COUNTY OF DARE

KILL DEVIL HILLS, NORTH CAROLINA 27948

600 MUSTIAN ST
PHONE (919) 441-776

BOB ORESKOVICH
SUPERINTENDENT
WATER PRODUCTION DEPARTMENT

MEMORANDUM

DATE: August 30, 1994

TO: Terry Wheeler, County Manager

FROM: Bob Oreskovich, Water Director

SUBJECT: Report of the Construction and Testing of the R.O. Plant Expansion wells #9 and #10

Please find attached a copy of the report by our Hydrogeolgoists on the new wells #9 and #10 at Fresh Pond.

Nothing to be concerned about. I have reviewed the report and the aquifer performance testing showed negligible effects on the surface water table wells at the two sites. This was attributed more to Fresh Pond pumping (about 0.6 mgd) rather than our aquifer/well testing.

I have forwarded a copy of the report to the Town's water superintendents for distribution and a copy to Jeff Smith of the Nags Head Woods Conservancy with a cover letter (copy attached) for his information and review.

If you have any questions, please call.

enclosures

COUNTY OF DARE

KILL DEVIL HILLS, NORTH CAROLINA 27948

600 MUSTIAN ST
PHONE (919) 441-778

BOB ORESKOVICH
SUPERINTENDENT
WATER PRODUCTION DEPARTMENT

August 30, 1994

Mr. Jeff Smith
Nags Head Nature Conservancy
701 W. Ocean Acres Dr.
Kill Devil Hills, NC 27948

Dear Jeff,

Enclosed please find a copy of the "Report on the Construction and testing..." of the Fresh Pond, R.O. Plant wells #9 and #10.

I have reviewed and highlighted pertinent information surrounding the effects, if any, the aquifer performance testing on these wells had on the two water table (surface) wells at these wells sites. The Hydrogeologists have commented to that effect.

We will continue to monitor the static water levels in these surface wells around the Fresh Pond and have this information available to you at your request.

If you have any questions concerning these wells or this report, please do not hesitate to call me.

Best regards,

Bob

Bob Oreskovich, Director
Dare County Water System

cc: Mr. Terry Wheeler, County Manager
Mr. Webb Fuller, Nags Head Town Manager
Mrs. Debbie Diaz, Kill Devil Hills Town Manager

enclosure

REPORT ON THE CONSTRUCTION AND TESTING OF THE DARE COUNTY WATER PRODUCTION DEPARTMENT REVERSE OSMOSIS WELLS #9 AND #10 DARE COUNTY, NORTH CAROLINA

Prepared for:

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

August, 1994

Prepared by:

ViroGroup, Inc.
428 Pine Island Road, SW
Cape Coral, Florida 33991

Project Number
01-02737.00

Wm. Scott Manahan
Project Manager

Jack Breland, P.G. #1524
Project Hydrogeologist

02737RGG.H01

ViroGroup
Air • Water • Soil
TECHNOLOGY

Missimer Division
ViroGroup, Inc.
428 Pine Island Road, S.W.
Cape Coral, FL 33991
Phone 813-574-1919
FAX 813-574-8106

August 17, 1994

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

Re: R.O. Wells #9 and #10 - Completion Report

Dear Bob:

Enclosed, please find three copies of the completion report prepared for the new production wells near the Fresh Pond in Nags Head. The report details the methods used to construct and test the wells. Pertinent recommendations concerning future use of the wells are also presented.

We are pleased to have had the opportunity to provide assistance on this project and look forward to working with you again. As always, if you have any questions or require additional information, please feel free to contact me.

Sincerely,

Wm. Scott Manahan
Hydrologic Engineer

WSM:gng

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES - CONTINUED

LIST OF TABLES

I. CONCLUSIONS AND RECOMMENDATIONS

The production capacity of the Dare County Water Production Department reverse osmosis wellfield has been expanded by the installation of two new production wells. The new production wells R.O. #9 and R.O. #10 tap the Mid-Yorktown aquifer and are located approximately one and a half miles south of the existing Baum Tract wellfield. The following conclusions and recommendations are made based on results of the drilling and testing conducted during well construction.

A. Conclusions

1. Two new reverse osmosis production wells have been installed near the Fresh Pond in Nags Head. A screen and gravel pack completion technique was used on both wells. The total depth and cased depth of the wells are approximately 400 and 275 feet respectively.

