REPORT ON THE CONSTRUCTION AND TESTING OF THE DARE COUNTY WATER PRODUCTION DEPARTMENT REVERSE OSMOSIS WELLFIELD IN RODANTHE, NORTH CAROLINA

Prepared for:

County of Dare
Water Production Department
600 Mustian Street
Kill Devil Hills, NC 27948

May 1995

Prepared by:

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Project No. 01-03159.00

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CERTIFICATION

This report has been prepared under the supervision of and reviewed by the following Professional Geologist licensed in the State of North Carolina:

NORTH CAROLINA LICENSED SEAL GEOLOGIST RAYMOND L. KNOX

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May 31, 1995

Mr. Bob Oreskovich
Dare County Water Production Department
600 Mustian Street
Kill Devil Hills, NC 27948

Re: Rodanthe, North Carolina - Wellfield Facilities

Dear Bob:

We are pleased to transmit three copies of the completion report documenting construction and testing of the wells at the Rodanthe facilities. Pertinent recommendations concerning future use of the wells are also presented.

ViroGroup appreciates the opportunity to provide assistance on this project and looks forward to working with you in the future. We thank you and your staff for your hospitality and the use of your office and lab facilities. As always, if you have any questions or require additional information, please feel free to contact our office.

Sincerely,

Jack Breland

Jack Breland
Project Hydrogeologist

/jlb

pc: William P. Bizzell, P.E. (Black & Veatch)

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I. EXECUTIVE SUMMARY

The production capacity of the Dare County Water Production Department reverse osmosis wellfield in Rodanthe, North Carolina, has been expanded by the addition of a new production well (R.O. #2). This production well taps the Mid-Yorktown aquifer between the depths of 293 and 395 feet below land surface. The following project summary and recommendations are made based on results of the drilling and testing conducted during well construction.

A. Project Summary

1. A new supply well for the Rodanthe reverse osmosis facility has been installed approximately 2000 feet south of the existing production well. The well production interval was set in a pronounced sandstone facies located between 293 and 363 feet below land surface in the Mid-Yorktown Aquifer.

2. The existing production well (R.O. #1) was inspected using an under water TV camera. The inspection showed the 12-inch diameter stainless steel casing and screen remained in good condition.

3. Step drawdown pump tests were performed on R.O. #1 and R.O. #2. Specific capacity values were determined for each well using pump test data. The specific capacity measured for production well R.O. #1 after pumping for 24 hours was 26.6 gpm/ft at the proposed pumping rate of 500 gpm. The specific capacity of production well R.O. #2 was 25.9 gpm/ft at the same rate.

4. Water quality samples were obtained from both wells during step drawdown and aquifer performance testing. At the end of the aquifer performance tests, well R.O. #1 had a total dissolved solids concentration of 1350 mg/l and well R.O. #2 had a total dissolved solids concentration of 1210 mg/l.

5. A deep monitor well was drilled into the Lower Yorktown Aquifer (Lower zone) and completed below the first confining layers of the Mid Yorktown Aquifer using the screen and gravel pack construction technique. The total dissolved solids concentration from the lower zone was 4,100 mg/l.

6. The Principal Aquifer (Upper Zone) and the Mid-Yorktown Aquifer (Middle Zone) are separated by low permeable sand and clay layers between 220 and 285 feet below land surface at the wellfield site. The existing monitor well , which was previously completed with in the Principal Aquifer, did not indicate any communication with the Mid-Yorktown Aquifer during pumpage of the production wells.

7. Shallow wells tapping the surficial aquifer were installed near both production wells. Based on water level data obtained from the shallow wells during aquifer testing, there appears to be no hydraulic communication between the Mid-Yorktown Aquifer and the water-table aquifer. Production from wells R.O. #1 and R.O. #2 is not anticipated to impact the water-table aquifer or surface environment.

8. Aquifer performance tests were conducted at both production well sites. Data collected during the tests were used to calculate aquifer hydraulic parameters. Transmissivity values between 47,000 and 57,000 gpd/ft were calculated from the pumping data at Site #1. Transmissivity values between 45,000 and 46,000 gpd/ft were calculated from the pumping data at Site #2.

B. Recommendations

1. The two reverse osmosis productions wells in Rodanthe, North Carolina, should be pumped at a rate between 450 and 500 gpm. Higher sustained production rates of 700 to 800 gpm may be feasible from the wells but are not

recommended until further monitoring provides a record of long term water quality performance.

2. A minimum pump intake setting depth of 65 feet below land surface is recommended for both production wells. This setting depth is conservative in that pumping water levels of approximately 20 to 25 feet below land surface are expected in the wells at the proposed production rates. Setting the pumps slightly deeper than required will allow for potential well yield deterioration over time. In the event that one of the production wells is shut down, this intake setting depth would be sufficient to allow an increased production rate to offset the loss of volume. This setting depth would also compensate for increased withdrawals for future demands.

3. Static and pumping water levels in the production wells should be measured periodically to assess well yields and specific capacities. These data should be recorded and charted. Remediation procedures should be considered if the specific capacity of a well declines by 25% or more from the initial values in the report.

4. Salinity parameters such as dissolved chloride concentrations and total dissolved solid concentrations should be monitored on a periodic basis. The data can be used later to evaluate aquifer water quality stability, in considerations of increasing pumping rates, or wellfield expansion.

5. Water quality should also be monitored on a periodic basis in the Lower Zone test well (TW-6) and the Upper Zone test well (TW-2). These data can be used to assess potential vertical migration of saline water into the new wellfield.

6. Water levels in the Lower Yorktown Aquifer should be monitored on a regular basis for several years to evaluate the potential for determining upward leakance

into the Mid-Yorktown Aquifer during production. A Steven type "F" recording device or similar would be beneficial to monitor this zone.

7. Water level and water quality within the Mid-Yorktown Aquifer in the production zone test well (TW-5) should be monitored and recorded on a regular basis. Information obtained from this well will show general water level trends in the aquifer and will provide valuable information on changes in water quality. Water samples from well TW-5 should be collected on a regular basis. Key water quality parameters such as total dissolved solids, chloride concentrations, conductivity, iron, sulfides, and pH, should be evaluated. This information can be used to evaluate potential salt water intrusion from the seaward side, and could help identify potential wellfield problems before the production wells are affected.

II. INTRODUCTION

ViroGroup, Inc. was authorized by the Dare County Water Production Department to perform hydrogeologic studies at two well sites in the town of Rodanthe on the Outer Banks of North Carolina. This report documents the procedures used during the drilling, construction, and testing of one production well (R.O. #2), and the aquifer hydraulic testing and analyses of the existing production well (R.O. #1). The well sites are located approximately one-half mile south of Pea Island National Wildlife Refuge (Figure II-1). Well locations at the two designated production sites are presented in Figure II-2. The production wells will be used to supply raw water to the Dare County Water Production Department Reverse Osmosis (R.O.) water treatment plant which will be located at Site #1. The treatment plant will produce potable water for Rodanthe, Waves, Salvo, and other nearby communities. The treatment plant raw water demands should average about 0.5 million gallons per day (MGD) during the winter, and just over 1.0 MGD, during the summer.

The scope of the project included technical advisement and review of the technical specifications prepared for this project by the engineering company Black and Veatch; on-site supervision of well construction and testing; aquifer hydraulic testing; and data analysis and evaluation.

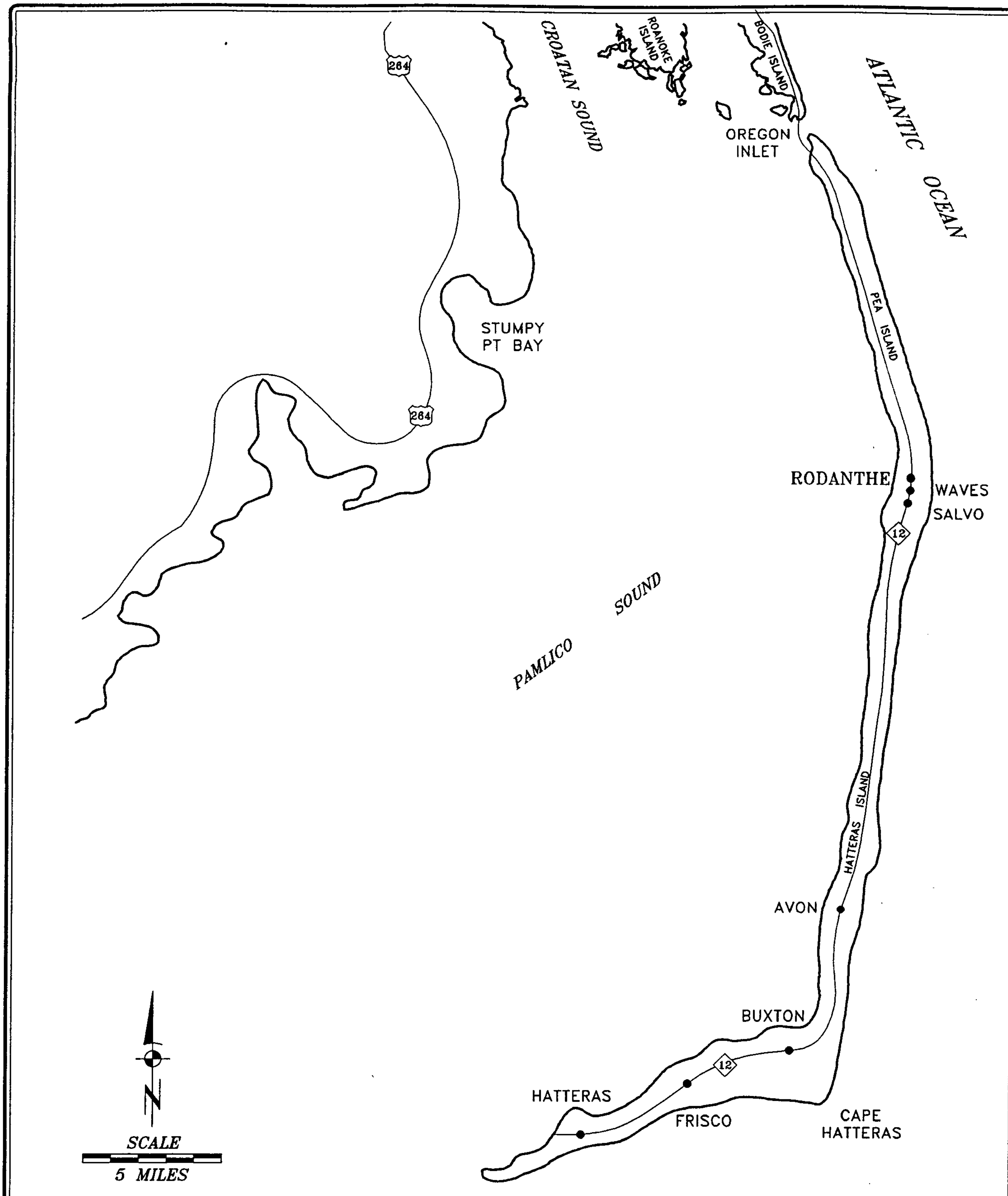

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FIGURE II-1. GENERAL LOCATION MAP OF SOUTHERN DARE COUNTY OUTER BANKS.

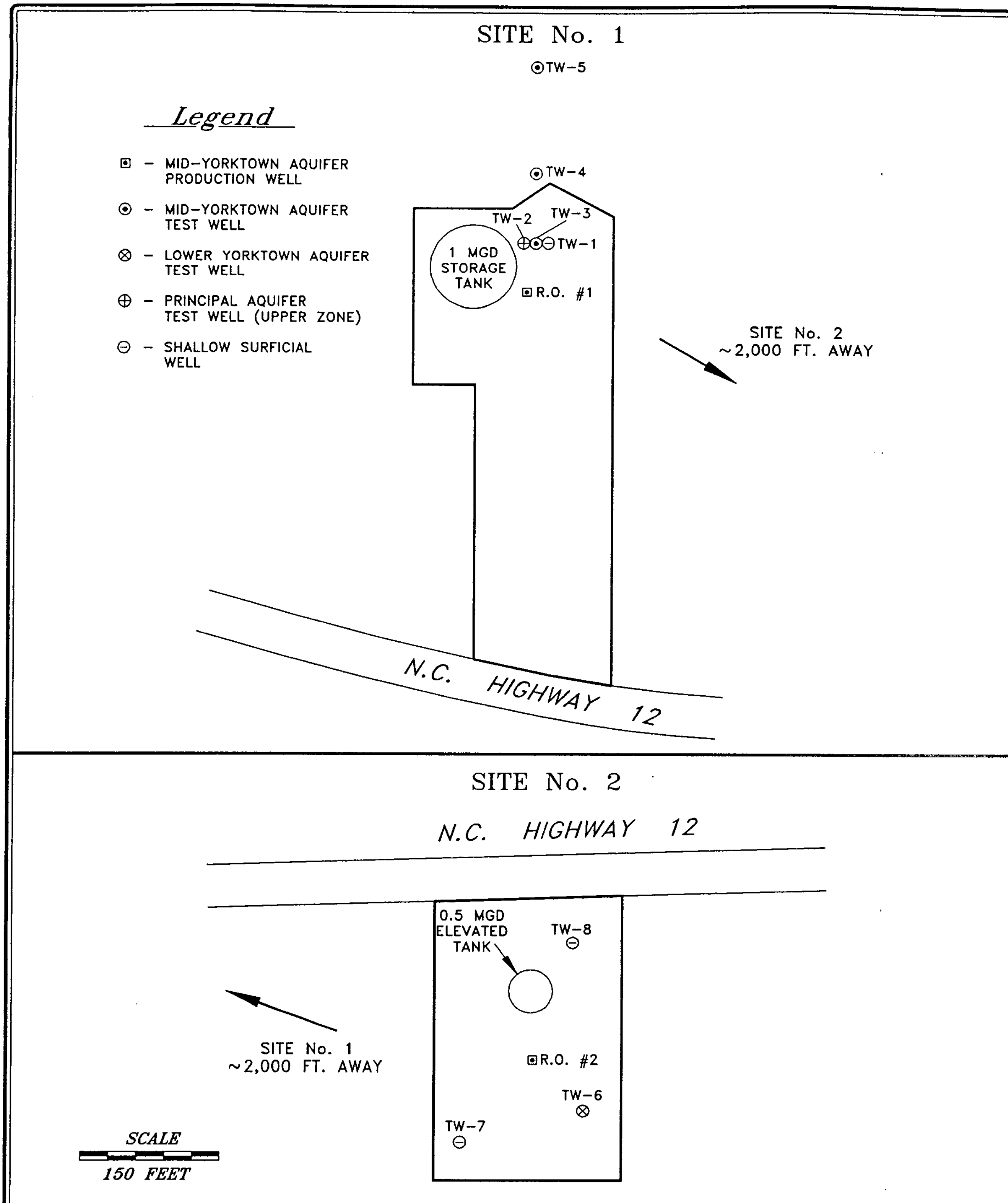

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FIGURE II-2. MAP SHOWING WELL LOCATIONS AT SITES 1 & 2, RODANTHE, NC.

III. REGIONAL HYDROGEOLOGY

A. Geology

The sediment sequence underlying the eastern coastal plain of North Carolina is typical of the Atlantic margin of the United States. It is a wedge-shaped accumulation of formations dipping and thickening seaward forming the coastal plain and continental shelf. This wedge contains a mixture of clastic sediments eroded from piedmont and internal highlands and marine carbonates deposited in a variety of near shore shelf environments (Brown, Miller, and Swain, 1972). These sediments range from Jurassic to Holocene in age and are approximately 6,200 feet thick in the Rodanthe, North Carolina area. The entire coastal plain and shelf is underlain by a crystalline basement of igneous and metamorphic rocks which has been projected to occur around 7,500 feet under the Rodanthe site. (Brown, Miller, and Swain, 1972).

A stratigraphic column of the shallow hydrogeological section beneath the wellfield site in Rodanthe, North Carolina is given in Figure III-1. Descriptions and nomenclature of lithologic units given in this report generally conform to previous work done by the U. S. Geological Survey and the North Carolina Department of Natural Resources and Community Development. Hydrostratigraphic nomenclature follows that used in previous reports by Missimer and Associates, Inc. (1987, 1992) and ViroGroup, Inc. (1994).

