REPORT ON THE CONSTRUCTION AND TESTING OF A MID-YORKTOWN AQUIFER TEST WELL AT THE WRIGHT BROTHERS MEMORIAL PARK

Prepared for:

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

By:

CDM./Missimer International, Inc.
8140 College Parkway, Suite 202
Fort Myers, FL 33919

February 2000

Project No. FH9-864
17952-27877

Wm. Scott Manahan, P.E.
Project Manager

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

MISSIMER INTERNATIONAL INC.

February 9, 2000

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

Re: Wright Brothers Memorial Park
Test Well Report

Dear Bob:

Please find enclosed 10 copies of the document entitled "Report on the Construction and Testing of a Mid-Yorktown Aquifer test well at the Wright Brothers Memorial Park." The report describes the procedures used to install and test a well at the Park Service property. Results of the investigation indicate that raw water supply development at the Park and nearby properties is feasible.

We appreciate having the opportunity to conduct this study for the county and are available to assist with implementation of the report recommendations. Please contact me if you have any questions or comments regarding the report.

Sincerely,

Wm. Scott Manahan, P.E.
Water Resource Engineer

WSM:lk
Enclosures

FH9-8642
8140 College Parkway, Suite 202
Fort Myers, Florida 33919

(941) 432-9494
FAX (941) 432-9453

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1. CONCLUSIONS AND RECOMMENDATIONS

A test well was constructed at the Wright Brothers Memorial Park Service property to evaluate the feasibility of constructing one or more production wells at the site or nearby properties to supply additional raw water to the Dare County Reverse Osmosis (RO) water plant in Kill Devil Hills. The conclusions and recommendations presented below are based on the results of the test well construction project.

1.1 Conclusions

- A 4-inch diameter test well (Park-1) was installed on the Park Service property approximately 1 mile north of the Kill Devil Hills RO plant. The well was completed within the Mid-Yorktown Aquifer with a screened interval between 290 and 390 feet below land surface.
- A step-drawdown pump test was conducted on well Park-1 after drilling and development were completed. A specific capacity value of 5.0 gpm/ft was calculated for the well at a pumping rate of 90 gpm.
- The transmissivity of the Mid-Yorktown Aquifer is estimated to range from approximately 36,500 gpd/ft to 47,500 gpd/ft at the Park Service property based on analyses of data collected while pump testing well Park-1. A conservative transmissivity value of 30,000 gpd/ft was used for computer modeling purposes to estimate drawdown impacts due to large scale pumpage at the site.
- Water quality samples were obtained from well Park-1 near the end of pump testing and sent to a laboratory for analyses. A dissolved chloride concentration of 840 mg/l and total dissolved solids of 1800 mg/l were determined indicating relatively low salinity levels in the Mid-Yorktown Aquifer at the test well location. The production wells that currently supply the RO plant have dissolved chloride concentrations that range from approximately 2500 to 2600 mg/l. Large scale pumpage for public supply purposes at the Park Service property would likely cause an increase in salinity levels within the aquifer at that location. However,

previous computer modeling studies have shown that spreading drawdown over a larger area will reduce the rate of water quality degradation in the aquifer as a whole.

- The installation of production wells on or in the vicinity of the Park Service property to increase the capacity of the wellfield that supplies raw water to the Kill Devil Hills RO plant is feasible. The construction cost for two wells including pump houses, submersible pumps, and a transmission main to the RO plant is estimated to be approximately $1.15 million.

1.2 Recommendations

- Consideration should be given to constructing two additional production wells at or near the Park Service property. The wells would provide additional raw water supply to the Kill Devil Hills RO plant and allow expansion of the plant finished water capacity by up to 1.0 MGD.
- The proposed production wells should be constructed with 12-inch diameter PVC casings to a depth of at least 150 feet below land surface and 8-inch diameter PVC casings below 150 feet to the appropriate setting depth (approximately 300 feet). The wells should be screened with 8-inch diameter stainless steel continuous wrap screens from the casing bottoms to approximately 400 feet below land surface. A coarse sand filter pack should be placed around the screens. A hydrogeologist should supervise construction of the wells and select final cased and total depths at each site based on lithologic analysis of formation samples obtained during drilling. A biodegradable type drilling fluid should be used to drill through the production zone interval. The wells should be thoroughly developed by compressed air pumping and horizontal jetting of the screens after drilling is complete.
- Step-drawdown pump tests should be conducted on the new production wells. Specific capacity values calculated based on the test results can be used to assess individual well yields and confirm the proposed pump setting depths and withdrawal rates. The new wells should be disinfected following development and pump testing.

- Submersible well pumps and well houses similar to those used on the existing production wells near the RO plant should be installed. Piping from the wells should be connected to a PVC raw water transmission main going to the RO plant placed adjacent to the east side of the Park Service property.
- Well Park-1 should be included in the on-going water level and water quality monitoring program conducted by the county. Water quality and water levels should also be monitored in the new production wells. The data collected will enable an evaluation of the performance of the new wells and help to identify potential problems.

2. INTRODUCTION

The Dare County Water Department operates a reverse osmosis (RO) plant in Kill Devil Hills, North Carolina that produces potable water for public supply purposes. Brackish water supplied by 10 Mid-Yorktown Aquifer production wells is the raw water source for the RO plant which has a current finished water production capacity of approximately 3.0 million gallons per day (MGD). The average pumping rate for the existing supply wells ranges between 400 and 500 gallons per minute (gpm). Expansion of the RO plant capacity to meet the increasing demand for potable water will be required. CDM/Missimer International, Inc. (CDM/MI) was authorized by the Dare County Water Department in December 1999 to construct a test well approximately one mile north of the RO plant on property owned by National Park Service. The RO plant and test well locations are shown on Figure 1.

The purpose of the project was to evaluate aquifer yield and water quality conditions within the Mid-Yorktown Aquifer to determine the feasibility of installing permanent production wells at or near the Park Service site. Additional supply wells will be needed to increase the raw water supply capacity of the existing wellfield in order to expand the RO plant capacity. The scope of the project included well construction, pump testing, water quality sampling, data analyses, and preparation of this summary report. The methods and procedures used during the investigation and the results obtained are presented herein.