2. Step drawdown pump tests were performed on both wells after they were completed. Specific capacity values were determined for each well using the pump test data. The specific capacity of well R.O. #9 is approximately 35 gpm/ft at a pumping rate of 500 gpm. The specific capacity of well R.O. #10 is approximately 21 gpm/ft at a pumping rate of 500 gpm. The specific capacity values were considered in the recommendation of production rates and pump setting depths.

3. 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. #9 had a total dissolved solids concentration of 1870 mg/l and well R.O. #10 had a total dissolved solids concentration of 2170 mg/l.

4. Shallow wells tapping the Water-Table Aquifer were installed near the new production wells. Based on water level data obtained from the shallow wells, there appears to be no hydraulic connection between the Mid-Yorktown Aquifer and the Water-Table Aquifer. Pumpage from wells R.O #9 and R.O. #10 will have no affect on the Water-Table Aquifer or surface environment.

5. Aquifer performance tests were conducted at both production well sites. Data collected during the tests were used to calculate aquifer hydraulic coefficients. The following coefficients were calculated conservatively based on the test data:

Aquifer Parameter	R.O. #9 Site	R.O. #10 Site
Transmissivity	85,700 gpd/ft	63,700 gpd/ft
Storage Coefficient	4.0×10^{-4}	6.4×10^{-4}

B. Recommendations

1. The following pumping rates are recommended for the new Dare County reverse osmosis production wells based on step drawdown test data. Well R.O. #9 should be pumped at a rate of 550 gpm. Well R.O. #10 should be pumped at a rate of 500 gpm. Higher sustained production rates are feasible from the wells but are not recommended because of the potential for accelerated water quality deterioration due to increased aquifer drawdown.

2. A minimum pump intake setting depth of 80 feet below land surface is recommended for both new production wells. This setting depth is conservative in that pumping water levels of approximately 50 to 55 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.

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

4. Water levels in the new test wells should also be monitored on a periodic basis and recorded. This data will show general water level trends in the aquifer and may be useful for future calibration of computer hydraulic flow models.

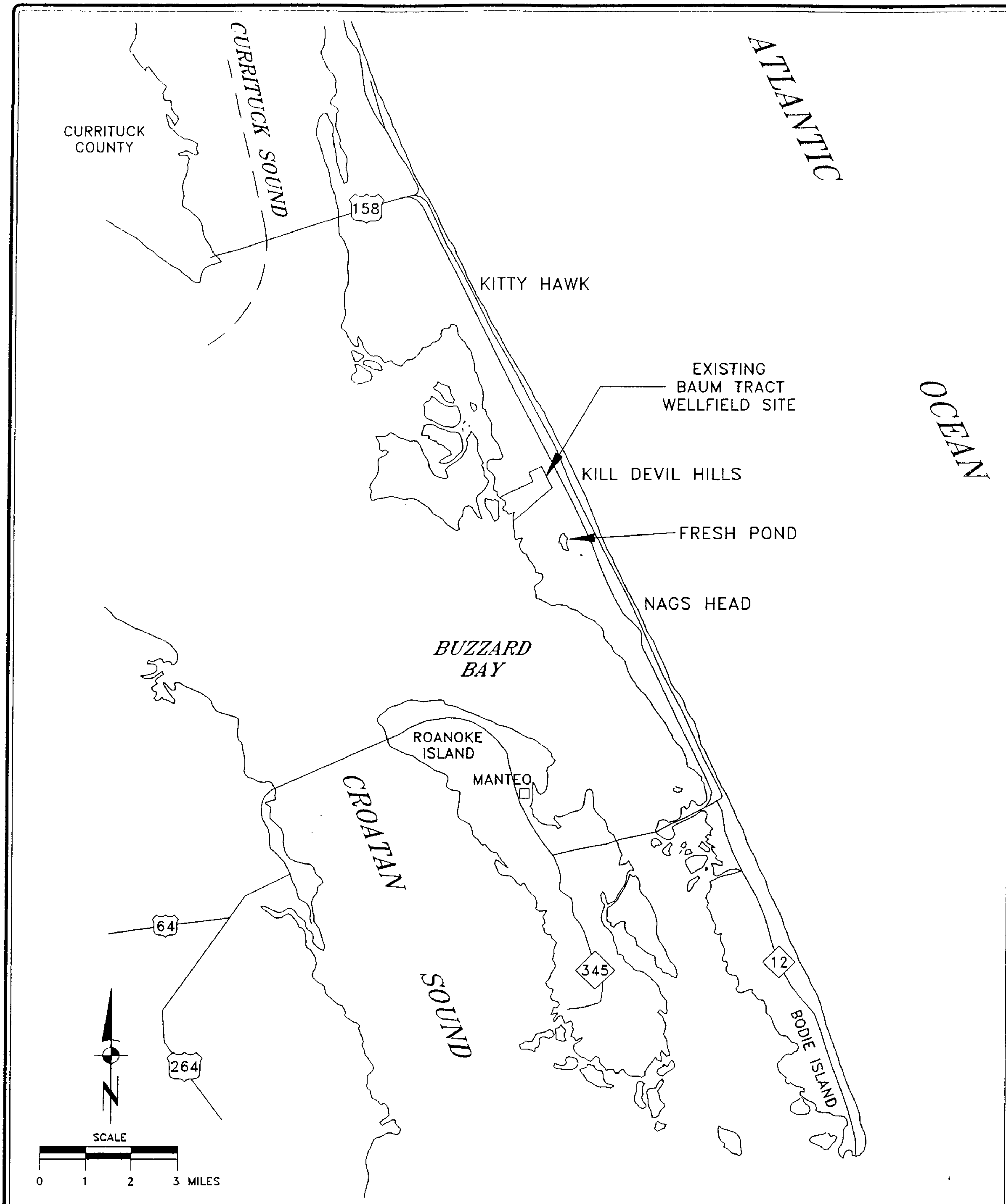
5. Water quality in the new production wells should be monitored closely; particularly when the wells first go into service. Salinity parameters such as dissolved chloride can be used to monitor water quality. The data can be used to assess performance of the new wells by determining the rate of water quality changes, identify potential problems, and may be useful during future calibration of solute transport (water quality) computer models.