The uppermost and youngest strata in northeastern North Carolina are undifferentiated, post-Miocene deposits consisting of marine and non-marine clastic sediments which lie principally in the Outer Banks area. The deposits are composed chiefly of fine to coarse quartz and phosphatic sands with occasional beds of shell or sandy clay. Permeable sediments within these deposits form the surficial aquifer which typically ranges from a few feet to more than 100 feet thick (Brown, Miller, and Swain, 1972).

DEPTH, IN FEET, BELOW LAND SURFACE: 0, 100, 200, 300, 400, 500

SERIES	FORMATION	LITHOLOGY	AQUIFER
HOLOCENE PLIO-PLEISTOCENE		SAND FINE TO COARSE QUARTZ	SURFICIAL AQUIFER
	?		
PLIOCENE	YORKTOWN	CLAY OLIVE GRAY, STIFF	CONFINING BED
		SAND, GRAVEL QUARTZ	PRINCIPAL AQUIFER
		CLAY OLIVE GRAY, FINE SANDY, SILTY, MINOR SHELL	CONFINING BEDS
		SAND AND SHELL, FINE TO MEDIUM GRAIN SIZE	MID-YORKTOWN AQUIFER
		SAND AND CLAY	CONFINING BEDS
		SANDSTONE, SAND, CLAY AND SHELL	LOWER YORKTOWN AQUIFER

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FIGURE III-1. HYDROGEOLOGIC COLUMN OF THE SHALLOW SUBSURFACE BENEATH RODANTHE, NC.

Directly underlying the surficial sand deposits are the Pliocene age deposits of the Yorktown Formation. The Yorktown Formation consists of fine to coarse grain quartz sand interbedded with dense clay units and containing varying quantities of shell and phosphate ranging in size from microscopic to pebble size.

Lithologic logs from production wells in the Nags Head area and the wells drilled in Rodanthe, North Carolina, indicate that these clay units within the Yorktown Formation divide the deposit into three or more distinct aquifer units. These units differ in terms of water quality, potentiometric surface, and hydraulic character. In this report, the upper zone is termed the Principal Aquifer, the middle zone is identified as the Mid-Yorktown Aquifer, and the lower zone is identified as the Lower Yorktown Aquifer. All three of these zones were penetrated in the deep test well (TW-6) at Site #2.

B. Aquifer Description

The uppermost aquifer unit and only freshwater aquifer on Pea Island of the Outer Banks area is commonly known as the Surficial Aquifer. Typically, the Surficial Aquifer is unconfined and its upper surface is marked by the fluctuating levels of the water table. Recharge to the aquifer comes exclusively from rainfall while discharge from the aquifer occurs by evaporation and transportation, flow to surface water bodies, and pumping from wells. The surficial aquifer is made up of the undifferentiated Holocene and Pleistocene deposits lying above the Yorktown Formation. In the study area at Rodanthe, North Carolina, the Surficial aquifer is used extensively for domestic and other low volume water supplies.

Lying beneath the Surficial Aquifer, separated from it by 70 to 90 feet of fine grained clays and sands, is the uppermost confined aquifer known locally as the Principal Aquifer. The Principal Aquifer is a permeable sand unit with minor clay and shell lying in the upper section of the Yorktown Formation. It is a major source of water in eastern North Carolina. The top of the aquifer was encountered in the test hole at Site

#2 between 140 and 150 feet below land surface. The overall thickness of the aquifer under the Rodanthe wellfield site is between 90 and 100 feet. Recharge of the aquifer occurs primarily by vertical leakage through the silty/sandy clay unit overlying the aquifer with minor lateral recharge coming from inland areas. Discharge from the aquifer is through well pumpage and to lesser extent lateral flow seaward. The salinity of this aquifer under the Rodanthe wellfield indicated chloride concentrations of almost 2,000 mg/l.

Below and marking the lower boundary of the Principal Aquifer at the wellfield site is approximately 65 feet of dense marine clay with very minor quantities of silt, sand, and shell. The thickness and lithology of this unit provides good confinement between the Principal Aquifer and the underlying Yorktown Aquifer.

The sand aquifer occurring between 293 and 400 feet below land surface (bls) is referred to in this report as the Mid-Yorktown Aquifer. The unit consists primarily of medium to fine grain quartz sand with phosphorite sand and common gravel. The thickness of the more permeable zones of the aquifer ranges between 70 and 100 feet. Some clayey sand units occur within the Yorktown Formation between 370 and 400 feet bls. These units were not utilized in the production well at Site #2 because of the diminished productivity and the poorer water quality.

Lying below the Mid-Yorktown Aquifer is a sequence of lower permeability sand and clay sediments, which have been referred to in previous reports as the "Mid-Yorktown aquitard". This sequence of beds impedes the vertical movement of water between the Mid- and Lower Yorktown aquifers. The Lower Yorktown Aquifer is used to refer to the clayey sand beds and the more transmissive sand and shell sequence lying below the confining beds.

The recharge into the Yorktown Aquifer beneath the Outer Banks is predominantly by lateral flow from inland areas. The Albemarle Sound and Pamlico Sand intersect the recharge area of the Yorktown Aquifer providing brackish water recharge to the aquifer. Since the Yorktown Aquifer consists primarily of clay north of Albemarle Sound, little to no recharge can occur in those areas. Consequently, the potential for fresh water recharge to the Yorktown Aquifer is limited chiefly to rainfall on mainland areas of Washington, Beaufort, Tyrrell, Dare, and Hyde counties.

C. Water Quality

Groundwater quality in the coastal region of North Carolina varies greatly with depth and areal extent due to the complex nature of the geology.

The Surficial Aquifer water quality is dependent upon ground elevation and the proximity to pumpage. Chloride concentrations on the mainland are generally potable while at the study area in Rodanthe, a freshwater lens around 5 to 15 feet floating on saline water, is the only fresh groundwater available. Below the fresh water lens lies saline water commonly of sea-water quality. Due to the low lying nature of the land mass at Pea Island, the water quality of the Surficial Aquifer fluctuates due to sea water encroachment during heavy storms.

Water quality within the Principal Aquifer is similar to that of the Surficial Aquifer. On the mainland and east onto Roanoake Island, it is generally potable while in Rodanthe, water with 1,950 mg/l chloride concentration are encountered. Similar water quality concentrations are reported within the Principal Aquifer in other test wells on the Outer Banks area.

The Yorktown Aquifer is generally more brackish that the Principal aquifer. However, at the Outer Banks, the aquifers are commonly more saline. Only in the inland recharge areas of the Yorktown Aquifer is the aquifer potable quality. In coastal areas, the Yorktown Aquifer is found to be density- stratified with higher quality water at the top of the aquifer. Table III-1 illustrates the variability of chloride concentrations with

TABLE III-1. VERTICAL AND AREAL DISTRIBUTION OF CHLORIDE CONCENTRATIONS IN THE YORKTOWN AQUIFER, OUTER BANKS, NC.

WELL LOCATION ON THE OUTER BANKS	DEPTH (FT BELOW LAND SURFACE)	DISSOLVED CHLORIDE CONCENTRATIONS (MG/L)
KITTY HAWK	305 - 315	6,760
	420 - 430	6,880
KILL DEVIL HILLS	320 - 330	330
	400 - 410	1,400
	495 - 505	4,400
NAGS HEAD	314 - 324	1,275
	363 - 373	4,700
RODANTHE	345 - 355	500
	400 - 490	2,800

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depth at several well sites on the Outer Banks. Chloride concentrations at the Rodanthe test site measured 390-400 mg/l in the 295-370 foot (bls) interval, and 2,800 mg/l was measured in the 400-500 feet (bls) interval. In a test well at Nags Head, chloride concentration in the 314-324 feet (bls) interval was 1,275 mg/l and in the 420-430 feet (bls) interval was 4,700 mg/l. A Yorktown Aquifer well in Kitty Hawk had chloride concentration of 6,760 mg/l in the 305-315 feet (bls) interval and 6,880 mg/l from 363-373 feet (bls). At the Kill Devil Hills test site, a chloride concentrations of 330 mg/l was measured in the 320-330 feet (bls) interval. A chloride concentration of 1,400 mg/l was measured in the 400-410 feet (bls) interval, and a chloride concentration of 4,400 mg/l was measured in the 495-505 feet (bls) interval.

IV. TEST WELL CONSTRUCTION AND TESTING

A. Drilling Methods and Testing

The construction and development of the lower zone test well (TW-6) screened in the Lower Yorktown Aquifer at Site #2 was conducted by Skipper's Well Drilling of Leland, North Carolina. A schematic diagram of (TW-6) is provided in Figure IV-1. ViroGroup, Inc. (VGI) staff provided on-site supervision, collected formation samples for lithologic analysis, and recommended final well design. The methods and materials used by the drilling contractor were in accordance with the technical specifications outlined in the contract documents and standards of the American Water Works Association for Water Wells (AWWA A100-90) and National Water Well Association Standards. Construction of the test well began in January, 1995 and was completed in February, 1995. Construction details of the Rodanthe test wells are presented in Table IV-1. The drilling procedures used are as follows.

The mud rotary method was used to drill the test well. Bentonite mud was used during all drilling. A string of 16-inch diameter steel surface casing was set to a depth of 40 feet below land surface and grouted in place. A nominal 7-inch diameter pilot hole was then drilled to a depth of 500 feet below land surface. An on-site VGI hydrogeologist collected lithologic samples for field analysis. Geologist's logs of the sediments encountered during drilling are included in Appendix A.

Formation sand samples were obtained from the 7-inch diameter pilot hole at three representative intervals within the Mid-Yorktown Aquifer for sieve analyses. These representative samples were sent to Wheelabrator Engineered Systems Laboratory and analyzed for grain size and distribution to assist in determining the screen slot sizes and gravel pack material for the production well (R.O. #2) to be drilled at Site #2.

RODANTHE WELLFIELD DEEP TEST WELL (TW-6)

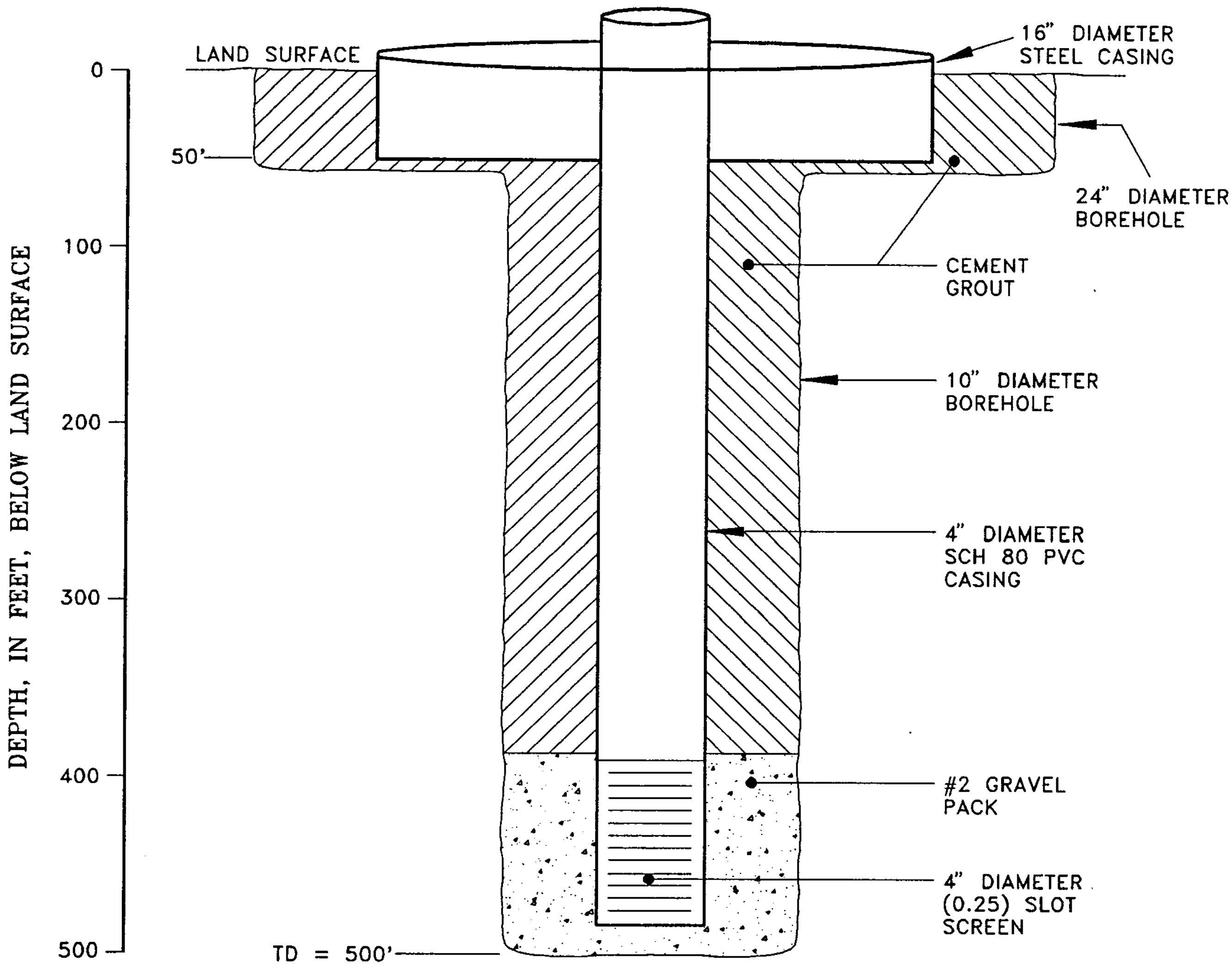

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FIGURE IV-1. SCHEMATIC DIAGRAM SHOWING CONSTRUCTION DETAILS OF THE LOWER ZONE TEST WELL AT SITE No. 2.

TABLE IV-1. TEST WELL CONSTRUCTION DETAILS OF EACH SITE

SITE	Test Well Number	Total Depth (ft bls)	Casing & Screen Diameter (inches)	Screened Interval (ft bls)	Aquifer	Annulus Material (ft bls) Cement Slurry	Annulus Material (ft bls) Gravel Pack
SITE #1	TW-1	30	3	30-40	Water-Table	0-25	25-40
	TW-2	220	3	210-220	Principal	0-200	200-220
	TW-3	355	3	345-355	Mid-Yorktown	0-325	325-355
	TW-4	355	3	345-355	Mid-Yorktown	0-325	325-355
	TW-5	355	3	345-355	Mid-Yorktown	0-325	325-355
SITE #2	TW-6	500	4	395-495	Lower Yorktown	0-390	390-500
	TW-7	40	4	30-40	Water-Table	0-25	25-40
	TW-8	40	4	30-40	Water-Table	0-25	25-4

Geophysical logs including natural gamma, single point resistance, and spontaneous potential were run inside the pilot hole. The data obtained from these logs was used to evaluate and plan construction of the production well R.O. #2.

Originally, the scope of services called for placing the screen within the Mid-Yorktown Aquifer. However, after examining the lithology and geophysical logs from the test hole drilled at Site #2 and reviewing the existing data at Site #1, it was decided to place the screened portion of the well into the Lower Yorktown Aquifer (lower zone). This change in the test well construction design not only aided in our construction of R.O. #2, but added important information to our understanding of the hydraulic connection between the Mid-Yorktown Aquifer and the Lower Yorktown Aquifer. The completed test well will subsequently serve as a Lower Yorktown Aquifer monitor well for purposes of monitoring water quality in the lower aquifer.

Following geophysical logging, the 7-inch diameter pilot hole was reamed to a nominal 10-inch diameter to the depth of 500 feet and 4-inch diameter PVC screen (0.025 slot) and Schedule 80 casing were installed. A coarse sand filter pack material (Morie #2) was placed by tremie pipe in the annular space between the borehole and screen to a height of approximately 5 feet above the screen in the well, and a compressed air pumping and surging technique was used to develop the well. The well was developed until the produced water was free of sediment material. The remaining annular space between the borehole and casing was grouted with neat Portland cement. Grouting was accomplished in one tremie stage. Additional cement was added as needed to bring grout levels to land surface.

