interpretation is correct, future withdrawals from the lower confined aquifer in this general area should be based on the assumption that the chloride concentration in the water could increase because of pumping.

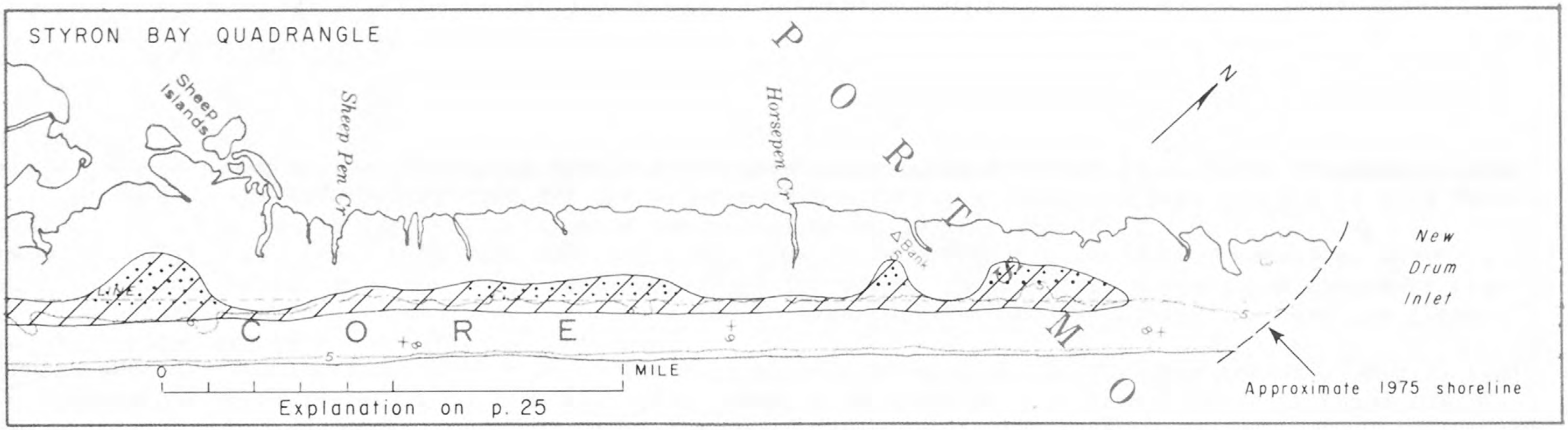

Figure 19.--New Drum Inlet area.

New Drum Inlet area.--This section describes the area from Gutter Creek to New Drum Inlet, which was opened by the U.S. Army Corps of Engineers in 1971 (fig. 19). There are no known water supplies in this section. Horizontal wells could be constructed in the freshwater lens in the central dune mass, but the dunes are subject to overwash from the ocean. The lens might contain colored water in some areas as shown in figure 19.

Data on the quality of water in the upper confined aquifer are not available for this section, but this aquifer may contain water that is marginally fresh as suggested by data from well Ct-143, which is 4.5 miles northeast of Drum Inlet. (See figure 3 and table 1.)

The lower confined aquifer in this area likely contains freshwater of similar quality to that in well Ct-133 (fig. 18 and table 1), but there is a possibility that saltwater encroachment could occur as a result of withdrawals.