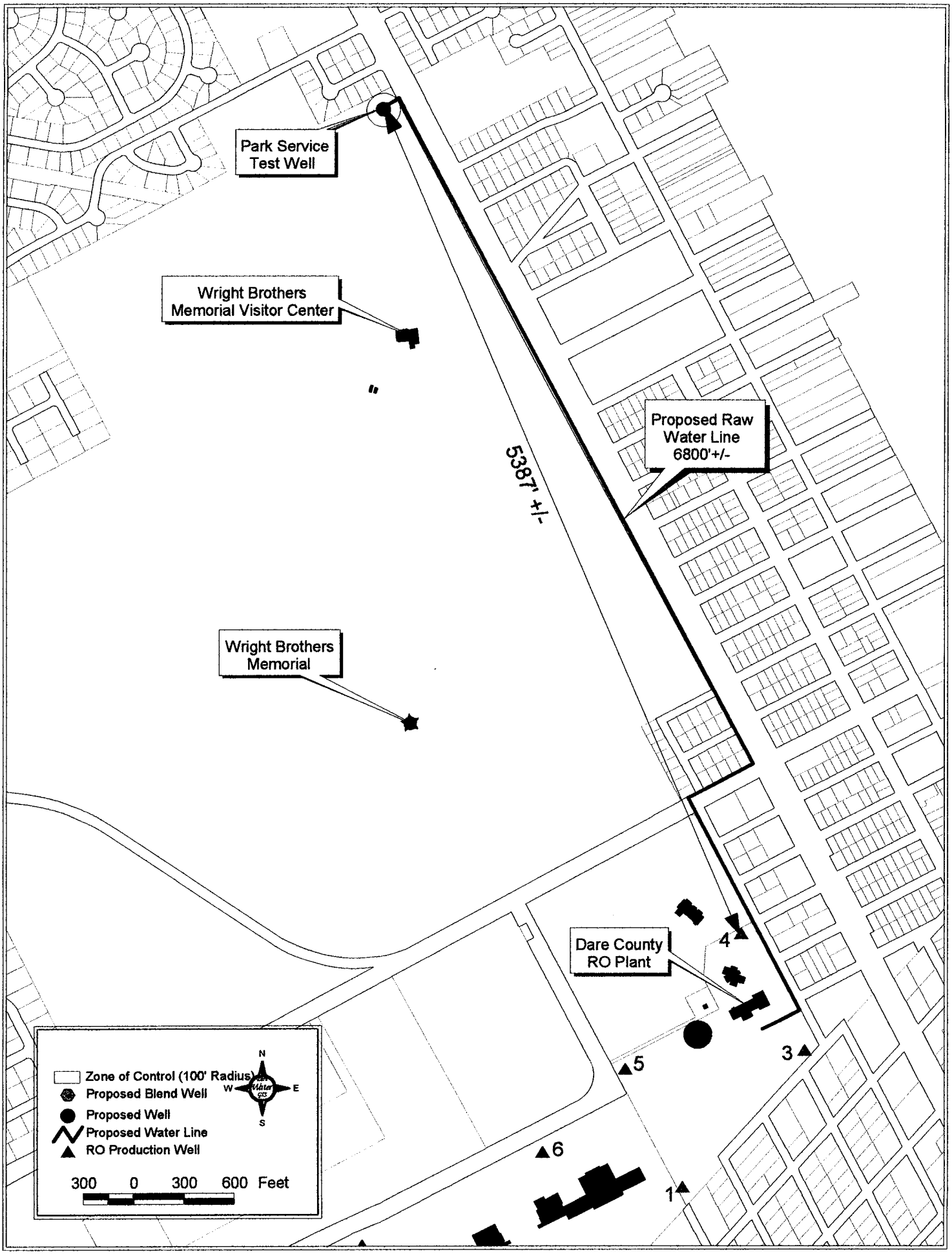


FIGURE 1. SITE MAP SHOWING THE R.O. PLANT AND PARK SERVICE TEST WELL LOCATION.

