Environmental Assessment

for

Expansion

of the

Cape Hatteras Water Association

prepared

October, 1995

Hobbs, Upchurch & Associates, P.A.
Consulting Engineers
290 Southwest Broad Street
Southern Pines, North Carolina 28388
(910) 692-5616

Hobbs, Upchurch & Associates, P.A.
Consulting Engineers
P.O. Box 1737 • 290 S.W. Broad Street • Southern Pines, NC 28388 • Telephone 910-692-5616

LETTER OF TRANSMITTAL

DATE: 8/24/95
JOB NO.: DR9502
ATTENTION: BOB O.
RE:
CAPE HATTERAS
R.O.

To DARE CO.
R. O. PLANT
KILL DEVIL HILLS, NC

WE ARE SENDING YOU ☐ Attached ☐ Under separate cover via ________ the following items:

☐ Shop drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications
☐ Copy of letter ☐ Change order ☐ ________

COPIES	DATE	NO.	DESCRIPTION
1			SCOPING COMMENTS FROM CLEARINGHOUSE

THESE ARE TRANSMITTED as checked below:

☐ For approval ☐ Approved as submitted ☐ Resubmit ____ copies for approval
☒ For your use ☐ Approved as noted ☐ Submit ____ copies for distribution
☐ As requested ☐ Returned for corrections ☐ Return ____ corrected prints
☐ For review and comment ☐ ________

FOR BIDS DUE ________ 19____ ☐ PRINTS RETURNED AFTER LOAN TO US

REMARKS ________

COPY TO ________

SIGNED: Eric J. Weathers

If enclosures are not as noted, kindly notify us at once.

FM208

RECEIVED AUG 2 4 1995

NORTH CAROLINA STATE CLEARINGHOUSE
DEPARTMENT OF ADMINISTRATION
116 WEST JONES STREET
RALEIGH NORTH CAROLINA 27603-8003

08-22-95

INTERGOVERNMENTAL REVIEW COMMENTS

MAILED TO

N.C. DEPT. OF EHNR
LINDA SEWALL
DIV. OF ENV. HEALTH
1330 ST. MARY'S ST./INTER-OFFI

FROM

MRS. CHRYS BAGGETT
DIRECTOR
N C STATE CLEARINGHOUSE

PROJECT DESCRIPTION

SCOPING - PROPOSED CONSTRUCTION OF A NEW REVERSE OSMOSIS WATER TREATMENT FACILITY WITH DEEP AQUIFER WELLS ON HATTERAS ISLAND

SAI NO 96E43000035 PROGRAM TITLE - SCOPING

THE ABOVE PROJECT HAS BEEN SUBMITTED TO THE NORTH CAROLINA INTERGOVERNMENTAL REVIEW PROCESS. AS A RESULT OF THE REVIEW THE FOLLOWING IS SUBMITTED ( ) NO COMMENTS WERE RECEIVED

(X) COMMENTS ATTACHED

SHOULD YOU HAVE ANY QUESTIONS, PLEASE CALL THIS OFFICE (919) 733-7232.

C.C. REGION R
Hobbs, Upchurch & Assoc.

State of North Carolina
Department of Environment,
Health and Natural Resources
Legislative & Intergovernmental Affairs

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
Henry M. Lancaster II, Director

DEHNR

MEMORANDUM

TO Chrys Baggett
State Clearinghouse

FROM: Melba McGee
Environmental Review Coordinator

RE: 96-0035 Scoping RO Facility, Dare County

DATE: August 21, 1995

The Department of Environment, Health, and Natural Resources has reviewed the proposed scoping notice. The attached comments list and describe information that is necessary for our divisions to evaluate the potential environmental impacts of the project. More specific comments will be provided during the environmental review.

Thank you for the opportunity to respond. The applicant is encouraged to notify our commenting divisions if additional assistance is needed.

attachments

RECEIVED
AUG 2 2 1995
N.C. STATE CLEARINGHOUSE

P.O. Box 27687, Raleigh, North Carolina 27611-7687 Telephone 919-733-4984

State of North Carolina
Department of Environment,
Health and Natural Resources
Division of Marine Fisheries

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
Bruce L. Freeman, Director

DEHNR

MEMORANDUM:

TO: Melba McGee, Office of Legislative and Intergovernmental Affairs

THROUGH: Katy West, Review Coordinator KW

FROM: Sara E. Winslow, Biologist Supervisor

SUBJECT: Project Number 96-0035, Scoping - NPDES Permit Application/Environmental Assessment - RO Facility - Dare County

DATE: 27 July 1995

The North Carolina Division of Marine Fisheries would request the following points be addressed in the EA.

What would be the discharge flow from the RO Water Treatment Facility? What would be the quality of the discharge and its chemical composition? The discharge points should be specified. The existing habitat should be described and any impacts that may result from the construction of the discharge points outlined.

This agency appreciates the opportunity to provide input for the EA.

P.O. Box 769, Morehead City, North Carolina 28557-0769 Telephone 919-726-7021 FAX 919-726-0254

DIVISION OF ENVIRONMENTAL MANAGEMENT

August 07, 1995

To: Ms. Chrys Baggett
NC State Clearinghouse

From: Al Hodge, Environmental Engineer
DEM/WQ Washington Office

Subject: Proposed NPDES Permit Application
Reverse Osmosis Water Treatment
Proj. 96-0035
Hatteras Island/Dare County

The points of consideration in locating a discharge,of this category is, type of pollution and the volume of dilution needed so that water quality standards in the receiving stream are not contravened. The Reverse Osmosis process is so efficient, the filter backwash is very concentrated and requires a great deal of dilution. Chlorides are a problem when discharged too fresh water streams. When possible the discharge should be located in salt waters.

An analysis of the filter backwash is needed to make an accurate recommendation. However, Brook's Creek is the best location of the two proposed. I would advise locating the discharge point as close to Kings Point as possible for greater dilution.

DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL HEALTH

Inter-Agency Project Review Response

Project Number 96-0035

County Dare

Project Name Dare Co.

Type of Project RO WTP on Hatteras Island

☒ The applicant should be advised that plans and specifications for all water system improvements must be approved by the Division of Environmental Health prior to the award of a contract or the initiation of construction (as required by 15A NCAC 18C .0300 et. seq.). For information, contact the Public Water Supply Section, (919) 733-2460.

☐ This project will be classified as a non-community public water supply and must comply with state and federal drinking water monitoring requirements. For more information the applicant should contact the Public Water Supply Section, (919) 733-2321.

☐ If this project is constructed as proposed, we will recommend closure of ____ feet of adjacent waters to the harvest of shellfish. For information regarding the shellfish sanitation progra m, the applicant should contact the Shellfish Sanitation Branch at (919) 726-6827.

☐ The spoil disposal area(s) proposed for this project may produce a mosquito breeding problem. For information concerning appropriate mosquito control measures, the applicant should contact the Public Health Pest Management Section at (919) 726-8970.

☐ The applicant should be advised that prior to the removal or demolition of dilapidated structures, an extensive rodent control program may be necessary in order to prevent the migration of the rodents to adjacent areas. The information concerning rodent control, contact the local health department or the Public Health Pest Management Section at (919) 733-6407.

☐ The applicant should be advised to contact the local health department regarding their requirements for septic tank installations (as required under 15A NCAC 18A .1900 et. seq.). For information concerning septic tank and other on-site waste disposal methods, contact the On-Site Wastewater Section at (919) 733-2895.

☐ The applicant should be advised to contract the local health department regarding the sanitary facilities required for this project.

☒ If existing water lines will be relocated during the construction, plans for the water line relocation must be submitted to the Division of Environmental Health, Public Water Supply Section, Plan Review Branch, 1330 St. Mary's Street, Raleigh, North Carolina, (919) 733-2460.

[signature] EH/PWSS 8/4/95

Reviewer | Section/Branch | Date

DEHNR 3198 (Revised 8/93)
Division of Environmental Health

State of North Carolina
Department of Environment, Health, and Natural Resources

INTERGOVERNMENTAL REVIEW — PROJECT COMMENTS

Reviewing Office: Washington Regional Office

Project Number: 96-0035

Due Date: 8-11-95

After review of this project it has been determined that the EHNR permit(s) and/or approvals indicated may need to be obtained in order for this project to comply with North Carolina Law.

Questions regarding these permits should be addressed to the Regional Office indicated on the reverse of the form.

All applications, information and guidelines relative to these plans and permits are available from the same Regional Office.

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (statutory time limit)
☐	Permit to construct & operate wastewater treatment facilities, sewer system extensions, & sewer systems not discharging into state surface waters.	Application 90 days before begin construction or award of construction contracts On-site inspection. Post-application technical conference usual	30 days (90 days)
☐	NPDES - permit to discharge into surface water and/or permit to operate and construct wastewater facilities discharging into state surface waters	Application 180 days before begin activity. On-site inspection. Pre-application conference usual. Additionally, obtain permit to construct wastewater treatment facility-granted after NPDES Reply time, 30 days after receipt of plans or issue of NPDES permit-whichever is later.	90-120 days (N/A)
☐	Water Use Permit	Pre-application technical conference usually necessary	30 days (N/A)
☐	Well Construction Permit	Complete application must be received and permit issued prior to the installation of a well.	7 days (15 days)
☐	Dredge and Fill Permit	Application copy must be served on each adjacent riparian property owner. On-site inspection. Pre-application conference usual. Filling may require Easement to Fill from N.C. Department of Administration and Federal Dredge and Fill Permit.	55 days (90 days)
☐	Permit to construct & operate Air Pollution Abatement facilities and/or Emission Sources as per 15A NCAC 21H.0600	N/A	60 days (90 days)
☑	Any open burning associated with subject proposal must be in compliance with 15A NCAC 2D.0520.	N/A	60 days (90 days)
☑	Demolition or renovations of structures containing asbestos material must be in compliance with 15A NCAC 2D.0525 which requires notification and removal prior to demolition. Contact Asbestos Control Group 919-733-0820		
☐	Complex Source Permit required under 15A NCAC 2D.0800.		
☐	The Sedimentation Pollution Control Act of 1973 must be properly addressed for any land disturbing activity. An erosion & sedimentation control plan will be required if one or more acres to be disturbed. Plan filed with proper Regional Office (Land Quality Sect.) at least 30 days before beginning activity. A fee of $30 for the first acre and $20.00 for each additional acre or part must accompany the plan		20 days (30 days)
☐	The Sedimentation Pollution Control Act of 1973 must be addressed with respect to the referrenced Local Ordinance.		(30 days)
☐	Mining Permit	On-site inspection usual. Surety bond filed with EHNR. Bond amount varies with type mine and number of acres of affected land. Any area mined greater than one acre must be permited. The appropriate bond must be received before the permit can be issued	30 days (60 days)
☐	North Carolina Burning permit	On-site inspection by N.C. Division Forest Resources if permit exceeds 4 days	1 day (N/A)
☐	Special Ground Clearance Burning Permit - 22 counties in coastal N.C. with organic soils	On-site inspection by N.D. Division Forest Resources required "if more than five acres of ground clearing activities are involved. Inspections should be requested at least ten days before actual burn is planned."	1 day (N/A)
☐	Oil Refining Facilities	N/A	90-120 days (N/A)
☐	Dam Safety Permit	If permit required, application 60 days before begin construction. Applicant must hire N.C. qualified engineer to: prepare plans, inspect construction, certify construction is according to EHNR approved plans. May also require permit under mosquito control program. And a 404 permit from Corps of Engineers. An inspection of site is necessary to verify Hazard Classification. A minimum fee of $200.00 must accompany the application. An additional processing fee based on a percentage or the total project cost will be required upon completion	30 days (60 days)

	PERMITS	SPECIAL APPLICATION PROCEDURES or REQUIREMENTS	Normal Process Time (statutory time limit)
☐	Permit to drill exploratory oil or gas well	File surety bond of $5,000 with EHNR running to State of N.C. conditional that any well opened by drill operator shall, upon abandonment, be plugged according to EHNR rules and regulations.	10 days (N/A)
☐	Geophysical Exploration Permit	Application filed with EHNR at least 10 days prior to issue of permit Application by letter. No standard application form.	10 days (N/A)
☐	State Lakes Construction Permit	Application fee based on structure size is charged. Must include descriptions & drawings of structure & proof of ownership of riparian property.	15-20 days (N/A)
☐	401 Water Quality Certification	N/A	60 days (130 days)
☐	CAMA Permit for MAJOR development	$250.00 fee must accompany application	55 days (150 days)
☐	CAMA Permit for MINOR development	$50.00 fee must accompany application	22 days (25 days)
☐	Several geodetic monuments are located in or near the project area. If any monuments need to be moved or destroyed, please notify N.C. Geodetic Survey, Box 27687, Raleigh, N.C. 27611		
☒	Abandonment of any wells, if required, must be in accordance with Title 15A, Subchapter 2C.0100		
☒	Notification of the proper regional office is requested if "orphan" underground storage tanks (USTS) are discovered during any excavation operation		
☐	Compliance with 15A NCAC 2H.1000 (Coastal Stormwater Rules) is required.		45 days (N/A)

Other comments (attach additional pages as necessary, being certain to cite comment authority):

REGIONAL OFFICES

Questions regarding these permits should be addressed to the Regional Office marked below.

- ☐ Asheville Regional Office
  59 Woodfin Place
  Asheville, NC 28801
  (704) 251-6208
- ☐ Mooresville Regional Office
  919 North Main Street, P.O. Box 950
  Mooresville, NC 28115
  (704) 663-1699
- ☒ Washington Regional Office
  1424 Carolina Avenue
  Washington, NC 27889
  (919) 946-6481
- ☐ Fayetteville Regional Office
  Suite 714 Wachovia Building
  Fayetteville, NC 28301
  (919) 486-1541
- ☐ Raleigh Regional Office
  3800 Barrett Drive, Suite 101
  Raleigh, NC 27609
  (919) 733-2314
- ☐ Wilmington Regional Office
  127 Cardinal Drive Extension
  Wilmington, NC 28405
  (919) 395-3900
- ☐ Winston-Salem Regional Office
  8025 North Point Blvd
  Suite 100

RECEIVED 10-12-95

Hobbs, Upchurch & Associates, P.A.
Consulting Engineers
290 S.W. Broad Street • Post Office Box 1737 • Southern Pines, NC 28388

October 9, 1995

Mr. Steve Tedder
Division of Environmental Management
NC Department of Environment, Health & Natural
Resources
Archdale Building
512 North Salisbury Street
Raleigh, North Carolina 27611-7687

RE: NPDES Permit Modification for Proposed
Cape Hatteras Water Plant Expansion Discharge - NPDES #NC0033103
HUA No. DR9502

Dear Mr. Tedder:

The Cape Hatteras Water Association presently operates a 1.5 mgd water treatment facility which treats raw water from a shallow surficial aquifer. A water supply plan prepared for the area projects a need of 3.0 mgd by the year 2020. Withdrawal from the existing raw water aquifer is limited by restrictions on new well locations as imposed by court action.

The Cape Hatteras Water Association proposes to supplement the existing water supply by withdrawing water from a deeper brackish aquifer, treating this water by reverse osmosis and blending this treated water with the existing supply. This approach will result in an adequate supply of drinking water for the area through the year 2020.

The reverse osmosis process will have a salty discharge of up to 1.8 mgd which must be disposed of by an NPDES permit. The existing plant currently has a permit to discharge water from the process currently being used. We request that this permit be modified to include the additional water from the proposed RO process.

Enclosed please find an environmental assessment of the proposed NPDES discharge. Copies of this environmental assessment have been forwarded to the NC Clearinghouse for review.

Please allow this letter to serve as a request for modification of the existing Cape Hatteras Water Association water treatment plant permit. Please contact me at my office for additional information or if this request needs to be forwarded in a different form. Thank you for your attention to this matter.

Sincerely,
HOBBS, UPCHURCH & ASSOCIATES, P.A.

Ron Huff

Ron Huff, P.E.

cc: Terry Wheeler, County Manager, Dare County
Bob Oreskovich, Superintendant, Dare County Water Department
Jim Coleman, Cape Hatteras Water Association

Southern Pines, NC	Telephone 910-692-5616	Fax 910-692-7342
Winston-Salem, NC	Telephone 910-759-3009	Fax 910-759-7590
Myrtle Beach, SC	Telephone 803-626-1910	Fax 803-626-1745

Hobbs, Upchurch & Associates, P.A.
Consulting Engineers
290 S.W. Broad Street • Post Office Box 1737 • Southern Pines, NC 28388

October 10, 1995

Ms. Monica Swihart
NC DEHNR
Division of Environmental Management
Archdale Building
512 North Salisbury Street
Raleigh, North Carolina 27611-7687

RE: NPDES Permit Modification for Proposed Cape Hatteras Water Plant Expansion Discharge - NPDES #NC0033103
HUA No. DR9502

Dear Ms. Swihart:

Enclosed please find eight (8) copies of an environmental assessment to support a request for modification of an existing NPDES permit held by the Cape Hatteras Water Association in conjunction with their water treatment plant. It is proposed that the water treatment plant be expanded from 1.5 mgd to 3.0 mgd. It is further proposed that the existing surficial aquifer raw water supply be supplemented by brackish water from another aquifer. This brackish water will undergo reverse osmosis and be blended with the existing treated water source. The discharge from the reverse osmosis process will have a flow of approximately 1.8 mgd and will contain salt.

Please review this document and furnish your comments at the earliest practical date. Feel free to contact me at my office if you have questions or need further information. Thank you very much for your consideration.

Sincerely,
HOBBS, UPCHURCH & ASSOCIATES, P.A.

Ron Huff

Ron Huff, P.E.

cc: Terry Wheeler, County Manager, Dare County
Bob Oreskovich, Director, Dare County Water Department
Jim Coleman, Cape Hatteras Water Association

Southern Pines, NC	•	Telephone 910-692-5616	•	Fax 910-692-7342
Winston-Salem, NC	•	Telephone 910-759-3009	•	Fax 910-759-7590
Myrtle Beach, SC	•	Telephone 803-626-1910	•	Fax 803-626-1745

ENVIRONMENTAL ASSESSMENT FOR

EXPANSION OF CAPE HATTERAS

WATER ASSOCIATION TREATMENT

CAPACITY TO 3 MGD

NORTH CAROLINA PROFESSIONAL SEAL 14907 ENGINEER RONALD S. HUFF

10-6-95

PREPARED BY

HOBBS, UPCHURCH & ASSOCIATES, P.A.
290 S.W. BROAD STREET
SOUTHERN PINES, NORTH CAROLINA

DECEMBER, 1994

TABLE OF CONTENTS

ENVIRONMENTAL ASSESSMENT

FOR

EXPANSION OF CAPE HATTERAS WATER ASSOCIATION

TREATMENT CAPACITY TO 3 MGD

I. OVERVIEW

The Cape Hatteras Water Association (CHWA) presently supplies potable water to the communities of Avon, Buxton, Hatteras and Frisco all of which are located on the southern portion of Hatteras Island. Figure 1 on the following page shows the island and communities served. The current peak water usage for these communities is approximately 1.2 million gallons per day (mgd) requiring an aquifer withdrawal of 1.4 mgd. The water supply is presently derived from 44 relatively shallow wells which draw their groundwater from the upper Buxton Woods aquifer which is recharged by rainwater which falls on the island. The present treatment plant and wells are operating near the limits of their capacity and a moratorium on the sale of new water connections has been imposed. Approximately 2,000 water impact fees were sold in 1985 in anticipation of a capacity upgrade from 1.0 to 2.0 mgd. Capacity was increased to only 1.5 mgd. Approximately 800 of the impact fees have not been activated. Plans for further expansion were stopped when permits to add more new wells in the aquifer were denied. Only excellent conservation has allowed the system to continue to adequately serve existing customers.

Although the current water supply is difficult to treat, CHWA has attempted to expand its current production by the location of additional shallow wells on the island. These attempts have been blocked due to environmental concerns. Extensive groundwater exploration has taken place in an effort to find additional sources of treatable water. It is anticipated that approximately 3 mgd of potable water will be required by the year 2020. Groundwater explorations have discovered an adequate source of salty water in the deeper Yorktown aquifer. The present proposal is to blend water obtained from a lower portion of the Buxton Woods aquifer with the treated salty (brackish) water from the Yorktown aquifer to obtain an adequate supply of potable water until the year 2020.

II. EXISTING ENVIRONMENT

Topography

Elevations on the southern portion of Hatteras Island vary from sea level to approximately 60 feet above mean sea level (msl) at the top of the dunes. Most of the dunes have elevations of approximately 40 feet. The majority of land on this portion of the island has elevations from

Figure 1

5 to 10 feet above msl. Because of the lack of topographic relief, a large portion of the land mass has been ditched and drained in the past to produce habitable areas. Much of the habitable area is below the 100 year flood elevation. The island has experienced extensive flooding in recent years from hurricane activity. Figure 3 on page 5 shows the topography of the area.

Wetlands

Wetlands are abundant on the island including many salt water areas on the north coast of the sound. The south and east coasts of the island are dominated by the Cape Hatteras National Seashore but contain areas of salt marsh. There are many fresh water wetland areas on the inland portions of the island. A portion of the land currently owned by CHWA which is slated for construction of the proposed water treatment plant consists of wetlands. The project will be planned and constructed for minimal impact to wetland areas. Figure 2 on the following page shows the CHWA land where the proposed plant will be built. Wetlands are shown on the map.

Land Use

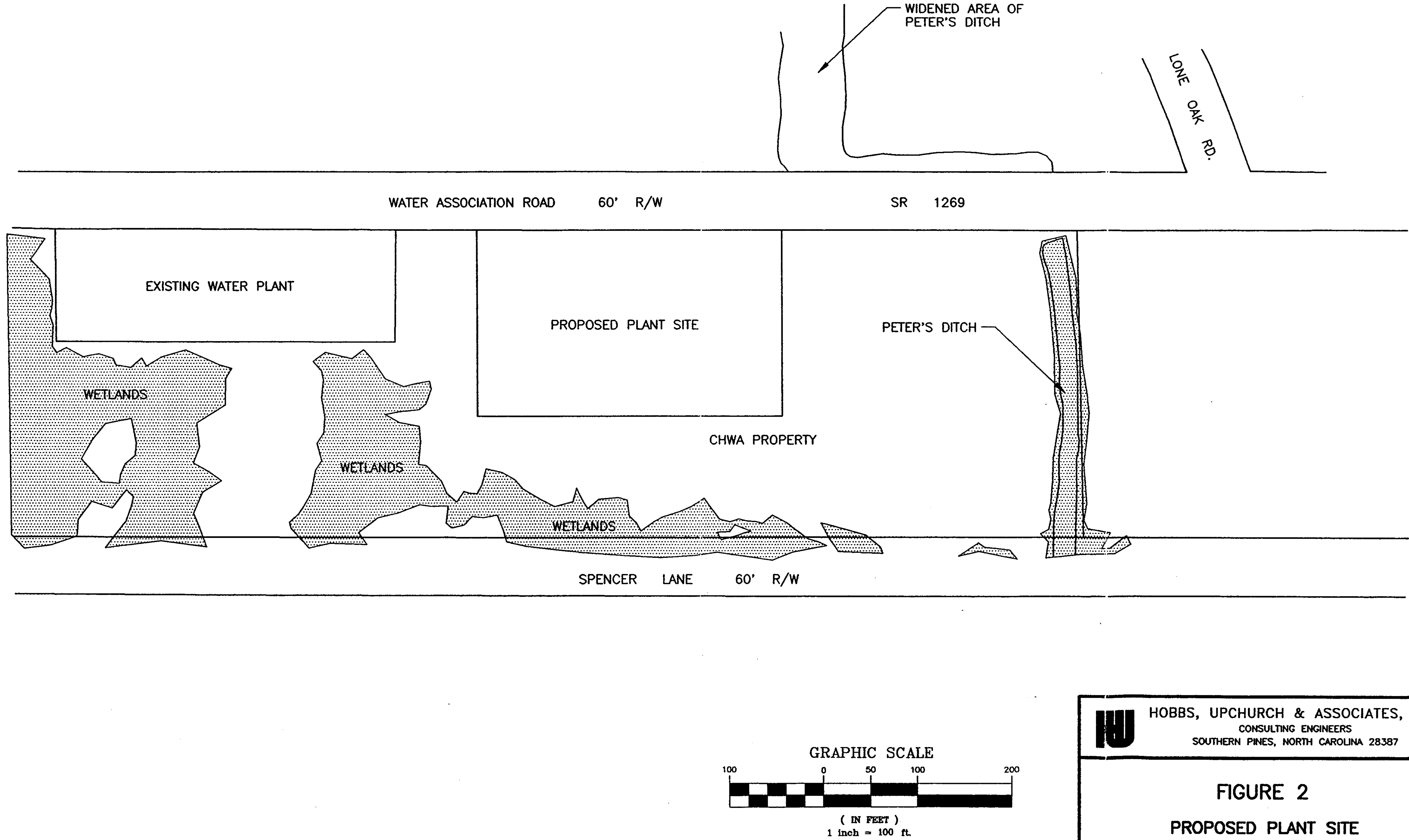
The current land uses on the southern portion of Hatteras Island are residential, commercial, and recreational. Both permanent and transient residents enjoy the recreational benefits of the area. The Cape Hatteras National Seashore dominates the southern portion of the area and includes the famous Cape Hatteras lighthouse. It is anticipated that future land use will be similar. It is unlikely that any significant industry will locate in this area.

Groundwater

Extensive hydrogeologic analysis has been performed on the area's groundwater. The present potable water supply is derived from the upper Buxton Woods aquifer. There are currently 44 wells ranging in depth from 40 to 50 feet which are spaced approximately 250 feet apart. The water is hard and contains iron and organic carbon. There is a considerable amount of color to this water. Treatment required to produce potable water from this source is expensive. Further exploration of the Buxton Woods aquifer has identified a deeper or lower permeable zone ranging in depth from approximately 60 to 75 feet. Initial groundwater extracted from this lower zone is of better quality than that currently extracted from the upper zone. Current plans are to replace the 44 upper zone wells which have served their projected life expectancy with approximately 22 new lower zone wells which will have a combined yield of approximately 2,160,000 gallons per day (gpd). The estimated continuous safe aquifer yield is approximately 700,000 gpd. This configuration could support peak treated water demands of approximately 1,700,000 gpd for continuous periods of approximately 90 days with an annual average daily use of approximately 595,000 gpd.

The existing and proposed Buxton Woods aquifer well field is referred to as the Frisco well field. Information presented here regarding this aquifer has been derived from the report by Ralph C. Heath, Consulting Hydrogeologist, "Report Related to Modification of the Frisco

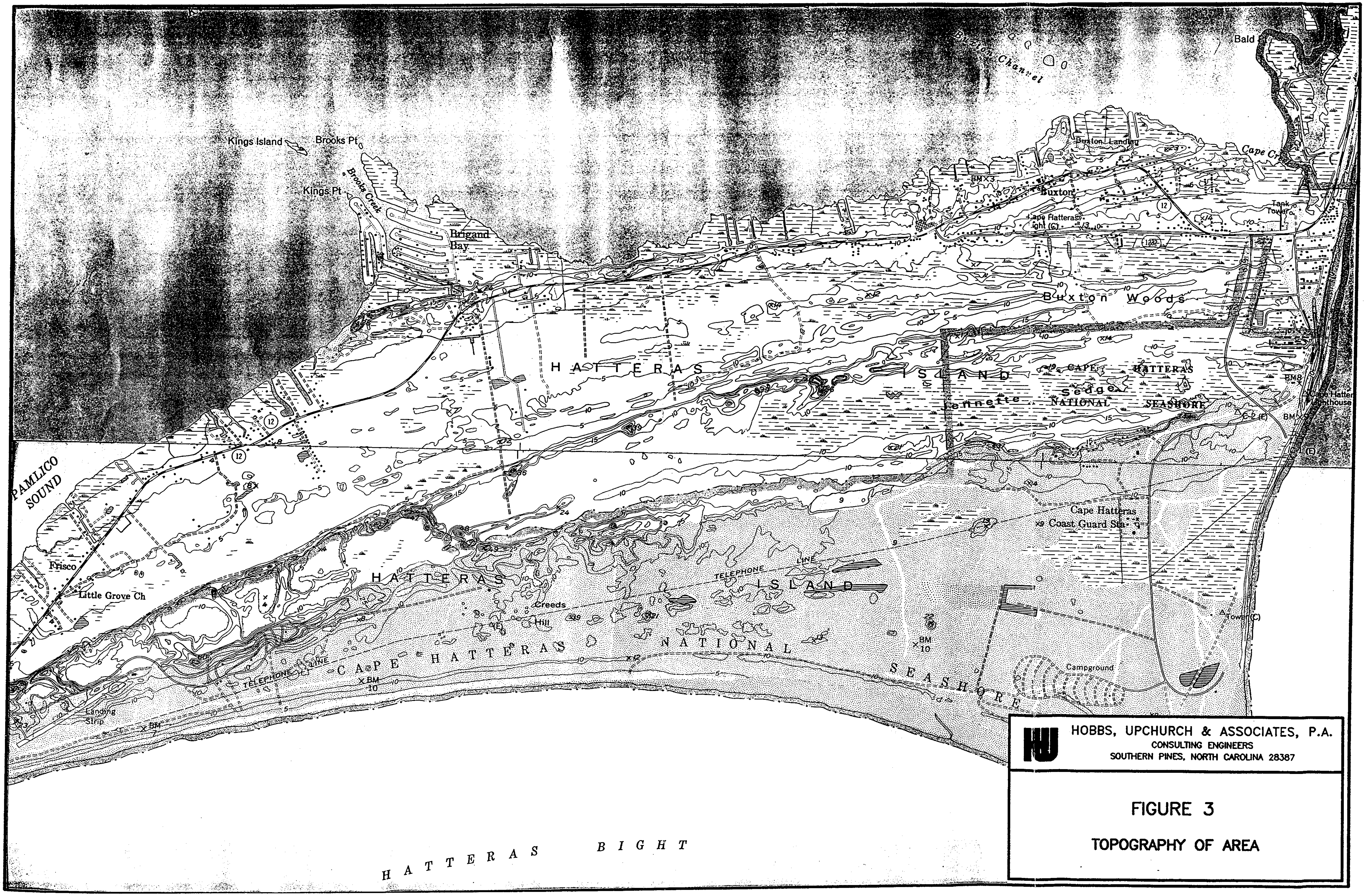
Figure 2



HOBBS, UPCHURCH & ASSOCIATES, P.A.
CONSULTING ENGINEERS
SOUTHERN PINES, NORTH CAROLINA 28387

FIGURE 2

PROPOSED PLANT SITE
WITH WETLAND AREAS



HOBBS, UPCHURCH & ASSOCIATES, P.A.
CONSULTING ENGINEERS
SOUTHERN PINES, NORTH CAROLINA 28387

FIGURE 3

TOPOGRAPHY OF AREA

Well Field of the Cape Hatteras Water Association" (See Appendix B). It is further reported that the quality of the water from the lower zone will diminish over time but should always be superior to the water currently withdrawn from the upper aquifer zone.

Additional exploration has identified a source of brackish water which can be withdrawn at approximately 4 mgd from the limestone Yorktown aquifer at depths of approximately 250 feet. Three test wells have been constructed into this aquifer. Although the chlorides vary in these wells, the water is economically treatable by reverse osmosis (RO). Initial chloride levels from this upper zone of the Yorktown aquifer range from 3,800 to 8,750 milligrams per liter (mg/l). It is anticipated that these levels will change over time. The proposed treatment scheme takes these anticipated changes into account.

Surface Water

Most surface waters on the lower portion of Hatteras Island are the results of man. The island has been ditched to lower groundwater levels in order to make the island habitable. Several large borrow pits used for construction in the past are now lakes. Withdrawals from these bodies of water would depend on the Buxton Woods aquifer for recharge and would offer no new water source. There is no adequate source of surface water for drinking purposes.

Air Quality

There is no air monitoring station near the project area. Air monitoring stations exist at Plymouth, Roanoke Rapids and Elizabeth City. The air quality of the area is free of industrial pollution and is very good. Air stagnation is uncommon due to persistent breezes. Appendix A contains air monitoring data from nearby stations.

Noise

Noise is not currently a problem on the island. The proposed project should have no impact on noise with the exception of temporary construction noise.

Historical and Archaeological Concerns

The State historical officer has been informed of the proposed project. As of this date, there are no known historical/archaeological sites which will be impacted by the proposed project.

Wildlife and Endangered Species

The proposed water treatment facility will produce two discharges which could be discharged either separately or together. The discharge from the conventional treatment of the Buxton Woods aquifer water will be very similar in character and volume to that which is currently discharged. The discharge from the proposed RO process will contain high levels of salt along with many other constituents and will eventually be approximately 1.8 mgd in volume.

The discharge point for this concentrate water will be located so as to minimize or eliminate any negative effects on aquatic organisms in the receiving waters. It is anticipated that the discharge from the conventional treatment system will continue to be discharged into Peter's Ditch per existing NPDES permit. No other wildlife or endangered species should be impacted by the project.

III. NEED

On peak flow days, the existing CHWA facility operates at effective full capacity. The area served by this Association is under a moratorium preventing the acceptance of new water customers due to lack of capacity. Approximately 800 connection impact fees have been sold by the Association for which there is inadequate water. Water conservation is encouraged by the Association and is enforced by a rate structure which places a premium cost on large water users.

A water supply plan has been formulated for the area. Table 1 shows the projected future population and water demand as published in the water supply plan.

TABLE 1

Future Population and Water Demand
(In millions of gallons per day)

Year	Population	Residential Use	Indus/Comm	Avg Daily Use	Peak Day
1992	6,900	.415	.283	0.698	1.310
2000	9,000	.585	.351	0.936	2.000
2010	11,000	.715	.492	1.207	2.500
2020	12,000	.780	.700	1.480	3.000

Projections from approved water supply plan.

It is projected that the peak day demand for the year 2020 will be 3 mgd. For this reason, the proposed well fields and treatment facilities are sized for an ultimate potable water output of 3 mgd.

In an attempt to obtain additional water for treatment, the addition of nine new wells to supplement the additional Frisco well field was proposed. Environmentalists were concerned that additional depletion of the upper Buxton Woods aquifer would result in damage to valuable plant life on the island. Although the original premise was discounted in court proceedings, CHWA was denied permission to locate additional wells as needed. The Court of Appeals found that these wells were not a permitted use of the public lands on which the wells were proposed. This has effectively limited the amount of withdrawal from the upper Buxton Woods aquifer to little more than the present amount.

Wastewater disposal on the island is currently managed through the use of individual septic tanks and drain fields. There is considerable concern over the potential contamination of private well in the Buxton Woods aquifer by septic tank drain fields. Because of careful placing and protection, CHWA wells are not threatened. These concerns have been documented by health officials in the past. Additional development will occur on the island with or without the proposed project. With or without the project, there will be additional septic tanks, additional private wells and increased potential for groundwater contamination of private wells.

The economy of the area is dependent on tourism. Without additional drinking water there can be no additional commercial development. The local population desires that the economy be allowed to grow and not remain stagnate.

IV. ALTERNATIVES

Several alternatives have been considered with respect to the current dilemma. The alternatives are as follows:

A. Do Nothing

The current water supply is not capable of allowing the collection of new impact fees. Without an additional public water supply, some additional development will occur but will be dependent on the use of private wells and the activation of taps where impact fees have already been collected. More private wells will increase the migration of groundwater and increase the potential for contamination of private wells from existing and additional septic systems. Other areas of the island currently have severe problems with the quality of water pumped from private wells. Many must resort to the use of bottled water for consumption. Without an acceptable public water supply, this trend is likely to continue and worsen.

The "do nothing" alternative is not deemed acceptable by the residents of the area.

B. Expand Current Well Field and Treatment System

As briefly explained in previous portions of this document, this alternative has already been pursued. CHWA requested permits for nine additional wells to augment the existing water supply from the Buxton Woods aquifer. These proposed nine wells, while helpful, would not have been adequate to supply the projected needs of the area to the year 2020. The proposed wells were to be on public lands in the Buxton Woods area of the island. In spite of the finding that these additional wells would cause no foreseeable damage to important island vegetation, the Court of Appeals ruled that these wells were not an acceptable use of public lands.

Additional exploration of the currently used Buxton Woods aquifer has been performed. This exploration has revealed a deeper permeable zone ranging in depth from approximately 60 to 75 feet below ground level. Water drawn from test wells has proven to be of better quality and yield than the existing 44 wells. While the installation of approximately 22 lower permeable zone wells to replace the old existing wells can effectively increase the well field yield from a present peak of 1,800,000 gpd to 2,160,000 gpd, this still would not be adequate for future use. The estimated constant safe yield of the aquifer is 700,000 gpd. It is estimated that an additional safe yield of 200,000 gpd could be achieved by restricting flow from drainage ditches.

Although this alternative has been pursued to increase current water production, it does not present a long-term solution to the potable water demands of the area.