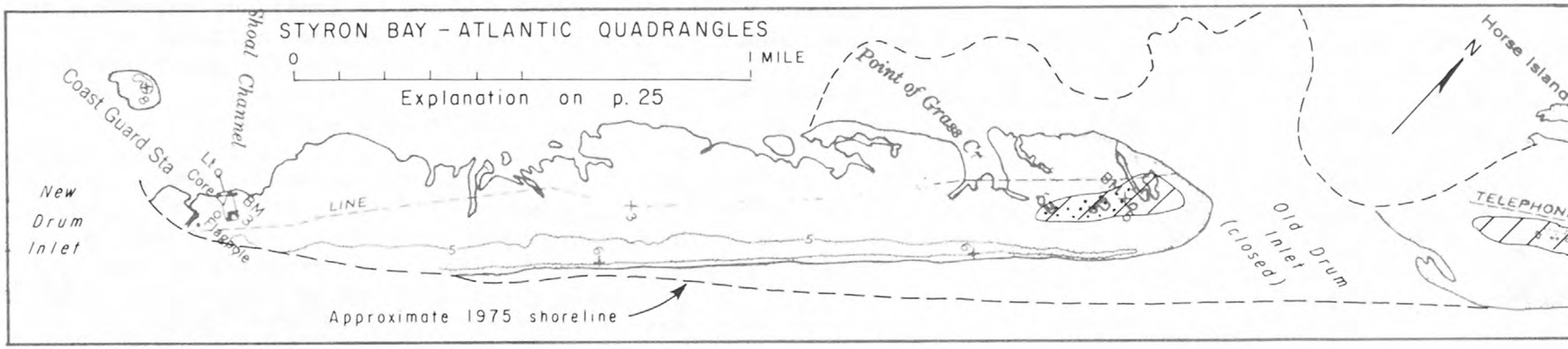

Figure 20.--Old Drum Inlet area.

Old Drum Inlet area.--This section of the Core Banks lies between new and old Drum Inlets (fig. 20). The area has been significantly modified since about 1971 when the old inlet closed and the new one was opened. The opened and filled areas shown on figure 20 are approximated from the Styron Bay and Atlantic orthophotoquad quad maps published by the U.S. Geological Survey in 1975 (fig. 1).

No recreation facilities or water supplies are known in this section of the Core Banks.

Because of the recent modifications in the island, dunes have not been built high enough to support a significant freshwater lens; much of the island is probably awash during minor storm tides. The dune mass near Point of Grass Creek may support a lens of freshwater of sufficient size to yield at least 1 or 2 gal/min to a horizontal well.

Data for the upper confined aquifer are not available to determine the availability of freshwater in it, but the aquifer may contain fresh water, as noted in the discussion of the New Drum Inlet area.

Ground water in the upper part of the lower confined aquifer is believed to be fresh under this part of the island (fig. 3), but the chloride concentration may be greater than that in water from well Ct-133 (table 1 and fig. 18). Freshwater yield of wells in this aquifer cannot be estimated without further data on the position of the freshwater-salt-water interface.

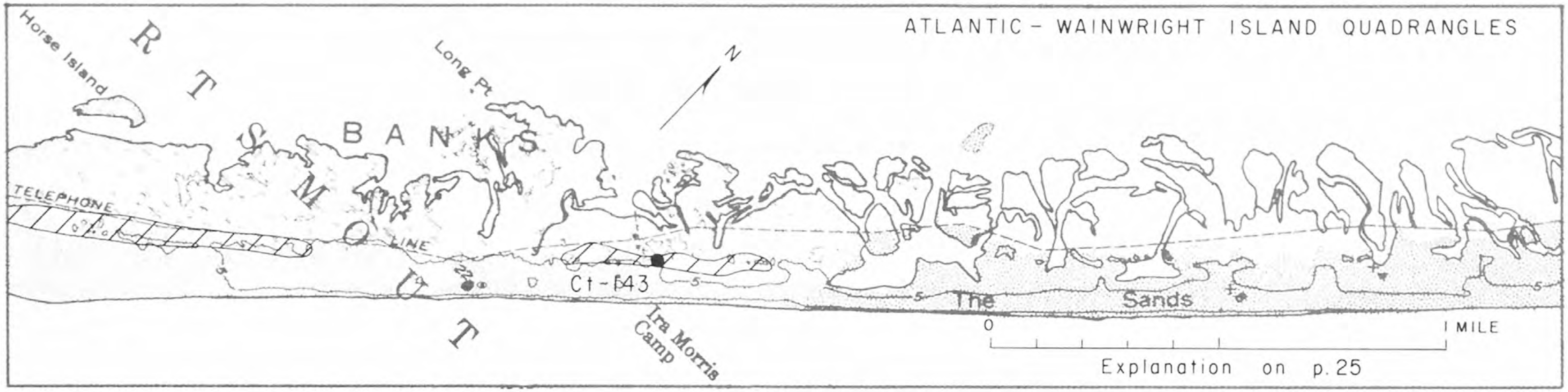

Figure 21.--Morris Camp area.

Morris Camp area .-- A cluster of fishing cabins, known as the Morris Camp (fig. 21), is served by a well described as follows:

Well Ct-143 (345355076151801)--date drilled, about 1948; owner, Don Morris; aquifer, upper confined; depth, 111 ft; diameter, 1-1/2 in; yield, 5-10 gal/min (est); chloride concentration, 130 mg/L on June 21, 1977.

The unconfined aquifer beneath the central dune mass at Morris Camp could yield freshwater to horizontal wells, but, after an overwash, water in the aquifer is likely to be salty for several months.