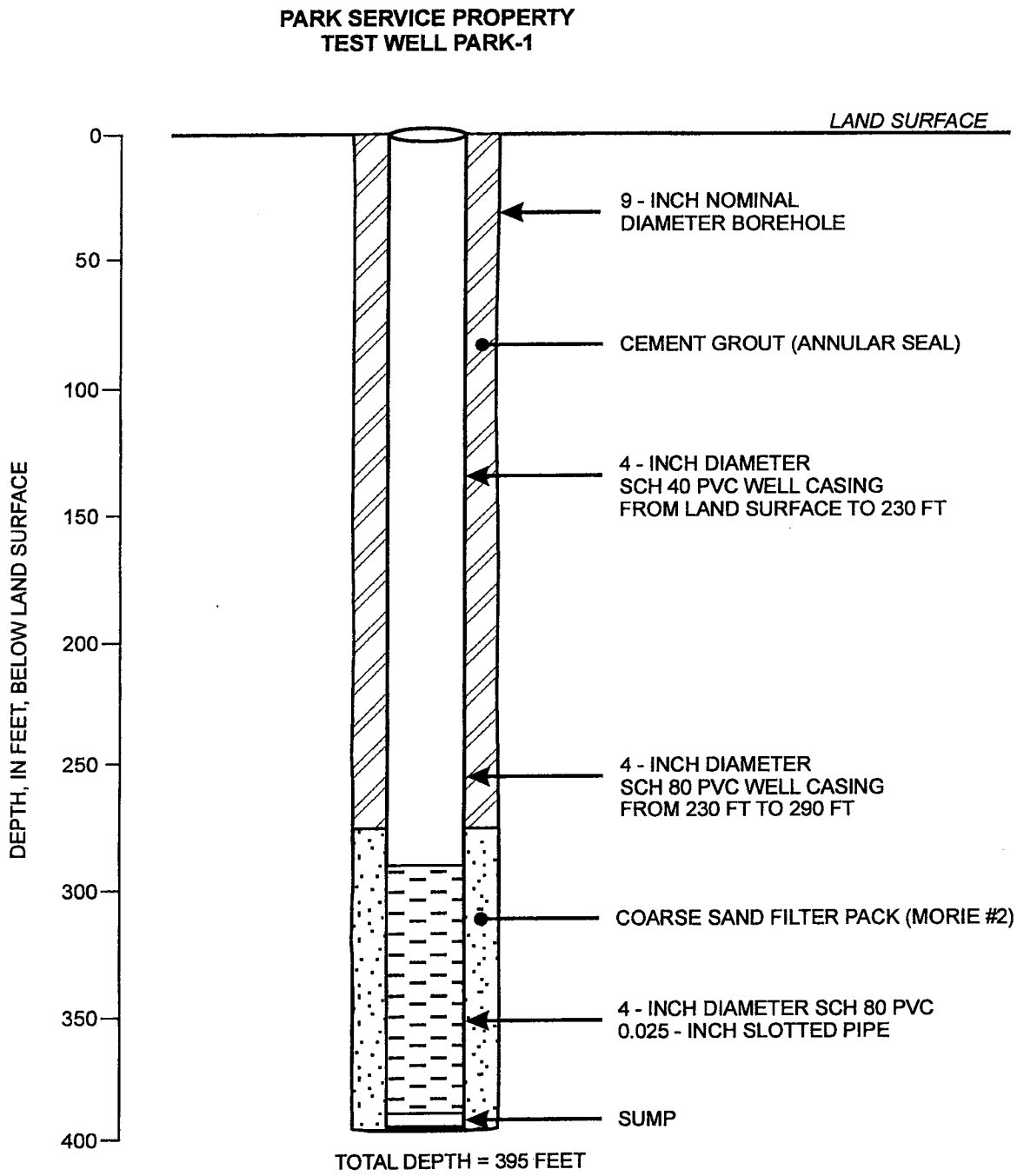
3. FIELD INVESTIGATION METHODS

3.1 Drilling

The Park Service test well (Park-1) was installed at the north end of the Wright Brothers Memorial Park property at the location shown on Figure 1. Skipper's Well Drilling from Leland North Carolina was subcontracted to construct the well and perform a pump test. Staff with CDM/MI provided on-site supervision during drilling and collected formation samples for lithologic analyses.

Drilling commenced on the morning of December 14, 1999. A nominal 9-inch diameter borehole was drilled using the mud rotary method to a depth of 400 feet below land surface. Electric and natural gamma ray geophysical logs were conducted on the bentonite mud filled borehole after the drill pipe had been removed. The on-site hydrologist selected the screen interval and determined final well design based on analysis of the formation samples and geophysical logs. Copies of the geologist's log and geophysical logs are included in the appendix. A fine to medium grained sand unit was encountered during drilling within the interval between approximately 290 and 400 feet below land surface. This is the approximate depth interval tapped by the existing 10 raw water wells that currently supply the RO plant.

A well string consisting of 100 feet of 4-inch diameter, 0.025-inch slotted Schedule 80 PVC pipe was placed in the borehole followed by 60 feet of 4-inch diameter Schedule 80 PVC casing and 230 feet of Schedule 40 PVC casing to land surface. A blank section of pipe five feet long was placed below the screen to act as a sump. Construction details for the well are shown on Figure 2. A coarse sand gravel pack (Morie #2) was placed around the screen through a tremie pipe to a height of approximately 10 feet above the screen and the well was then developed with compressed air. The well was developed for approximately six hours and subsequently grouted with neat Portland cement from the top of the gravel pack to land surface.



MISSIMER INTERNATIONAL, INC.

Pr. Name: DARE CO PARK SERVICE PROPERTY		
Pr. No. TMMDARE	Date: 12/22/99	
DWG No. PARKSERV	Rev. No.	

GROUNDWATER
AND
ENVIRONMENTAL SERVICES

FIGURE 2. SCHEMATIC DIAGRAM SHOWING CONSTRUCTION DETAILS OF THE PARK SERVICE TEST WELL PARK-1.

3.2 Pump Testing

A 5-hp electric submersible pump was placed in well Park-1 with the intake set at 95 feet below land surface. The well was pumped at three separate rates ranging from 60 to 90 gpm. Drawdown in the well was measured with a pressure transducer coupled to an electronic data logger. Results of the step-drawdown test are summarized in Table 1. A specific capacity value of 5.0 gpm/ft was determined at a pumping rate of 90 gpm indicating the yield potential of the Mid-Yorktown Aquifer at this location is moderate to low. An additional test was conducted by pumping test well Park-1 at a constant rate of 90 gpm for approximately 21 hours. Drawdown in the well was measured at closely spaced time intervals and a semi-log plot of drawdown vs. time was constructed for analysis purposes (Figure 3).

3.3 Water Quality Sampling

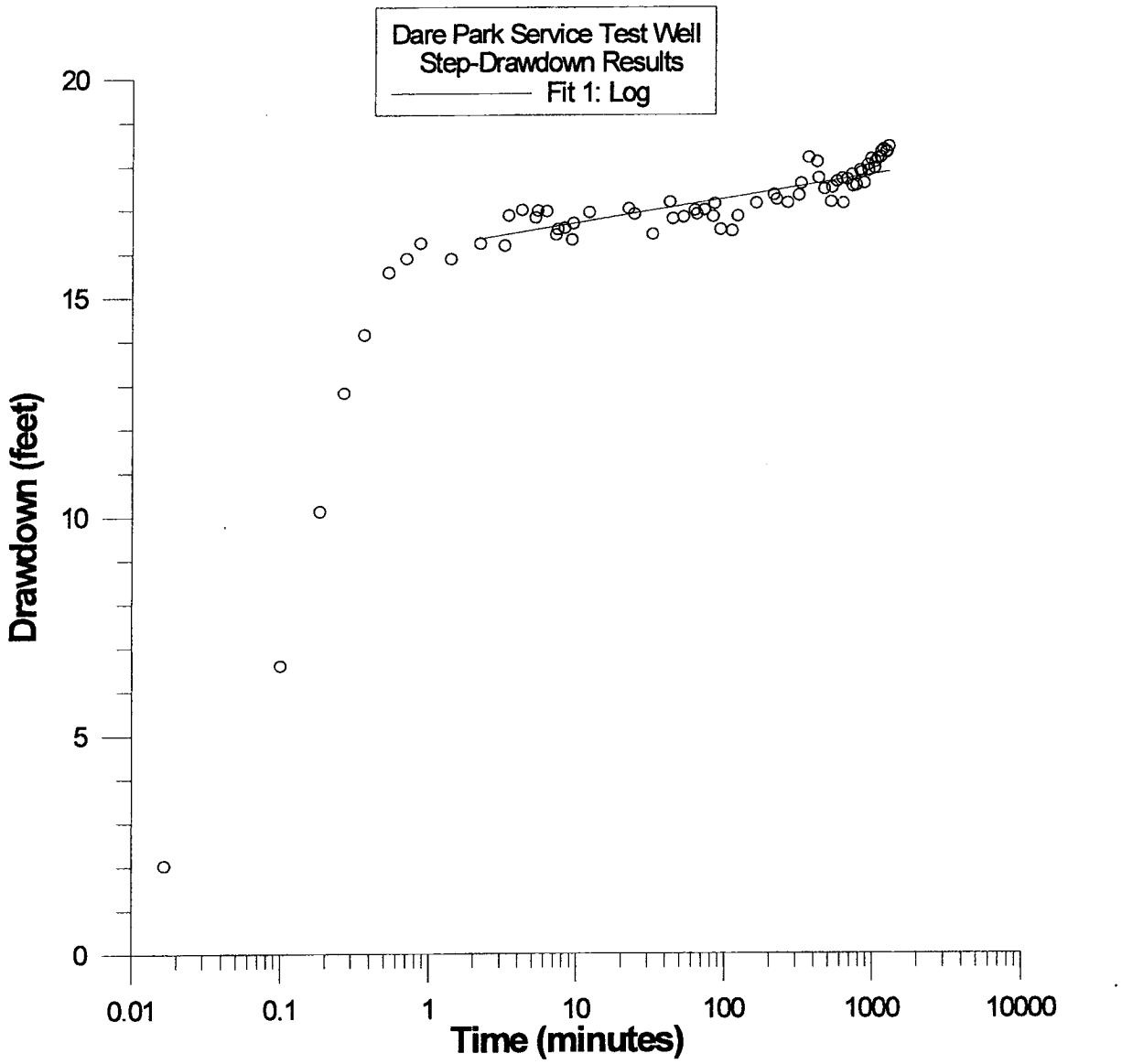
Water samples were obtained from the test well Park-1 near the end of constant rate testing after the well had been pumped at rates of up to 90 gpm for over 24 hours. Detailed analyses of the samples were conducted by the Dare County Water Department staff and also by STL Savannah Laboratories in Tampa, Florida. Analytical reports with the analyses results are included in the appendix. A discussion of the water quality analyses results is included in the following section of this report.

