POTENTIAL GROUND-WATER SUPPLIES FOR ROANOKE ISLAND AND THE DARE COUNTY BEACHES, NORTH CAROLINA

BY

HARRY M. PEEK, LIKIE A. REGISTER AND PERRY F. NELSON

REPORT OF INVESTIGATIONS NO. 9

GROUND WATER DIVISION
OFFICE OF WATER AND AIR RESOURCES
NORTH CAROLINA
DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES

RALEIGH
1972

CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

Investigation of potential sources of fresh water supplies for the Dare Beaches Water and Sewer Authority was begun by the Ground Water Division in 1972. This study is being made as a part of the Division's capacity-use investigation of the area and also in response to the immediate need for information by the Dare Beaches Water and Sewer Authority for Development of a water supply for the Dare County Beaches. The area of study covered in this report is shown in *Fig. 1*.

PREVIOUS GROUND WATER STUDIES

Previous ground-water studies in Dare County include a reconnaissance study of the entire county and several studies concerned with the beach areas and parts of Roanoke Island (*See references*). Very little subsurface information is available for the county and only a few wells have been drilled deeper than 200 feet. Drilling projects in previous studies have generally included only auger holes, generally less than 150 feet in depth. Thus, knowledge obtained of the hydrogeologic units, and particularly the fresh-water bearing units, was not adequate to evaluate the potential as a source of water supply.

EXPLORATION AND TEST WELLS

Exploratory drilling and the construction of test wells is an essential part of evaluating a ground-water system. Exploration and test wells were completed at 8 sites *(Fig. 1)* to provide the basic information on ground water conditions in the

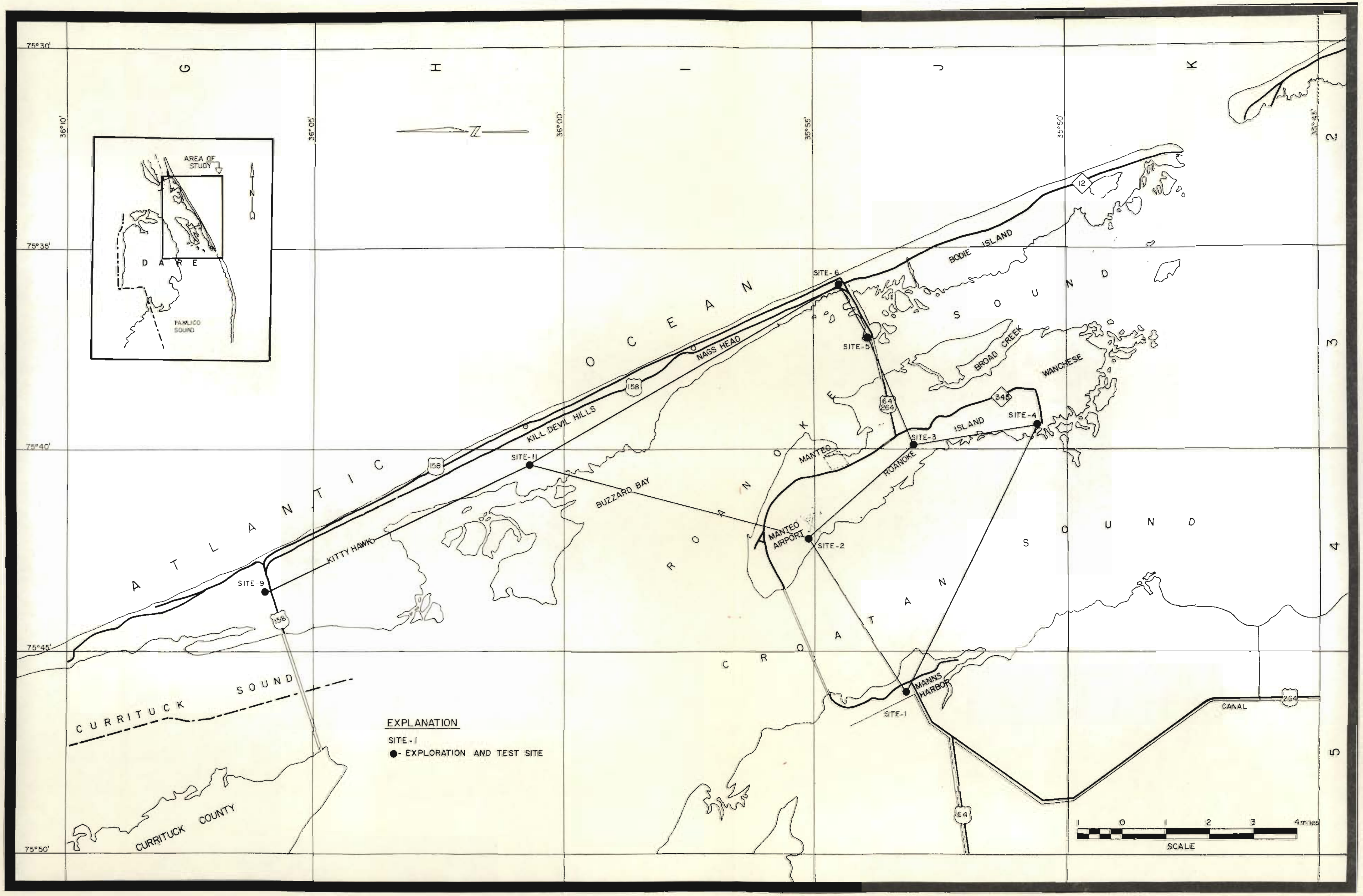

FIGURE 1.- MAP SHOWING LOCATION OF STUDY AREA, TEST SITE AND CROSS-SECTION

study area.

The procedure at each site was to drill an exploratory hole to a depth of about 500 feet, collecting formation samples at ten-foot depth intervals. Geophysical logs were made in the borehole and lithologic logs were prepared from examination of the formation samples. On the basis of the hydrogeologic information, zones in the principal water bearing units were selected for collecting water samples, making water level measurements and determining water quality. After collection of the water samples, a permanent observation well was constructed in the principal artesian aquifer (except at Site 6) and a pumping test was made. An observation well was also constructed in the water-table aquifer at most of the sites. Data from these wells are shown in *Table 1*.

HYDROGEOLOGIC UNITS

The exploratory wells penetrated six significant hydrogeologic units above a depth of 500 feet. These units, shown on cross sections in *Figs. 2, 3, 4 and 5*, include three aquifers and three confining beds or non aquifers.

The uppermost unit is a water-table or "unconfined" aquifer consisting primarily of sand with some shells and some thin interbedded clays and silty sands. This aquifer extends from the land surface to depths ranging from about 30 feet below sea level at Manns Harbor to more than 100 feet at Kitty Hawk. Because of the beds of clay and silty sand, the water is confined at some localities and depths. This aquifer is the source