The upper confined aquifer contains freshwater in this area as indicated by data from well Ct-143. Water from this well meets water quality standards (National Academy of Sciences and National Academy of Engineering, 1973) (table 1), although the chloride concentration suggests that the freshwater-saltwater interface may be nearby. Data are insufficient to determine an optimum yield from the upper confined aquifer at this time.

There are two possible sources of the freshwater in the upper confined aquifer: (1) movement of freshwater from mainland recharge areas (3 to 4 mi minimum distance), or (2) upward leakage of freshwater from the lower limestone aquifer (nearly 250 ft below the base of well Ct-143 as shown in fig. 3).

The chloride concentration in water in the lower confined aquifer may increase toward Portsmouth Island as suggested in figure 3, but the position of the freshwater-saltwater interface is not known.

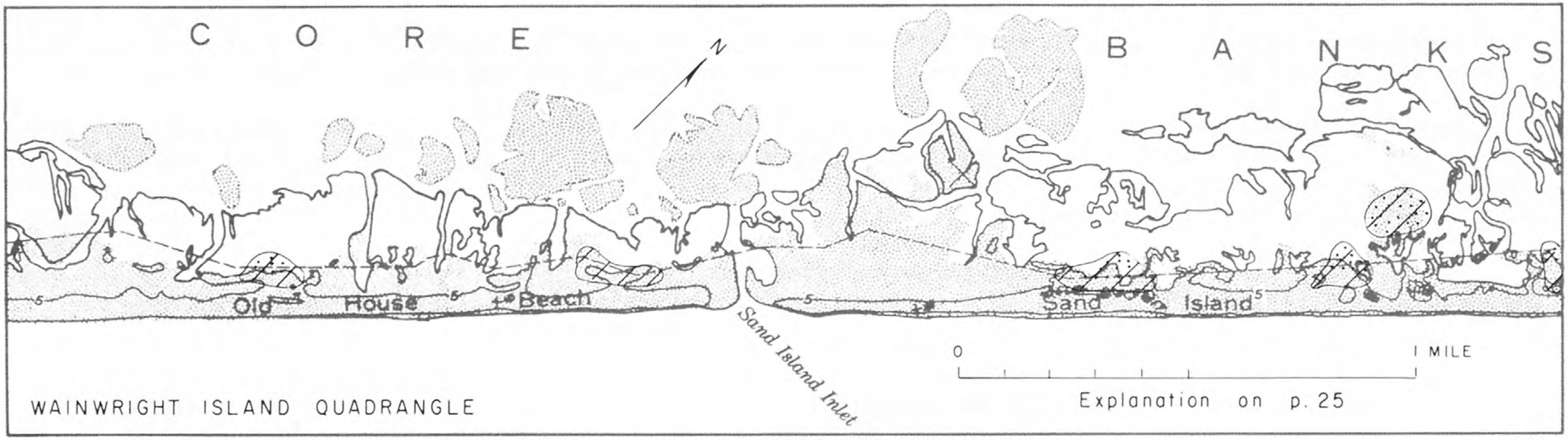

Figure 22.--Sand Island area.

Sand Island area.--This section centers on the area around the former Sand Island Inlet, which closed sometime between 1950 and 1975 (fig. 22). The approximate shoreline in 1975 at the former inlet is shown in figure 22 and is taken from the Wainwright Island orthophotoquad map published in 1975 by the U.S. Geological Survey.

There are no known recreation facilities or water supplies in this section of the Seashore, except, possibly, for some isolated cabins and associated water supplies. Fresh ground water may be available in the unconfined aquifer beneath the larger dunes as shown in figure 22.

No data are available for the upper confined and lower limestone aquifers. The chloride concentrations in water in these aquifers are believed to exceed the recommended limit of 250 mg/L (National Academy of Sciences and National Academy of Engineering, 1973).