B. Water Quality Testing

Water samples were obtained from the zone above and within the Mid-Yorktown Aquifer at Site #1 and in the lower zone beneath the Mid-Yorktown Aquifer at Site #2. These samples were analyzed by professional personnel with the Dare County Water

Production Department. Table IV-2 presents a comparison of water quality parameters at the Rodanthe wellfield within the Principal Aquifer, Mid-Yorktown Aquifer, and the Lower Yorktown Aquifer. As indicated, the salinity of the water within the upper and lower zones at the Rodanthe sites is considerably higher than the salinity within the middle production zone. The variation in water quality parameters as listed in Table IV-1 suggests good confinement between the three zones.

During pumpage of the Mid-Yorktown Aquifer, leakage of water from the lower zone will likely be the primary recharge source. This conclusion is based on the thickness of the marine clay units that separates the Principal Aquifer from the Mid-Yorktown Aquifer which is approximately 65 feet while the confining clay unit that separates the Lower Yorktown from the Mid-Yorktown Aquifer is about 10 feet thick. There is a hydraulic connection between the Mid-Yorktown Aquifer and the underlying permeable sediments of the Lower Yorktown Aquifer through leakage across the confining beds. This condition has also been identified at the Baum Tract wellfield and is related to water production from wells located at Kill Devil Hills, North Carolina. The influence of water quality from the Lower Yorktown and the projected rate of salinity increase are not addressed in this report.

TABLE IV-2. WATER QUALITY IN THE UPPER, MIDDLE, AND LOWER YORKTOWN FORMATION ZONES AT RODANTHE, NC.

AQUIFER NAME	AQUIFER ZONE	CHLORIDE CONCENTRATION (MG/L)	CONDUCTIVITY (OHMS)	TOTAL DISSOLVED SOLIDS (MG/L)
PRINCIPAL	Upper Zone (SITE #1)	1,950	9,170	3,960
MID-YORKTOWN	Middle Zone (SITE #1)	500	2,660	1,340
LOWER YORKTOWN	Lower Zone (SITE #2)	2,500	8,300	4,150

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V. R.O. WELL CONSTRUCTION AND TESTING

A. R.O. #1 Testing

The construction and development of production well R.O. #1 in Rodanthe was completed in 1986. The information on construction details was obtained through the Dare County Water Production Department. The construction details for the existing production well (R.O. #1) are presented in Table V-1. A schematic diagram of R.O. #1 is shown in Figure V-1. Recent testing of R.O. #1 was conducted by Skipper's Well Drilling during February and March of 1995. Supervision was provided VGI staff during all phases of the testing activities. The work on R.O. #1 well included video surveying, step-drawdown testing, and aquifer performance testing. Aquifer performance testing and the step-drawdown testing are discussed in Sections V and VI.

The existing production well R.O. #1 was inspected using an underwater TV camera. The video survey was performed in March by the State of North Carolina's Natural Resource Department. The inspection of R.O. #1 showed the 12-inch diameter steel casing and screen to be in good condition. A copy of the video survey is not available at this time, but will be provided at a later date through Skipper's Well Drilling.

B. R.O. #2 Construction and Testing

The construction, development, and testing of production well R.O. #2 in Rodanthe were performed by Skipper's Well Drilling during February and March of 1995. This work was supervised by an on-site ViroGroup hydrogeologist. The work performed during the construction and testing phase included: drilling and reaming of the pilot hole, setting of the screen and casing, developing of the well, step-drawdown testing, and aquifer performance testing. The final well design was based on results of sieve analyses, geophysical logs, and lithologic analyses of formation samples obtained

TABLE V-1. CONSTRUCTION DETAILS OF WELLS R.O. #1 AND R.O. #2

Well	Total Depth (feet bls)	Casing Depth (feet bls)	Casing Diameter (inches)	Casing Type	Screen Type	Screened Interval (feet bls)
*R.O. #1	410	395	12	Steel	Stainless steel (shutter)	305-395
R.O. #2	365	293	8 to 12	Sch 80 PVC	Stainless Steel (Continuous Wrapped)	293-363

* R.O. #1 was installed in 1986 by Layne-Atlantic Company. The information was obtained by video surveying and existing reports from Dare County and Black & Veatch.

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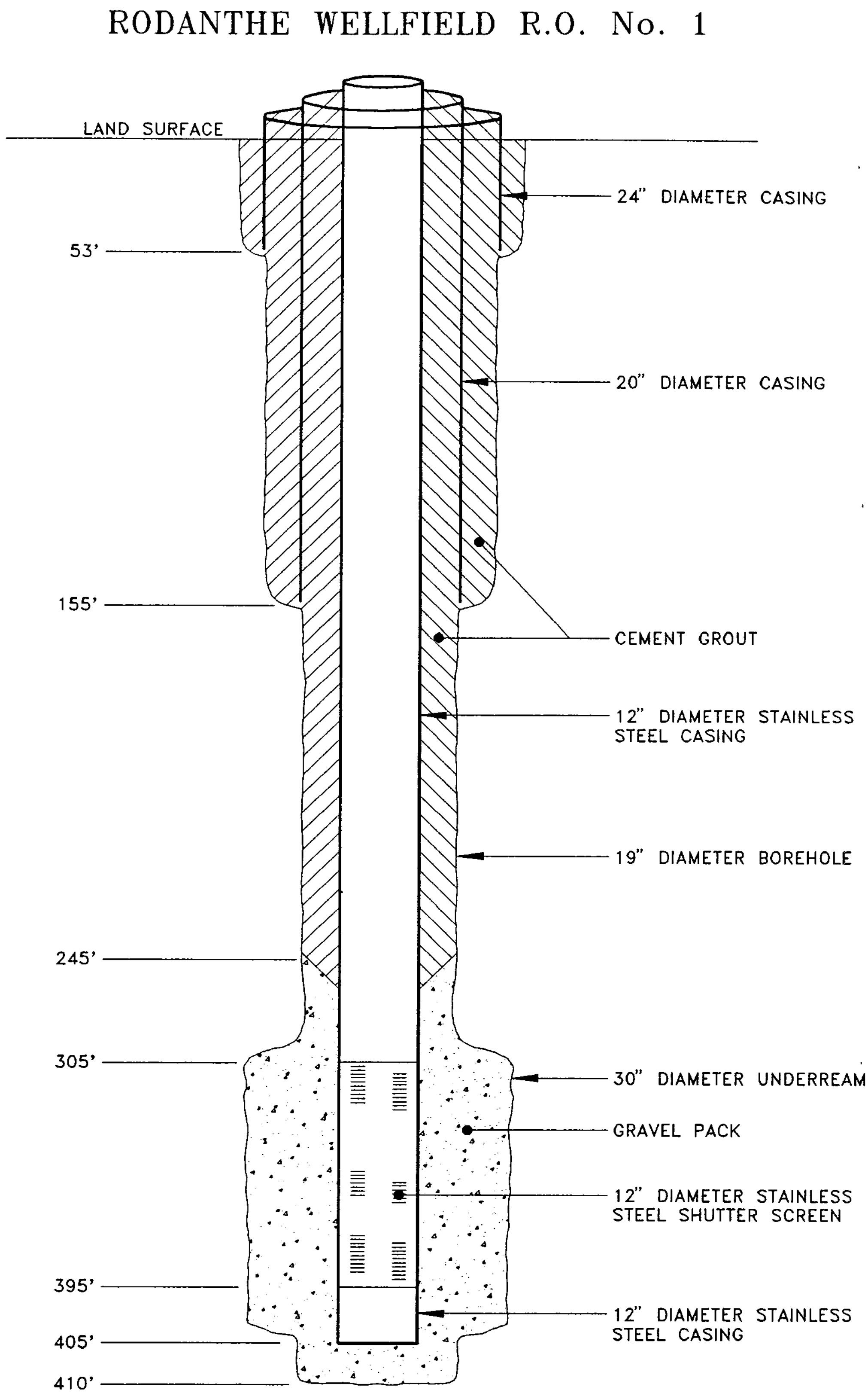

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	PROJECT NAME: RODANTHE R.O.		NUMBER: 01-03159.00

FIGURE V-1. SCHEMATIC DIAGRAM SHOWING THE CONSTRUCTION DETAILS OF R.O. No. 1.

during the construction and testing of the lower zone test well at Site #2 as described in Section IV. Construction details for R.O. #2 are summarized in Table V-1 and shown graphically in Figure V-2.

The methods and materials used by the drilling contractor were in accordance with the technical specifications outlined in the contract documents and standards of the American Water Works Association for Water Wells (AWWA A100-90) and National Water Well Association Standards.

The mud rotary method was used to drill the production well, R.O. #2. Bentonite mud was used during drilling of the surface and intermediate casing boreholes. Revert, a biodegradable drilling fluid, was used during drilling of the borehole to be screened. A string of 24-inch diameter steel surface casing was set to a depth of 40 feet below land surface at site #2 and grouted in place. A nominal 24-inch diameter borehole was then drilled to the depth of 293 feet below land surface.

The 18-inch diameter intermediate casing was installed and grouted in place at a depth of 265 feet below land surface. A nominal 16-inch diameter borehole was then drilled to 375 feet below land surface. An 8-inch diameter stainless steel, 0.035-inch continuous slot screen was installed in the production interval of the borehole, located between 293-363 feet below land surface. A section of stainless steel casing with an end cap was placed on the end of the screen as a sump. The production casing string consisted of 8-inch diameter Schedule 80 PVC casing from the top of the screen to a depth the depth of 156 feet below land surface. The casing was then extended at this depth to 12-inches in diameter to land surface for well development purposes.

Following installation of the well screen and casing, a coarse sand filter pack (Morie #2) was placed in the annular space between the borehole and screen in the well. The filter pack material was placed in the well to a height of 20 feet above the screen

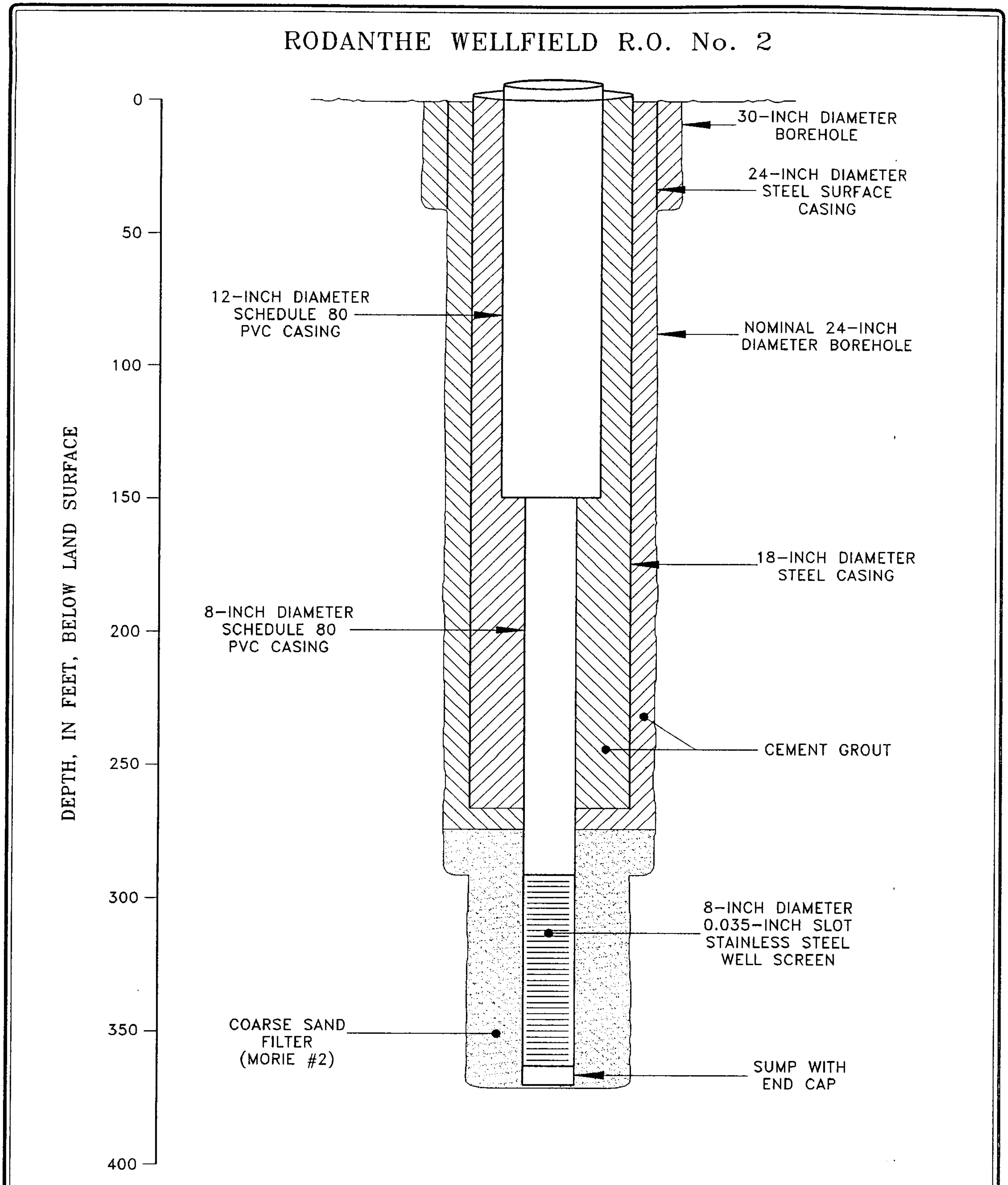

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FIGURE V-2. CONSTRUCTION DETAILS OF R.O. No. 2.

using the tremie pipe method. This depth was picked in order to cement the base of the 18-inch diameter casing.

Compressed air pumping, gravity surging, and horizontal jetting with chlorinated water were used to develop the wells. The entire screen length in the well was jetted and the well was surged repeatedly until the water produced was relatively clear and free of sediment. The well was developed by this method until the specific capacity stabilized. A total of approximately 14 hours of development time was required. The gravel pack material was maintained 20 feet above the top of the 8-inch diameter screen interval during the development stage using a tremie line. Following completion of well development, the annular space between the inside casing and the intermediate casing was grouted with neat Portland cement on March 7, 1995.

C. Step Drawdown Testing of Production Wells

Step-drawdown tests were conducted on the Rodanthe production wells to assess individual well yield and to determine efficient pumping rates and pump setting depths. The wells were test pumped using an electric powered submersible pump with the pump intake set at 73 feet below land surface. The flow rate was monitored using an in-line totalizing flowmeter. Water was directed away from the site using a temporary discharge line.

Production wells were tested at four distinct pumping rates (steps). Each rate was maintained for approximately 2 hours. Water levels were measured manually at set time intervals using an electric water level indicator. Time and drawdown data recorded during the tests are listed in Tables C-1 and C-2 (Appendix C). Listed for each step is the pumping rate, the pumping water level, the measured drawdown, and the calculated specific capacity in gpm/ft at the end of each step. A summary of the test results are presented in Table V-2. Plots of specific capacity versus pumping rates for both wells are provided in Figures V-3 and V-4.