TABLE 1. DARE COUNTY WATER DEPARTMENT
STEP DRAWDOWN TEST WELL PARK-1

Test Date: 12/16/99
Recorded By: Scott Manahan
Static Water Level: 22.90 ft. Below Measuring Point (BMP)*

Pumping Rate (GPM)	Time (Minutes)	Pumping Water Level (ft. BMP)	Drawdown (ft.)	Specific Capacity (GPM/ft.)
60	5	33.40	10.50	5.8
	10	33.06	10.16	
	20	32.93	10.03	
	30	32.97	10.07	
	40	33.06	10.16	
	50	33.18	10.28	
	60	32.72	9.82	
80	5	38.11	15.21	5.1
	10	38.26	15.36	
	20	38.38	15.48	
	30	38.29	15.39	
	40	38.70	15.80	
	50	38.51	15.61	
	60	37.94	15.04	
90	5	40.81	17.91	5.0
	10	40.54	17.64	
	20	40.34	17.44	
	30	40.45	17.55	
	40	40.01	17.11	
	50	40.08	17.18	
	60	40.27	17.37	

*Measuring point is top of casing approximately 2.8 feet above land surface.



MISSIMER INTERNATIONAL, INC.

Pr. Name: DARE PARK SERVICE TEST WELL	
Pr. No. FH9-864	Date: 1/25/00
DWG No.	Rev. No.

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FIGURE 3. SEMI-LOG GRAPH SHOWING DRAWDOWN IN TEST WELL PARK-1 WHILE PUMPING AT 90 GPM.

4. HYDROGEOLOGY

4.1 Geology

The geology of Dare County has been investigated by various government agencies and private consultants including CDM/Missimer International, Inc. A brief description of the sediments underlying the Wright Brothers Memorial Park is provided herein. Detailed discussions of the geologic conditions at Kill Devil Hills and throughout the Outer Banks are provided in the reports included in the reference section of this report.

The uppermost strata encountered at the Park Service test well location include undifferentiated fine to coarse grained sand units with common shell beds and minor amounts of interbedded clay. Permeable sediments within these deposits form the water-table aquifer which is approximately 100 feet thick at the Park Service test well site.

The Yorktown Formation of Miocene age lies beneath the surficial sand deposits. The formation consists of beds of fine to coarse grained sand and dense clay units with a thickness that can exceed 500 feet in eastern Dare County. At the Park Service property, the upper part of the Yorktown Formation includes interbedded sand and clay units with varying amounts of shell and phosphate material. The clay beds have a very low hydraulic conductivity and provide confinement between the surficial sands and the Mid-Yorktown Aquifer.

The Mid-Yorktown Aquifer was encountered at a depth of approximately 290 feet below land surface in test well Park-1. The aquifer consists primarily of medium to very fine grain quartz sand with occasional shell and only trace amounts of clay. The formation has a large proportion of fine grained sand at the Park Service test well location. Generally coarser grained sediments were encountered within the production zone of the Mid-Yorktown Aquifer further to the south at the site of the RO plant. The formation sediments generally continue to get finer northward where a clay facies is encountered.

4.2 Aquifer Hydraulic Characteristics

The method developed by Jacob (1952) was used to analyze the data collected during the constant rate pump test on well Park-1. A straight line segment is selected from the semi-log plot of drawdown vs. time (Figure 3) and the change in drawdown over one log cycle is determined and substituted into equation (1) to determine the aquifer transmissivity.

$$T = \frac{264\,Q}{\Delta S} \qquad (1)$$

where,

T = transmissivity (gpd/ft)
Q = pumping rate (gpm)
ΔS = head difference between log cycles (feet)

Transmissivity values for the Mid-Yorktown Aquifer calculated from the drawdown and recovery data obtained during testing range from 36,500 gpd/ft to 47,500 gpd/ft. Aquifer performance testing conducted following the installation of the original eight raw water supply wells near the RO plant and production wells #9 and #10, which are located approximately one mile south of the plant, yielded transmissivity values that ranged from 63,700 gpd/ft to over 100,000 gpd/ft. The lower transmissivity of the aquifer at the Park Service test site is attributed to the fact that the aquifer material is comprised of finer grained sediments than at the well locations further to the south. Although the aquifer transmissivity is lower at the Park Service property, the site does have the potential for raw water supply development. It is likely that a large diameter, properly designed and constructed well could produce at a rate of 400 gpm or more at this location. The potential of the site for water supply development is discussed in more detail in the following section of this report.

4.3 Water Quality

The laboratory analyses results for the samples obtained from well Park-1 indicate that water quality in the Mid-Yorktown Aquifer at the test site is brackish but less saline than the water obtained from the existing wellfield. Salinity parameters are summarized in the table below.

TABLE 2. MID-YORKTOWN AQUIFER WELL PARK-1 WATER QUALITY
(December, 1999)

Dissolved Chloride Concentration (mg/l)		**Total Dissolved Solids (mg/l)**	
Dare County Lab	STL Savannah Lab	Dare County Lab	STL Savannah Lab
820	840	1680	1800

By comparison, the average dissolved chloride concentration of the raw water from the production wells currently supplying the RO plant is approximately 2500-2600 mg/l. It should be noted that production wells #9 and #10 produced water with a dissolved chloride concentration of approximately 1000 mg/l when they were initially put on-line and there was a relatively rapid increase in dissolved chloride concentration in the water obtained from these wells. Wells #9 and #10 currently produce water with a salinity level comparable to the original eight production wells.