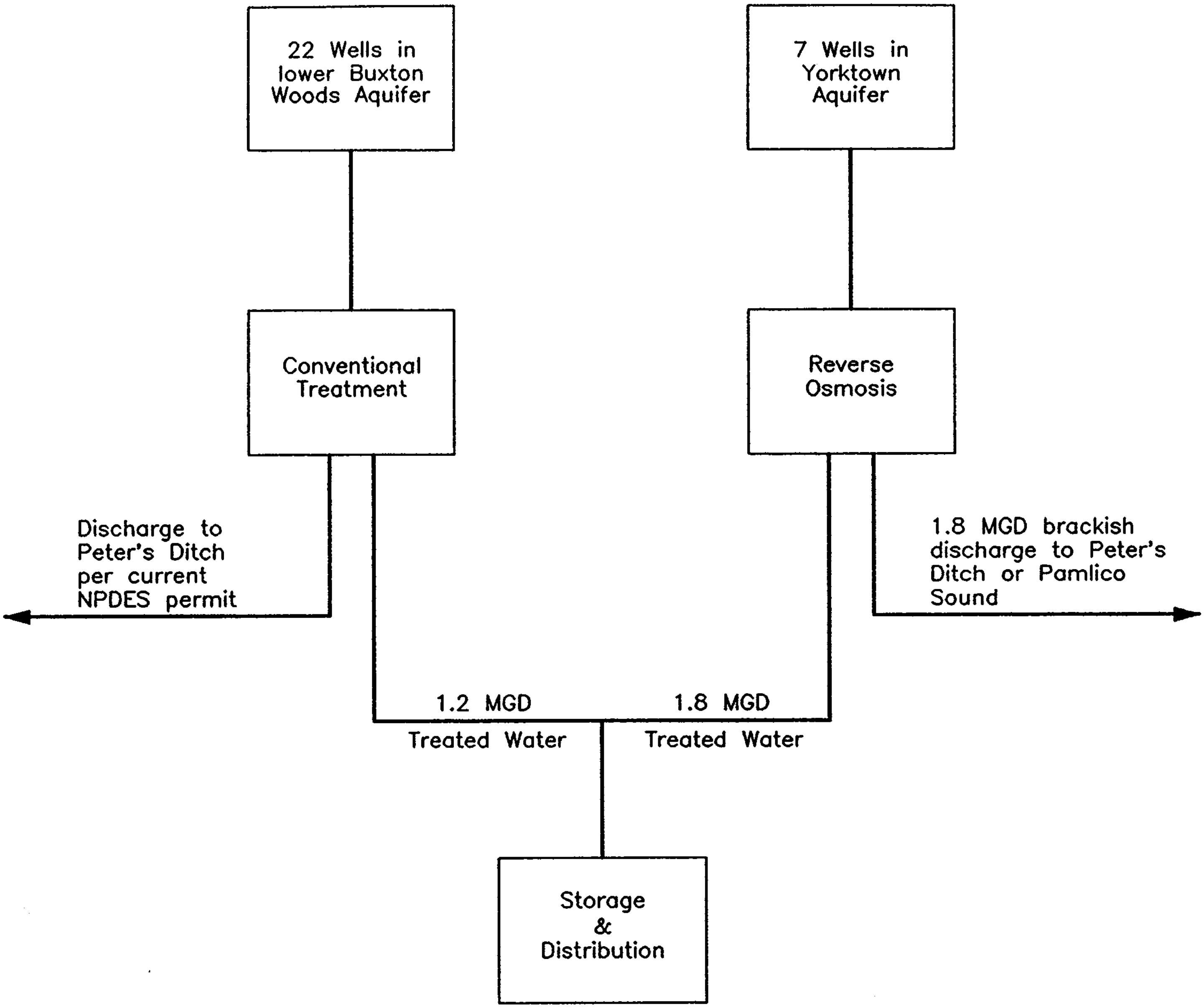
C. **Provide a Blend of Conventionally Treated and Desalinated Water from Two Separate Aquifers**

While the available water from the currently used Buxton Woods Aquifer is expensive to treat and inadequate for long range supply needs, it can be successfully blended with desalinated water obtained from the limestone Yorktown aquifer at depths of approximately 250 feet below ground level. Figure 4 on the following page is a schematic of the proposed water supply and treatment system. Results of test wells in the Yorktown aquifer show that while this aquifer can yield up to 4 mgd of flow, it alone is also inadequate for all future needs because of the intensity of treatment which would be required to produce 3 million gallons per day of potable water from this source. Although each individual source is inadequate, a blend of water treated from both sources should supply an excellent and adequate water supply until the year 2020. The blend of desalted water from the Yorktown aquifer and treated water from the Buxton Woods aquifer will be controlled by characteristics of the blend. It is anticipated that water quality from both aquifers will deteriorate somewhat over time requiring that the initial blend be different from the future blend. Deterioration of the aquifers has been projected by hydrogeologists who are thoroughly familiar with groundwater resources of the area. These projections are conservative and should represent a worst case scenario in terms of withdrawal, treatment and discharge from the treatment process. Appendix B contains reports from Ralph Heath on the Buxton aquifer, Missimer and Associates on the Yorktown aquifer and Boyle Engineering on the blending and treatment of the sources from both aquifers.

The proposed treatment system will be a combination of two treatments for two separate groundwater sources. It is anticipated that treatment of the Buxton Woods aquifer water will be either manganese greensand filtration, ion exchange, or a combination of the two. Treatment of the brackish water from the deeper Yorktown aquifer will be accomplished by RO. A blended product of less than 500 mg/l TDS with hardness and alkalinity of approximately 100 mg/l each should be available from the treatment process.

This alternative appears to be feasible from both a technical and economic standpoint. The fact that neither source of groundwater on its own is as good as a combination of sources makes this the preferred alternative for meeting the potable water demands of

Figure 4

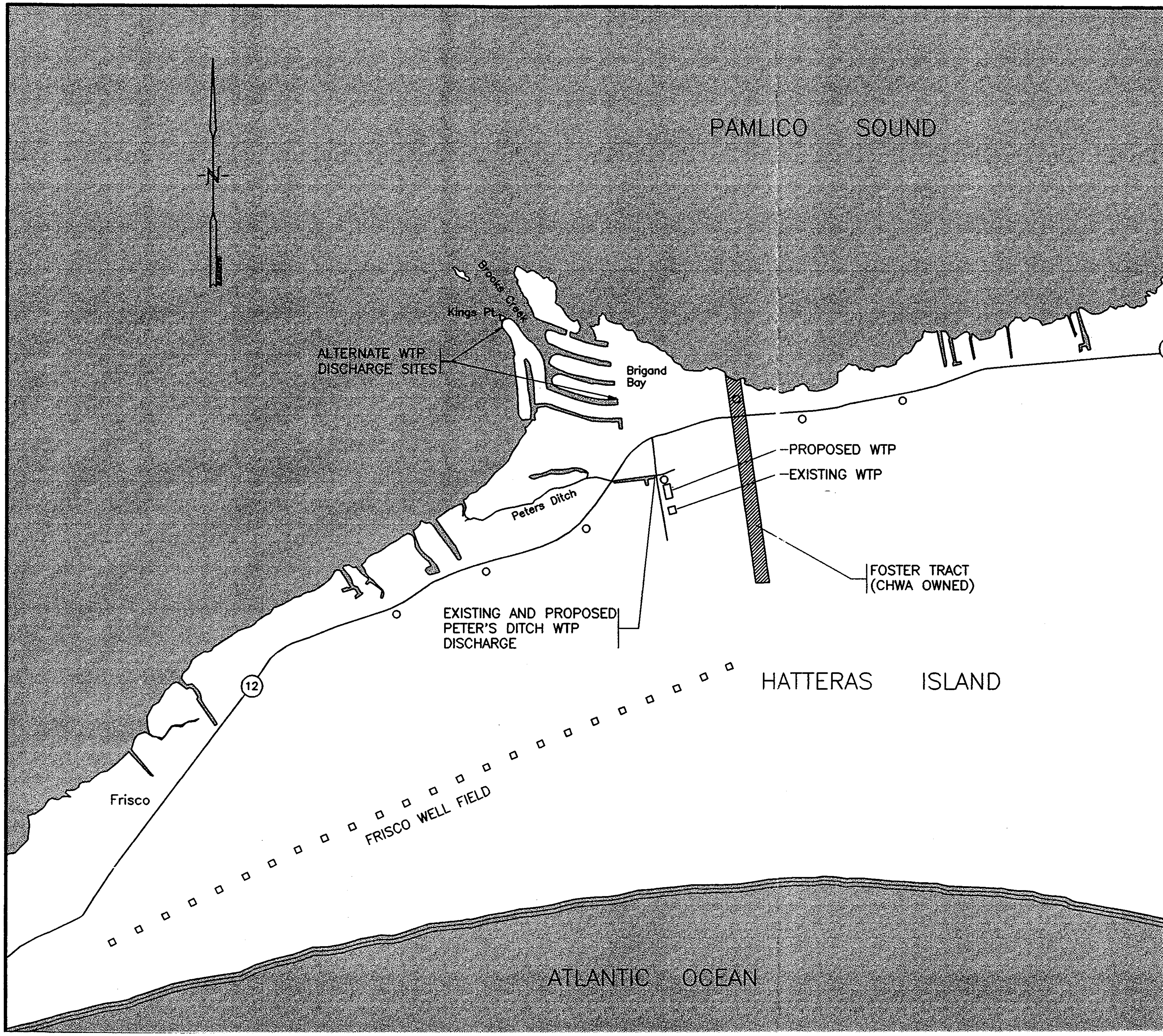


HOBBS, UPCHURCH & ASSOCIATES, P.A.
CONSULTING ENGINEERS
SOUTHERN PINES, NORTH CAROLINA 28387

FIGURE 4

SCHEMATIC OF WATER SUPPLY AND TREATMENT SYSTEM

Figure 5



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CONSULTING ENGINEERS
SOUTHERN PINES, NORTH CAROLINA 28387

FIGURE 5

PROPOSED PROJECT FACILITIES LOCATION

the area through the year 2020. Figure 5 on page 11 shows projected locations of elements of the proposed project.

V. ENVIRONMENTAL IMPACTS OF PREFERRED ALTERNATIVE

A. Change in Land Use

The proposed project will facilitate additional development on Hatteras Island. It is not anticipated that the nature of the development will be altered. Most new development should be residential and commercial in nature. Small areas of currently platted land will be claimed by this development resulting in a small loss of low grade wildlife habitat.

B. Wetlands

Lands needed for construction of the proposed project will be for construction of the water treatment facility and for the installation of raw water wells. It is currently anticipated that the water treatment plant will be built on high ground presently owned by the CHWA. Two CHWA owned sites were originally evaluated for the plant site. These were the Foster Tract and a track adjacent to the existing plant. An extensive investigation of both tracts by consulting biologists, J.H. Carter III and Associates, resulted in the recommendation that the proposed plant be built on the tract adjacent to the existing plant (See Carter Report Appendix C). While this property contains wetlands, no disturbance of these wetlands is planned. Figure 2 shows the proposed plant site.

It is anticipated that approximately seven wells will eventually be needed to draw water from the Yorktown aquifer. The report by Boyle Engineering suggests that these wells should be located adjacent to Hwy 12. A preliminary survey of lands bordering the highway show sufficient available land of nonwetland character to allow for the eventual placement of these wells outside of any wetland areas.

The proposed project should result in no damage to wetlands.

C. Prime or Unique Agricultural Lands

There are no prime or unique agricultural lands associated with the proposed project.

D. Public Lands

A large portion of Hatteras Island in the immediate project area is contained in the Cape Hatteras National Seashore. The proposed use of public lands in this area for the location of additional Buxton Woods aquifer wells has been denied by court action. The proposed project will not directly impact public lands in the area.

Additional development of the area induced by adequate water supplies from the proposed project will likely result in additional use of these public lands.

E. **Scenic and Recreational Areas**

The economy of the area is based largely on scenic and recreational aspects of the island. The proposed project will not directly impact any areas which would be particularly scenic or which are currently used for recreational purposes. Lands used for construction of the proposed project are either currently owned by CHWA and are located adjacent to the existing water treatment plant or are wooded areas adjacent to Hwy 12.

No scenic or recreational areas should be negatively impacted by the proposed project.

F. **Areas of Archaeological or Historical Value**

There are no known areas of archaeological or historical value which will be directly impacted by the proposed project. There have been no concerns of an archaeological or historic nature raised in spite of a scoping letter which has been circulated through the North Carolina Clearinghouse.

G. **Air Quality**

Air quality data as gathered from the nearest air monitoring stations is included in Appendix A to this report. There are no known air quality problems in the area. Other than temporary fumes from construction equipment during the construction phase, there should be no negative impacts on air quality as a result of the project. Traffic in the area should increase with additional development, however, it is not foreseen that this will create air quality problems of any significance.

H. **Groundwater Quality**

The proposed project will rely on extraction of groundwater from both the shallow Buxton Woods surficial aquifer and the deeper brackish Yorktown aquifer. The Buxton Woods aquifer is recharged by rainwater falling on the island. The Yorktown aquifer receives its recharge from mainland rainfall as well as the intersection of the aquifer with the sound. The mixing of these two sources results in the brackish water withdrawn from recent test wells. The quality of groundwater from the upper Buxton Woods aquifer is not as good as that from the lower zone of the aquifer. This has been verified in recent test well explorations (see Heath report in Appendix B). It is anticipated that impurities found in the upper zone will gradually be drawn downward into the lower zone. Lower zone quality should remain superior because of additional sand filtration. There should be no effect on private water wells because of the great distance to the wells.

The proposed project should reduce the need for utilization of groundwater of questionable quality for potable use by increasing the availability of a safe potable drinking water source.

Additional development on the island as induced by the proposed project will likely result in additional septic tank systems. Unless carefully designed, these might result in some deterioration of groundwater qualities in private wells if leaching occurs. There will be no impact on CHWA wells.

I. **Noise Levels**

Other than the temporary noise of construction machinery, no significant adverse noise should emanate from the proposed facilities. Some noise will be associated with the proposed wells and treatment facilities, however, these should be minimal.

J. **Water Supplies**

The proposed project will greatly increase the supply of safe potable drinking water to the residents of the area. Withdrawal from both aquifers will be managed so that supplies will not be reduced.

K. **Shellfish or Fish and Their Habitats**

The proposed project will consist of two separate methods of water treatment, each of which will produce a waste stream which will be discharged into surface or sound waters by permit obtained by the NC Division of Environmental Management. The improper handling of these discharges represents a potential negative environmental impact of the proposed project. The proper permitting and management of the discharges should result in little if any negative environmental impact.

The current water treatment system treats water withdrawn from the upper portion of the Buxton Woods aquifer. This water undergoes conventional treatment processes and produces a discharge into an area of Peter's Ditch adjacent to the water treatment plant. The proposed treatment system will have a similar discharge from the treatment of water also withdrawn from the Buxton Woods aquifer. It is anticipated that initial quality of the proposed raw water will be better than that currently treated. The quality of this water withdrawn should always be superior to that currently treated because of additional ground filtration. The net effect should be that discharge water from the treatment of the Buxton Woods aquifer water should be equal to or better in quality and equal to or less in quantity than the current discharge into Peter's Ditch. No new impacts are foreseen.

Of more concern is the discharge of concentrate from the RO treatment of water withdrawn from the Yorktown aquifer. RO effectively concentrates most constituents in raw water including dissolved solids into a portion of the raw water which is discharged from the treatment process as concentrate. The permeate from the process is water that has been forced by pressure through special membranes and effectively filtered of most impurities. While the permeate (treated water) is exceptionally clean, the discharge or concentrate contains most of the impurities of the raw water. The discharged concentrate will contain more salt than the raw water.

With the production of 3 mgd of potable water from the proposed facility, approximately 1.8 mgd of concentrate from the RO process will be discharged. Table 2 presents a projection of the quality of this discharge based on present and future projected quality of test well water. This quality should present a worst case scenario of discharge water.

It is currently anticipated that the discharges from both processes will be regulated under a modification of the existing NPDES permit. The proposed location of the discharge is the current discharge point into Peter's Ditch. (Figure 5 on page 11)

Peter's Ditch was constructed as a drainage ditch in the past. It was widened in the area of the existing treatment plant as dirt was extracted to fill adjacent areas to create buildable property. The widened portion of the ditch received alum sludge from a previous treatment process for many years and currently holds a large quantity of this sludge. Beyond Hwy 12, the ditch once again narrows and winds to its ultimate discharge into the sound. The interaction of the tides cause water to flow both in and out of Peter's Ditch. The nature of water quality and identification of aquatic species in Peter's Ditch at the proposed point of discharge have not been fully determined.

Comments from the regional office of the Division of Environmental Management express concern over discharge of the salty concentrate into the widened area of Peter's Ditch. There is concern over the amount of dilution which the discharge would encounter at this point and the possible toxicity of the discharge to aquatic organisms.

Alternative points of discharge of the RO concentrate are being considered in the area of Brook's Creek and Brigand Bay (Figure 5). Waters in the canals and the creek itself contain high levels of salt. This water is believed to have chlorides of approximately 12,000 mg/l and should not suffer from the discharge of the salty RO concentrate. Two possible points of discharge are one of the canals in Brigand Bay and at King's Point near the mouth of Brook's Bay. Discharge into a canal could serve to flush out the canal and Brook's Bay and improve overall water quality. The greatest degree of dilution and mixing might occur at King's Point where a deeper channel and more direct tidal action could be beneficial.

Considerable additional cost of approximately $75,000 would be incurred to discharge into a canal at Brigand Bay. Discharge at King's Point could cost an additional $150,000. It should be proven that the environment will benefit sufficiently before additional funds are expended to relocate the discharge from Peter's Ditch.

TABLE 2

PROJECTED DISCHARGE
FROM REVERSE OSMOSIS PROCESS
(3 MGD Total Production)

DISCHARGE FLOW = 1.8 MGD

Constituent	Concentration (mg/l)
Ca	526.00
Mg	1143.60
Na	8529.00
K	301.00
NH4	0.00
Ba	0.00
Sr	17.80
CO_3	.60
HCO_3	512.00
SO_4	1568.00
Cl	16363.30
F	1.56
NO_3	0.42
Total Alkalinity ($CaCO_3$)	384.00
Total Hardness ($CaCO_3$)	5900.00
Calcium Hardness ($CaCO_3$)	1704.00
Mg ($CaCO_3$)	4196.00
Ca ($CaCO_3$)	682.00
Color	0.00
Silica (SiO_2)	39.40
Iron	.29
Cu	.06
Mn	0.24
PO_4	0.528
Zn	0.34
Pb	0.00
Turbidity (NTU)	0.46
TDS	29000.00
SO_4	1335.00
Sulfide	0.00
pH	7.74

There are oyster beds located east of King's Point and Brigand Bay. We know of no negative potential impact to these shellfish waters at either of the potential RO discharge points. This is more fully discussed in the report of Dr. J.H. Carter III as included in Appendix C.

L. **Wildlife and Their Habitats**

It is not anticipated that the proposed project will directly affect wildlife on the island. Construction sites will be located where impacts are minimum. No wetlands will be disturbed. There will be a small loss of forested area. Much of this forest is currently dying from the effects of Hurricane Emily. The Carter report as included in Appendix C discusses the local population of wildlife in more detail.

M. **Introduction of Toxic Substances**

The toxicity of a substance is relative to the organisms subjected to that substance. Dissolved salt in pure water is toxic to fresh water aquatic species above certain concentrations. Of concern is the discharge from the RO treatment process. This discharge will be high in dissolved salt and will be approximately 1.8 mgd in volume. Without considerable dilution, this discharge would be toxic to *Ceriodaphnia dubia*, the organism commonly used to judge the toxicity of discharges to fresh water aquatic organisms. As there has been no quantification of fresh water flows through Peter's Ditch, there is presently no data to determine the projected resultant salt concentration of the RO discharge as diluted in Peter's Ditch. In the report "Study of Peter's Ditch and Pamlico Sound" prepared by HydroScience in April, 1995, it was stated that a review of water quality data indicated that pH, salinity, and specific conductivity levels in the widened portion of Peter's Ditch were similar to background levels collected from Peter's Ditch upstream of this area. These background levels of salinity were reported to range from 0.5 to 1 percent. If the discharge is subjected to toxicity testing using the fresh water organism *Ceriodaphnia dubia,* there may be little tolerance for additional salt beyond background levels of Peter's Ditch. A great deal of dilution of 1.8 mgd of this RO discharge would be required to keep conductivity levels in the acceptable 1800 to 2000 umhos range for *Ceriodaphnia dubia.* A current estimate of RO discharge conductivity is 58,000 umho. The concentration of chlorides in the Pamlico Sound near Buxton was measured at 11,750 mg/l, with the total dissolved solids being 17,950 mg/l. Estimated dissolved solids of the RO discharge are 29,000 mg/l. From this comparison it is evident that the discharge from the RO process will have a higher salt content than the Pamlico Sound to which it will ultimately discharge.

Table 2 presents a projection of the makeup of the RO discharge water. Since the Yorktown aquifer groundwater is composed of a mixture of rainwater and water from the sound, it seems unlikely that these constituents although concentrated will have a toxic effect on marine organisms. Toxicity screening is currently being planned for the proposed discharge.

N. **Eutrophication of Receiving Waters**

The discharge of waters from the proposed water treatment plant should have no detrimental effect on the eutrophication of receiving waters.

VI. MITIGATIVE MEASURES

In order to minimize adverse environmental impacts, facilities for the proposed project will be built in areas that have diminimus impacts to wetlands, wildlife habitats and aesthetics. Discharges from the water treatment process will be located so that detriment to water quality and aquatic organisms is eliminated or at levels judged to be acceptable by NCDEM.

During construction, negative impacts will be mitigated by the use of proper erosion and siltation control measures. Construction machinery will be properly maintained to prevent excessive noise, pollution and spills of petroleum products.

The withdrawal of groundwater from both the Buxton Woods and Yorktown aquifers will be managed to prevent degradation of these water supplies. In addition, the balance of treatment techniques and blend water has been designed to minimize the use of energy needed for the treatment processes within limits imposed by the requirement to produce adequate volumes of safe potable drinking water.

APPENDIX A

AIR MONITORING DATA

I. AMBIENT AIR QUALITY STANDARDS

Ambient air quality progress is determined by measuring ambient pollutant concentrations and comparing the measured concentrations to the corresponding standard. The "ambient air" is defined by the Environmental Protection Agency (EPA) as "that portion of the atmosphere, external to buildings, to which the general public has access." The ambient air quality standards are classified as primary standards, secondary standards, or both. The primary standards were established allowing an adequate margin of safety for protection of public health. Secondary standards were established with an adequate margin of safety to protect the public welfare from adverse effects associated with pollutants in the ambient air. In protecting public welfare, air pollution effects on the following are considered: soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, climate, property, transportation, economy, personal comfort, and well-being. The scientific criteria upon which the standards are based are periodically reviewed by EPA and the standards are re-established or changed based upon the findings. An "exceedance" is defined as a measurement that is greater than the ambient air quality standard for a specific averaging time.

The national primary and secondary standards and the North Carolina ambient air quality standards are summarized in Table I. Brief descriptions of air pollutants for which ambient air quality standards exist are included in Section III of this report.

TABLE I: Summary Of National And N.C. Ambient Air Quality Standards

POLLUTANT	TIME OF AVG.	NAT. PRIM. STD	NAT. SEC. STD	N.C. STD
TSP[a]	Ann. Geo. Mean	75 µg/m[3a]	None	75 µg/m³
	24 Hour[b]	260 µg/m[3a]	150 µg/m[3a]	150 µg/m³
PM-10	Ann. Arith. Mean[a]	50 µg/m[3a]	Same as prim.[a]	50 µg/m[3a]
	24 Hour[a,c]	150 µg/m[3a]	Same as prim.[a]	150 µg/m[3a]
SO_2	Ann. Arith. Mean	80 µg/m³	None	80 µg/m³
	24 Hour[b]	365 µg/m³	None	365 µg/m³
	3 Hour[b]	None	1300 µg/m³	1300 µg/m³
NO_2	Ann. Arith. Mean	.053 ppm	Same as prim.	.053 ppm
CO	8 Hour[b]	9 ppm	None	9 ppm
	1 Hour[b]	35 ppm	None	35 ppm
O_3	1 Hour[c]	0.12 ppm	Same as prim.	0.12 ppm
Pb	Quarterly Arith. Mean[b]	1.5 µg/m³	Same as prim.	1.5 µg/m³

a. The National Total Suspended Particulate (TSP) standards were replaced by National Particulate Matter-10 micrometer, aerodynamic diameter, (PM-10) standards on 7-31-87 by EPA. The North Carolina PM-10 standard is effective July 1, 1988.

b. Not to be exceeded more than once per year.

c. Not to be exceeded on more than an average of one day per year. (Four days with an exceedance at a site in three years or less is a violation.)

µg/m³ - micrograms per cubic meter of air
microgram - one millionth of a gram, where 454 grams = 1 pound
ppm - parts per million

DATE 95/06/08
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EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

SUSPENDED PARTICULATE (11101) NORTH CAROLINA UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM 24-HR VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	GEO MEAN	GEO STD
37-021-0003	1	3	ASHEVILLE	BUNCOMBE CO	HEALTH & SOCIAL SERVICES BL	94	004	57	67	64	57	56	33	30	1.7
37-031-0003	1	3	MOREHEAD CITY	CARTERET CO	ARENDELL & 4TH MOREHEAD CT	94	001	60	135	91	74	69	46	42	1.5
37-035-0004	1	3	HICKORY	CATAWBA CO	1650 1ST. ST.	94	001	60	124	94	89	87	53	50	1.4
X 37-047-0001	1	3		COLUMBUS CO	ACME-DELCO SAMPLING SITE HW	94	001	58	71	60	58	56	31	28	1.6
37-051-0004	1	3	FAYETTEVILLE	CUMBERLAND CO	F.S. # 5 3296 VILLAGE DR.	94	001	56	132	93	88	87	47	43	1.5
37-057-1002	1	3	THOMASVILLE	DAVIDSON CO	400 SALEM STREET	94	001	50	72	66	64	60	39?	36?	1.5
37-071-0014	1	3	GASTONIA	GASTON CO	RANKIN LAKE RD,GASTONIA,NC	94	001	60	63	58	56	55	35	32	1.5
37-085-0001	1	3	DUNN	HARNETT CO	MUNICIPAL BUILDING	94	001	60	101	85	78	77	47	43	1.5
37-119-0001	1	3	CHARLOTTE	MECKLENBURG CO	600 EAST TRADE STREET	94	003	58	100	95	80	77	48	46	1.4
37-119-0010	1	3	CHARLOTTE	MECKLENBURG CO	FIRE STA #10 2136 REMOUNT R	94	003	56	82	82	62	61	40	38	1.4
37-121-0001	1	3	SPRUCE PINE	MITCHELL CO	CITY HALL SUMMIT ST	94	001	56	101	100	87	86	49	45	1.6
37-129-0005	1	3	WILMINGTON	NEW HANOVER CO	NINTH AND ORANGE STREETS	94	001	15	88	64	58	54	43?	39?	1.6
37-129-0007	1	3	WILMINGTON	NEW HANOVER CO	WAREHSE & RECEIVING ST UNCW	94	001	32	56	46	44	43	28?	27?	1.5
37-139-0001	1	3	ELIZABETH CITY	PASQUOTANK CO	WATER PLANT N WILSON ST	94	001	57	97	79	74	64	35	31	1.6
37-155-0003	1	3	LUMBERTON	ROBESON CO	SO. WATER ST.	94	001	57	107	73	71	66	36	32	1.6
37-175-0002	1	3	BREVARD	TRANSYLVANIA CO	HWY 64	94	001	59	75	60	60	58	36	34	1.4
37-183-0003	1	3	RALEIGH	WAKE CO	FIRE STATION #9 SIX FORKS R	94	001	59	85	81	80	77	42	39	1.6
37-187-0002	1	3	PLYMOUTH	WASHINGTON CO	OLD ACRE RD.	94	001	57	91	80	72	69	38	36	1.5

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA
EXCEPTIONAL EVENT DATA EXISTS IN AT LEAST ONE OF THE ABOVE SITES BUT IS NOT INCLUDED IN THE SUMMARY CALCULATIONS

DATE 95/06/08
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

NITROGEN DIOXIDE (42602) NORTH CAROLINA UNITS: 007 PPM

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAX 1ST	1-HR 2ND	MAX 1ST	24-HR 2ND	ARIT MEAN	METH
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREATION	94	001	2972	.030	.030			.005?	075
37-037-0004	1	3		CHATHAM CO	RT4 BOX62 PITTSBORO NC2731	94	001	2558	.040	.020			.003?	075
37-063-0013	1	3	DURHAM	DURHAM CO	2700 NORTH DUKE STREET	94	001	2402	.050	.047			.009?	082
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	94	002	7861	.072	.072			.017	025
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	94	002	2522	.056	.056			.014?	074
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMORIAL DRI	94	002	2467	.049	.048			.008?	074
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH ST	94	001	2657	.040	.030			.005?	075
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLANT JOHN	94	001	2513	.040	.040			.006?	075
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	94	001	2564	.050	.040			.008?	075
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	94	003	8383	.068	.064			.016	014
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	94	003	2563	.049	.049			.012?	014
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG CAB CO	94	003	2217	.047	.046			.009?	014
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHANY SCHOO	94	002	2862	.040	.030			.006?	075
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL AVENUE	94	001	2555	.030	.030			.006?	075
37-183-0015	2	3	RALEIGH	WAKE CO	908 NORTH STATE STREET	94	001	1069	.050	.050			.009?	075
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STREET	94	001	1909	.030	.030			.006?	075

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/06/08
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

NITROGEN DIOXIDE (42602) NORTH CAROLINA UNITS: 007 PPM

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAX 1-HR 1ST	1-HR 2ND	MAX 24-HR 1ST	24-HR 2ND	ARIT MEAN	METH
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREATION	94	001	2972	.030	.030			.005?	075
37-037-0004	1	3		CHATHAM CO	RT4 BOX62 PITTSBORO NC2731	94	001	2558	.040	.020			.003?	075
37-063-0013	1	3	DURHAM	DURHAM CO	2700 NORTH DUKE STREET	94	001	2402	.050	.047			.009?	082
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	94	002	7861	.072	.072			.017	025
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	94	002	2522	.056	.056			.014?	074
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMORIAL DRI	94	002	2467	.049	.048			.008?	074
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH ST	94	001	2657	.040	.030			.005?	075
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLANT JOHN	94	001	2513	.040	.040			.006?	075
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	94	001	2564	.050	.040			.008?	075
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	94	003	8383	.068	.064			.016	014
~~37-119-0034~~	~~2~~	~~3~~	~~CHARLOTTE~~	~~MECKLENBURG CO~~	~~PLAZA ROAD AND LAKEDELL~~	94	003	2563	.049	.049			.012?	014
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG CAB CO	94	003	2217	.047	.046			.009?	014
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHANY SCHOO	94	002	2862	.040	.030			.006?	075
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL AVENUE	94	001	2555	.030	.030			.006?	075
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STREET	94	001	1069	.050	.050			.009?	075
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STREET	94	001	1909	.030	.030			.006?	075

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/06/08
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EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

PM-10 TOTAL 0-10UM (81102)

NORTH CAROLINA

UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	NUM OBS	SCHEDULED NUM OBS	SCHEDULED % OBS	NUM REQ	----MAXIMUM VALUES----- 1ST	2ND	3RD	4TH	VALS > 150 MEAS	VALS > 150 EST	WTD ARITH MEAN	METH
37-001-0002	1	3	BURLINGTON	ALAMANCE C	827 S GRAHAM & HOPEDA	94	001	58	58	92	63	62	51	45	43	0	0.00	24	062
37-003-0003	1	2		ALEXANDER	STATE ROAD 1177	94	001	59	59	94	63	59	46	42	41	0	0.00	22	062
37-013-0005	1	2	WASHINGTON	BEAUFORT C	SLATESTONE ROAD (NEAR	94	001	59	59	94	63	35	32	32	27	0	0.00	17	062
37-021-0003	1	2	ASHEVILLE	BUNCOMBE C	HEALTH & SOCIAL SERVI	94	004	60	60	95	63	34	33	32	31	0	0.00	19	063
37-021-0032	1	2	ASHEVILLE	BUNCOMBE C	LONDON RD ASHVILLE NC	94	004	355	355	97	365	66	58	51	50	0	0.00	25	079
37-021-0033	1	2	SWANNANOA	BUNCOMBE C	US70 WEST SWANNANOA N	94	004	347	347	95	365	59	53	49	45	0	0.00	22	079
37-025-0004	1	2	KANNAPOLIS	CABARRUS C	FLOYD ST. KANNAPOLIS	94	001	54	54	86	63	60	41	38	36	0	0.00	22?	062
37-035-0004	1	2	HICKORY	CATAWBA CO	1650 1ST. ST.	94	001	55	55	87	63	60	45	41	41	0	0.00	26	062
37-037-0004	1	3		CHATHAM CO	RT4 BOX62 PITTSBORO N	94	001	39	39	91	195	45	34	34	33	0	0.00	21?	062
* 37-051-0004	1	1	FAYETTEVIL	CUMBERLAND	F.S. # 5 3296 VILLAGE	94	001	53	53	84	63	58	44	41	41	0	0.00	25?	063
37-057-0002	1	2	LEXINGTON	DAVIDSON C	S.SAILSBURY ST.LEXING	94	001	58	58	92	63	82	48	43	39	0	0.00	26	062
37-057-1002	1	2	THOMASVILL	DAVIDSON C	400 SALEM STREET	94	001	54	54	86	63	41	39	37	36	0	0.00	24?	062
37-059-0099	1	3		DAVIE CO	FORK RECREATION CENTE	94	001	59	59	94	63	132	37	35	32	0	0.00	21	000
37-063-0001	1	1	DURHAM	DURHAM CO	HEALTH DEPT 300 E MAI	94	001	57	57	90	63	47	35	35	33	0	0.00	22	063
37-065-0002	1	2	ROCKY MOUN	EDGECOMBE	LEGETT RD.,WASTE TREA	94	001	58	58	92	63	53	41	38	37	0	0.00	21	062
37-065-0099	1	3		EDGECOMBE	RT 2, BOX 195 TARBORO	94	001	61	61	97	63	47	35	34	32	0	0.00	19	062
37-067-0009	1	2	WINSTON-SA	FORSYTH CO	INDIANA AV & AKRON DR	94	002	61	61	97	63	49	43	40	39	0	0.00	25	063
37-067-0013	1	3	WINSTON-SA	FORSYTH CO	720 RIDGE AVENUE	94	002	50	50	79	63	47	43	42	40	0	0.00	27?	063
37-067-0023	1	2	WINSTON-SA	FORSYTH CO	1401 CORPORATION PARK	94	002	59	59	94	63	55	45	44	44	0	0.00	28	063
37-067-0023	2	2	WINSTON-SA	FORSYTH CO	1401 CORPORATION PARK	94	002	365	365	100	365	66	61	57	57	0	0.00	26	079
37-067-0024	1	3	WINSTON-SA	FORSYTH CO	NORTH FORSYTH HIGH SC	94	002	60	60	95	63	39	39	37	36	0	0.00	23	063
37-067-1001	1	2	KERNERSVIL	FORSYTH CO	BODENHEIMER ST	94	002	57	57	90	63	48	42	41	38	0	0.00	25	063
37-077-0002	1	3	OXFORD	GRANVILLE	3200 WEBB SCHOOL RD	94	001	46	46	84	55	45	36	33	33	0	0.00	19?	062
37-081-0009	1	2	GREENSBORO	GUILFORD C	EDGEWORTH & BELLEMEAD	94	001	61	61	97	63	42	41	40	36	0	0.00	23	063
37-081-1005	1	2	HIGH POINT	GUILFORD C	E GREEN & S CENTENNIA	94	001	54	54	86	63	44	43	43	34	0	0.00	24	062
37-083-0002	1	2	ROANOKE RA	HALIFAX CO	NE CORNER OF 5TH & CA	94	001	56	56	89	63	47	36	34	33	0	0.00	22	062
37-085-0001	1	2	DUNN	HARNETT CO	MUNICIPAL BUILDING	94	001	58	58	92	63	52	45	42	41	0	0.00	25	063
37-087-0002	1	2	CANTON	HAYWOOD CO	ROOF, CANTON FIRE DEP	94	004	54	53	84	63	40	37	33	33	0	0.00	22	063
37-089-1006	1	2	HENDERSONV	HENDERSON	CORNER OF ALLEN & WAS	94	001	54	54	86	63	42	42	36	34	0	0.00	22	062
37-109-0003	1	2	LINCOLNTON	LINCOLN CO	EAST CONGRESS ST	94	001	61	61	97	63	45	44	43	37	0	0.00	24	062
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	94	001	25	25	78	184	39	34	34	30	0	0.00	23?	062
37-111-0002	1	2	MARION	MC DOWELL	COURTHOUSE	94	001	60	60	95	63	54	43	42	41	0	0.00	27	063
37-119-0003	1	2	CHARLOTTE	MECKLENBUR	FIRE STA #11 620 MORE	94	003	61	61	97	63	59	56	47	46	0	0.00	30	063
37-119-0010	1	1	CHARLOTTE	MECKLENBUR	FIRE STA #10 2136 REM	94	003	60	60	95	63	56	47	47	46	0	0.00	29	064
37-119-1001	1	2	DAVIDSON	MECKLENBUR	FILTER PLANT	94	003	61	61	97	63	47	46	40	39	0	0.00	24	063
37-119-1005	1	3		MECKLENBUR	400 WESTINGHOUSE BLVD	94	003	57	57	90	63	61	54	51	51	0	0.00	30	063
37-121-0001	1	2	SPRUCE PIN	MITCHELL C	CITY HALL SUMMIT ST	94	001	57	57	90	63	53	53	51	50	0	0.00	30	063
37-129-0005	1	2	WILMINGTON	NEW HANOVE	NINTH AND ORANGE STRE	94	001	14	14	93	15	45	30	27	25	0	0.00	22?	063
37-129-0007	1	2	WILMINGTON	NEW HANOVE	WAREHSE & RECEIVING S	94	001	29	29	78	189	34	28	27	27	0	0.00	20?	063
37-133-0004	1	2	JACKSONVIL	ONSLOW CO	2553 ONSLOW DRIVE, J	94	001	54	54	86	63	67	37	37	30	0	0.00	20?	063
37-139-0001	1	2	ELIZABETH	PASQUOTANK	WATER PLANT N WILSON	94	001	46	46	73	63	81	35	28	27	0	0.00	17?	062
37-147-0003	1	2		PITT CO	1500 BEATTY ST GREENV	94	001	56	56	89	63	43	37	32	32	0	0.00	19	062
37-159-1006	1	2	SALISBURY	ROWAN CO	CORNER OF CHURCH & KE	94	001	57	57	90	63	46	44	39	35	0	0.00	23?	062
37-183-0003	1	1	RALEIGH	WAKE CO	FIRE STATION #9 SIX F	94	001	58	58	92	63	48	38	37	36	0	0.00	22	063

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

OZONE (44201)