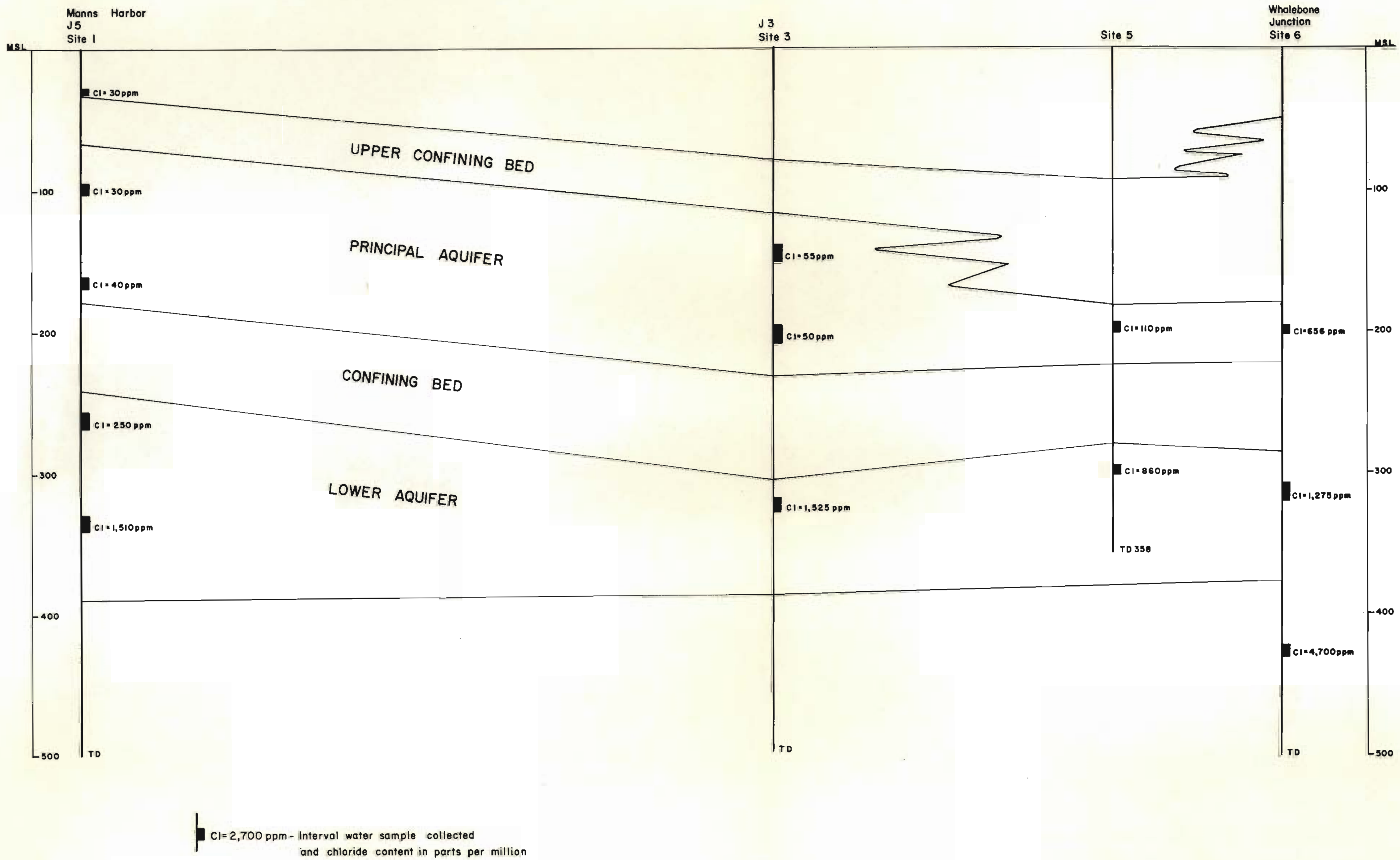

FIGURE 2.- HYDROGEOLOGIC CROSS-SECTION, SITE 1 TO SITE 6

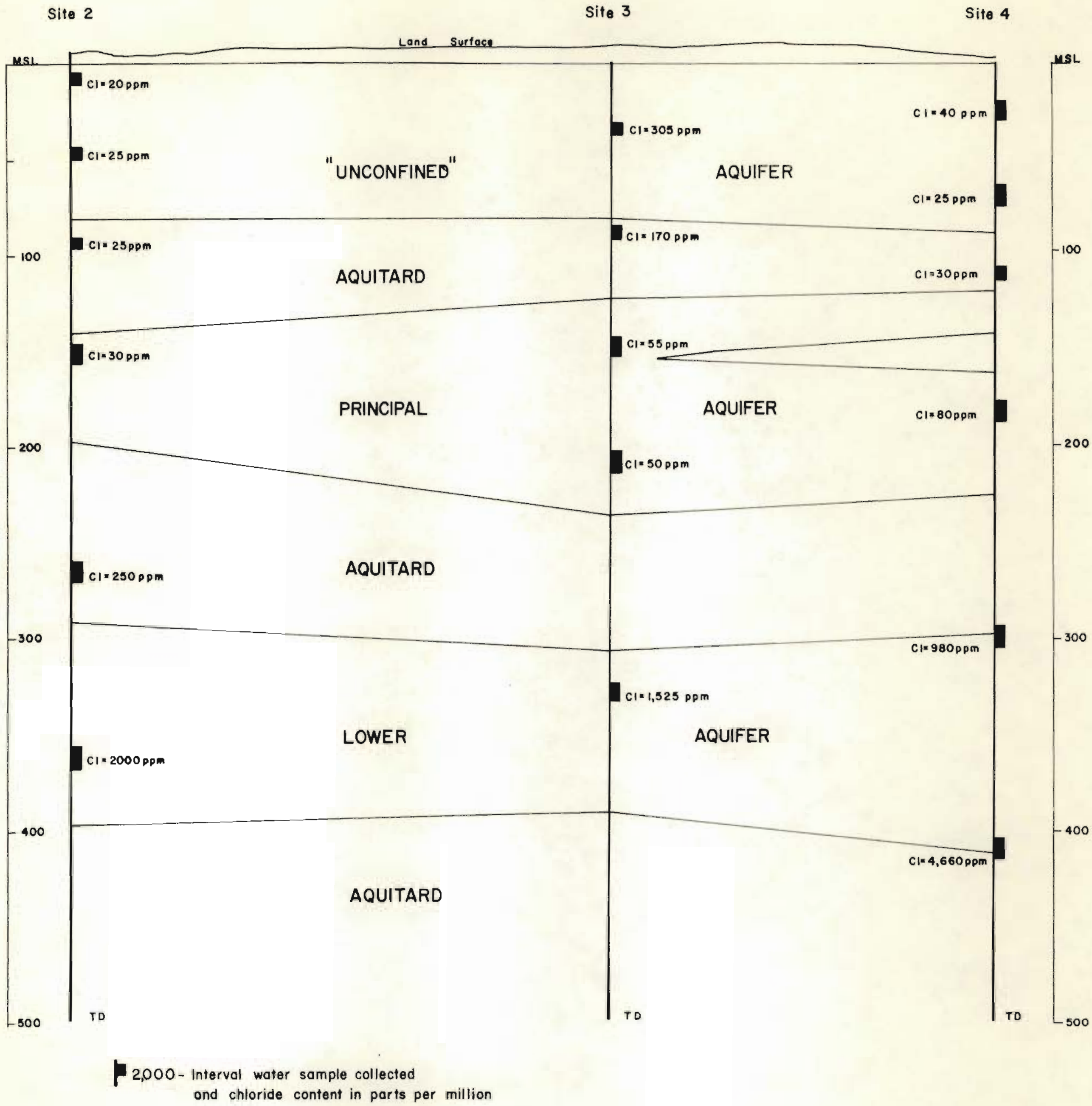

FIGURE 3.- HYDROGEOLOGIC CROSS-SECTION, SITE 2 TO SITE 4

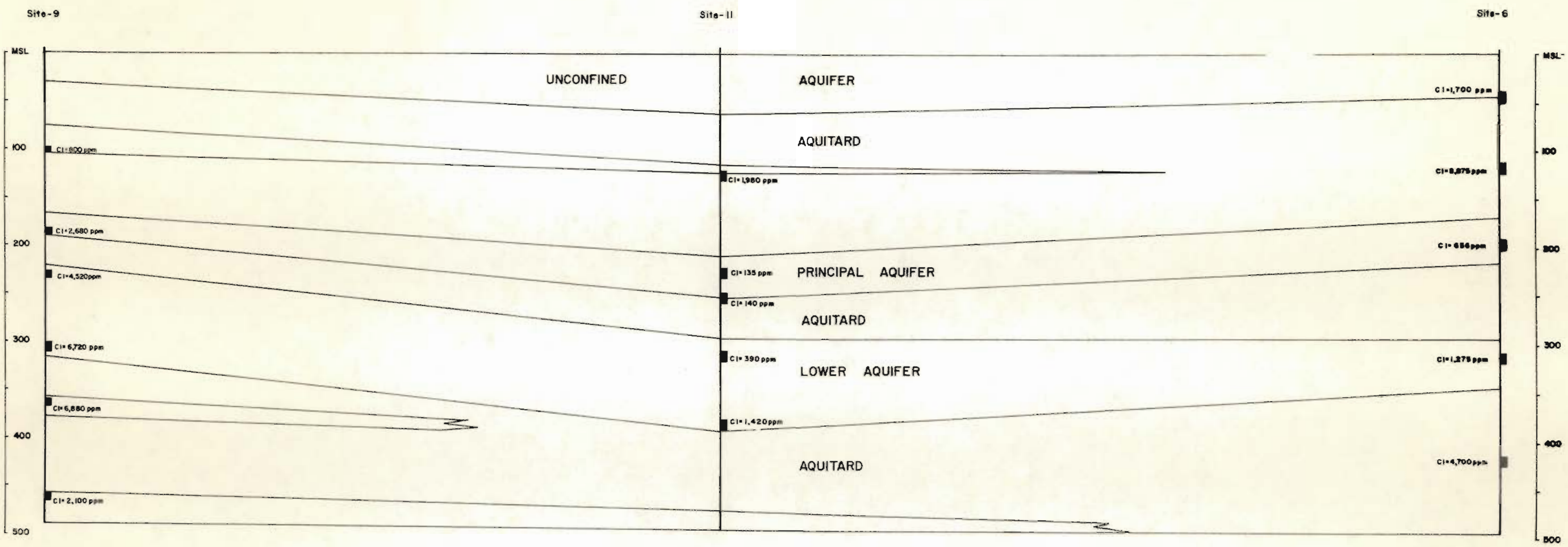

FIGURE 4 - HYDROGEOLOGIC CROSS-SECTION, SITE 9 TO SITE 6

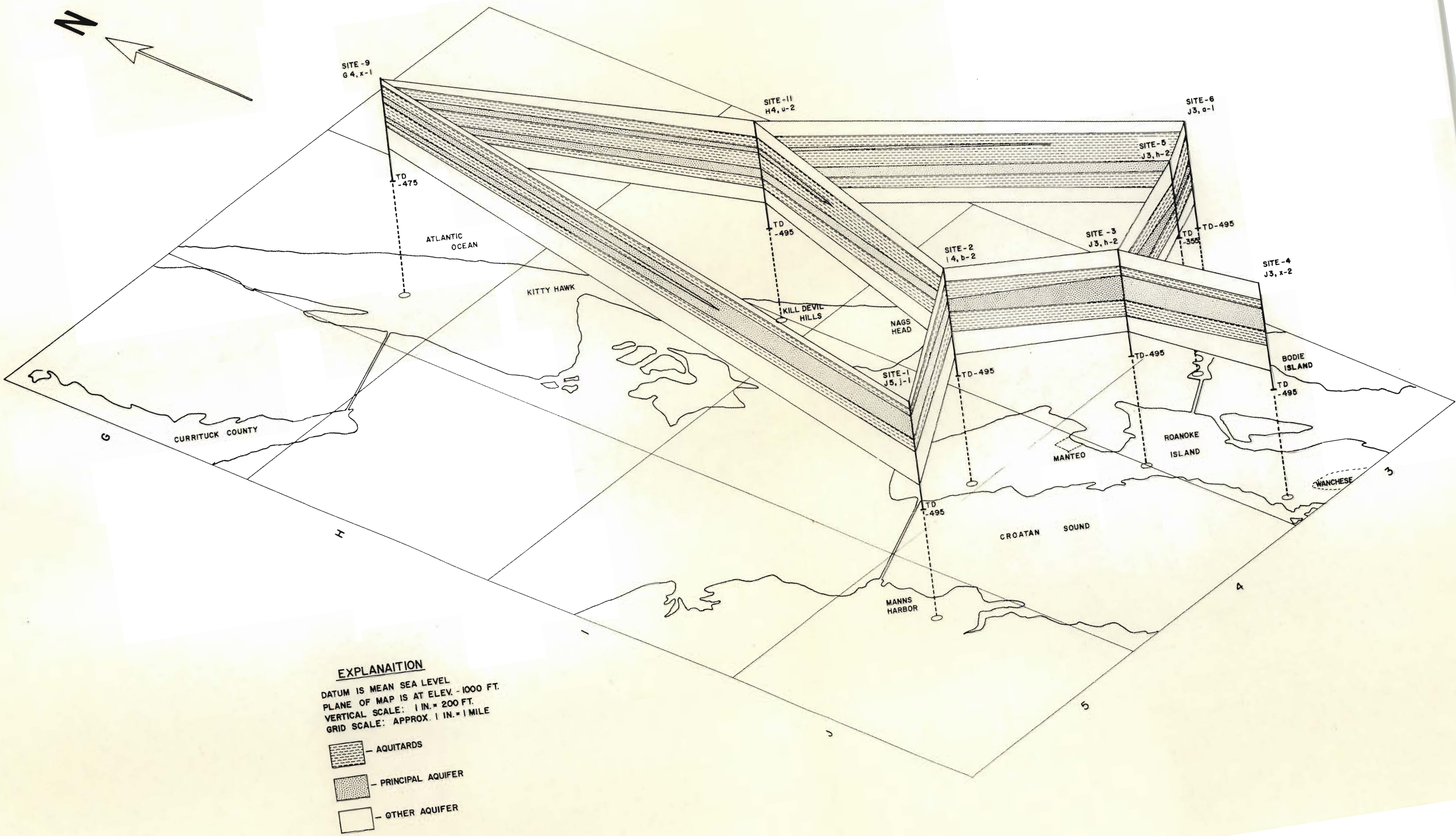

FIGURE 5.- HYDROGEOLOGIC DIAGRAM, DARE COUNTY BEACHES

of water for muncipal wells at Manteo and many other domestic and commercial wells in the area. It may be a significant reservoir for recharge to the underlying confined aquifer in some parts of the area.

The water-table aquifer is underlain by a layer of clay and interbedded clay and sand that ranges in thickness from about 35 feet to more than 100 feet. This unit is the confining bed for the uppermost confined aquifer, which appears to be the most significant aquifer in the area, and is referred to in this report as the principal aquifer.

The top of the principal aquifer ranges from about 65 feet below sea level at Manns Harbor to about 200 feet at Kitty Hawk (*Fig. 6*). The aquifer consists of fine to coarse, but predominantly medium-grained sand with some shell fragments and some clay lenses. As may be noted on the cross sections, the upper part of the aquifer grades into clayey sands or slay, so that the aquifer at Nags Head is only about 45 feet thick, whereas the thickness at Site 3 on Roanoke Island and at Manns Harbor is more than 110 feet (*Fig. 7*). The aquifer is a source of water to many domestic wells in the vicinity of Wanchese and other wells on Roanoke Island.

Another clay layer lies beneath the principal aquifer, separating it from the lower confined aquifer. The top of the confining bed ranges from about 175 feet to 230 feet below sea level, and the thickness ranges from about 60 to more than 100 feet.

The top of the lower confined aquifer ranges in depth from about 240 to 300 feet below sea level, and in thickness from