6. If rapid water quality deterioration is noted in the new production wells it may be necessary to investigate the cause of the problem. Such an investigation might initially involve drilling and collection of lithologic and water quality samples from zones beneath the production zone of the Mid-Yorktown Aquifer. Drilling and testing will provide data that will assist in evaluating the degree of connection between the Mid-Yorktown and Lower Yorktown aquifers.

II. INTRODUCTION

This report documents the procedures used during the drilling, construction and testing of two new Mid-Yorktown Aquifer production wells for the Dare County Water Production Department in Kill Devil Hills on the outer banks of North Carolina. The new wells are located approximately one and a half miles south of the existing Baum Tract wellfield near the Fresh Pond in Nags Head as shown on Figure II-1. The wells will be used to supply raw water to the Dare County Water Production Department Reverse Osmosis (R.O.) water treatment plant which is located within the Baum Tract wellfield site. The treatment plant produces potable water for Kill Devil Hills, Nags Head and other nearby communities. The treatment plant raw water demands have averaged from less than 1.5 million gallons per day (MGD), during the winter, to over 2.5 MGD, during the summer. The new production wells will be used to supplement withdrawals from the existing Baum Tract wellfield.

Well construction techniques and well design for the production wells were based on results of test well construction at both well sites. The scope of the project included technical advisement and review of the technical specifications prepared for construction and testing of the new wells; assistance in the bidding process; on-site supervision of well construction and testing; aquifer performance testing; and data analysis and evaluation. This report was prepared to document the procedures used during construction and testing of the wells. Recommendations concerning pumping and operation of the wells are also included in the report.