NORTH CAROLINA

UNITS: 007 PPM

OZONE SEASON: APR 01 TO OCT 31

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	*NUM *MEAS	NUM REQ	VALID DAILY 1-HR MAXIMUM MAXIMA 1ST	2ND	3RD	4TH	VALS>.125 MEAS	EST	* MISS DAYS * ASSUMED < * STANDARD	METH
37-003-0003	1	2		ALEXANDER C	STATE ROAD 1177	94	001	207	214	.094	.092	.089	.086	0	0.0	3	019
37-021-0030	1	2	ASHEVILLE	BUNCOMBE CO	ROUTE 191 S BREV	94	004	214	214	.090	.084	.082	.080	0	0.0	0	019
37-023-0004	1	3	MORGANTON	BURKE CO	126 AND 1254	94	028	214	214	.103	.101	.098	.096	0	0.0	0	047
37-029-0099	1	2		CAMDEN CO	COUNTY ROAD 1136	94	001	198	214	.098	.095	.094	.094	0	0.0	10	019
37-033-0001	1	3		CASWELL CO	CHERRY GROVE REC	94	001	169	214	.123	.113	.109	.092	0	0.0	3	019
37-051-0008	1	1		CUMBERLAND	1/4MI SR1857/US3	94	001	213	214	.101	.098	.095	.094	0	0.0	1	019
37-051-1002	1	1	FAYETTEVILLE	CUMBERLAND	HOPE MILLS POLIC	94	001	210	214	.106	.096	.091	.091	0	0.0	4	019
37-059-0099	1	2		DAVIE CO	FORK RECREATION	94	001	213	214	.086	.085	.082	.079	0	0.0	1	019
37-061-0002	1	3		DUPLIN CO	HWY 50 KENANSVIL	94	001	211	214	.093	.088	.084	.083	0	0.0	2	019
37-063-0013	1	1	DURHAM	DURHAM CO	2700 NORTH DUKE	94	001	210	214	.104	.102	.097	.095	0	0.0	0	019
37-067-0007	1	2		FORSYTH CO	5337 OLD RURAL H	94	002	209	214	.121	.111	.106	.105	0	0.0	2	047
37-067-0022	1	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE	94	002	210	214	.104	.098	.098	.093	0	0.0	2	019
37-067-0027	1	2		FORSYTH CO	7635 HOLLYBERRY	94	002	212	214	.094	.094	.084	.082	0	0.0	2	047
37-067-1008	1	2		FORSYTH CO	3656 PIEDMONT ME	94	002	209	214	.106	.105	.095	.093	0	0.0	0	047
37-069-0001	1	2		FRANKLIN CO	431 S HILLBOROUG	94	001	213	214	.115	.105	.105	.101	0	0.0	1	019
37-077-0001	2	1		GRANVILLE C	WATER TREATMENT	94	001	208	214	.102	.101	.100	.096	0	0.0	2	019
37-081-0011	1	2		GUILFORD CO	KEELY PARK, KEEL	94	001	211	214	.114	.110	.106	.105	0	0.0	3	019
37-087-0035	1	3		HAYWOOD CO	TOWER BLUE RIDGE	94	004	115	214	.078	.077	.075	.074	0	0.0	1	019
37-101-0099	1	2		JOHNSTON CO	HIGHWAY 301 & SR	94	001	211	214	.107	.103	.097	.097	0	0.0	3	019
37-109-0004	1	2	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	94	001	212	214	.115	.108	.108	.107	0	0.0	2	019
37-119-0034	1	1	CHARLOTTE	MECKLENBURG	PLAZA ROAD AND L	94	003	213	214	.110	.106	.106	.101	0	0.0	1	047
37-119-1005	1	2		MECKLENBURG	400 WESTINGHOUSE	94	003	212	214	.115	.114	.108	.099	0	0.0	0	047
37-119-1009	1	1		MECKLENBURG	29 N@ MECKLENBUR	94	003	212	214	.115	.113	.110	.105	0	0.0	2	047
37-129-0002	1	2		NEW HANOVER	6028 HOLLY SHELT	94	001	212	214	.106	.104	.096	.095	0	0.0	2	019
37-147-0099	1	2	FARMVILLE	PITT CO	US 264 NEAR FARM	94	001	202	214	.087	.086	.085	.084	0	0.0	12	019
37-157-0099	1	2		ROCKINGHAM	6371 NC 65 @ BET	94	002	214	214	.111	.108	.103	.103	0	0.0	0	019
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD H	94	001	180	214	.124	.116	.110	.108	0	0.0	0	019
37-183-0014	1	1	RALEIGH	WAKE CO	E MILLBROOK JR H	94	001	213	214	.122	.107	.104	.102	0	0.0	1	019
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD	94	001	187	214	.117	.111	.106	.101	0	0.0	0	019
37-199-0003	1	3		YANCEY CO	BLUE RIDGE PARKW	94	001	167	214	.093	.092	.090	.089	0	0.0	4	019

DATE 95/06/08
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EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

SO2 MAX 5-MIN AVG (42406)

NORTH CAROLINA

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	94	002	5129	471	353	352	331	29.2?	039	001	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

PM-10 TOTAL 0-10UM (81102) NORTH CAROLINA UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	NUM OBS	SCHEDULED NUM OBS	SCHEDULED % OBS	NUM REQ	MAXIMUM VALUES 1ST	2ND	3RD	4TH	VALS > 150 MEAS	VALS > 150 EST	WTD ARITH MEAN	METH
37-189-0003	1	3	BOONE	WATAUGA CO	HARDIN PRK ELEMENTARY	94	001	37	36	75	275	38	36	35	34	0	0.00	21?	062
37-191-0004	1	2	GOLDSBORO	WAYNE CO	HWY 70 WEST PATROL ST	94	001	61	61	97	63	50	39	39	38	0	0.00	21	062
37-195-0002	1	2	WILSON	WILSON CO	N.W. CORNER OF KENAN	94	001	60	60	95	365	52	49	39	39	0	0.00	22?	062

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/06/08
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

OXIDES OF NITROGEN (42603)

NORTH CAROLINA

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREA	94	001	2973	.05	.04	.04	.04	.005?	075	007	1
37-037-0004	1	3		CHATHAM CO	RT4 BOX62 PITTSBORO	94	001	2552	.04	.03	.02	.02	.003?	075	007	1
37-063-0013	1	3	DURHAM	DURHAM CO	2700 NORTH DUKE STR	94	001	2412	.124	.100	.093	.065	.0127?	082	007	1
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	94	002	7661	.368	.320	.318	.309	.0282	025	007	1
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	94	002	2521	.093	.093	.084	.082	.0145?	074	007	1
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMOR	94	002	2467	.050	.050	.050	.049	.00867	074	007	1
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH S	94	001	2004	.05	.05	.04	.04	.005?	075	007	1
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLA	94	001	2513	.05	.05	.04	.04	.007?	075	007	1
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	94	001	2564	.05	.05	.05	.05	.010?	075	007	1
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	94	003	8383	.488	.481	.481	.462	.0398	014	007	1
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	94	003	2563	.051	.051	.051	.051	.0155?	014	007	1
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG C	94	003	2217	.050	.050	.050	.050	.0114?	014	007	1
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHAN	94	002	2862	.05	.05	.05	.05	.007?	075	007	1
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL	94	001	2555	.04	.04	.04	.04	.006?	075	007	1
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STR	94	001	1069	.05	.05	.05	.05	.011?	075	007	1
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STR	94	001	1909	.04	.04	.04	.03	.006?	075	007	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/06/08
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

NITRIC OXIDE (42601)

NORTH CAROLINA

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREA	94	001	2985	.03	.02	.01	.01	.001?	075	007	1
37-037-0004	1	3		CHATHAM CO	RT4 BOX62 PITTSBORO	94	001	2558	.02	.02	.01	.01		075	007	1
37-063-0013	1	3	DURHAM	DURHAM CO	2700 NORTH DUKE STR	94	001	2402	.111	.078	.062	.058	.0068?	082	007	1
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	94	002	7861	.326	.275	.274	.274	.0128	025	007	1
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	94	002	2521	.054	.049	.048	.047	.0058?	074	007	1
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMOR	94	002	2466	.044	.043	.029	.028	.0052?	074	007	1
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH S	94	001	2657	.05	.04	.03	.03	.001?	075	007	1
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLA	94	001	2513	.05	.04	.03	.02	.001?	075	007	1
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	94	001	2564	.05	.05	.04	.04	.002?	075	007	1
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	94	003	8383	.464	.460	.453	.444	.0243	014	007	1
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	94	003	2563	.051	.050	.050	.050	.0075?	014	007	1
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG C	94	003	2218	1.000	.050	.050	.048	.0066?	014	007	1
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHAN	94	002	2862	.05	.05	.04	.04	.002?	075	007	1
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL	94	001	2555	.03	.03	.03	.03	.001?	075	007	1
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STR	94	001	1068	.05	.05	.05	.05	.002?	075	007	1
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STR	94	001	1909	.03	.02	.02	.02	.001?	075	007	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/06/08
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EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

SUSPENDED PARTICULATE (11101) NORTH CAROLINA UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	--MAXIMUM 24-HR VALUES-- 1ST	2ND	3RD	4TH	ARITH MEAN	GEO MEAN	GEO STD
37-021-0003	1	3	ASHEVILLE	BUNCOMBE CO	HEALTH & SOCIAL SERVICES BL	94	004	57	67	64	57	56	33	30	1.7
37-031-0003	1	3	MOREHEAD CITY	CARTERET CO	ARENDELL & 4TH MOREHEAD CI	94	001	60	135	91	74	69	46	42	1.5
37-035-0004	1	3	HICKORY	CATAWBA CO	1650 1ST. ST.	94	001	60	124	94	89	87	53	50	1.4
* 37-047-0001	1	3		COLUMBUS CO	ACME-DELCO SAMPLING SITE HW	94	001	58	71	60	58	56	31	28	1.6
37-051-0004	1	3	FAYETTEVILLE	CUMBERLAND CO	F.S. # 5 3296 VILLAGE DR.	94	001	56	132	93	88	87	47	43	1.5
37-057-1002	1	3	THOMASVILLE	DAVIDSON CO	400 SALEM STREET	94	001	50	72	66	64	60	39?	36?	1.5
37-071-0014	1	3	GASTONIA	GASTON CO	RANKIN LAKE RD,GASTONIA,NC	94	001	60	63	58	56	55	35	32	1.5
37-085-0001	1	3	DUNN	HARNETT CO	MUNICIPAL BUILDING	94	001	60	101	85	78	77	47	43	1.5
37-119-0001	1	3	CHARLOTTE	MECKLENBURG CO	600 EAST TRADE STREET	94	003	58	100	95	80	77	48	46	1.4
37-119-0010	1	3	CHARLOTTE	MECKLENBURG CO	FIRE STA #10 2136 REMOUNT R	94	003	56	82	82	62	61	40	38	1.4
37-121-0001	1	3	SPRUCE PINE	MITCHELL CO	CITY HALL SUMMIT ST	94	001	56	101	100	87	86	49	45	1.6
37-129-0005	1	3	WILMINGTON	NEW HANOVER CO	NINTH AND ORANGE STREETS	94	001	15	88	64	58	54	43?	39?	1.6
37-129-0007	1	3	WILMINGTON	NEW HANOVER CO	WAREHSE & RECEIVING ST UNCW	94	001	32	56	46	44	43	28?	27?	1.5
37-139-0001	1	3	ELIZABETH CITY	PASQUOTANK CO	WATER PLANT N WILSON ST	94	001	57	97	79	74	64	35	31	1.6
* 37-155-0003	1	3	LUMBERTON	ROBESON CO	SO. WATER ST.	94	001	57	107	73	71	66	36	32	1.6
37-175-0002	1	3	BREVARD	TRANSYLVANIA CO	HWY 64	94	001	59	75	60	60	58	36	34	1.4
37-183-0003	1	3	RALEIGH	WAKE CO	FIRE STATION #9 SIX FORKS R	94	001	59	85	81	80	77	42	39	1.6
37-187-0002	1	3	PLYMOUTH	WASHINGTON CO	OLD ACRE RD.	94	001	57	91	80	72	69	38	36	1.5

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA
EXCEPTIONAL EVENT DATA EXISTS IN AT LEAST ONE OF THE ABOVE SITES BUT IS NOT INCLUDED IN THE SUMMARY CALCULATIONS

DATE 95/06/08
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

RESULTANT SPEED (61103)

NORTH CAROLINA

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMOR	94	002	560	16.7	16.4	16.2	15.5	5.40?	020	013	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/06/08
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

RESULTANT DIRECTION (61104)

NORTH CAROLINA

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMOR	94	002	560	359	359	359	359	128.37	020	014	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

STD DEV HZ WND DIR (61106)

NORTH CAROLINA

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-067-1008	1	3		FORSYTH CO	3656 PIEDMONT MEMOR	94	002	560	51.0	49.0	48.0	45.0	12.68?	020	014	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DAT /01/19
AMP.

EPA AEROMETRIC [redacted] RETRI [redacted] SYSTE[redacted]RS)
AIR QUALITY SUBSYS
QUICK LOOK REPORT

OXIDES OF NITROGEN (42603) NORTH CAROLINA

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREA	93	001	1185	.048	.040	.031	.031	.0059?	014	007	1
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	93	002	8139	.425	.402	.344	.328	.0255	025	007	1
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	93	002	2930	.194	.159	.135	.134	.0154?	074	007	1
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH S	93	001	1160	.047	.047	.046	.043	.0087?	014	007	1
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLA	93	001	1971	.042	.041	.035	.035	.0076?	014	007	1
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	93	001	1632	.050	.050	.050	.050	.0130?	014	007	1
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	93	003	8073	.493	.445	.439	.406	.0371	014	007	1
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	93	003	1740	.116	.110	.110	.104	.0193?	014	007	1
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG C	93	003	1467	.050	.050	.050	.050	.0119?	014	007	1
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHAN	93	002	1612	.050	.048	.048	.046	.0074?	074	007	1
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL	93	001	1214	.046	.043	.041	.038	.0078?	014	007	1
37-183-0015	1	3	RALEIGH	WAKE CO	808 NORTH STATE STR	93	001	3070	.306	.276	.271	.268	.0248?	082	007	1
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STR	93	001	1862	.186	.177	.169	.153	.0106?	014	007	1
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STR	93	001	2183	.101	.082	.057	.057	.0060?	014	007	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE 95/01/19
AMP450

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

CARBON MONOXIDE (42101) NORTH CAROLINA UNITS: 007 PPM

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAX 1-HR 1ST	MAX 1-HR 2ND	OBS> 35	MAX 8-HR 1ST	MAX 8-HR 2ND	OBS> 9	METH
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREATION	93	001	1087	.9	.9	0	.8	.8	0	011
37-051-0007	1	2	FAYETTEVILLE	CUMBERLAND CO	CUMBERLAND CO ABC BOARD,	93	001	8694	8.7	7.9	0	6.3	6.3	0	054
37-063-0010	1	2	DURHAM	DURHAM CO	CITY PARK ON UNIVERSITY	93	001	1080	6.4	5.4	0	3.9	3.7	0	054
37-063-0011	1	2	DURHAM	DURHAM CO	201 NORTH ROXBORO ST	93	001	8698	9.1	7.8	0	6.5	5.3	0	054
37-063-0012	1	2	DURHAM	DURHAM CO	4001 CHAPEL HILL BLVD	93	001	7217	5.6	5.2	0	4.4	4.3	0	054
37-067-0018	1	2	WINSTON-SALEM	FORSYTH CO	201 N. MAIN ST.	93	002	1406	7.1	6.7	0	3.7	2.5	0	054
37-067-0022	1	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	93	002	1495	1.9	1.8	0	1.3	1.2	0	011
37-067-0023	1	2	WINSTON-SALEM	FORSYTH CO	1401 CORPORATION PARKWAY	93	002	8642	8.2	8.1	0	5.9	5.5	0	054
37-067-0025	1	2	WINSTON-SALEM	FORSYTH CO	100 SW STRATFORD RD	93	002	8708	5.0	4.4	0	3.1	3.0	0	054
37-067-0026	1	2	WINSTON-SALEM	FORSYTH CO	1590 BOLTON STREET	93	002	7286	5.0	4.8	0	3.4	3.2	0	054
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH ST	93	001	1234	1.0	1.0	0	.8	.8	0	011
37-071-0015	1	3	GASTONIA	GASTON CO	1555 EAST GARRISON BLVD	93	001	3515	6.9	6.3	0	4.3	4.1	0	054
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLANT JO	93	001	2081	.9	.9	0	.8	.6	0	011
37-081-1011	1	2	GREENSBORO	GUILFORD CO	401 WEST WENDOVER	93	001	8661	8.3	6.0	0	4.0	3.9	0	054
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	93	001	1676	1.0	1.0	0	.9	.9	0	011
37-119-0032	1	2	CHARLOTTE	MECKLENBURG CO	5137 CENTRAL AVE.	93	003	8580	12.4	12.0	0	8.1	6.5	0	054
37-119-0034	1	1	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	93	003	8510	10.7	9.7	0	5.3	5.1	0	054
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	93	003	1740	1.9	1.9	0	1.8	1.7	0	011
37-119-0035	1	2	CHARLOTTE	MECKLENBURG CO	1330 SPRING ST GRNVILLE	93	003	8633	7.4	7.0	0	5.9	5.7	0	054
37-119-0037	1	1	CHARLOTTE	MECKLENBURG CO	415 EAST WOODLAWN RD	93	003	8643	9.0	9.0	0	4.7	4.7	0	054
37-119-0038	1	2	CHARLOTTE	MECKLENBURG CO	301 N TRYON ST	93	003	8641	12.9	11.9	0	7.2	5.8	0	054
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG CAB CO	93	003	1421	1.0	1.0	0	.9	.7	0	011
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHANY SCH	93	002	1466	.9	.8	0	.5	.4	0	011
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL AVEN	93	001	1048	.9	.9	0	.7	.6	0	011
37-183-0011	1	2	RALEIGH	WAKE CO	420 S PERSON ST	93	001	8654	9.7	9.4	0	7.3	7.2	0	054
37-183-0013	1	3	RALEIGH	WAKE CO	EF HUTTON, HWY 70 WEST	93	001	4215	7.1	6.7	0	4.8	4.4	0	054
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STREET	93	001	1578	1.9	1.9	0	1.9	1.8	0	011
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STREET	93	001	1659	1.0	.9	0	.5	.5	0	011

DAT: /01/19
AMP450

EPA AEROMETRIC INFORMATION RETRIL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

PM-10 TOTAL 0-10UM (81102) NORTH CAROLINA UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	NUM OBS	SCHEDULED NUM OBS	SCHEDULED % OBS	NUM REQ	MAXIMUM VALUES 1ST	2ND	3RD	4TH	VALS > 150 MEAS	VALS > 150 EST	WTD ARITH MEAN	METH
37-001-0002	1	3	BURLINGTON	ALAMANCE C	827 S GRAHAM & HOPEDA	93	001	13	13	100	13	33	29	27	26	0	0.00	20?	062
37-003-0003	1	2		ALEXANDER	STATE ROAD 1177	93	001	57	56	89	63	63	53	45	44	0	0.00	23	062
37-013-0005	1	2	WASHINGTON	BEAUFORT C	SLATESTONE ROAD (NEAR	93	001	12	12	86	14	42	30	26	20	0	0.00	18?	062
37-021-0003	1	2	ASHEVILLE	BUNCOMBE C	HEALTH & SOCIAL SERVI	93	004	58	58	92	63	56	53	52	49	0	0.00	22	063
37-021-0032	1	2	ASHEVILLE	BUNCOMBE C	LONDON RD ASHVILLE NC	93	004	101	101	55	184	48	44	42	42	0	0.00	24?	079
37-021-0033	1	2	SWANNANOA	BUNCOMBE C	US70 WEST SWANNANOA N	93	004	76	76	83	92	43	40	40	39	0	0.00	21?	079
37-025-0004	1	2	KANNAPOLIS	CABARRUS C	FLOYD ST. KANNAPOLIS	93	001	55	55	87	63	55	49	48	43	0	0.00	25	062
37-035-0004	1	2	HICKORY	CATAWBA CO	1650 1ST. ST.	93	001	55	55	87	63	63	50	49	48	0	0.00	26?	062
37-051-0004	1	1	FAYETTEVIL	CUMBERLAND	F.S. # 5 3296 VILLAGE	93	001	57	57	90	63	59	55	47	45	0	0.00	27	063
37-057-0002	1	2	LEXINGTON	DAVIDSON C	S.SAILSBURY ST.LEXING	93	001	59	59	94	63	53	52	50	48	0	0.00	29	062
37-057-1002	1	2	THOMASVILL	DAVIDSON C	400 SALEM STREET	93	001	56	56	89	63	57	53	49	48	0	0.00	29	062
37-059-0099	1	3		DAVIE CO	FORK RECREATION CENTE	93	001	59	59	94	63	53	45	44	44	0	0.00	22	062
37-063-0001	1	1	DURHAM	DURHAM CO	HEALTH DEPT 300 E MAI	93	001	54	54	86	63	59	50	42	41	0	0.00	26?	063
37-065-0002	1	2	ROCKY MOUN	EDGECOMBE	LEGETT RD.,WASTE TREA	93	001	56	56	89	63	41	41	40	39	0	0.00	23	062
37-065-0099	1	3		EDGECOMBE	RT 2, BOX 195 TARBORO	93	001	58	58	92	63	43	41	38	38	0	0.00	20	062
37-067-0009	1	2	WINSTON-SA	FORSYTH CO	INDIANA AV & AKRON DR	93	002	60	60	95	63	61	59	51	49	0	0.00	27	063
37-067-0013	1	3	WINSTON-SA	FORSYTH CO	720 RIDGE AVENUE	93	002	60	60	95	63	59	54	53	52	0	0.00	28	063
37-067-0020	1	2	WINSTON-SA	FORSYTH CO	SILAS CREEK PKWY AT H	93	002	57	57	90	63	57	56	49	46	0	0.00	27	063
37-067-0023	1	2	WINSTON-SA	FORSYTH CO	1401 CORPORATION PARK	93	002	57	57	90	63	64	62	53	53	0	0.00	31	063
37-067-0023	2	2	WINSTON-SA	FORSYTH CO	1401 CORPORATION PARK	93	002	85	85	92	92	41	40	39	39	0	0.00	23?	079
37-067-0024	1	3	WINSTON-SA	FORSYTH CO	NORTH FORSYTH HIGH SC	93	002	57	57	90	63	64	62	50	47	0	0.00	24	063
37-067-1001	1	2	KERNERSVIL	FORSYTH CO	BODENHEIMER ST	93	002	53	53	84	63	63	56	49	46	0	0.00	26	063
37-081-0009	1	2	GREENSBORO	GUILFORD C	EDGEWORTH & BELLEMEAD	93	001	61	61	97	63	57	54	51	46	0	0.00	27	063
37-081-1005	1	2	HIGH POINT	GUILFORD C	E GREEN & S CENTENNIA	93	001	55	55	95	58	55	54	46	46	0	0.00	27	062
37-083-0002	1	2	ROANOKE RA	HALIFAX CO	NE CORNER OF 5TH & CA	93	001	50	50	79	63	54	49	49	48	0	0.00	25?	062
37-085-0001	1	2	DUNN	HARNETT CO	MUNICIPAL BUILDING	93	001	52	52	83	63	47	47	47	45	0	0.00	28?	063
37-087-0002	1	2	CANTON	HAYWOOD CO	ROOF, CANTON FIRE DEP	93	004	60	60	95	63	74	56	50	48	0	0.00	27	063
37-109-0003	1	2	LINCOLNTON	LINCOLN CO	EAST CONGRESS ST	93	001	52	51	81	63	57	49	45	45	0	0.00	25?	062
37-111-0002	1	2	MARION	MC DOWELL	COURTHOUSE	93	001	50	50	79	63	77	61	50	47	0	0.00	27?	063
37-119-0003	1	2	CHARLOTTE	MECKLENBUR	FIRE STA #11 620 MORE	93	003	57	57	90	63	62	54	52	49	0	0.00	30	063
37-119-0010	1	1	CHARLOTTE	MECKLENBUR	FIRE STA #10 2136 REM	93	003	61	61	97	63	62	51	46	44	0	0.00	28	064
37-119-1001	1	2	DAVIDSON	MECKLENBUR	FILTER PLANT	93	003	61	61	97	63	58	51	50	42	0	0.00	24	063
37-119-1005	1	3		MECKLENBUR	400 WESTINGHOUSE BLVD	93	003	57	57	90	63	63	49	48	47	0	0.00	28	063
37-121-0001	1	2	SPRUCE PIN	MITCHELL C	CITY HALL SUMMIT ST	93	001	50	50	79	63	71	54	53	50	0	0.00	30	063
37-129-0005	1	2	WILMINGTON	NEW HANOVE	NINTH AND ORANGE STRE	93	001	56	56	89	63	48	45	40	39	0	0.00	22	063
37-133-0004	1	2	JACKSONVIL	ONSLOW CO	2553 ONSLOW DRIVE, J	93	001	58	58	92	63	51	43	43	41	0	0.00	23	063
37-139-0001	1	2	ELIZABETH	PASQUOTANK	WATER PLANT N WILSON	93	001	59	59	94	63	42	40	40	38	0	0.00	19	062
37-147-0003	1	2		PITT CO	1500 BEATTY ST GREENV	93	001	60	60	95	63	42	40	38	38	0	0.00	22	062
37-159-1006	1	2	SALISBURY	ROWAN CO	CORNER OF CHURCH & KE	93	001	59	59	94	63	56	49	44	44	0	0.00	25	062
37-183-0003	1	1	RALEIGH	WAKE CO	FIRE STATION #9 SIX F	93	001	61	61	97	63	45	44	43	41	0	0.00	24	063
37-191-0004	1	2	GOLDSBORO	WAYNE CO	HWY 70 WEST PATROL ST	93	001	61	61	97	63	46	39	38	38	0	0.00	24	062
37-195-0002	1	2	WILSON	WILSON CO	N.W. CORNER OF KENAN	93	001	59	59	94	365	44	41	40	40	0	0.00	23?	062

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

[redacted] EPA [redacted] ETRI [redacted] ORMAT [redacted] ETRI [redacted] (ST [redacted] RS) [redacted]
AMP450

AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

NITROGEN DIOXIDE (42602) NORTH CAROLINA UNITS: 007 PPM

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAX 1-HR 1ST	1-HR 2ND	MAX 24-HR 1ST	24-HR 2ND	ARIT MEAN	METH
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREATION	93	001	1185	.029	.027			.005?	014
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	93	002	8139	.077	.076			.017	025
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AVENUE	93	002	2929	.079	.076			.016?	074
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH ST	93	001	1160	.046	.041			.008?	014
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLANT JOHN	93	001	1972	.029	.029			.007?	014
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	93	001	1632	.044	.043			.009?	014
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	93	003	8073	.061	.055			.017	014
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKEDELL	93	003	1740	.069	.067			.015?	014
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG CAB CO	93	003	1467	.046	.043			.010?	014
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHANY SCHOO	93	002	1612	.036	.034			.006?	074
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL AVENUE	93	001	1214	.036	.033			.007?	014
37-183-0015	1	5	RALEIGH	WAKE CO	808 NORTH STATE STREET	93	001	3070	.062	.059			.015?	082
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STREET	93	001	1862	.049	.049			.007?	014
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STREET	93	001	2161	.030	.029			.004?	014

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

DATE J1/19
AMP450

EPA AEROMETRIC INFORMATION RETRIEV YSTEM (AIRS)
AIR QUALITY SUBSYSTEM
QUICK LOOK REPORT

SULFUR DIOXIDE (42401) NORTH CAROLINA UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAX 24-HR 1ST	MAX 24-HR 2ND	OBS > 365	MAX 3-HR 1ST	MAX 3-HR 2ND	OBS > 1300	MAX 1-HR 1ST	MAX 1-HR 2ND	ARIT MEAN	METH
37-003-0003	1	3		ALEXANDER CO	STATE ROAD 1177	93	001	8252	45	45	0	196	84	0	472	117	10	009
37-013-0003	1	3		BEAUFORT CO	NC HIGHWAY 306	93	001	7997	48	44	0	321	189	0	334	320	9	009
37-013-0004	1	2		BEAUFORT CO	SOUTH FERRY LANDI	93	001	6565	43	40	0	167	145	0	270	267	9?	009
37-029-0099	1	3		CAMDEN CO	COUNTY ROAD 1136	93	001	3112	40	32	0	71	55	0	80	77	9?	009
* 37-047-0001	1	2		COLUMBUS CO	ACME-DELCO SAMPLI	93	001	8150	28	26	0	89	66	0	169	100	8	009
37-051-1002	1	3	FAYETTEVILLE	CUMBERLAND C	HOPE MILLS POLICE	93	001	8277	27	25	0	68	48	0	77	74	9	009
37-061-0002	1	3		DUPLIN CO	HWY 50 KENANSVILL	93	001	8067	23	21	0	45	43	0	55	50	7	009
37-065-0099	1	3		EDGECOMBE CO	RT 2, BOX 195 TAR	93	001	7701	27	26	0	184	181	0	548	537	7	009
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE	93	002	8140	129	57	0	456	199	0	702	422	15	039
37-101-0099	1	3		JOHNSTON CO	HIGHWAY 301 & SR	93	001	8145	28	27	0	196	43	0	584	52	8	009
37-147-0099	1	3	FARMVILLE	PITT CO	US 264 NEAR FARMV	93	001	364	28	25	0	55	49	0	101	79	11?	009

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA.

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PM-10 TOTAL 0-10UM (81102) NORTH CAROLINA UNITS: 001 UG/CU METER (25 C)

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	NUM OBS	SCHEDULED NUM OBS	SCHEDULED % OBS	NUM REQ	MAXIMUM VALUES 1ST	2ND	3RD	4TH	VALS > 150 MEAS	VALS > 150 EST	WTD ARITH MEAN	METH
37-001-0002	1	3	BURLINGTON	ALAMANCE C	827 S GRAHAM & HOPEDA	93	001	13	13	100	13	33	29	27	26	0	0.00	20?	062
37-003-0003	1	2		ALEXANDER	STATE ROAD 1177	93	001	57	56	89	63	63	53	45	44	0	0.00	23	062
37-013-0005	1	2	WASHINGTON	BEAUFORT C	SLATESTONE ROAD (NEAR	93	001	12	12	86	14	42	30	26	20	0	0.00	18?	062
37-021-0003	1	2	ASHEVILLE	BUNCOMBE C	HEALTH & SOCIAL SERVI	93	004	58	58	92	63	56	53	52	49	0	0.00	22	063
37-021-0032	1	2	ASHEVILLE	BUNCOMBE C	LONDON RD ASHVILLE NC	93	004	101	101	55	184	48	44	42	42	0	0.00	24?	079
37-021-0033	1	2	SWANNANOA	BUNCOMBE C	US70 WEST SWANNANOA N	93	004	76	76	83	92	43	40	40	39	0	0.00	21?	079
37-025-0004	1	2	KANNAPOLIS	CABARRUS C	FLOYD ST. KANNAPOLIS	93	001	55	55	87	63	55	49	48	43	0	0.00	25	062
37-035-0004	1	2	HICKORY	CATAWBA CO	1650 1ST. ST.	93	001	55	55	87	63	63	50	49	48	0	0.00	26?	062
* 37-051-0004	1	1	FAYETTEVIL	CUMBERLAND	F.S. # 5 3296 VILLAGE	93	001	57	57	90	63	59	55	47	45	0	0.00	27	063
37-057-0002	1	2	LEXINGTON	DAVIDSON C	S.SAILSBURY ST.LEXING	93	001	59	59	94	63	53	52	50	48	0	0.00	29	062
37-057-1002	1	2	THOMASVILL	DAVIDSON C	400 SALEM STREET	93	001	56	56	89	63	57	53	49	48	0	0.00	29	062
37-059-0099	1	3		DAVIE CO	FORK RECREATION CENTE	93	001	59	59	94	63	53	45	44	44	0	0.00	22	062
37-063-0001	1	1	DURHAM	DURHAM CO	HEALTH DEPT 300 E MAI	93	001	54	54	86	63	59	50	42	41	0	0.00	26?	063
37-065-0002	1	2	ROCKY MOUN	EDGECOMBE	LEGETT RD.,WASTE TREA	93	001	56	56	89	63	41	41	40	39	0	0.00	23	062
37-065-0099	1	3		EDGECOMBE	RT 2, BOX 195 TARBORO	93	001	58	58	92	63	43	41	38	38	0	0.00	20	062
37-067-0009	1	2	WINSTON-SA	FORSYTH CO	INDIANA AV & AKRON DR	93	002	60	60	95	63	61	59	51	49	0	0.00	27	063
37-067-0013	1	3	WINSTON-SA	FORSYTH CO	720 RIDGE AVENUE	93	002	60	60	95	63	59	54	53	52	0	0.00	28	063
37-067-0020	1	2	WINSTON-SA	FORSYTH CO	SILAS CREEK PKWY AT H	93	002	57	57	90	63	57	56	49	46	0	0.00	27	063
37-067-0023	1	2	WINSTON-SA	FORSYTH CO	1401 CORPORATION PARK	93	002	57	57	90	63	64	62	53	53	0	0.00	31	063
37-067-0023	2	2	WINSTON-SA	FORSYTH CO	1401 CORPORATION PARK	93	002	85	85	92	92	41	40	39	39	0	0.00	23?	079
37-067-0024	1	3	WINSTON-SA	FORSYTH CO	NORTH FORSYTH HIGH SC	93	002	57	57	90	63	64	62	50	47	0	0.00	24	063
37-067-1001	1	2	KERNERSVIL	FORSYTH CO	BODENHEIMER ST	93	002	53	53	84	63	63	56	49	46	0	0.00	26	063
37-081-0009	1	2	GREENSBORO	GUILFORD C	EDGEWORTH & BELLEMEAD	93	001	61	61	97	63	57	54	51	46	0	0.00	27	063
37-081-1005	1	2	HIGH POINT	GUILFORD C	E GREEN & S CENTENNIA	93	001	55	55	95	58	55	54	46	46	0	0.00	27	062
37-083-0002	1	2	ROANOKE RA	HALIFAX CO	NE CORNER OF 5TH & CA	93	001	50	50	79	63	54	49	49	48	0	0.00	25?	062
37-085-0001	1	2	DUNN	HARNETT CO	MUNICIPAL BUILDING	93	001	52	52	83	63	47	47	47	45	0	0.00	28?	063
37-087-0002	1	2	CANTON	HAYWOOD CO	ROOF, CANTON FIRE DEP	93	004	60	60	95	63	74	56	50	48	0	0.00	27	063
37-109-0003	1	2	LINCOLNTON	LINCOLN CO	EAST CONGRESS ST	93	001	52	51	81	63	57	49	45	45	0	0.00	25?	062
37-111-0002	1	2	MARION	MC DOWELL	COURTHOUSE	93	001	50	50	79	63	77	61	50	47	0	0.00	27?	063
37-119-0003	1	2	CHARLOTTE	MECKLENBUR	FIRE STA #11 620 MORE	93	003	57	57	90	63	62	54	52	49	0	0.00	30	063
37-119-0010	1	1	CHARLOTTE	MECKLENBUR	FIRE STA #10 2136 REM	93	003	61	61	97	63	62	51	46	44	0	0.00	28	064
37-119-1001	1	2	DAVIDSON	MECKLENBUR	FILTER PLANT	93	003	61	61	97	63	58	51	50	42	0	0.00	24	063
37-119-1005	1	3		MECKLENBUR	400 WESTINGHOUSE BLVD	93	003	57	57	90	63	63	49	48	47	0	0.00	28	063
37-121-0001	1	2	SPRUCE PIN	MITCHELL C	CITY HALL SUMMIT ST	93	001	50	50	79	63	71	54	53	50	0	0.00	30	063
37-129-0005	1	2	WILMINGTON	NEW HANOVE	NINTH AND ORANGE STRE	93	001	56	56	89	63	48	45	40	39	0	0.00	22	063
37-133-0004	1	2	JACKSONVIL	ONSLOW CO	2553 ONSLOW DRIVE, J	93	001	58	58	92	63	51	43	43	41	0	0.00	23	063
37-139-0001	1	2	ELIZABETH	PASQUOTANK	WATER PLANT N WILSON	93	001	59	59	94	63	42	40	40	38	0	0.00	19	062
37-147-0003	1	2		PITT CO	1500 BEATTY ST GREENV	93	001	60	60	95	63	42	40	38	38	0	0.00	22	062
37-159-1006	1	2	SALISBURY	ROWAN CO	CORNER OF CHURCH & KE	93	001	59	59	94	63	56	49	44	44	0	0.00	25	062
37-183-0003	1	1	RALEIGH	WAKE CO	FIRE STATION #9 SIX F	93	001	61	61	97	63	45	44	43	41	0	0.00	24	063
37-191-0004	1	2	GOLDSBORO	WAYNE CO	HWY 70 WEST PATROL ST	93	001	61	61	97	63	46	39	38	38	0	0.00	24	062
37-195-0002	1	2	WILSON	WILSON CO	N.W. CORNER OF KENAN	93	001	59	59	94	365	44	41	40	40	0	0.00	23?	062

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

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QUICK LOOK REPORT

SUSPENDED PARTICULATE (11101) — NORTH CAROLINA — UNITS: 001 UG/CU METER (25 C)

SITE ID	P O C	M T	CITY	COUNTY	ADDRESS	REP YR	ORG	#OBS	--MAXIMUM 24-HR VALUES-- 1ST	2ND	3RD	4TH	ARITH MEAN	GEO MEAN	GEO STD
37-001-0001	1	3	BURLINGTON	ALAMANCE CO	1136 E.WEBB AVE.BURLINGTON,	93	001	31	127	67	63	59	39?	35?	1.6
37-021-0003	1	3	ASHEVILLE	BUNCOMBE CO	HEALTH & SOCIAL SERVICES BL	93	004	55	85	67	62	60	34?	30?	1.7
37-031-0003	1	3	MOREHEAD CITY	CARTERET CO	ARENDELL & 4TH MOREHEAD CI	93	001	60	101	98	89	83	44	38	1.8
37-035-0004	1	3	HICKORY	CATAWBA CO	1650 1ST. ST.	93	001	51	83	76	75	64	44	41	1.4
* 37-047-0001	1	3		COLUMBUS CO	ACME-DELCO SAMPLING SITE HW	93	001	60	74	57	52	48	30	27	1.6
* 37-051-0004	1	3	FAYETTEVILLE	CUMBERLAND CO	F.S. # 5 3296 VILLAGE DR.	93	001	58	83	80	74	72	45	42	1.5
37-057-1002	1	3	THOMASVILLE	DAVIDSON CO	400 SALEM STREET	93	001	50	84	78	72	66	43?	40?	1.5
37-067-0023	1	3	WINSTON-SALEM	FORSYTH CO	1401 CORPORATION PARKWAY	93	002	44	102	95	89	82	57?	54?	1.4
37-071-0014	1	3	GASTONIA	GASTON CO	RANKIN LAKE RD,GASTONIA,NC	93	001	54	104	93	64	59	36	31	1.7
37-081-1005	1	3	HIGH POINT	GUILFORD CO	E GREEN & S CENTENNIAL ST	93	001	5	34	30	26	19	26?	25?	1.3
37-085-0001	1	3	DUNN	HARNETT CO	MUNICIPAL BUILDING	93	001	51	91	88	79	74	46?	42?	1.6
37-119-0001	1	3	CHARLOTTE	MECKLENBURG CO	600 EAST TRADE STREET	93	003	61	78	77	74	67	40	38	1.5
37-119-0010	1	3	CHARLOTTE	MECKLENBURG CO	FIRE STA #10 2136 REMOUNT R	93	003	61	82	70	62	62	38	35	1.5
37-121-0001	1	3	SPRUCE PINE	MITCHELL CO	CITY HALL SUMMIT ST	93	001	51	89	86	86	80	45	40	1.6
37-129-0005	1	3	WILMINGTON	NEW HANOVER CO	NINTH AND ORANGE STREETS	93	001	59	64	62	61	57	33	31	1.5
37-139-0001	1	3	ELIZABETH CITY	PASQUOTANK CO	WATER PLANT N WILSON ST	93	001	61	81	60	57	56	31	27	1.7
37-155-0003	1	3	LUMBERTON	ROBESON CO	SO. WATER ST.	93	001	58	135	119	110	93	45	39	1.7
37-175-0002	1	3	BREVARD	TRANSYLVANIA CO	HWY 64	93	001	56	77	76	71	68	36	33	1.6
37-183-0003	1	3	RALEIGH	WAKE CO	FIRE STATION #9 SIX FORKS R	93	001	61	90	80	71	67	37	34	1.6
37-187-0002	1	3	PLYMOUTH	WASHINGTON CO	OLD ACRE RD.	93	001	58	62	58	57	54	35	32	1.6

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA
EXCEPTIONAL EVENT DATA EXISTS IN AT LEAST ONE OF THE ABOVE SITES BUT IS NOT INCLUDED IN THE SUMMARY CALCULATIONS

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AIR QUALITY SUBSYS...

