RALPH C. HEATH
Consulting Hydrogeologist
4821 Kilkenny Place
Raleigh, N. C. 27612
(919) 782-0171

REPORT ON THE PROPOSED BUXTON WOODS WELL FIELD OF THE CAPE HATTERAS WATER ASSOCIATION

Prepared by
Ralph C. Heath

For the
Cape Hatteras Water Association, Inc.
P.O. Box 578
Buxton Woods, N.C. 27920

June 1990

AMERICAN INSTITUTE OF HYDROLOGY
Certificate Number 104
RALPH C. HEATH
Professional Hydrogeologist

NORTH CAROLINA LICENSED GEOLOGIST
SEAL 226
RALPH C. HEATH

CONTENTS

ILLUSTRATIONS

REPORT ON THE PROPOSED BUXTON WOODS WELL FIELD OF THE CAPE HATTERAS WATER ASSOCIATION

by Ralph C. Heath
Consulting Hydrogeologist

SUMMARY OF FINDINGS

1. Test-well construction program - In May 1990, the Cape Hatteras Water Association constructed four test wells on the State-owned property in Buxton Woods in connection with a proposal to develop a new well field to meet the increasing water needs of the Cape Hatteras-Avon area of Hatteras Island.

2. Hydrogeologic conditions - Data obtained from the test wells confirm that the thickness, hydraulic characteristics, and water quality of the Buxton Woods aquifer in the area of the proposed well field are similar to those in the existing CHWA well field. A relatively coarse-grained zone between 60 and 70 feet below land surface appears to be well suited for the development of supply wells.

3. Design of the proposed well field - A well field consisting of nine supply wells spaced 425 feet apart can be constructed on the State-owned property. The proposed location of the wells is along the north side of the sand ridge that borders Jennette Sedge on the north. The continuous (long-term sustained) yield of the area that will supply water to the wells is estimated to be about 390,000 gallons per day. This yield could be obtained by pumping water continuously from each of the nine wells at a rate of 30 gallons per minute. However, in order to meet peak water demands and to provide for cutoff periods for well and water-plant maintenance, the supply wells should be designed to provide the maximum estimated yield of 120 gallons per minute per well.

4. Effect on environmental conditions - The physical characteristics of the aquifer are such that the lowering of the water table in response to the pumping will be spread out over a large area and therefore will not be excessive in any area. As a result, the lowering of the water surface in Jennette Sedge and other swales is not expected to have any adverse effect on the wetland vegetation. The forest vegetation on the sand ridges relies largely on soil moisture which will not be affected by the proposed well field.

TEST-WELL CONSTRUCTION PROGRAM

Between April 30 and May 15, 1990, the Magette Well and Pump Co., Inc., Ahoskie, N.C., constructed four test wells on State-owned land in the Buxton Woods area of Hatteras Island in the area proposed for a new well field of the Cape Hatteras Water Association. Construction of the test wells was approved by the North Carolina Division of Coastal Management under CAMA Minor Permit No. 89-125, dated January 8, 1990; and by the North Carolina Department of Environment, Health, and Natural Resources under Well-Construction Permit No. 27-0099-WM-0066, dated February 20, 1990.

The purpose of the test wells was to determine the physical (hydrogeologic) characteristics and water-quality conditions in the area and the extent to which the characteristics and conditions differ from those in the existing well field area to the west.

The location of the test wells are shown on Figure 1 and brief descriptions of each of the four test wells are contained in the following paragraphs.

Descriptions of Wells

Test Well 1 - was drilled near the center of the proposed well field to determine the geologic characteristics of the Buxton Woods aquifer, the depth to the confining bed that underlies the aquifer, and the chloride content (salinity) of the water in the aquifer and in the confining bed. It was finished as a permanent water-level and chloride observation well with a 5-ft length of screen set between depths of 118 and 123 ft in a permeable layer in the upper part of the confining bed. Test well 1, being located near the center of the proposed well field, will show the effect of the maximum draw-down in the water table of the Buxton Woods aquifer on the water level and chloride content of the upper part of the confining bed. The purpose of test well 1 is, therefore, to provide warning of any change in the natural hydrologic conditions in response to withdrawals from the well field.

Test Well 1A - was drilled about 5 ft north of test well 1 and was screened between depths of 63 and 68 ft in the coarsest-grained zone of the Buxton Woods aquifer penetrated in test well 1. It is

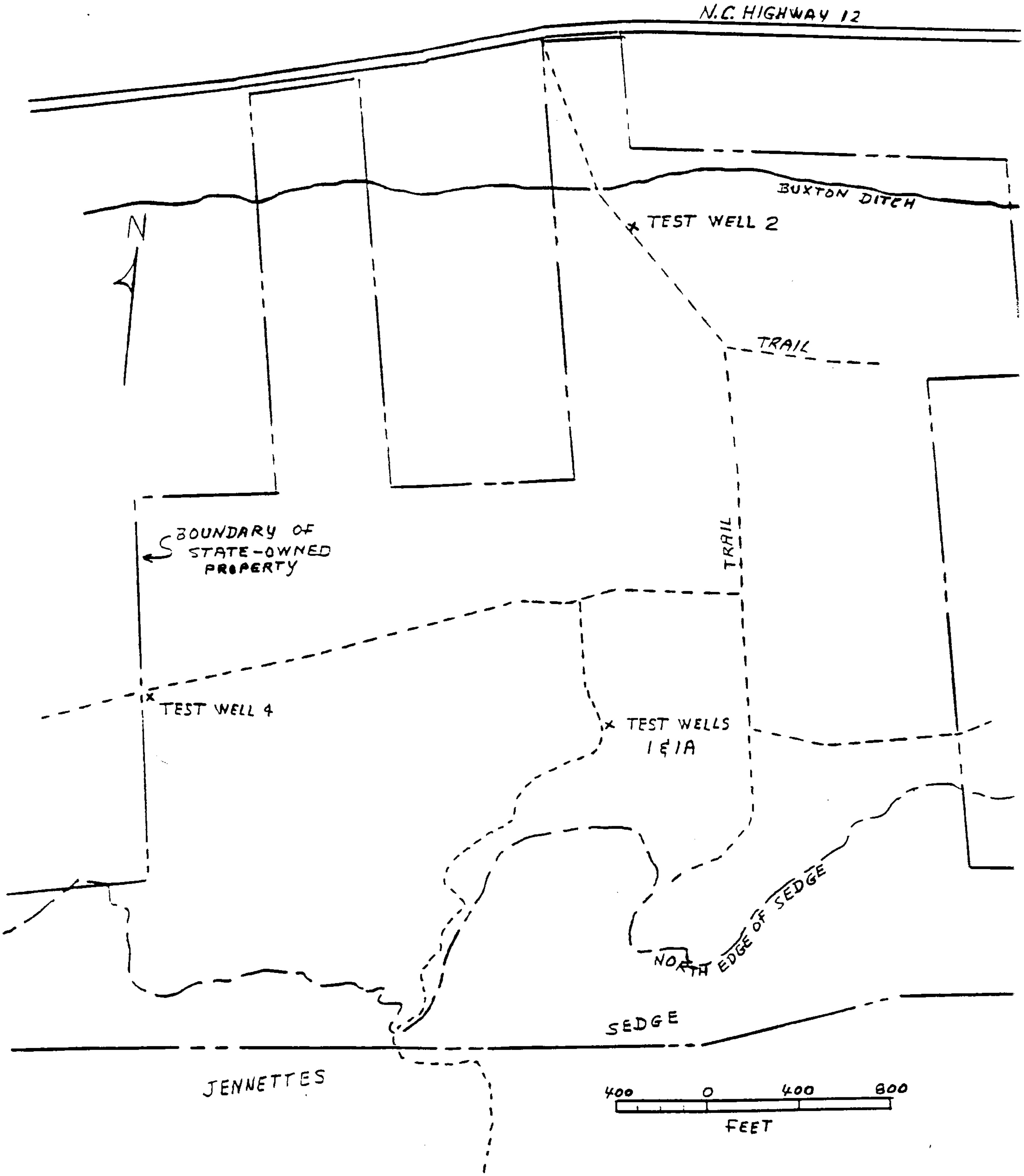


Figure 1.--- Map showing State-owned property in Buxton Woods on Hatteras Island, N.C., and the locations of test wells drilled May 1990 by the Cape Hatteras Water Association.

anticipated that this zone, where present, will be the source of water for supply wells in the proposed well field. The purpose of test well 1A is to provide data on the chemical quality of water in the producing zone of the Buxton Woods aquifer for use in design of a water-treatment plant. Following construction of the supply wells, test well 1A will be used for water-level measurements.

Test Well 2 - was drilled 200 ft south of the Buxton Ditch to determine the chloride content of the water in the lower part of the Buxton Woods aquifer near the northern hydrologic boundary of the aquifer. It is screened in the lower part of the Buxton Woods aquifer, between depths of 67 and 72 ft, and will serve as an "outpost" observation well in which any changes in water level and chloride content caused by withdrawals from the proposed well field can be observed.

Test well 4 - is located near the western end of the proposed well field and was drilled both to determine the geologic and water-quality conditions in the Buxton Woods aquifer and to provide a permanent observation well for water-level measurements and chloride analyses. During construction of test well 4, two different techniques for determining the iron content of water in the aquifer were evaluated. These techniques and the results will be discussed below.

Test-Well Construction

The test wells described above were drilled with the "normal" mud rotary method - that is, water to which Quik Gel drilling mud had been added was pumped through a column of drill pipe to which a bit was attached. The drilling mud, carrying sediments penetrated by the bit, returned to the land surface through the annular space between the sides of the hole and the drill column and, in the process, formed a mud wall on the side of the drill hole which prevented caving of the hole.

Samples of the material penetrated by the drill bit were collected from the drilling fluid. However, these samples give only a rough idea of the grain-size distribution of the sediments being penetrated because the finer-grained fraction tends to stay in suspension in the drilling mud. In an effort to alleviate some of this problem, the drill rods were removed from the holes at 20-ft intervals and a "split-spoon" sampling tube attached to the end of a line of $1\frac{1}{4}$ inch pipe was driven into the bottom of the hole. Through this means, relatively undisturbed cores of material were obtained. After noting the grain-size distribution and stratification (layering) of the sediments, the core was placed in a filter press and air pressure was applied to extract the water contained in the core. The water samples from the cores were analyzed to determine the chloride content and, from test well 4, to determine the iron content.

Filter-Press Samples

Water samples forced by air pressure from the sediment samples placed in the filter press pass through a paper filter. This filter has no effect on the chloride concentration because the chloride ion is dissolved in the water and, therefore, passes with the water through the filter.

Iron, on the other hand, oxidizes in the presence of air and forms an insoluble precipitate which is readily removed by the paper filter in the filter press. In an effort to obtain an estimate of iron concentrations from the cores obtained from test well 4, all of the paper filter was removed except for the outer $\frac{1}{4}$ inch which was needed to provide an air-tight seal. The results will be discussed in the section on iron data.

HYDROGEOLOGY

Appendix A contains well construction records and electric and gamma-ray logs of the test wells constructed on the State-owned property in Buxton Woods. (Electric and gamma-ray logs were not made for test well 1A because it is only about 5 ft from test well 1.) Appendix B contains particle-size analyses of split-spoon core samples obtained from test wells 1 and 4. The logs and other data obtained from test well 1 are shown in Figure 2. Results of the sieve analyses of the core samples obtained from test well 1 are shown graphically in Figure 3.

Previous test wells drilled in the Cape Hatteras area, including the CHWA well-field area, have shown a surficial layer of fine to coarse-grained sand that grades downward into very fine to medium sand and silt. This finer grained layer is, in turn, underlain by inter-

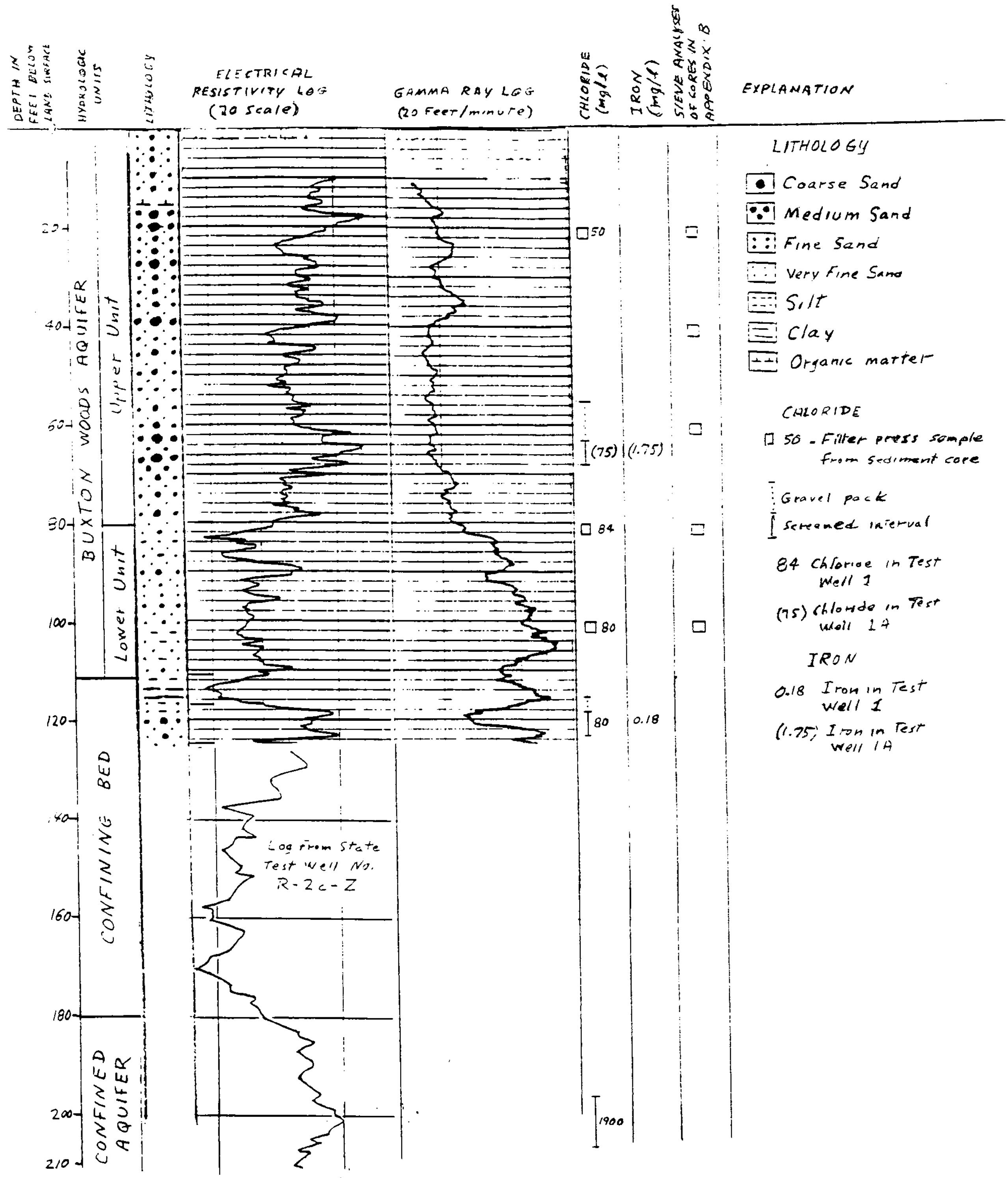


FIGURE 2.--- LOGS AND OTHER DATA FROM TEST WELLS 1 AND 1A DRILLED BY THE CAPE HATTERAS WATER ASSOCIATION IN BUXTON WOODS, HATTERAS ISLAND, N.C., IN MAY 1990.

bedded very fine sandy silt and clay. The two uppermost layers - that is, the layers from land surface down to the interbedded sandy silt and clay - are generally referred to as the Buxton Woods aquifer. The sandy silt and clay are referred to as a confining bed and they are, in turn, underlain by sands that comprise a confined aquifer.