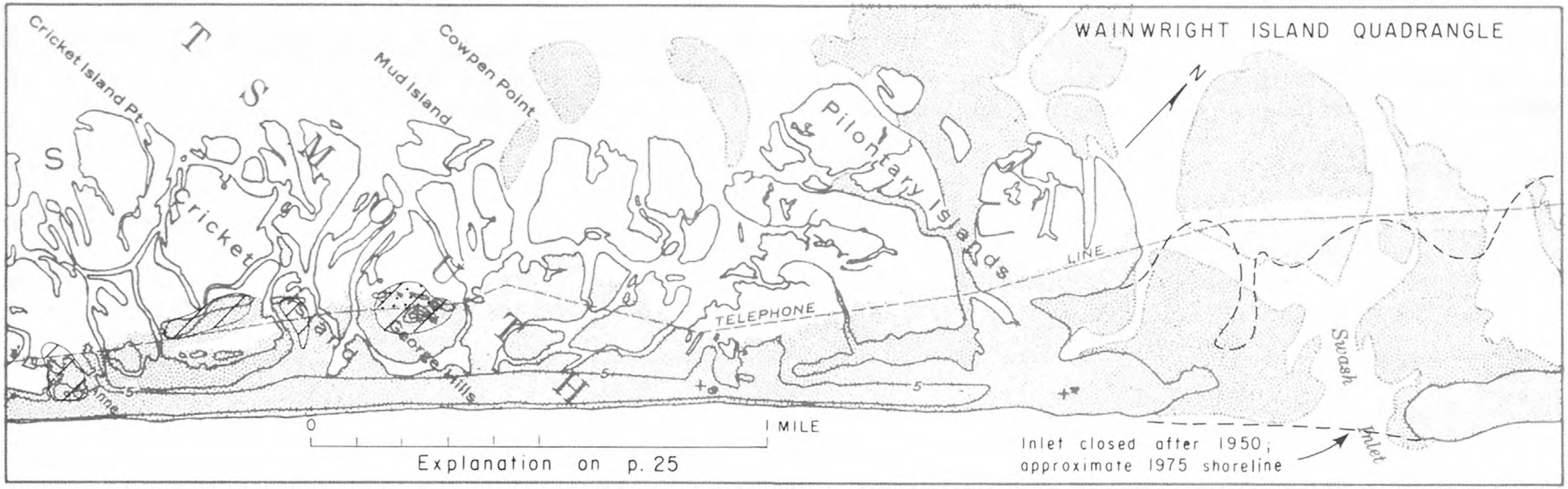

Figure 23.--Pilontary Islands area.

Pilontary Islands area.--The approximate shoreline at former Swash Inlet in 1975 shown on figure 23 was sketched from the Wainwright Island orthophotoquad published in 1975 by the U.S. Geological Survey (fig. 1). Swash Inlet, before its closure after 1950, was the traditional division between the Core Banks to the southwest and Portsmouth Island to the northeast.

There are no known camps or water supplies in this map section. Dune masses on Cricket Island and George Hills average about 5 ft in altitude, and may support freshwater lenses in the unconfined aquifer; however, these dunes are subject to overwash. Northeast of George Hills, dune masses are too small to support a significant lens of freshwater, and the areas are not suitable for the development of ground water.

Data for the upper confined and lower confined aquifers are not available for this part of the Seashore, but data in figure 3 suggest that both aquifers may contain water having a chloride concentration in excess of 250 mg/L.