QUICK LOOK REPORT

OXIDES OF NITROGEN (42603) NORTH CAROLINA

SITE ID	POC	MT	CITY	COUNTY	ADDRESS	YR	REP ORG	#OBS	MAXIMUM VALUES 1ST	2ND	3RD	4TH	ARITH MEAN	METH	UNITS	INT
37-033-0001	1	3		CASWELL CO	CHERRY GROVE RECREA	93	001	1185	.048	.040	.031	.031	.0059?	014	007	1
37-067-0022	1	2	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	93	002	8139	.425	.402	.344	.328	.0255	025	007	1
37-067-0022	2	3	WINSTON-SALEM	FORSYTH CO	1300 BLK. HATTIE AV	93	002	2930	.194	.159	.135	.134	.0154?	074	007	1
37-069-0001	1	3		FRANKLIN CO	431 S HILLBOROUGH S	93	001	1160	.047	.047	.046	.043	.0087?	014	007	1
37-077-0001	1	3		GRANVILLE CO	WATER TREATMENT PLA	93	001	1971	.042	.041	.035	.035	.0076?	014	007	1
37-109-0004	1	3	LINCOLNTON	LINCOLN CO	RIVERVIEW ROAD	93	001	1632	.050	.050	.050	.050	.0130?	014	007	1
37-119-0034	1	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	93	003	8073	.493	.445	.439	.406	.0371	014	007	1
37-119-0034	2	3	CHARLOTTE	MECKLENBURG CO	PLAZA ROAD AND LAKE	93	003	1740	.116	.110	.110	.104	.0193?	014	007	1
37-119-1009	1	3		MECKLENBURG CO	29 N@ MECKLENBURG C	93	003	1467	.050	.050	.050	.050	.0119?	014	007	1
37-157-0099	1	3		ROCKINGHAM CO	6371 NC 65 @ BETHAN	93	002	1612	.050	.048	.048	.046	.0074?	074	007	1
37-159-0021	1	3		ROWAN CO	WEST ST & GOLD HILL	93	001	1214	.046	.043	.041	.038	.0078?	014	007	1
37-183-0015	1	3	RALEIGH	WAKE CO	808 NORTH STATE STR	93	001	3070	.306	.276	.271	.268	.0248?	082	007	1
37-183-0015	2	3	RALEIGH	WAKE CO	808 NORTH STATE STR	93	001	1862	.186	.177	.169	.153	.0106?	014	007	1
37-183-0016	1	3	FUQUAY-VARINA	WAKE CO	201 NORTH BROAD STR	93	001	2183	.101	.082	.057	.057	.0060?	014	007	1

? INDICATES THAT THE MEAN DOES NOT SATISFY SUMMARY CRITERIA

APPENDIX B

HEATH, MISSIMER, BOYLE REPORTS

RALPH C. HEATH
Consulting Hydrogeologist

4821 Kilkenny Place
Raleigh, N. C. 27612
(919) 782-0171

REPORT RELATED TO MODIFICATION OF THE FRISCO WELLFIELD OF THE CAPE HATTERAS WATER ASSOCIATION

Prepared by

Ralph C. Heath
Consulting Hydrogeologist
August 1995

For the

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

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

NORTH CAROLINA LICENSED GEOLOGIST
SEAL 225
RALPH C. HEATH

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APPENDICES

TABLES

REPORT RELATED TO MODIFICATION OF THE FRISCO WELLFIELD OF THE CAPE HATTERAS WATER ASSOCIATION

Prepared by

Ralph C. Heath
Consulting Hydrogeologist

Introduction

It became apparent in 1988 that the yield of the Cape Hatteras Water Association's Frisco wellfield was not sufficient to meet the water needs of the Association's service area. Efforts begun at that time to develop a second wellfield to the east, in the area referred to as Buxton Woods, were unsuccessful. However, test wells constructed in 1990 in the proposed Buxton Woods wellfield area showed the presence of a moderately permeable zone between depths of about 60 and 70 ft.

Test wells constructed at the same time along Waterplant Road showed the occurrence of a moderately permeable zone between depths of about 50 and 75 ft in Test Well No. 6, at the waterplant, and about 49 to 54 ft in Test Well No. 7, about 800 ft to the south. This zone will be referred to in this report as the deeper (or lower) permeable zone of the Buxton Woods aquifer.

In the summer of 1994, Supply Well No. 3 at the west end of the Frisco wellfield was redrilled and screened in the permeable zone discussed above, between depths of about 60 and 70 ft. The water produced by the "New" Well No. 3 was of such excellent quality that immediate consideration was given to replacing all of the wells in the Frisco wellfield with wells screened in the deeper permeable zone.

In the meantime, in April 1995, construction was started on test wells to determine the yield and water quality of permeable zones between depths of about 200 and 600 ft to evaluate the feasibility of developing an additional water supply using reverse-osmosis (RO) technology to remove dissolved salts from brackish water. The results of this testing program are contained in reports by Missimer International, Fort Myers, FL, and Boyle Engineering Corp., Santa Rosa, CA, and will be referred to in this report only to the extent that they may apply to the proposed changes in the Frisco wellfield.

water-quality characteristics require that the water be subjected to a complex and expensive treatment process. Table 1 contains a partial chemical analysis of the raw water from the existing Frisco wellfield.

Table 1 also contains a partial analysis of water from the deeper zone now penetrated by Well No. 3. Note, especially, the values of color, total organic carbon, iron, and manganese. If water of this quality can be obtained from the lower permeable zone of the Buxton Woods aquifer, it will greatly simplify the treatment process.

The major uncertainty regarding the wisdom of screening the Frisco supply wells in the lower part of the Buxton Woods aquifer concerns the possibility of the deeper wells causing an upconing of salty water along the line of the wellfield. This concern is discussed in the 4th paragraph of the October 17 letter and is discussed in greater detail in the following section.

Saltwater Encroachment and the Frisco Wellfield

Freshwater on oceanic islands, such as Hatteras, occurs as a lens floating on denser (heavier) brackish or salty water. The **freshwater-saltwater relationship** in the Cape Hatteras area and the data available at that time on the chloride content of the ground water were discussed in some detail on pages 48-56 of my 1988 report. A copy of these pages are included in Appendix No. 4 at the back of this report.

The discussion in Appendix No. 4 deals with the effect of withdrawals from the Frisco wellfield on the freshwater-saltwater conditions. As was noted, the withdrawals were expected to result in both a lateral (landward) movement of the saltwater front in the Buxton Woods aquifer and an "upconing" of saltwater in the sediments beneath the aquifer.

In an effort to determine the lateral position of the freshwater-saltwater front in the Buxton Woods aquifer, between the wellfield and Pamlico Sound, two test wells were drilled along Waterplant Road in 1990. The results obtained, which are contained in my 1990 outpost observation-well report, suggested that the leading edge of the freshwater-saltwater interface was a few hundred feet south of the waterplant. See Appendix No. 5 which is a copy of a sketch contained in the outpost observation-well report.

Before discussing upconing of salty water beneath the wellfield, it is desirable to first discuss the vertical position of aquifers and confining beds. Table 2 contains data on the depth to aquifers and confining beds, a description of their composition, and the chloride content of water samples from some of the units. The depths in the table have been rounded to the nearest 5 ft because they were derived from different wells and because the depth to the units is different in different parts of the area.

Table 2 shows that the Buxton Woods aquifer can be divided into 3 zones; (1) an upper permeable zone, in which the present Frisco wells are screened, (2) a low-permeability zone between depths of about 45 and 55 ft, and (3) a lower permeable zone between depths of about 55 and 80 ft. The low-permeability layer between 45 and 55 ft is not a true confining layer but appears to be sufficiently impermeable as to have a beneficial effect on water quality because water in the lower zone, in areas not affected by the Frisco wellfield, has a lower iron and, presumably, a lower organic carbon content than water in the upper zone.

From the base of the Buxton Woods aquifer, at a depth of about 80 ft, to the top of the limestone aquifer at a depth of about 245 ft, I have identified several confining beds and confined aquifers, as shown in Table 2. These identifications are based largely on the electric and gamma-ray logs from test wells at the research site in Buxton Woods and from Well RO TW#1. These identifications are somewhat subjective (tentative?) because there are no really prominent deflections in the logs in this section. In other words, the logs indicate a complex alternation of very fine-grained layers (clay & silt) with coarser-grained layers of fine to coarse-grained sand and shells. Importantly, in this section there do not appear to be either prominent aquifers or confining beds.

Relatively little data were available in 1988 regarding the chloride content of the water in the sediments below the Buxton Woods aquifer. The data that were available suggested that the chloride content of water in the thin confined aquifer screened in Well 21E at a depth of about 120 ft was 200 mg/l. (See page 52 in Appendix No. 4.) (References to page numbers in the Appendices are to the page numbers in the source report and not to the page numbers in this report.) Data from a test well drilled in the Buxton maintenance area of the National Park Service also indicated that the chloride content was about 1900 mg/l at a depth of about 200 ft.

The most valuable data regarding the quality of the ground water in the deeper aquifers at Cape Hatteras were obtained from the test wells that were constructed during the summer of 1995 to locate a suitable source of brackish water for a reverse-osmosis plant. The well designated as RO-TW #1 was constructed on the east side of Waterplant Road about 25 ft north of Peters Ditch and Well RO-TW #2 was constructed midway between supply wells 19A and 20 in the Frisco

Table 2.--Notable Hydrogeologic Units and Chloride Content of Ground Water in the Cape Hatteras Area.

Depth (feet)	Description	Chloride content (mg/l)
0-45	**Buxton Woods aquifer** (upper permeable zone)-interbedded fine to very coarse sand	**50**
45-55	**Buxton Woods aquifer** (low permeability layer)-interbedded silt & very fine to medium sand	
55-80	**Buxton Woods aquifer** (lower permeable zone)-interbedded fine to very coarse sand	**35** (New well #3)
80-115	**Confining bed** - interbedded clay, silt & very fine to medium sand	**80** (Buxton Woods TW#1)
115-130	**Confined aquifer** - very fine to medium sand	**80** (Buxton Woods TW#1) **200** (Frisco well 21 E)
130-170	**Confining bed** - clay with some fine sand & shell	
170-220	**Interbedded permeable & impermeable layers** (?) --- tentative identification from electric and gamma-ray logs of RO-TW#1	**1900** (Test well in NPS Buxton maintenance area)
220-245	**Confining bed** - clay, sand, and shell	
245-410	**Limestone aquifer** - 245-300 very permeable, 355-365 clay-rich zone	**3800** (RO-TW#1) **8800** (RO-TW#2)
410-580	**Confining bed** - interbedded clay and sand	
580-650	**Sandstone aquifer** - interbedded soft & hard layers	**10,000** (RO-TW#1) **10,800** (RO-TW#2)

wellfield. The chloride content of water samples from both of these wells from both the limestone aquifer and the sandstone aquifer are shown in Table 2.

The chloride concentration of 3,800 mg/l in water from the limestone aquifer at a depth of about 245 to 300 ft in Well RO-TW #1 seems to be consistent with the 1,900 mg/l found at a depth of about 200 ft in the deep test well drilled in the Buxton maintenance area and, therefore, was not unexpected. The chloride concentration of 8,800 mg/l of water from the limestone aquifer penetrated in Well RO-TW #2, on the other hand, was not expected and raises an important question relative to the Frisco wellfield.

The larger chloride concentration in Well RO-TW #2, compared to that in Well RO-TW #1, is believed to be due to one of the following two causes. First, it may reflect the natural increase in chloride content of the water in the limestone aquifer in the oceanward direction because the ocean is presumably the original source of the water. Or, second, it may reflect an upconing of salty water beneath the line of the Frisco wellfield.

The possibility of upconing resulting from withdrawals from the wellfield was recognized and discussed in my 1988 report. (See Appendix No. 4.) Also, conclusion No. 6 on page vii and recommendation No. 6 on page 113 of the 1988 report deals specifically with this subject. The fact that upconing has been recognized as a potential problem as far back as the initial design of the Frisco wellfield in 1967, makes it important to evaluate the chloride data from the RO test wells in view of the proposed deepening of the Frisco wells.

The most striking aspect of the chloride data is the more that doubling of the concentration in the limestone aquifer between wells RO-TW #1 and RO-TW #2. Because Well RO-TW #2 is in the Frisco wellfield, where upconing has always been expected to occur, my first reaction on learning of the data was that it indicated upconing. This conclusion was also consistent with the fact that the 5,000 mg/l increase in chloride in the 3600 ft between wells RO-TW #1 and RO-TW #2 was, for reasons whose explanations are beyond the scope of this report, much larger than would have been expected to occur naturally in the limestone aquifer. The increase in chloride concentration of 800 mg/l in the sandstone aquifer between wells RO-TW #1 and RO-TW #2 is more consistent with what would have been expected in the limestone aquifer.

The preceding paragraph deals with the factors that support the upconing theory. What about factors that do not support it? Upconing, if it is occurring, is a result of the lowering of the ground-water level in the Buxton Woods aquifer caused by the withdrawals. For upconing to occur, an upward hydraulic gradient would have to exist between the limestone aquifer and the upper zone of the Buxton Woods aquifer. Because of the obviously small vertical hydraulic conductivity of the confining beds between the Buxton Woods aquifer and the limestone aquifer, it is difficult to believe that withdrawals from the Buxton Woods aquifer will cause even a detectable lowering of the artesian pressure in the limestone aquifer.

Also, the Frisco wellfield is pumped intermittently so that the average annual water level in the wellfield, based on the data collected along Transect No. 1 of the N.C. State University research project, appears to be at least 2 to 3 ft above sea level. Compare this elevation with the average annual elevation of the water table at well RO-TW #1 which is located only about 25 ft from Peters Ditch in which the average annual water surface is probably only a fraction of a foot above sea level. The average annual elevation of the water table at the position of well RO-TW #1 should be only slightly higher. Therefore, if lowering of the water table by the Frisco wellfield causes upconing, one would expect Peters Ditch to also cause upconing. This possibility was in fact recognized in Figure 21 of my 1988 report. (See page 56 of Appendix No. 4.)

Without belaboring the point further, it seems safe to conclude at this time that neither the Frisco wellfield nor Peters Ditch have had any effect on the chloride content of the water in either the limestone or the sandstone aquifers. This, however, does not completely rule out all possibility of upconing of salty water beneath the wellfield. As is suggested by Table 2, all of the water-bearing layers below a depth of about 130 ft appear to contain brackish water. Withdrawals from the wellfield may have a significant effect on the water levels in the uppermost of these layers and, therefore, result in some upconing. I do not believe, however, that this problem is imminent enough at this time to affect decisions regarding deepening of the supply wells in the wellfield.

Monitoring Saltwater Encroachment

In the 1988 report I recommended that water samples be collected annually from wells 3D, 21D, and 21E in order to determine if, and when, upconing of salty water occurs. In the outpost observation-well report in 1990, I recommended that Test Wells 6 and 7 be sampled twice a year to determine if salty water was moving laterally in the Buxton Woods aquifer toward the Frisco wellfield.

Samples collected from wells 3D, 21D, TW 6, and TW 7 have not shown any progressive increase in chloride content. Efforts to collect representative samples from well 21E have not been successful, apparently because of collapse of the screen or casing. Furthermore, the upper part of the well was damaged by mowing equipment about 1993 which has also hampered sampling efforts.

Relative to the future, as plans to deepen the Frisco wells proceed it is important to establish and operate a chloride sampling program in order to determine if and when any changes occur in the lateral or vertical positions of the freshwater-saltwater front. New monitoring wells needed as part of this program were discussed in my letter of November 23, 1994 (Appendix No. 2). However, as a result of the data recently obtained from the RO test wells, it is appropriate at this time to modify the recommendations made in the November 23 letter.

Test well RO-TW #2, which is located between supply wells 19A and 20, is to be retained as a monitoring well (Jim Coleman, oral communication, August 14, 1995). This well consists of an outer 8-inch diameter PVC casing open to the limestone aquifer between depths of 246 and 400 ft and an inner 4-inch diameter steel casing open to the sandstone aquifer between depths of about 625 and 650 ft. Observations of both water-level fluctuations and changes in chloride content in this well will be of great value if a wellfield for a reverse-osmosis plant is developed in the vicinity of NC Highway 12.

Observation of both water-level fluctuations and changes in chloride content in the limestone aquifer should also be made prior to construction of a reverse-osmosis wellfield in order to confirm, if that is the case, that the Frisco wellfield does not have any effect on the limestone aquifer. These observations should be started during the fall of 1995.

As noted in the preceding section, it is anticipated that any upconing of salty water caused by the Frisco wellfield will occur in the sediments immediately below a depth of about 130 ft. Therefore, it is recommended that a monitoring well 3-inches or so in diameter be constructed within about 15 ft of well RO-TW #2. This well should be screened in the confined aquifer that is expected to occur between about 115 and 130 ft. (See Table 2.) This well will, in effect, replace well 21E.

This well should be equipped immediately with a water-level recording device to determine if withdrawals from the Frisco wellfield have a detectable effect on the water level in the confined aquifer. A sample of water should also be collected and analyzed for chloride content. If the chloride content exceeds about 250 mg/l, a monthly sampling program should be instituted immediately to determine if a progressive increase in chloride is occurring.

The new monitoring well discussed in the two preceding paragraphs should be the first well constructed as a part of the modification program for the Frisco wellfield.

In addition to the monitoring discussed above, samples should continue to be collected twice a year (in the spring and fall) from Test Wells 6 and 7. This sampling program will be especially important because the deeper supply wells may result in an increase in the chloride content of Test Well 6.

Proposed Modifications of the Frisco Wellfield

My letter dated October 17, 1994 (Appendix No.1) contains preliminary thoughts regarding replacement of the original Frisco wells with supply wells screened in the lower permeable zone of the Buxton Woods aquifer. The letters of November 23 and December 6, 1994 (Appendices No. 2 and 3) deal with the technical details of the replacement-well contract and well design and testing. Because all of these letters are included in this report, the details they contain will not be repeated in this report.

Because the new wells will be deeper, and thus have a larger available drawdown than the original wells, it is anticipated that their average yield will be substantially larger than the original wells. Therefore, it will be necessary to replace only the remaining 19 of the original 20 wells (Well No.3 having already been replaced). This means that the replacement wells will be spaced about 500 ft apart, in contrast to the 250 ft spacing that now exists from Well No. 7 to Well No. 22.

Both the lower permeable zone of the Buxton Woods aquifer and the overlying low-permeability zone that separates it from the upper permeable zone appear, on the electric and gamma-ray logs now available, to vary both in character and thickness and in their depths below land surface. If the well driller selected to construct the supply wells is not experienced in this area, these variations may pose a problem. It is essential that the screens be set in the most permeable part of the lower zone and that neither the screen nor the gravel packs, if they are used, be placed into or extend above the low permeability zone.

Because of the variations in the character, thickness, and position of the lower permeable zone, it will probably be desirable to obtain at least an electrical-resistivity log, and if possible a gamma-ray log, of the monitoring well drilled near Well RO-TW#2. If difficulty

is encountered in identifying the low-permeability zone and the lower permeable zone in the new supply wells, it may become necessary to require that these wells also be logged before the depths for the screens and gravel packs are selected.

Relative to modification of the Frisco wellfield, the Association has recently acquired an additional 900 ft of property east of the present wellfield property. Because supply wells cannot be placed within 100 ft of a property boundary, this provides and additional 800 ft in which new wells can be drilled. This distance is enough for two wells so that the modified wellfield, when completed, will consist of a total of 22 wells.

Yield of the Modified Wellfield

The next topic that needs to be considered is the yield of the modified wellfield. The analysis on which my letter of December 6, 1994, was based indicated that Supply Wells 3 through 8 can be pumped at a rate of 50 gpm and all wells to the east - that is, Supply Wells 9 through 22, plus the two new wells to be drilled on the new property, which I will refer to here as Supply Wells 27 and 28, can be pumped at a rate of 75 gpm. None of the information that has become available since 1994 suggests that these pumping rates should be changed. Therefore, the yield of the Frisco wellfield, with all supply wells screened in the lower permeable zone, should be as follows:

Wells 3 thru 8: 6 wells x 50 gpm = 300 gpm
Wells 9 thru 22 plus 27 and 28: 16 wells x 75 gpm = 1200 gpm
Total yield (all wells) = 1500 gpm = 2,160,000 gpd

It will be useful at this point to compare the total yield of the modified wellfield, of 2,160,000 gpd, with the wellfield as it now exists. The pumping rate of each of the wells was measured in 1988 and the total yield of the field at that time, if it were operated continuously for 24 hours, was 1,369,449 gpd. (See table on page 83 of the 1988 report.) Beginning about 1990, the Association began a program of replacing the 1/2 and 3/4 horsepower (HP) pumps on many of the wells with 1 1/2 HP pumps. As a result, by 1992, the yield of the wellfield, with all wells on line, was about 1,800,000 gpd. Thus, it is anticipated that the yield of the wellfield after the modification is completed will be 20% larger (360,000 gpd) than the existing field from only half as many wells.

Needless to say, it is not anticipated that the modified wellfield will ever be pumped at the rate shown above, just as the existing field is never pumped at a rate of 1,800,000 gpd, because of the down time each day when filters are being back flushed and the chemical dispensers are being replenished.

There is one final point that needs to be covered relative to the yield of the modified wellfield and that is **average annual daily yield.** This is the term I use to refer to the long-term "safe yield" of the part of the Buxton Woods aquifer that the wellfield draws from. It is the yield of the aquifer, in contrast to the yield of the wellfield. In 1988, I estimated the average annual daily yield of the aquifer to be about 610,000 gpd (rounded to 600,000 gpd).

Since 1991, the average annual daily withdrawals have exceeded 625,000 gallons, reached a maximum of about 710,000 gallons in 1993, and were 660,000 gallons in 1994.

During this period, at least through July 1994, there had been no increase in chloride content of water samples from Test Wells 6 and 7 which is interpreted to mean that no lateral encroachment has occurred in the Buxton Woods aquifer as a result of the increase in withdrawals.

There has also been no increase in chloride content in wells 3D and 21D, both of which are screened at a depth of 90 ft at each end of the wellfield. As noted earlier, it has not been possible to obtain valid samples from well 21E since 1988. However, the absence of an increase in chloride content in wells 3D and 21D suggests that upconing is not occurring or, at least, has not been detected.

With the above facts in mind, I am inclined to believe that my 1988 estimate of aquifer yield is too low. I intended at that time that the estimate be conservative and it appears that I succeeded. I believe one of the reasons why the aquifer yield is larger than I estimated is the westward flow of surface water through the wellfield sedge. This flow could not be evaluated in 1988 and still cannot but is obviously a significant amount.

Based on the withdrawals over the last few years and the lack of increase in the chloride content of water samples from the observation wells, I believe the aquifer yield, when the wellfield is extended 800 ft to the east, will be at least 700,000 gpd.

One final note on aquifer yield and the westward flow of surface water through the wellfield sedge, informal discussions in the past have included the possibility of increasing the yield by building a low water-level control across the sedge 100 ft or so west of well No. 3. Such a control could be operated both to maintain full storage in the aquifer from late fall to late spring and to prevent flooding of the sedge with brackish water from Pamlico sound during hurricanes. Maintaining the aquifer storage could possibly increase the aquifer yield to the wellfield by as much as 200,000 gpd.

Maintaining aquifer storage and preventing brackish water inundation would also greatly enhance preservation of the wellfield sedge wetland. Thus, a water-level control across the wellfield sedge would, ironically, have the reverse effect on the wellfield sedge wetland as the present wetland drainage system at the east end of the Cape Hatteras area is having on the wetlands in that area.

Effect of Wellfield Modification on Water Quality

The final topic that needs to be considered is that of water quality. Specifically, the question that needs to be answered, if possible, is whether the quality of the water pumped from the lower permeable zone will gradually change until it is similar in composition to the water now pumped from the upper permeable zone.

Clearly, the water in the lower zone is derived from recharge at the land surface and which, therefore, has passed through the upper part of the Buxton Woods aquifer. While passing through the upper permeable zone, did it acquire the high organic carbon and iron content of water now produced by the Frisco wellfield from the upper zone and were these constituents *"filtered-out"* or reduced in concentration as the water passed through the low-permeability layer in the Buxton Woods aquifer and through the confining bed that underlies the aquifer?

Water-quality data related to the Buxton Woods aquifer were discussed in both my 1988 report and in my 1990 report on the proposed Buxton Woods wellfield. The pertinent sections of those reports are included in this report in Appendices 4 and 6.

Water with a low iron content and with either a confirmed or assumed low organic carbon content has been obtained from:

(1) New Frisco Supply Well 3 - from the lower permeable zone (Table 1).

(2) Buxton Woods Test Well No. 2 drilled in 1990 near Peters (Buxton) Ditch - screened in the lower permeable zone (Appendix No. 6, p. 13).

(3) Buxton Woods Test Well No. 1 drilled in 1990 near the center of the proposed Buxton Woods wellfield and screened between 118 and 123 ft in the confined aquifer below the Buxton Woods aquifer (Appendix No. 6, p. 13).

Water with a high iron content and with either a confirmed or assumed high organic carbon content has been obtained from:

(4) All of the original wells in the Frisco wellfield except Well 25A (Appendix 6, p. 41),

(5) The National Park Service supply wells in the Buxton maintenance area, which are believed to be screened in the upper permeable zone of the Buxton Woods aquifer,

(6) Buxton Woods Test Well No. 1A which is located 5 ft from Test Well No. 1 and is screened in the lower permeable zone from 63 to 68 ft (Appendix 6, p.13),

(7) Test Well No. 4 which is screened in the lower permeable zone near the west end of the proposed Buxton Woods wellfield (Well Construction Record in the 1990 report on the proposed Buxton Woods wellfield) , and

(8) Test Well No. 6 which is screened in the lower permeable zone at the south end of the CHWA water treatment plant (Well Construction Record in the 1990 outpost observation well report).

The data outlined above are not sufficient to show conclusively (1) which water-bearing zones in the Cape Hatteras area contain water with a low iron and organic carbon content, and (2) whether the quality of the water produced by wells screened in the lower permeable zone in the Frisco wellfield will, in time, resemble the quality of the water from the present wellfield. However, the data do suggest that **all of the Buxton Woods aquifer** contained water high in iron and organic carbon prior to construction of the Frisco wellfield. This conclusion is supported by the iron content in both the Frisco and NPS wellfields and by the data from Test Wells 1A, 4, and 6 (Statements (4) through (8) above).

The data also suggest that the confined aquifer that occurs at a depth of about 115 to 130 feet contains water low in iron and organic carbon (Statement (3) above).

Are these conclusions consistent with the water quality produced by New Well No. 3 in the Frisco wellfield and Test Well No. 2 near Peters Ditch? I think so. Relative to Well No. 3, the withdrawals from the "original" well No. 3 from 1968 until it was deepened in 1994 doubtless caused water in the confined aquifer to move upward into the lower permeable zone of the Buxton Woods aquifer. This water, as confirmed by Buxton Woods Test Well No. 1, is low in iron and, presumably, also low in organic carbon. The upward movement of water from the confined aquifer beneath the Frisco wellfield probably also explains the decrease in iron content of water from the Frisco supply wells between 1979 and 1990, as discussed in Appendix 6, p. 15, last paragraph.

The above seems to explain everything except Test Well No. 2, the only well, other than New Well No. 3, to produce water with a low iron content from the lower permeable zone of the Buxton Woods aquifer. Actually, it also explains the data from Test Well No. 2. That well was located only about 200 ft from (south) of Peters Ditch (which I referred to as the Buxton Ditch in all my earlier reports) in order to be in the area of influence of the ground-water discharge line formed by the ditch. In other words, Peters Ditch has long been recognized as a ground-water discharge line for the Buxton Woods aquifer and, presumably, for the underlying confined aquifers, and the location of Test Well No. 2 was selected to be within the area affected by ground-water discharge to the ditch. Therefore, water samples obtained from Test Well No. 2 are believe to be water that has moved upward from the confined aquifer enroute to discharge in the ditch.

Now, to the final question - What changes, if any, will occur in the water quality produced by the Frisco wellfield once all of the wells are screened in the lower permeable zone? I believe the water will have a low iron and organic carbon content while it is drawing on the water that has moved upward from the confined aquifer. This water now occupies the storage space in the lower permeable zone, the overlying low-permeability zone, and part of the lower part of the upper permeable zone in an area possibly several hundred feet wide along the line of the wellfield. As this water is withdrawn, I expect the iron, and the other undesirable quality characteristics of the water from the present wellfield, to gradually increase as more and more of the water withdrawn is derived from the zone now tapped by the existing wells. However, because a larger proportion of the water from the deeper wells will be water from the confined aquifer, I expect the final, stabilized, quality to be significantly better than the water produced by the present wellfield.

Finally, my last guess is that between 100,000,000 and 200,000,000 gallons of good quality water are now present in the lower part of the Buxton Woods aquifer along the line of the Frisco wellfield. If this guess is correct, the quality of the water obtained from the deeper wells should begin to change before the wells have been in operation for a full year.

October 17, 1994

Mr. Jim Coleman
Cape Hatteras Water Assn.
PO Box 578
Buxton, NC 27920

Dear Jim:

This letter is written to confirm our recent discussions regarding replacement of the supply wells in the Frisco wellfield. As you know, the first 20 supply wells were constructed during the winter of 1967-68 and are now about 27 years old. This is well past the normal expected life of about 20 years for supply wells and explains why you are encountering increasing difficulties with screen failure and sand production by your supply wells.

In planning well replacement, an important question concerns the depth at which the new supply wells should be screened. The results of last summer's experiment, when the depth at which well No. 3 is screened was increased from 60 ft to 70 ft with a resulting dramatic improvement in water quality, suggests that all new supply wells should be screened in the lowest permeable zone in the Buxton Woods aquifer. Such wells will not only produce much better quality water, which will reduce treatment costs, but will also have larger yields because of the larger available drawdown.

Relative to the "lowest permeable zone," the electric and gamma-ray logs obtained during the test-well drilling program in 1990 shows, in all wells except test well No. 7, a relatively permeable zone between about 50 and about 80 ft. In test wells No. 1, 2, 4, and 6 this zone in fact appears to be more permeable than the zone screened in the existing Frisco wells. I suggest, therefore, that in your well-permit application you indicate that a 10 ft length of screen will be installed in the most permeable zone penetrated between depths of 50 ft and 80 ft. The determination of the actual depth screened at each well to be based on well cuttings and/or electric and gamma-ray logs.

The existing wells in the Frisco wellfield were screened at a shallower depth than that discussed in the preceding paragraph because of concern about upconing of salty water below the confining bed. There is no indication so far that upconing has or is occurring. However, this may change when the new supply wells are screened at a lower level. In order to determine if this does in fact occur, I suggest that you also request permission to install at least four deep monitoring wells. Three of these wells should be located between 5 and 10 ft from supply well Nos. 8, 14, and 20. The fourth well, if needed, would be drilled at a site to be determined later based on data collected from the new supply and monitoring wells. It might be desirable, for example, to locate this well near well No. 14 in the middle of the wellfield and screen it at the depth at which the water contains 250 mg/l of chloride. You should indicate in the well-permit application that the first three monitoring wells will be finished with a 3 to 5 ft length of screen in the most permeable zone between depths of about 110 and 120 ft.

I believe this covers all the items of concern at this point except to note that you are living on "borrowed time" with the 20 original supply wells. I therefore urge you to replace these wells as quickly as conditions permit.

Sincerely,

Ralph C. Heath

rch/mh

November 23, 1994

Mr. William C. Diehl
Diehl & Phillips
219 E. Chatham St.
Cary, N.C. 27511

Dear Bill:

At the meeting in your office on October 18 we agreed that I would furnish you some of the technical details to be included in the drilling contract covering replacement of both the original supply wells in the Frisco wellfield of the Cape Hatteras Water Association and the construction of new monitoring wells.

We could not decide at that time whether to include both the monitoring wells and supply wells in the same contract because of the need to obtain both electric and gamma-ray logs of the monitoring wells. I believe Jim intended to talk to Glenn Anderson about this.

Anyway, my thoughts and suggestions regarding the items that should be included in the contract follow. Note that I have used 1 1/2 spacing for material that you may wamt to include in the contract, after revision, of course. Explanatory notes, on the other hand, are in boxes in italics. Aren't these modern computer word-processing programs wonderful!

MONITORING WELLS

Explanatory Note - The purpose of the monitoring well (s) are to:

1. *Provide data on the position, thickness, and character of the permeable and less-permeable layers based on drill samples and geophysical logs,*
2. *Provide data on the chloride content of the water in the confined aquifer beneath the confining bed, and*
3. *Provide a permanent observation well for monitoring water levels and changes in chloride content in the confined aquifer.*

Chloride analyses from the deep monitoring wells at each end of the Frisco wellfield (Wells 3 D and 21 D and 21 E) do not show any increase in chloride content since 1968. This suggests that there has been no upconing of salty water in response to wellfield withdrawals. On the other hand, these wells may not truly indicate the chloride content of water in the confined aquifer due to casing failure or some other problem. Also, these wells, being located at each end of the wellfield, are at locations least likely to show upconing.

If any upconing has occurred, it is most likely to be detected in the middle of the 1968 line of wells. Therefore, the first monitoring well should be drilled near the middle of the Frisco wellfield. If a well screened at this location in the permeable zone that I expect to be penetrated *at a depth of about 120 ft yields water with a chloride less than about 200 mg/l, it may be safe to assume that either upconing has not occurred or is negligible. In this case, no other monitoring well needs to be drilled, at least at this time.*

On the other hand, if the chloride content exceeds about 250 mg/l, two other monitoring wells should be drilled to and screened in the 120 ft permeable zone at the quarter points of the wellfield.

These wells should be drilled first because the samples and logs obtained from them will be used in deciding on what depths to screen the supply wells.

The contract should provide for the construction of a minimum of one well and a maximum of three wells.

First Well - to be drilled at an accessible site within about 15 ft of existing Frisco supply well No. 14. The well is to be no less than 6" in diameter, drilled by the direct (normal) mud-rotary method using either REVERT or other commercial drilling clay, and to a depth of not more than 125 ft.

Samples of the geologic materials penetrated by the well shall be collected at 5-ft intervals and at each change in formation (change in sediment composition).

Note - *I think this is the only well that needs to be logged (electric and gamma) and I believe we can get the NC Groundwater Section to do this logging. If we agree that this is the only well that needs to be logged, you will need to insert a statement in the contract that the logs will be provided by the Association.*

The well shall be completed as a permanent monitoring well by installing a line of 2" diameter Schedule 40 PVC plastic pipe to which a 5 ft length of slotted plastic screen is affixed to the bottom. The bottom of the screen will be sealed with a permanent cap to prevent the entry of sediment.

The depth below land surface at which the screen will be installed will be determined by the project Engineer on the basis of the sediment samples and geophysical logs. It is anticipated that the well will be screened in a permeable zone that occurs in other wells in the area at a depth of about 120 ft.

Upon completion of each monitoring well, drilling mud and fine-grained sediment will be removed, by well-development techniques, from the area occupied by the screen to insure that the well is in free hydraulic connection with the aquifer sediments. Development of the well will be continued until it produces sediment-free water at a rate of at least 1/2 gallon per minute.

Second and Third Wells - The decision whether to drill either or both of these wells will be made by the project Engineer on the basis of the chloride content of water from the first well.

All construction and drilling specifications for the First Well are applicable to these wells.

If required, the Second well will be drilled at a readily accessible site near existing supply well No. 20, or at another accessible site designated by the project Engineer.

Also, if required, the Third well will be drilled near existing supply well No. 8 or at another site designated by the project Engineer.

Note - The above specifications require a 6" diameter hole and a 2" casing and screen. This is the same as in the specifications for the Buxton Woods test wells. Note that a gravel pack around the screen is not specified because I could not find any mention of a gravel pack in the Buxton Woods test-well contract. However, Bill Magette installed No. 2(very coarse sand) "gravel" packs in all of the Buxton Woods wells. (See the Well Record forms at the back of my Buxton Woods report.) I think it might be desirable to specify gravel packs in the monitoring wells but, if we do, it is important that the gravel not extend more than a ft or two above the screen. In other words, we do not want gravel to extend across the confining bed above the screen.

SUPPLY WELLS

PURPOSE:

The purpose of the wells to be drilled, cased, developed, and pumped in accordance with these specifications is to replace selected existing supply wells in the Frisco wellfield of the Cape Hatteras Water Association.

WORK TO BE DONE:

It is the intention and meaning of these specifications to secure the drilling and development water-supply wells to maximum depths of about 70 ft, the furnishing and installing of casing and screens, and developing and pumping the wells. The proposal shall be based upon providing the material, labor, and services, and for doing all things necessary for the construction and completion of the work called for under these specifications.

The supply wells shall be drilled by the hydraulic rotary method and shall have a minimum diameter of 6" for the entire depth of the hole. The work shall include: drilling; furnishing and installing casing; cleaning and developing; conducting well-acceptance tests; and preparation of logs of all materials penetrated and conditions encountered.

The job will involve the drilling of a minimum of nineteen supply wells at the locations shown on the attached map and the construction of permanent supply wells in each hole as specified hereinafter. The order in which the wells will be drilled will be specified by the project Engineer.

Note- I seem to recall from the conference in your office that it is Jims intention to have this contract cover the construction of all 19 supply wells. If this is, in fact, his intent, will the CHWA also contract for the work involved in disconnecting the existing wells from the wellfield main and connecting the new wells? This will be no small job.

The alternative, of course, would be to contract for, say, five new supply wells at a time. If this course were followed, the first five wells should be either in the center of the 1968 line or drilled as replacements for wells now causing sand problems.

LOCATION:

The wells are to be drilled near Buxton, North Carolina, at the sites shown on the attached map. All sites are within 10' of the existing supply wells and are readily accessible from the wellfield service road.

LOCAL CONDITIONS AND GEOLOGY

It is expected that the wells will be drilled through interbedded fine to medium sand, shell layers, and clayey silt. Information concerning the nature of the formations is not guaranteed by the Engineer.

EQUIPMENT TO BE FURNISHED BY THE CONTRACTOR

(Same as the Buxton Woods contract, except that makeup water can be obtained from the existing supply wells.)

DRILLING PROCEDURES

Note- I assume you will want to specify in this section either that REVERT must be used or that it can be used at the driller's option.

I do not believe that geophysical logs are needed. I also don't think that samples of the material are needed, except to the extent that the driller needs samples to guide him on screen placement. I assume, however, that you will require the driller to keep a log of each well in the section on DRILLERS LOGS.

Glenn Anderson did not gravel pack the No. 3 replacement well because, I assume, it was not feasible in the space he had. I believe it will be worthwhile to gravel pack these wells. See pages 39-40 in my Buxton Woods report and pages 82-87 in my 1988 Cape Hatteras report. If it is decided to gravel pack, we will need to change the diameter specified above.

WELL-ACCEPTANCE TESTS

Upon completion of the well-development phase at each supply well, the Contractor will provide and install all necessary equipment and appurtenances required and will conduct a well-acceptance test to determine the specific capacity of each well. The equipment will include a pump with a power rating of no less that 2 1/2 nor more than 3 1/2 horsepower; a discharge pipe long enough to reach the nearest body of surface water or, if no nearby standing water, a surface depression that will prevent return of the water on the land surface to the well site; an accurately calibrated positive displacement flow meter capable of measuring flows of at least 75 gallons per minute; a gate valve on the discharge line; and an access port into the well for water-level measurements.