5. WATER SUPPLY EVALUATION

5.1 Modeling

Data collected during the installation and testing of well Park-1 indicate that the Park Service property has potential for raw water supply development. Transmissivity values calculated for the Mid-Yorktown Aquifer at the site range from 36,500 gpd/ft to 47,500 gpd/ft. An analytical computer model simulation was used to estimate the drawdown impacts associated with pumpage at the Park Service property. Input data to the model included a transmissivity value of 30,000 gpd/ft and a leakance of 5×10^{-4} gpd/ft^3. Leakance cannot be determined from single well test data, however, the value utilized was determined during aquifer performance testing conducted near the RO plant.

The model simulates two wells with a pumping rate of 450 gpm each. One well is placed near test well Park-1 and the other 2000 feet to the southeast. The model simulated drawdown in each production well due to the proposed pumpage is approximately 40 feet. A print out of the model results is included in the appendix. The model simulation does not consider well inefficiency which causes additional drawdown. In addition, the static water level in the Mid-Yorktown Aquifer at the proposed well locations is anticipated to be approximately 20 feet below land surface. A pumping water level of 80 to 90 feet below land surface in the wells may be expected with each well pumping at 450 gpm It should be noted that these are estimated pumping water levels based on computer model simulations. Actual well yields and pumping water levels may vary. Step-drawdown testing of newly constructed production wells would be required to assess individual well yields.

Solute transport modeling to estimate water quality changes that might occur within the Mid-Yorktown Aquifer due to withdrawals from two additional wells on the Park Service property was beyond the scope of this investigation. However, previous modeling studies and operational data have shown that spreading pumpage over a larger area is effective in reducing the rate of water quality degradation in the source aquifer. The water obtained from production wells constructed on the Park Service or nearby properties would very likely have a lower salinity level than water from

the existing production wells. The lower salinity water from these wells may allow an increase in the blend ratio used at the RO plant. It is anticipated that salinity levels in production wells constructed on or near the Park Service property would increase over time due to pumpage. The rate of water quality degradation would be directly related to the magnitude and duration of pumpage.

5.2 Construction Cost Estimate

The results of testing conducted on the Park Service property indicate that the construction of two additional production wells to increase the raw water supply capacity to the Kill Devil Hills RO plant is feasible. Well houses, submersible pumps, and a transmission main would be required to complete the installation. A pumping rate of 450 gpm from each well would increase the finished water capacity of the RO plant by approximately 1 MGD. Estimated costs for the well construction project are presented below. Construction costs for wells and associated facilities at the Park Service and adjacent properties should be similar to those incurred for the construction of wells #9 and #10 in 1994 with an increase of 10% to 15% for inflation. Land acquisition cost is estimated to be approximately $200,000 per well site. It is our understanding that the National Park Service will allow the county to place one well on their property free of charge. Further discussion with the Park Service to request additional well sites is recommended considering the potential for land acquisition cost savings.

OPINION OF PROBABLE COST
PARK SERVICE PRODUCTION WELLS

Item	Cost
Well construction (2 wells)	$300,000.00
Pumping testing and water quality analyses (2 wells)	20,000.00
Well houses (2)	150,000.00
Submersible pumps (2)	130,000.00
Earthwork, piping, miscellaneous (2 wells)	100,000.00
Transmission main (10-inch C-900)*	250,000.00
Land acquisition (1 well site)	200,000.00

Constructed Cost:	$1,150,000.00
Engineering @ 10%:	115,000.00
Contingency @ 15%:	172,500.00
Estimated Project Cost** (2 wells):	$1,437,500.00

*Transmission main costs may be reduced significantly if well pointing (dewatering) is not required during installation.

**Estimated project cost for one well is approximately $750,000.00.

6. SELECTED REFERENCES

Jacob, C. E., and Lohman, S. W., 1952, Nonsteady flow to a well of constant drawdown in an extensive aquifer: A Geophysical Union Trans., v. 33, p. 559-569.

Missimer & Associates, Inc., 1987, Modeling of pumping induced groundwater quality changes at the Dare County, North Carolina wellfield (Kill Devil Hills site): Rept. To Black & Veatch, Inc., Asheboro, North Carolina, 177 p.

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Missimer International, Inc., 1998, Dare County-Wide Hydrogeological Study and Groundwater Resource Evaluation: Rept. to the Dare County Water Department, Kill Devil Hills, North Carolina, 98 p.

Peek, H. M., Register, L. A., and Nelson, P. F., 1972, Potential Ground-Water Supplies for Roanoke Island and the Dare County Beaches, North Carolina: Rept. of investigations No. 9, Ground Water Division Office of Water and Air Resources, North Carolina Department of Natural and Economic Resources, Raleigh, North Carolina, 26 p.

Steggewentz, J. H., and J. L. VanNess, 1939, Calculating the yield of a well, taking into account replenishment of the Ground Water above. Water Eng., Vol. 41, Page b, Equation 9.

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: Rept. to the Dare County Water Production Department, Kill Devil Hills, North Carolina, 39 p.