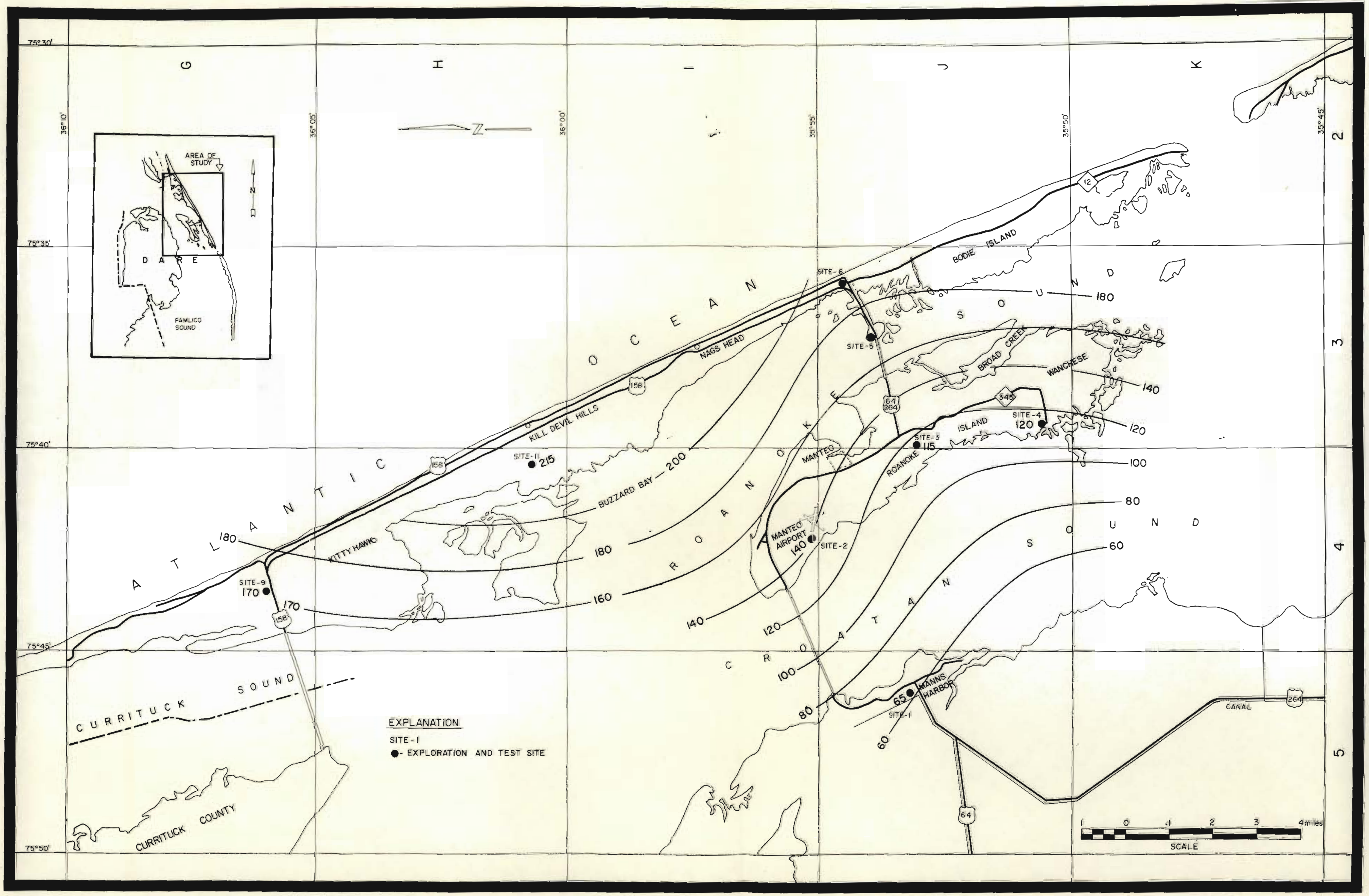

FIGURE 6.- DEPTH TO TOP OF PRINCIPAL AQUIFER

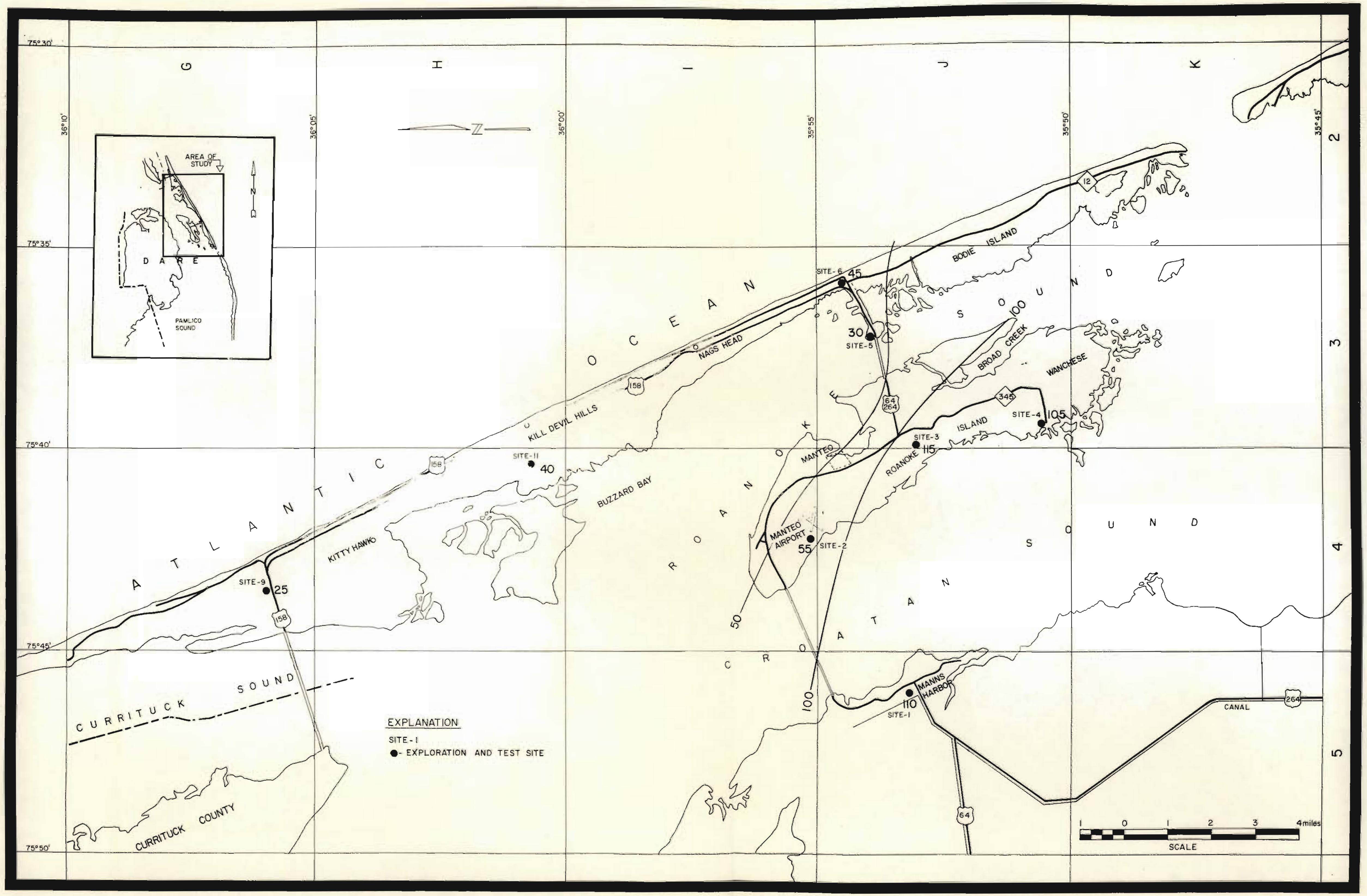

FIGURE 7. - THICKNESS OF PRINCIPAL AQUIFER

about 90 to about 150 feet *(Fig. 8)*. The aquifer is a fine to medium-grained sand with interbedded clays and some shells. The data indicate that the permeability of the aquifer decreases with depth. This aquifer is not used as a source of water supply in the area.

The lower aquifer is underlain by a unit consisting of interbedded clay and fine sands of relatively lower permeability, which is generally considered as a "non-aquifer". This unit ranges in depth from about 315 feet to about 400 feet below sea level.

HYDRAULIC CHARACTERISTICS OF THE AQUIFERS

The scope of this study did not include extensive pumping tests to determine the hydraulic characteristics of all the significant aquifers, but short-term pumping tests were made to evaluate the characteristics of the principal aquifer. At most of the sites, a permanent well was installed in the principal aquifer, which was used as a production well for a pumping test, with a temporary observation well for measuring drawdown constructed in the exploration borehole.

Analyses of these tests indicate a wide range in transmissivity of the principal aquifer *(Table 1)* corresponding in part to differences in aquifer thickness and in part to differences in permeability. The transmissivity, as indicated by the tests, ranges from less than 1000 gallons per day per foot at Site 11 to about 60,000 at Site 4 *(Fig. 9)*. No tests were made at Site 9, but the transmissivity appears to be very low.

No tests were made to determine the hydraulic character of the lower confined aquifer or the "unconfined aquifer. The only

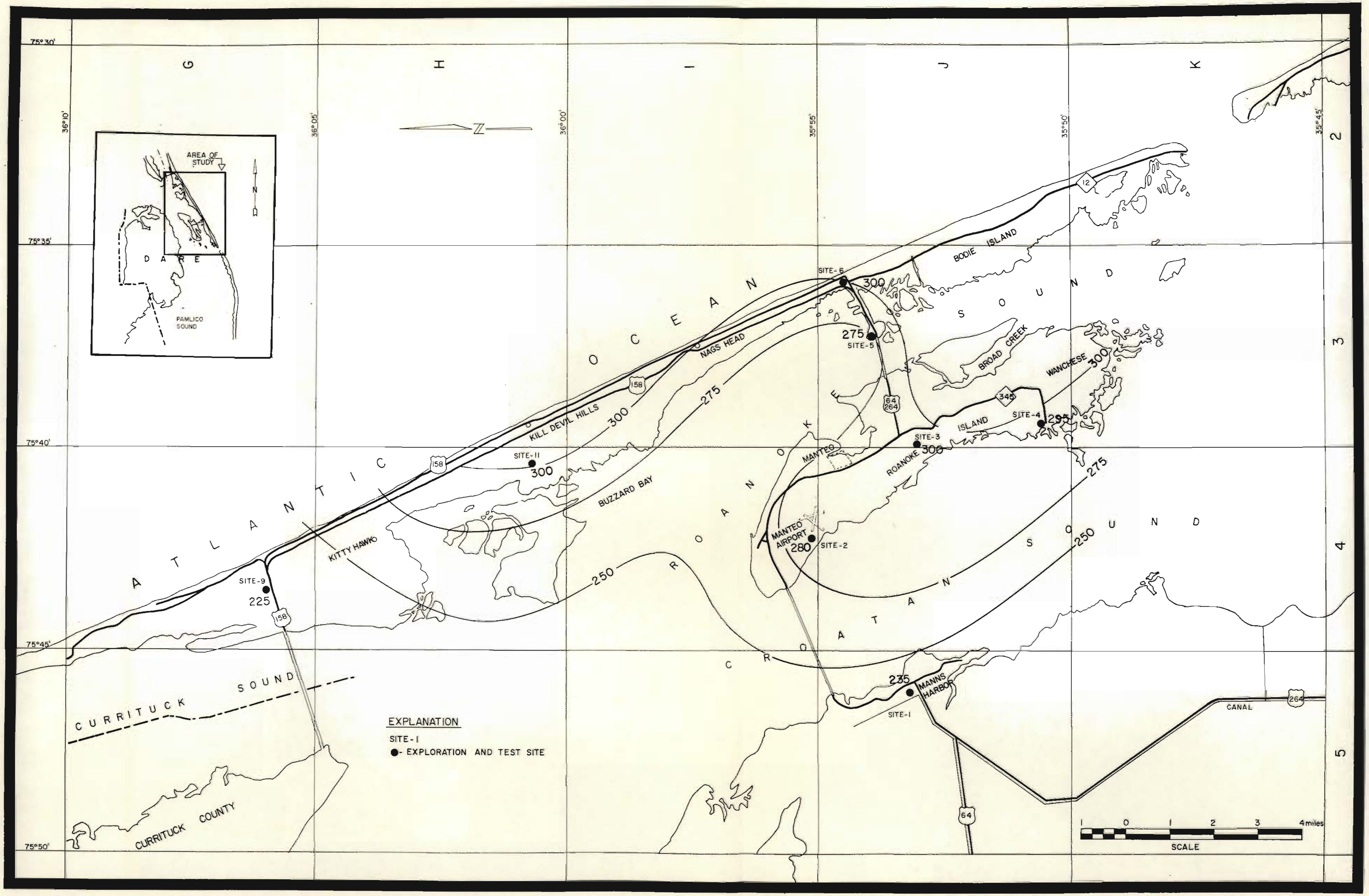

FIGURE 8.- DEPTH TO TOP OF LOWER CONFINED AQUIFER

indices of permeability are the yields obtained from the test zones in sampling procedures. Yields of 30 to 40 gallons per minute *(gpm)* were pumped from the test zones in the lower confined aquifer at most sites.