TABLE V-2. SUMMARY OF STEP-DRAWDOWN TEST RESULTS IN R.O. #1 AND R.O. #2

Production Well	Pumping Rate (GPM)	Drawdown (Feet)	Specific Capacity (GPM/Ft)
R.O. #1	200	6.14	32.6
	425	13.67	31.1
	800	26.49	30.2
	950	32.53	29.2
R.O. #2	250	8.60	29.1
	450	16.85	26.7
	650	25.59	25.4
	850	24.34	24.3

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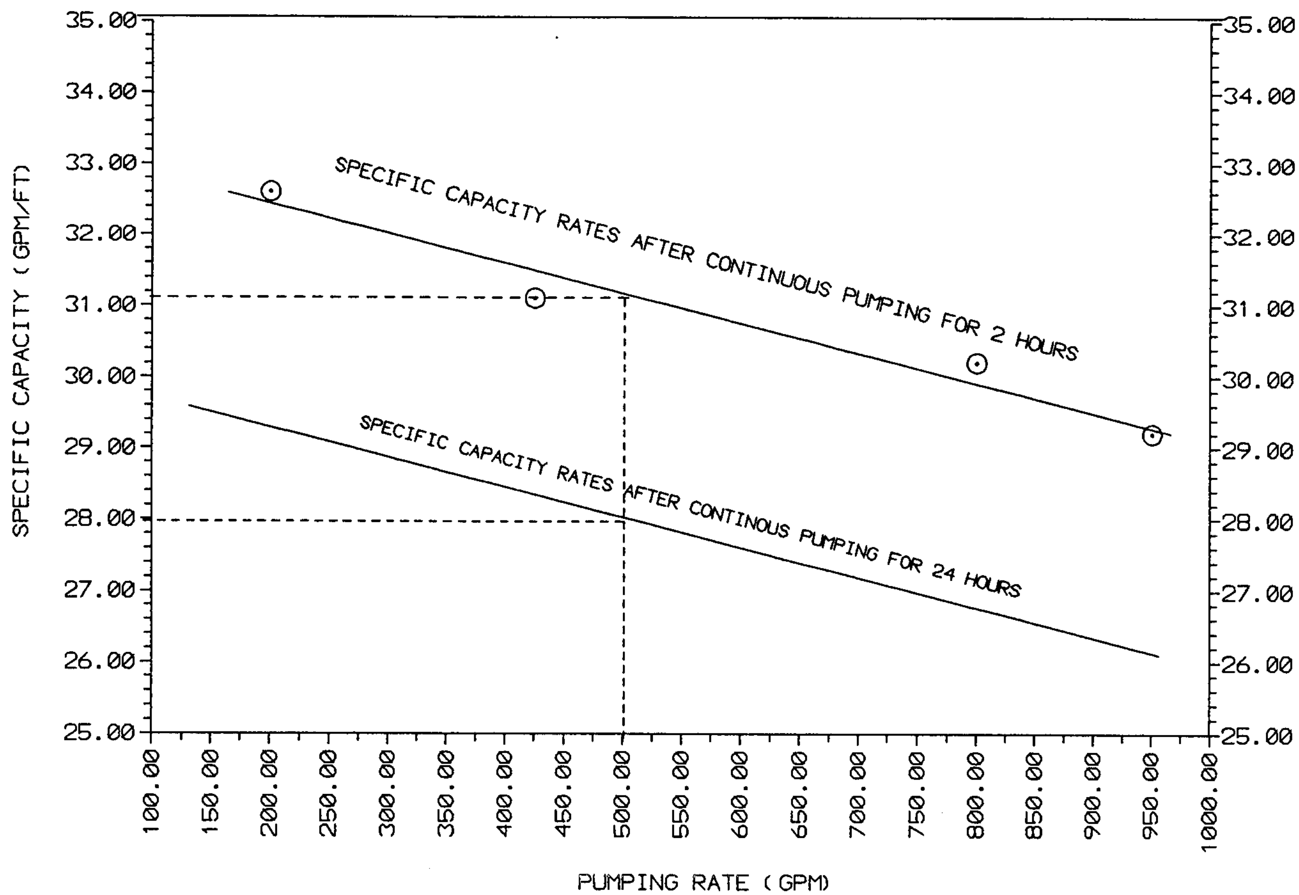

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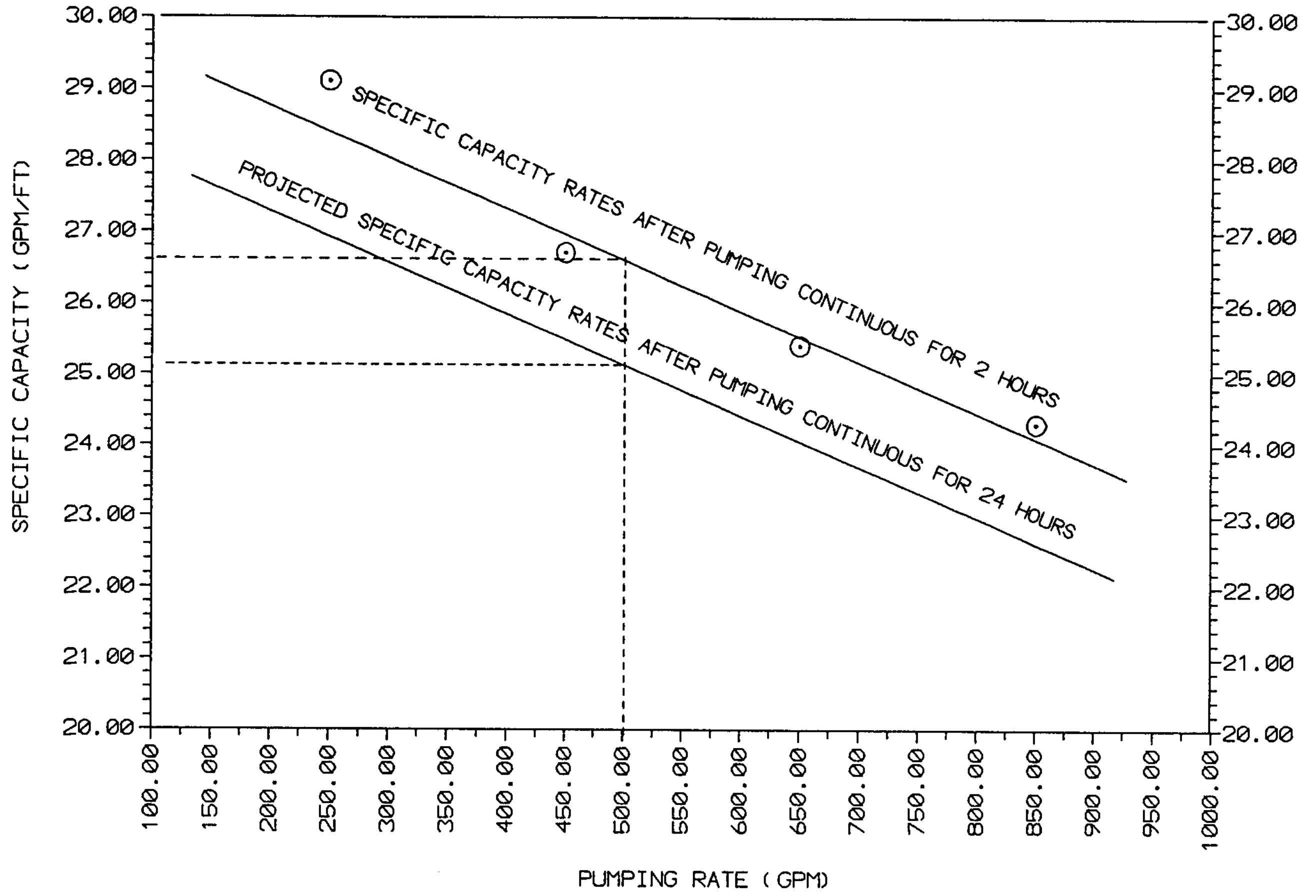
FIGURE V-3. GRAPH OF SPECIFIC CAPACITY VS. PUMPING RATE FOR WELL R.O. #1.



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PROJECT NAME: RODANTHE R.O. PROJECT NUMBER: 01-03159.00

FIGURE V-4. GRAPH OF SPECIFIC CAPACITY VS. PUMPING RATE FOR WELL R.O. #2.

Well R.O. #1 was tested on February 21, 1995. Prior to test start, static water level in the well was 2.9 feet below the measuring point, or approximately 2 feet below land surface. The well was pumped at rates ranging from 200 gpm to 950 gpm with corresponding drawdowns ranging from approximately 6 feet to 33 feet. The specific capacities calculated for well R.O. #1 ranged from 33.6 gpm/ft to 29.2 gpm/ft.

Well R.O. #2 was tested on March 7, 1995. Prior to test start, static water level in the well was 2.56 feet below the measuring point, or approximately 1 foot above land surface. The well was pumped at rates ranging from 250 gpm to 850 gpm with corresponding drawdowns ranging from approximately 7 feet to 24 feet. The specific capacities calculated for well R.O. #2 ranged from 29.1 gpm/ft to 24.3 gpm/ft.

Test results indicate that both wells are capable of producing approximately 450 to 500 gpm on a sustained basis. Higher production rates of 700 to 800 gpm are feasible, but are not recommended until further monitoring provides a record of long term water quality performance.

A minimum pump intake setting of 65 feet below land surface is recommended for both production wells. Pumping water levels of approximately 20 to 25 feet below land surface are expected in the wells at the proposed production rates. Setting the pumps deeper than required will allow for potential declines in specific capacity over time. In the event that one of the production wells is shut down, the deeper pump setting depth would also allow for an increased pumping rate in the remaining well.

D. Water Quality Analysis of Production Wells

Water samples were obtained from both production wells during the step drawdown and aquifer performance tests to assess any variation in selected water quality parameters with time, or while pumping at variable rates. The samples were analyzed by Dare County Water Production Department staff for dissolved chloride concentrations and for total dissolved solids (TDS). Results of the analyses are presented in Tables V-3 and V-4.

Chloride and TDS concentrations remained stable throughout both tests. Chloride concentrations ranged between 500 and 530 mg/l in well R.O. #1 and between 390 and 450 mg/l in well R.O. #2. Total dissolved solids concentrations ranged between 1,340 and 1,400 mg/l in well R.O. #1 and between 1,130 and 1,275 mg/l in well R.O. #2.

Water quality parameters such as dissolved chloride concentration should be monitored on a monthly basis in both production wells and in nearby monitor wells to assess potential changes in water quality associated with wellfield withdrawals. A hydraulic solute transport model should be developed to provide predictive scenarios of anticipated water quality changes associated with wellfield withdrawals.

TABLE V-3. WATER QUALITY ANALYSES RESULTS DURING STEP-DRAWDOWN TESTS OF R.O. #1 AND R.O. #2

Sample Selected Time	Well R.O. #1		Well R.O. #2	
	Dissolved Chloride Concentration (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Chloride Concentration (mg/l)	Total Dissolved Solids (mg/l)
End Step 1	530	1,400	450	1,275
End Step 2	520	1,340	400	1,200
End Step 3	510	1,350	400	1,200
End Step 4	500	1,340	400	1,200

* WATER QUALITY ANALYSIS PERFORMED BY DARE COUNTY WATER PRODUCTION DEPARTMENT STAFF

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TABLE V-4. WATER QUALITY ANALYSES RESULTS DURING THE AQUIFER PERFORMANCE TESTS IN R.O. #1 AND R.O. #2

WELL R.O. #1 PUMPING AT 700 GPM		
Time Sample Selected (hours)	**Dissolved Chloride Concentration (mg/l)**	**Total Dissolved Solids (mg/l)**
.5	510	1,350
24	500	1,340
48	520	1,340
61	510	1,350

WELL R.O. #2 PUMPING AT 850 GPM		
Time Sample Selected (hours)	**Dissolved Chloride Concentration (mg/l)**	**Total Dissolved Solids (mg/l)**
.5	390	1160
24	390	1160
48	390	1130
61	400	1210

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VI. AQUIFER PERFORMANCE TESTING

A. Testing Procedures

Aquifer Performance Tests (APT) were performed at Sites 1 & 2 to determine site specific aquifer coefficients of the Mid-Yorktown aquifer. Test production wells R.O. #1 and R.0. #2 were pumped at a constant rate and drawdown was monitored in observation wells tapping the middle aquifer, and in observation wells completed in the surficial aquifer, the Principal Aquifer and in the Lower-Yorktown aquifer. Time-Drawdown data (Appendix B) were plotted logrithmically and analyzed using appropriate methods to obtain estimates of aquifer coefficients.

The test production wells were pumped using an electric powered submersible pump with the pump intake set at 73 feet below land surface. The flow rate was monitored using an in-line totalizing flowmeter. Water was directed away from the site using a temporary discharge line. Flow rate was maintained by monitoring the flowmeter and adjusting the gate valve or engine throttle when necessary to obtain a constant pumping rate. Drawdown in observation wells were monitored using pressure transducers and an InSitu, Inc. Hermit 2000 data logger, and with continuous water level recorders. Aquifer recovery levels were monitored following pump shut down.

Site #1 was tested on March 2, 1995. Production well R.O. #1 was pumped at a constant rate of 700 gpm for 24 hours. Drawdown in the Mid-Yorktown Aquifer was measured in observation wells TW-3 and TW-4 located 50 and 125 feet from the pumped well. Water-Table aquifer water levels were monitored in well TW-1, located approximately 50 feet from the production well. Water levels in the Principal Aquifer were monitored in test well TW-2. A graph of water levels in well TW-2 during the APT is shown in Figure VI-1. Water levels in the Principal Aquifer rose continuously throughout the test, indicating no significant communication between the Principal Aquifer and the Mid-Yorktown Aquifer. Time drawdown data from observation wells

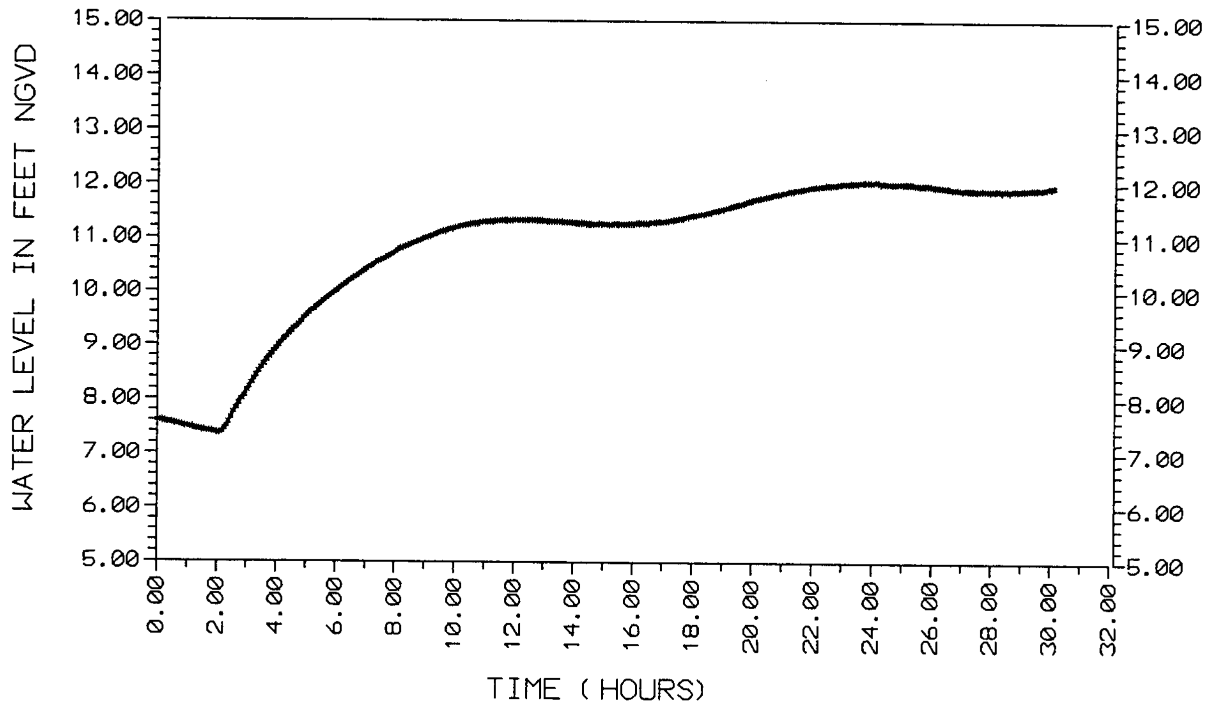

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FIGURE VI-1. WATER LEVELS IN THE PRINCIPAL AQUIFER (TW-2) DURING THE AQUIFER PERFORMANCE TEST OF WELL R.O. #1.

TW-3 and TW-4 are given in Appendix B.

Site #2 was tested starting on March 7, 1995. Production well R.O. #2 was pumped at a continuous rate of 850 gpm for 60 hours. Drawdown in the Mid-Yorktown Aquifer was measured in the pumped well (R.O. #2) at Site #2. Production well R.O. #1 and test well TW-3, located at Site #1 approximately 2000 and 2050 feet from the pumped well, also monitored the Mid-Yorktown Aquifer during the APT. Surficial aquifer water levels were monitored in well TW-7, located approximately 90 feet from the production well. Water levels in the Lower-Yorktown aquifer were monitored during the steady state test in well TW-6, located approximately 80 feet from R.O. #2.

The lower zone exibited a water level decrease of approximately 0.25 feet during the test (Figure VI-2). Pressure influences originating in the Mid-Yorktown aquifer may have caused a reduction of the pressure level in the Lower-Yorktown aquifer during the APT, as noted from the background information obtained in TW-6 before the test. However, a conclusive interpretation of the communication between these layers will need to be obtained once R.0. #2 is brought on-line. Long-term monitoring of the lower zone while withdrawing from the Mid-Yorktown Aquifer will provide additional data to determine the degree of hydraulic connection between the Lower and Mid-Yorktown aquifers.