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	PROJECT NAME: DARE COUNTY R.O. WELLFIELD NUMBER: 01-02737.00	

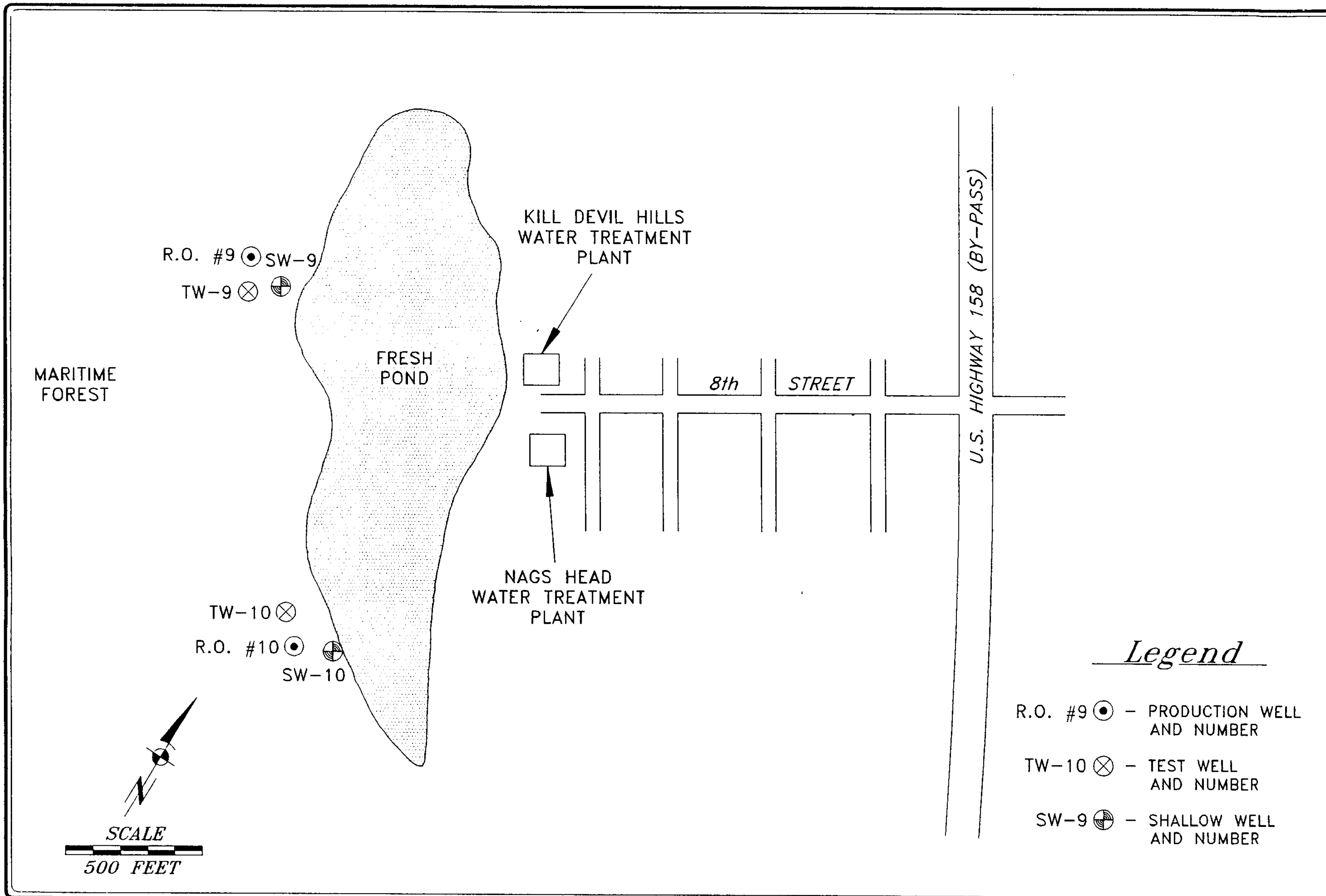
FIGURE II-1. GENERAL LOCATION MAP OF NORTHERN DARE COUNTY OUTER BANKS.

III. TEST WELL CONSTRUCTION AND TESTING

A. Drilling Methods

The construction, development, and pump testing of the Dare County Water Production Department test wells TW-9 and TW-10 were conducted by Skipper's Well Drilling of Leland, North Carolina. 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 wells began late in March of 1994 and was completed in May, 1994. The drilling procedures used were similar for both wells and are described below. A site map showing the relative locations of the wells is provided as Figure III-1.

The mud rotary method was used to drill the test wells. 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 in both wells. After allowing the cement to cure a nominal 6-inch diameter pilot hole was drilled to a depth of 475 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. Additional formation samples were obtained for sieve analyses. Geophysical logs including natural gamma, single point resistance, and spontaneous potential were run in the pilot holes. Casing depth, screened intervals, and gravel pack selection were based on the geologist's logs, sieve analyses, and geophysical logs. The pilot holes were then reamed to a nominal 14-inch diameter to the appropriate depth and screen and casing were installed. A coarse sand filter pack (Morie #2) was placed by tremie pipe in the annular space between the borehole and screen to a height of 20 feet above the screen in both wells. Copies of the



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DRN. BY: CAM DWG NO. A-012737KB-1 DATE: 8/8/94

PROJECT NAME: DARE COUNTY R.O. PROJECT NUMBER: 01-02737.00

FIGURE III-1. SITE MAP SHOWING THE FRESH POND AND LOCATIONS OF THE WELLS.

geophysical logs and sieve analyses are included in the appendices. The construction details of the test wells are given in Table III-1 and shown graphically in Figure III-2.