WATER LEVELS

As a part of the testing in the exploration borehole at each site, water-level measurements were made for most of the zones tested. However, because development of the tested zones was incomplete in some cases, water-level measurements for some zones may be inaccurate. Water levels measured in observation wells are accurate within one-tenth of a foot.

Figure 10 shows the piezometric surfaces of the water in the principal aquifer. As indicated by the contours, the elevation of the surface ranges from less than one foot above mean sea level *(msl)* to more than six feet above msl. The configuration of the contours shows that recharge to the principal aquifer occurs on Roanoke Island and on the mainland. The natural discharge area includes the sounds, some parts of Roanoke Island and the Dare Beaches.

Water levels for the lower confined aquifer indicate that the recharge to this aquifer is probably on the mainland, and that the natural discharge area would include the discharge area of the principal aquifer.

WATER QUALITY

To determine the quality of the water relative to salinity, water samples were collected at several depths at each site. The chloride content and specific conductance of these samples

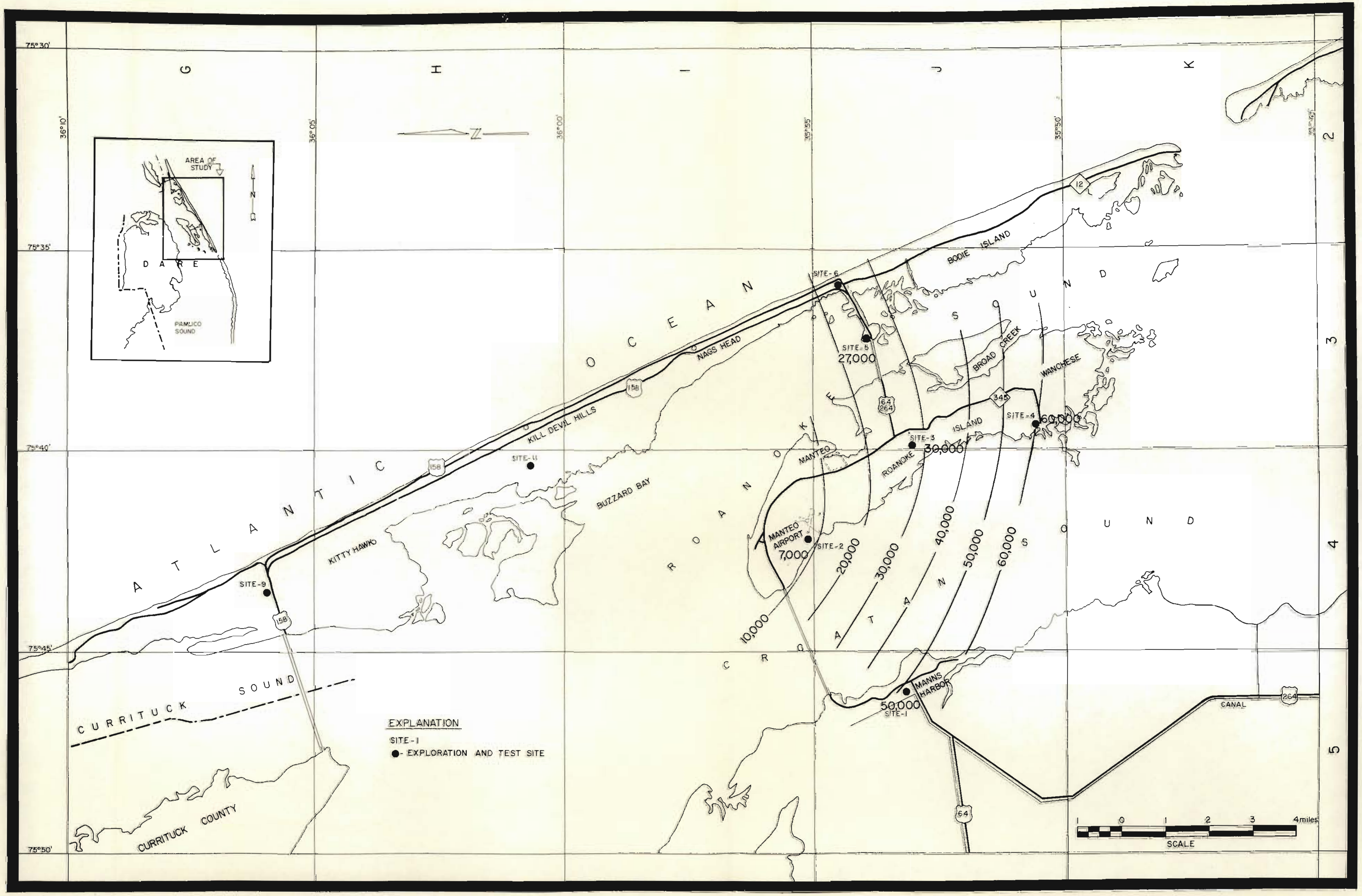

FIGURE 9. - TRANSMISSIVITY OF PRINCIPAL AQUIFER

were determined in the field, as shown in *Table 1* and on *Figs. 2, 3, 4 and 11*. Samples for comprehensive analyses of the chemical constituents were collected from the principal aquifer. *(Table 2)*

As indicated by the conductivity and chloride content, the salinity of the water varies considerably with depth at each site. The differences in salinity reflect differences in permeability of the hydrogeologic units and the hydrologic conditions at the site and in the area.

The chloride content of the water from the "unconfined" aquifer has a wide range because of the difference in conditions at the different sites, as might be expected. At Site 5, on the causeway, and Site 6, on the beach, the chloride content ranges up to more than 8000 parts per million *(ppm)*. At Site 3, it ranges from 15 to more than 300 ppm. At Sites 1, 2 and 4, the chloride content is less than 50 ppm.

The chloride content of the water in the principal aquifer appears to be relatively uniform, ranging from about 30 to 140 ppm except at Sites 6 and 9. It is about 650 ppm at Site 6 and about 2680 at Site 9. The low chloride content throughout most of the area apparently reflects the permeability of the aquifer and the extensive circulation of the fresh water through it.

The chloride content of the water in the lower confined aquifer, although considerably higher than in the principal aquifer, is not extremely high. In the upper part of the unit, it ranges from about 250 ppm to more than 1500 ppm; in the lower part of the unit, from about 1500 to more than 4600 ppm.