No significant drawdown was recorded in the Water Table Aquifer while pumping R.0. #2. A graph showing water level fluctuations in the Water Table Aquifer during the test is presented in Figure VI-3. Additionally, no significant drawdown was recorded in the two wells monitoring the Mid-Yorktown aquifer at Site #1.

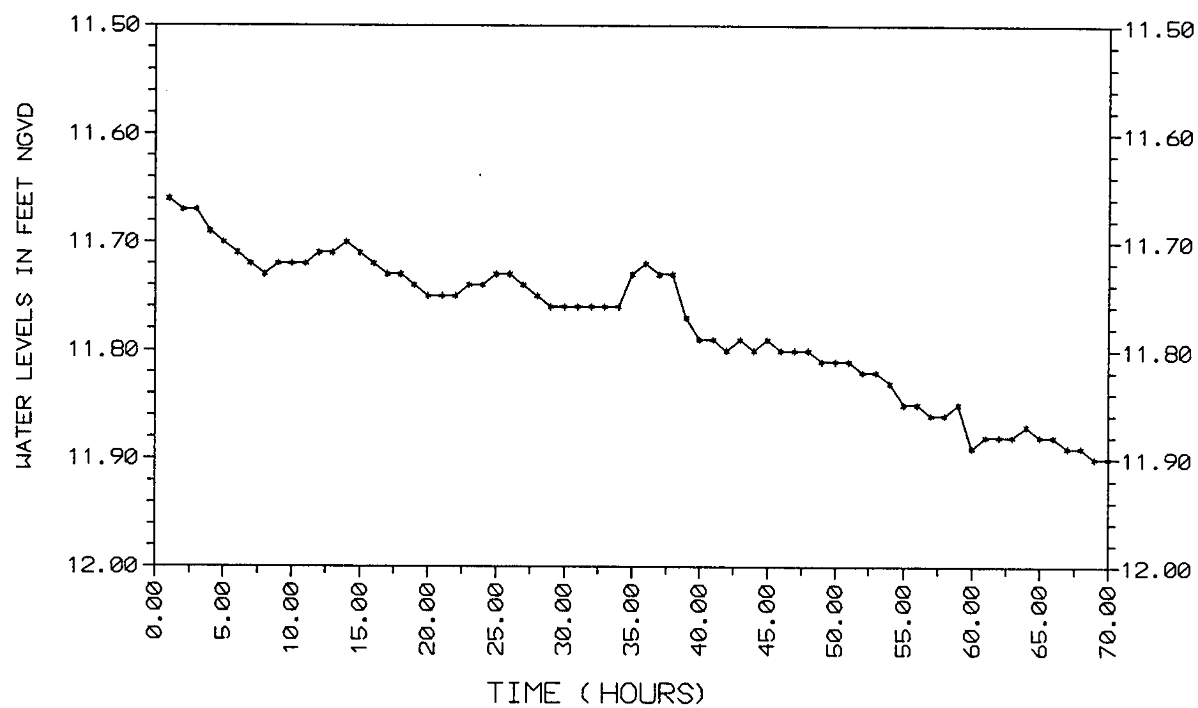

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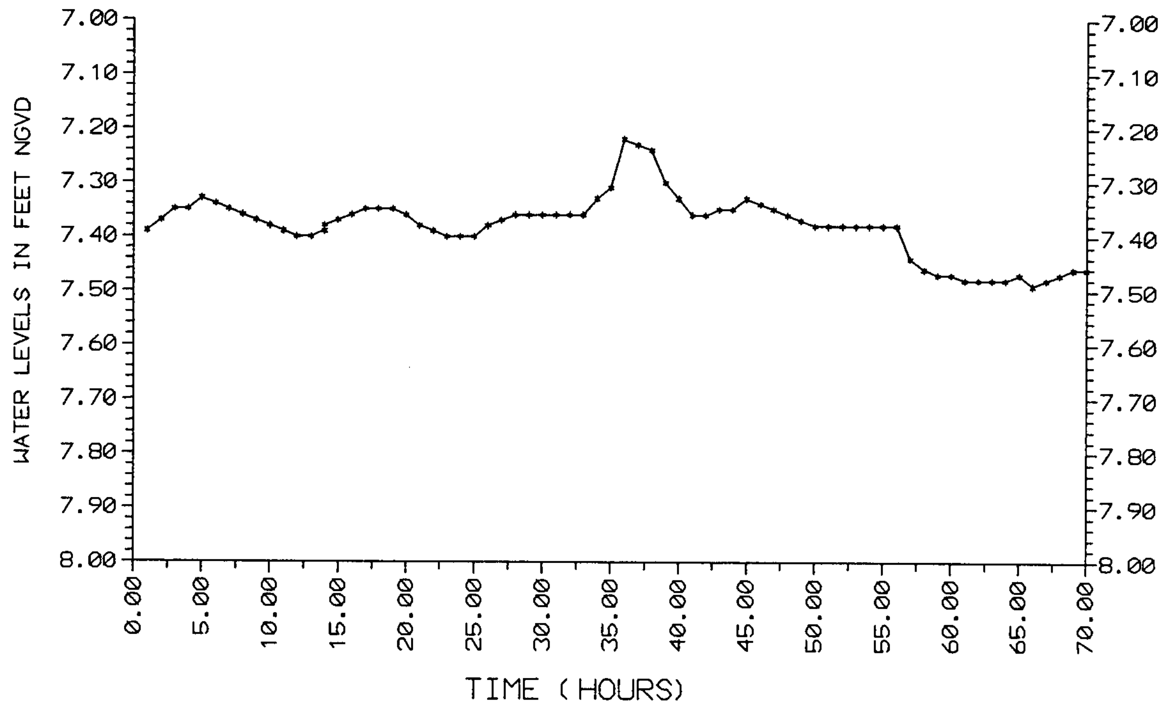
FIGURE VI-2. WATER LEVELS IN THE LOWER YORKTOWN AQUIFER (TW-6) DURING THE AQUIFER PERFORMANCE TEST OF R.O. #2.



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	PROJECT NAME: RODANTHE R.O.		PROJECT NUMBER: 01-03159.00

FIGURE VI-3. WATER LEVELS IN THE WATER TABLE AQUIFER (TW-7) DURING THE AQUIFER PERFORMANCE TEST OF WELL R.O. #2.

B. Data Analysis

Analysis of the data collected at Site #1 during the 24 hour aquifer performance test was accomplished using the method developed by Cooper (1963). Logarithmic plots of drawdown vs. time were constructed using data from the Mid-Yorktown Aquifer wells TW-3 and TW-4. The log-log graphs are included as Figures VI-4 and VI-5. The plots were compared to the appropriate type curves and match points were obtained. The data were substituted into the following equations to obtain the aquifer coefficients of transmissivity, storage, and leakance.

$$T = \frac{114.6\ Q\ LW(u)}{s} \qquad (1)$$

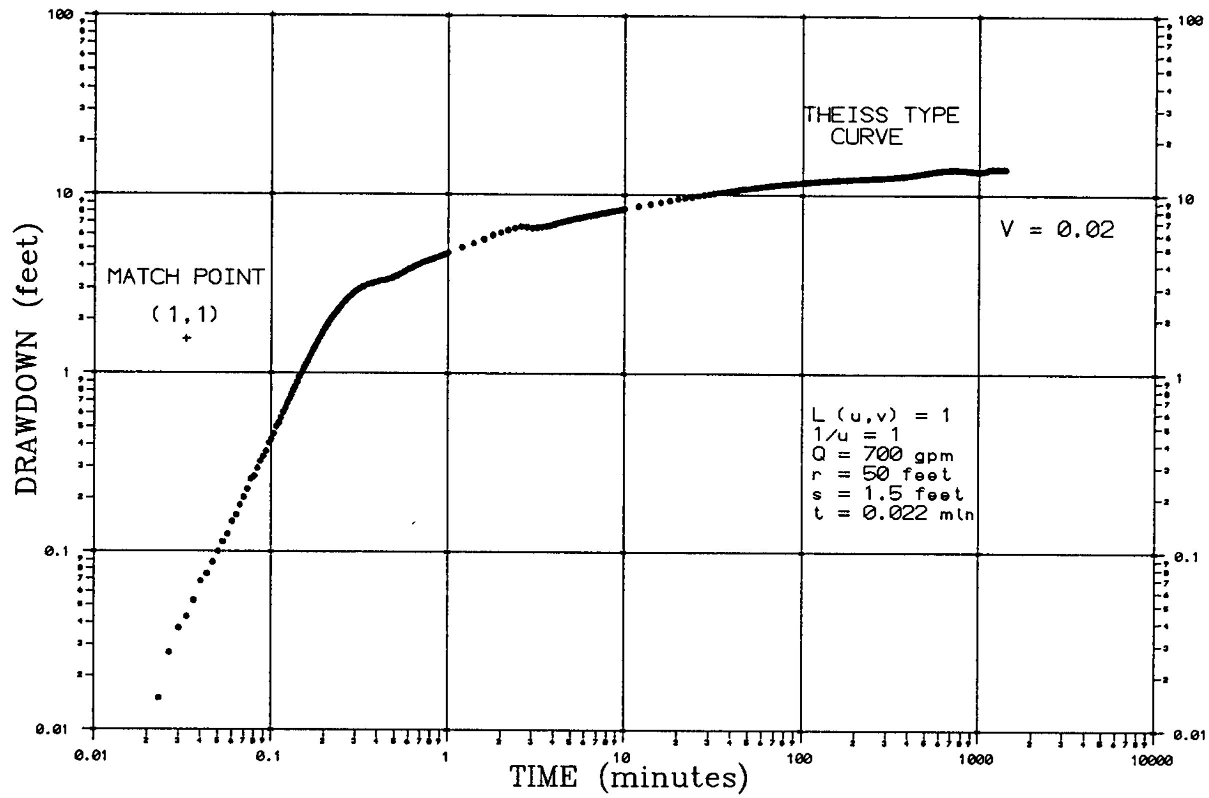
$$S = \frac{Ttu}{2693\ r^2} \qquad (2)$$

$$L = \frac{4Tt(v)^2}{r^2} \qquad (3)$$

where,

T = transmissivity (gpd/ft)
Q = pumping rate (gpm)
s = drawdown (feet)
L (u,v) = curve function
(1/u) = curve function
S = storage coefficient, dimensionless
t = time (days)
r = distance from pumped well (feet)
v = curve function (=2v)
L = leakance (gpd/ft^3)

Additional analysis was conducted with the method developed by Jacob (1952) using semi-logarithmic plots of drawdown vs. time. The semi-log plots of time-drawdown data are presented in Figures VI-6 and VI-7. A straight line segment is selected from



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	PROJECT NAME: RODANTHE R.O. PROJECT NUMBER: 01-03159.00

FIGURE VI-4. LOG PLOT OF TIME-DRAWDOWN DATA FOR TW-3, SITE 1 APT.

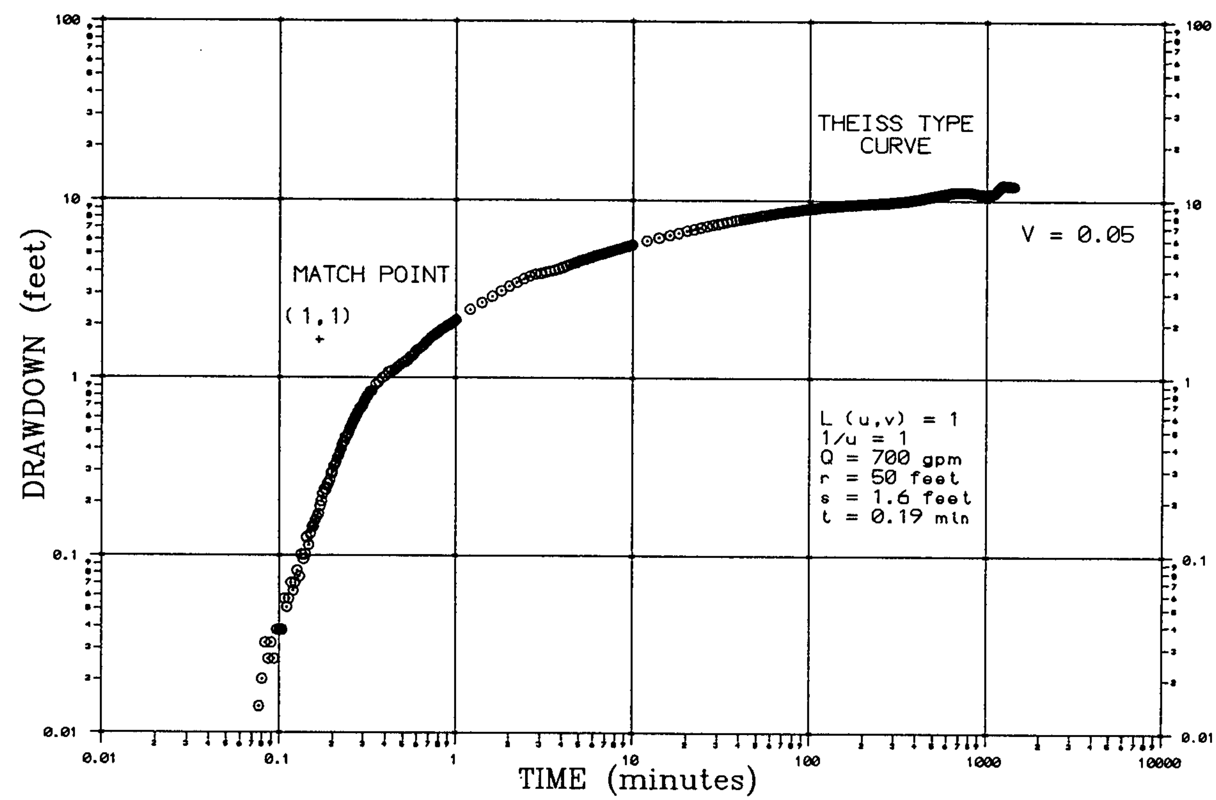

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FIGURE VI-5. LOG PLOT OF TIME-DRAWDOWN DATA FOR TW-4, SITE 1 APT.