Compressed air pumping and horizontal water jetting were used to develop the wells. The entire length of screen was jetted and the wells were surged repeatedly until the water was relatively clear and free of sediment. The wells were developed for a total of approximately 30 hours each. The remaining annular space between the borehole and casing in both wells was grouted with neat portland cement. Grouting was accomplished in two stages in both wells using the tremie pipe method. The first stage grout was allowed to set for a minimum of 12 hours and its height was tagged before pumping the second stage. Additional cement was added as needed to bring grout levels to land surface.

B. Step Drawdown Testing

The completed test wells were pump tested to assess well yield and to obtain samples for water quality analyses. A description of the procedures used to pump the wells and a summary of pump test results are given below.

An electric submersible pump powered by a generator was used to withdraw water from the test wells. The pump intake was set at 70 feet below land surface. An in-line Flowmeter was used to measure discharge rates. Water was directed away from the test site using a temporary discharge line. Both of the wells were pumped at four separate, steady pumping rates ranging from 100 to 480 gpm. Static water levels in the wells were measured before beginning the tests. Drawdown in the wells was measured during the test at each pumping rate at specified time intervals. The drawdown data were used in conjunction with the pumping rates to obtain specific capacity values for each of the wells. Results of the pump tests are summarized in Table III-2. Tables showing all of the time and drawdown data collected during the tests are included in the appendices.

TABLE III-1. CONSTRUCTION DETAILS OF THE DARE COUNTY WATER PRODUCTION DEPARTMENT TEST WELLS #9 AND #10

WELL NUMBER	TOTAL DEPTH (FEET) BLS	CASING DEPTH (FEET) BLS	CASING DIAMETER (INCHES)	CASING TYPE	SCREENED INTERVALS (FEET) BLS	AQUIFER
TW-9	400	280	8	PVC	280-295 315-400	MID-YORKTOWN
TW-10	395	270	8	PVC	270-290 310-395	MID-YORKTOWN
* Both wells were constructed with 0.025-inch slot PVC screen						