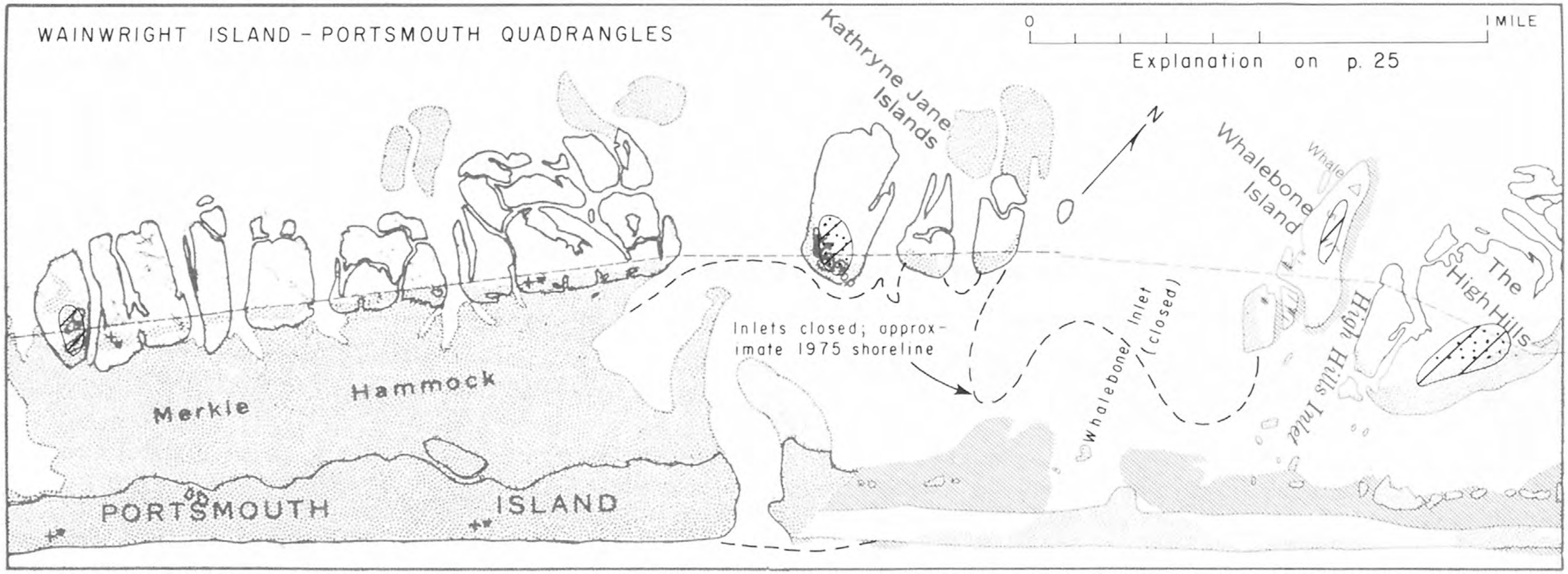

Figure 24.--Whalebone Inlet area.

Whalebone Inlet area.--Whalebone and another unnamed inlet have closed since 1950, and the shoreline existing in 1975 at these inlets is sketched from orthophotoquad maps (Wainwright Island and Portsmouth Quadrangles) published by the U.S. Geological Survey in 1975 (fig. 1).

Portsmouth Island consists of three district topographic features (fig. 24): (1) a narrow beach and low dunes along the ocean, and (2) low marsh islands separated from the beach by (3) low sandy flats that are generally awash at high tides. The overall width of Portsmouth Island increases northeastward marked largely by the increase in the width of the sandy flats separating the beach and marsh islands.

No water supplies are known to exist along this section of the Seashore. Freshwater lenses are likely to occur in the unconfined aquifer beneath dunes that occur on the larger marsh islands, namely Kathryne Jane Islands and The High Hills, but all of this section is subject to saltwater overwash.

Based on data near Portsmouth and at Ocracoke both the upper confined and lower confined aquifers are likely to contain saltwater in this section (fig. 3).