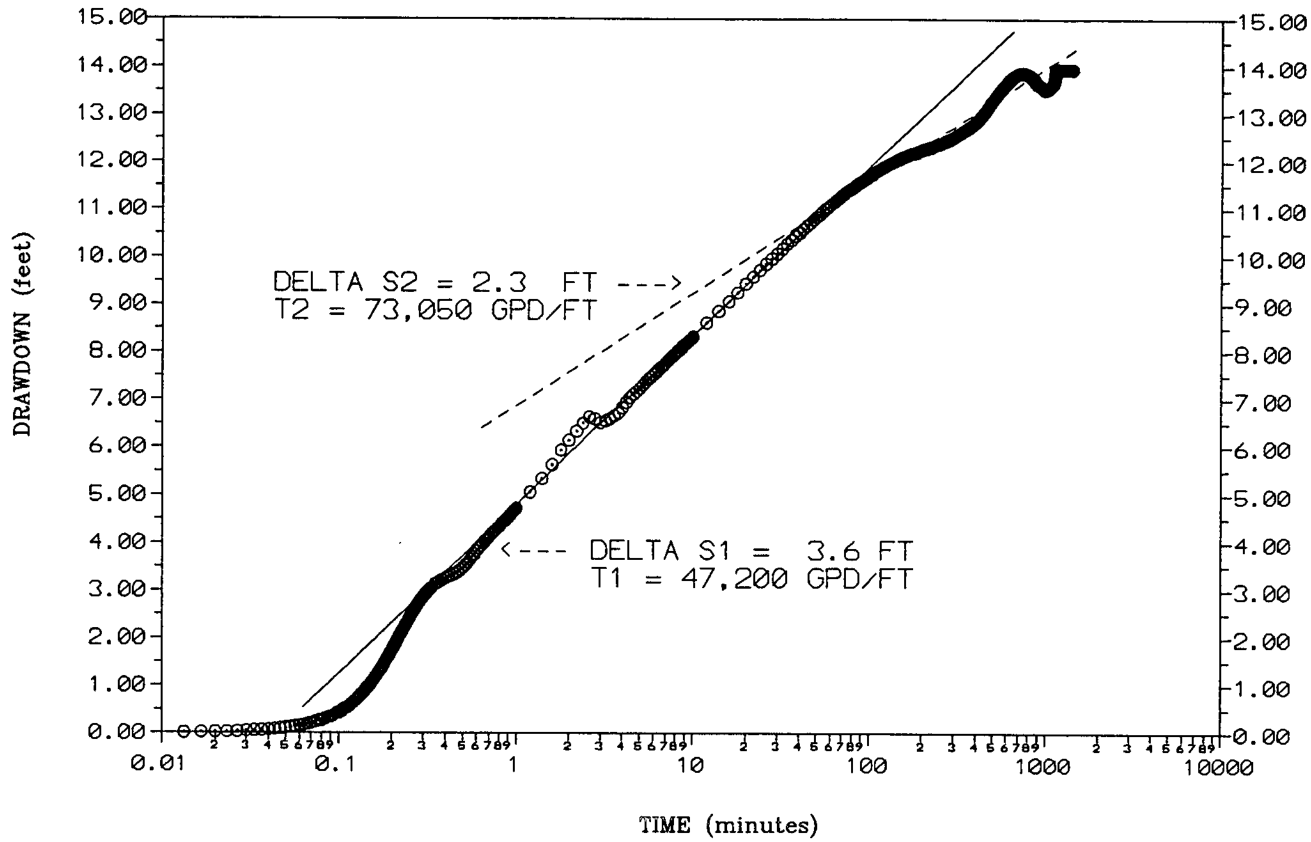

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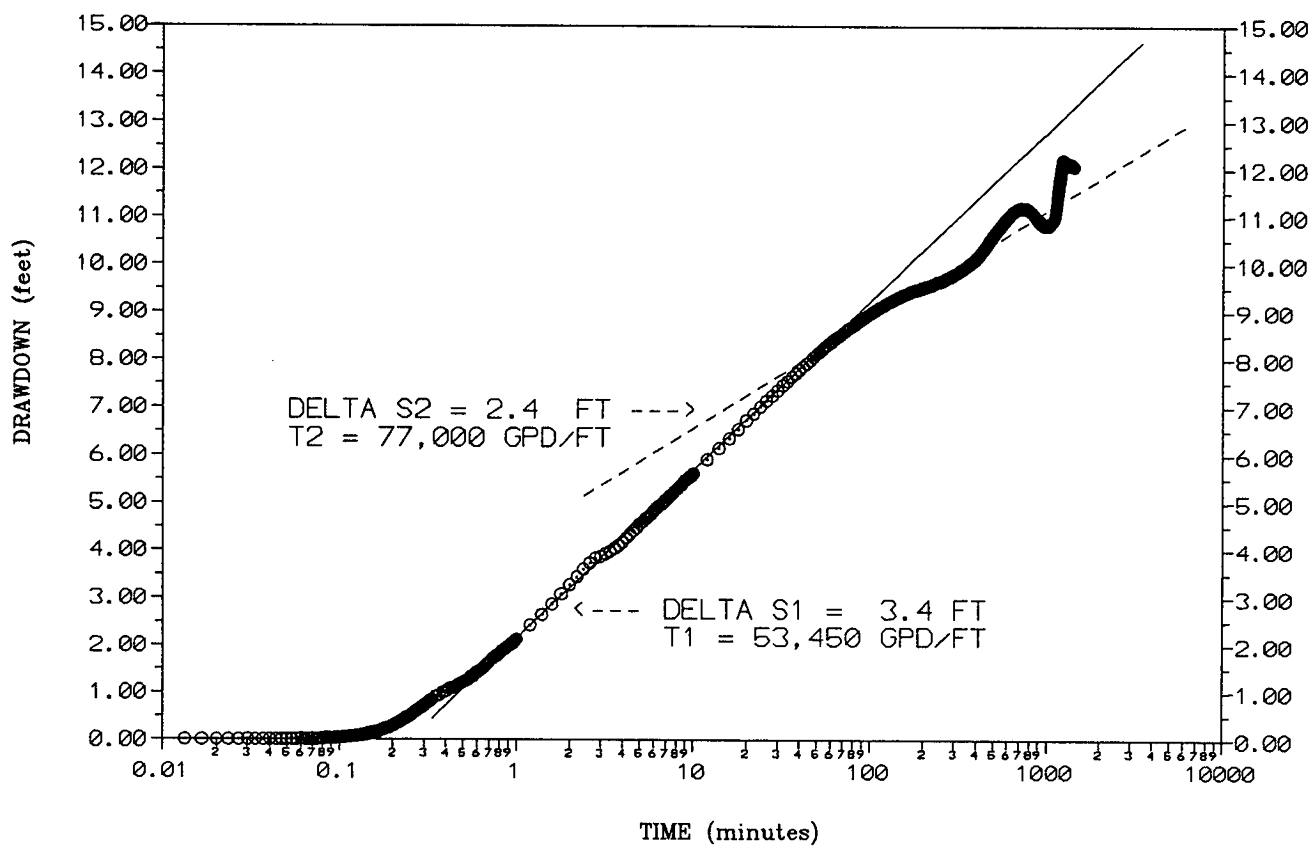
FIGURE VI-6. SEMI-LOG PLOT OF TIME-DRAWDOWN DATA FOR WELL TW-3, SITE 1 APT.



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	PROJECT NAME: RODANTHE R.O.	PROJECT NUMBER: 01-03159.00

FIGURE VI-7. SEMI-LOG PLOT OF TIME-DRAWDOWN DATA FOR WELL TW-4, SITE 1 APT.

each plot for this method and the change in drawdown between one log cycle is determined and substituted into equation (4) to determine transmissivity. Storage coefficient values are determined utilizing equation (5). Leakance values cannot be determined using this method.

$$T = \frac{264\,(Q)}{\Delta s} \tag{4}$$

$$S = \frac{Tto}{4790\, r^2} \tag{5}$$

where,

Δs = head difference between log cycles (feet)
to = time at zero drawdown (minutes)

Recovery data was also analyzed using Log-Log graph techniques as described above and are presented in Figures VI-8 and VI-9.

Analysis of the data collected during the Aquifer Performance Test (APT) at Site #2 was performed using the Steggewentz and Van Ness solution for discharge from a leaky artisan aquifer. A transmissivity value can be obtained from this model by using the data obtained from R.O. #2 during the APT and from the drawdown data obtained from the lower zone obtained in TW-6. Results of this analysis are presented in Table VI-1 (labeled UCAM) along with results of the other analysis techniques.

A summary of the hydraulic coefficients calculated for Mid-Yorktown Aquifer at both test sites is given in Table VI-1. The early data used in the straight line analysis method yielded transmissivity values in the range of values obtained from curve matching techniques utilized on drawdown and recovery data. Transmissivity values in the vicinity of Site #1 are therefore estimated to be approximately 50,000 gpd/ft. Storage is calculated to be approximately $2\text{x}10^{-4}$ and leakance was calculated to be

$3x10^{-2}$ gpd/ft^3. Transmissivity values obtained at Site #2 compare to those obtained at Site #1, being slightly under 50,000 gpd/ft.

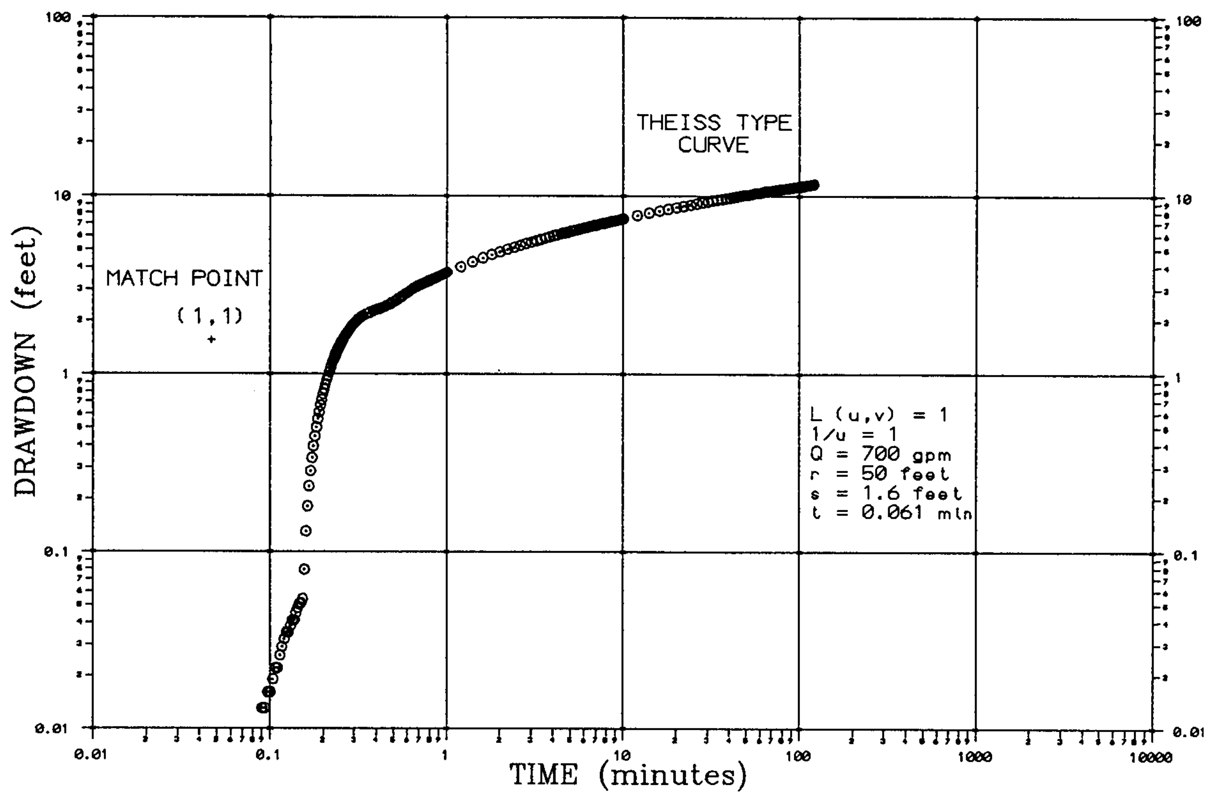

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FIGURE VI-8. LOG PLOT OF TIME-RECOVERY DATA FOR TW-3, SITE 1 APT.

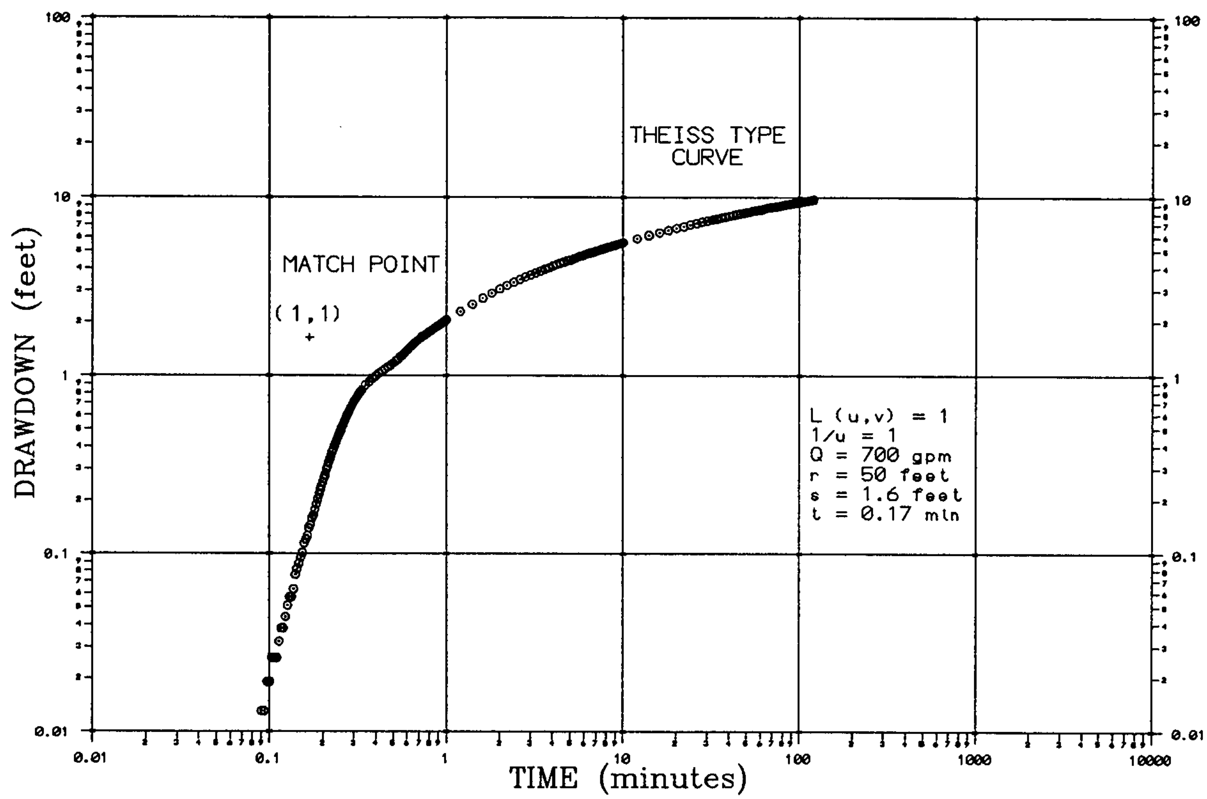

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FIGURE VI-9. LOG PLOT OF TIME-RECOVERY DATA FOR TW-4, SITE 1 APT.

TABLE VI-1 AQUIFER HYDRAULIC COEFFIECIENT CALCULATED FOR THE MID-YORKTOWN AQUIFER AT SITES #1 AND #2

WELL #	TRANSMISSIVITY			STORAGE COEFFICIENT			LEAKANCE		
SITE #1	THEISS ANALYSIS	JACOB ANALYSIS	RECOVERY ANALYSIS	THEISS ANALYSIS	JACOB ANALYSIS	RECOVERY ANALYSIS	THEISS ANALYSIS	JACOB ANALYSIS	RECOVERY ANALYSIS
TW-3	53,500	47,200 (EARLY) 73,050 (LATE)	50,100	2.5×10^{-4}	1.8×10^{-4} (EARLY) 6.1×10^{-4} (LATE)	4.5×10^{-4}	3.4×10^{-2}	-	-
TW-4	50,100	53,500 (EARLY) 77,000 (LATE)	53,500	2.3×10^{-4}	1.7×10^{-4} (EARLY) 1.0×10^{-5} (LATE)	2.1×10^{-4}	3.2×10^{-2}	-	-
SITE #2	THEISS ANALYSIS	JACOB ANALYSIS	UCAM ANALYSIS	THEISS ANALYSIS	JACOB ANALYSIS	RECOVERY ANALYSIS	THEISS ANALYSIS	JACOB ANALYSIS	UCAM ANALYSIS
R.O. #2	46,386	-	45,000	-	-	-	-	-	4.0×10^{-3}

SITE #1 : R.O. #1 WAS PUMPED AT A RATE OF 700 GPM

SITE #2 : R.O. #2 WAS PUMPED AT A RATE OF 850 GPM

VII. REFERENCES

Brown, P.M., Miller, J.A. and Swain, F.M., 1972, Structural and stratigraphic frame work and spacial distribution of permeability of the Atlantic coastal Plain, North Carolina to New York: U.S. Geological Survey Professional Paper 796, 79 p.

Cooper, H.H., Jr., 1963, Type curves for nonsteady radial flow in an infinite leaky artesian aquifer, in Bentall, Ray, compiler, Shortcuts and special problems in aquifer tests: U.S. Geological survey Water-Supply Paper 1545-C, p. C48-C55

Driscoll, F.G., 1986, Groundwater and Wells, Johnson Division, St, Paul,Minnesota, 1098 p.

Fetter, C.W., Jr., Ed., 1980, Applied Hydrogeology, Charles E. Merrill Publishing Co., 488 p.

Jacob, C.E., and Lohman, S.W., 1952, Nonsteady Flow to a Well of Constant Drawdown in an Extensive Aquifer: An Geophysical Union Trans., V. 33, p. 559-569.

Missimer and Associates, Inc., 1987, Modelling of pumping induced groundwater quality changes at the Dare County, North Carolina, wellfield (Kill Devil Hills Site): report to Black & Veatch, Inc., Asheboro, North Carolina, 117 p.