At least two hours prior to the beginning of each well-acceptance test, the Contractor will arrange for the Association to discontinue withdrawals from the existing supply well that is being replaced. The Contractor will, through the use of an electric tape or a chalked steel tape, measure to the nearest 0.1' the depth to the static water level in the well below the top of the casing, or some other convenient fixed point.

At the start of the test, the gate valve on the discharge line will be wide open and the clock time when the pump is started will be recorded by the Contractor to the nearest minute. The Contractor will measure and record the depth to the water level, the pumping rate, and clock time at intervals no longer than two minutes for the first twenty minutes. As necessary during this period, the Contractor will reduce the opening through the gate valve on the discharge line to prevent the water level from declining to the level of the pump.

Through changes in the setting of the gate valve, the Contractor will, within the first hour of the test, establish a steady drawdown in the well of no less than 30' and no more than 40'. The pumping rate of the well, when the drawdown is within this range, will be measured and recorded. Thereafter, and for the remainder of the test, the yield of the well will be maintained at <u>a constant rate</u> by small, incremental increases in the gate-valve opening. After the pumping rate has been stabilized, the test will be continued for a period of at least four hours. During this period, both the pumping rate and the drawdown will be measured and recorded at least every 1/2 hour. At the end of the test, the Contractor will calculate and record the specific capacity by dividing the pumping rate by the drawdown.

Note - *State regulations require 24-hour well-acceptance tests for public water-supply wells. (See p. 82 of my 1988 Cape Hatteras report.) Our knowledge of the response of the Buxton Woods aquifer makes such long tests unnecessary. Can the CHWA get a "variance" from Fred Hill?*

It is the intent of the Association and of these specifications to insure, through design and effective well development, the construction of hydraulically-efficient wells. The specific capacity of the existing supply wells in the Frisco wellfield ranges from 0.4 gpm/ft to 5.8 gpm/ft and, for the 44 wells, averages 3 gpm/ft. It is expected that wells drilled under this contract will have specific capacities between 3 and 4 gpm/ft. No well with a specific capacity less than 2.0 gpm/ft will be accepted by the Association and the Contractor must undertake, without cost to the Association, additional development and any other actions needed to increase the specific capacity.

If the Contractor fails to bring the specific capacity up to a minimum of 3.0 gpm/ft, the Association will reduce its payment to the Contractor for all reimbursement due under the contract for the well by 2% for each 0.1 gpm/ft that the specific capacity is less than 3.0 gpm/ft.

On the other hand, the payment to the Contractor by the Association will be increased by 2% for each 0.1 gpm/ft that the specific capacity of any well exceeds 4 gpm/ft.

Note - *I am not sure the penalty and reward clauses above are in the proper legal form and I am sure we will want to discuss this idea before the contract is in final form.*

I am sending Jim a copy of this letter because I know he will want to respond to some of my comments.

Sincerely,

Ralph C. Heath

rch/mh
cc Coleman

RALPH C. HEATH

Consulting Hydrogeologist

4821 Kilkenny Place
Raleigh, N. C. 27612
(919) 782-0171

December 6, 1994

Mr. William Diehl
Diehl & Phillips
219 E. Chatham St.
Cary, N.C. 27511

Dear Bill:

Our three-way telephone conversation with Jim last Friday prompted me to give additional thought to the design of the replacement supply wells for the CHWA Frisco wellfield. The results are presented in this letter for your consideration later when you prepare the drilling contract.

The references that I looked at are:

1. ***Basic Ground-Water Hydrology;*** USGS WSP 2220, p. 56-57

2. ***Groundwater and Wells,*** 2nd Ed. - Chapter 13, Water Well Design

3. ***Report on the Proposed Buxton Woods Well Field...*** - Figure 3.

4. ***Ground Water Manual;*** U.S. Bureau of Reclamation, Table 11-9 (copy attached).

I will refer to these in the following paragraphs as Ref. 1, Ref. 2, etc.

Ref. 3 shows sieve analyses of the split-spoon samples obtained in 1990 during the construction of Buxton Woods test well No. 1. Note especially sample No. 3, from a depth of 60-62 ft, which I assume represents the grain-size distribution in the zone we intend to screen in the Frisco wells. The position of the sample in relation to the electric log is shown in Figure 2 of Ref. 3.

The median grain size of sample No. 3 is about 0.25 mm, or about 0.01 inch. Ref. 2 (p. 435) suggests that the slot size of screens in naturally-developed wells have openings that will retain about 50% of the formation. This means that the finest-grained 50% will be removed during well development. Using this criterion, naturally-developed wells in the Buxton Woods aquifer would be finished with 10 slot screens (10/1000 inch openings).

On the other hand, if the wells are gravel packed with No. 2 "gravel," which is very coarse sand with a diameter of about 1 mm or 0.04 inch, a larger slot-size screen could be used. Incidentally, No. 2 gravel appears to be the appropriate size, according to the criteria on p. 441 of Ref. 2. If No. 2 gravel is used, a slot opening that will retain 90% of the gravel can be used. I do not have a sieve analysis of the No. 2 gravel but I believe a 30-slot screen would be the recommended size.

With the above points in mind, I next want to consider the actual well design. This topic is covered on pages 56-57 of Ref. 1. Because we anticipate that wells at the west end of the field (west of well No. 9) will be pumped at a smaller rate than those to the east, I am going to consider the design of wells with two different yields - 50 gpm and 75 gpm. The basic design criteria will be that the entrance velocity through the screen openings not exceed 6 ft/min.

Naturally - developed wells

(1) Yield 50 gpm = 6.7 ft ^{3}/min.

Screen opening 10/1000 inch (10 slot)

Screen diameter 6 in : open area = 0.136 ft^2/ft (Ref. 4)

Open area needed

= Yield ÷ entrance velocity = 6.7 ft^3/min ÷ 6 ft/min = 1.1 ft^2

Length of screen = 1.1 ft^2 ÷ 0.136 ft^2/ft = 8.1 ft

Add 50% to compensate for partial blockage of screen openings by sand (values rounded) 8 ft + 4 ft = 12 ft

Length of screen needed = 12 ft (round downward to 10 ft?)

(2) Yield 75 gpm = 10 ft^3/min

Multiply length of screen in (1) by 1.5 (ratio of yields)

Length of screen needed = 18 ft (12+6) (I will comment on this below.)

Gravel - Packed Wells

(3) Yield 50 gpm = 6.7 ft^3/min

Screen opening 30/1000 inch (30 slot)

Screen diameter 6 in: open area = 0.34 ft^2/ft (rounded from 0.339)

Open area needed = 1.1 ft^2 (see above under (1))

Length of screen 1.1 ft^2 ÷ 0.34 ft^2/ft = 3.2 ft

Add 50% : 3.2 ft + 1.6 ft = 4.8 ft

Length of screen needed = 5 ft (rounded from 4.8 ft)

(4)Yield 75 gpm = 10 ft^3/min

Multiply length of screen in (3) by 1.5

Length of screen needed = 7.5 ft (round to 8 ft)

Wells constructed according to the above designs, if effectively developed, should have specific capacities larger than 4 gpm/ft.

However, in deciding on the final design and in preparing the drilling contract, there are two very important considerations to keep in mind. First, in No. (2) above the calculated length of screen needed is 18 ft. However, the electric log of Test Well 1 in Buxton Woods indicates that the most permeable zone occurs between 61 and 69 ft and thus is only about 8 ft thick. (See p. 29 of Ref. 3). This is believed to be the zone now screened in well No. 3 in the Frisco field and, presumably, is the zone that contains the good-quality water. In an effort to insure that this quality of water is obtained from the new supply wells, I do not believe that screens longer than 10 ft should be used and the above calculations show that if the wells are gravel packed the maximum length of screen needed is 8 ft.

The second point concerns the length of the gravel packs, if you decide to gravel pack the wells. You may recall that the wells drilled in 1968 and wells 7A through 16A were apparently finished with 5 ft lengths of 40 slot screens set at the bottom of a 20 to 25 ft very coarse sand "gravel" pack. (See p. 80-81 of my 1988 report.) In an effort to keep the new supply wells isolated from the poor-quality water that occurs above the 60-70 ft zone, I do not believe gravel packs should extend more than about 2 ft above the top of the screens.

Now, let me see if I can summarize the highlights of the preceding paragraphs. They are:

Wells 4 thru 8 - Yields limited to 50 gpm and can be either naturally developed or gravel packed. If naturally developed, install 10 ft of 10 slot screen. If gravel packed, install 5 ft of 30 slot screen in an 8 ft long very coarse sand pack.

Wells 9 thru 22 - Yields limited to 75 gpm and wells must be gravel packed. Install 8 ft of 30 slot screen in 10 ft long very coarse sand pack.

Finally, Jim mentioned during our conversation that Glenn Anderson has data supplied by Cook Screens that shows that 4-inch diameter screens have the same open area per ft of length as 6-inch diameter screens. This indicates that a thicker wire is used in the 6-inch screens than in the 4 inch screens. Thicker wire is, of course, stronger and can tolerate more corrosion. Ref. 4 (attached) also deals with Cook screens and shows that when the same size wire is used the open area of 6-inch screens is about 50% larger than that in 4-inch screens

I believe that covers all the points that I wanted to cover at this time.

Sincerely,

Ralph C. Heath

rch/mh
copy to: Jim Coleman

GROUND WATER MANUAL

A WATER RESOURCES TECHNICAL PUBLICATION

A guide for the investigation, development, and management of ground-water resources

FIRST EDITION
1977

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

TABLE 11–9.—*Minimum open areas of screens in square feet per linear foot and the percentage of open area* [1]—Continued

[Cage-type wire-wound screen—telescoping sizes (from Cook Well Strainer Company)]

Sscreen size, inches	Wire size, inches	Slot size, thousandth of an inch										
		10	20	25	30	40	50	60	70	80	100	125
4	0.09	0.097	0.178	0.213	0.245	0.302	0.350	0.392	0.430	0.461	0.516	---------
		10.0	18.2	21.7	25.0	30.7	35.7	40.0	43.8	47.0	52.6	---------
6		0.136	0.247	0.295	0.339	0.418	0.485	0.542	0.593	0.637	0.722	---------
		10.0	18.2	21.7	25.0	30.8	35.7	40.0	43.8	47.0	52.6	---------
8		0.196	0.356	---------	0.490	0.604	0.700	0.784	0.858	0.923	1.032	---------
		10.0	18.2	---------	24.9	30.8	35.7	39.9	43.8	47.0	52.6	---------
8	.1467	0.125	0.236	0	0.334	0.421	0.500	0.571	0.625	0.694	0.797	0.904
		6.4	12.0	---------	17.0	21.5	25.5	29.9	32.4	35.4	40.6	46.1
10	.09	0.248	0.447	0.553	0.621	0.765	0.869	0.993	1.101	1.168	1.307	1.440
		10.0	18.7	21.7	25.0	30.8	35.7	39.9	43.6	47.0	52.6	58.0
10	.1467	0.159	0.299	---------	0.423	0.533	0.633	0.723	0.805	0.879	1.010	1.146
		0.64	12.0	---------	17.0	21.5	25.5	29.1	32.4	35.4	40.6	46.1
10	.1875	0.126	0.241	0.294	0.345	0.440	0.528	0.607	0.682	0.749	0.872	1.003
		5.0	9.6	11.7	13.7	17.5	21.0	24.2	27.1	29.8	34.7	40.0
12	.09	0.300	0.546	---------	0.751	0.926	1.115	1.208	1.316	1.414	1.582	1.054
		10.0	18.1	---------	24.9	30.8	35.7	39.9	43.7	47.0	52.6	58.0
12	.1467	0.192	0.362	---------	0.512	0.646	0.767	0.876	0.974	1.064	1.222	1.387
		6.4	12.0	---------	17.0	21.4	25.5	29.1	32.4	35.3	40.5	46.1
12	.1875	0.153	0.292	0.356	0.417	0.532	0.638	0.733	0.824	0.905	1.053	1.213
		5.0	9.7	11.7	13.7	17.5	21.0	24.2	27.1	29.8	34.7	40.0
14	.1875	0.180	0.345	---------	0.492	0.630	0.755	0.874	0.962	1.071	1.248	1.435
		5.0	9.7	---------	11.9	13.7	17.5	21.0	24.2	29.8	34.7	40.0
16	1.469	0.245	0.460	---------	0.652	0.821	0.975	1.117	1.239	1.353	1.555	1.764
		6.4	12.0	---------	17.0	21.4	25.5	29.1	32.4	35.3	40.5	46.1
16	.1875	0.191	0.367	---------	0.447	0.523	0.669	0.803	0.925	1.138	1.325	1.527
		5.0	9.7	---------	11.7	13.7	17.5	21.0	24.2	29.8	34.7	40.0
18	.1875	0.219	0.416	0.510	0.596	0.762	0.913	1.050	---------	1.296	1.505	1.735
		5.0	9.7	11.7	13.7	17.5	21.0	24.2	---------	29.8	34.7	40.0
20	.1875	0.246	0.468	0.571	0.669	0.854	1.027	1.177	---------	1.458	1.690	1.945
		5.0	9.7	11.7	13.7	17.5	21.0	24.2	---------	29.8	34.7	40.0
24	.1875	0.298	0.567	0.692	0.811	1.034	1.240	1.426	1.599	1.760	2.047	2.180
		5.0	9.6	11.7	13.7	17.5	21.0	24.2	27.1	29.9	34.7	40.0

[1] Top value shown is ft^2/ft and bottom value is percent.

APPENDIX NO. 4

GROUND-WATER RESOURCES OF THE CAPE HATTERAS AREA OF NORTH CAROLINA

September 1988

RALPH C. HEATH

Consulting Hydrogeologist

4821 Kilkenny Place
Raleigh, N. C. 27612
(919) 782-0171

If we assume that the slope of the static water levels in the CHWA wells is the same as the slope of the water-table divide, and that under natural (pre-pumping) conditions the elevation of the water-table divide opposite the east end of the well field was about 6 ft, then the average elevation of the divide would have been about 3.5 ft south of Frisco and about 9 ft south of Jennette Sedge. Data supplied by the NPS on well elevations and water levels for the new supply wells at the Buxton maintenance area, which are near the divide, tend to confirm the estimated elevation of the water-table divide near the eastern end of the area.

Freshwater-Saltwater Relationship

It is widely known that fresh ground water on islands and in coastal areas occurs as a lens "floating" on saltwater. This situation exists because, when equal volumes are considered, freshwater weighs slightly less than seawater. The difference in weights of freshwater and seawater are such that under ideal conditions, which seldom exist in nature, the freshwater lens extends 40 times as far below sea level as the height of the water table above sea level. This relation is commonly referred to in ground-water reports as the Ghyben-Herzberg relationship.

It is important to note at this point that there is not a sharp plane of contact between freshwater above and saltwater below. Saltwater moves a short distance inland during incoming tides and mixes with the outflowing freshwater. This results in a zone of diffusion across which the salinity changes from that of freshwater to that of seawater. The width of the zone of diffusion depends on the range in the tides and differences in horizontal and vertical hydraulic conductivity. It ranges in thickness, in different aquifers, from less than 100 ft to several 100 ft.

In a stratified aquifer, such as Buxton Woods, the depth to the zone of diffusion between freshwater and saltwater is substantially less than 40 times the height of the water table above sea level because of the difference in horizontal and vertical hydraulic conductivity of the aquifer materials. The USGS, in its study of the ground-water resources of the Cape Hatteras National Seashore (Winner, 1975, sheet 1), estimated that the Ghyben-Herzberg ratio in the Frisco area is about 1:25 - that is, the freshwater zone is only 25 times as far below sea level as the elevation of the water table above sea level. A chloride content of 250 milligrams per liter (mg/l) was used by the USGS as the "contact" between freshwater and saltwater.

When water tables are lowered, as by withdrawals from wells, saltwater advances into aquifers in the process referred to as salt-water encroachment. Saltwater encroachment can be understood by realizing that the position of the freshwater-saltwater contact is controlled by ground-water discharge. The ground-water discharge is, in turn, controlled by ground-water recharge. Therefore, under natural (non-pumping) conditions, when all recharge reaches the shoreline as natural ground-water discharge, the freshwater lens has its greatest vertical and lateral extent. When water is withdrawn through wells and moved by pipelines to distant locations, the natural discharge is reduced and the saltwater front moves landward to a new position that is in balance with the smaller rate of natural discharge. The advance of the saltwater front into an aquifer can be detected from chloride analyses 1/ of water samples from wells.

1/ The dominant mineral dissolved in seawater is common salt or sodium chloride (chemical symbol NaCl). Therefore, the concentration of salt in a water sample can be determined simply by analyzing the chloride (Cl) content.

Chloride analyses of water samples from both supply wells and observation wells in the CHWA well field are listed in the table of well records in Appendix C. These include analyses of water samples collected in 1968 from the initial wells and analyses of samples collected in June 1988. The "normal" chloride content of the water in the upper part of the Buxton Woods aquifer at the CHWA wells ranges from about 30 to about 50 mg/l. Comparison of the analyses of water samples collected from the supply wells in 1968 and 1988 do not show any consistent or significant change.

From the standpoint of the CHWA water supply, the most significant chloride analyses are those from the deep observation wells at each end of the well field, specifically wells 3D, 21D, and 21E.

Wells 3D and 21D are screened near the bottom of the Buxton Woods aquifer and well 21E is screened in the silty clay confining bed that underlies the aquifer. (See log for well 21E in Appendix A.) Assuming that water in the aquifer beneath the confining bed is saltier than the water in the Buxton Woods aquifer and assuming that the confining bed is somewhat leaky, as the description of the material suggests, these three wells, and especially well 21E, should be the first to show an increase in chloride content in response to the withdrawals. Instead of showing an increase, the chloride content of well 3D, during the 20 years between 1968 and 1988, decreased from 76 to 55 mg/l. During the same period, the chloride content in well 21D decreased from about 70 to 55 mg/l.

The lack of a significant change in the chloride content of well 21D over the last 20 years is surprising in view of a test conducted by Magette Well Co. in 1967. During the test, which was probably conducted in late November, well 21 was pumped continuously for 33 hours at a rate of 25 gpm and water samples for chloride analyses were collected at intervals from well 21D. The results are shown in the following table.

Chloride Test on Well 21D

Hours after pump started	Chloride content (mg/l)	Hours after pump started	Chloride content (mg/l)
0	38	13	62
1	40	17	66
2	45	21	66
3	45	25	67
4	49	29	70
5	49	33	70
9	57		

This test suggests that salty water moved upward across the confining bed, in the process referred to as "upcoming," as a result of the drawdown in water level caused by pumping well 21. Based on this test, I expected to find a significant increase in chloride content in 1988 in both wells 3D and 21D. This, however, is not the case.

Unfortunately, the situation with well 21E is much more complicated. The USGS established a brief water-level measurement and chloride-sampling program in late 1969 on three wells at the east end of the well field. Two of the wells (USGS Nos. Da 348 and Da 349) were reported to be located north of the waterplant road between the well field and the waterplant. These wells apparently no longer exist and efforts to locate the site in 1988 were not successful. The third well in the USGS program (USGS No. Da 350) is well 21E. According to the USGS record for well 21E, it was to be sampled monthly for chloride but only one value, of 60 mg/l, is reported and that for April 1, 1970. Attempts to find other analyses in the USGS files were unsuccessful.

Complications with respect to these three USGS observation wells arise in connection with wells Da 348 and Da 349. Well Da 348 is reported to be 13 ft deep and Da 349 is reported to be 8 ft deep. Thinking that it is unlikely that the USGS would operate two such shallow observation wells at the same site, I assume that an error was made in recording the depth of Da 348 and that it was, in fact, 43 ft deep which is the depth shown on the driller's log. The chloride content of well Da 348 is shown in the USGS records as about 40-45 mg/l, except for one questionable analysis (USGS question, not mine) of 107 mg/l in early January 1971. An analysis of chloride is reported for well Da 349 and it a surprising value of 1200 mg/l on December 11, 1969. Thinking such a value is not likely for an 8-ft deep well, I assumed that the samples were mislabeled and the value of 1200 mg/l really applied to well 21E. Again, two attempts to locate the original laboratory records in the USGS files were unsuccessful.

Regardless of the values reported by the USGS, it was clearly essential to obtain a sample of water from well 21E as a part of this study. Efforts to obtain a sample for chloride analysis in June 1988 were at first unsuccessful because of blockage of the screen by silt and clay. An air compressor was used to unplug the screen and to clear the stagnant water from the casing. The sample of water obtained in this operation had a chloride content of 200 mg/l and a specific conductivity of 1200 micromhos.

The fact that the specific conductivity in 1988 had the same numerical value as the chloride content reported by the USGS in 1969 suggests the possibility that specific conductivity may have been recorded as chloride in 1969. It seems, at this point, that there are three choices for the chloride content of well 21E. These are:

1. The chloride content was 60 mg/l in 1969 and was 200 mg/l in 1988,
2. The chloride content was 200 mg/l in 1969 (with a specific conductivity of 1200 micromhos) and was still 200 mg/l in 1988, or
3. The chloride content was 1200 mg/l in 1969 and was 200 mg/l in 1988.

If choice No. 1 is correct, the chloride content has increased about 3 times since 1969. If choice No. 2 is correct, there is no change. If choice No. 3 is correct, the chloride content has decreased to 1/6 its value in 1969. Of these choices, I am presently inclined to accept No. 1.

In order to learn more about the freshwater-saltwater relationship in the Cape Hatteras area, we must look at chloride data from other parts of the area. Water samples were obtained from two intervals in the deep test well drilled by the N.C. Groundwater Section at the NPS Buxton maintenance area in 1971. Water in the interval from 196 ft to 206 ft had a chloride content of about 1900 mg/l, or about 1/10 that of seawater. The chloride analysis for the second interval sampled, 375-384 ft, could not be found but the chloride content is estimated to be about the same as seawater on the basis of a reported specific conductivity of 50,000 micromhos/cm. On the basis of these analyses, it seems safe to conclude that all permeable zones below the confining bed that underlies the Buxton Woods aquifer contain salty water. In other words, the confining bed separates the freshwater in the Buxton Woods from the underlying salty water in the central part of the Cape Hatteras area where water-table elevations are high enough to have caused saltwater to be completely flushed from the aquifer.

The next topic of interest at this point is the nature of the freshwater-saltwater contact in the ground-water discharge areas. As noted in the preceding section, the elevation of the water table declines toward these areas and, remembering the Ghyben-Herzberg relationship, the freshwater-saltwater contact must rise.

The USGS conducted comprehensive sampling programs in connection with studies for the NPS at both cape point and the Frisco Campground. Chloride content of water samples collected in 1960 in the cape point study are shown opposite the depths sampled on Figure 6. The chloride contents range from 12 mg/l, in well B3, to 3,950 mg/l in well B7, which was the closest well to the point. Figure 20 is a cross section through the north-south line of wells on which lines showing equal chloride concentrations have been drawn. Such lines are referred to as isochlors and, as expected, they rise toward the south in the direction of the ground-water discharge area along the shoreline. Another significant feature to note is the "wavy" shape of the isochlor lines. This shape is a result of differences in hydraulic conductivity of the different layers comprising the aquifer. Salty water flushes more rapidly from the permeable, coarse-grained layers than from the fine-grained layers with the result that fresh water extends farther to the south in the more permeable layers.

An "interfingering" of fresh and salty water like that shown in Figure 20 was also observed in the intensive sampling program conducted by the USGS in the Frisco Campground area (Harris and Wilder, 1964, p.8) and probably exists along the entire south coast of the Cape Hatteras area. This is a significant hydrologic feature which is, incidentally, consistent with Fisher's findings relative to recent changes in the Cape Hatteras land area. As noted in the section entitled Origin of Hatteras Island, Fisher found that the southern third of the Cape Hatteras area is less than 350 years old with the youngest area being that along the south coast. The fact that freshwater is closest to the coast in the more permeable zones in this area indicates that salty water is still being actively flushed from the Buxton Woods aquifer along the south coast. In other words, the time interval since this area was formed is not yet long enough for the seawater, that was present in the sediments when they were deposited, to be flushed out. It is worth noting here that where saltwater encroachment is occurring, salty water will extend farther landward in the more permeable zones. In other words, the reverse of the situation that existed in the cape point area along the south coast in 1960.

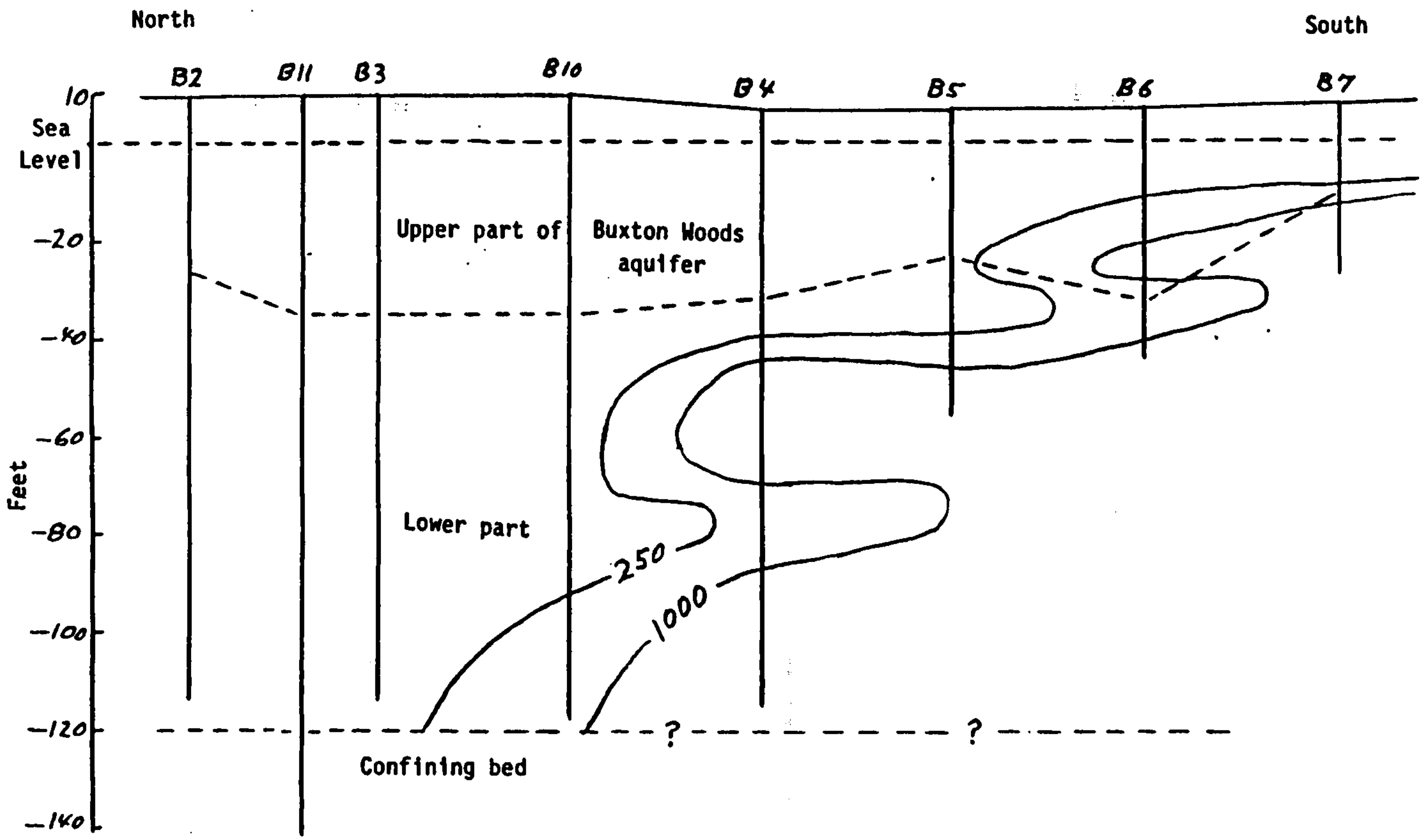


Figure 20.-- Cross section of the cape point area showing lines of equal chloride content. Concentrations are in mg/l.

With the preceding discussion of freshwater-saltwater relationships in mind, it will be useful at this point to present a generalized sketch of the freshwater lens along line A-A' on Figure 2. This sketch is shown in Figure 21. The confining bed that underlies the Buxton Woods aquifer is shown on the sketch to dip toward the south on the basis of the different depths at which it was penetrated by well 21E and the deep USGS test well in the Frisco Campground.

One well in each of the CHWA well lines is also shown on the sketch. The contact between freshwater and saltwater on the sketch is intended to represent the position of the 250 mg/l isochlor. The interfingering of freshwater and saltwater on the ocean side of the area is schematic and does not necessarily represent the actual position of coarse-grained and fine-grained layers. The "upconing" of salty water beneath the drainage ditch is intended to reflect the effect on the freshwater-saltwater interface of the lowering of the water table by the ditch.

Finally, I noted near the beginning of this section that the chloride content of the water produced by the CHWA supply wells ranges from about 30 to 50 mg/l and that there has been no significant change since 1968. Now, note that the chloride content of the water in the upper part of the Buxton Woods aquifer in wells B2, B3, and B11 near the center of the island in the cape point area, as shown on Figure 6, is less than 20 mg/l. These values are believed to represent the chloride content of the recharge reaching the water table. Why then is the chloride content of water from the CHWA supply wells more than twice that of the cape point wells? Two possible explanations come to mind. First, the chloride content of ground water in the low northern part of the area may have been (and is being increased) by evapotranspiration from the saturated zone in the swales in this area. Or, second, the higher chloride content in the CHWA wells may be a result of inundation of the low swales in the northern part of the area by seawater during an exceptionally severe storm at some time in the past.

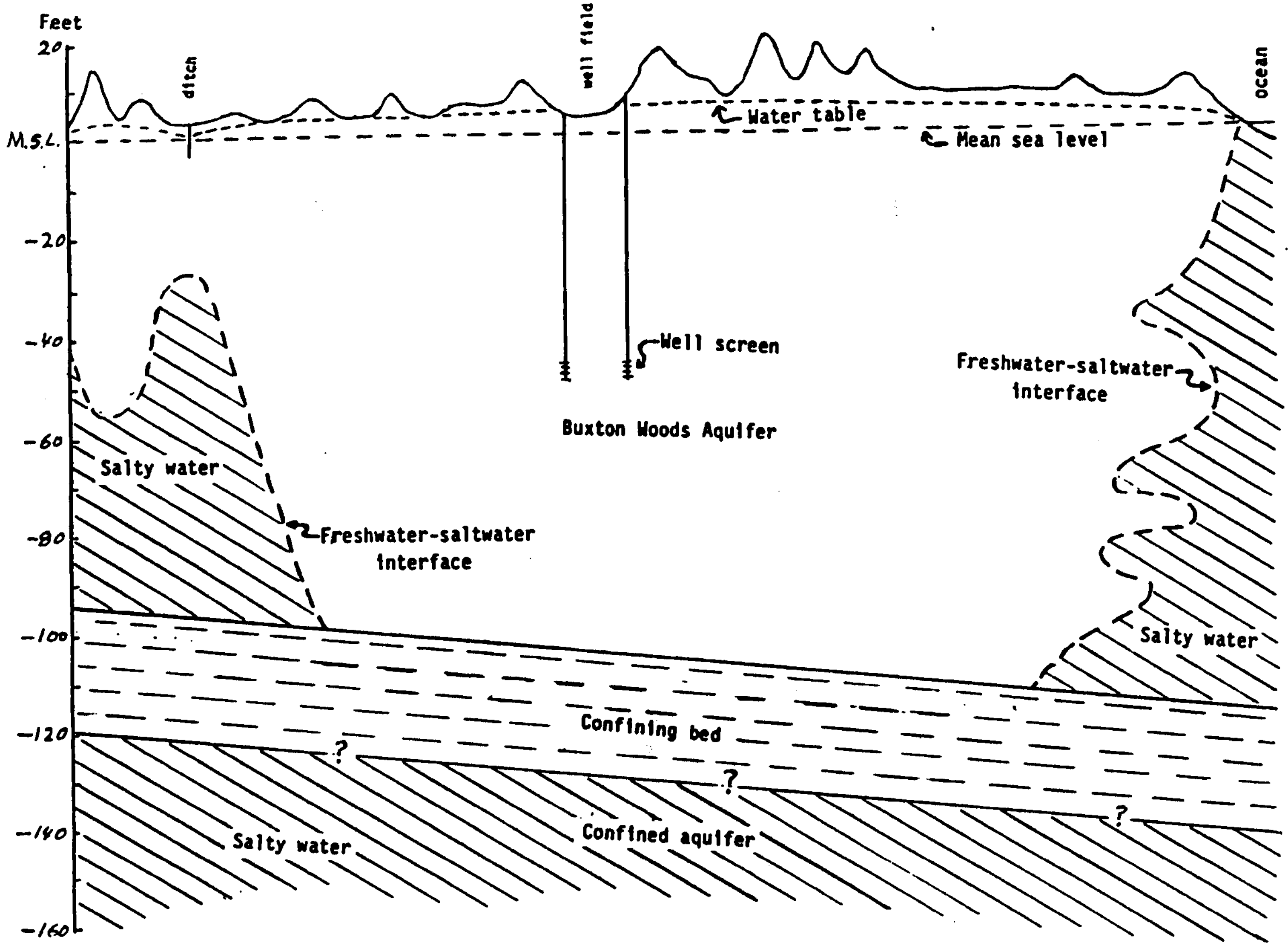


Figure 21.--Generalized sketch of the freshwater lens of the Buxton Woods aquifer along line A-A' on Figure 2.

well development or reevaluation of the use of plastic screens. The very small average specific capacity of the wells constructed in 1977 without gravel packs emphasizes the importance of gravel packs for wells in the Buxton Woods aquifer.

The preceding paragraphs of this section have dealt with the yields and the specific capacities of the CHWA supply wells. All of the values of these two parameters are tabulated in Appendix C. However, for the purpose of system management, a convenient means is needed for comparing the performance of the different wells and the different groups of wells. Figures 32 and 33 are an attempt to provide such a means.

The points at the top of each line on these figures show the position of the static (non-pumping) water level and the points at the bottom of the lines show the pumping water level. The lengths of the lines, therefore, graphically show the drawdown in each well. The numbers at the top of the lines show the pumping rates. The numbers of the wells are shown at the bottom of each line.

The relative inefficiency of wells 18A, 19A, and 20A, three of the wells that do not have gravel packs, is readily apparent on Figure 32. At some convenient time in the future it might be desirable to pull the pump from one of these wells to see if additional development will improve its performance. Well 20 has a small drawdown but also has a small yield (7 gpm). This suggests the need to replace the pump in this well. Figure 33 suggests that it might be useful also to do additional development on wells 22A, 24A, 25A, 26, and 26A whenever the pumps on those wells are pulled for repair or replacement.

Water Quality of the Buxton Woods Aquifer

The water pumped by the CHWA supply wells from the Buxton Woods aquifer is very hard, moderately colored, and contains an excessive concentration of iron. The water, therefore, requires treatment prior to delivery to members of the association. The following table contains selected water-quality data from two representative supply wells.

Data on Water Quality of the CHWA Supply Wells

Constituent or property	Units	Well No. 7	Well No. 7A
Color	Std. units	42	115
Chloride	mg/l	37	35
Iron	mg/l	1.27	3.94
Total hardness (as $CaCO_3$)	mg/l	232	274
Turbidity	mg/l SiO_2	15	4.2
Date sampled		3/15/68	1/30/79

Analyses by Division of Health Services, N.C. Dept. of Human Resources

Analyses of samples from the same well over the period of operation of the well field, which would show time-related changes in water quality, were not located. Therefore, the above analyses, which are for wells about 250 ft apart, were selected.

It might be useful at this point to comment briefly on the significance of the above analyses relative to the Buxton Woods aquifer.

Color is a property imparted to water by complex organic substances, some of which are in suspension in the water and some of which are dissolved. The brown color of surface water in the swales is due to the presence of these substances. The color of the water from the Buxton Woods aquifer may be due either to recharge derived from swales or to organic substances dissolved from buried swamp deposits.

Chloride has previously been mentioned in the discussion of the freshwater-saltwater relationship and need not be covered here.

Iron in concentrations of a few tenths of a mg/l imparts an objectionable taste to water and causes staining of laundry and water fixtures. Some of the iron in water from the Buxton Woods aquifer may be dissolved when the water moves through buried swamp deposits and some of it may be attached to the organic matter that causes color.

Total hardness is a measure of the concentration of dissolved compounds containing calcium and magnesium. It is objectionable in water for domestic use when it exceeds about 100 mg/l. The calcium and magnesium compounds dissolved in water from the Buxton Woods aquifer are derived from the aquifer layers containing fossil sea-shells which are reported in most of the test-well logs.

Turbidity is a property imparted to water when it contains very fine-grained particles of aquifer material such as clay and silt. Excessively large values suggest inadequate well development and, for this reason, the turbidity should decrease with time as wells are pumped.

Chemical analyses of water from the Buxton Woods aquifer suggests that there are significant differences in water quality both from place to place in the aquifer and from one depth to another. Because treatment of the water is a significant expense and one that will increase in the future along with increasing costs of energy and chemicals, it seems desirable, when the well field is extended into new areas, that a careful sampling program be conducted during test-well construction to locate producing zones that have the best quality water.

The water-quality analyses available at this time also suggest that some of the constituents and properties may change with time. Such changes are suggested by the following data on color for wells drilled in 1967 and in 1977.

Data on Color in the CHWA Supply Wells

Well group	No. of wells	Color (in standard units)	
		Average	Range
1967	17	48	25-75
1977	14	186	45-325

Because the 1977 wells were drilled midway between the wells drilled in 1967, it seems most likely that the increase in color shown in the above table is a result of increased recharge from the swale along which the wells were drilled. An alternate explanation is that the differences in color are due to differences in well construction. In either case, the differences emphasize the need for a more intensive water-quality sampling program.