BLS - Below Land Surface

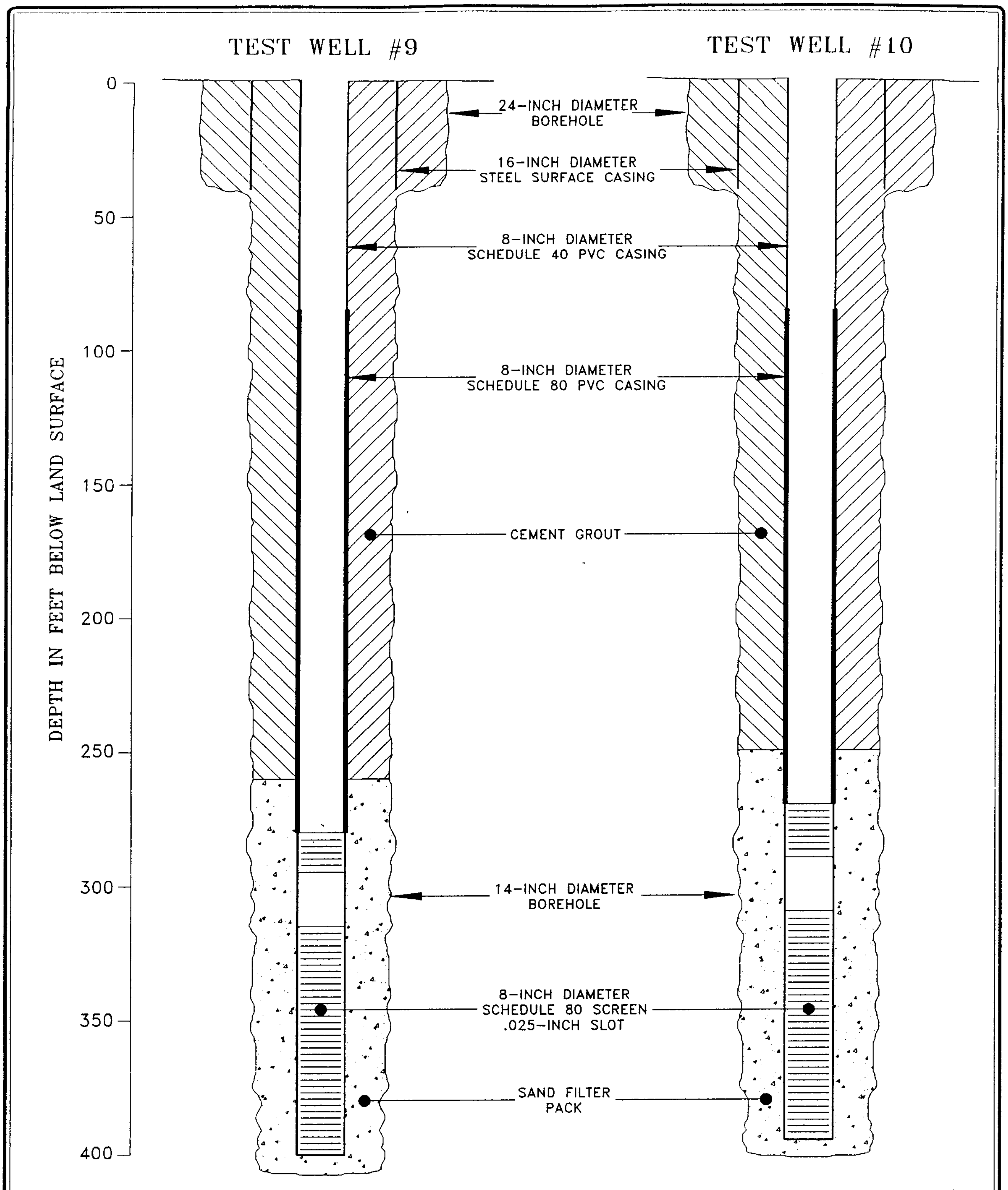

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FIGURE III-2. SCHEMATIC DIAGRAM SHOWING THE CONSTRUCTION DETAILS OF DARE COUNTY TEST WELLS #9 AND #10.

TABLE III-2. DARE COUNTY R.O. TEST WELLS #9 AND #10
SUMMARY OF STEP DRAWDOWN TEST RESULTS

Well	Pumping Rate (GPM)	Drawdown (Feet)	Specific Capacity (GPM/Ft)
Test Well #9	100	5.27	19.0
	200	11.19	17.9
	350	21.65	16.2
	480	31.83	15.1
Test Well #10	100	7.20	13.9
	200	15.30	13.1
	350	29.97	11.7
	470	43.72	10.8

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The specific capacity of test well TW-9 was almost 50% greater than TW-10 at similar pumping rates. The greater specific capacity of well TW-9 was expected to a certain extent because the formation at this site contained a larger fraction of coarse grained sand. However, the pump test results indicated that both sites possessed suitable productive capacity for the installation of permanent production wells.

C. Water Quality

Water samples were obtained from the test wells near the end of each step during the step drawdown pump tests. The samples were analyzed for dissolved chloride concentration and total dissolved solids by personnel with the Dare County Water Production Department at the reverse osmosis plant. The analyses results are shown in Table III-3. The water quality analyses results at the end of the step-drawdown test on test well TW-9 indicates a chloride concentration of 780 mg/l and total dissolved solids of 1590 mg/l. Test well TW-10, at the completion of the step-drawdown test, had a chloride concentration of 880 mg/l and total dissolved solids of 1720 mg/l.

D. Shallow Wells

Shallow wells tapping the Water-Table aquifer were installed at both well sites. These wells were constructed to determine what, if any, affect pumpage from the Mid-Yorktown Aquifer would have on the Water-Table aquifer or surface environment. The wells were constructed with a screen and gravel pack design utilizing the mud rotary method. Construction details for the wells are given in Table III-4. Locations of the wells are shown on Figure III-1.