It was decided, prior to drilling the test wells in Buxton Woods, that drilling test well 1 to a depth of 125 ft would provide sufficient data for the CHWA. It was assumed, on the basis of logs of other wells on Hatteras Island, that at a depth of 125 ft test well 1 would either be well into the confining bed or through the confining bed and into the underlying confined aquifer.

Buxton Woods Aquifer

The data obtained during the test-well-drilling program in Buxton Woods indicate that the dominant material comprising the upper part of the Buxton Woods aquifer is fine to medium-size quartz sand - that is, sand grains that range in diameter from about 0.005 inches (0.125 mm) to about 0.02 inches (0.5 mm). (See Fig. 3.) However, as would be expected for a sedimentary deposit formed in an offshore-island environment, the internal structure of the aquifer is moderately complex. The surface of the island in the past, just as in the present, must have consisted of sand ridges separated by swampy swales. Overwash during major storms eliminated much of the surface relief by covering the swamp deposits with sand from the ridges. Thus, thin organic-rich layers of clayey, silty, very fine sand that formed in the swales are interbedded with relatively thick layers of fine to medium-grained sand. At places, which may represent deposits formed near inlets between islands, the sediments consist of relatively thin layers of coarse to very coarse-grained sand mixed with gravel up to ¼ inch in diameter and containing a large percentage of broken shells.

Some of the split-spoon cores consisted of 1 to 2 ft of fine to medium-grained dark gray sand with no evident stratification (layering). Other cores consisted of layers of fine to medium-grained sand 2 to 4 in. thick interbedded with ½ in. thick layers of coarse to very coarse sand containing both whole immature shells and shell fragments. Only one core, and that from a depth of 70 ft in test well 4, consisted of coarse to very coarse sand. It appears, from both the cores and from the washed samples collected from the drilling mud, that the coarse-grained layers are both relatively thin - from a fraction of an inch to several inches thick - and represent a relatively small percentage of the total thickness of the aquifer.

Cores obtained from the lower part of the Buxton Woods aquifer consist of layers of very fine to fine-grained silty sand 2 to 3 inches thick interbedded with 1 to 2 inch thick layers of bluish gray silty clay. (See the graphs of core samples No. 4 and 5 on Fig. 3.)

Data obtained from the cores appears to reflect what might be termed the "micro scale" stratification of the aquifer. The electrical resistivity and the gamma-ray logs, on the other hand, appear to show larger, or "macro-scale," stratification of both the aquifer and the underlying confining bed. (As is commonly the case in shallow wells that penetrate only the freshwater zone, the self-potential logs, with the exception of that for test well 1, are relatively featureless and do not provide any useful information. The reason for the numerous fluctuations in the self-potential log of test well 1 is not readily apparent but may have been caused by "noise" in the electronic circuitry of the logger.)

The electrical-resistivity logs consist of irregular "wavy" lines that show differences in resistivity of the different layers of material penetrated by the test wells. Because the water contained in the pores of the material has the greatest effect on resistivity, the deflections in the resistivity logs are primarily controlled by porosity. Porosity is, in turn, related to grain size of the material to the extent that the finer-grained material tends to have the largest porosity and the lowest resistivity. Therefore, deflections to the right - in the direction of increasing resistivity - indicate coarser-grained, less porous, layers and deflections to the left indicate finer-grained, more porous layers.

With these points in mind, note that the electrical resistivity logs show a complex alternation of layers having different porosities. The different layers indicated by the logs appear to range in thickness from a foot or less to several feet. Relative to the assumption that deflections to the right indicate coarser-grained, less porous layers, note on Figure 2 that the three pronounced deflections to the right, between depths of 60 and 70 ft on the log of test well 1, co-

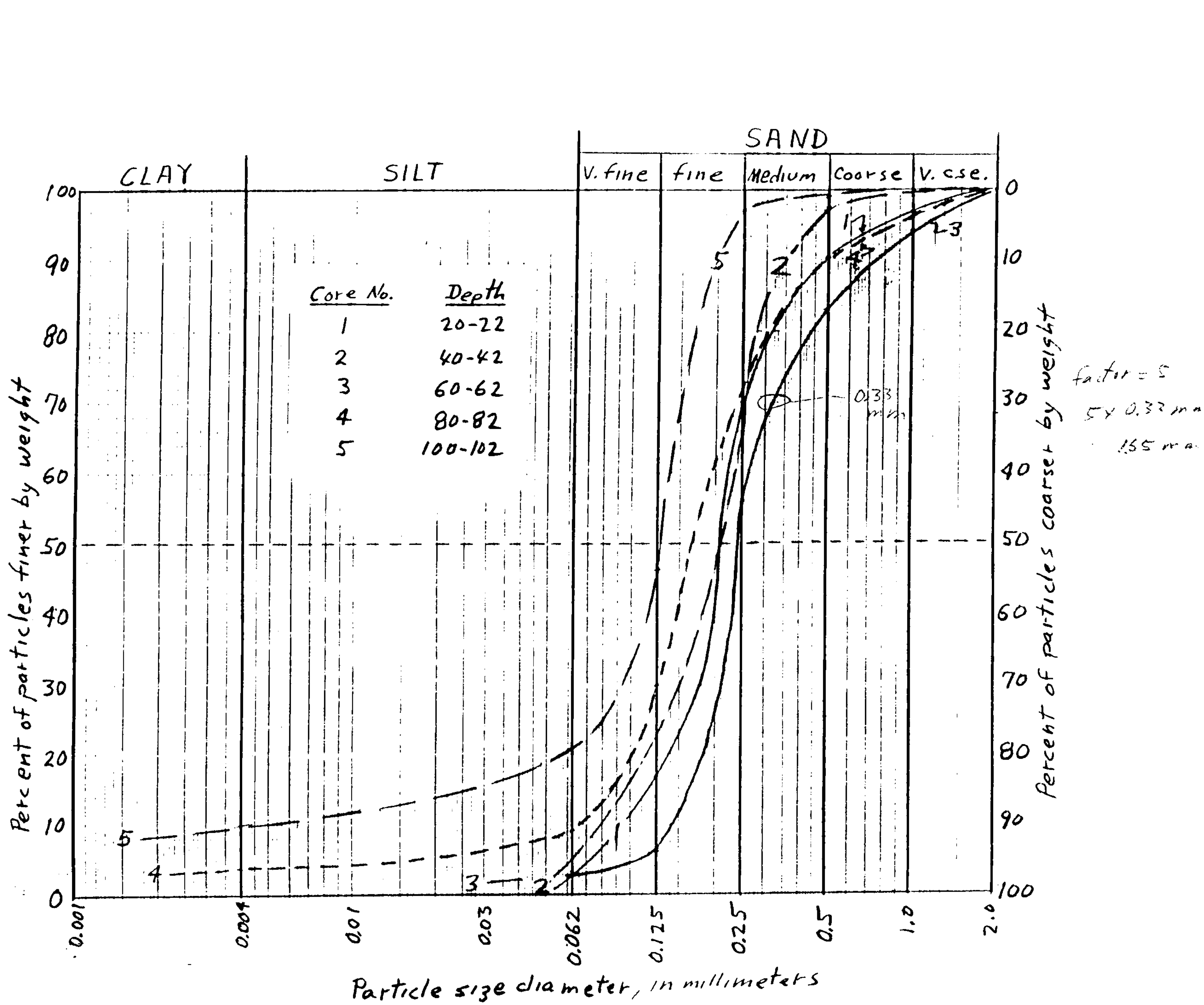


Figure 3.--- Particle-size distribution of core samples obtained from Test well 1 drilled by the Cape Hatteras Water Association in May 1990 in the Buxton Woods area of Hatteras Island, N.C.

incide with the appearance in the washed samples of coarse to very coarse sand and small gravel. Also, on the log for test well 1, the general deflection to the left between depths of 80 and 111 ft, compared to the average position of the resistivity line between depths of 10 and 80 ft, indicates a marked increase in finer-grained layers below 80 ft (Fig. 2). A core from a depth of 100 ft consisted of very fine to fine sand and clayey silt (Fig. 3).

With the preceding discussion of the resistivity log for test well 1 in mind, it will be useful at this point to discuss the gamma-ray logs. These logs record the rate of emission of gamma rays by natural radioactive materials contained in the sediments. The rate of emission increases toward the right so that deflections to the right show an increasing rate of gamma-ray emission.

There is a strong affinity between fine-grained sediments, such as silt and clay, and radioactive substances. Therefore, deflections to the right on the gamma-ray log show increases in the percentage of silt and clay. The log for test well 1 shows a marked increase in fine-grained materials, including silt and clay, beginning at about 80 ft (Fig. 2).

The hydrologic units penetrated by test well 1 are shown in the 2nd column of Figure 2. As is frequently the case in studies of complex sedimentary environments, it is not possible to unequivocally identify the boundaries of the hydrogeologic units penetrated by the test wells drilled in Buxton Woods. Thus, in test well 1, the section between depths of 80 and 111 ft can either be viewed as a leaky unit of the confining bed or as a relatively impermeable lower unit of the Buxton Woods aquifer. On the basis of cores and sediment samples and the resistivity and gamma-ray logs, I believe the section between 80 and 111 ft should be classified as a lower-relatively impermeable unit of the Buxton Woods aquifer and that is what is shown on Figure 2.

Confining Bed

Deep test wells drilled in the past in the Cape Hatteras area have shown that the Buxton Woods aquifer is underlain by sediment layers composed of very fine-grained sand, silt, and clay that serve as a hydraulic barrier between the aquifer and underlying sand layers that contain salty water. A fine-grained layer that serves as a hydraulic barrier is referred to as a confining bed. The sand layers that underlie the confining bed comprise a confined aquifer. The presence of a confining bed beneath the Buxton Woods aquifer is of great hydrologic importance because it prevents upward movement of salty water from the underlying confined aquifer.

Both the resistivity and gamma-ray logs for test well 1 indicate the presence of a clay-rich layer, probably silty clay, between depths of about 111 and 117 ft (Fig. 2). Below this layer, between 117 and 124 ft, the test hole penetrated a dark gray fine to medium sand. The layer between 111 and 117 ft clearly has a very small hydraulic conductivity and should be considered a part of the confining bed that underlies the Buxton Woods aquifer. However, it is important to determine if additional confining layers exist beneath the sand layer that occurs between 117 and 124 ft. The only information available on this topic is the electric and gamma-ray logs of test well No. R-2c-Z which was drilled by the State Groundwater Section in the Buxton maintenance area of the National Park Service in 1971. This test well reached a depth of 570 ft.

Comparison of the logs of CHWA test well 1 and the log of the State test well show close similarity in the overlapping parts of the logs between depths of 100 and 124 ft. (Because the State test well was cased to a depth of 100 ft at the time the log was made, the resistivity log begins at a depth of 100 ft.) Figure 2 shows, among other data, the resistivity and gamma-ray logs of test well 1 from 10 to 124 ft. The resistivity log for State test well R-2c-Z between depths of 125 and 210 ft is also shown on the figure. The logs shown on Figure 2 suggests that the confining bed extends from about 111 to 180 ft. It is important to note, however, that the confining bed is not a single, massive layer of clay but instead consists of several layers of material having different grain sizes.

Production Zone

Based on the sediment samples, the resistivity and gamma-ray logs, and on well-hydraulic considerations, it appears that supply wells in the proposed well field should be screened in the relatively coarse-grained material that was penetrated between depths of 60 and 70 ft in both test well 1 and test well 4. Depending on the characteristics of the resistivity logs of the supply wells, gravel packs should extend from the bottom of the wells up to depths of 40 to 45 ft. Placing 5 ft of screen in the 60 to 70 ft zone will result in an available drawdown of 15 to 20 ft more than that of wells in the existing well field. This should result in a substantially larger yield from each well than can be obtained from the wells in the existing well field.

WATER-QUALITY CONDITIONS

Two aspects of water quality are especially important relative to the development of a well field in Buxton Woods. The first is the chloride content of the water near the northern hydrologic boundary of the aquifer, along the Buxton Ditch, and the chloride content in permeable zones below the aquifer in the vicinity of the proposed well field. The second is the iron content of the water in the producing zone of the aquifer.

Chloride Data

Relative to data on chlorides, test well 2 was drilled 200 ft south of the Buxton Ditch to determine the chloride content near the bottom of the Buxton Woods aquifer. Water in a core obtained from a depth of about 80 ft contained 280 mg/l of chloride. The chloride content in a core from a depth of about 100 ft was 850 mg/l. These analyses appear to confirm the fact that the Buxton Ditch effectively serves as the northern hydrologic boundary of the main part of the Buxton Woods aquifer. In order to observe the effect of the proposed well field on both the ground-water level and chloride content, a permanent observation well was installed in test well 2 by installing a 5-ft screen between depths of 67 and 72 ft. Water from this well contained 75 mg/l of chloride when sampled on May 2, 1990.

Data collected from test wells 1 and 4, located near the line of the proposed well field, show that the chloride content of water in the upper, more permeable, part of the Buxton Woods aquifer ranges from about 40 to about 60 mg/l. Water from the lower unit of the aquifer has a chloride content of about 80 mg/l. It is also important to note that water from test well 1, which is screened between depths of 118 and 123 ft, had a chloride content of 80 mg/l.

Iron Data

Composite water samples from the present CHWA well field contain about 2.2 mg/l of iron. Treatment to remove this iron represents a significant continuing expense. The concentration of iron in some sedimentary deposits, including deposits similar to those that underlie the Cape Hatteras area, differ markedly between different layers. One of the objectives of the test-well drilling program was to determine if this was the case in the Buxton Woods aquifer.