Missimer and Associates, Inc., 1992, Investigation and Predictive Modeling of Water Quality Changes within the Yorktown Aquifer, Dare County, North Carolina, Volume I: report to the County of Dare Water Production Department, Kill Devil Hills, North Carolina, 129 p.

Steggewentz, J.H., and Van Nes, J.L., 1939, Calculating the yield of a well, taking into account replenishment of the ground water above, Water Engineering, vol. 41: In Walton, W.C., 1970, Groundwater resource evaluation, McGraw-Hill, Inc., New York, 664 p.

ViroGroup, Inc., 1994, Report on the Construction and Testing of the Dare County Water Production Department Reverse Osmosis Wells #9 and #10, Dare County, North Carolina: report to the County of Dare Water Production Department, Kill Devil Hills, North Carolina, 39 p.

APPENDIX A

GEOLOGIST'S LOGS

1. R.O. #2
2. TW-6

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GEOLOGIST LOG OF R.O. #2

DEPTH	LITHOLOGY
0 - 34	Sand, quartz, yellowish gray (5Y 8/1), fine to medium grain, minor coarse grains, rounded to surrounded, moderatelyy sorted, common shells and shell fragments, medium to high permeability.
34 - 42	Clay, light gray (N7) to medium gray N6), soft, gummy texture, traces of shell fragments and very fine quartz sand, low permeability.
42 - 50	Sand, quartz, light gray (N7) to light olive gray (5Y 5/2), fine to medium grained, rounded, well sorted.
50 - 60	Sand, quartz, light gray (N7) to medium gray (N6), fine to medium grains, traces of coarse grains, surrounded to rounded moderately sorted, high permeability.
60 - 70	Sand, quartz, light olive gray (5Y 5/2), medium to fine grained, surrounded to rounded, moderately sorted, traces of coarse sand, medium to high permeability.
70 - 80	Sand, quartz, very fine to fine grained, minor medium grains, light olive gray (5Y 5/2), rounded, well sorted, abundant shells and shell fragments, traces of heavy minerals, medium permeability.
80 - 90	Sand, quartz, light olive gray (5Y 5/2), very fine grained, minor fine grains, abundant shell fragments, traces of heavy minerals, medium apparent permeability.
90 - 100	Sand, quartz, light olive gray (5Y 5/2), very fine grained, rounded to well rounded, abundant shell and shell fragments, common layers of soft interbedded clay layers with depth, low apparent permeability.

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GEOLOGIST LOG OF R.O. #2 (cont.)

DEPTH	LITHOLOGY
100 - 110	Clay, light gray (N7) to dark gray (N4), sample contains soft and lithified clay, interbedded with minor amounts of very fine sand and silt, low permeability.
110 - 140	Clay, medium gray (N6), soft and common lithified clay, common amounts of silty clay present within sample, common shell fragments, low permeability.
140 - 150	Sand, quartz, greenish gray (5g 6/1) to medium gray (N6), very fine to fine grained, well sorted and well rounded, silty, common soft clay layers, increase in shell fragments, low to medium permeability.
150 -160	Sand, quartz, light olive gray (5Y 5/2), medium gray (N6), very fine to fine grained, rounded, well sorted, traces of clay layers, traces of shell fragments, low to medium permeability.
160 - 170	Sand, quartz, as above, except medium to fine grains and increasing coarse grains with depth, abundant shell and shell fragments, medium to high permeability.
170 - 180	Sand, quartz, light gray (N7) to light olive gray (5Y 5/2), fine to medium grained, traces of coarse grains, rounded to well rounded, moderately sorted, decreasing shell fragments, medium to high permeability.
180 - 200	Sand, quartz, light gray (N7) to medium gray (N6), fine to coarse grained, moderately sorted, surrounded to well rounded, common finely phosphatic grains, and shell fragments, medium to high permeability.

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GEOLOGIST LOG OF R.O. #2 (cont.)

DEPTH	LITHOLOGY
200 - 210	Sand, quartz, light gray (N7) to medium gray (N6), medium grained, minor fine grained, traces of coarse grains, rounded to well rounded, moderately to well sorted, abundant finely phosphatic grains, common shell fragments, high apparent permeability.
210 - 220	Sand, quartz, light olive gray (5Y 5/2), as above except, increase in medium and coarse grains, surrounded to rounded, well sorted, minor phosphatic grains and shell fragments, high permeability.
220 - 230	Sand, quartz, light gray to medium gray, coarse to medium grained, rounded to well rounded, well sorted, minor phosphatic grains and shell fragments, traces of heavy minerals, high permeability.
230 - 240	Clay, medium gray (N6), to dark gray (N4), soft, cohesive, minor shell fragments and phosphatic grains.
240 - 260	Clay, medium gray (N6), soft cohesive, traces of silty clay, traces of shell fragments, low apparent permeability.
260 - 275	Clay, as above except picking up very fine to fine grained quartz sand with depth (10%), traces of finely phosphatic grains, low permeability.
275 - 290	Clay, as above except increase in very fine to fine quartz sand (20%).
290 - 300	Sand, dark gray (N4) to medium gray (N6), very fine to fine grained, traces of medium grains, surrounded to rounded moderately sorted, Encountered very hard layer at 293 feet.
300 - 310	Sand, quartz, medium gray (N6), medium to fine grained, traces of coarse grains, abundant yellowish gray shells and shell fragments, traces of phosphate grains

GEOLOGIST LOG OF R.O. #2 (cont.)

DEPTH	LITHOLOGY
310 - 320	Sand, increasing coarse grains and decreasing fine grains, medium hard to medium soft, off white (N9) to light gray (N7), sandstone layers.
320 - 350	Sandstone, off white (N9), light gray (N7) to medium gray (N6), medium hard to medium soft, abundant reworked shell fragments, minor medium to fine unconsolidated quartz sand, high apparent porosity and permeability.
350 - 360	Sandstone, as above except, increase in unconsolidated fine to coarse quartz grains, surrounded to rounded, moderately sorted, traces of heavy minerals and multicolored shell fragments, high apparent permeability.
360 - 372	Sandstone, fine to medium grained, medium hard, common shell fragments, and finely phosphatic grains, medium to low apparent permeability.
372 - 378	Limemud, off white (N9) to very light gray (N8), soft, gummy texture, interbedded sandstone layers, as above, low apparent permeability.
378 - 384 (TD)	Interbedded sandstone and limemud layers, as above.

VIROGROUP

GEOLOGIST LOG OF TEST WELL TW-6

DEPTH	LITHOLOGY
0 - 50	No Sample
50 - 60	Sand, quartz, light gray (N7) to light olive gray (5Y 5/2), fine to medium grained, subangular to surrounded, moderately sorted, traces of soft, cohesive clay streamers at crown, medium to high permeability.
60 - 70	Sand, quartz, light gray (N7) to medium gray (N6), medium to coarse grains, traces of fine grains, rounded to well rounded and sorted, very high permeability.
70 - 80	Sand, quartz, light olive gray (5Y 5/2), medium to fine grained, subangular to surrounded, moderately sorted, traces of silty sand, medium to high permeability.
80 - 90	Clay, Note: Color change in drilling fluid to a greenish gray (5G 6/1), sample contains lithified clay interbedded with minor amounts of very fine sand and silt, low permeability.
100 - 120	Clay, greenish gray (5G 6/1), lithified, common amounts of silty clay present within sample, traces of shell fragments, low permeability.
120 - 140	Sand, quartz, greenish gray (5g 6/1) to medium gray (N6), very fine to fine grained, well sorted and well rounded, silty, common lithified clay layers, increase in shell fragments, low to medium permeability.
140 - 150	Sand, quartz, light olive gray (5Y 5/2), fine to medium grained, subrounded, to rounded, well sorted, traces of clay stringers, medium permeability.
150 -160	Sand, quartz, as above, increasing coarse grains with depth approximately 10%.
160 - 170	Sand, as above except, increasing fine grains and decreasing coarse size quartz sand.

VIROGROUP

GEOLOGIST LOG OF TEST WELL TW-6 (cont.)

DEPTH	LITHOLOGY
170 - 180	Sand, quartz, light gray (N7) to light olive gray (5Y 5/2), fine to medium grained, surrounded to rounded, moderately sorted, traces of heavy minerals and shell fragments, medium to high permeability.
180 - 190	Sand, quartz, as above except, increase to shell fragments and finely phosphatic grains, medium to high permeability.
190 - 200	Sand, quartz, light gray (N7) to medium gray (N6), medium to coarse grains, rounded to well rounded, well sorted, phosphatic (20%), high permeability.
200 - 210	Sand, quartz, light olive gray (5Y 5/2), medium to fine grained, surrounded to rounded, well sorted, minor phosphatic grains and shell fragments, high permeability.
210 - 230	Sand, quartz, dusty yellow green (5GY 5/2), coarse to medium grained, surrounded to rounded, well sorted, minor phosphatic grains and shell fragments, high permeability.
240 - 250	Silty clay, greenish gray (5G 6/1), lithified, common amounts of very fine sand present within sample, traces of shell fragments and phosphatic grains, low permeability.
250 - 280	Clay, greenish gray (5g 6/1) to medium gray (N6), lithified, decrease in shell fragments, low permeability. Note: the nominal 7-inch diameter drag bit is most likely the reason for not obtaining significant amounts of the clay formation. 90% of the formation is dissolved within the drilling fluid.
280 - 295	Clay, as above except picking up very fine to fine grained quartz sand with depth, traces of clay stringers, low apparent permeability.

VIROGROUP

GEOLOGIST LOG OF TEST WELL TW-6 (cont.)

DEPTH	LITHOLOGY
295 - 300	Sand, quartz, light gray (N7) to dark gray (N5), fine to coarse grained, surrounded to rounded, moderately sorted, traces of heavy minerals and multicolored shell fragments, high apparent permeability.
300 - 310	Sand, quartz, fine to medium grained, increased shell fragments and finely phosphatic grains, medium to high permeability.
310 - 320	Sand, quartz, light gray (N7) to dark gray (N5), fine to coarse grained, surrounded to rounded, moderately sorted, traces of heavy minerals and multicolored shell fragments, high permeability.
320 - 330	Sand, light olive gray (5Y 5/2) to off white (N9) medium to fine grained, surrounded to rounded, well sorted, minor phosphatic grains and shell fragments, high permeability.
330 - 360	Sand, quartz, as above except increase in shell fragments with depth, off white in color, well sorted, minor phosphatic grains traces of coarse grains, high permeability.
360 - 380	Sand, quartz, as above, No change in formation.
380 - 390	Sand, Quartz, dark gray (N5) to medium gray (N6) fine grains, minor medium grains, common shell fragments and phosphatic grains. medium apparent permeability.
390 - 400	Sand, quartz, dark gray (N5) to medium gray (N6), surrounded to rounded, well sorted, medium grains, increasing to fine grains with depth, traces of silty clay at base. low apparent permeability.
400 - 410	Sand, quartz, as above except increase in silty clay stringers, low permeability.

VIROGROUP

GEOLOGIST LOG OF TEST WELL TW-6 (cont.)

DEPTH	LITHOLOGY
410 - 420	Sandstone, quartz, yellowish gray (5Y 8/1), medium soft to medium hard, increased shell fragments and finely phosphatic grains, medium to low permeability.
420 - 430	Interbedded sandstone and clay layers; sandstone is yellowish gray (5Y 8/1), medium soft. Clay is dark gray as noticed by the change in drilling fluid, traces of heavy minerals and multicolored shell fragments, low permeability.
430 - 450	Sandstone and clay as above except minor layers of fine grained quartz sand, traces of phosphatic grains and shell fragments, low apparent permeability.
450 - 460	Sand, quartz, light gray (N7), fine grained, rounded, well sorted, common shell fragments, traces of phosphatic grains traces of medium size quartz grains, low to medium permeability.
460 - 470	Sand and Clay; Clay is lithified in the drilling fluid as previously discussed. Sand, as above.
470 - 480	As above except increase in sand content and minor interbedded shell layers, medium apparent permeability.
480 - 500 (TD)	Sand, quartz, dark gray (N5) to medium gray (N6), surrounded to rounded, well sorted, fine grained, traces of medium grains, traces of silty clay at base. low to medium apparent permeability.

APPENDIX B

AQUIFER TEST DATA

1. Site 1, Wells TW-3 & TW-4
2. Site 2, R.O. #2
3. Site 2, TW-6
4. Site 2, TW-7

SITE #1

DRAWDOWN IN PRODUCTION ZONE DURING 24 HOUR APT

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
0.001	0.002	0.001	0.019
0.01	0.005	0.01	0.019
0.02	0.008	0.02	0.013
0.03	0.005	0.03	0.013
0.04	0.008	0.04	0.019
0.05	0.005	0.05	0.019
0.06	0.005	0.06	0.019
0.07	0.008	0.07	0.013
0.08	0.002	0.08	0.019
0.09	0.002	0.09	0.019
0.1	0.008	0.1	0.001
0.11	0.008	0.11	0.013
0.12	0.008	0.12	0.013
0.13	0.014	0.13	0.019
0.14	0.014	0.14	0.013
0.15	0.011	0.15	0.013
0.16	0.011	0.16	0.013
0.17	0.011	0.17	0.019
0.18	0.014	0.18	0.019
0.19	0.018	0.19	0.019
0.2	0.011	0.2	0.013
0.21	0.027	0.21	0.013
0.22	0.018	0.22	0.019
0.23	0.021	0.23	0.013
0.24	0.024	0.24	0.019
0.25	0.024	0.25	0.013
0.26	0.024	0.26	0.019
0.29	0.014	0.29	0.019
0.3	0.008	0.3	0.019
0.31	0.014	0.31	0.001
0.32	0.008	0.32	0.007

SITE #1

WATER LEVELS IN PRODUCTION ZONE DURING 24 HOUR APT
-CONTINUED-

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
0.33	0.008	0.33	0.019
0.4	0.008	0.4	0.013
0.45	0.008	0.45	0.013
0.5	0.018	0.5	0.007
0.55	0.002	0.55	0.019
0.6	0.011	0.6	0.019
0.65	0.018	0.65	0.013
0.7	0.014	0.7	0.013
0.75	0.011	0.75	0.025
0.8	0.014	0.8	0.025
0.85	0.008	0.85	0.019
0.9	0.011	0.9	0.001
0.95	0.005	0.95	0.013
1	0.011	1	0.013
1.2	0.011	1.2	0.013
1.4	0.018	1.4	0.001
1.6	0.008	1.6	0.019
1.8	0.014	1.8	0.007
2	0.011	2	0.005
2.2	0.011	2.2	0.013
2.4	0.008	2.4	0.005
2.6	0.018	2.6	0.007
2.8	0.014	2.8	0.007
3	0.014	3	0.005
3.2	0.014	3.2	0.005
3.4	0.014	3.4	0.007
3.6	0.011	3.6	0.001
3.8	0.018	3.8	0.005
4	0.021	4	0.007
4.2	0.018	4.2	0.013
4.4	0.018	4.4	0.001

SITE #1

WATER LEVELS IN PRODUCTION ZONE DURING 24 HOUR APT
-CONTINUED-

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
4.6	0.018	4.6	0.007
4.8	0.021	4.8	0.013
5	0.033	5	0.013
5.2	0.002	5.2	0.007
5.4	0.014	5.4	0.001
5.6	0.011	5.6	0.007
5.8	0.03	5.8	0.007
6	0.014	6	0.013
6.2	0.021	6.2	0.013
6.4	0.021	6.4	0.007
6.6	0.021	6.6	0.001
6.8	0.024	6.8	0.001
7	0.018	7	0.012
7.2	0.024	7.2	0.007
7.4	0.021	7.4	0.012
7.6	0.037	7.6	0.018
7.8	0.021	7.8	0.005
8	0.027	8	0.005
8.2	0.033	8.2	0.005
8.4	0.021	8.4	0.012
8.6	0.037	8.6	0.012
8.8	0.027	8.8	0.012
9	0.04	9	0.012
9.2	0.03	9.2	0.012
9.4	0.027	9.4	0.005
9.6	0.049	9.6	0.007
9.8	0.033	9.8	0.005
10	0.027	10	0.001
12	0.04	12	0.018
14	0.043	14	0.018
16	0.049	16	0.037