GEOLOGIST'S LOG

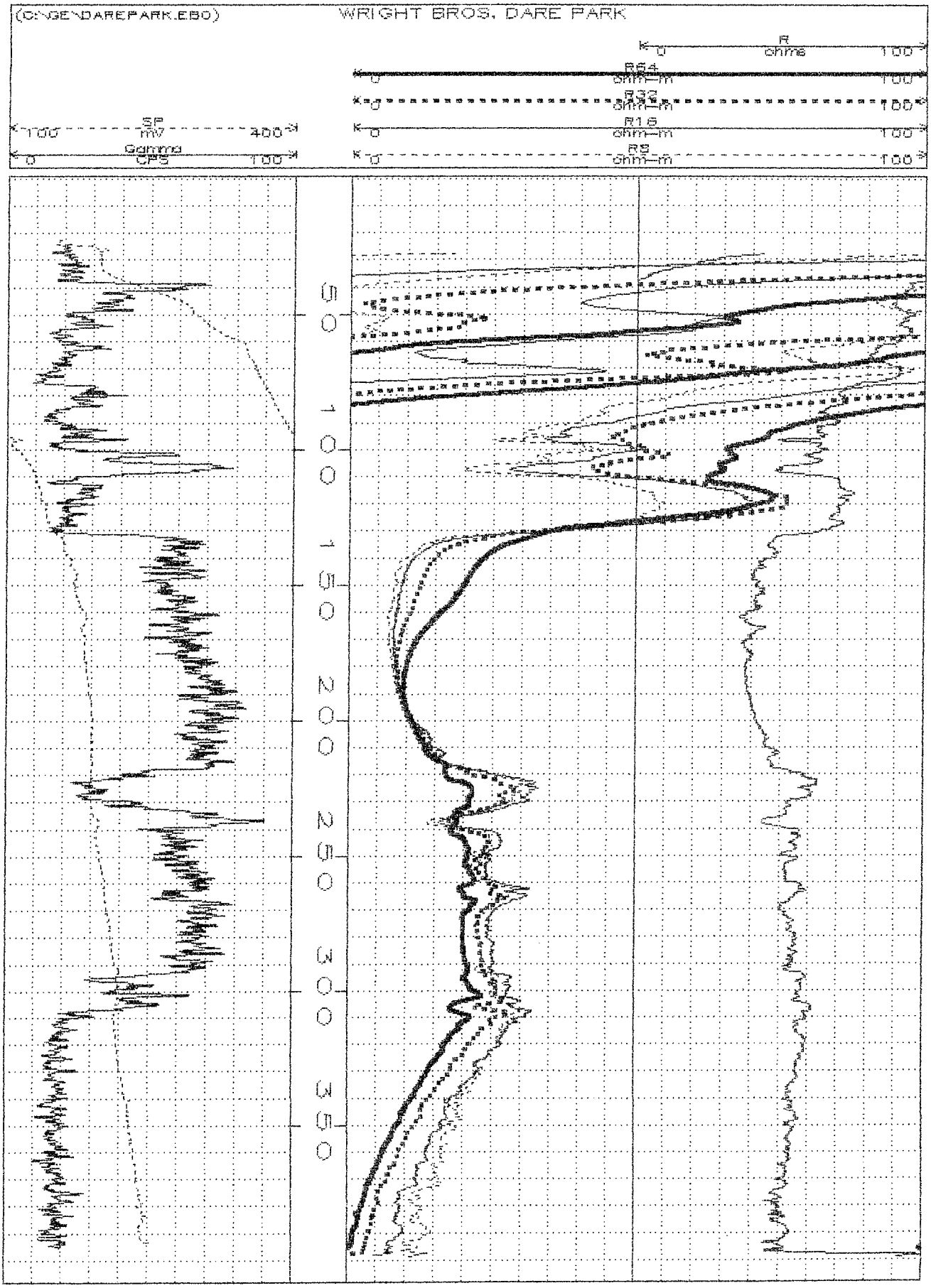
DARE COUNTY WATER DEPARTMENT
GEOLOGIST'S LOG OF TEST WELL PARK-1

Depth (feet)	Description
0-5	Sand, grayish-brown (5Y 3/2) to moderate brown (5YR 4/4), fine, well sorted, subangular, occasional organics.
5-15	Sand, light gray (N7) to medium gray (N5), fine, well sorted, subangular.
15-35	Sand, light gray (N7) to medium gray (N5), fine, well sorted, subangular, minor shell fragments.
35-45	Sand, medium gray (N5), fine, well sorted, subangular, minor black organic matter, minor gray clay.
45-50	Sand, medium gray (N5), fine, well sorted, subangular, occasional shell fragments.
50-65	Sand, medium gray (N5), fine, well sorted, subangular, common shell fragments, interbedded with dark gray (N3) clayey sand.
65-75	Sand, multicolored, fine to very coarse and pebble sizes, well rounded, poorly sorted, common shell fragments, some drilling fluid loss.
75-90	Sand, multicolored, fine to coarse, rounded, poorly sorted, occasional shell, interbedded, medium gray (N5) clay layers. Minor drilling fluid loss.
90-105	Sand, multicolored, medium to coarse and pebble sizes, moderately sorted, well rounded, minor shell fragments. Some drilling fluid loss.
105-110	Clay, dark gray (N3), soft, sticky, phosphatic, minor sand.
110-130	Sand, medium gray (N5) and multicolored, medium to coarse, moderately sorted, well rounded.
130-150	Clay, dark gray (N3), soft, sticky, sandy, phosphatic.
150-175	Clay, olive gray (5Y 4/1), soft, sticky, minor shell fragments, minor fine gray sand layers interbedded.
175-215	Clay, olive gray (5Y 4/1) to grayish gray (5G 6/1), stiff, cohesive, finely phosphatic, occasional fine sand layers interbedded.
215-235	Sand, medium gray (N5), very fine to medium, moderately sorted, common shell, common fine phosphate.
235-240	Clay, olive gray (5Y 4/1), soft, sticky, sandy, minor shell.
240-275	Interbedded sand, shell, and clay layers, sand is medium gray (N5), fine to medium with abundant fine phosphate grains. Shell is multicolored. Clay is gray, sticky, phosphatic.
275-290	Clay, greenish-gray (5G 6/1), stiff, cohesive, highly phosphatic, occasional shell.

DARE COUNTY WATER DEPARTMENT
GEOLOGIST'S LOG OF TEST WELL PARK-1
PAGE TWO

Depth (feet)	Description
290-310	Sand and shell. Sand is medium gray (N5), fine to medium, subrounded, phosphatic, hard lense between 290 and 295 feet (sandstone?). Shell is multicolored. Minor clay layers interbedded.
310-325	Sand and shell as above. No clay layers.
325-350	Sand, medium gray (N5), fine, well sorted, subangular, minor shell, trace clay.
350-375	Sand as above.
375-400	Sand, medium gray (N5) to dark gray (N3), very fine to fine, subangular, moderately well sorted, minor shell fragments, trace clay.

GEOPHYSICAL LOG


(C:\GE\DAREPARK.EBO)
WRIGHT BROS. DARE PARK
R
ohms
0
100
R64
ohm-m
R32
R16
R8
SP
mv
-100
400
Gamma
CPS
0
100
50
100
150
200
250
300
350

WATER QUALITY ANALYSES

Dare County, North Carolina
Regional Water system

Date Sample Drawn: 12-17-99 Operators: nc,cp,dh

Date Analysis Completed: 12-18-99 Wells: park serv. well

	well	MCL
Alkalinity as CaCO3, mg/L	0	N/A
Total Alkalinity CaCO3, mg/L	220	N/A
Bicarbonate as HCO3, mg/L	268.29	N/A
Carbonate as CO3, mg/L	0	N/A
Hydroxide as OH, mg/L	0	N/A
Total Hardness as CaCO3, mg/L	22	150*
Calcium Hardness as CaCO3, mg/L	20	N/A
Magnesium as CaCO3, mg/L	2	N/A
Calcium as Ca, mg/L	8	60*
Color	27	15^
Silica as SiO2, mg/L	8.8	N/A
Conductivity	3,270	N/A
Iron, Fe, mg/L	0.086	0.3^
Potassium K, mg/L	42.1	N/A
Copper, Cu, mg/L	< 70ug/l	1.0*
Manganese, Mn mg/L	0.04	N/A
Phosphate as PO4, mg/L	0.628	5.0*
Chloride as Cl-, mg/L	820	250.0*
Fluoride, F, mg/L	0.28	4.0*
Nitrate as NO3, mg/L	0.132	10^
Zinc, Zn, mg/L	0.521	5.0^
Chlorine (free Cl2), mg/L	0	0.2@
Lead, Pb, mg/L	<5ug/l	0.05^
Corrosivity	-0.02	N/A
pH	8.00	6.5-8.5*
pHs	7.83	N/A
Turbidity, N.T.U.	0.16	1.0^
Total Suspended Solids (TSS), mg/L	0.5	N/A
Total Dissolved Solids (TDS), mg/L	1,680	500.0*
Sulfate as SO4, mg/L	0.13	250.0*
Sodium, Na, mg/L	594.76	250.0^
Sulfide as S, mg/L	0	N/A