The iron content in water from test well 2 near the Buxton Ditch, which is screened between depths of 67 and 72 ft, is only about 0.15 mg/l. the iron content in water from test well 1 near the center of the proposed well field, which is screened between depths of 118 and 123 ft, is about 0.18 mg/l. The iron content in water from well 1A, on the other hand, which is screened between depths of 63 and 68 ft, is about 1.75 mg/l. It appears from these data that water in the lower, less permeable part of the Buxton Woods aquifer and water in the more permeable layers in the confining bed has an iron content only about 1/10 that of the upper, more permeable zone.

Three different methods were used during the construction of test well 4 in an effort to obtain water samples for iron analyses from different levels in the aquifer. In the first method, the drill rods were removed from the hole when it was at a depth of 40 ft and a line of 1¼ in. diameter casing equipped with a 30 in. screened drive point was driven into the bottom of the hole. All efforts to produce water from the 1¼ in. casing were unsuccessful. When the casing was pulled the screen was found to be blocked with drilling mud.

The second method consisted of obtaining cores at 10-ft intervals beginning at a depth of 50 ft, placing the cores in the filter press, and forcing the water out with air pressure. Previous tests at the water plant, using water with a large iron content, had shown that if all the paper filter was removed except for a ¼ in. wide outer band, which is needed for a seal, water samples obtained from the filter press gave approximately correct iron values. Using this method water samples were obtained from cores from depths of about 50, 60, 70, and 80 ft. Drilling was stopped at 80 ft.

The third method which might, for convenience, be referred to as the "temporary-well method," consisted of installing in the hole a line of 2 in. diameter PVC casing equipped with a 5-ft screen, flushing the mud column out of the casing and annular space, pouring gravel around the screen, and using air pressure to "develop" the zone open to the screen. Following development, water was pumped from the well for periods ranging from 20 minutes to more than an hour before being sampled. After each water sample was collected, the casing was raised to the next zone to be tested and the development and pumping procedures were repeated.

The results obtained with the 2nd and 3rd methods - that is, with samples from cores and with samples from the "temporary wells" are listed below.

Core Samples		Temporary well Samples			
Depth	Iron 1/	Depth	Iron	Chloride	Total Hardness
		20-22 2/	1.18	55	
50	0.1	46-51	2.2	45	260
60	.1	60-65	2.7	40	240
70	.05	72-77	3.8	55	360
80	.6				

1/ All chemical constituents are in milligrams per liter

2/ Temporary driven well used to supply water for the drilling operation.

As can be seen from the above table, there are large differences between the iron content of the core samples and those from the temporary wells. Whether these differences are real or result from problems with the methods cannot be determined from the information presently available.

The small iron content in the core samples could reflect a failure of the filter press to produce a representative sample for iron in spite of the results obtained in the test at the water plant. On the other hand, if the iron content in the core samples are approximately correct, they could indicate that some layers in the aquifer do, in fact, yield water with a small iron content. Even if this is the case, however, the layers would probably be too thin and too difficult to locate to be utilized by the CHWA. In other words, supply wells commonly are finished with 5-ft screens and gravel packs as much as 20 to 25 ft long so that if the iron-free zones were not at least 15 to 20 ft thick, it would not be practical to develop them.

Therefore, the results obtained from the test wells indicate that the only zone in the Buxton Woods aquifer that yields water with a small iron content and which is thick enough to be developed for a water supply is the lower part of the aquifer immediately above the confining bed. This is the least permeable part of the Buxton Woods aquifer but this may not be an insurmountable problem. A more important problem might be upward movement of saline water from the brackish water zones below the confining bed. Relative to this problem, note that chloride determinations are shown on Figure 2, including a value of 1900 mg/l for a sample from depths of 196 to 206 ft in State test well No. R-2c-Z. In other words, there appears to be a difference in chloride content of about 1800 mg/l between the top and bottom of the confining bed.

In an effort to better understand the occurrence of iron in water from the Buxton Woods aquifer and the results obtained during the test-well construction program, additional data were collected on the iron content of water from wells in the existing well field. Although these data are not directly related to the subject of this report, they are presented in Appendix D so that they will be available for future reference. The data include iron analyses of water samples from the wells that were in operation on June 7, 1990, and analyses of samples collected on January 30, 1979, from 14 of the wells.

Because the samples both in 1979 and 1990 were collected over a relatively short period, they represent, in effect, a "snapshot" of the areal differences in iron content in the well field. With this in mind, note that in 1979 the range in iron content of the 14 wells is from 0.46 mg/l to 17 mg/l and that the average iron content of the 13 wells sampled in 1979 that were also sampled in 1990 is 4.8 mg/l.

Thirty eight wells were sampled in 1990 and the iron content ranged from 0.10 mg/l to 5.8 mg/l; well No. 11A, which had an iron content of 17 mg/l in 1979, was not operating in 1990. The average iron content of the 38 wells sampled in 1990 is 3.1 mg/l and the average iron content in 1990 of the 13 wells that were also sampled in 1979 is 3.2 mg/l. Note that this value is 1.6 mg/l less than in 1979.

Assuming that the difference in average iron content between 1979 and 1990 is not a result of differences in analytical procedures, does it show that the iron content is decreasing with time, as a result of the CHWA withdrawals? Or, is the difference related to differences in the seasonal rate of withdrawals? In other words, water use in January 1979 was obviously much less than that in June 1990. None of these questions can be answered now but they are important questions that need to be studied in the future.

Finally, with respect to the proposed well field in Buxton Woods, I might note that the iron content of water from test wells 1A and 4 was 1.7 and 2.2 mg/l, respectively, or about 1 mg/l less than the average of the 38 wells sampled in the existing well field.

WELL-FIELD DESIGN

Hydrologic conditions on the State-owned property in Buxton Woods, as determined in the test-drilling program, are favorable for the development of a well field to supply the increasing water needs of the Cape Hatteras-Avon area. Unfortunately, iron-free zones suitable for the development of supply wells were not found.

Location and Spacing of Supply Wells

In order to develop the maximum yield, it is necessary to locate supply wells as close to the water-table divide as possible. On the basis of relatively sparse information, I estimated in my 1988 report on the ground-water resources of the Cape Hatteras area that the water-table divide in the Buxton Woods area is along a line near the south side of the wetland referred to as Jennette Sedge. Development of a well field along this line would involve some disturbance of wetland and, therefore, might involve a lengthy approval process. Because of this aspect, it was deemed desirable to move the well-field line to the north side of the sand ridge along the north side of the Sedge.

The State-owned land along the line of the sand ridge north of Jennette Sedge is about 3600 ft wide. Nine wells spaced about 450 ft apart can be located along this line. Figure 4 is a map showing the State-owned land on which the approximate position of the nine supply

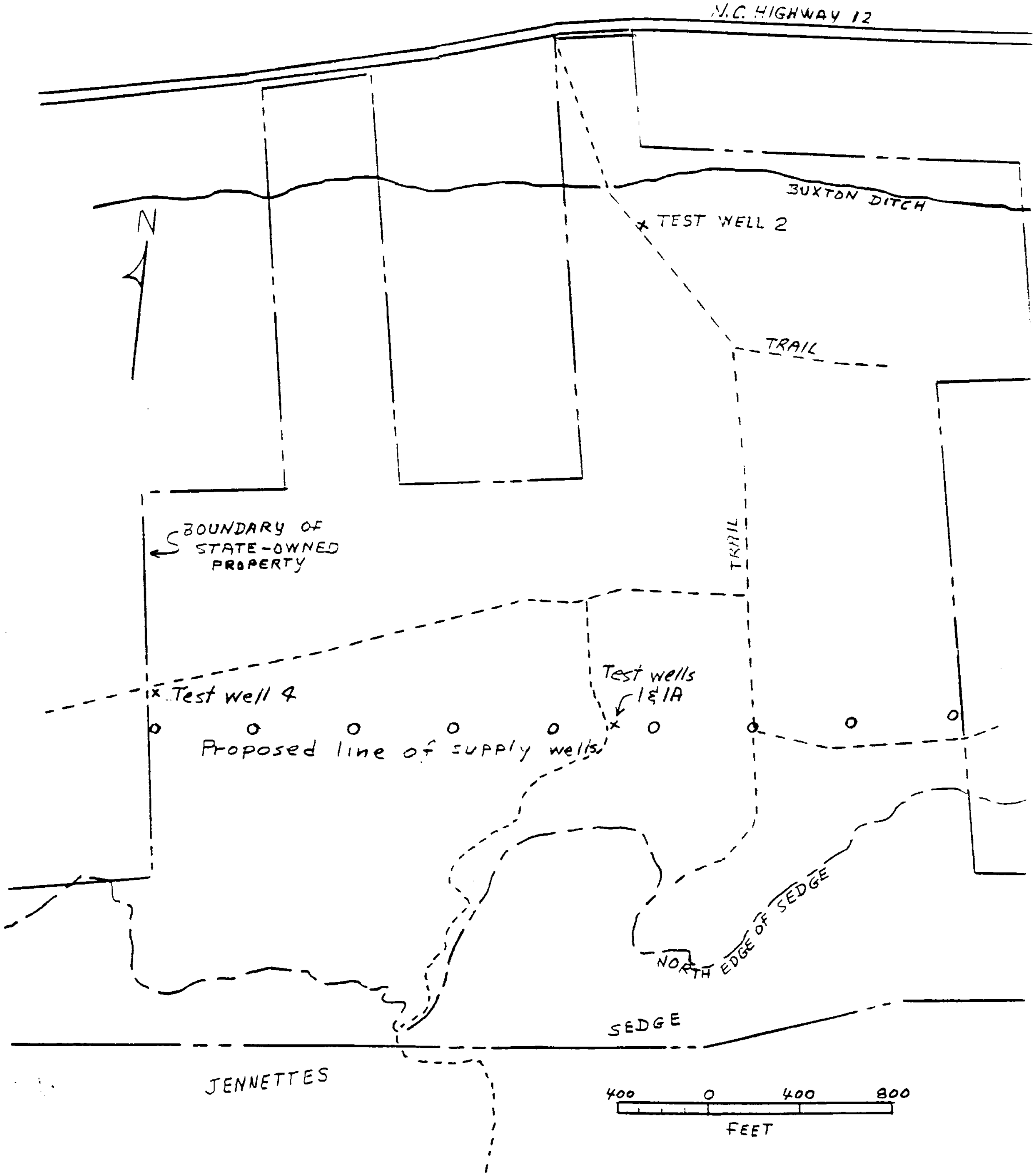


Figure 4.--- Map showing State-owned property in Buxton Woods and the location of the proposed well field of the Cape Hatteras Water Association.

wells are shown. Figure 5 is an enlargement of a section of the U.S. Geological Survey topographic map on which the approximate positions of the wells are shown as large solid dots. This map shows the position of the wells in relation to both the sand ridge and Jennette Sedge.

Relative to spacing of the supply wells, I should note that State regulations require that all land within 100 ft of a supply well either be owned or under the legal control of the association. In the case of the State-owned land in Buxton Woods, this means that the wells at each end of the well field must be 100 ft from the State-property boundary. This, in effect, reduces the length of the well line to about 3400 ft so that the spacing of the wells will be reduced from about 450 ft to about 425 ft. This reduction will not have any significant effect on the yield of the field.

Estimated Yield of the Proposed Well Field

The proposed line of wells is in segment E of Figure 28 in my September 1988 report on the Cape Hatteras area. The estimated yield of this segment, if wells were placed near the water-table divide, is 419,000 gallons per day. The proposed well line is estimated to be about 2,000 ft north of the divide which is expected to result in a sustained yield of somewhat less than 419,000 gpd. The question, of course, is how much less.

In dealing with this question, I should first note that the segments shown on Figure 28 of the Cape Hatteras report, including segment E, are 4,000 ft wide, whereas the length of the proposed well line is only about 3400 ft. However, because ground water will move to the end wells in the line from areas beyond the State property, we can safely assume that the effective hydraulic length of the well line is at least 4,000 ft. Therefore, no reduction in yield is necessary because the well line is not as long as the width of the map segment.

At the time I estimated the yield of the Buxton Woods aquifer in 1988, no information was available on the effect of the existing well field on the position of the freshwater-saltwater front nor on the effect of the Buxton Ditch on the chloride content of water in the aquifer. Because of these deficiencies in information, I intentionally tried to be conservative. Both of these deficiencies were partly eliminated in the May 1990 test-well drilling program.

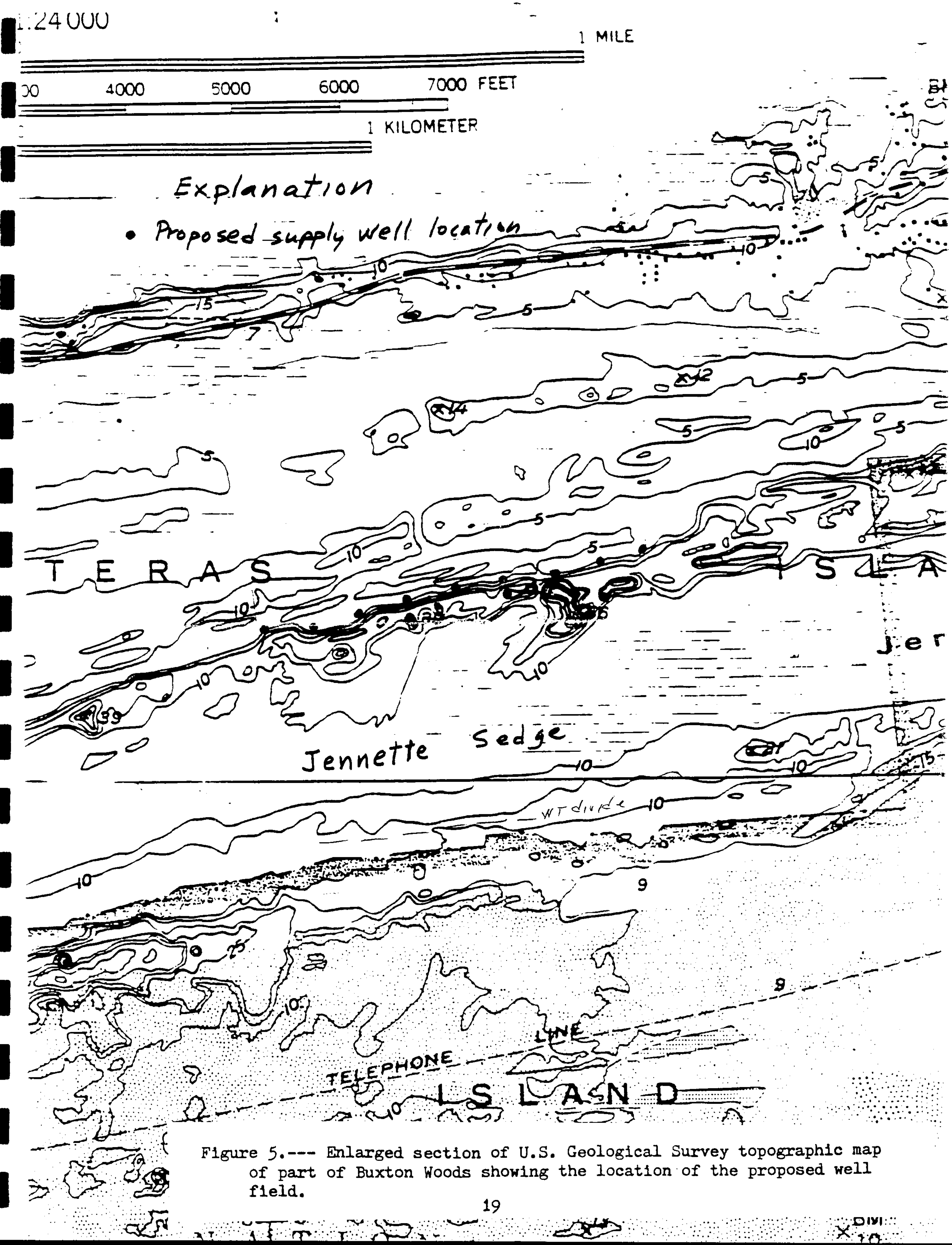


Figure 5.--- Enlarged section of U.S. Geological Survey topographic map of part of Buxton Woods showing the location of the proposed well field.