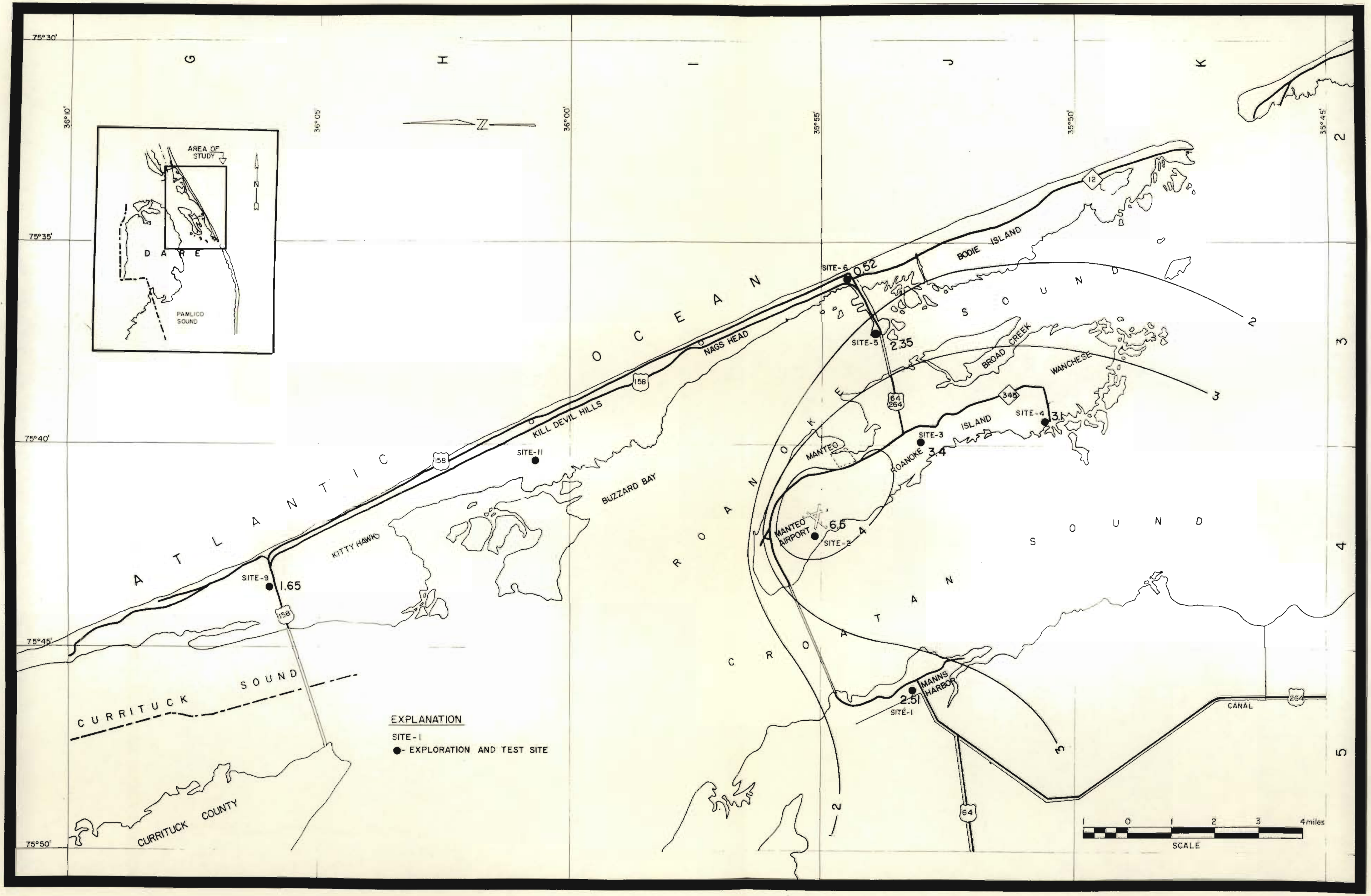

FIGURE 10. - PIEZOMETRIC SURFACE OF PRINCIPAL AQUIFER - JANUARY 1973

WATER-SUPPLY POTENTIAL OF THE PRINCIPAL AQUIFER

The exploration and test data show the principal aquifer to be an extensive and productive source of water supply in most of the study area. The water-supply potential appears to be more than adequate to meet the needs of the area in the forseeable future.

Because of the high degree of permeability of the aquifer in most of the area, it has been largely flushed of saline water. The confining beds above and below the aquifer provide good protection from vertical encroachment of saline water. Rainfall on the mainland is the source of recharge where the confining bed above the aquifer is absent, thin, or relatively permeable. The data indicate the major center of recharge is on the west side of Croatan Sound where the confining bed possibly terminates, and where the permeability and transmissivity of the aquifer are highest. From the recharge area the water moves beneath the Sounds toward Roanoke Island and the Beaches. The three areas that appear most favorable for development of water supplies are shown in *Fig. 12* and discussed briefly below.

KILL DEVIL HILLS - NAGS HEAD AREA

The test data from Site 11 at Kill Devil Hills show that water-supplies to supplement or replace the existing supplies can probably be developed from the principal aquifer in the beach area between Kill Devil Hills and Nags Head. The data show the water in the aquifer to have a chloride content of about 140 ppm at Site 11 and about 110 ppm at Site 5, indicating that water of

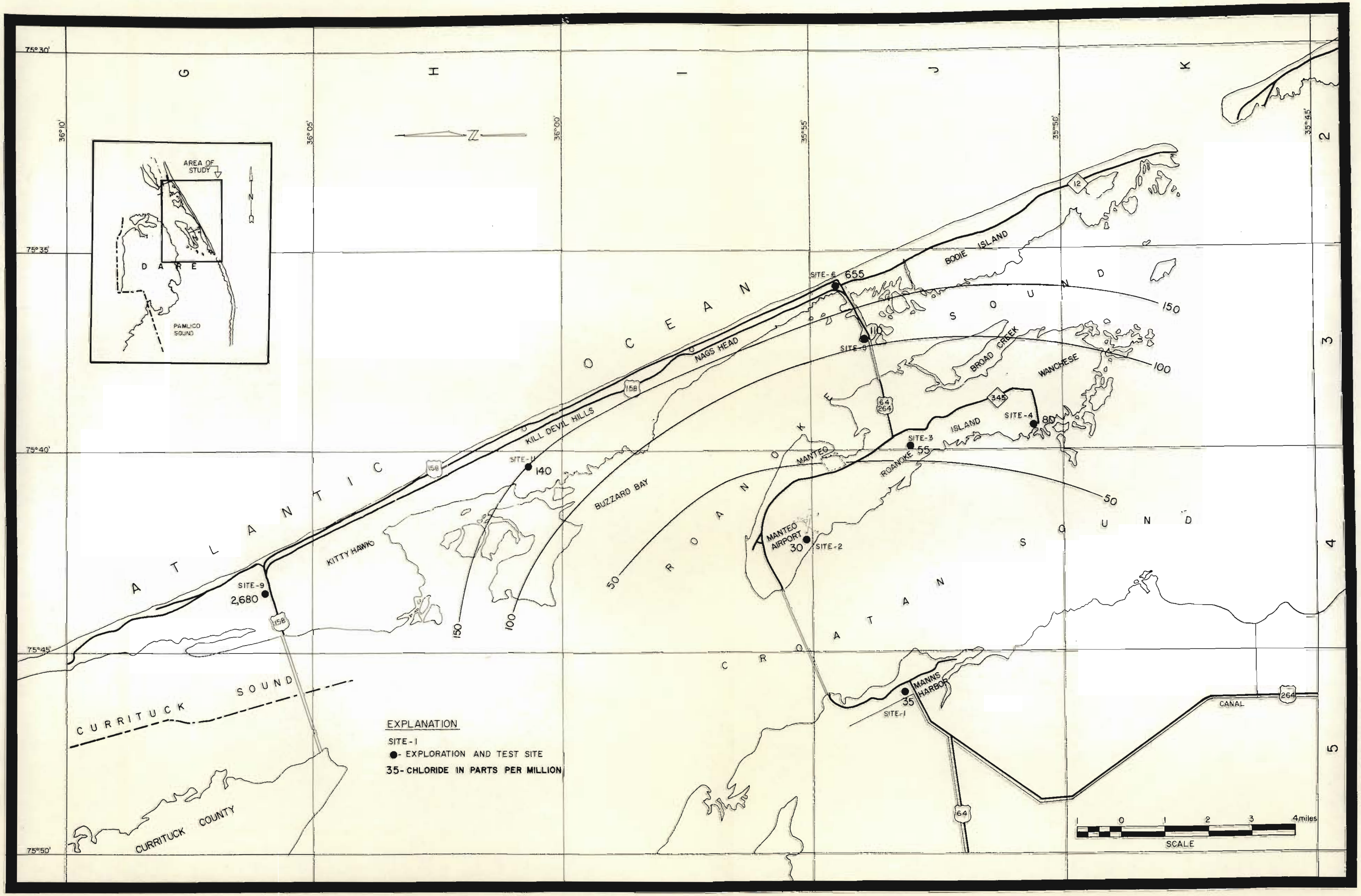

FIGURE 11. - CHLORIDE CONTENT OF WATER IN PRINCIPAL AQUIFER

fairly good quality may be available. Water from the test well at Site 11 was somewhat high in organic color, however, this is probably a local condition, as no significant color was noted for the water at any other sites.

As additional and more desirable water supplies are urgently needed for Kill Devil Hills and Nags Head, these municipalities should give immediate consideration to the construction of additional test wells between Sites 11 and 5.

The data indicate that water supplies with a chloride content less than 250 ppm can probably be developed on Bodie Island. Quantities adequate for the needs of this part of the National Seashore Park should be available from wells about 250 to 300 feet deep.

ROANOKE ISLAND

The principal aquifer extends beneath all of Roanoke Island and has been the source of water supplies for many years. The productivity of the aquifer and the good quality of the water were briefly described in a report by Perry F. Nelson in 1964.

The data from the exploration and test wells show the southern half of the island to be very favorable for the development of relatively large water supplies should not place excessive stress on the aquifer. Drawdown of the piezometric surface created by withdrawal of several MGD would probably intercept zones of brackish water that may occur naturally in the aquifer; however, the rate of movement of the brackish water would be extremely slow. Significant detriment to the supply would probably not occur for many years and may never occur.