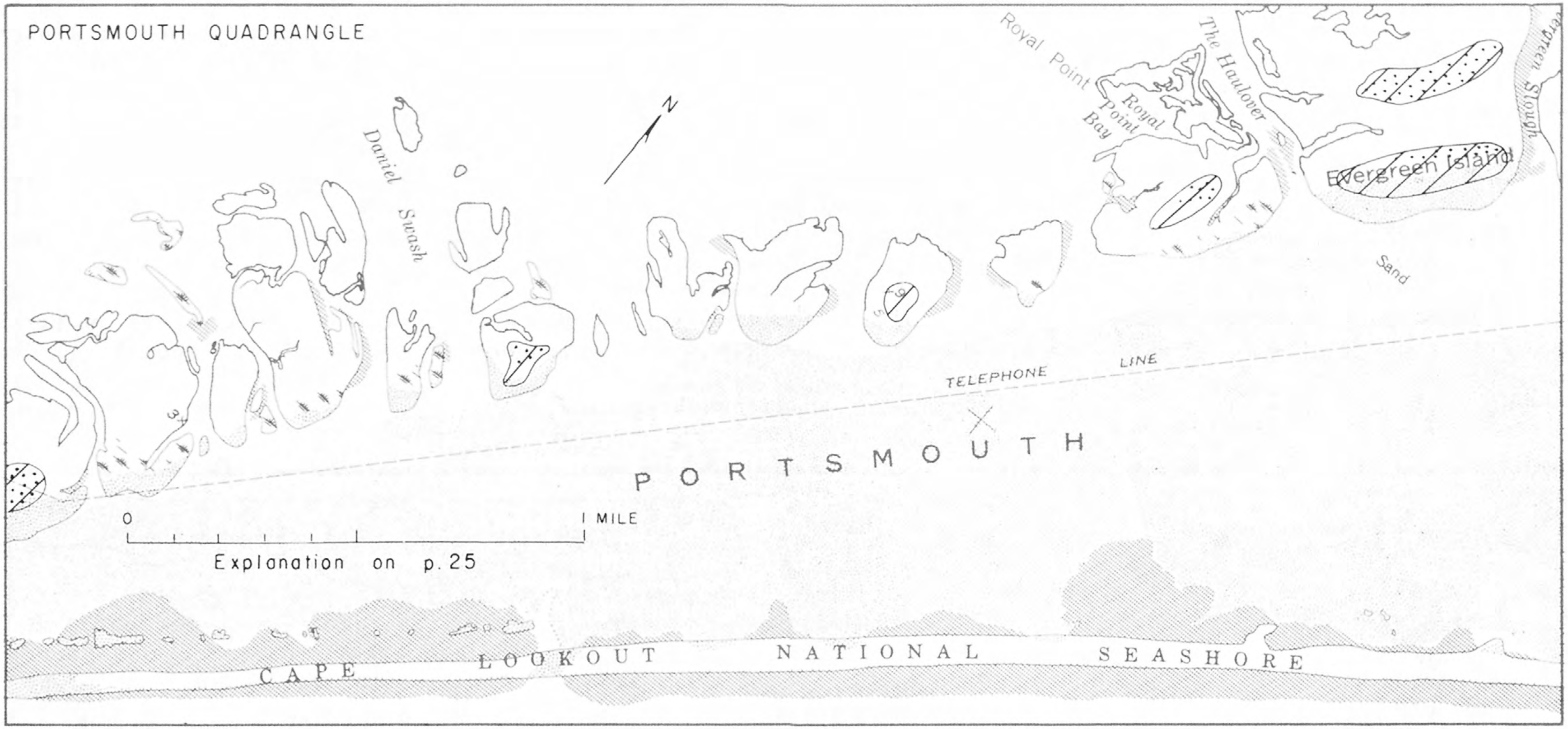

Figure 25.--Central Portsmouth Island area.

Central Portsmouth Island area.--Central Portsmouth Island includes the area between The High Hills and Evergreen Island (fig. 25). There are no known recreation facilities or water supplies are in this section of Portsmouth Island, with a possible exception at Evergreen Island where there are a few houses and a landing strip. Fresh ground water is likely under dunes on several of the larger marsh islands.

Data for the upper confined and lower confined aquifers are not available, but it is believed that both aquifers contain water with chloride concentration in excess of 250 mg/L.