Relative to the effect of the existing well field on the fresh-water-saltwater front, two test wells were constructed along the Waterplant Road; one at the south edge of the plant and one 800 ft farther south. Preliminary analysis of the chloride content in the lower part of the aquifer in the well at the plant suggests that a small increase in chloride has occurred, possibly as a result of withdrawals at the well field. No increase in chloride content was detected in the test well 800 ft south of the plant. These results suggest that the present withdrawals from the existing well field do not exceed the yield of the aquifer in the area supplying the wells and that the yield may, in fact, be somewhat larger than was estimated in 1988.

Relative to conditions near the Buxton Ditch, I noted earlier in this report that the Buxton Ditch is believed to form the northern hydrologic boundary of the main part of the Buxton Woods aquifer. Therefore, test well 2 was drilled to determine what effect the ditch has had on the chloride content of water in the lower part of the aquifer. If the ditch forms a hydrologic boundary, the chloride content of the water in the bottom of the aquifer should be larger than is normal for the aquifer due to upward discharge of saline water from the aquifer beneath the confining bed. As expected, water samples from the upper part of the confining bed in test well 2 contained relatively large concentrations of chloride. On the other hand, a water sample from the finished well, which is screened between depths of 67 and 72 ft in the lower part of the aquifer, does not show any obvious elevation in chloride content.

The chloride content of water from the confining bed at test well 2 appears to confirm that the Buxton Ditch forms a hydrologic boundary. The chloride content of water from the lower part of the aquifer suggests, however, that the confining bed is moderately impermeable so that the quantity of water moving upward across the confining bed is very small compared to the volume of water moving laterally through the aquifer. From a water-supply standpoint, this is a favorable condition because the less permeable the confining bed, the less the danger of salty water either upcoming into the supply wells or moving laterally from the ground-water discharge zone along the Buxton Ditch.

The data both from the wells near the water plant and from test well 2 near the Buxton Ditch suggests that the aquifer yields estimated in September 1988 are well on the conservative side. Based on the presently available information, I estimate that the yield of the line of 9 wells shown on Figure 4 is about 390,000 gpd. This volume of water can be obtained by pumping each of the wells at an average continuous rate of about 30 gpm.

Yield of Supply Wells

A distinction must be made between the yield of the well field and the yield of the supply wells. As noted above, the estimated yield of the well field can be obtained by pumping each of 9 wells continuously at a rate of 30 gpm. It is not feasible, however, to pump all the wells continuously because they must be off during periods when the filters in the water-treatment plant are being back flushed and during other maintenance operations. Also, the water needs of the Association vary widely from one season to another and, in order to meet peak demands, it is necessary that the rate at which the wells can be pumped exceed the yield of the aquifer. In other words, no adverse effect would result if the wells were pumped for periods of several weeks at rates considerably larger than the average continuous rate of 30 gpm mentioned above.

Comparison of the descriptions of the sediments penetrated by the test wells in Buxton Woods with descriptions of the material penetrated by wells in the existing well field, suggest that there are no significant differences in grain size, sorting, and stratification. Therefore, there should be no significant difference in water-bearing characteristics and it should be possible to estimate the maximum yield of supply wells in Buxton Woods on the basis of experience at the existing field.

The maximum yield of a supply well can be calculated by multiplying the specific capacity of the well by the available drawdown. Specific capacity is calculated by dividing the yield of a well in gallons per minute by the difference, in feet, between the static and the pumping water levels in the well. Values of specific capacity are reported in units of gallons per minute per foot (gpm/ft). Available drawdown is the difference between the static water level and the lowest pumping level that can be imposed on the well without causing an undesirable effect. The lowest pumping level is, in nearly all screened wells, above the top of the well screen. However, because of natural seasonal fluctuations in the position of the water table, interference (drawdowns) caused by other nearby wells, and other considerations, it is common practice to designate the available drawdown at some level above the top of the screen.

For the purpose of estimating the maximum yield of the 20 wells drilled in 1967 in the existing well field, I assumed a pumping level 20 ft above the top of the screens. (See p.100 in my Cape Hatteras report.) This value is believed to be well on the conservative side and will also be used in estimating the maximum yield of supply wells in Buxton Woods.

The elevation above sea level of the static water level in the proposed supply wells is estimated, on the basis of the U.S. Geological Survey topographic map of the area and the position of the water level in test well 1A, to be about five feet above sea level. If the wells are screened between depths of about 60 and 65 ft, this will place the top of the screens at an elevation of about 50 ft below sea level. Subtracting the 20 ft safety factor, the pumping water level will be 30 ft below sea level. Adding the 5 ft elevation of the static water level, we obtain an available drawdown of about 35 ft.

Relative to the specific capacity of the supply wells, note that the specific capacity of the test wells is shown under item No. 8 on the well construction record forms in Appendix A. These range from 0.8 gpm/ft for test well 4 to 1.9 gpm/ft for test well 2. Considering the fact that these wells are only 2 in. in diameter and were not developed for supply wells, the values are very encouraging and support the view that the hydraulic characteristics of the aquifer in Buxton Woods is very similar to those in the existing well field. With this in mind, it is expected that the specific capacity of the supply wells in Buxton Woods will be as large, if not larger, than the specific capacity of the wells in the existing field.

The specific capacity of supply wells in the existing field range from 0.4 gpm/ft to 5.8 gpm/ft and the average of 123 measurements made prior to September 1988 is 3 gpm/ft. The average specific capacity in 1988 of the 20 wells drilled in 1967 was 3.4 gpm/ft. Therefore, with proper well design and effective development, the specific capacity of the proposed supply wells in Buxton Woods should average at least 3.5 gpm/ft. Multiplying the estimated available drawdown of 35 ft by a specific capacity of 3.5 gpm/ft, we obtain an average maximum yield for each well of 122 gpm. If we round this value to 120 gpm and multiply by 9 wells, we obtain a yield for the well field of 1,080 gpm. Multiplying by the number of minutes in a day, the yield of the field, when pumped continuously for 24 hours, would be about 1,500,000 gallons per day. This maximum yield would readily permit the association to meet the peak demands of the heavy-use period from Memorial Day through Labor Day. In considering this number, however, one should keep in mind the estimated long-term continuous yield of the well field of 390,000 gpd.

ENVIRONMENTAL EFFECTS OF PROPOSED WELL FIELD

In response to a request in April 1989 from the North Carolina Division of Coastal Management, several agencies and organizations raised questions regarding the effect of the proposed well field on ecologic conditions in Buxton Woods. It is important that these concerns be considered in this report.

The two major points of concern deal with the effect of the well field on (1) the maritime forest, exclusive of the wetland swales, and (2) on the vegetation of the swales. Each of these are discussed in the following sections.

Effect on the Maritime Forest

The term "maritime forest," as used in this discussion relates to the mature forest vegetation developed on the sand ridges in Buxton Woods. The tops of these ridges range from about 15 ft to about 60 ft above sea level. The concern expressed to the Division of Coastal Management relates to the lowering of the water table caused by the proposed well field and the effect of this lowering on the vegetation.

The elevation of the water table along the line of the well field is estimated to be about 5 ft above sea level. South of Jennette Sedge, near the water-table divide, the water table may reach an elevation of 8 to 10 ft. Therefore, the depth to the water table below the sand ridges ranges from a minimum of about 5 ft to a maximum of about 50 ft and probably averages 10 to 20 ft. Based on these depths to the water table, it seems evident that the forest vegetation is maintained primarily by soil moisture which is replenished by the frequent rains that occur in the area. Because any lowering of the water table caused by the well field will not affect soil moisture, it is concluded that the well field will have little, if any, effect on the maritime forest vegetation. This conclusion is supported by the apparent lack of effect of the existing well field on the vegetation of the ridge adjacent to the supply wells.

Effect on Swales

Water on the land surface in swales is in direct hydraulic contact with the ground-water zone and the water surface in the swales is, in fact, a surface expression of the water table. Therefore, to the extent that the proposed supply wells lower the water table in the vicinity of a swale, the water surface in the swale will also be lowered. It is, therefore, important to consider in some detail the effect of the proposed well field on nearby swales and especially on Jennette Sedge.

The alternation (stratification) of the coarse-grained and fine-grained layers of sediment that comprise the Buxton Woods aquifer, which were discussed in the preceding section on hydrogeology, cause the aquifer to respond to short-period stresses as a confined aquifer. (This effect was observed in an aquifer test conducted at the existing well field and is discussed on page 30 of my Cape Hatteras report.) The stratification of the aquifer is of considerable importance relative to the effect of the well field on the water table, to the extent that it causes the cone of depression formed by pumping wells, during any pumping cycle, to spread laterally and to encompass a larger area than would otherwise be the case. Thus, the drawdown in the immediate vicinity of pumping wells is not excessive and the lowering of water levels in nearby swales is not a significant problem. This situation will be especially the case with the proposed well field because the supply wells in it will be screened about 20 ft lower in the aquifer than those in the existing well field.

It is important to note that the natural position of the water level in swales varies seasonally through a relatively wide range as a

see note over

result of short-period variations in precipitation and the seasonal variations in evapotranspiration. The vegetation in swales is obviously adjusted to these natural variations in water level. Drawdowns in swale water levels caused by pumping wells simply causes a slight expansion in the magnitude of the natural fluctuations. This conclusion is also clearly supported by the experience at the existing well field where there has been no obvious effect on vegetation in the swale alongside the well field. In fact, a prolific cattail swamp exists between the parallel lines of supply wells at the east end of the well field.

Earlier, I noted that the proposed line of supply wells is along the north side of the ridge located north of Jennette Sedge, although the yield of the field would have been larger if the wells had been located south of the sedge. The selection of the proposed position was not based on concern about excessive lowering of the sedge water level but rather concern about land-surface disturbance resulting from construction of the access road and wells. However, because the well line, as now proposed, is several hundred feet from the sedge, the effect on the sedge water level will be even less than if the wells had been located along the south side of the sedge.

WELL-FIELD NAMES

I have used the names "existing well field" and "proposed well field" in this report to differentiate between the well field established in 1967 near Frisco and the well field now proposed to be developed on the State-owned property in Buxton Woods. In order to avoid confusion in the future, it is desirable that separate and distinct names be adopted immediately for each well field. Figure 6 shows the locations of the well fields in relation to other geographic features of the Cape Hatteras area.

I believe Frisco well field would be an appropriate name for the existing well field and Buxton Woods well field would also be appropriate for the proposed well field. I realize, of course, that the name "Buxton Woods" is normally applied to all of the Cape Hatteras area that is occupied by maritime forest, including the forested area in which the existing well field is located. However, the name Frisco is a logical choice for the existing well field and naming the proposed field the Buxton Woods well field seems desirable because it calls attention to its location and also emphasizes one of the most important reasons for preserving the maritime forest.