*Recommended State Maximum
@Mandatory State Minimum
^Mandatory State Maximums
N/A - Not Applicable

Savannah Laboratories
a division of Severn Trent Laboratories, Inc.
6712 Benjamin Road, Suite 100 · Tampa, FL 33634 · (813) 885-7427 · Fax (813) 885-7049 · www.stlsavlab.com

LOG NO: B9-53814
Received: 20 DEC 99
Reported: 10 JAN 00
Revised: 11 JAN 00 (1)

Mr. Scott Manahan
Missimer International, Inc.
8140 College Parkway, Suite 202
Fort Myers, FL 33919

Project: KDH PARK SERVICE TEST WELL
Sampled By: Client
Code: 145700111

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE/ TIME SAMPLED
53814-1	KDH PARK SERVICE TEST WELL	12-17-99/10:00

PARAMETER	53814-1
Boron, mg/l	1.0
Prep Date	12.28.99
Analysis Date	01.05.00
Copper, mg/l	<0.020
Prep Date	12.20.99
Analysis Date	01.03.00
Iron, mg/l	0.12
Prep Date	12.20.99
Analysis Date	01.03.00
Nickel, mg/l	<0.040
Prep Date	12.20.99
Analysis Date	01.03.00
Manganese, mg/l	<0.010
Prep Date	12.20.99
Analysis Date	01.03.00
Sodium, mg/l	660
Prep Date	12.20.99
Analysis Date	01.03.00
Strontium, mg/l	0.68
Prep Date	12.28.99
Analysis Date	01.05.00

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LOG NO: B9-53814
Received: 20 DEC 99
Reported: 10 JAN 00
Revised: 11 JAN 00 (1)

Mr. Scott Manahan
Missimer International, Inc.
8140 College Parkway, Suite 202
Fort Myers, FL 33919

Project: KDH PARK SERVICE TEST WELL
Sampled By: Client
Code: 145700111

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE/ TIME SAMPLED
53814-1	KDH PARK SERVICE TEST WELL	12-17-99/10:00

PARAMETER	53814-1
Zinc, mg/l	<0.020
Prep Date	12.20.99
Analysis Date	01.03.00
Bromide (300.0), mg/l	3.1
Prep Date	01.07.00
Analysis Date	01.07.00
Chloride (4500-Cl C), mg/l	840
Analysis Date	12.22.99
Fluoride (340.2), mg/l	<0.20
Analysis Date	12.21.99
Sulfate as SO4 (375.4), mg/l	35
Analysis Date	12.20.99
Total Dissolved Solids (160.1), mg/l	1800
Analysis Date	12.21.99
Alkalinity (to pH 4.5) as CaCO3, mg/l	290
Analysis Date	12.20.99
Noncarbonate Hardness as CaCO3	
Hardness as CaCO3, mg/l	<3.3
Prep Date	12.20.99
Analysis Date	01.03.00

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LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE/ TIME SAMPLED
53814-1	KDH PARK SERVICE TEST WELL	12-17-99/10:00

PARAMETER	53814-1
Hardness as CaCO3, mg/l	130
Prep Date	12.20.99
Analysis Date	01.03.00
Bicarbonate Alkalinity as CaCO3 (2320B), mg/l	290
Analysis Date	12.20.99
Sulfide (376.2), mg/l	<0.10
Prep Date	12.23.99
Analysis Date	12.23.99
Silica as SiO2, mg/l	14
Prep Date	12.28.99
Analysis Date	01.07.00

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES	DATE/ TIME SAMPLED
53814-2	Method Blank	
53814-3	Accuracy (%Rec)	
53814-4	Precision (%RPD)	

PARAMETER	53814-2	53814-3	53814-4
Boron, mg/l	<0.050	106 %	1.9 %
Prep Date	12.28.99	12.28.99	12.28.99
Analysis Date	01.05.00	01.05.00	01.05.00
Copper, mg/l	<0.020	98 %	0.39 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	01.03.00	01.03.00	---
Iron, mg/l	<0.050	87 %	0.67 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	12.21.99	12.21.99	---
Nickel, mg/l	<0.040	104 %	0.29 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	12.21.99	12.21.99	---
Manganese, mg/l	<0.010	104 %	0.10 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	12.21.99	12.21.99	---
Sodium, mg/l	<0.50	108 %	3.0 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	12.21.99	12.21.99	---
Strontium, mg/l	<0.010	94 %	1.1 %
Prep Date	12.28.99	12.28.99	12.28.99
Analysis Date	01.05.00	01.05.00	01.05.00

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES	DATE/ TIME SAMPLED
53814-2	Method Blank	
53814-3	Accuracy (%Rec)	
53814-4	Precision (%RPD)	

PARAMETER	53814-2	53814-3	53814-4
Zinc, mg/l	<0.020	105 %	0.38 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	12.21.99	12.21.99	---
Bromide (300.0), mg/l	<1.0	100 %	---
Prep Date	01.07.00	01.07.00	---
Analysis Date	01.07.00	01.07.00	---
Chloride (4500-Cl C), mg/l	<1.0	102 %	0 %
Analysis Date	12.22.99	12.22.99	---
Fluoride (340.2), mg/l	<0.20	98 %	1.9 %
Analysis Date	12.21.99	12.21.99	---
Sulfate as SO4 (375.4), mg/l	<5.0	115 %	7.4 %
Analysis Date	12.20.99	12.20.99	---
Total Dissolved Solids (160.1), mg/l	<5.0	100 %	0.20 %
Analysis Date	12.21.99	12.21.99	---
Alkalinity (to pH 4.5) as CaCO3, mg/l	<1.0	97 %	0.87 %
Analysis Date	12.20.99	12.20.99	---
Noncarbonate Hardness as CaCO3			
Hardness as CaCO3, mg/l	<3.3	---	---
Prep Date	12.20.99	---	---
Analysis Date	12.21.99	---	---