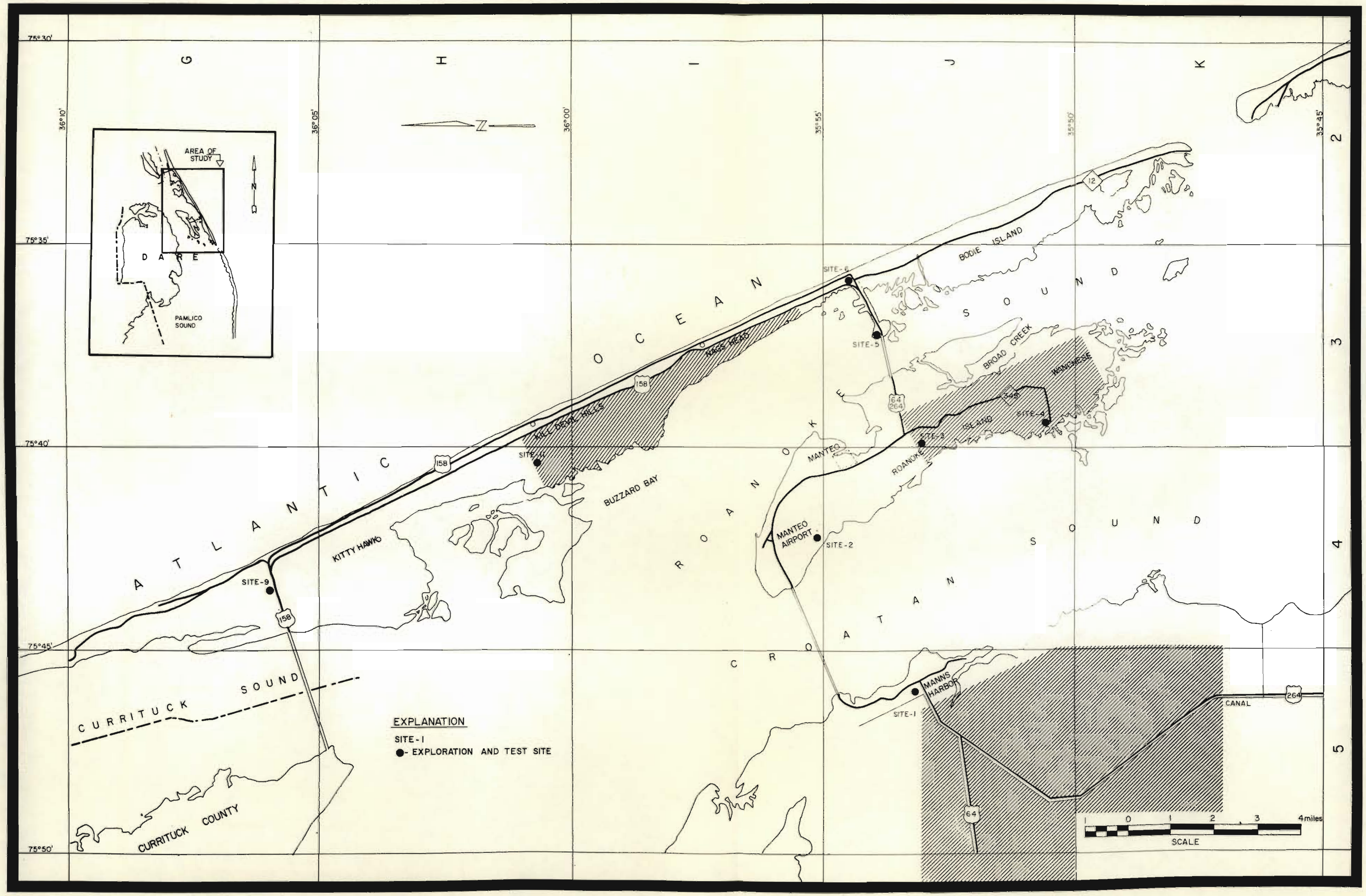

FIGURE 12.- AREAS FAVORABLE FOR WELL-FIELD DEVELOPMENT

Development of water supplies on the island should be planned with proper spacing of production wells and installation of monitor wells for mapping the drawdown pattern and observing any changes in water quality. The data indicate the spacing between wells should be about .5 mile.

MAINLAND SOUTH OF MANNS HARBOR

The exploration and test data indicate that the area south of Manns Harbor on the mainland is ideal for development of large water supplies. This area includes or is adjacent to the center of recharge and also the greatest thickness and transmissivity of the aquifer. The quality of the water appears to be excellent and salt-water encroachment is not likely to be a problem for many decades, if ever. Development of the aquifer will require wells less than 200 feet deep and yields of 500 gpm or more should be possible.

NEED FOR MANAGEMENT OF THE AQUIFER

Development of the principal aquifer has been very limited to date, and has been restricted primarily to domestic wells on Roanoke Island. Present withdrawals of water are not significant, but the demand will rapidly increase to meet the expanding requirements of the area and particularly the beaches and Roanoke Island. If managed properly, the aquifer offers an excellent and adequate source of water supply for the anticipated population growth in the area.

In order to insure proper development and protection of the aquifer, a comprehensive management plan should be established as soon as possible. A Capacity-Use Area that includes Dare County should be designated at an early date and water-management regulations established.

SUMMARY

For many years, the need for locating and developing a more adequate source of water supply for the Dare County Beaches has been recognized. Extensive studies have been made of the shallow aquifer beneath the islands, and these aquifers have been used as a water-supply source, but with the rapid growth and development of facilities on the beaches they are no longer adequate.

To assist the beach areas, and as a part of a Capacity-Use Study to evaluate the ground-water resources of the region, the Ground Water Division conducted a program of exploratory drilling and testing in northeastern Dare County in 1972. The exploration and testing to a depth of about 500 feet at 8 sites provided a great quantity of new and valuable information on ground-water conditions in the area.

Three significant water-bearing sand units lie beneath the area that include an "unconfined" aquifer and two confined aquifers. The aquifers are separated by beds of clay and sandy clay that serve as effective confining beds or aquitards throughout most of the study area.

The unconfined aquifer extends to depths of about 35 to 100 feet and has been the principal source of supply in the area. The water may be high in iron and organic color at some localities.

The water is subject to pollution from septic tanks and salt water occurs at shallow depths in most of the beach area. Significant quantities of water are available from the aquifer on Roanoke Island and the mainland. Recharge is from local rainfall with perhaps some leakage upward from the confined aquifers.

The upper confined aquifer, identified in this report as the principal aquifer, is shown by test data to be a productive source of water supply in most of the study area and the water quality is generally good. The confining beds above and below the aquifer offer good protection from vertical encroachment of salt water. Rainfall on Roanoke Island and on the mainland where the confining beds are absent or relatively permeable is the source of recharge. This aquifer offers an excellent and adequate source of water supply for the area, however, long-range planning and proper development and protection of the aquifer are essential. Under a Capacity-Use Area designation, management regulations should be established as soon as possible.

The lower confined aquifer contains water with a salt content that is not extremely high but too great for general use in the study area. Beneath most of the mainland, this aquifer may be a productive source of fresh water, but additional exploration is needed to evaluate the ground-water conditions for the remainder of Dare County.