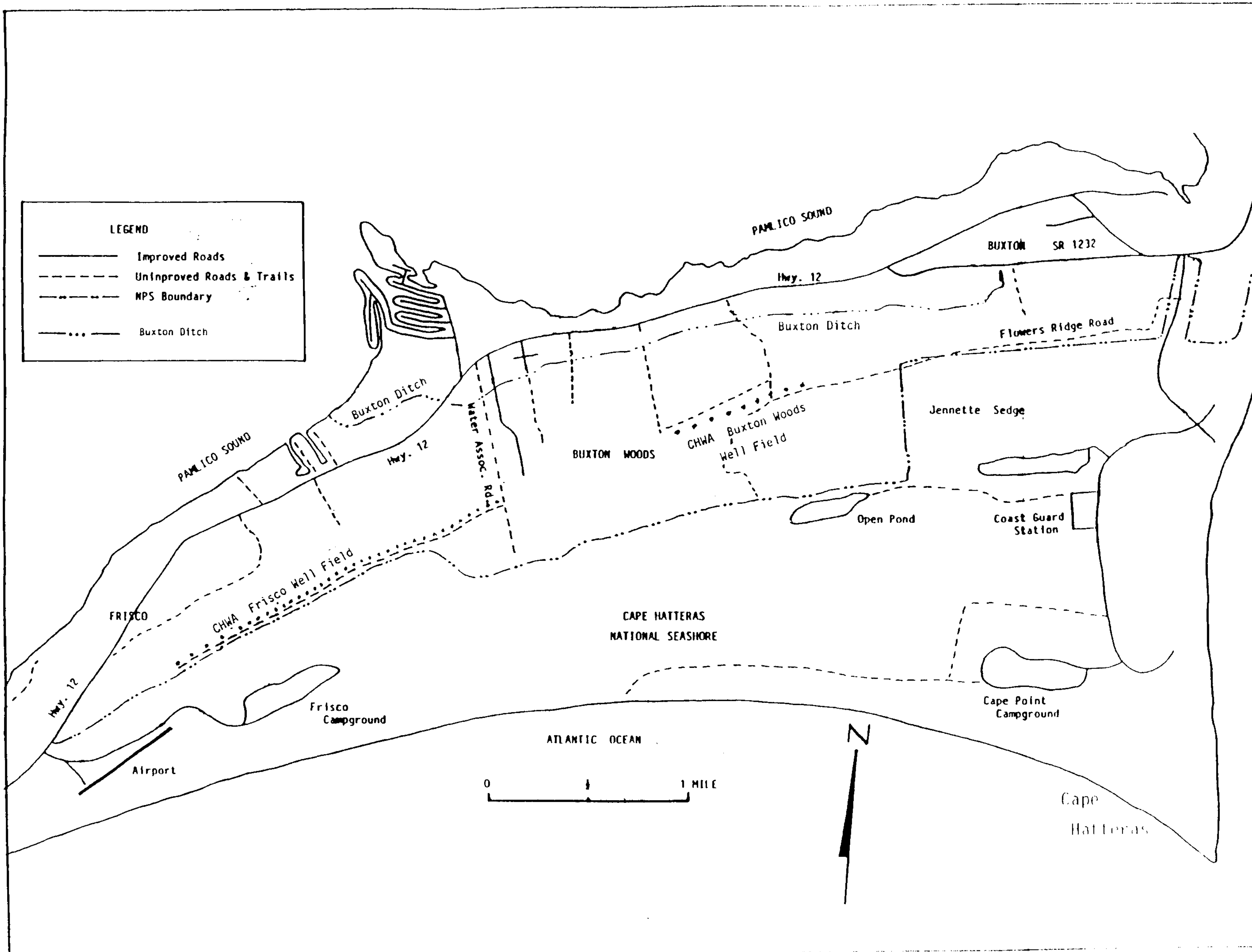
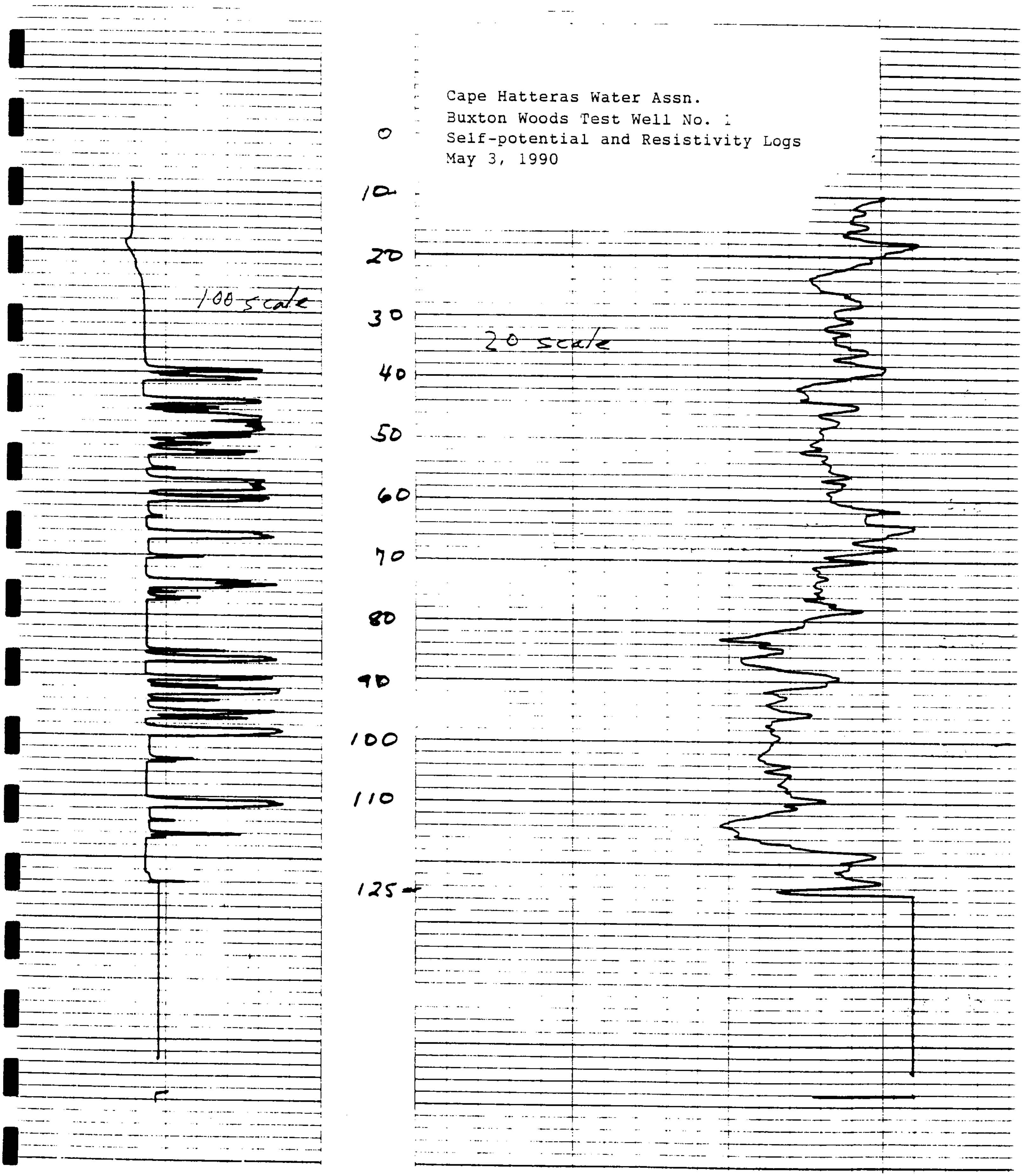


Figure 6.--- Map of the Cape Hatteras area showing the existing Frisco well field and the proposed Buxton Woods well field.

APPENDIX A - Well construction Records and Electric and Gamma-Ray logs of test wells drilled in May 1990 by the Cape Hatteras Water Association on State-owned land in Buxton Woods, Hatteras Island, N.C.


Cape Hatteras Water Assn.
Buxton Woods Test Well No. 1
Self-potential and Resistivity Logs
May 3, 1990
100 scale
20 scale
0
10
20
30
40
50
60
70
80
90
100
110
125

NORTH CAROLINA DEPARTMENT OF NATURAL RESOURCES AND COMMUNITY DEVELOPMENT
DIVISION OF ENVIRONMENTAL MANAGEMENT - GROUNDWATER SECTION
P.O. BOX 27687 - RALEIGH,N.C. 27611, PHONE (919)733-3221

WELL CONSTRUCTION RECORD

FOR OFFICE USE ONLY

Quad. No. ______ Serial No. ______
Lat. ______ Long. ______ Pc ______
Minor Basin ______
Basin Code ______
Header Ent. ______ GW-1 Ent. ______

DRILLING CONTRACTOR Magette Well & Pump Co.

DRILLER REGISTRATION NUMBER 008

CHWA Test Well No.1

STATE WELL CONSTRUCTION PERMIT NUMBER: 27-~~009~~-WM-0066 0099

1. WELL LOCATION: (Show sketch of the location below)

Nearest Town: Buxton (near the N.side of the sand ridge along the N.side of Jeannette Sedge

(Road, Community, or Subdivision and Lot No.)

County: Dare

2. OWNER Cape Hatteras Water Assn.

ADDRESS PO Box 578 (Street or Route No.)

Buxton NC 27920
City or Town State Zip Code

3. DATE DRILLED May 3,1990 USE OF WELL Test

4. TOTAL DEPTH 124 ft CUTTINGS COLLECTED [X] Yes [ ] No

5. DOES WELL REPLACE EXISTING WELL? [ ] Yes [X] No

6. STATIC WATER LEVEL: ______ FT. [ ] above [X] below TOP OF CASING.
TOP OF CASING IS 1.5 FT. ABOVE LAND SURFACE.

7. YIELD (gpm): 17 METHOD OF TEST Pump (1 hr)

8. WATER ZONES (depth): 5-80 ft, 118-125
specific capacity 1.3 gpm/ft

9. CHLORINATION: Type ______ Amount ______

10. CASING:

	Depth		Diameter	Wall Thickness or Weight/Ft.	Material
From	+ 1.5	To 118 Ft.	2 in.	Sche.40	PVC
From		To Ft.			
From		To Ft.			

11. GROUT:

	Depth		Material	Method
From	0	To 20 Ft.	Portland	pumped
From		To Ft.		

12. SCREEN:

	Depth		Diameter	Slot Size	Material
From	118	To 123 Ft.	2 in. in.	10 in.	PVC
From		To Ft.	in.	in.	
From		To Ft.	in.	in.	

13. GRAVEL PACK:

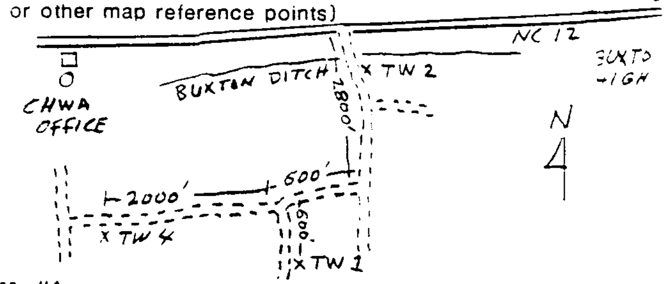
	Depth		Size	Material
From	115	To 125 Ft.	No.2	quartz
From		To Ft.		

DRILLING LOG

Depth From	Depth To	Formation Description
0	5	Sand, fn-med, road fill
5	20	Same,some cse sd & brown or
20	40	Sand,stratified fn-med qtz. in 2-4 in layers & fn-cse sd 1 in thick containing shell
40	60	Sand,v.fn-med & shell frag.2-in thick bet. fn-med layers
60	70	Sand,med-v.cse.,some pea gra
70	80	Sand, v.fn-med,brown,shells
80	110	Sand,silty-v.fn, shell frag
110	118	Clayey Silt & v.fn-fn sand
118	125	Sand, fn-med & shells

If additional space is needed use back of form.

LOCATION SKETCH
(Show direction and distance from at least two State Roads, or other map reference points)



TW #1 provides data on geol. of Buxton Woo aquifer & the upper part of the underlying bed which was penetrated at a depth of 111 ft.

Water-Quality Data

Depth	Chloride (mg/l)
20-22	50
80-82	84
100-102	80
228-123	80

14. REMARKS: Well is to be used for periodic water level & chloride meas.of confined zone bel. Buxton Woods aquifer

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15 NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

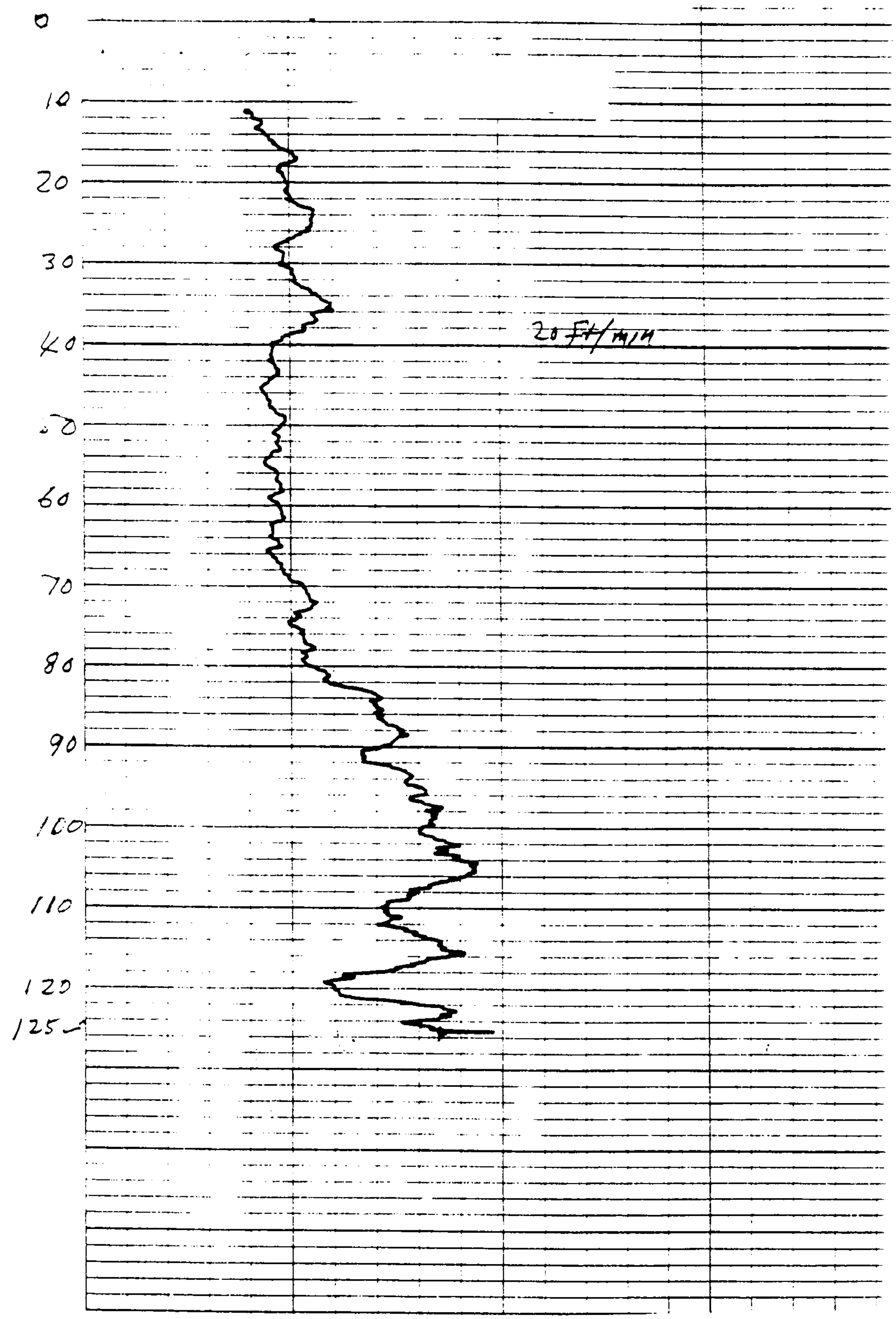
Ralph C. Heath May 10, 1990

SIGNATURE OF ~~CONTRACTOR OR~~ AGENT DATE

GW-1 Revised 6/88

Submit original to Division of Environmental Management and copy to well owner.

Cape Hatteras Water Assn.
Buxton Woods Test Well No. 1
Gamma-ray Log
May 3, 1990



NORTH CAROLINA DEPARTMENT OF NATURAL RESOURCES AND COMMUNITY DEVELOPMENT
DIVISION OF ENVIRONMENTAL MANAGEMENT - GROUNDWATER SECTION
P.O. BOX 27687 - RALEIGH, N.C. 27611, PHONE (919)733-3221

WELL CONSTRUCTION RECORD

FOR OFFICE USE ONLY

Quad. No. ____ Serial No. ____
Lat. ____ Long. ____ Pc ____
Minor Basin ____
Basin Code ____
Header Ent. ____ GW-1 Ent. ____

DRILLING CONTRACTOR Magette Well & Pump Co.