Ralph C. Heath

APPENDIX NO. 5

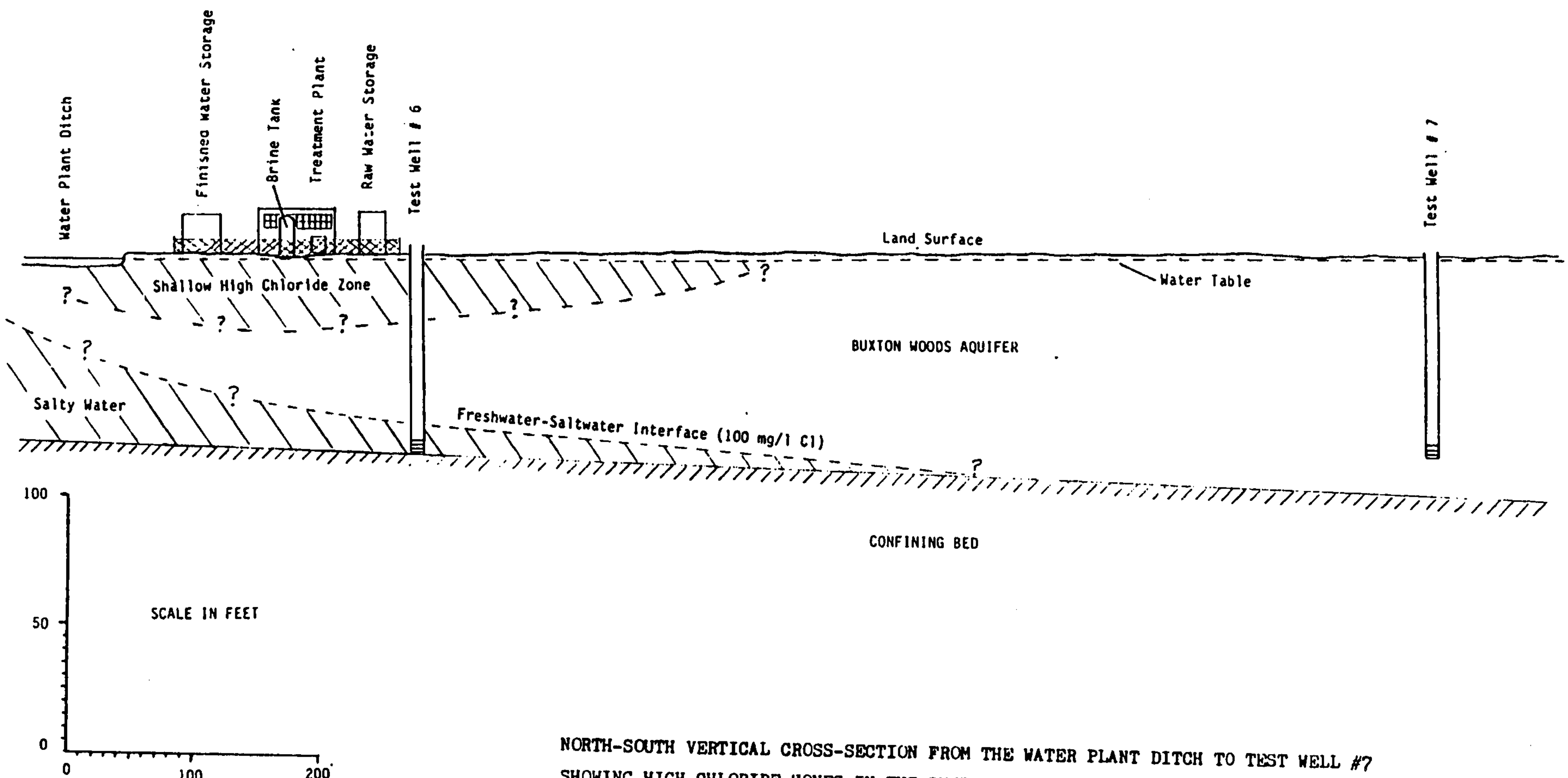
REPORT ON OUTPOST OBSERVATION WELLS OF THE FRISCO WELL FIELD OF THE CAPE HATTERAS WATER ASSOCIATION

June 1990

RALPH C. HEATH

Consulting Hydrogeologist

4821 Kilkenny Place
Raleigh, N. C. 27612
(919) 782-0171



NORTH-SOUTH VERTICAL CROSS-SECTION FROM THE WATER PLANT DITCH TO TEST WELL #7 SHOWING HIGH CHLORIDE ZONES IN THE BUXTON WOODS AQUIFER.

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

June 1990

RALPH C. HEATH

Consulting Hydrogeologist

4821 Kilkenny Place
Raleigh, N. C. 27612
(919) 782-0171

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

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.

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SUMMARY OF PRELIMINARY REVERSE OSMOSIS TEST WELL CONSTRUCTION FOR THE CAPE HATTERAS WATER ASSOCIATION BUXTON, NORTH CAROLINA

Prepared for

Cape Hatteras Water Association
P.O. Box 578
Buxton, North Carolina 27920

Prepared by

Missimer International, Inc.
8140 College Parkway, Suite 202
Fort Myers, Florida 33919

August, 1995

Project Number
FH4-088

Wm. Scott Manahan
Project Manager

W. Kirk Martin, P.G.
North Carolina
Professional Geologist #1112

FH4-088.RP1

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I. CONCLUSIONS AND RECOMMENDATIONS

A preliminary evaluation of the brackish groundwater resources available beneath Hatteras Island has been completed. The study was undertaken because additional water for public supply purposes is required to meet increased demands associated with population growth on the island. The following conclusions and recommendations are presented based on the results of drilling and testing conducted as part of this preliminary investigation.

A. Conclusions

1. Three test wells were constructed near the Cape Hatteras Water Association (CHWA) water treatment plant on Hatteras Island. The wells were completed within the Miocene age Yorktown Formation. Two of the wells were completed as dual zone piezometers. A high permeability limestone unit was encountered in each of the wells between the approximate depths of 240 and 280 feet below land surface.

2. Pump tests were conducted on all three of the test wells. The productive capacity of the upper zone in each of the test wells was very good based on the pump test results. Calculated specific capacity values ranged from 90 to 190 gpm/ft in the upper zone. Both the upper and lower potential production zones were tested in test well TW-2. The lower zone in well TW-2, however, exhibited poor yield potential.

3. Water quality varied considerably in the test wells. The dissolved chloride concentration of samples obtained from the upper limestone unit during the study ranged from 3800 mg/l in well TW-1 to 8750 mg/l in well TW-2. Samples obtained from the lower zone in well TW-2 had a dissolved chloride concentration of 10,800 mg/l.

4. The highly productive limestone unit encountered between the approximate depths of 240 and 280 feet below land surface is the most viable source of brackish raw water supply for reverse osmosis treatment. This source appears to be adequate to supply 4 MGD or more of raw water if the resource is properly managed. Additional testing and analysis will be required to fully evaluate the yield characteristics and long term water quality of the zone.

B. Recommendations

1. Aquifer performance testing should be conducted to determine pertinent aquifer hydraulic coefficients. The existing test well TW-3 should be utilized as the test/production well and pumped at a high rate for a duration of at least 72 hours. Three observation wells should be constructed to tap the producing zone for the purpose of measuring drawdowns in the aquifer during the test. The observation wells should be located at approximate distances of 100, 300, and 1000 feet from the test/production well.

2. Additionally, monitor wells that tap discreet intervals should be constructed near the bottom of the producing zone and at the base of the limestone unit. Anticipated completion depths are from 300 to 310 feet below land surface and 400 to 410 feet, respectively. These open hole type wells will provide information on the vertical variation of water quality in the sediments underlying the proposed wellfield area. The monitor wells should be located near the test/production well proposed for use during aquifer performance testing. Additional monitor wells should be constructed near the distal ends of the proposed wellfield alignment to further assess water quality variations in the aquifer. All of the wells can be used for monitoring water levels and water quality when the proposed wellfield is in operation. Data obtained from the wells can be used to evaluate wellfield performance and can also provide an early warning of potential problems or

unexpected water quality changes in the wellfield. The well top elevations should be surveyed so that water levels can be referenced to NGVD.

3. A hydrogeologist should supervise construction of the proposed monitor wells and recommend cased and total depths for each of the wells. Lithologic logs of the sediments encountered during drilling should be prepared. The hydrogeologist should also supervise the aquifer performance test and determine pumping rate, water level measurement, and sampling intervals.

4. Water samples should be obtained from the monitor and observation wells before and after the aquifer performance test. Samples should be taken from the test/production well periodically throughout the test and analyzed for salinity parameters. The water quality data should be reviewed to assess the effects of pumpage on water quality in the aquifer.

5. Hydraulic and solute transport computer models of the brackish aquifer system underlying Hatteras Island should be developed. Aquifer hydraulic coefficients, water quality, and other input data used in the model should be determined from the results of on-site testing and analysis. The models should be used to determine a wellfield design and operation schedule that results in the most stable and reliable feedwater for the proposed reverse osmosis plant. Once developed, the models can also be used to evaluate the feasibility of various future wellfield expansion scenarios.

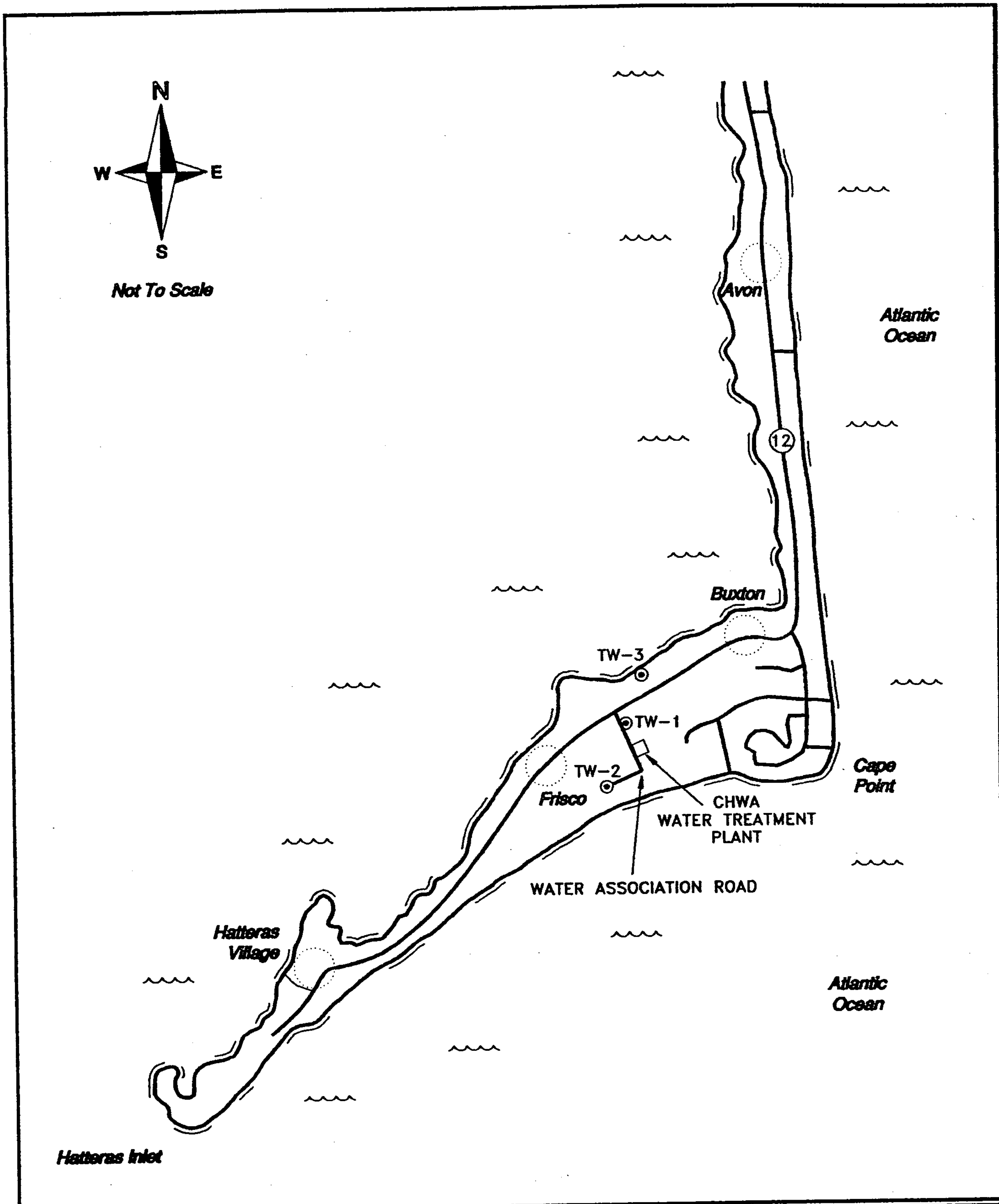
6. A report should be prepared that describes the procedures and methods used during monitor well construction and aquifer performance testing. All pertinent data should be assembled in the report along with a description of how the computer models were set up and utilized. Conclusions and recommendations regarding the design and operation of the proposed wellfield should be presented.

7. Technical specifications for the construction and testing of the proposed reverse osmosis supply wells should be prepared based on results of the investigation. The specifications should include drilling methods, well completion techniques, and anticipated cased and total depths of the wells. The specifications should be made available to potential contractors for bidding the job.

II. INTRODUCTION

Missimer International, Inc. (MI) was authorized in March of 1995 to conduct test drilling for the Cape Hatteras Water Association (CHWA) on Hatteras Island, North Carolina. Drilling and testing were conducted to obtain information on the geologic and hydrologic conditions beneath the island. The information was collected in order to make a preliminary evaluation of the potential for developing a brackish raw water supply for reverse osmosis treatment on the island. The CHWA plans on developing a source of water that may ultimately generate 2.4 million gallons per day (MGD) or more of potable water for public supply purposes. Freshwater resources available in the water-table aquifer are currently being utilized to the maximum extent possible. Increased pumpage from the water-table aquifer is not allowable due to regulatory concerns of environmental impacts and the potential for saltwater intrusion into the wellfield.

The original scope of the investigation was to include the construction and testing of a single test well into the Mid-Yorktown Aquifer. The proposed cased and total depths for the well and completion technique were based on regional information from deep wells constructed in surrounding areas. The geologic sequence encountered in the initial test well was similar to that expected; however water quality conditions were not. Two additional test wells were constructed because of the variability in water quality encountered. The locations of the test drilling sites and the CHWA water treatment plant are shown on Figure II-1. The drilling and testing procedures utilized during the investigation are described in the following section of this report.



MISSIMER INTERNATIONAL	Pr Name: CAPE HATTERAS R.O. TEST WELL	Groundwater and Environmental Services
	Pr No. FH4-088 Date: 08/18/95	
	DWG No. FH4088S1.DWG Rev.No. 3	

FIGURE II-1. SITE MAP SHOWING THE LOCATIONS OF THE CAPE HATTERAS WATER ASSOCIATION WATER TREATMENT PLANT AND TEST WELLS TW-1, TW-2, AND TW-3.

III. WELL CONSTRUCTION AND TESTING

Skipper's Well Drilling, Inc. from Leland, North Carolina was contracted to conduct the test drilling. A hydrogeologist from MI supervised all drilling and testing activities and collected formation samples for lithologic analyses. Geologic descriptions of the various units penetrated during drilling are provided in Section IV of this report. Geologist's logs of the sediments encountered in each test well are provided in the appendices.

The mud rotary method was used to drill the three test wells. Drilling of the initial test well TW-1 began in the last week of March, 1995. The location of the well is shown on Figure II-1. The proposed design for the well was based on regional geologic data obtained during the construction of public supply water wells and oil exploration wells in the area. The original plan was to construct a 4-inch diameter well with a cased depth of approximately 300 feet below land surface and a screened section from a depth of approximately 300 feet to 400 feet.

During drilling, a severe loss of circulation zone encountered at a depth of approximately 255 feet below land surface temporarily halted the drilling operation. Well construction design was modified in order to test the zone for water production potential by constructing a 6-inch diameter PVC cased open hole well. Geophysical logs were conducted prior to setting casing and are included in the appendices. Casing was set at 240 feet and grouted in place. An open hole section was then drilled to a depth of 275 feet below land surface and the well was thoroughly developed to remove drilling mud and residual cuttings.

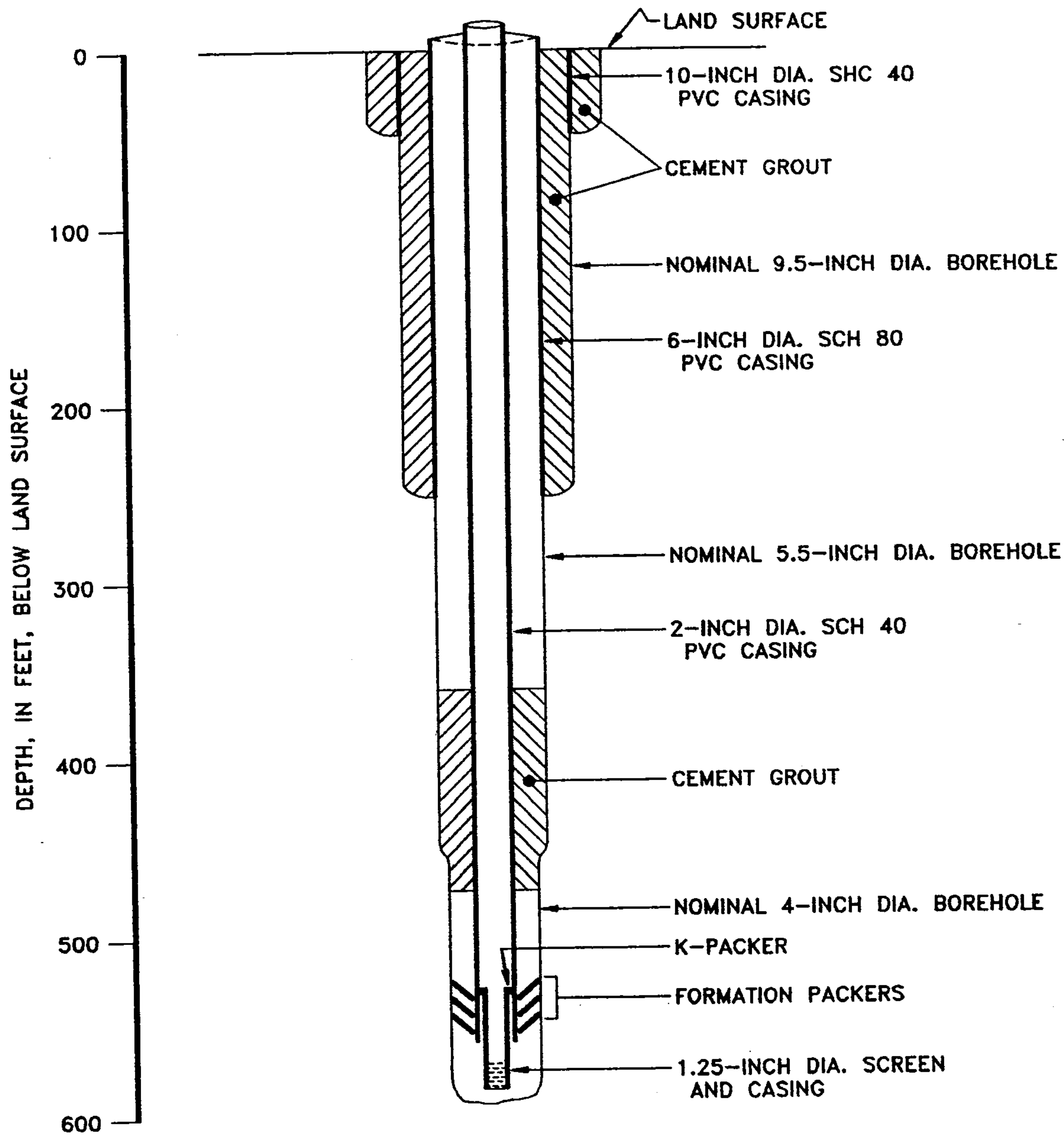
An aquifer test was conducted on the well after development was complete. Results of the pump test yielded a specific capacity of 189 gpm/ft at a pumping rate of 100 gpm. Water samples were obtained during the test and analyzed for dissolved chloride concentration. The samples obtained from well TW-1 had an average dissolved chloride concentration of 3800 mg/l. Water within the zone tested was more saline than anticipated so test drilling was continued in an attempt to locate a zone of better quality water.

A sandstone unit was encountered at a depth of 560 feet below land surface and penetrated to a total depth of 588 feet. Geophysical logging was again conducted prior to setting casing in the well. A string of 2-inch diameter casing was installed to the top of the sandstone unit, however, attempts to obtain a good representative water sample from the zone were unsuccessful due to the problems encountered in the upper part of the hole. A 1¼-inch diameter screen was then set in the well but a good water sample still could not be obtained. Final construction details for the well are shown in Figure III-1. Based on the data collected, water within the sandstone unit in well TW-1 is at least as saline or more saline than the water within the upper limestone unit in the well. The upper zone was therefore selected as the most likely source of reverse osmosis feedwater supply.

Initially, a comprehensive program of drilling, testing, data analysis, and computer modeling was recommended to further evaluate the long-term water supply potential of the target zone. However, due to the unexpected poor water quality encountered in the first test well, it was decided to construct an additional test well to assess the yield potential and water quality of the proposed production zone and underlying sandstone unit at a location distant from well TW-1.

Construction of well TW-2 commenced on July 10, 1995 at the location shown on Figure II-1. This well was constructed with 8-inch diameter schedule 80 PVC to a depth of 247 feet below land surface. The upper limestone unit was tested between the depths of 247 feet and 285 feet in the well. Again, the productive capacity of the well was very high. The calculated specific capacity of the well was 90 gpm/ft at a pumping rate of 290 gpm. Analyses of water samples obtained during testing indicate that the salinity of the water

CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1



MISSIMER INTERNATIONAL	Pr Name: CAPE HATTERAS R.O. TEST WELL		Groundwater and Environmental Services
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FIGURE III-1. SCHEMATIC DIAGRAM SHOWING THE FINAL CONSTRUCTION DETAILS OF THE CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1.

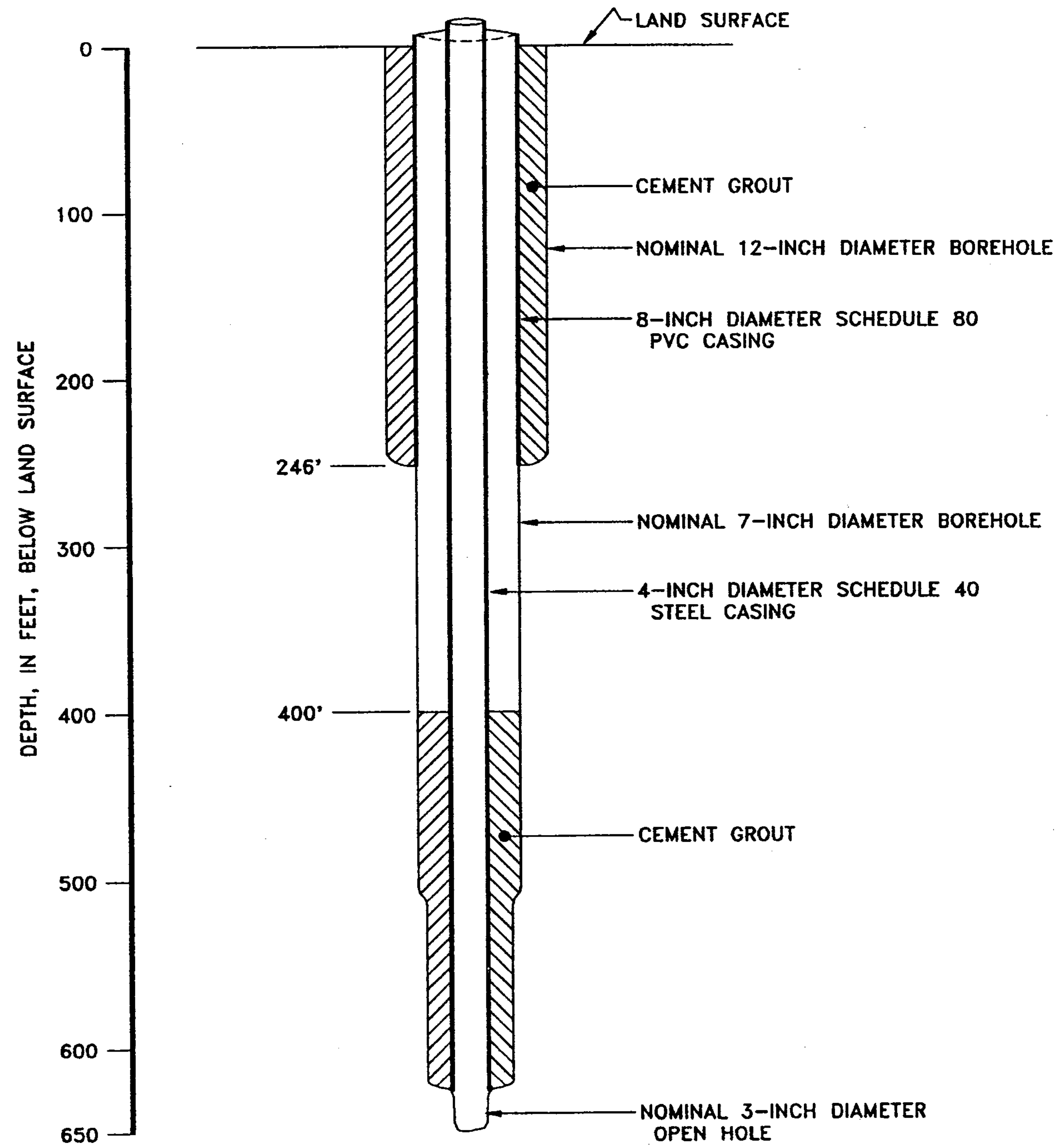
in the limestone unit at this location is considerably higher than that encountered at test well TW-1. The dissolved chloride concentrations of samples obtained during the test ranged from 8300 mg/l to 8750 mg/l and stabilized at 8750 mg/l. Drilling continued in order to test the underlying sandstone unit.

A string of 4-inch diameter steel pipe was set into the sandstone unit at a depth of 625 feet below land surface and an open hole section was drilled below the casing to a depth of 650 feet. A pump test was conducted on this zone and water samples were obtained for analyses. The dissolved chloride concentration of water samples obtained near the end of the test stabilized at approximately 10,800 mg/l. Testing was discontinued since salinity levels in the sandstone unit were higher than in the upper limestone unit at the site. A schematic diagram showing the construction details of well TW-2 is included as Figure III-2.

Because of the high salinity levels encountered in test well TW-2, a third test well was constructed. Test well TW-3 is located north of test wells TW-1 and TW-2 as shown on Figure II-1. Well TW-3 was constructed to further assess water quality trends within the target aquifer and for the purpose of conducting a high rate pumping test.

Construction of well TW-3 began on August 1, 1995 and was completed on August 3. A string of 10-inch diameter schedule 80 PVC casing was installed to a depth of 248 feet below land surface and grouted in place with neat portland cement. An open hole section was drilled out to a depth of 276 feet. Construction details of the well are shown in Figure III-3. The well was developed by compressed air pumping from within the casing for approximately 2 hours. After development was complete, a centrifugal pump was used to pump the well at rates ranging from 700 gpm to 1375 gpm. A maximum drawdown of 8.0 feet was measured in the well at a pumping rate of 1375 gpm confirming that the aquifer is highly productive. Water samples were obtained periodically throughout the test and analyzed for dissolved chloride concentration. Concentrations varied from

CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-2



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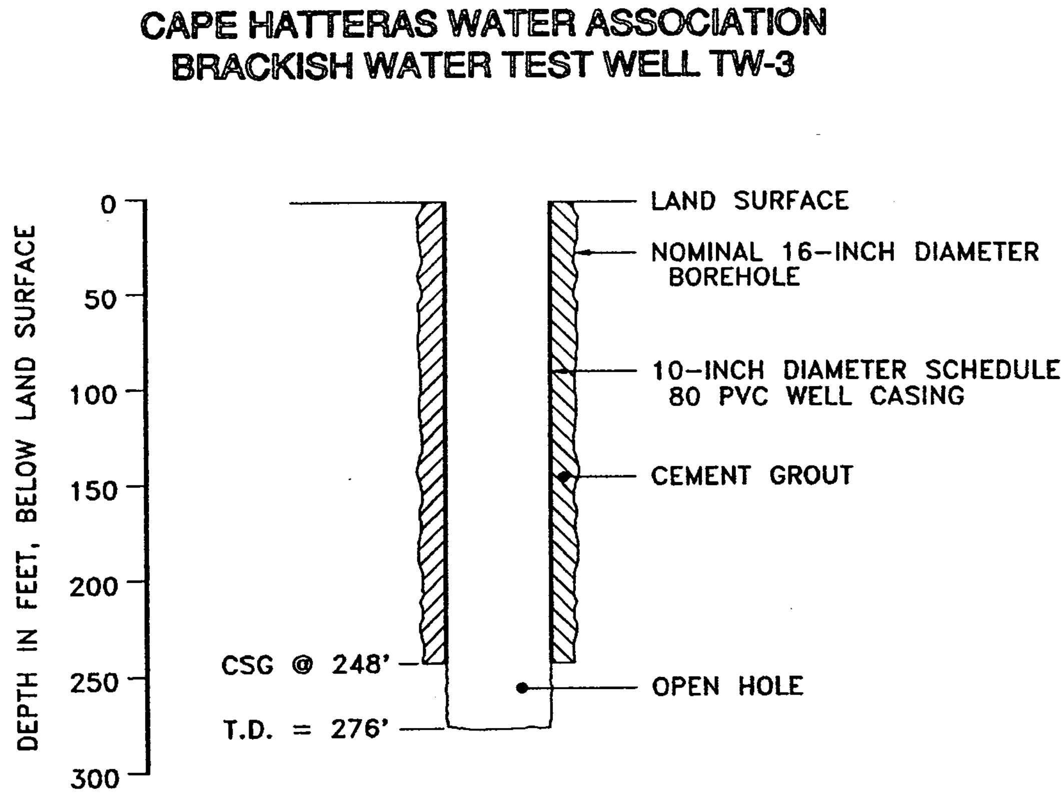
Pr Name: CAPE HATTERAS R.O. TEST WELL	
Pr No. FH4-088	Date: 08/18/95
DWG No. FH4088W2.DWG	Rev.No. 3

Groundwater and Environmental Services

FIGURE III-2. SCHEMATIC DIAGRAM SHOWING THE FINAL CONSTRUCTION DETAILS OF THE CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-2.



MISSIMER INTERNATIONAL	Pr Name: CAPE HATTERAS	Groundwater and Environmental Services
	Pr No. FH4-088 Date: 08/18/95	
	DWG No. FH4088T3.DWG Rev.No. 2	

FIGURE III-3. SCHEMATIC DIAGRAM SHOWING THE CONSTRUCTION DETAILS OF THE CAPE HATTERAS WATER ASSOCIATION BRACKISH WATER TEST WELL TW-3.

4250 to 4900 mg/l during pump testing. Tables showing the aquifer test data and water quality analyses for each well are included in the appendices. Pertinent information for all three wells is summarized in Table III-1.

TABLE III-1. SUMMARY OF CONSTRUCTION DETAILS, AQUIFER TEST RESULTS AND WATER QUALITY DATA FOR THE CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELLS

Well Number and Zone Tested	Casing Depth (feet)	Casing Diameter and Type	Specific Capacity (gpm/ft)	Dissolved Chloride Concentration (mg/l)
TW-1 Upper Zone (238'-275')	240	6-inch Sch 80 PVC	189 @ 100 gpm	3800
Lower Zone (557'-588')	560	2-inch Sch 40 PVC	N/A	4000-10,000*
TW-2 Upper Zone (244'-285')	246	8-inch Sch 80 PVC	90 @ 290 gpm	8750
Lower Zone (583'-650')	625	4-inch Sch 40 Steel	2.8 @ 50 gpm	10,800
TW-3 Upper Zone (244'-276')	248	10-inch Sch 80 PVC	172 @ 1400 gpm	4900

*A consistent reading could not be obtained from this zone because of well construction problems.

FH4-088.TAB

IV. HYDROGEOLOGY

A. Geology

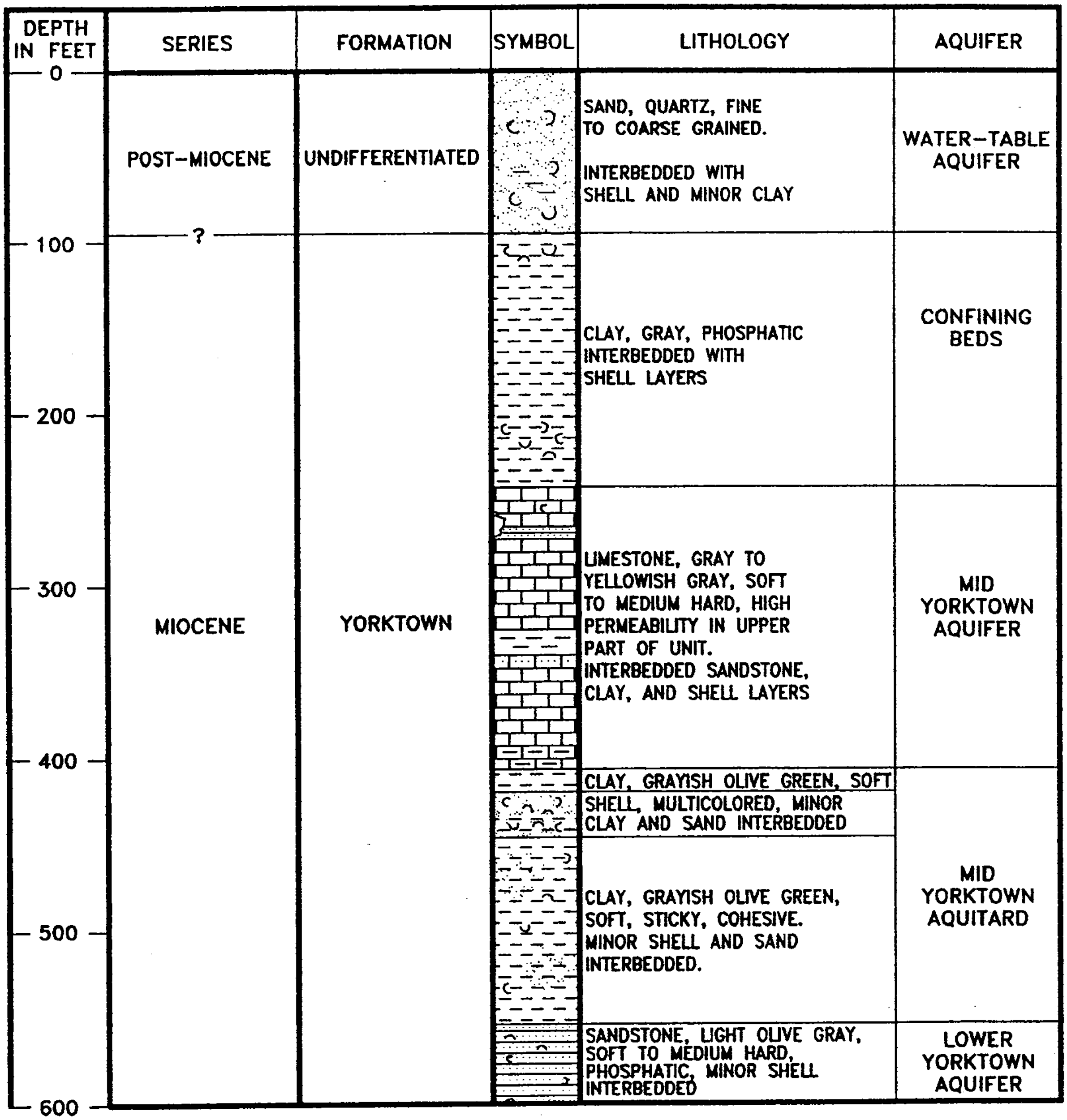
The geologic descriptions provided herein are based on information obtained through the drilling of the CHWA reverse osmosis test wells. A stratigraphic column of the sediments encountered during the drilling of test well TW-1 is included as Figure IV-1. The descriptions and nomenclature of lithologic units given generally conform with previous work done by the U.S. Geological Survey, the North Carolina Department of Environment, Health, and Natural Resources, and various consultants including Missimer International, Inc. The focus of this investigation is on confined aquifers containing brackish water within the Yorktown Formation. Therefore, only a brief discussion of the upper stratigraphic units is presented.

The uppermost and youngest strata encountered during drilling of the test wells consist of undifferentiated marine and non-marine clastic sediments of post-Miocene age. The primary constituents include fine to coarse grained quartz sand with common shell beds and minor amounts of interbedded clay and fine grained phosphorite sand. Permeable sediments within these deposits form the water-table aquifer which is roughly 100 feet thick in the study area.

The Yorktown Formation of late-Miocene to early Pliocene age underlies the surficial sand deposits. The formation consists of beds of fine to coarse grained sand and dense clay units with sandy limestone and sandstone layers also present in some locations. Thickness of the formation can exceed 500 feet in eastern Dare County. The Yorktown Formation is described in more detail below beginning with the upper confining beds.

The upper Yorktown Formation confining beds in the study area consist of olive-gray marine clays with interbedded fine sand, shell, and phosphate material. Thickness of the

CAPE HATTERAS WATER ASSOCIATION
REVERSE OSMOSIS TEST WELL TW-1



MISSIMER INTERNATIONAL

Pr Name: CAPE HATTERAS R.O. TEST WELL	
Pr No. FH4-088	Date: 08/18/95
DWG No. FH4088L1.DWG	Rev.No. 3

Groundwater and Environmental Services

FIGURE IV-1. STRATIGRAPHIC COLUMN OF THE SEDIMENTS ENCOUNTERED DURING DRILLING OF THE CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1.

confining unit ranged from 116 to 150 feet in the recently constructed test wells. These beds have a very low hydraulic conductivity which provides good confinement between the surficial sands and the underlying Mid-Yorktown Aquifer.

The Mid-Yorktown Aquifer lies beneath the upper Yorktown Formation confining beds in eastern Dare County. In most areas, the aquifer consists primarily of medium to fine grain quartz sand with occasional shell, phosphatic material, and coarse sand layers. A limestone facies within the aquifer was encountered in the test wells constructed during this investigation. The limestone unit is a relatively well consolidated, dark gray, biogenic, skeletal limestone with well developed secondary porosity. The upper part of the unit also contains occasional shell, sand, and phosphate as well as interbedded loosely consolidated sandstone layers. Secondary solutioning in the upper part of the aquifer has resulted in cavernous or highly permeable zones evidenced by the lost circulation problems encountered in each of the test wells during drilling. The entire thickness of the limestone unit was penetrated in test wells TW-1 and TW-2 and was found to be 167 and 166 feet, respectively.

Underlying the Mid-Yorktown Aquifer is a mixed sequence of clay, sand, and shell that forms the Mid-Yorktown Aquitard. Thickness of the unit is approximately 150 feet in the area where test drilling was conducted. Sandy clay is the predominant lithology present and thus the vertical hydraulic conductivity of the unit is low. The unit provides confinement between the Mid-Yorktown Aquifer and the Lower Yorktown Aquifer.

The final sequence encountered during the test drilling project was a sandstone and sand unit of the Lower Yorktown Aquifer. This unit was encountered at a depth of 557 feet in well TW-1 and at 565 feet in well TW-2. A soft to medium hard, friable sandstone is the predominant lithology. Minor amounts of shell and phosphate material are also present in the unit. The sandstone was penetrated to a depth of 650 feet in test well TW-2.

B. Aquifer Descriptions

The water-table aquifer is the uppermost water bearing unit on the island and by definition is unconfined or in direct contact with atmospheric pressure. Fine to coarse grained quartz sand and shell are the predominant lithologies present in the zone which attains a thickness of approximately 100 feet in the study area. This aquifer is currently the source of public supply drinking water on Hatteras Island and it is also used for domestic supply and irrigation at individual homes. Recharge to the aquifer is by direct infiltration of precipitation on the island. Discharge occurs through pumpage, evapotranspiration, and outflow to surface water bodies.