TABLE 1 - EXPLORATORY AND TEST WELL DATA FOR NORTHEASTERN DARE COUNTY

SITE	WELL NO.	SCREEN DEPTH (FEET)	WATER LEVEL (FT.BELOW LS)	CASING (FT.ABOVE LS)	YIELD (GPM)	TEMP. °F	CHLORIDE (MG/L)	SPECIFIC CONDUCTANCE MICROMHOS	PUMPING PERIOD (MINUTES)	APPARENT TRANSMISSIVITY	ESTIMATED PERMEABILITY
1	Supply from small water table lake										
	J-5, j-1a	332-342	4.68	1.5	30		1510	5600			
	b	258-268	4.15	1.5	25		250	1450			
	c	162-172	4.20	1.5	30		40	710			
	J-5, j-2a	34-39	7.80	1.5	10		30	175			
	b	92-102	4.90	1.5	15		30	220			
	c	162-172	3.80	1.52*	75		40	700	100	50000	450
2	I-4, v-1(Supply)	10-14	7.10	1.0	25		20	100			
	I-4, v-2a	360-370	8.20	1.5	35		2000	8100			
	b	264-274	7.70	1.5	2		250	1900			
	c	150-160	9.30	1.5	20		30	650			
	I-4, v-3a	50-55	8.20	1.5	1		25	395			
	b	92-97	7.00	1.5	2		25	410			
	c	150-160	11.34	1.85*	125		30	610	100	6600	120
3	J-3, f-1(Supply)	10-14	4.70	1.0	30		15	130			
	J-3, f-2a	40-45	4.80	2.0	15		305	1750			
	b	84-89	2.40	2.0	2		170	1100			
	c	324-334	3.00	1.5	35		1525	6500			
	d	200-210	4.71	1.5	35		50	670			
	J-3, f-3a	134-144	4.08	1.5	30		35	645			
	b	199-209	3.40	2.19*	55		50	650	120	30000	260
4	J-3, y-1(Supply)	5-9	3.40	1.0	7	63	20	195			
	J-3, y-2a	21-31	4.69	1.5	30	63	40	530			
	b	63-73	3.98	1.5	25	68	30	660			
	c	405-415	3.39	1.5	5	72	4780	15000			
	d	295-305	2.95	1.5	35	66	980	3800			
	e	189-199	2.65	1.5	25		80	540			
	J-3, y-3a	105-115		1.5	5		30	520			
	b	180-190	4.18	2.17*	63		80	540	120	60000	700
5	Supply from Nags Head										
	J-3, h-1a	40-50	5.28	1.5	20		13400				
	b	25-30	7.46	1.5	30		8420	30000			
	J-3, h-2a	85-90	4.79	2.0	30		6140	20000			
	b	294-304	20.00**	1.5	30		860	3900			
	c	197-207	3.25	1.5	40		110	860			
	J-3, h-3	197-207	3.59	1.33*	83		110	860	120	27000	600
	J-3, h-4	5-10	4.94	1.0	10		160	960			
	J-3, h-5	10-15	4.63	1.0	10		460	2000			
6	Supply from Nags Head										
	J-3, a-1a	420-430	9.90	1.0	5		4700				
	b	314-324	4.36	1.0	30		1275				
	c	197-207	4.57	1.0	30		656				
	d	118-128	6.84	1.0	10		8875				
	J-3, a-2	43-53	5.40	1.0	30		1700				
7	NOT DRILLED										
8	NOT DRILLED										
9	Supply from Lagoon						410	1300			
	G-4, x-1a	461-471	.00	1.5	1/4		2100	8100			
	b	363-373	3.00	1.5	1/4		6880	20500			
	c	305-315	119.00**	1.5	1/4		6760	20500			
	d	228-238	4.40	1.5	10-15		4520	15500			
	e	187-197	40.70**	1.5	1/4		2680	10150			
	f	101-106	3.30	1.5	15		800	3200			
10	NOT DRILLED										
11	H-4, u-1(Supply)	5-9		1.12*	30	62	25	300			
	H-4, u-2a	386-396	8.20	1.50	25	66	1420	4000			
	b	315-325	5.70	1.50	10	65	390	1500			
	c	256-266	3.18	1.50	10	64	140	1175	70	700	
	d	228-238	5.95	1.50	10	64	133	1275			
	e	126-136	5.60	2.0*	10	62	1980	5000			

* Measured
** Not Recovered

12-12-1972

TABLE 2 - COMPREHENSIVE WATER ANALYSIS OF PRINCIPAL AQUIFERS IN NORTHEASTERN DARE COUNTY

(ANALYSES MADE BY U. S. GEOL. SURVEY. RESULTS OF CHEMICAL ANALYSES IN MILLIGRAMS PER LITER)

Site	Well	Screen	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (CL)	Fluoride (F)	Nitrate (NO_3) as N	Phosphate (PO_4)	Dissolved Solids (Sum)	Hardness (as $CaCO_3$)	pH	Color	Alk ($CaCO_3$)	Spec. Cond. (µmhos @ 25° C)
1	J-5, j-1a	332-342	14	.370	.000	.014	27	69	1030	51	0	548	87	1470	.2	3.30	.038	3040	370	8.2	10	548	5000
	1b	258-268	15	.204	.000	.012	22	27	245	22	0	448	.6	244	.4	1.70	.054	780	165	8.1	10	367	1300
	1c	162-172	24	.165	.096	.000	68	7.8	66	8.5	0	398	1.6	29	.2	.20	.000	405	202	7.7	10	326	650
	j-2a	34- 39	5.3	.000	.000	.000	25	3.8	16	.9	0	90	13	17	.1	1.20	.000	131	78	7.2	0	74	230
	j-2b	92-102	13	.048	.000	.016	29	2.3	14	1.2	0	106	.6	18	.1	.10	.000	131	82	7.4	0	87	220
2	I-4, v-1	10- 14	7.9	.000	.000	.014	6.7	.7	6.9	.9	0	20	.2	15	.1	.0	.000	48	20	6.4	0	16	85
	v-2a	360-370	18	.830	1.132	.016	21	73	1340	55	0	518	15	2050	.3	3.00	.000	3850	354	8.1	15	425	6500
	2b	264-274	9.9	.374	.081	.015	8.3	8	350	13	0	594	13	238	.8	2.00	.120	948	54	8.2	140	487	1550
	2c	150-160	34	.176	.040	.006	12	6.7	94	13	0	315	.8	19	.5	.07	.190	339	58	7.6	30	258	525
	v-3a	50- 55	15	.096	.000	.021	40	2.7	29	1.4	0	178	8.2	20	.1	.00	.000	205	111	7.4	0	146	350
	3b	92- 97	17	.195	.109	.008	28	2.0	41	3.8	0	162	10.0	20	.3	.07	.000	203	78	7.3	0	133	330
3	J-3, f-2a	40- 45	12	.199	.000	.014	139	12.0	116	3.0	0	316	2.4	283	.2	.10	.000	726	395	7.8	25	259	1280
	f-2b	84- 89	19	.043	.000	.008	47	8.4	64	3.0	0	104	3.4	152	.1	.07	.000	349	152	7.7	0	85	720
	f-2c	324-334	16	.366	.198	.026	22	36	1070	37.0	0	600	11	1480	.6	1.0	.066	2980	202	8.1	20	492	5000
	f-2d	200-210	17	.000	.000	.014	61	8.0	34	5.8	0	252	6.2	43	.2	.00	.000	301	185	7.8	0	206	500
	f-3a	134-144	32	.239	.248	.000	71	10	34	8.9	0	299	.6	42	.2	.00	.000	349	218	7.6	5	189	550
4	J-3, y-2a	21- 31	6.9	.038	.000	.008	27	8.6	23	1.4	0	131	7.4	30	.1	.02	.000	169	103	7.5	0	107	300
	y-2b	63-73	13	.139	.050	.012	32	4.5	46	2.3	0	164	26	32	.1	.05	.000	238	99	7.6	10	134	390
	y-2e	189-199	21	.067	.000	.052	43	5.8	56	7.5	0	250	3.0	44	.2	.00	.043	306	132	7.7	5	205	500
	y-3a	105-115	37	.122	.000	.022	43	11	42	9.2	0	197	25	45	.3	.2	.000	311	152	7.7	10	162	500
5	h-2b	294-304	16	.294	.295	.004	8.7	12	750	23	0	668	2.4	828	1.1	2.9	.15	1990	70	7.9	50	548	3200
	h-2c	197-207	22	.215	.078	.000	24	3.4	167	10	0	412	1.8	90	.3	.05	.093	525	74	7.8	40	338	900
9	G-4, x-1a	461-471	2.6	.240	.000	.046	47	37	1260	47	0	294	9.4	1970	.4	.7	.000	3520	268	7.7	10	241	5800
	x-1b	363-373	2.2	.667	.000	.204	90	184	3860	136	0	234	74	6480	.5	.2	.000	10900	938	7.6	10	192	18000
	x-1c	305-315	6.2	.864	.000	.051	99	198	3980	126	0	476	46	6640	.4	.09	.000	11300	1060	7.9	20	390	17000
	x-1d	228-238	12	.696	.000	.040	58	155	2840	78	0	436	35	4710	.7	2.8	.076	8120	773	7.7	30	358	12200
	x-1e	187-197	1.6	.474	.059	.014	45	96	1740	50	0	381	27	2900	.5	.07	.000	5050	506	8.2	30	312	9000
	x-1f	101-106	15	.428	.381	.014	65	60	475	30	0	451	2.2	780	.5	.7	.093	1660	407	8.1	30	370	2800

REFERENCES

Brown, P. M., 1960, *Ground-water supply of Cape Hatteras National recreational area:* N. C. Department of Water Resources, Report of Investigation No. 1, 14 p.

Kimrey, J. O., 1960, *Ground-water supply of Cape Hatteras National Seashore recreational area, Part 2:* N. C. Department of Water Resources, Report of Investigation No. 2, 28 p.

Kimrey, J. O., 1961, *Ground-water supply for the Dare Beaches Sanitary District:* N. C. Department of Water Resources, Report of Investigation No. 3, 20 p.

Lloyd, O. B. and Wilder, H. B., 1968, *Ground-water supply of Cape Hatteras National Seashore recreational area, North Carolina, Part 4;* N. C. Department of Water Resources Report of Investigation No. 5, 19 p.

Nelson, P. F., 1964, *Geology and ground-water resources of the Swanquarter area, North Carolina:* N. C. Department of Water Resources, Ground-water Bulletin No. 4, 79 p.