DRILLER REGISTRATION NUMBER 008

CHWA TEST HOLE No. 1A

STATE WELL CONSTRUCTION PERMIT NUMBER: 27-0099-WM-0066

1. WELL LOCATION: (Show sketch of the location below)
   Nearest Town: Buxton, 10 ft E. of a trail near the N. side of the sand ridge N. of Jeannette Sedge
   (Road, Community, or Subdivision and Lot No.)
   County: Dare
2. OWNER Cape Hatteras Water Assn.
   ADDRESS PO Box 578 (Street or Route No.)
   Buxton (City or Town) NC (State) 27920 (Zip Code)
3. DATE DRILLED 5/7/90 USE OF WELL Observation
4. TOTAL DEPTH 68 ft CUTTINGS COLLECTED ☐ Yes ☐ No
5. DOES WELL REPLACE EXISTING WELL? ☐ Yes ☒ No
6. STATIC WATER LEVEL: 4.5 FT. ☐ above ☒ below TOP OF CASING.
   TOP OF CASING IS 2 FT. ABOVE LAND SURFACE.
7. YIELD (gpm): 12 gpm METHOD OF TEST pump
8. WATER ZONES (depth): 5-70
   spec. cap. 1.4 gpm/ft
9. CHLORINATION: Type none Amount ____
10. CASING:

	Depth From	Depth To	Diameter	Wall Thickness or Weight/Ft.	Material
	+2	68 Ft.	2	Sche.40	PVC
		Ft.			
		Ft.			

11. GROUT:

Depth From	Depth To	Material	Method
0	20 Ft.	Portland	pump
	Ft.		

12. SCREEN:

Depth From	Depth To	Diameter	Slot Size	Material
63	68 Ft.	2 in.	20 in.	PVC
	Ft.	in.	in.	
	Ft.	in.	in.	

13. GRAVEL PACK:

Depth From	Depth To	Size	Material
55	68 Ft.	No.2	quartz
	Ft.		

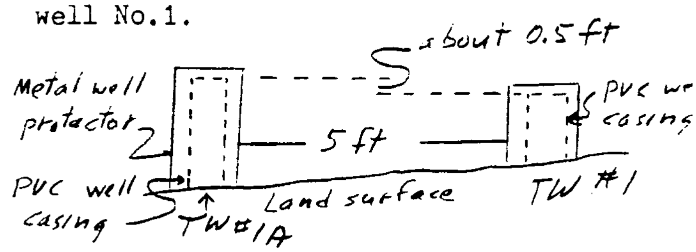
Depth From	Depth To	DRILLING LOG Formation Description
		See log of CHWA Test Well No. 1
		WATER QUALITY FROM SCREENED ZONE
		Cl - 75 mg/l
		Fe - 1.75 mg/l

If additional space is needed use back of form.

LOCATION SKETCH

(Show direction and distance from at least two State Roads, or other map reference points)

Well No.1A is located 5 ft N.of CHWA Test well No.1.



May 11,1990,1:00 pm
D to W, 1A, bel.MP = 3.8 ft
" , 1 , " = 3.45 ft
Water level in Well No.1 about 0.1 ft abov water level in Well 1A.

14. REMARKS: Well 1A was screened in the coarsest-grained zone observed in Well No.1, 5 ft S.

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15 NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

Ralph C. Heath — May 19, 1990

SIGNATURE OF ~~CONTRACTOR OR~~ AGENT — DATE

GW-1 Revised 6/88

Submit original to Division of Environmental Management and copy to well owner.

NORTH CAROLINA DEPARTMENT OF NATURAL RESOURCES AND COMMUNITY DEVELOPMENT
DIVISION OF ENVIRONMENTAL MANAGEMENT - GROUNDWATER SECTION
P.O. BOX 27687 - RALEIGH,N.C. 27611, PHONE (919)733-3221

WELL CONSTRUCTION RECORD

FOR OFFICE USE ONLY

Quad. No. ______ Serial No. ______
Lat. ______ Long. ______ Pc ______
Minor Basin ______
Basin Code ______
Header Ent. ______ GW-1 Ent. ______

DRILLING CONTRACTOR Magette Well & Pump Co.

DRILLER REGISTRATION NUMBER 008

CHWA TEST WELL NO. 2
STATE WELL CONSTRUCTION PERMIT NUMBER: 27-0099-WM-0066

1. WELL LOCATION: (Show sketch of the location below)
Nearest Town: Buxton (5 ft N. of ungraded road & 200 ft S. of Buxton Ditch) County: Dare
(Road, Community, or Subdivision and Lot No.)

2. OWNER Cape Hatteras Water Assn
ADDRESS PO Box 578 (Street or Route No.)
Buxton (City or Town) NC (State) 27920 (Zip Code)

3. DATE DRILLED 5/1/90 USE OF WELL Test

4. TOTAL DEPTH 100 ft CUTTINGS COLLECTED ☒ Yes ☐ No

5. DOES WELL REPLACE EXISTING WELL? ☐ Yes XX No

6. STATIC WATER LEVEL: 5.1 FT. ☐ above XX below TOP OF CASING. TOP OF CASING IS 3 FT. ABOVE LAND SURFACE.

7. YIELD (gpm): 7 METHOD OF TEST Pump (1 hour)

8. WATER ZONES (depth): 15-33, 55-70
Specific capacity 1.9 gpm/ft

9. CHLORINATION: Type ______ Amount ______

10. CASING:

Depth From	To	Diameter	Wall Thickness or Weight/Ft.	Material
+3	67 Ft.	2 in	Sche.40	PVC
	Ft.			
	Ft.			

11. GROUT:

Depth From	To	Material	Method
0	20 Ft.	Portland	Pumped
72	100 Ft.	Portland	"

12. SCREEN:

Depth From	To	Diameter	Slot Size	Material
67	72 Ft.	2 in.	10 in.	PVC
	Ft.	in.	in.	
	Ft.	in.	in.	

13. GRAVEL PACK:

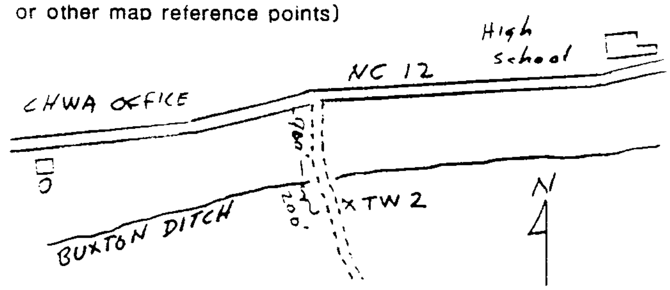
Depth From	To	Size	Material
63	72 Ft.	No.2	quartz
	Ft.		

DRILLING LOG

Depth From	To	Formation Description
0	5	Fine-med. qtz sand
5	15	fine to med.qtz sand, dark g with shell fragments
15	33	Sand,fine to v.cse.,rounded, gray,5%(?) shell fragments
33	55	Sand,fine to med., dark gray shell fragments
55	72	Sand,v fine to med., qtz,da gray,shell frag. Possibly t clayey silt layers.
72	95	V.fine to fine sand,silt & increasing downward,shells (incl.unbroken coquinas).
95	100	Sand,v.fn to fn, clayey sil

If additional space is needed use back of form.

LOCATION SKETCH
(Show direction and distance from at least two State Roads, or other map reference points)



TW #2 was drilled near the northern hyd logic boundary of the main part of the Buxton Woods aquifer to determine chlor content. Top of underlying confining b is at a depth of about 75 ft.

Depth	Chloride (mg/l)	
80-82	280	67-72 ft - Cl 75,
100-102	850	Fe 0.15

14. REMARKS: Well to be used for periodic water level & chloride meas. (outpost obs. well)

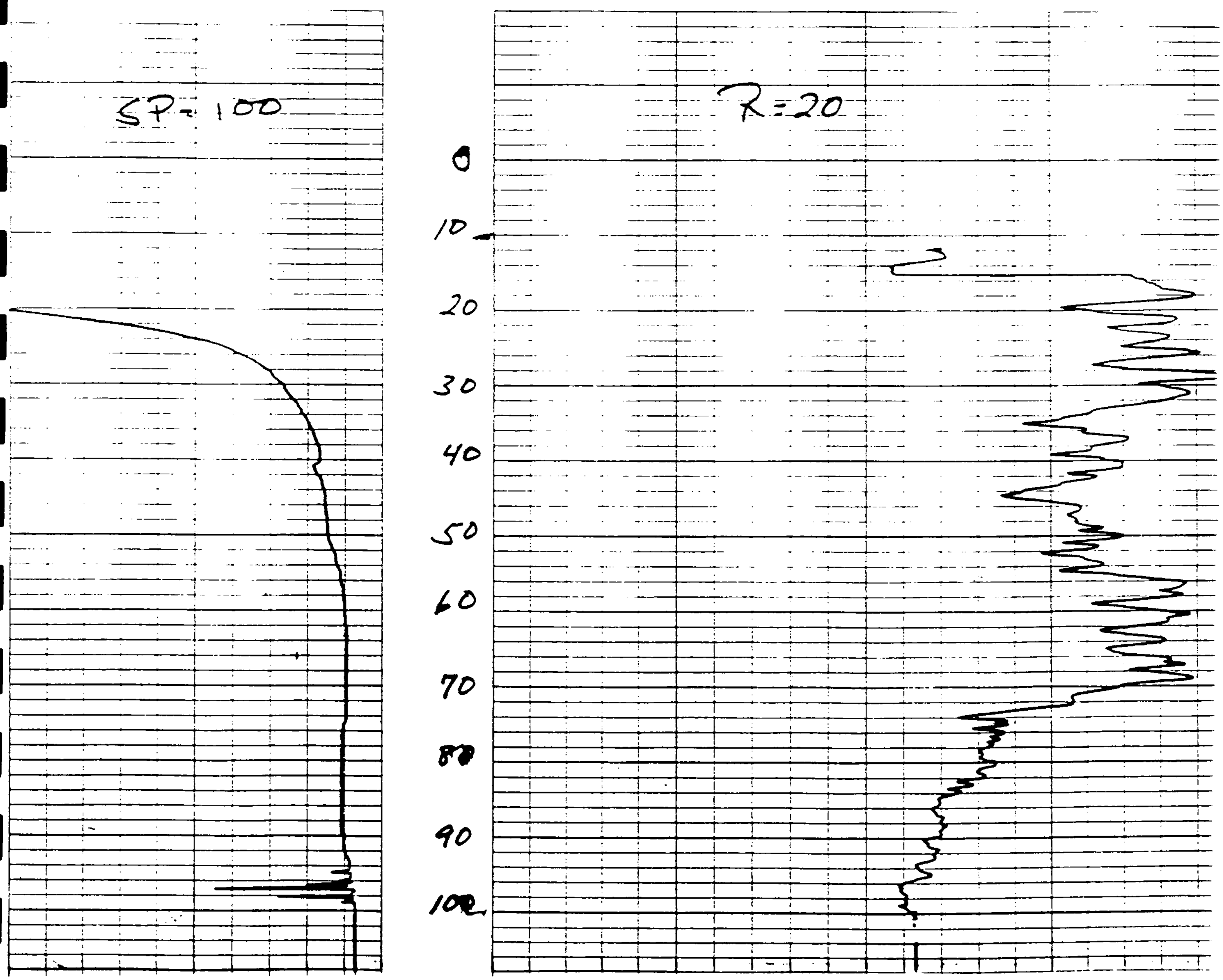
I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15 NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

Ralph C. Heath — May 2, 1990
SIGNATURE OF ~~CONTRACTOR OR~~ AGENT — DATE

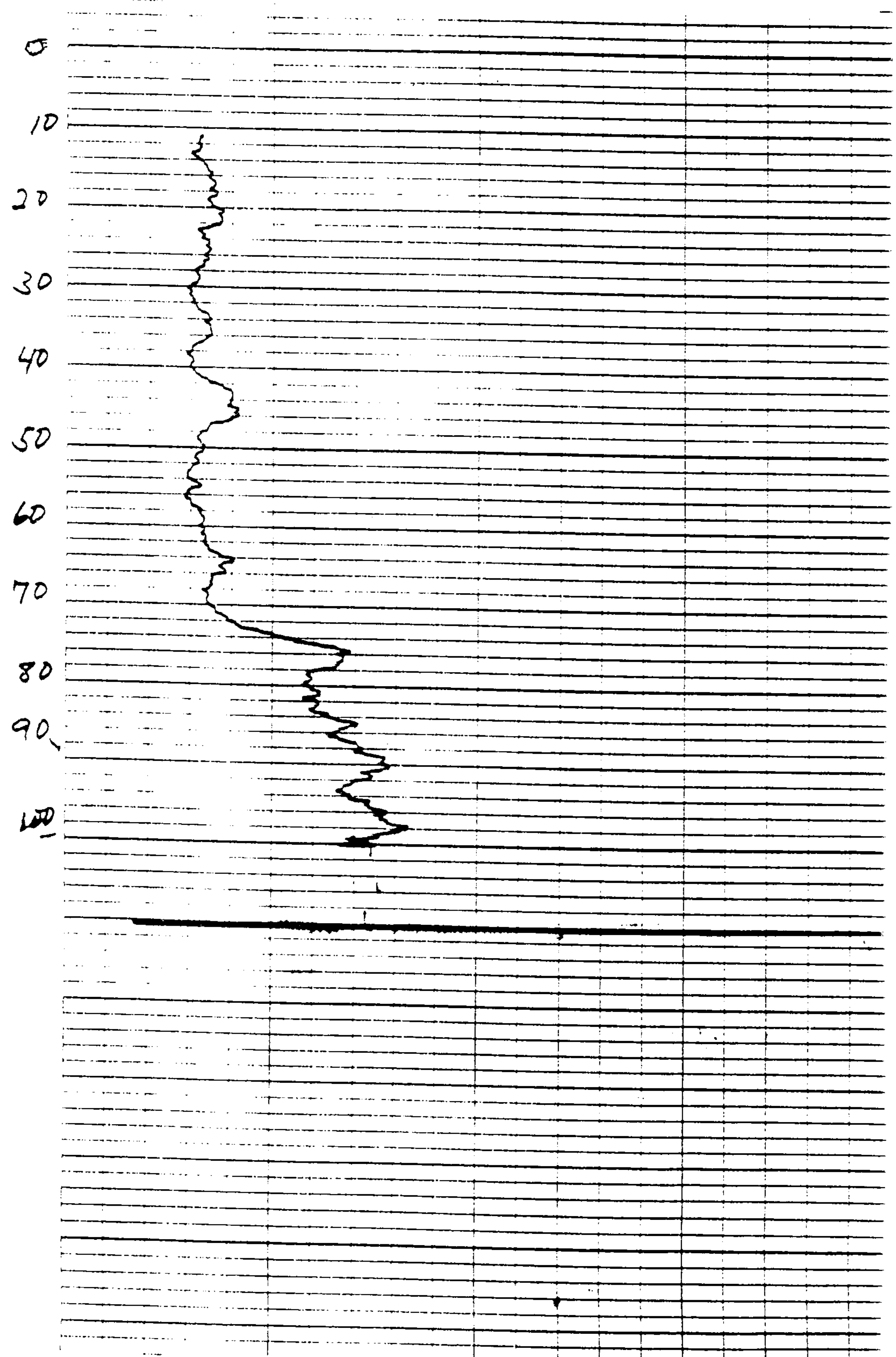
GW-1 Revised 6/88

Submit original to Division of Environmental Management and copy to well owner.