The Mid-Yorktown Aquifer is considered the most likely source of reverse osmosis feedwater on Hatteras Island and was the focus of this investigation. The aquifer occurs within a skeletal limestone facies of the Yorktown Formation. The upper part of the limestone unit is highly permeable due to secondary dissolution of the rock material. Cavernous zones were encountered during drilling in the upper 30 to 40 feet of the unit which caused loss of drilling fluid circulation. Aquifer tests conducted on the upper part of the limestone unit indicate that the productive capacity of the zone is very high. Transmissivity of the zone is estimated to be in the range of 200,000 to 400,000 gpd/ft based on the preliminary aquifer test results.

Recharge to the aquifer occurs on the mainland west and north of Hatteras Island, primarily from direct rainfall infiltration where the Yorktown Formation crops out at land surface. In addition, some brackish water recharge occurs where the Albemarle and Pamlico Sounds intersect the recharge area of the Yorktown Aquifer. The regional hydraulic gradient within the aquifer is not known, however, it is estimated to be less than one foot per mile. Surveying of well top elevations and water level measurement in the test wells will need to be accomplished in order to more precisely determine the hydraulic gradient. During pumpage, additional recharge will likely be induced by vertical leakage through the overlying and underlying semi-confining units.

Water quality in the Mid-Yorktown Aquifer was evaluated based on analyses of samples obtained during the aquifer tests. Dissolved chloride concentrations varied widely from 3800 mg/l in well TW-1 to 8750 mg/l in well TW-2. Well TW-3 had a dissolved chloride concentration of approximately 4900 mg/l at the end of long-term, high capacity pump testing. The variation in water quality within the aquifer is likely related to the relative proximities of saline surface water bodies and the distant mainland aquifer recharge areas. Density stratification of water within the aquifer is considered likely since dissolved chloride concentrations tended to increase with pumping rates during the test on well TW-3.

The sandstone unit underlying the Mid-Yorktown Aquitard was the final water producing zone encountered. An aquifer test was conducted on the zone in well TW-2. The productive capacity of the unit is relatively low compared to that encountered in the Mid-Yorktown Aquifer. Water quality was extremely poor in the unit so testing of the unit was discontinued. The sandstone unit is not considered a potential source of reverse osmosis feedwater on the island because of the low yield characteristics and poor water quality.

APPENDIX A

Geologist's Logs

GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1

Depth (feet)	Description
0-45	No sample. Driller reports mix of fine to coarse grained sand and shell with clayey sand at the bottom of the interval.
45-50	Shell, multicolored, interbedded with sand. Sand is quartz, medium to coarse, subrounded, with some pebble sizes.
50-60	Sand, quartz, grayish-black (N2), very fine to coarse, poorly sorted, subrounded, abundant shell, black (N1), good apparent permeability.
60-82	Sand and shell as above.
82-89	Shell, grayish-black (N2), interbedded with fine sand and sandy clay, medium gray (N5).
89-99	Shell as above with less clay.
99-110	Clay, dark gray (N3), sandy, fine medium gray (N5) sand interbedded, abundant shell.
110-120	Shell, very pale orange (10 YR 8/2), interbedded with fine sand and occasional medium gray (N5) clay.
120-135	Clay, medium dark gray (N4), interbedded with fine sand and shell, very pale orange (10 YR 8/2), low apparent permeability.
135-150	Clay, medium dark gray (N4), sandy, common shell and fine sand interbedded, low permeability.
150-160	Clay, as above.
160-175	Clay, medium gray (N5), sandy, soft, common shell.
175-196	Clay, medium gray (N5), soft, sticky, minor shell fragments, minor fine sand, finely phosphatic.

Continued:

GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1

Depth (feet)	Description
196-215	Shell, multicolored, minor coarse sand, minor medium gray (N5) clay interbedded.
215-223	Shell, multicolored, interbedded with common medium gray (N5) clay, and fine to coarse grained quartz sand.
223-238	Clay, medium gray (N5), soft, sticky, common shell interbedded.
238-250	Limestone, medium dark gray (N4) to medium gray (N5), soft to medium hard, shell casts and molds, trace white lime mud, minor shell.
250-275	Limestone, medium gray (N5), soft to medium hard, casts and molds, common shell, high permeability. Interbedded with soft, medium dark gray (N4), friable sandstone. Severe loss of circulation zones encountered at 255 feet and 265 feet.
275-285	Limestone, medium dark gray (N4), sandy, soft to medium hard, friable, finely phosphatic, common shell fragments. Good apparent permeability.
285-294	Limestone, yellowish-gray (5 Y 8/1), sandy, medium hard, moderately well indurated, common shell fragments.
294-303	Limestone, yellowish-gray (5 Y 8/1), sandy, medium hard, moderately well indurated, casts and molds, common shell fragments, good apparent permeability.
303-313	Limestone, yellowish-gray (5 Y 8/1), soft, friable, clayey, poorly indurated, occasional shell fragments, fast rate of penetration, low to medium apparent permeability.
313-325	Limestone, as above.

Continued: GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1

Depth (feet)	Description
325-334	Limestone, medium gray (N5), soft to medium hard, friable, poorly to moderately indurated, finely phosphatic, abundant shell fragments, minor white carbonate mud.
334-339	Limestone, as above.
339-345	Clay, brownish-gray (5 YR 4/1), soft, cohesive, carbonate, common shell and limestone fragments, low apparent permeability.
345-355	Sandy limestone, yellowish-gray (5 Y 8/1), soft to medium hard, poorly to moderately indurated, friable, minor shell. Low to medium apparent permeability.
355-366	Limestone, as above with minor clay interbedded.
366-376	Limestone, medium light gray (N6), soft to medium hard, poorly to moderately indurated, friable, abundant shell fragments, medium apparent permeability.
376-400	Limestone, yellowish-gray (5 Y 8/1), soft to medium hard, friable, occasional shell fragments, minor clay interbedded. Low to medium apparent permeability.
400-405	Limestone and clay, as above.
405-415	Clay, grayish-olive green (5 GY 3/2), soft, cohesive, common limestone and shell fragments.
415-421	Shell, multicolored, common limestone fragments, minor clay and sand interbedded.
421-442	Shell, multicolored, interbedded with coarse, rounded quartz sand. Formation taking fluid during drilling, medium to high apparent permeability.

Continued:

GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-1

Depth (feet)	Description
442-462	Clay, grayish-olive green (5 GY 3/2), soft, sticky, minor shell and limestone fragments, low permeability.
462-525	Clay, grayish-olive green (5 GY 3/2), soft, sandy, carbonate, minor shell interbedded, low permeability.
525-546	Clay, dusky yellowish-brown, soft, sandy, cohesive, trace shell. Sand is very fine grained.
546-557	Clay, as above.
557-567	Sandstone, light olive-gray (5 Y 5/2), soft to medium hard, friable, poorly to moderately indurated, finely phosphatic, shell lense at the top of the unit. Minor casts and molds, minor shell interbedded with sandstone, medium apparent permeability.
567-588	Sandstone, light gray (N7) to light brownish-gray (5 YR 6/1), soft to hard, friable, finely phosphatic (salt & pepper effect), minor shell fragments, minor casts and molds.

GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION
REVERSE OSMOSIS TEST WELL TW-2

Depth (feet)	Description
0-7	Sand, medium gray (N5), fine grained, quartz, well sorted, subrounded.
7-20	Sand and gravel, medium gray (N5), and multi-colored, fine to gravel sized, quartz, poorly sorted, subangular to well rounded, 20-25% shell fragments.
20-30	Sand, gravel and shell, as above.
30-40	Sand and shell, medium gray (N5), and greenish-gray (5 GY 6/1), fine to coarse grained, quartz and assorted minerals, poorly sorted, minor interbedded clay.
40-50	Sand and shell, as above.
50-60	Sand, medium gray (N5), fine to coarse grained, quartz, minor shell and echinoid fragments, very minor interbedded clay.
60-75	Sand as above, higher % shell fragments.
75-100	Shell, interbedded with fine to coarse quartz sand, multi-colored, minor interbedded clay.
100-107	Shell, as above.
107-128	Sand, medium gray (N5), to light olive-gray (5 Y 6/1), fine grained, quartz, minor shell.
128-142	Clay, greenish-gray (5 GY 5/1), soft, semi-cohesive, interbedded with fine sand and shell, low apparent permeability.
142-175	Clay, light olive-gray (5 Y 6/1), soft, slightly cohesive, interbedded with fine sand and shell, slightly phosphatic, low apparent permeability.
175-195	Clay and interbedded shell, light olive-gray (5 Y 6/1), soft, minor fine sized sand, low apparent permeability.

Continued: GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-2

195-220	Interbedded clay, shell and sand, as above, gastropods abundant from 215-220 feet.
220-244	Interbedded clay, shell and sand, as above, finely phosphatic.
244-255	Limestone, medium gray (N5) to light olive-gray (5 Y 6/1), medium hard to soft, packstone, some friable pieces, vuggy, moldic, common shell fragments, good apparent permeability, minor fine phosphate, minor quartz sand.
255-264	Limestone, as above, but a little harder.
264-275	Limestone, as above, common casts and molds, hard, minor lost circulation zone.
275-285	Limestone, as above, severe lost circulation zone at 280 feet.
285-300	Limestone, medium gray (N5) and yellowish-gray (5 GY 8/1), packstone, hard to soft, vuggy, moldic, minor fine sand, common bivalves and gastropods, good apparent permeability.
300-315	Limestone, yellowish-gray (5 Y 7/1), packstone, soft, friable, moldic, common shells, slightly phosphatic, minor clay (white lime mud).
315-340	Limestone, as above, but harder.
340-368	Limestone, as above.
368-385	Limestone, as above.
385-406	Limestone, light to very light gray (N) and yellowish-gray (5 Y 6/2), hard to medium hard, moldic, vuggy, common shell fragments, minor fine sand, good apparent permeability, minor lost circulation.
406-410	Limestone, yellowish-gray (5 Y 7/2), as above, interbedded sandy clay.

Continued:

GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-2

410-425	Clay, light olive-gray (5 Y 5/2), soft, semi-cohesive, abundant fine sand and silt, minor shell, low apparent permeability.
425-440	Clay, as above, common shell and limestone fragments.
440-450	Shell, multi-colored, common limestone fragments, minor sand and clay, interbedded.
450-475	Sandy clay, light olive-gray (5 Y 5/2), very soft, minor shell, minor fine phosphate, low apparent permeability.
475-498	Sandy clay, as above.
498-523	Clay, light olive-gray (5 Y 4/2), soft, semi-cohesive, sandy, finely phosphatic, minor shell.
523-545	Clay, as above.
545-565	Clay, light olive-gray to yellowish-gray (5 Y 7/2), soft, semi-cohesive, sandy, finely phosphatic, minor shell, low permeability.
565-583	Sand, light olive-gray, fine grained, quartz, minor shell and clay, finely phosphatic, interbedded sandstone, as below.
583-598	Sandstone, light olive-gray (5 Y 6/1) to yellowish-gray (5 Y 8/1), fine to medium grained quartz, soft to hard, some friable pieces, minor clay and shell, finely phosphatic, medium apparent permeability.
598-623	Sandstone, as above, minor casts and molds.
623-635	Sandstone, as above.
635-650	Sandstone, light olive-gray (5 Y 6/1) to yellowish-gray (5 Y 8/1), fine to medium grained, soft to medium hard, loosely consolidated, finely phosphatic, minor clay and shell, medium permeability.

GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-3

Depth (feet)	Description
0-18	No samples collected. Drillers describe fine to medium grained sand with some shell present.
18-48	Sand and shell, medium gray (N5) to multi-colored, fine to coarse grained, quartz, poorly sorted, subrounded, minor black sand.
48-60	Sand and shell, as above.
60-74	Sand and shell, as above, minor gravel sized quartz.
74-95	Sand and shell, medium gray (N5) sand, shell is grayish-black (N2), fine grained, quartz, minor phosphate.
95-106	Clay, greenish-gray (5 GY 5/1), soft, semi-cohesive, low apparent permeability and porosity, shells and fine sand common.
106-112	Sandy clay, greenish-gray (5 GY 5/1), soft, semi-cohesive, low apparent permeability, very fossiliferous (gastropods, bivalves).
112-124	Clay, as above, less sand.
124-145	Clay with interbedded sand and shell, as above.
145-175	Clay, light olive-gray (5 Y 5/1) to medium gray (N5), soft, cohesive, low apparent permeability, finely phosphatic, minor interbedded sand and shell (common gastropods).
175-218	Clay, as above.
218-245	Clay and interbedded shell, light olive-gray (5 Y 6/1), soft, cohesive, low permeability, finely phosphatic, common gastropod and echinoid fragments, minor sand.

Continued: GEOLOGIST'S LOG OF CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-3

Depth (feet)	Description
245-260	Limestone, medium gray (N5), to yellowish-gray (5 Y 8/1), medium hard to soft, some friable pieces, packstone, moldic and vuggy, good apparent permeability and porosity, common shell and fine sand, minor phosphate.
260-276	Limestone, as above, lost circulation zone from 260 to 265 and 270 to 276.

APPENDIX B

Pump Test and Water Quality Data For Wells TW-1, TW-2, and TW-3

TABLE A-1.1

CAPE HATTERAS WATER ASSOCIATION
REVERSE OSMOSIS TEST WELL TW-1 PUMP TEST OF THE LIMESTONE UNIT

Test Date: 4/10/95

Recorded By: Scott Manahan

Static Water Level: 2.04 feet below measuring point (BMP) which is top of the PVC casing which is approximately 0.9 feet above land surface

Pumping Rate: 100 gpm

Elapsed Time (minutes)	Pumping Water Level (ft. BMP)	Drawdown (feet)
5	2.55	0.51
10	2.56	0.52
15	2.57	0.53
20	2.55	0.51
30	2.54	0.50
45	2.50	0.46
60	2.52	0.48
120	2.47	0.43
245	2.41	0.37
425	2.56	0.52

Specific Capacity = $\frac{100 \text{ gpm}}{0.53}$ = 189 gpm/ft

FH4-088.TAB

TABLE A-1.2. **WATER QUALITY ANALYSES RESULTS**
CAPE HATTERAS REVERSE OSMOSIS TEST WELL TW-1

April 11, 1995
Chloride and Conductivity samples taken while pump testing at 100 gpm

Time* (minutes)	Sample Number	Conductivity umhos/cm	Chloride mg/l
10	35	11700	3800
60	15	11410	3875
120	41	11610	3750
245	23	11630	3750
425	16	11630	3750

*Time since beginning pump test

TABLE A-1.3. **CAPE HATTERAS REVERSE OSMOSIS TEST WELL TW-1**

Sample Drawn: 4/11/95
Date Analysis Completed: 4/11/95
Sample taken after pump testing at 100 gpm for seven hours

Parameter	Concentration
P - Alkalinity as $CaCO_3$, mg/l	0
Total Alkalinity $CaCO_3$, mg/l	210
Bicarbonate as HCO_3, mg/l	256
Carbonate as CO_3, mg/l	0
Hydroxide as OH, mg/l	0
Total Hardness as $CaCO_3$, mg/l	560
Calcium Hardness as $CaCO_3$, mg/l	224
Magnesium as $CaCO_3$, mg/l	336
Calcium as Ca, mg/l	81.65
Color	0
Silica as SiO_2, mg/l	17.2
Conductivity as umhos/cm	11,550
Iron, Fe, mg/l	.025
Potassium, K, mg/l	40.33
Copper, Cu, mg/l	4.78
Manganese, Mn, mg/l	.123
Phosphate as PO_4, mg/l	.172
Chloride as Cl-, mg/l	3,800
Fluoride as F, mg/l	.78
Nitrate as NO_3, mg/l	.21
Zinc as Zn, mg/l	.168
Chlorine (free Cl_2), mg/l	---
Lead as Pb, mg/l	---
Corrosivity	.39
pH	7.35
pHs	7.74
Turbidity, N.T.U.	.11
Total Suspended Solids, mg/l	3.2
Total Dissolved Solids, mg/l	5800
Sulfate as SO_4, mg/l	156
Sodium as Na, mg/l (Est.)	1882.29
Sulfide as S, mg/l	0

TABLE A-2.1. CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-2 PUMP TEST OF THE LIMESTONE UNIT

Test Date: 7/13/95

Recorded By: Mike Romero

Static Water Level: 4.19 ft. below measuring point (BMP) which is top of PVC casing which is approximately 1.25 feet above land surface

Pumping Rate: 290 gpm

Elapsed Time (minutes)	Pumping Water Level (ft. BMP)	Drawdown (feet)
1	6.38	2.19
5	6.61	2.42
10	6.62	2.43
20	6.65	2.46
30	6.65	2.46
40	6.75	2.56
50	6.71	2.52
60	6.74	2.55
220	6.96	2.77
720	7.23	3.04
1080	7.28	3.09
1200	7.41	3.22

$$\text{Specific Capacity} = \frac{290\ \text{gpm}}{3.22\ \text{ft.}} = 90\ \text{gpm/ft}$$

FH4-088.TAB

TABLE A-2.2. WATER QUALITY ANALYSIS RESULTS (DISSOLVED CHLORIDE CONCENTRATION) FOR THE LIMESTONE UNIT CAPE HATTERAS REVERSE OSMOSIS TEST WELL TW-2

Test Date: 7/13/95

Chloride samples taken while pump testing at 290 gpm

Time* (minutes)	Sample Number	Dissolved Chloride Concentration (mg/l)
10	66	8375
60	19	8300
220	14	8300
720	24	8550
780	46	8600
855	54	8750
1080	13	8750
1200	bottle	8750
1440	bottle	8750

* Time since beginning pump test

TABLE A-2.3.

WATER QUALITY ANALYSES RESULTS (UPPER ZONE)
CAPE HATTERAS REVERSE OSMOSIS TEST WELL TW-2

Parameter	Measured Concentration	Drinking Water Standard
P-Alkalinity as CaCO3, mg/l	0	N/A
Total Alkalinity CaCO3, mg/l	192	N/A
Bicarbonate as HCO3, m/gl	234	N/A
Carbonate as CO3, mg/l	0	N/A
Hydroxide as OH, mg/l	0	N/A
Total Hardness as CaCO3, mg/l	2950	*150
Calcium Hardness as CaCO3, mg/l	852	N/A
Magnesium as CaCO3, mg/l	2098	N/A
Calcium as Ca, mg/l	341	*60
Color	0	**15
Silica as SiO2, mg/l	19.7	N/A
Conductivity as umhos/cm	26560	N/A
Iron, Fe, mg/l	0.144	**.3
Potassium, K, mg/l	46.5	N/A
Copper, Cu, mg/l	5.01	*1.0
Manganese, Mn, mg/l	0.12	N/A
Phosphate as PO4, mg/l	0.264	*5
Chloride as Cl-, mg/l	7800	*250
Fluoride as F, mg/l	1.16	*4
Nitrate as NO3, mg/l	0.44	10
Zinc as Zn, mg/l	0.114	**5
Chlorine (free Cl2), mg/l	---	~.2
Lead as Pb, mg/l	---	**.05
Corrosivity	-.05	N/A
pH	7.24	*6.5-8.5
pHs	6.85	N/A
Turbidity N.T.U.	0.23	**1
Total Suspended Solids, mg/l	0.5	N/A
Total Dissolved Solids, mg/l	13280	*500
Sulfate as SO4, mg/l	667.5	*250
Sodium as Na, mg/l (Est.)	1074	**250
Sulfide as S, mg/l	0	N/A
RECOMMENDED STATE MAXIMUMS*		
MANDATORY STATE MAXIMUMS**		
MANDATORY STATE MINIMUMS~		
NOT AVAILABLE NO LIMIT-N/A		

The sample was obtained after pumping the well for approximately 12 hours at a rate of 290 gpm.

TABLE A-2.4. CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-2 PUMP TEST OF THE SANDSTONE UNIT

Test Date: 7/25/95

Recorded By: Mike Romero

Static Water Level: 9.80 ft. below measuring point (BMP) which is top of steel casing which is approximately 3.1 feet above land surface

Pumping Rate: 40-50 gpm*

Elapsed Time (minutes)	Pumping Water Level (ft. BMP)	Drawdown (feet)
5	29.40	19.60
10	29.50	19.70
20	29.10	19.30
30	29.07	19.27
40	29.04	19.24
50	29.01	19.21
60	28.65	18.85
70	28.60	18.80
90	28.40	18.60
150	28.30	18.50
300	27.60	17.80
360	27.60	17.80

Specific Capacity = $\frac{50\ \text{gpm}}{17.8\ \text{ft.}}$ = 2.8 gpm/ft

* The 5-hp submersible pump was operated with an unrestricted open discharge. The initial pumping rate was 40 gpm. The pumping rate increased to 50 gpm after approximately 3 hours into the test and stabilized at that rate.

TABLE A-2.5. WATER QUALITY ANALYSIS RESULTS FOR THE SANDSTONE UNIT
CAPE HATTERAS REVERSE OSMOSIS TEST WELL TW-2

Test Date: 7/25/95

Recorded By: Mike Romero

Chloride samples taken while pump testing at 40-50 gpm

Time* (minutes)	Sample Number	Chloride (mg/l)
10	22	10,000
60	None	10,250
150	None	10,700
300	None	9,000
360	11A	11,010
480	8A	10,600
660	9	10,800

* Time since beginning pump test

TABLE A-3.1. CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-3 PUMP TEST OF THE LIMESTONE UNIT

Test Date: 8/04/95

Recorded By: Mike Romero

Static Water Level: 4.62 ft. below measuring point (BMP) which is top of PVC casing

Pumping Rate: ~700 gpm

Elapsed Time (minutes)	Pumping Water Level (ft. BMP)	Drawdown (feet)
1	6.93	2.31
3	7.34	2.72
5	7.55	2.93
10	7.73	3.11
15	7.88	3.26
20	7.69	3.07
25	7.78	3.16
30	8.07	3.45
40	8.25	3.63
50	8.15	3.53
60	8.05	3.43
120	7.97	3.35
1260	8.60	3.98
1380	8.44	3.87
1680	8.56	3.94
2040	8.97	4.35
2760	8.79	4.17
3120	8.87	4.25
3400	8.94	4.32
4140	8.90	4.28
4440	9.20	4.58
4800	8.94	4.32

Specific Capacity = 153 gpm/ft

FH4-088.TAB

TABLE A-3.1. CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-3 PUMP TEST OF THE LIMESTONE UNIT (CONTINUED)

2nd Step: 8/08/95

Static Water Level: 4.58 ft.

Pumping Rate: ~1000 gpm

Elapsed Time (minutes)	Pumping Water Level (ft. BMP)	Drawdown (feet)
1	8.09	3.51
3	9.14	4.65
5	9.53	4.95
7	9.95	5.37
10	10.04	5.46
15	10.16	5.58
20	10.31	5.73
25	10.38	5.80
30	10.34	5.76
35	10.41	5.83
40	10.35	5.77
50	10.23	5.65
60	10.27	5.64
300	10.43	5.85
630	10.30	5.72
1380	10.37	5.75

Specific Capacity = 171 gpm/ft

TABLE A-3.1. CAPE HATTERAS WATER ASSOCIATION REVERSE OSMOSIS TEST WELL TW-3 PUMP TEST OF THE LIMESTONE UNIT (CONTINUED)

3rd Step

Recorded By: Mike Romero

Pumping Rate: ~1375 gpm

Elapsed Time (minutes)	Pumping Water Level (ft. BMP)	Drawdown (feet)
1	11.87	7.29
3	11.97	7.39
5	12.25	7.67
10	12.43	7.85
15	---	---
20	12.07	7.49
25	12.07	7.49
30	12.06	7.48
40	12.57	7.99
50	11.69	7.11
60	12.36	7.78
300	12.58	8.00
480	12.50	7.92

Specific Capacity = 172 gpm/ft

TABLE A-3.2. WATER QUALITY ANALYSIS RESULTS (DISSOLVED CHLORIDE CONCENTRATION) FOR THE LIMESTONE UNIT CAPE HATTERAS REVERSE OSMOSIS TEST WELL TW-3

Test Date: 8/04/95

Chloride samples taken while pumping at 700 gpm

Time* (minutes)	Sample Number	Dissolved Chloride Concentration (mg/l)
10	1	4350
60	10	4250
1380	25	4700
2760	X	4800
3120	210	4450
3400	14	4400
4140	4	4400
4440	12	4550
4800	13	4600

* Time since beginning pump test

Chloride samples taken while pumping at 1000 gpm

Time* (minutes)	Sample Number	Dissolved Chloride Concentration (mg/l)
60	6	4550
300	3	4450
480	22A	4300
630	2	4450
1380	210	4450

* Time since beginning pump test

Chloride samples taken while pumping at 1375 gpm

Time* (minutes)	Sample Number	Dissolved Chloride Concentration (mg/l)
60	7	4800
300	27	4650
480	21A	4650
810	32	4900

* Time since beginning pump test

FH4-088.TAB

APPENDIX C

Geophysical Logs

Cape Hatteras Water Association

CAPE HATTERAS, NORTH CAROLINA

Future Water Supply Study

September 5, 1995

CERTIFICATION

I hereby certify that this Future Water Supply Study for Cape Hatteras Water Association, North Carolina, was prepared by me or under my direct supervision.

Signed, sealed and dated this 8th day of September, 1995.

NORTH CAROLINA
PROFESSIONAL
SEAL
12532
ENGINEER
IAN CHARLES WATSON

By: _______________

IAN C. WATSON, P.E.
Reg. No. 12532

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Introduction

Subsequent to the construction and testing of the first brackish water test well, TW-1 (Figure 1). Boyle Engineering Corporation (BEC) prepared a report for the Cape Hatteras Water Association (CHWA) which summarized the results of the test and the resultant assessment of the cost of water from a Reverse Osmosis (RO) plant constructed to process the well water (Brackish Water Exploration Test Well – Final Report, June 2, 1995). As recommended in the letter transmitting this report to CHWA, a second test well program was proposed, prior to embarking on a costly hydrogeologic investigation designed to confirm and reinforce the preliminary RO process design assumptions. The recommendation was accepted, and TW-2 was constructed (Figure 1). As part of this program, the aquitard under the limestone formation was to be penetrated and the well extended into the underlying sandstone. This was accomplished, and while the test confirmed the superior productivity of the limestone aquifer, the chlorides found in TW-2 were more than twice the value of TW-1 chlorides. In addition, the sandstone aquifer chlorides exceeded 10,000mg/l, confirming the assumptions based on TW-1 results.

One explanation of higher chlorides was that TW-2 was significantly closer to the Atlantic Ocean than TW-1 and because of the apparently high transmissivity of the limestone, the water quality was more heavily influenced by the open seawater than TW-1.

As a result of this finding, and the identification of good quality shallow groundwater that could be used as blend water, a third test well, to be constructed as a designed well into the limestone unit only, was authorized by CHWA. This well was constructed on CHWA property on the North side of Hwy 12, not far from CHWA offices in Buxton.

As a parallel effort, CHWA also authorized their consulting hydrogeologist, Ralph C. Heath, to investigate the presence, longevity and safe yield of the lower permeable zone of the shallow aquifer system. Upon completion of these two parallel tasks, BEC was to review the data and conclusions, and re-evaluate the opinions of cost, both capital and O&M, prepared as part of the first test well program.

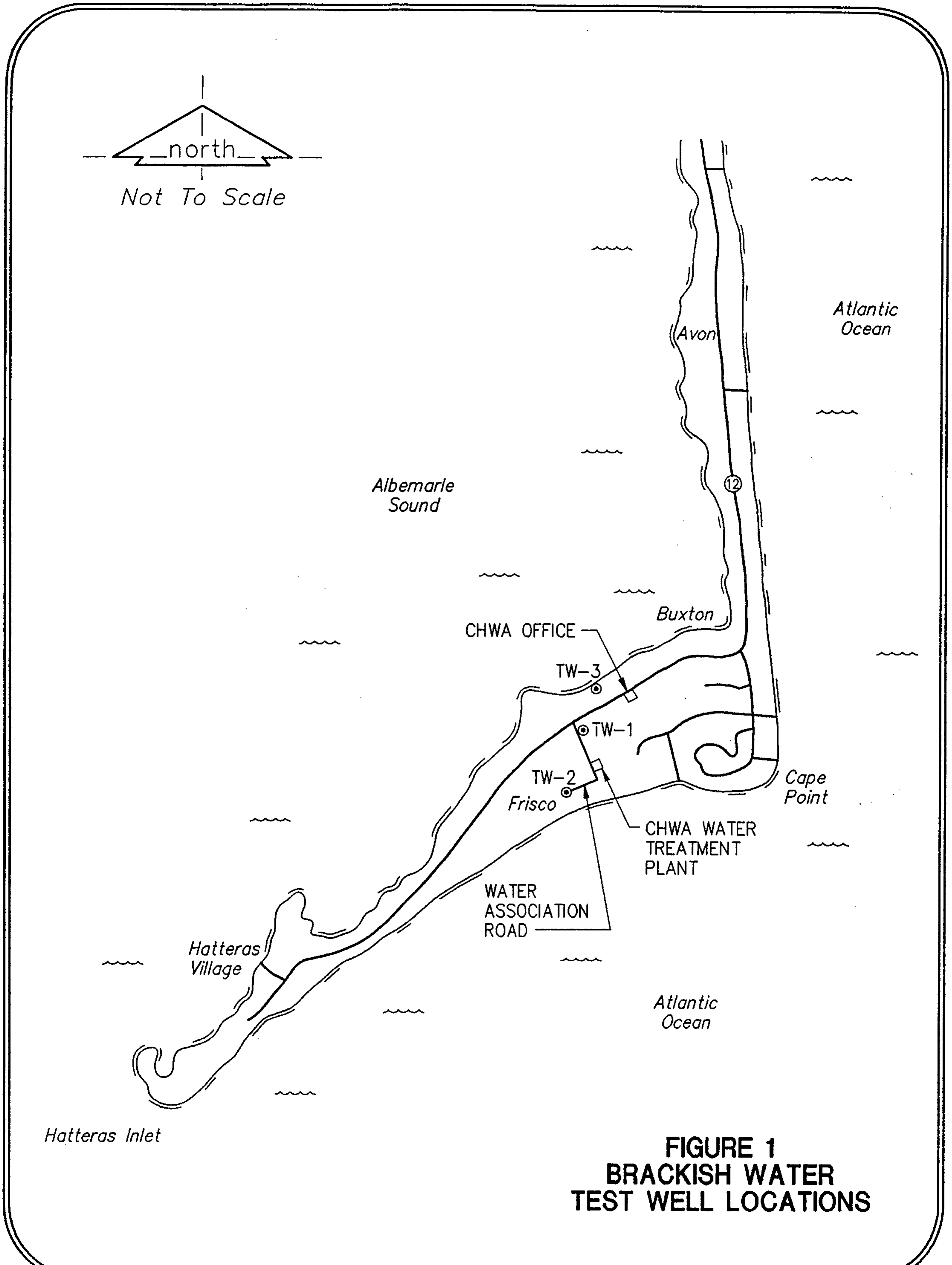

FIGURE 1
BRACKISH WATER
TEST WELL LOCATIONS

Conclusions and Recommendations

A water treatment plant consisting of part brackish water desalting and part shallow groundwater treatment appears technically feasible for a lower Hatteras Island water supply, based on current knowledge of the brackish limestone aquifer. Future viability of brackish water desalting can be reinforced by additional groundwater exploration. A treatment plant capable of meeting near term summer average day demand, and 5-year additional demand can be constructed for about $7.5 million. The cost to produce blended water from this facility, not including labor, distribution and overhead costs is about $0.80/kgal. This cost is predicted to increase to about $0.95/kgal in the future, assuming current membrane performance improvements continue. All costs are based on 1995 dollars.

In order to support such a facility, it is recommended that the following actions are taken.

1. Continue to look for supplemental sources of relatively low TDS brackish water.
2. Continue to increase basic knowledge of the limestone aquifer characteristics.
3. Continue investigation into the optimum method of treating the shallow groundwater.
4. Plan to pilot test the limestone aquifer water with currently available ultra-low pressure membranes, to define operating characteristics and limitations.
5. Continue to investigate shallow groundwater treatment methodologies, and pilot test as appropriate.

Discussion of Options

As discussed in the first BEC report, the proposed RO plant was conceptualized on a reasonably conservative basis. It was projected that the feedwater TDS would stabilize at about 10,000 mg/l, with chloride concentration approaching 6,000 mg/l. The recovery was kept low, at 60%, for two reasons: first, the operating pressure required for higher recovery, and the resultant power cost could not be justified based on the apparent availability of groundwater; and second, the concentration of the waste stream needed to be kept as low as possible for discharge permitting reasons.

Both of these constraints are still valid. However, because of the potential for blending good quality shallow ground water, the stress on the limestone aquifer will be reduced, as will the volume of concentrate. Therefore, if future water quality permits, a higher recovery and thus lower RO feed pump power could result, at least initially.

Review of the report by Ralph Heath (Report Related to Modification of the Frisco Wellfield of CHWA, August 1995) reveals two significant conclusions: first that the water pumped from the lower zone of the shallow aquifer is of good quality with low iron and organic content, but that the quality will deteriorate as a downward flow is induced in the upper zone; and second, that the rate of deterioration will be rapid, possibly reaching near equilibrium with the upper zone in less than one year. As a result, the intended blend water may possibly be enriched in iron and organic materials, making it similar to the current raw water supply. In this state, it cannot be blended with RO permeate without additional treatment.

The report on the brackish water tests wells (Summary of Preliminary Reverse Osmosis Test Wells Construction for CHWA, Buxton, NC, by Missimer International, August 1995) substantially supports the program's earlier findings concerning productivity of the limestone formation. A potential sustainable yield of 4.0 mgd appears to be available, given appropriate wellfield design, and proper management.

The quality (both current and future) is more difficult to predict, but TW-3 did exhibit quality indicators more closely allied to TW-1 than to TW-2. If in fact the chloride concentration in the water contained in the upper zone of the limestone decreases as the distance from the Atlantic increases, then wells along Hwy 12 would appear to be the optimum placement. It is anticipated that this orientation will minimize salt water intrusion.

The capacity of the RO plant proposed for CHWA future water supply has been defined as 3.0 mgd at full size. Initially, based on current pumpage data, and an initial estimate of the demand for water when it again is available, an initial capacity of 2.4 mgd was proposed in the BEC June 2 report. This was based on 3x800,000 mgd RO units. If the supply was provided by **blended** production (i.e. using shallow ground water with hardness and alkalinity to blend with RO permeate), a flow sheet as shown in Figure 2 could result, and the RO portion of the system would be smaller. The RO system would start at 1.2 mgd, expandable to 1.8, with an initial 0.6 mgd of blend, expanded to 1.2 mgd.

Table 1 is reproduced from the Heath Report, and compares the quality of the water from the upper and lower zones of the shallow aquifer. The values for iron (Fe) and total organic carbon (TOC) are significantly lower than in the upper zone, at the west end of the wellfield. However, recent data indicates that at the east end, the quality is more similar to the existing pumped zone. Assuming that the iron, manganese and TOC can be controlled at an appropriate level by "conventional treatment", the RO permeate/shallow zone blend ratio can be controlled by other parameters. In this case, it is recommended that hardness and alkalinity be used, and that each be established at 100 ppm as $CaCO_3$ in the blended water.

Table 1
Partial Chemical Analysis of Water from the Frisco Wellfield

Constituent or Property	Wellfield Raw Water[1]	"New" Well No. 3[2]
Alkalinity, mg/l	272	260
Chloride, mg/l	43	34
Iron, as Fe, mg/l	3.5	0.15
Manganese, as Mn. mg/l	0.08	0.035
Apparent color, units	200	15
Total hardness, as $CaCO_3$ mg/l	308	268
Total dissolved solids, mg/l	440	356
Total organic carbon, as C, mgl	19	3.2
Turbitity, NTU	2	<1

[1]Analysis by Oxford Laboratories, Wilmington, NC. All determinations, except those for total dissolved solids and total organic carbon made on sample collect on June 6, 1990. Total dissolved solids are for a sample collected in 1993 - date unknown. Total organic carbon is for a sample collected on June 29, 1995

[2]Analysis by Oxford Laboratories of sample collected on October 3, 1994

Source: Report Related to the Modification of the Frisco Wellfield of the Cape Hatteras Water Association; Ralph E. Heath; August 1995

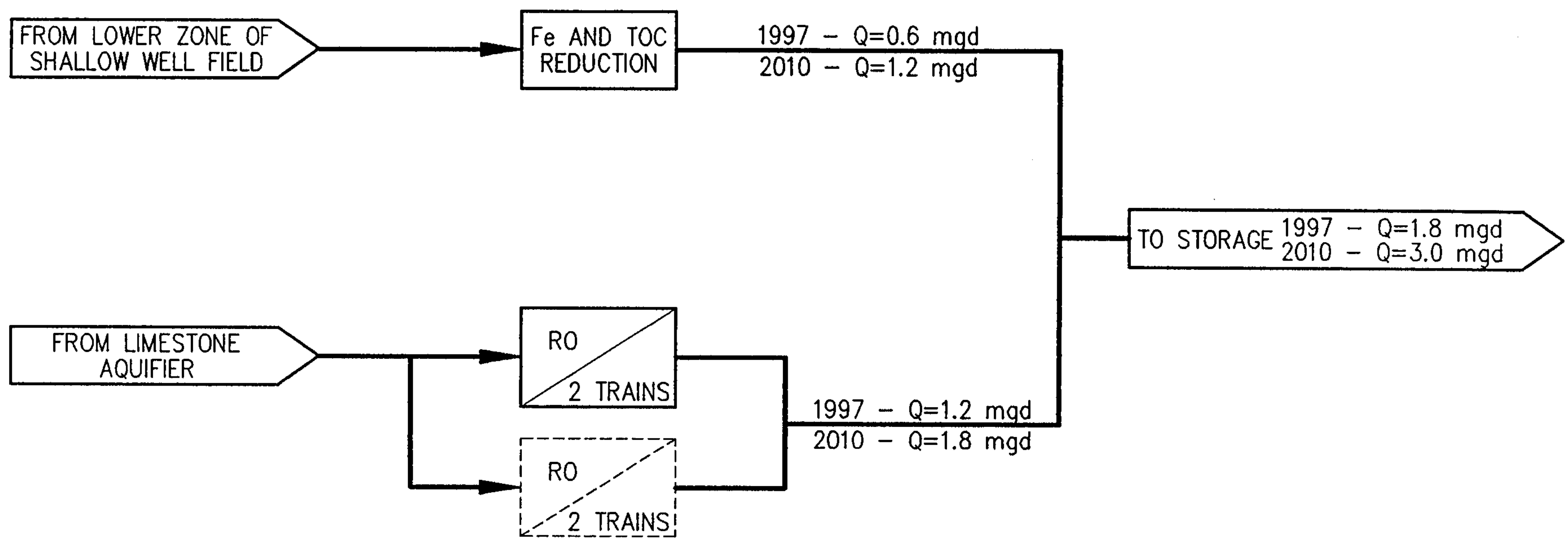

FIGURE 2
PROPOSED CAPE HATTERAS SYSTEM FLOWSHEET FOR BLENDED PRODUCT

A101–2.DWG

BOYLE ENGINEERING CORPORATION

Since the BEC report of June 2, 1995, at least two membrane manufacturers have announced that the ultra-low pressure membranes discussed in that report are now commercially available. The rumored membrane price structure, at least initially, will place a premium of $200 to $300 per element on these devices. However, given the significant energy advantage of these devices, the conceptual RO plant discussed here and in the later cost section is assumed to use the new membranes, if not initially, then in the future. Initial process designs must be developed accordingly.