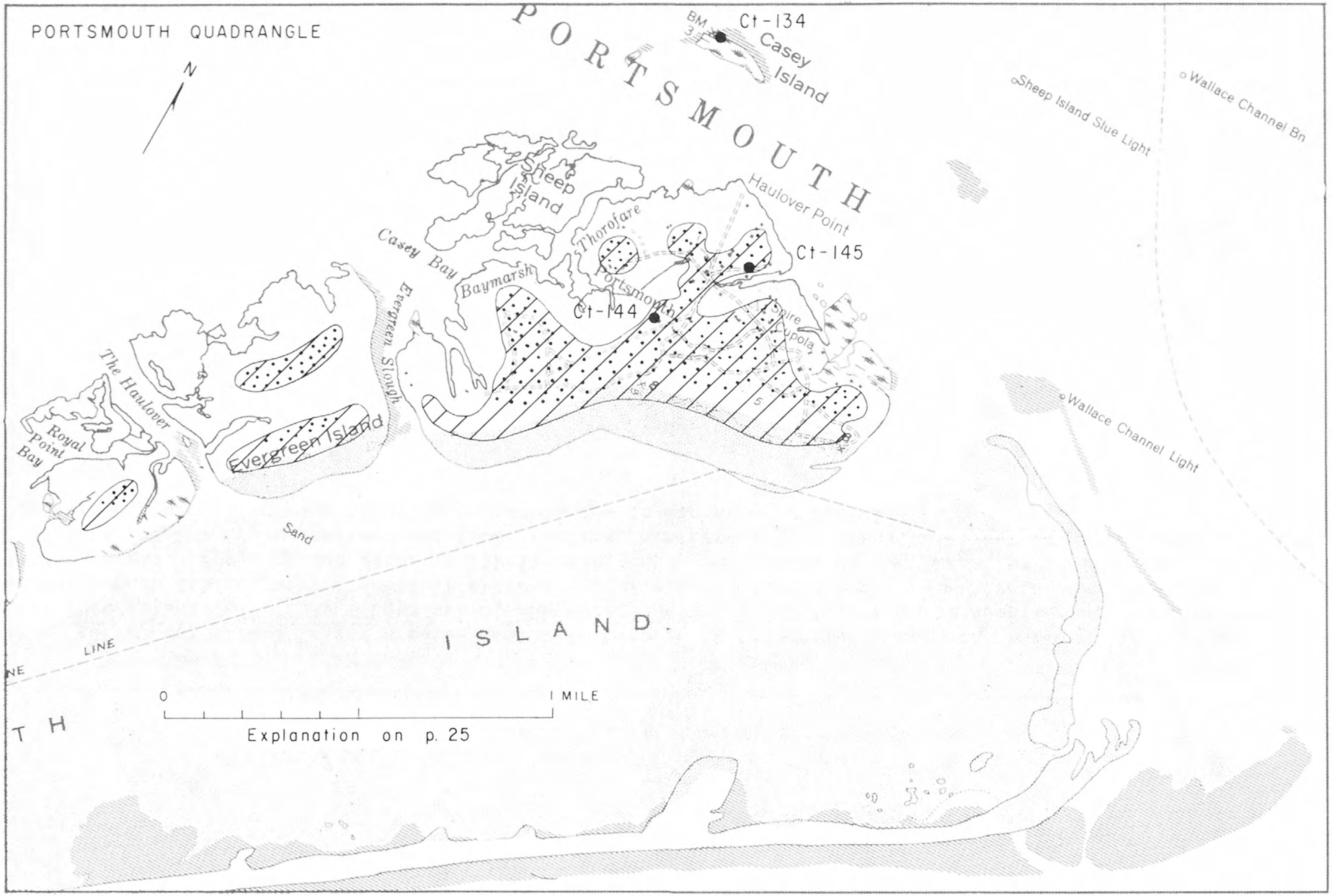

Figure 26.--Portsmouth Village area.

Portsmouth Village area.--This section includes the northernmost part of the Cape Lookout Seashore from Evergreen Island to Ocracoke Inlet (fig. 26). The abandoned village of Portsmouth is at the north end of the Seashore on the largest of the marsh islands that are separated from the beach by a wide (5,000 ft) sand flat.

Many of the old buildings of the village will be maintained or restored by the Park Service, and several have shallow wells for water supplies. A deep well was drilled on Casey Island in the early 1900's for a fish-processing plant. This well and two shallow wells are described as follows:

Well Ct-134 (350440076041001)--date drilled, about 1910; owner, NPS; aquifer, undetermined; depth, 490 ft reported, 306 ft measured; diameter, 4 in; yield, 12 gal/min flow; chloride concentration, 630 mg/L on June 22, 1977.

Well Ct-144 (350401076035501)--date drilled, unknown; owner, Margaret Wallace; aquifer, unconfined; depth, 8 ft; diameter, 1-1/4 in; yield, 5 gal/min; chloride concentration, 68 mg/L on June 22, 1977.

Well Ct-145 (350414076034601)--date drilled, unknown; owner, Charles McKay; aquifer, unconfined; depth, 3 ft; diameter, 1-1/4 in; yield, 5 gal/min; chloride concentration, 58 mg/L on June 22, 1977.

A relatively large area around the Village of Portsmouth is estimated to be underlain by a lens of freshwater, based on the data from wells Ct-144 and Ct-145 (fig. 26). Most of the island, however, is less than 5 ft in altitude and is subject to overwash from storms, which could temporarily contaminate the freshwater lens with saltwater. Ground water in or near the marsh areas could be highly colored. Water from well Ct-144 had a pale yellow color, and that from Ct-145 had the appearance of dark tea.

The data from well Ct-134 on Casey Island may represent the upper confined aquifer. The reported depth of the well (490 ft) is below the upper confined aquifer in confining sediments separating the upper and lower confined aquifers, but the well was sounded to just over 300 ft, which would place the well near the bottom of the upper confined aquifer (fig. 3). However, there could be a caved hole or collapsed casing in this old well so that the water from the well may represent more than one aquifer.

Data for a test well (HY-T-3) at Ocracoke, about 5 mi northeast of Portsmouth, showed that water in the lower confined aquifer was salty (table 1). It is probable that the aquifer also contains saltwater beneath this section of Portsmouth Island.

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