Cape Hatteras Water Assn.
Buxton Woods Test Well No. 2
Self-potential and Resistivity Logs
May 1, 1990



Cape Hatteras Water Assn.
Buxton Woods Test Well No. 2
Gamma-ray Log
May 1, 1990



NORTH CAROLINA DEPARTMENT OF NATURAL RESOURCES AND COMMUNITY DEVELOPMENT
DIVISION OF ENVIRONMENTAL MANAGEMENT - GROUNDWATER SECTION
P.O. BOX 27687 - RALEIGH, N.C. 27611, PHONE (919)733-3221

WELL CONSTRUCTION RECORD

FOR OFFICE USE ONLY

Quad. No. ______ Serial No. ______
Lat. ______ Long. ______ Pc ______
Minor Basin ______
Basin Code ______
Header Ent. ______ GW-1 Ent. ______

DRILLING CONTRACTOR Magette Well & Pump Co.

DRILLER REGISTRATION NUMBER 008

CHWA TEST WELL NO. 4

STATE WELL CONSTRUCTION PERMIT NUMBER: 27-0099-WM-0066

1. WELL LOCATION: (Show sketch of the location below)

Nearest Town: Buxton, 10 ft S. of woods trail & 10 ft E. of the W. boundary of State-owned land.
(Road, Community, or Subdivision and Lot No.)

County: Dare

2. OWNER Cape Hatteras Water Assn.

ADDRESS PO Box 578
(Street or Route No.)
Buxton NC 27920
City or Town State Zip Code

3. DATE DRILLED 5/11/90 USE OF WELL Observation

4. TOTAL DEPTH 53 CUTTINGS COLLECTED ☒ Yes ☐ No

5. DOES WELL REPLACE EXISTING WELL? ☐ Yes ☒ No

6. STATIC WATER LEVEL: 11.5 FT. ☐ above ☒ below TOP OF CASING.
TOP OF CASING IS 2 FT. ABOVE LAND SURFACE.

7. YIELD (gpm): 8 gpm METHOD OF TEST pump

8. WATER ZONES (depth): 16-30, 40-52, 61-65, 67-76
Specific capacity 0.8 gpm/ft

9. CHLORINATION: Type none Amount ______

10. CASING:

Depth From	To	Diameter	Wall Thickness or Weight/Ft.	Material
+2	48 Ft.	2 in	Sche 40	PVC
	Ft.			
	Ft.			

11. GROUT:

Depth From	To	Material	Method
0	20 Ft.	Portland	pump
	Ft.		

12. SCREEN:

Depth From	To	Diameter	Slot Size	Material
48	53 Ft.	2 in. in.	10 in.	PVC
	Ft.	in.	in.	
	Ft.	in.	in.	

13. GRAVEL PACK:

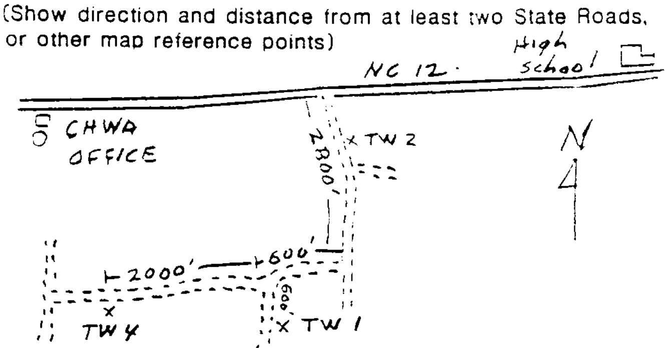
Depth From	To	Size	Material
39	78 Ft.	#2 (v.small)	quartz
	Ft.		

DRILLING LOG

Depth From	To	Formation Description
0	10	Sand, fn-med, tan, organic mat
10	25	Sand, fn-vicse, tan, shells
25	40	Sand, interbedded fn-med with cse-v.cse layers cont. shell color now gray.
40	52	Sand, v. fn-med, gray, shell frag., & some v.sm. gravel
52	62	Same
62	72	Sand, med-vicse.
72	82	Sand, v fn-fn, large % dark minerals & shell frag. clay toward bottom

If additional space is needed use back of form.

LOCATION SKETCH
(Show direction and distance from at least two State Roads, or other map reference points)



TW #4 is located near the W. end of the proposed new well field line.

Depth	Chloride	Iron	Total Hardness
48-53	45	2.2	260
60-65	40	2.7	240
72-77	55	3.8	360

14. REMARKS: Well near W. end of proposed well field. Drilled to det. geo & W.Q. cond. & provide an observation well.

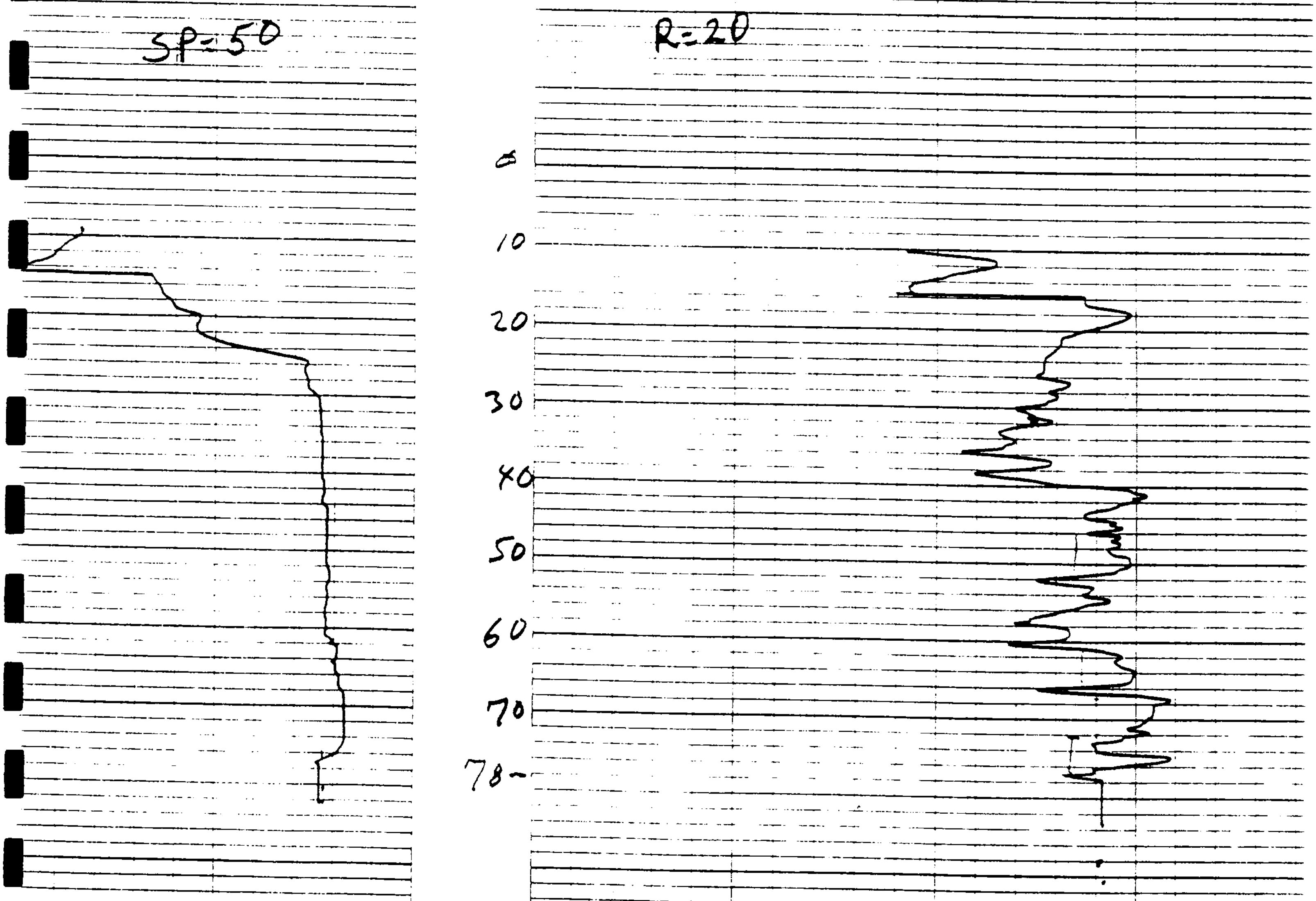
I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15 NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

Ralph C. Heath — May 12, 1990
SIGNATURE OF CONTRACTOR OR AGENT — DATE

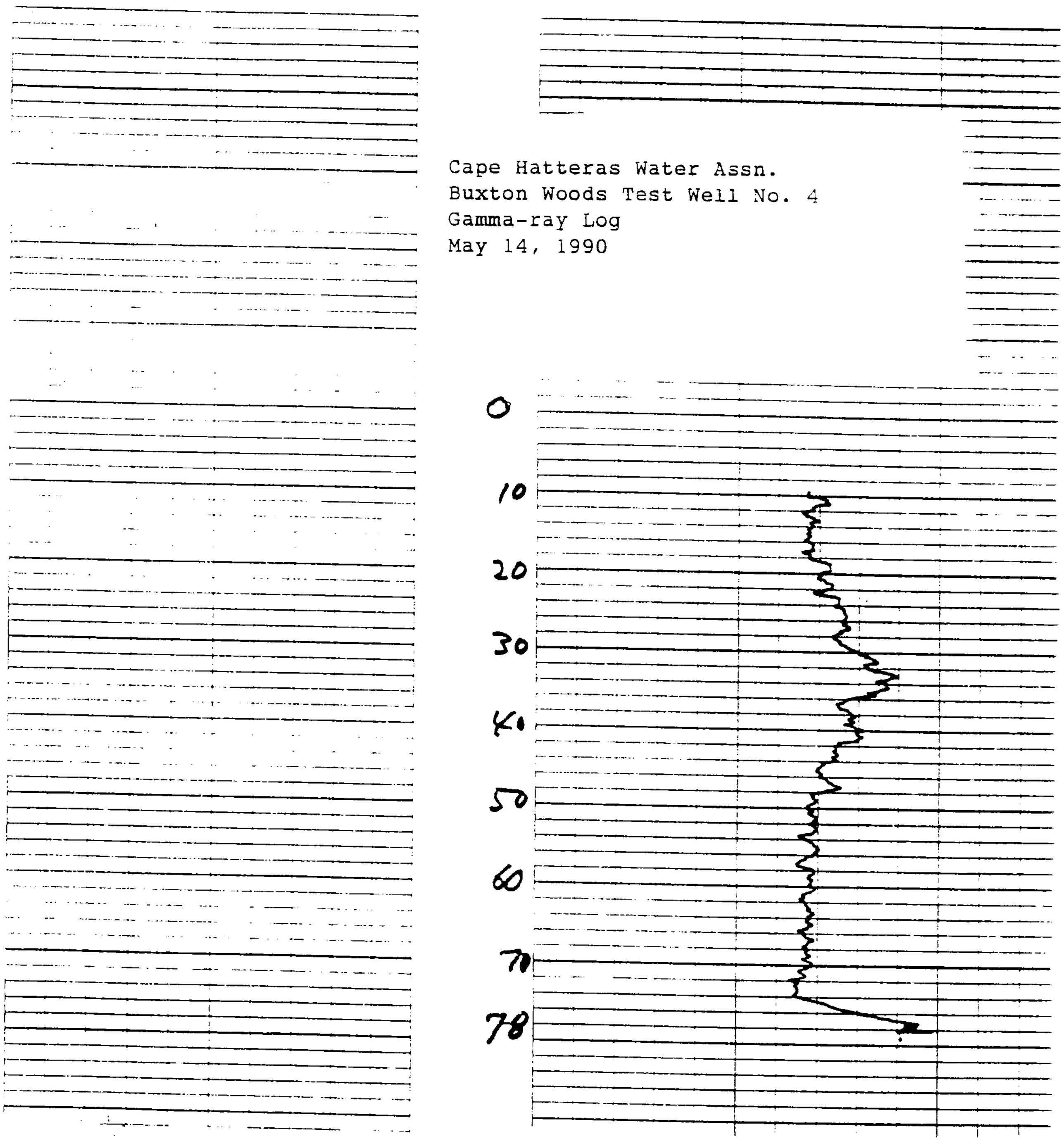
GW-1 Revised 6/88

Submit original to Division of Environmental Management and copy to well owner.

Cape Hatteras Water Assn.
Buxton Woods Test Well No. 4
Self-potential and Resistivity Logs
May 14, 1990



Cape Hatteras Water Assn.
Buxton Woods Test Well No. 4
Gamma-ray Log
May 14, 1990



APPENDIX B. Particle-size analyses of core samples obtained from test wells 1 and 4 drilled by the Cape Hatteras Water Association in the Buxton Woods area of Hatteras Island, N.C. (Analyses by Roberta Miller-Haraway, North Carolina State University Soils Laboratory.)

Sand Fractions for CHWA wells

sample no.	depth ft.	sand wt.	vcs wt.	% vcs	cs wt.	% cs	ms wt.	% ms	fs wt.	% fs	vfs wt.	% vfs	% total sand
Well 1 #1	18-20	9.74	0.35	3.5	0.61	6.1	2.06	20.6	5.31	53.1	1.41	14.1	97.4
Well 1 #2	40-42	9.45	0.04	0.4	0.15	1.5	3.17	31.7	4.4	44.0	1.69	16.9	94.6
Well 1 #3	60-62	9.66	0.63	6.3	1.02	10.2	2.74	27.5	4.98	50.0	0.29	2.9	97.0
Well 1 #4	80-82	9.07	0.42	4.2	0.54	5.4	1.92	19.3	4.11	41.3	2.08	20.9	91.2
Well 1 #5	100-102	7.85	0.05	0.5	0.06	0.6	0.21	2.1	4.99	50.4	2.54	25.7	79.3
Well 4 #1	50-52	9.44	0.01	0.1	1.2	12.0	4.42	44.2	2.41	24.1	0.4	4.0	94.5
Well 4 #2	60-62	9.41	0.2	2.0	0.93	9.3	5.06	50.7	2.67	26.7	0.55	5.5	94.2
Well 4 #3	70-72	9.58	2.8	28.1	4.6	46.2	1.08	10.8	0.48	4.8	0.62	6.2	96.2
Well 4 #4	80-82	9.41	0.36	3.6	0.53	5.3	0.93	9.3	6.98	70.0	0.61	6.1	94.4

Particle Size Analysis for CHWA wells

sample no.	depth ft.	Sand	Silt	Clay
		------------%	------------	------------
Well 1 #1	18-20	97.4	2.7	-0.1
Well 1 #2	40-42	94.6	4.9	0.5
Well 1 #3	60-62	97.0	2.2	0.8
Well 1 #4	80-82	91.2	5.1	3.7
Well 1 #5	100-102	79.3	10.9	9.8
Well 4 #1	50-52	94.5	6.7	-1.2
Well 4 #2	60-62	94.2	5.8	0.0
Well 4 #3	70-72	96.2	4.1	-0.2
Well 4 #4	80-82	94.4	5.2	0.4

APPENDIX C - Design of Supply Wells

The yield of the proposed supply wells will be larger than that of any other wells constructed for the CHWA and this, together with the increasing cost of electricity, makes the design of these wells important. Items that should be considered in the design are discussed in the following paragraphs.