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53814-2	Method Blank	
53814-3	Accuracy (%Rec)	
53814-4	Precision (%RPD)	

PARAMETER	53814-2	53814-3	53814-4
Hardness as CaCO3, mg/l	<3.3	110 %	5.0 %
Prep Date	12.20.99	12.20.99	---
Analysis Date	12.21.99	12.21.99	---
Bicarbonate Alkalinity as CaCO3 (2320B), mg/l	<1.0	97 %	0.87 %
Analysis Date	12.20.99	12.20.99	---
Sulfide (376.2), mg/l	<0.10	98 %	3.0 %
Prep Date	12.23.99	12.23.99	---
Analysis Date	12.23.99	12.23.99	---
Silica as SiO2, mg/l	<0.50	97 %	2.1 %
Prep Date	12.28.99	12.28.99	---
Analysis Date	01.07.00	01.07.00	---

Methods: EPA SW-846, EPA 600/4-79-020
DOH Certification #'s 84385, E84282, 87279, E87052, 87375, E87089

Michael F. Valder, Project Manager

MODELING RESULTS

***** SUMMARY OF INPUT DATA *****

STEADY-STATE LEAKY CONFINED AQUIFER MODEL
TRANSMISSIVITY = 30000.
LEAKANCE (GPD/FT**3) = 0.000500
NODE SPACING = 200.00

WELL DESCRIPTIONS

X-LOCATION	Y-LOCATION	Q(GPM)
5.00	5.00	450.00
15.00	5.00	450.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
25	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.8	5.7	5.7	5.6	5.5	5.4	5.3
24	5.8	5.9	6.0	6.1	6.1	6.2	6.2	6.2	6.3	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.0	5.9	5.8	5.7	5.6	5.5
23	6.0	6.1	6.2	6.3	6.4	6.5	6.5	6.5	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7
22	6.3	6.4	6.5	6.6	6.7	6.7	6.8	6.8	6.9	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.4	6.3	6.2	6.0	5.9
21	6.6	6.7	6.8	6.9	7.0	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.1	7.1	7.0	6.9	6.8	6.7	6.6	6.4	6.3	6.1
20	6.8	7.0	7.1	7.2	7.3	7.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.4	7.3	7.2	7.1	7.0	6.8	6.7	6.5	6.4
19	7.1	7.3	7.4	7.6	7.7	7.7	7.8	7.9	7.9	7.9	7.9	7.9	7.8	7.7	7.7	7.6	7.4	7.3	7.1	7.0	6.8	6.6
18	7.4	7.6	7.8	7.9	8.0	8.1	8.2	8.3	8.3	8.3	8.3	8.3	8.2	8.1	8.0	7.9	7.8	7.6	7.4	7.3	7.1	6.9
17	7.8	8.0	8.1	8.3	8.4	8.5	8.6	8.7	8.7	8.7	8.7	8.7	8.6	8.5	8.4	8.3	8.1	8.0	7.8	7.6	7.4	7.1
16	8.1	8.3	8.5	8.7	8.8	9.0	9.1	9.1	9.2	9.2	9.2	9.1	9.1	9.0	8.8	8.7	8.5	8.3	8.1	7.9	7.7	7.4
15	8.5	8.7	8.9	9.1	9.3	9.4	9.5	9.6	9.7	9.7	9.7	9.6	9.5	9.4	9.3	9.1	8.9	8.7	8.5	8.2	8.0	7.7
14	8.9	9.1	9.4	9.6	9.8	9.9	10.1	10.1	10.2	10.2	10.2	10.1	10.1	9.9	9.8	9.6	9.4	9.1	8.9	8.6	8.3	8.0
13	9.3	9.6	9.9	10.1	10.3	10.5	10.6	10.7	10.8	10.8	10.8	10.7	10.6	10.5	10.3	10.1	9.9	9.6	9.3	8.9	8.6	8.3
12	9.7	10.1	10.4	10.7	10.9	11.1	11.2	11.3	11.4	11.4	11.4	11.3	11.2	11.1	10.9	10.7	10.4	10.1	9.7	9.3	8.9	8.6
11	10.1	10.6	11.0	11.3	11.6	11.8	11.9	12.0	12.0	12.0	12.0	12.0	11.9	11.8	11.6	11.3	11.0	10.6	10.1	9.7	9.3	8.8
10	10.6	11.1	11.6	12.0	12.3	12.5	12.6	12.6	12.7	12.7	12.7	12.6	12.6	12.5	12.3	12.0	11.6	11.1	10.6	10.1	9.6	9.1
9	11.1	11.7	12.3	12.8	13.2	13.4	13.4	13.4	13.3	13.3	13.3	13.4	13.4	13.4	13.2	12.8	12.3	11.7	11.1	10.5	9.9	9.4
8	11.6	12.3	13.1	13.8	14.3	14.4	14.3	14.1	14.0	13.9	14.0	14.1	14.3	14.4	14.3	13.8	13.1	12.3	11.6	10.8	10.2	9.6
7	12.0	12.9	14.0	15.1	15.7	15.7	15.2	14.8	14.6	14.5	14.6	14.8	15.2	15.7	15.7	15.1	14.0	12.9	12.0	11.1	10.4	9.8
6	12.3	13.4	14.8	16.7	18.2	17.3	16.1	15.4	15.0	14.8	15.0	15.4	16.1	17.3	18.2	16.7	14.8	13.4	12.3	11.3	10.6	9.9
5	12.4	13.6	15.2	17.9	38.8	18.5	16.5	15.6	15.1	15.0	15.1	15.6	16.5	18.5	38.8	17.9	15.2	13.6	12.4	11.4	10.6	9.9
4	12.3	13.4	14.8	16.7	18.2	17.3	16.1	15.4	15.0	14.8	15.0	15.4	16.1	17.3	18.2	16.7	14.8	13.4	12.3	11.3	10.6	9.9
3	12.0	12.9	14.0	15.1	15.7	15.7	15.2	14.8	14.6	14.5	14.6	14.8	15.2	15.7	15.7	15.1	14.0	12.9	12.0	11.1	10.4	9.8
2	11.6	12.3	13.1	13.8	14.3	14.4	14.3	14.1	14.0	13.9	14.0	14.1	14.3	14.4	14.3	13.8	13.1	12.3	11.6	10.8	10.2	9.6
1	11.1	11.7	12.3	12.8	13.2	13.4	13.4	13.4	13.3	13.3	13.3	13.4	13.4	13.4	13.2	12.8	12.3	11.7	11.1	10.5	9.9	9.4
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

X AXIS