Table 2 compares the water quality in terms of the significant ions and parameters from each of the three limestone test wells. Also shown is the design point analysis used in the Boyle report on Test Well #1. It will be seen that an approximate doubling of the TDS was assumed, to represent the anticipated degradation in water quality.

Table 2
Comparison of Water Quality from Three Limestone Test Wells from Lab Reports

Ion or Property (3)	TW-1	TW-2	TW-3(2)	TW-1 (1) Projected
Calcium	81.65	341	219	384
Magnesium	82.0	512	341	82
Sodium	1882	4070	2270	3656
Potassium	40	47	78	40
Barium	—	—	0.41	—
Strontium	—	—	8.95	—
Iron	0.025	0.14	0.06	—
Bicarbonate	256	234	272	256
Chloride	3800	7800	4749	5782
Sulphate	156	667.5	166	862
Fluoride	0.78	1.16	—	0.8
Silica	17.2	19.7	19.4	17.2
TDS	5800	13280	8125	11080.8
pH	7.35	7.24	7.30	7.60
Temperature °C	20	20	20	20

(1) Ionic values used for membrane performance projections in the Test Well #1 report by Boyle, June 2, 1995
(2) Analysis by US Filter, August 1995.
(3) In mg/l or as noted.

From Table 2, it can be seen that the water quality found in TW-3, although better than TW-2 as expected, is higher in chlorides and TDS than TW-1. To properly estimate the cost of desalting this water, the process must be capable of accepting future conditions. Based on the location of TW-2 and potential future well sites, it is prudent to anticipate a worsening of quality with time. However, as wells are constructed along Hwy 12, the preferred alignment to the west, it is entirely possible that the limestone formation may terminate. But given the westerly direction, the source of well water that supplies Ocracoke may be encountered. This source is lower in chlorides than even TW-1.

Because of this possibility, a future plant raw water quality was constructed consisting of 75% TW-3 water, and 25% standard seawater. The resultant quality can be seen in Table 3.

Table 3
Actual and Projected Water Quality for TW-1 & TW-3

	TW-1		TW-3	
Ion — mg/l	Pump Test	Projected	Pump Test	Projected
Calcium	82	384	219	264
Magnesium	82	82	341	573
Sodium	1882	3656	2270	4342
Potassium	40	40	78	153
Barium	—	—	0.41	0.41
Strontium	—	—	8.95	8.95
Bicarbonate	256	256	272	240
Chloride	3800	5782	4749	8307
Sulphate	156	862	166	787
Fluoride	0.78	0.78	—	—
Silica	17.2	17.2	19.4	17
TDS	5,800	11,081	8,125	14,690
pH	7.35	7.60	7.24	7.40
Temperature °C	20	20	20	20

Based on the quality available from the desalting plant, a blended product water of less than 500 mg/l TDS, and with hardness and alkalinity approximately 100 mg/l each, as discussed previously, can be produced. The analysis of initial and future product are shown in Table 4.

This water was used to make projections using both the standard low pressure membranes, and the new ultra-low pressure products. Both membranes can produce a potable quality water from the design feedwater at 50% recovery, with a concentrate quality of about 29,000 mg/l TDS. Membrane area in addition to that required for initial operations will need to be added, the array will need to be changed from two-stage to single stage, and the concentrate volume will increase to 1.8 mgd. A small volume of wastewater of similar quality to the existing WTP discharge will be generated by the shallow groundwater treatment equipment. An estimate at buildout is 50,000 gpd. The relevant data can be seen in the "Conceptual RO System Evaluation" tables in Appendix A. The membrane projection data can be found in Appendix B.

Table 4
Blended Product Water Quality

Ion-mg/l	RO Permeate Initial	RO Permeate Future	Shallow(1)	Blend Initial(3)	Blend Future(5)
Calcium	1.4	2.1	92	31.6	38.1
Magnesium	2.1	4.5	8.8	4.3	6.2
Sodium	67.8	161.0	17	50.9	103.4
Potassium	2.9	7.1	2.6	2.8	5.3
Bicarbonate	11.1	13.3	287	103.1	122.8
Chloride	108.8	257.2	70	95.9	182.3
Sulphate	1.0	6.1	10	4.0	7.7
TDS(6)	214	451.6	487	292.6	465.8
TH	12	23.5	265	96.5	120.3
TAlk	9.1	10.9	235	84.5	100.7
pH	5.91	6.34	7.62	7.0(4)	7.3
CO_2	25.2	11.2	10.9(2)	20.4	11.1
LSI	—	—	—	-1.11	–0.68

(1) Based on Dare County Analysis - 7/18/95 - assumes treatment
(2) Calculated from pH and HCO_3
(3) Based on 2:1 ratio, permeate: shallow
(4) Calculated from CO_2 and alkalinity
(5) Based on 3:2 ratio, permeate: shallow
(6) TDS is "sum of the ions."

Opinion of Cost

The proposed water treatment plant concept developed in this study has been conceived in an attempt to minimize the stress on and perhaps the deterioration of both the limestone and the lower zone of the shallow aquifer. The facility will need to be modified as the quality from each aquifer changes, and the cost of the blended water will increase with time.

Initially, two RO units, with ULP membranes in the first stage, LP membranes in the second stage and a boost pump between stages will be installed. With performance based on the initial water quality, these units will be designed to accommodate additions and modifications required in the future. The shallow water treatment plant will be installed as a single system, but with vessel redundancy. This treatment is assumed to be either manganese greens and filtration, ion exchange, or a combination of the two. The initial installation is priced at $0.75/gpd, with the future addition priced at $0.50/gpd. It is assumed that some of the existing ion exchange equipment can be retrofitted.

Energy recovery devices have now been included in the cost opinion for RO because the relatively high pressure and low recovery make such devices attractive for a brackish water system. Based on a 70% on-stream factor, the payback for energy recovery is expected to be about three (3) years.

		$M		
		Initial	Addition	Total
1.	RO equipment	1.25	0.50	1.75
2.	Blend treatment	0.45	0.30	0.75
3.	RO wells (3)	0.75	0.30	1.05
4.	Shallow wells (4)	0.18	0.18	0.36
5.	Raw water transmission (2)	0.50	0.25	0.75
6.	Finished Water Storage, 3mg	0.75	—	0.75
7.	High service pumping	0.25	0.15	0.40
8.	Treatment Plant Bldg (1)	0.75	—	0.75
	Opinion of Constructed Cost	4.88	1.68	6.56
	Contingency @ 20%	0.98	0.34	1.32
		5.86	2.02	7.88
	Legal, admin, engineering, etc. @ 25%	1.47	0.50	1.97
	Opinion of Project Cost:	7.33	2.52	9.85

The following cost assumptions were made in preparing the capital cost opinion.

1. Building cost at $100/sqf
2. The previous raw water transmission main cost remains valid. Part of the cost can be deferred until additional wells are needed for expansion in the future. The existing wellwater system is assumed to be used for future supply.
3. Five (5) RO wells are needed for the initial installation, with two (2) additional required for the future addition.
4. 18 shallow wells at 50 gpm will be required, 9 now and 9 in the future.

APPENDIX A

Conceptual RO System Evaluation

Cape Hatteras Water Association

Based on Pumped & Projected Water Quality from TW-3

Operating Parameter	Unit of measure	Initial Operation with **Hybrid** Membrane System	Future Operation with **Low** Pressure Membrane	Future Ops with **Ultra Low** Pressure Membrane
Feedwater flow, one RO unit	gpd	923,077	1,200,000	1,200,000
Permeate flow	gpd	600,000	600,000	600,000
Recovery	%	65	50	50
Permeate quality	ppm TDS	214	330	440
Est. blended product quality(1)	ppm TDS	487	379	466
Number of Membranes	ea	120	144	132
Prod'n per membrane	gpd/element	5000	4167	4545
Feed pressure 1st stage	psig	227	373	332
Interstage Pressure	psig	333		
Permeate backpressure	psig	8	8	8
Pressure allowance, fouling	psig	20	20	20
Feed pump suction pressure	psig	15	15	15
Misc. piping losses	psig	3	3	3
Feed pump boost pressure	psig	243	389	348

(1) Blended with treated shallow groundwater.

Conceptual RO System Evaluation

Cape Hatteras Water Association

Based on Pumped & Projected Water Quality from TW-3

Operating Parameter	Unit of measure	Initial Operation with **Hybrid** Membrane System	Future Operation with **Low** Pressure Membrane	Future Ops with **Ultra Low** Pressure Membrane
Feedpump efficiency	%	78	78	78
Interstage Pump efficiency	%	75		
Feedpump shaft power	hp	117	243	217
Interstage Pump power	hp	39		
Motor & VFD efficiency	%	88	88	88
Recovered power	hp	22	46	41
Net pump power	hp	134	197	176
Unit power	kwhr/kgal of permeate	4.53	6.67	5.97
Balance of plant	kwhr/kgal of permeate	2	2	2
Plant power	kwhr/kgal of permeate	6.53	8.67	7.97
Acid(93%)	ppm	0	0	0
	#/kgal of permeate	0.00	0.00	0.00
Scale Inhibitor	ppm	4.20	6.00	6.00
	#/kgal of permeate	0.05	0.10	0.10
Caustic Soda, 50%	#/kgal of permeate	0.62	0.40	0.40
Chlorine, @ 3ppm	#/kgal of permeate	0.03	0.03	0.03

Conceptual RO System Evaluation

Cape Hatteras Water Association

Based on Pumped & Projected Water Quality from TW-3

Cost Component	Unit Cost	Units	Initial Operation with **Hybrid** Membrane System	Future Operation with **Low** Pressure Membrane	Future Ops with **Ultra Low** Pressure Membrane
Power, $/kw-hr	0.07	$/kgal of product	0.457	0.607	0.558
Acid, $/#	0.10	$/kgal of product	0.000	0.000	0.000
Scale Inh., $/#	1.25	$/kgal of product	0.067	0.125	0.125
Caustic, $/#	0.22	$/kgal of product	0.136	0.088	0.088
Chlorine, $/#	0.20	$/kgal of product	0.005	0.005	0.005
Membrane, $/each	900	$/kgal of product	0.099	0.118	0.108
Cartridges, $/kgal	0.02	$/kgal of product	0.020	0.020	0.020
Cleaning, $/kgal	0.02	$/kgal of product	0.020	0.020	0.020
Opinion of Operating Cost			0.804	0.983	0.924

APPENDIX B

Initial Operation, Hybrid 1st stage

HYDRANAUTICS RO system design software -- v 5.6 (c) 1995 09-04-95
RO program licensed to: Ian Watson
Calculation created by: Ian C. Watson

Project name:	CAPE HATTERAS TW-3 95	Permeate flow:	415400.0 GPD
HP Pump flow:	641.0 GPM	Raw water flow:	923111.1 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	45.0 %
Raw water pH:	7.30	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	25.2 PPM	3 yr salt passage increase:	1.4
Feed pressure:	227.4 PSI	Recommended pump pressure:	240.3 PSI
Average flux rate:	14.4 GFD	Feed water:	Well water

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	641.0	53.4	352.6	29.4	1.07	199.5	8040-UHY-ESPA	72	12x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	219.0	546.1	219.0	546.1	1.2	3.0	397.2	990.5
Mg	341.0	1403.3	341.0	1403.3	1.9	7.8	618.5	2545.1
Na	2270.0	4934.8	2270.0	4934.8	59.8	130.0	4078.3	8866.0
K	78.0	100.0	78.0	100.0	2.6	3.3	139.7	179.1
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.4	0.3	0.4	0.3	0.0	0.0	0.7	0.5
Sr	8.9	10.2	8.9	10.2	0.0	0.1	16.2	18.5
CO3	0.2	0.3	0.2	0.3	0.0	0.0	0.4	0.6
HCO3	272.0	223.0	272.0	223.0	9.8	8.1	486.5	398.8
SO4	166.0	172.9	166.0	172.9	0.8	0.9	301.1	313.7
Cl	4749.0	6698.2	4749.0	6698.2	95.9	135.2	8556.1	12067.9
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	19.4		19.4		0.2		35.1	
TDS	8124.0		8124.0		172.2		14629.9	
pH	7.30		7.30		5.86		7.55	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	2.1%	2.1%	4.4%
SrSO4 / Ksp * 100:	5.5%	5.5%	11.4%
BaSO4 / Ksp * 100:	356.5%	356.5%	732.5%
SiO2 saturation:	14.9%	14.9%	27.0%
Langelier Saturation Index:	0.29	0.29	1.04
Stiff & Davis Saturation Index:	-0.09	-0.09	0.42
Ionic strength:	0.16	0.16	0.30
Osmotic pressure:	86.3 PSI	86.3 PSI	156.4 PSI

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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Initial Operation, Hybrid 2nd stage

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Calculation created by: Ian C. Watson

Project name:	CAPE HATTERAS TW-3 95	Permeate flow:	186400.0 GPD
HP Pump flow:	355.6 GPM	Raw water flow:	512087.9 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	36.4 %
Raw water pH:	7.55	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H_2SO_4	Flux decline coefficient:	-0.030
Acidified feed CO_2:	25.2 PPM	3 yr salt passage increase:	1.3
Feed pressure:	333.0 PSI	Recommended pump pressure:	348.7 PSI
Average flux rate:	9.7 GFD	Feed water:	RO concentrate

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	355.6	44.5	226.2	28.3	1.05	309.4	8040-LHY-CPA2	48	8x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	397.2	990.5	397.2	990.5	2.2	5.4	623.3	1554.3
Mg	618.5	2545.1	618.5	2545.1	3.4	14.0	970.5	3993.7
Na	4078.3	8866.0	4078.3	8866.0	107.0	232.6	6351.3	13807.1
K	139.7	179.1	139.7	179.1	4.6	5.9	217.1	278.3
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.7	0.5	0.7	0.5	0.0	0.0	1.2	0.8
Sr	16.2	18.5	16.2	18.5	0.1	0.1	25.5	29.1
CO3	0.4	0.6	0.4	0.6	0.0	0.0	0.6	1.0
HCO3	486.5	398.8	486.5	398.8	17.5	14.3	754.9	618.8
SO4	301.1	313.7	301.1	313.7	1.5	1.6	472.6	492.3
Cl	8556.1	12067.9	8556.1	12067.9	171.6	242.0	13354.8	18836.1
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	35.1		35.1		0.4		55.0	
TDS	14629.9		14629.9		308.2		22826.6	
pH	7.55		7.55		6.11		7.74	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	4.4%	4.4%	7.8%
SrSO4 / Ksp * 100:	11.4%	11.4%	19.9%
BaSO4 / Ksp * 100:	732.5%	732.5%	1260.0%
SiO2 saturation:	27.0%	27.0%	42.3%
Langelier Saturation Index:	1.04	1.03	1.60
Stiff & Davis Saturation Index:	0.42	0.42	0.80
Ionic strength:	0.30	0.30	0.47
Osmotic pressure:	156.4 PSI	156.4 PSI	246.0 PSI

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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Future Operation, Ultra Low Pressure

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Calculation created by: Ian C. Watson

Project name:	CAPE HATT TW-3 FUTURE	Permeate flow:	600000.0 GPD
HP Pump flow:	833.3 GPM	Raw water flow:	1200000.0 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	50.0 %
Raw water pH:	7.60	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	11.2 PPM	3 yr salt passage increase:	1.4
Feed pressure:	332.5 PSI	Recommended pump pressure:	346.3 PSI
Average flux rate:	11.4 GFD	Feed water:	Well water

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	833.3	37.9	416.7	18.9	1.04	317.7	8040-UHY-ESPA	132	22x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	264.0	658.4	264.0	658.4	2.0	5.0	526.0	1311.7
Mg	574.0	2362.1	574.0	2362.1	4.4	18.0	1143.6	4706.3
Na	4343.0	9441.3	4343.0	9441.3	157.0	341.3	8529.0	18541.3
K	154.0	197.4	154.0	197.4	6.9	8.9	301.1	386.0
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	8.9	10.2	8.9	10.2	0.1	0.1	17.8	20.4
CO3	0.3	0.5	0.3	0.5	0.0	0.0	0.6	1.0
HCO3	240.0	196.7	240.0	196.7	12.9	10.6	467.1	382.8
SO4	787.0	819.8	787.0	819.8	6.0	6.2	1568.0	1633.4
Cl	8307.0	11716.5	8307.0	11716.5	250.7	353.6	16363.3	23079.4
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	17.0		17.0		0.3		33.7	
TDS	14695.3		14695.3		440.3		28950.2	
pH	7.60		7.60		6.33		7.89	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	7.7%	7.7%	18.2%
SrSO4 / Ksp * 100:	16.4%	16.4%	38.5%
BaSO4 / Ksp * 100:	0.0%	0.0%	0.0%
SiO2 saturation:	13.1%	13.1%	26.0%
Langelier Saturation Index:	0.60	0.60	1.46
Stiff & Davis Saturation Index:	-0.01	-0.01	0.58
Ionic strength:	0.30	0.30	0.59
Osmotic pressure:	156.5 PSI	156.5 PSI	312.6 PSI

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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Future Operation, Low Pressure

HYDRANAUTICS RO s

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Calculation created by: Ian C. Watson

Project name:	CAPE HATT TW-3 FUTURE	Permeate flow:	600000.0 GPD
HP Pump flow:	833.3 GPM	Raw water flow:	1200000.0 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	50.0 %
Raw water pH:	7.60	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	11.2 PPM	3 yr salt passage increase:	1.3
Feed pressure:	373.0 PSI	Recommended pump pressure:	390.9 PSI
Average flux rate:	10.4 GFD	Feed water:	Well water

Pass	Feed Pass GPM	Flow Vessel GPM	Conc. Pass GPM	Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	833.3	34.7	416.7	17.4	1.07	359.0	8040-LHY-CPA2	144	24x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	264.0	658.4	264.0	658.4	1.5	3.7	526.5	1313.0
Mg	574.0	2362.1	574.0	2362.1	3.3	13.4	1144.7	4710.9
Na	4343.0	9441.3	4343.0	9441.3	117.6	255.6	8568.4	18627.0
K	154.0	197.4	154.0	197.4	5.2	6.7	302.8	388.2
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	8.9	10.2	8.9	10.2	0.1	0.1	17.8	20.4
CO3	0.3	0.5	0.3	0.5	0.0	0.0	0.6	1.0
HCO3	240.0	196.7	240.0	196.7	9.7	8.0	470.3	385.5
SO4	787.0	819.8	787.0	819.8	4.5	4.7	1569.5	1634.9
Cl	8307.0	11716.5	8307.0	11716.5	187.6	264.7	16426.4	23168.3
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	17.0		17.0		0.2		33.8	
TDS	14695.3		14695.3		329.6		29060.9	
pH	7.60		7.60		6.21		7.89	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	7.7%	7.7%	18.2%
SrSO4 / Ksp * 100:	16.4%	16.4%	38.5%
BaSO4 / Ksp * 100:	0.0%	0.0%	0.0%
SiO2 saturation:	13.1%	13.1%	26.0%
Langelier Saturation Index:	0.60	0.60	1.46
Stiff & Davis Saturation Index:	-0.01	-0.01	0.59
Ionic strength:	0.30	0.30	0.60
Osmotic pressure:	156.5 PSI	156.5 PSI	313.9 PSI

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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APPENDIX C

CARTER REPORT

BIOLOGICAL ASSESSMENT FOR A
NEW WATER TREATMENT PLANT
CAPE HATTERAS, DARE COUNTY, NORTH CAROLINA

6 October 1995

Prepared By:

Dr. J.H. Carter III and Ms. Tracy E. Hippensteel
Dr. J.H. Carter III and Associates, Inc.
Environmental Consultants
P.O. Box 891
Southern Pines, NC 28388
and
Dr. Leon S. Jernigan
Consulting Biologist
3717 Old Fairground Road
Angier, NC 27501

Submitted To:

Hobbs, Upchurch and Associates, Inc.
Consulting Engineers
P.O. Box 1737
Southern Pines, NC 28388

BIOLOGICAL ASSESSMENT FOR A NEW WATER TREATMENT PLANT CAPE HATTERAS, DARE COUNTY, NORTH CAROLINA

INTRODUCTION

The Cape Hatteras Water Association/County of Dare is proposing to improve water quality and quantity by building a new water treatment plant and discharge site. One location for the new water treatment plant, an alternative location, and 3 potential discharge sites were evaluated. This assessment was written to assess the suitability of each of these sites, and to evaluate the potential impacts of this project on jurisdictional wetlands and species listed as threatened or endangered, or proposed for such listing, by the U.S. Fish and Wildlife Service (USFWS), pursuant to Section 7 of the Endangered Species Act, as amended. State listed species were also considered.

PROJECT AREA

The proposed treatment plant site and the alternative site are located on Hatteras Island, near Frisco (Figure 1). Buxton Woods is located east of the proposed sites, and includes approximately 3,000 acres of dense maritime forest and relict dune-swale communities, of which 920 acres are managed as part of the Cape Hatteras National Seashore. Another 330 acres are managed by the State as part of the North Carolina Coastal Reserve. The remaining 1,750 acres are subdivided into hundreds of privately owned parcels ranging from small lots to tracts over 100 acres.

One large area (170 acres) comprises the wellfield of the Cape Hatteras Water Association (CHWA). The wellfield is a State designated public water and Area of Environmental Concern (AEC), with 44 shallow wells providing drinking water for Hatteras, Frisco, Buxton, and Avon.

Most of the woods located north of N.C. Highway 12 have been developed, with small established communities dotting the estuarine shoreline, and businesses scattered along both sides of the highway. The area to the south of Highway 12 is far less developed, with a few houses

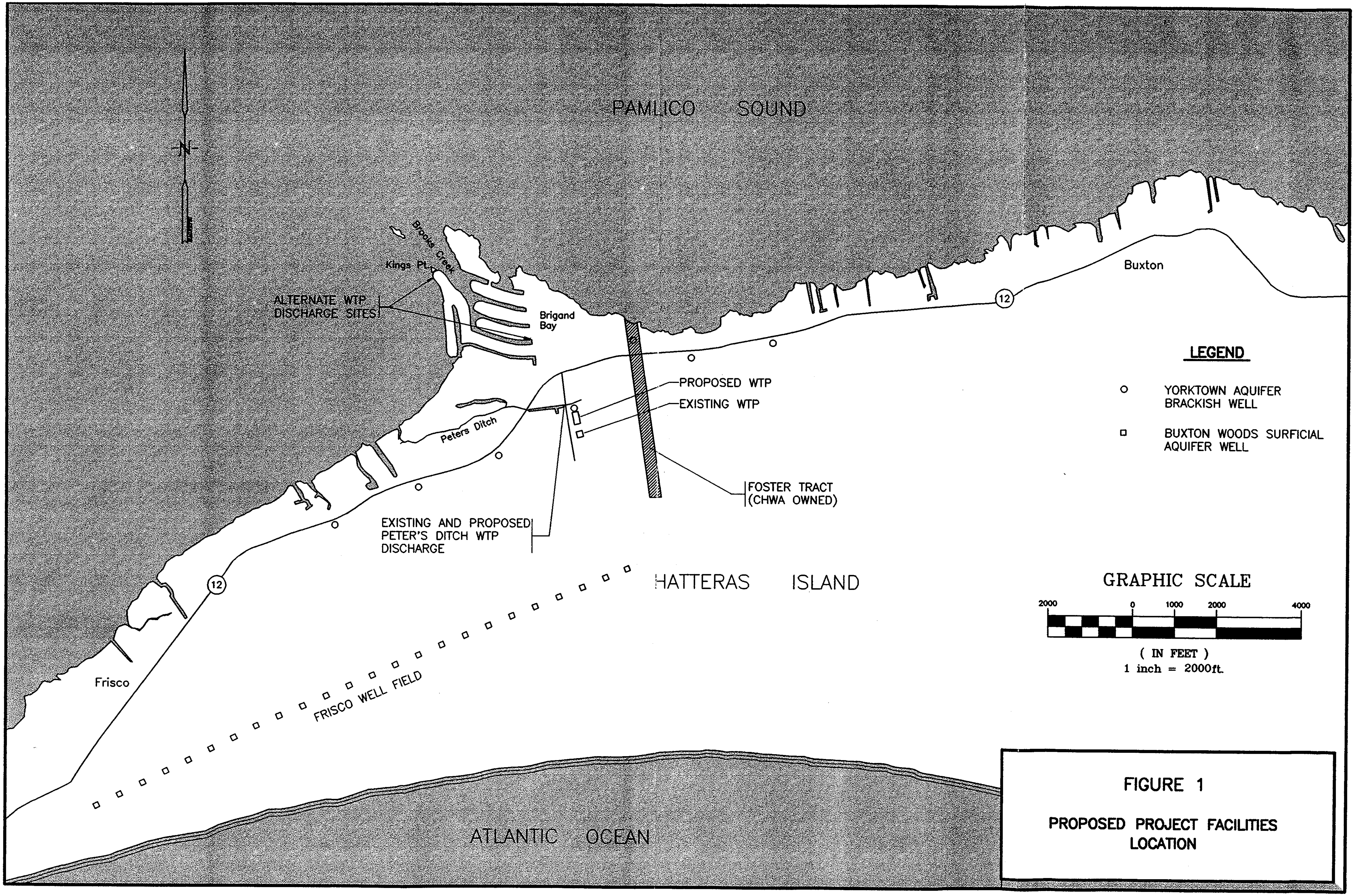

FIGURE 1

PROPOSED PROJECT FACILITIES LOCATION

tucked inside the dense forest. Interior sections of the woods have recently come under increased pressure from development. Several unimproved sand roads provide access for recreational vehicles, hunting, picnicking, and hiking on trails along dune ridges. Roadside dumps and sand borrow-pits are also found in parts of the forest.

The dominant overstory species throughout the woods are live oak (*Quercus virginiana*), loblolly pine (*Pinus taeda*), and laurel oak (*Quercus laurifolia*). Abundant understory species include redbay (*Persea borbonia*), wax myrtle (*Myrica cerifera*), ironwood (*Carpinus caroliniana*), yaupon holly (*Ilex vomitoria*), flowering dogwood (*Cornus florida*), American holly (*Ilex opaca*), and the above oak species. The topography of the interior forest is a series of dune ridges which can reach a height of 20 meters. Between these ridges are broad swales, some of which are open marshes that contain standing water much of the year. These freshwater marshes are called "sedges", and are vegetated by wild rice (*Zizania aquatica*), knotweeds (*Polygonum* spp.), sawgrass (*Cladium jamaicense*), and common cattail (*Typha latifolia*). Associated with the open sedges are swamp forest and wetland shrub communities. Swamp dogwood (*Cornus stricta*), wax myrtle, and redbay are the most abundant woody species in these areas. Vines are also very abundant including bamboo-vine (*Smilax laurifolia*), cross vine (*Anisostichus capreolata*), climbing hempweed (*Mikania scandens*), pepper-vine (*Ampelopsis arborea*), and rattan-vine (*Berchemia scandens*). Ground cover is usually sparse and consists primarily of ferns.

PROJECT DESCRIPTION

The Cape Hatteras Water Association/Dare County is proposing to build a reverse osmosis (RO) plant supplied by 7 deep groundwater wells. Poor water quality and insufficient water quantity have prompted this improvement to the current facilities. The plant site will disturb approximately 5 acres for the necessary facilities and associated parking. Each well will be located on a 1 acre or smaller parcel, but will disturb only approximately 0.25 acres. Deep well water will be mixed with water from shallow aquifer wells from the existing wellfield. Up to 1.8 million gallons a day (MGD) of saline water will be discharged to Pamlico Sound as a byproduct. This water will be considerably saltier than that of the Pamlico Sound.

METHODS

On 7 August 1995, the proposed sites for the new water treatment plant and the alternative were visited. Each of the 2 sites was surveyed on foot by 3 biologists. One of the proposed discharge sites (Peter's Ditch) was also reviewed on foot at Water Association Road, where it crosses Highway 12 and just above its confluence with Pamlico Sound. The other 2 potential discharge sites were visited briefly. Proposed well sites were not designated at the time of the survey, but the general area for installation along Highway 12 was checked.

PROJECT SITE DESCRIPTIONS

Proposed Treatment Plant Site:

The proposed treatment plant site is located between Water Association Road and Spencer Lane adjacent to the existing plant (Figure 1). This tract is 8.9 acres in size, with 6.3 acres of uplands and 2.6 acres of jurisdictional wetlands. The soil type is Psamments. Most or all of the natural soil has been disturbed or covered, and the surface layer consists of sandy marine deposits (fill).

Psamments are poorly suited for plant growth because of poor fertility. This site has revegetated with a loblolly pine overstory, with wax myrtle, redbay, and beautyberry (*Callicarpa americana*) in the understory. Vine species also were common including pepper-vine, Virginia creeper (*Parthenocissus quinquefolia*), greenbrier (*Smilax bona-nox*), yellow jasmine (*Gelsemium sempervirens*), and poison ivy (*Toxicodendron radicans*). The ground cover was very sparse, and consisted of the vines mentioned previously, and scattered patches of cane (*Arundinaria tecta*) and sawgrass.

Alternative Treatment Plant Site:

An alternative site, the Foster Tract, is located approximately 2000 feet east of Water Association Road on either side of N.C. Highway 12 (Figure 1). This tract contains 9.59 acres (from the sound to Peter's Ditch). The portion of the tract south of N.C. Highway 12 was severely impacted by Hurricane Emily in October 1993, with most of the overstory blown over or broken off. Several loblolly pines remain but they are in poor condition due to increased exposure to wind and salt spray. Other overstory trees, such as live oak and water oak (*Quercus nigra*), were mostly undamaged, as were most of the understory trees such as flowering dogwood, ironwood, and persimmon (*Diospyros virginiana*). Vine species, including muscadine grape (*Vitis rotundifolia*), catbriers (*Smilax* spp.), Virginia creeper, yellow jasmine, and cross-vine, covered much of the understory vegetation. The ground cover was also dominated by vine species, but also contained scattered patches of bracken fern (*Pteridium aquilinum*) and cane.

Excessively-drained Fripp fine sand is found throughout the area on the dune ridges on the sound side of the island, and the associated vegetation is generally protected from salt spray. Permeability is rapid and the soil is strongly to mildly acid. The seasonal high water table is more than 6 feet below the surface. Steep slopes and seepage limit the use of this soil type for development. Grading can create more favorable slopes for building, but it destroys the native vegetation and causes severe soil blowing. Dune ridges should not be graded because they provide protection from ocean storms and improve the stability of the barrier island.

The dune ridges and slopes support a maritime forest of live oak, laurel oak, loblolly pine, and black cherry (*Prunus serotina*). The understory consisted of yaupon holly, and small live and laurel oaks. The ground cover was sparse in most areas, and was composed generally of vines such as yellow jasmine, muscadine grape, and Virginia creeper. Dog fennel (*Eupatorium capillifolium*) and bracken fern were also common.

The soil type found on the lower slopes of the dune ridges is Ousley fine sand. This is a moderately well-drained soil with rapid permeability and is very strongly to strongly acid. The seasonal high water table is 1.5 to 3.0 feet below the surface. This soil is subject to rare flooding during hurricanes or exceptionally strong wind tides.

The dominant canopy trees on this soil type were loblolly pine, live oak, laurel oak, and water oak. Understory dominants included yaupon holly, flowering dogwood, redbay, wax-myrtle, and sapling oaks. The ground cover was sparse to dense and was generally dominated by vines and/or bracken fern.

Low lying areas contain Conaby muck soils. The surface layer is made up of highly decomposed organic material that has moderate or moderately slow permeability. The underlying mineral layers have moderately rapid permeability. This soil ranges from extremely acid to strongly acid, the seasonal high water table is at or near the surface, and the soil is subject to rare flooding.

Dominant trees/shrubs in these areas were swamp dogwood, wax myrtle, redbay, swamp willow (*Salix caroliniana*), red maple (*Acer rubrum*), and elderberry (*Sambucus canadensis*). Ground cover species included blackberry (*Rubus* sp.), Virginia chain-fern (*Woodwardia virginica*), marsh fern (*Thelypteris palustris*), marsh pennywort (*Hydrocotyle verticillata*), false nettle (*Boehmeria cylindrica*), and sawgrass. Numerous vines were also present in these wetter areas, and included poison ivy, bamboo-vine, climbing hempweed, pepper vine, and rattan-vine.

The depressions between the forested dunes, known locally as sedges, contain Currituck mucky peat. This soil is very poorly drained with moderate to moderately rapid permeability. It ranges from very strongly acid to moderately acid in the upper organic layers, to extremely acid to moderately acid in the lower organic and mineral layers. The seasonal high water table is 1 foot above to 1 foot below the surface, and sites are frequently flooded.

The dominant trees and shrubs surrounding these areas were swamp dogwood, wax-myrtle, redbay, and swamp willow (*Salix caroliniana*). Vines were also very common in the trees and shrubs around the margin and included bamboo-vine, climbing hempweed, pepper vine, and rattan-vine. Herbaceous vegetation included sawgrass, wild rice, royal fern (*Osmunda regalis*), fireweed (*Erechtites hieracifolia*), knotweeds, buttonweed (*Diodia virginiana*), and marsh fleabane (*Pluchea foetida*).

The soil type nearest the sound is Carteret sand. This nearly level, very poorly drained soil is in broad marshes on the sound side of the island. Permeability is rapid or very rapid, and the soil ranges from moderately acid to moderately alkaline. The seasonal high water table is 3 feet above to 1 foot below the surface, and sites are frequently flooded by tides.

The dominant species in the marshes was black needlerush (*Juncus romerianus*) and saltmeadow cordgrass (*Spartina patens*). Other vegetation included scattered patches of bullrush (*Scirpus robustus*), sea oxeye (*Borrichia frutescens*), marshelder (*Iva frutescens*), and sea-myrtle (*Baccharis halmifolia*).

Proposed Saline Water Discharge Sites:

Peter's Ditch is the preferred discharge point for the water treatment plant site located along Water Association Road. Peter's Ditch between Water Association Road and N.C. Highway 12 is a manmade ditch up to 50 feet wide in places (Figure 1). This portion of the ditch has been dredged in the past, and soils along its edges are classed as Psamments (described earlier). The vegetation consisted of loblolly pine, waxmyrtle, sea-myrtle, redbay, black cherry, and vines such as catbriers, Virginia creeper, muscadine grape, and peppervine.

From N.C. Highway 12 to the Pamlico Sound, Peter's Ditch follows a more meandering course, though it has been channelized in the past. Habitat becomes more natural as you near the sound with high salt meadows on either side that become wider near the sound. The soil type in this area is Carteret sand (described previously). The dominant vegetation was black needlerush and saltmeadow cordgrass. Other vegetation included scattered patches of bullrush, sea oxeye , marshelder, and sea-myrtle. A few areas were dominated by the invasive non-native common reed (*Phragmites communis*). The ditch north of Highway 12 contained numerous small fish and other animal life associated with estuarine systems.

Two alternative discharge points are located north of N.C. Highway 12, one off of King's Point into Brooks Creek and another into 1 of the boat slips (canals) in Brigand Bay (Figure 1). This general area has been developed as a residential community with large boat slips dredged into the uplands. Little natural vegetation remains in this area. The discharge would be piped from the water treatment plant directly into the sound at the end of King's Point or into the closed end of one of the boat slips.

RESULTS

The protected species which may occur in the area are listed in Table 1. No protected species were seen at the time of the 1 day survey. Most of these species are most likely to be found along the ocean beaches of the island. The federally threatened seabeach amaranth (*Amaranthus pumilus*) is found on ocean beaches, and the federal candidate dune bluecurls (*Trichostema* sp.1) is found on beach dunes. Seabeach knotweed (*Polygonum glaucum*), a State Candidate species also occurs on ocean beaches.

Table 1. Federally listed species which may occur in the project area for the proposed water treatment plant, Cape Hatteras, Dare County, North Carolina.

Scientific Name	Common Name	Status Federal	Status State
ANIMALS:			
Caretta caretta	loggerhead turtle	T	T
Charadrius melodus	piping plover	T	T
Chelonia mydas	green turtle	T	T
Falco peregrinus	peregrine falcon	E	E
Haliaeetus leucocephalus	bald eagle	E	E
Laterallus jamaicensis	black rail	C2	SR
Lepidochelys kempii	Atlantic ridley turtle	E	E
Sterna dougallii	roseate tern	E	E
PLANTS:			
Amaranthus pumilus	seabeach amaranth	T	T
Cyperus dentatus	toothed flatsedge		C
Eleocharis halophila	saltmarsh spikerush		T
Helianthemum georgianum	Georgia sunrose		C
Liliaeopsis carolinensis	Carolina grasswort		T
Ludwigia lanceolata	lanceleaf seedbox		C
Polygonum glaucum	seabeach knotweed		C
Trichostema sp.1	dune bluecurls	C2	C

Federal:
E = Endangered
T = Threatened
C2 = Candidate

State:
E = Endangered
T = Threatened
C = Candidate
SR = Significantly Rare

Species such as toothed flatsedge (*Cyperus dentatus*), saltmarsh spikerush (*Eleocharis halophila*), and Carolina grasswort (*Lilaeopsis carolinensis*) are State listed for the area and occur in tidal and brackish marshes. Lanceleaf seedbox (*Ludwigia lanceolata*) occurs in interdune ponds and Georgia sunrose (*Helianthemum* georgianum) occurs in maritime forests. None of these species were seen during the survey.

Vertebrate species listed for the area include the bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*). Both of these species may pass through the area, but no nesting habitat is present in the immediate project area. Other listed birds include the piping plover (*Charadrius melodus*), the roseate tern (*Sterna dougallii*), the caspian tern (*Sterna caspia*), and the black rail (*Laterallus jamaicensis*). The former 3 species primarily occur on ocean beaches and the latter species occurs in large brackish to salt marshes. This project should not affect any of these species.

Several sea turtles are listed for the area. They include the loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), and Atlantic ridley turtle (*Lepidochelys kempii*). These species should not be affected by the water treatment plant as they nest on ocean beaches and spend most of their life cycle in the ocean.

This survey did not specifically address impacts to special concern species. If any Special Concern species were seen during the survey they would have been noted.

DISCUSSION

The most logical site for the new water treatment plant would be on Water Association Road. This site is located next to the existing treatment facility and has been severely disturbed in the past. Further disturbance would not impact any "natural" habitat. Building the water treatment plant on the Foster Tract would disturb the natural dune system of the area and decrease the stability of the barrier island.

The preferred saline water discharge site is Peter's Ditch at Water Association Road. However, the potential discharge of up to 1.8 MGD of water more saline than the Sound will certainly adversely affect the estuarine "nursery" in the portion of Peter's Ditch below NC Highway 12. Discharging into Pamlico Sound off King's Point or into the canal in Brigand Bay should be seriously considered, however insufficient data are available at this time to fully assess impacts of the discharge into Peter's Ditch or these other sites.

No State or Federal, threatened or endangered species, or species proposed for such listing were found during our survey.