1. Selection of well screens - Well screens can be either stainless steel or plastic. Whether steel or plastic, the screens should be of the continuous-slot type with an opening 40/1000 inch wide (40 slot). The total open area of the screen should be such that the entrance velocity - that is, the velocity of water moving through the screen openings- does not exceed 0.1 ft/sec at the maximum pumping rate. A pumping rate of 120 gpm equals 16 cu ft/min or 0.27 cu ft/sec. In order for the entrance velocity not to exceed 0.1 ft/sec, the open area of the screen must therefore be about 2.7 sq ft (0.27/0.1).

The open area of stainless steel screens is about twice that of plastic. For example, 6-in. diameter continuous 40-slot, stainless steel screen has an open area of 77 sq.in/ft of length, whereas continuous 40-slot plastic screen has an open area of 45 sq in/ft. Therefore, the supply wells should be finished with either 5 ft of stainless steel screen or 9 ft of plastic screen.

2. Selection of gravel pack - Because of the relatively small grain size of the material comprising the Buxton Woods aquifer, it is important that the gravel used in the gravel pack be compatible with the formation. The particle-size distribution graph for core No. 3 in Figure 3 provides the basic information needed for this purpose.

The "rule of thumb" used in gravel-pack design is that the grain diameter of the 70% coarser by weight particles of the gravel should be between 5 and 10 times the diameter of the 70% coarser by weight size of the aquifer material. The 70% coarser by weight size of the particles in core No. 3 is about 0.22 millimeters, or about 0.01 inch. Multiplying by 5, we obtain 0.05 inch (1.27 mm) as the diameter of the 70% coarser by weight size of the material in the gravel pack. This particle diameter is very coarse sand size. "Gravel" sized to be compatible with the Buxton Woods aquifer should therefore range in grain size from coarse sand to very fine gravel.

3. Placement of screens and gravel pack - Electrical resistivity, and possibly gamma-ray logs should be made on each hole prior to the placement of well casings and screens. The screens should be placed in the coarsest-grained zone based on interpretation of the logs. A blank piece of casing at least 5 ft long should be attached to the bottom of the screen to serve as a "sand trap." Gravel should be installed from the bottom of the blank casing to a position 10 to 15ft above the top of the screen, depending on the length of the screen.

APPENDIX D - Iron analyses of water samples from wells in the existing CHWA well field near Frisco. (January 30, 1979, samples analyzed by N.C. Division of Health Services Laboratory. June 7, 1990, samples analyzed by Shelly Rollinson, Cape Hatteras Water Association.)

Well	Iron (mg/l)		Well	Iron (mg/l)	
No	Jan 30, 1979	June 7,1990	No	Jan 30, 1979	June 9, 1990
3		5.1	16		2.9
4		2.0	16A	5.0	3.8
5		2.8	17		4.0.
6		3.1	17A	.46	3.3
7		N.O.1/	18		2.4
7A	3.9	2.6	18A	4.5	2.6.
8		2.8	19		1.7
8A	4.8	3.2	19A	3.7	1.1
9		3.3	20		3.4
9A	4.6	2.6	20A	5.6	3.6
10		2.6	21		N.O.
10A	6.2	3.5	21A	6.7	5.0
11		3.3	22		4.0.
11A	17	N.O.	22A		N.O.
12		3.2	23		3.8
12A	6.9	2.6	23A		3.3
13		2.1	24		3.1
13A		3.8	24A		5.8
14		2.1	25		4.4
14A	4.2	3.3	25A		0.1
15		N.O.	26		N.O
15A	5.4	3.8	26A		1.8

1/ N.O. - Well not in operation.

APPENDIX E - Chemical Analyses of water from Test Wells 1A and 4.

Chemical & Environmental Technology, Inc.

ENVIRONMENTAL ENGINEERING AND LABORATORY SERVICES

JOHN M. OGLE
PRESIDENT

P. O. BOX 12298
RESEARCH TRIANGLE PARK. N. C. 27709
PHONE (919) 467-3090
FAX (919) 467-3515

NEW WELL INORGANIC SCAN

LABORATORY ID #: 37724 DATE: 6-15-90
WATER SYSTEM ID #: - - COUNTY:
TYPE OF SYSTEM: CAPE HATTERAS WATER ASSOC.
TYPE OF SAMPLE: W = SOURCE
COLLECTED ON: DATE: TIME: : M
LOCATION WHERE COLLECTED: TEST WELL #1A
COLLECTED BY: W.C. DIEHL SOURCE CODE: 0 0 0
MAIL RESULTS TO: TYPE OF SUPPLY:
( ) COMMUNITY
( ) NTNC
( ) NON-COMMUNITY
( ) PRIVATE
WATER SOURCE:
( ) GROUND

DIEHL & PHILLIPS, P.A.
219 E. CHATHAM ST.
CARY, NC 27511

TELEPHONE #: (919) 467-9972

CONTAM CODE	NAME	METHOD CODE	RESULTS	ALLOW. LIMITS
0100	TURBIDITY, ntu	001	1.1	N/A
1005	ARSENIC, mg/l	125	0.004	0.050
1010	BARIUM, mg/l	101	<0.2	1.000
1015	CADMIUM, mg/l	101	<0.001	0.010
1016	CALCIUM, mg/l	101	81.8	N/A
1017	CHLORIDE, mg/l	127	44.4	N/A
1020	CHROMIUM, mg/l	101	0.001	0.050
1022	COPPER, mg/l	101	0.003	1.000
1025	FLUORIDE, mg/l	107	0.22	4.000
1028	IRON, mg/l	101	1.27	0.300
1030	LEAD, mg/l	125	<0.001	0.050
1031	MANGESIUM, mg/l	101	5.40	N/A
1032	MANGANESE, mg/l	101	0.053	0.050
1035	MERCURY, mg/l	103	<0.0002	0.002
1040	NITRATE, mg/l	105	0.26	10.00
1045	SELENIUM, mg/l	125	<0.001	0.010
1050	SILVER, mg/l	101	<0.001	0.050
1052	SODIUM, mg/l	101	31.6	N/A
1068	ACIDITY, mg/l	157	<1	N/A
1095	ZINC, mg/l	101	0.049	5.00
1905	COLOR, units	129	80	15.00
1915	TOTAL HARDNESS, mg/l	141	226	N/A
1925	pH, units	135	7.2	G 6.5
1927	ALKALINITY, mg/l	142	212	N/A

SAMPLE UNSATISFACTORY ( ) RESAMPLE REQUESTED ( )
DATE ANALYSES BEGUN: 05/24/90 DATE ANALYSES COMPLETED: 06/13/90

CET SAMPLE #: 37991 CERTIFIED BY: Jessie Litzenberger

Chemical & Environmental Technology, Inc.
ENVIRONMENTAL ENGINEERING AND LABORATORY SERVICES

JOHN M. OGLE
PRESIDENT

P. O. BOX 12298
RESEARCH TRIANGLE PARK, N. C. 27709
PHONE (919) 467-3090
FAX (919) 467-3515

POTENTIAL TRIHALOMETHANE ANALYSIS

LABORATORY ID #: 37724 DATE: 6-15-90
WATER SYSTEM ID #: - - COUNTY:
TYPE OF SYSTEM: CAPE HATTERAS WATER ASSOC.
TYPE OF SAMPLE: W = SOURCE
COLLECTED ON: DATE: TIME: : M
LOCATION WHERE COLLECTED: TEST WELL #1A
COLLECTED BY: W.C. DIEHL SOURCE CODE: 0 0 0
MAIL RESULTS TO:

DIEHL & PHILLIPS, P.A.
219 E. CHATHAM ST.
CARY, NC 27511

TELEPHONE #: (919) 467-9972

TYPE OF SUPPLY:
( ) COMMUNITY
( ) NTNC
( ) NON-COMMUNITY
( ) PRIVATE
WATER SOURCE:
( ) GROUND

CONTAM CODE	NAME	METHOD CODE	RESULTS	ALLOW. LIMITS
******	********************	******	*******	******
2941	CHLOROFORM,ug/l		798	100
2942	BROMOFORM,ug/l		BDL	100
2943	BROMODICHLOROMETHANE,ug/l		148	100
2944	CHLORODIBROMOMETHANE,ug/l		BDL	100
2950	TOTAL POTENTIAL TRIHALOMETHANES,ug/l		946	100

SAMPLE UNSATISFACTORY ( ) RESAMPLE REQUESTED ( )
DATE ANALYSES BEGUN: 05/24/90 DATE ANALYSES COMPLETED: 06/13/90

CET SAMPLE #: 37991 CERTIFIED BY: ____________________

CTE

Chemical & Environmental Technology, Inc.

ENVIRONMENTAL ENGINEERING AND LABORATORY SERVICES

JOHN M. OGLE
PRESIDENT

P. O. BOX 12298
RESEARCH TRIANGLE PARK, N. C. 27709
PHONE (919) 467-3090
FAX (919) 467-3515

NEW WELL INORGANIC SCAN

LABORATORY ID #: 37724 DATE: 6-15-90
WATER SYSTEM ID #: - - COUNTY:
TYPE OF SYSTEM: CAPE HATTERAS WATER ASSOC.
TYPE OF SAMPLE: W = SOURCE
COLLECTED ON: DATE: TIME: : M
LOCATION WHERE COLLECTED: TEST WELL #4
COLLECTED BY: W.C. DIEHL SOURCE CODE: 0 0 0
MAIL RESULTS TO: TYPE OF SUPPLY:

DIEHL & PHILLIPS, P.A.
219 E. CHATHAM ST.
CARY, NC 27511

TELEPHONE #: (919) 467-9972

( ) COMMUNITY
( ) NTNC
( ) NON-COMMUNITY
( ) PRIVATE
WATER SOURCE:
( ) GROUND

CONTAM CODE	NAME	METHOD CODE	RESULTS	ALLOW. LIMITS
******	********************	******	*******	******
0100	TURBIDITY, ntu	001	1.3	N/A
1005	ARSENIC, mg/l	125	0.003	0.050
1010	BARIUM, mg/l	101	<0.2	1.000
1015	CADMIUM, mg/l	101	<0.001	0.010
1016	CALCIUM, mg/l	101	67.5	N/A
1017	CHLORIDE, mg/l	127	38.8	N/A
1020	CHROMIUM, mg/l	101	0.002	0.050
1022	COPPER, mg/l	101	0.002	1.000
1025	FLUORIDE, mg/l	107	0.11	4.000
1028	IRON, mg/l	101	2.67	0.300
1030	LEAD, mg/l	125	<0.001	0.050
1031	MANGESIUM, mg/l	101	3.90	N/A
1032	MANGANESE, mg/l	101	0.068	0.050
1035	MERCURY, mg/l	103	<0.0002	0.002
1040	NITRATE, mg/l	105	0.27	10.00
1045	SELENIUM, mg/l	125	<0.001	0.010
1050	SILVER, mg/l	101	<0.001	0.050
1052	SODIUM, mg/l	101	24.1	N/A
1068	ACIDITY, mg/l	157	<1	N/A
1095	ZINC, mg/l	101	0.018	5.00
1905	COLOR, units	129	150	15.00
1915	TOTAL HARDNESS, mg/l	141	204	N/A
1925	pH, units	135	7.1	G 6.5
1927	ALKALINITY, mg/l	142	204	N/A

SAMPLE UNSATISFACTORY ( ) RESAMPLE REQUESTED ( )
DATE ANALYSES BEGUN: 05/24/90 DATE ANALYSES COMPLETED: 06/13/90

CET SAMPLE #: 37992 CERTIFIED BY:

AMERICAN COUNCIL OF INDEPENDENT LABORATORIES, INC.

Chemical & Environmental Technology, Inc.

ENVIRONMENTAL ENGINEERING AND LABORATORY SERVICES

JOHN M. OGLE
PRESIDENT

P. O. BOX 12298
RESEARCH TRIANGLE PARK, N. C. 27709
PHONE (919) 467-3090
FAX (919) 467-3515

POTENTIAL TRIHALOMETHANE ANALYSIS

LABORATORY ID #: 37724 DATE: 6-15-90
WATER SYSTEM ID #: - - COUNTY:
TYPE OF SYSTEM: CAPE HATTERAS WATER ASSOC.
TYPE OF SAMPLE: W = SOURCE
COLLECTED ON: DATE: TIME: : M
LOCATION WHERE COLLECTED: TEST WELL #4
COLLECTED BY: W.C. DIEHL SOURCE CODE: 0 0 0
MAIL RESULTS TO:

DIEHL & PHILLIPS, P.A.
219 E. CHATHAM ST.
CARY, NC 27511

TELEPHONE #: (919) 467-9972

TYPE OF SUPPLY:
( ) COMMUNITY
( ) NTNC
( ) NON-COMMUNITY
( ) PRIVATE

WATER SOURCE:
( ) GROUND

CONTAM CODE	NAME	METHOD CODE	RESULTS	ALLOW. LIMITS
******	********************	******	*******	******
2941	CHLOROFORM, ug/l		1090	100
2942	BROMOFORM, ug/l		BDL	100
2943	BROMODICHLOROMETHANE, ug/l		161	100
2944	CHLORODIBROMOMETHANE, ug/l		BDL	100
2950	TOTAL POTENTIAL TRIHALOMETHANES, ug/l		1250	100

SAMPLE UNSATISFACTORY ( ) RESAMPLE REQUESTED ( )
DATE ANALYSES BEGUN: 05/24/90 DATE ANALYSES COMPLETED: 06/13/90

CET SAMPLE #: 37992 CERTIFIED BY: ____________________

AMERICAN COUNCIL OF INDEPENDENT LABORATORIES, INC.