SITE #1

WATER LEVELS IN PRODUCTION ZONE DURING 24 HOUR APT
-CONTINUED-

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
18	0.059	18	0.037
20	0.068	20	0.043
22	0.075	22	0.05
24	0.084	24	0.075
26	0.097	26	0.062
28	0.097	28	0.081
30	0.1	30	0.081
32	0.109	32	0.094
34	0.116	34	0.094
36	0.119	36	0.081
38	0.128	38	0.113
40	0.135	40	0.1
42	0.147	42	0.119
44	0.147	44	0.144
46	0.15	46	0.138
48	0.147	48	0.144
50	0.173	50	0.157
52	0.173	52	0.151
54	0.173	54	0.138
56	0.176	56	0.151
58	0.176	58	0.157
60	0.188	60	0.151
62	0.195	62	0.176
64	0.195	64	0.169
66	0.207	66	0.169
68	0.214	68	0.182
70	0.22	70	0.201
72	0.229	72	0.188
74	0.236	74	0.201
76	0.245	76	0.214
78	0.248	78	0.226

SITE #1

WATER LEVELS IN PRODUCTION ZONE DURING 24 HOUR APT
-CONTINUED-

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
80	0.248	80	0.232
82	0.255	82	0.232
84	0.258	84	0.214
86	0.261	86	0.232
88	0.267	88	0.245
90	0.261	90	0.245
92	0.277	92	0.245
94	0.277	94	0.264
96	0.28	96	0.239
98	0.28	98	0.251
100	0.28	100	0.251
102	0.277	102	0.264
104	0.289	104	0.264
106	0.286	106	0.264
108	0.289	108	0.27
110	0.296	110	0.27
112	0.302	112	0.277
114	0.311	114	0.264
116	0.302	116	0.277
118	0.296	118	0.277
120	0.299	120	0.283
122	0.302	122	0.277
124	0.315	124	0.27
126	0.305	126	0.289
128	0.308	128	0.277
130	0.308	130	0.289
132	0.308	132	0.283
134	0.318	134	0.283
136	0.315	136	0.283
138	0.302	138	0.277
140	0.315	140	0.283

SITE #1

WATER LEVELS IN PRODUCTION ZONE DURING 24 HOUR APT
-CONTINUED-

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
142	0.315	142	0.289
144	0.315	144	0.296
146	0.318	146	0.283
148	0.315	148	0.283
150	0.315	150	0.289
152	0.318	152	0.302
154	0.321	154	0.302
156	0.324	156	0.296
158	0.315	158	0.283
160	0.315	160	0.289
162	0.308	162	0.296
164	0.315	164	0.283
166	0.318	166	0.283
168	0.311	168	0.283
170	0.308	170	0.277
172	0.305	172	0.277
174	0.308	174	0.277
176	0.311	176	0.277
178	0.311	178	0.296
180	0.305	180	0.283
182	0.308	182	0.27
184	0.315	184	0.277
186	0.311	186	0.27
188	0.318	188	0.277
190	0.318	190	0.289
192	0.315	192	0.296
194	0.315	194	0.283
196	0.315	196	0.289
198	0.305	198	0.277
200	0.308	200	0.277
202	0.305	202	0.277

SITE #1

WATER LEVELS IN PRODUCTION ZONE DURING 24 HOUR APT
-CONTINUED-

TW-3		TW-4	
TIME	DRAWDOWN	TIME	DRAWDOWN
204	0.302	204	0.277
206	0.299	206	0.27
208	0.302	208	0.283
210	0.299	210	0.277
212	0.293	212	0.251
214	0.28	214	0.264
216	0.286	216	0.264
218	0.293	218	0.264
220	0.286	220	0.264
222	0.286	222	0.264
224	0.286	224	0.264
226	0.283	226	0.27
228	0.277	228	0.258
230	0.283	230	0.239
232	0.27	232	0.245

SITE #2

WATER LEVELS IN R.O. #2

DATA COLLECTED IN R.O. #2 DURING 60 HOUR APT TEST			
TIME	DRAWDOWN	TIME	DRAWDOWN
0.08	14.00	95	31.85
0.25	18.00	100	32.00
0.50	19.25	120	32.25
0.75	20.75	150	33.45
1.0	22.00	180	34.39
2.0	23.50	360	35.96
3.0	24.75	540	37.05
4.0	25.25	660	37.22
5.0	25.75	780	37.39
6.0	26.00	960	37.58
7.0	26.50	1080	37.62
8.0	27.00	1200	37.65
9.0	27.50	1320	37.68
10	27.75	1440	37.71
15	28.25	1560	37.82
20	28.60	1680	37.91
25	28.80	1740	37.93
30	28.90	1860	38.04
35	29.30	2340	38.35
40	29.65	2520	38.43
45	30.00	2700	38.50
50	30.45	2820	38.51
55	30.75	2880	38.59
60	31.15	2970	38.95
65	31.25	3090	38.90
70	31.35	3300	38.61
75	31.45	3420	38.47
80	31.55	3480	38.52
85	31.60	3540	38.57
90	31.75	3600	38.52

SITE #2

WATER LEVER DATA

LOWER YORKTOWN AQUIFER
TW-6

WATER LEVEL DATA DURING 60 HOUR APT			
SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)	SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)
1	2.795	25	2.868
2	2.800	26	2.861
3	2.800	27	2.862
4	2.820	28	2.870
5	2.830	29	2.878
6	2.840	30	2.885
7	2.850	31	2.885
8	2.855	32	2.889
9	2.852	33	2.890
10	2.850	34	2.885
11	2.848	35	2.855
12	2.840	36	2.850
13	2.835	37	2.860
14	2.830	38	2.858
15	2.832	39	2.895
16	2.838	40	2.895
17	2.849	41	2.920
18	2.855	42	2.921
19	2.864	43	2.930
20	2.870	44	2.921
21	2.876	45	2.926
22	2.875	46	2.933
23	2.876	47	2.933
24	2.870	48	2.932

SITE #2

WATER LEVEL DATA

LOWER YORKTOWN AQUIFER
TW-6

-CONTINUED-

WATER LEVEL DATA DURING 60 HOUR APT			
SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)	SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)
49	2.940		
50	2.940		
51	2.940		
52	2.950		
53	2.954		
54	2.960		
55	2.976		
56	2.980		
57	2.985		
58	2.990		
59	2.982		
*60	3.018		
*61	3.010		
*62	3.010		
*63	3.010		
*64	3.002		
*65	3.005		
*66	3.011		
*67	3.020		
*68	3.022		
*69	3.030		
*70	3.032		

SITE #2

WATER TABLE AQUIFER
TW-7

WATER LEVEL DATA DURING 60 HOUR APT			
SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)	SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)
1	3.29	25	3.30
2	3.27	26	3.28
3	3.25	27	3.276
4	3.23	28	3.263
5	3.24	29	3.26
6	3.25	30	3.26
7	3.26	31	3.26
8	3.27	32	3.26
9	3.28	33	3.26
10	3.29	34	3.26
11	3.30	35	3.22
12	3.30	36	3.123
13	3.29	37	3.122
14	3.28	38	3.145
15	3.26	39	3.14
16	3.256	40	3.202
17	3.256	41	3.235
18	3.256	42	3.26
19	3.257	43	3.261
20	3.26	44	3.252
21	3.283	45	3.23
22	3.29	46	3.24
23	3.30	47	3.249
24	3.30	48	3.258

SITE #2

WATER TABLE AQUIFER
TW-7
-CONTINUED-

WATER LEVEL DATA DURING 60 HOUR APT			
SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)	SELECTED TIME (HOURS)	WATER LEVELS (FEET BMP)
49	3.27		
50	3.28		
51	3.28		
52	3.28		
53	3.28		
54	3.281		
55	3.281		
56	3.281		
57	3.34		
58	3.36		
59	3.37		
60	3.371		
*61	3.38		
*62	3.38		
*63	3.38		
*64	3.379		
*65	3.37		
*66	3.369		
*67	3.368		
*68	3.369		
*69	3.369		
*70	3.368		

* WATER LEVEL DATA AFTER PUMP WAS SHUT OFF

APPENDIX C

STEP DRAWDOWN TEST TABLES

1. R.O. #1
2. R.O. #2

TABLE C-1

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #1 / R.O. #1
STEP DRAWDOWN TEST

Test Date: 2/21/95

Recorded by: Jack Breland

Static Water Level: 2.90 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
200	5	7.66	4.76	
	10	7.87	4.97	
	15	7.99	5.09	
	20	8.12	5.22	
	25	8.22	5.32	
	30	8.31	5.41	
	35	8.38	5.48	
	40	8.43	5.53	
	45	8.50	5.60	
	50	8.55	5.65	
	55	8.59	5.69	
	60	8.64	5.74	
	65	8.71	5.81	
	70	8.74	5.84	
	75	8.79	5.89	
	80	8.81	5.93	
	85	8.83	5.93	
	90	8.87	5.97	
	95	8.88	6.98	
	100	8.91	6.01	
	105	8.02	6.12	
	110	9.06	6.16	
	115	9.98	6.08	
	120	9.02	6.12	
	125	9.06	6.16	
	130	9.04	6.18	32.36

TABLE C-1
- CONTINUED -

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #1 / R.O. #1
STEP DRAWDOWN TEST

Test Date: 2/21/95

Recorded by: Jack Breland

Static Water Level: 2.90 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
425	5	14.57	11.67	
	10	14.79	11.89	
	15	15.01	12.11	
	20	15.19	12.29	
	25	15.32	12.42	
	30	15.42	12.52	
	35	15.55	12.65	
	40	15.61	12.71	
	45	15.69	12.71	
	50	15.76	12.86	
	55	15.86	12.96	
	60	15.90	13.00	
	65	15.95	13.05	
	70	16.03	13.13	
	75	16.10	13.20	
	80	16.16	13.26	
	85	16.17	13.27	
	90	16.19	13.29	
	95	16.22	13.32	
	100	16.27	13.37	
	105	16.31	13.41	
	110	16.34	13.44	
	115	16.39	13.49	
	120	16.51	13.51	
	125	16.43	13.53	
	130	16.46	13.56	
	135	16.49	13.59	
	140	16.56	13.66	
	145	16.56	13.66	
	150	16.57	13.67	31.09

TABLE C-1
- CONTINUED -

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #1 / R.O. #1
STEP DRAWDOWN TEST

Test Date: 2/21/95

Recorded by: Jack Breland

Static Water Level: 2.90 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
800	5	26.13	23.23	
	10	27.89	23.99	
	15	27.51	24.61	
	20	27.72	24.82	
	25	28.91	25.01	
	30	28.12	25.22	
	35	28.27	25.37	
	40	28.44	25.54	
	45	28.55	25.65	
	50	28.67	25.77	
	55	28.77	25.87	
	60	28.85	25.95	
	65	28.91	26.01	
	70	29.00	26.10	
	75	29.04	26.04	
	80	29.13	26.13	
	85	29.20	26.20	
	90	29.23	26.23	
	95	29.27	26.27	
	100	29.32	26.32	
	105	29.35	26.35	
	110	29.37	26.37	
	115	29.38	26.38	
	120	29.39	26.39	30.20

TABLE C-1
- CONTINUED -

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #1 / R.O. #1
STEP DRAWDOWN TEST

Test Date: 2/21/95

Recorded by: Jack Breland

Static Water Level: 2.90 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
950	5	34.15	31.25	
	10	34.37	31.47	
	15	34.52	31.62	
	20	34.63	31.73	
	25	34.75	31.85	
	30	34.82	31.92	
	35	34.91	32.01	
	40	34.97	32.07	
	45	35.01	32.11	
	50	35.06	32.16	
	55	35.10	32.20	
	60	35.13	32.23	
	65	35.16	32.26	
	70	35.18	32.28	
	75	35.22	32.32	
	80	35.26	32.36	
	85	35.28	32.38	
	90	35.30	32.40	
	95	35.32	32.42	
	100	35.35	32.45	
	105	35.37	32.47	
	110	35.38	32.48	
	115	35.39	32.49	
	120	35.40	32.50	
	125	35.42	32.52	
	130	35.41	32.51	
	135	35.43	32.53	
	140	35.41	32.51	
	145	35.42	32.52	
	150	35.43	32.53	29.20

Measuring point is approximately half a foot above land surface.

BMP = Below Measuring Point
TOC = Below Top of Casing
GPM = Gallons Per Minute
MIN = Minutes
FT = Feet

TABLE C-2

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #2 / R.O. #2
STEP DRAWDOWN TEST

Test Date: 3/7/96

Recorded by: Jack Breland

Static Water Level: 2.56 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
250	5	9.54	7.38	
	10	9.77	7.61	
	15	9.94	7.78	
	20	9.99	7.83	
	25	10.09	7.93	
	30	10.16	8.00	
	35	10.22	8.06	
	40	10.29	8.13	
	45	10.23	8.07	
	50	10.33	8.37	
	55	10.41	8.45	
	60	10.45	8.49	
	65	10.49	8.43	
	70	10.52	8.56	
	75	10.57	8.51	
	80	10.60	8.64	
	85	10.62	8.66	
	90	10.63	8.67	
	95	10.65	8.69	
	100	10.67	8.61	
	105	10.69	8.63	
	110	10.72	8.76	
	115	10.74	8.78	
	120	10.76	8.70	29.1

TABLE C-2
- CONTINUED -

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #2 / R.O. #2
STEP DRAWDOWN TEST

Test Date: 3/7/95

Recorded by: Jack Breland

Static Water Level: 2.56 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
450	5	17.70	15.54	
	10	17.88	15.72	
	15	18.02	15.86	
	20	18.12	15.96	
	25	18.24	16.08	
	30	18.18	16.02	
	35	18.17	16.01	
	40	18.22	16.06	
	45	18.26	16.10	
	50	18.30	16.14	
	55	18.39	16.23	
	60	18.45	16.29	
	65	18.51	16.35	
	70	18.66	16.50	
	75	18.76	16.60	
	80	18.87	16.71	
	85	18.91	16.75	
	90	18.95	16.79	
	95	18.98	16.82	
	100	18.97	16.81	
	105	18.99	16.83	
	110	18.99	16.83	
	115	19.00	16.84	
	120	19.01	16.85	26.7

TABLE C-2
- CONTINUED -

DARE COUNTY, RODANTHE, NORTH CAROLINA
SITE #2 / R.O. #2
STEP DRAWDOWN TEST

Test Date: 3/7/95

Recorded by: Jack Breland

Static Water Level: 2.56 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
650	5	25.80	23.64	
	10	26.18	24.02	
	15	26.24	24.08	
	20	26.42	24.26	
	25	26.57	24.41	
	30	26.65	24.49	
	35	26.77	24.61	
	40	27.07	24.91	
	45	27.19	25.03	
	50	27.26	25.10	
	55	27.33	25.17	
	60	27.42	25.26	
	65	27.47	25.31	
	70	27.52	25.36	
	75	27.55	25.39	
	80	27.59	25.43	
	85	27.66	25.50	
	90	27.67	25.51	
	95	27.68	25.52	
	100	27.69	25.53	
	105	27.70	25.54	
	110	27.72	25.56	
	115	27.74	25.58	
	120	27.75	25.59	25.4

TABLE C-2
- CONTINUED -

DARE COUNTY, RODANTHE, NORTH CAROLINA SITE #2 / R.O. #2 STEP DRAWDOWN TEST Test Date: 3/7/95 Recorded by: Jack Breland Static Water Level: 2.56 feet below measuring point (ft. BMP)				
PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
850	5	35.12	32.96	
	10	35.35	33.19	
	15	35.62	33.46	
	20	35.93	33.77	
	25	36.00	33.84	
	30	36.08	33.92	
	35	36.15	33.99	
	40	36.22	34.06	
	45	36.34	34.18	
	50	36.43	34.27	
	55	36.50	34.34	
	60	36.59	34.43	
	65	36.63	34.47	
	70	36.67	34.51	
	75	36.75	34.59	
	80	36.81	34.65	
	85	36.88	34.72	
	90	36.92	34.76	
	95	36.96	34.80	
	100	37.01	34.85	
	105	37.03	34.87	
	110	37.05	34.89	
	115	37.06	34.90	
	120	37.08	34.92	24.3

Measuring point is approximately three feet above land surface.

BMP = Below Measuring Point
TOC = Below Top of Casing
GPM = Gallons Per Minute
MIN = Minutes
FT = Feet