TABLE III-3. DARE COUNTY R.O. TEST WELLS TW-9 AND TW-10
STEP DRAWDOWN TEST
WATER QUALITY ANALYSES RESULTS

Time Sample Selected	Well TW-9		Well TW-10	
	Dissolved Chloride Concentration (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Chloride Concentration (mg/l)	Total Dissolved Solids (mg/l)
End Step 1	830	1670	840	1680
End Step 2	830	1640	850	1660
End Step 3	800	1620	870	1670
End Step 4	780	1590	880	1720

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TABLE III-4. DARE COUNTY WATER PRODUCTION DEPARTMENT
SHALLOW MONITOR WELLS AT WELL SITES #9 AND #10

Shallow Well Number	Total Depth (Feet) BLS	Casing & Screen Diameter (inches)	Screened Interval (Feet) BLS	Screen Slot Size (inches)	Annulus Material (Feet) BLS: Cement Slurry	Annulus Material (Feet) BLS: Gravel Pack
SW-9	40	4	30-40	0.025	0-25	25-40
SW-10	40	4	30-40	0.025	0-25	25-40

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IV. PRODUCTION WELL CONSTRUCTION AND TESTING

A. Drilling Methods

The construction, development, and testing of Dare County reverse osmosis production wells R.O. #9 and R.O. #10 were conducted by Skipper's Well Drilling during June and July of 1994. Supervision was provided by ViroGroup, Inc. (VGI) staff during critical phases of the construction activity. These included setting of the screen and casing, development of the wells, step-drawdown testing, and aquifer performance testing. Production well design was based on results of sieve analyses, geophysical logs, and lithologic analyses of formation samples obtained during the construction and testing of the test wells at each site as described in the previous section. 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 drilling procedures used were similar for both wells and are described below. Locations of the wells are shown on Figure III-1.

The mud rotary method was used to drill the production wells. Bentonite mud was used during drilling of the surface and intermediate casing boreholes. Revert, a rapid destructing biodegradable drilling fluid was used during drilling of the screen borehole. A string of 24-inch diameter steel surface casing was set to a depth of 60 feet below land surface in both production wells and grouted in place. A nominal 24-inch diameter borehole was then drilled to the appropriate casing depth in each production well. The 18-inch diameter intermediate casings were installed and grouted in place. Nominal 16-inch diameter boreholes were drilled in each well to the depths previously determined and the screen and production casing were installed. Stainless steel, 0.035-inch continuous slot screen with a diameter of 8-inches was used in both production wells. A section of stainless steel casing with an end cap was placed on the end of each 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 of 145 feet below land surface followed by 12-inch diameter schedule 80 PVC casing to land surface. Construction details for both wells are summarized in Table IV-1 and shown graphically in Figures IV-1 and IV-2. After installing the well screens, a coarse sand filter pack (Morie #2) was placed in the annular space between the borehole and screen in both wells. The filter pack material was placed in the wells to a height of 20 feet above the screens using the tremie pipe method.

Compressed air pumping and horizontal jetting with chlorinated water were used to develop the wells. The entire screen length in both wells was jetted and the wells were surged repeatedly until the water produced was relatively clear and free of sediment. The wells were developed by this method for total of approximately 24 hours each. The remaining annular space between the borehole and screen was grouted with neat portland cement. Grouting was accomplished in stages using the tremie pipe method until the grout level was at land surface.

B. Step Drawdown Testing

The completed production wells were pump tested to assess well yield and aid in selection of pump setting depths. A description of the procedures used to pump the wells and a summary of the pump test results are given below.

An electric submersible pump powered by a generator was used to withdraw water from the production wells. The pump intake was set at 70 feet below land surface. An in-line flowmeter was used to measure discharge rates. Water was directed away from the well sites using a temporary discharge line. Both of the production wells were pumped at four separate, steady pumping rates ranging from 200 to 890 gpm. Static water levels in the wells were measured before beginning the tests. Pumping levels in the wells were measured during the test at each pumping rate at specified time intervals. The drawdown data were used in conjunction with the pumping rates

TABLE IV-1. CONSTRUCTION DETAILS OF THE DARE COUNTY WATER PRODUCTION DEPARTMENT PRODUCTION WELLS R.O. #9 AND R.O. #10

Well Number	Total Depth (feet) BLS	Casing Depth (feet) BLS	Casing Diameter (inches)	Casing Type	Screened Intervals (feet) BLS	Aquifer
R.O. #9	410	275	8 to 12	Schedule 80 PVC	282-297 314-405	Mid-Yorktown
R.O. #10	402	272	8 to 12	Schedule 80 PVC	274-295 312-396	Mid-Yorktown
*Both wells were constructed with 0.035-inch continuous slot stainless steel screen						

Total Screened Lengths
#9 - 106'
#10 - 105'

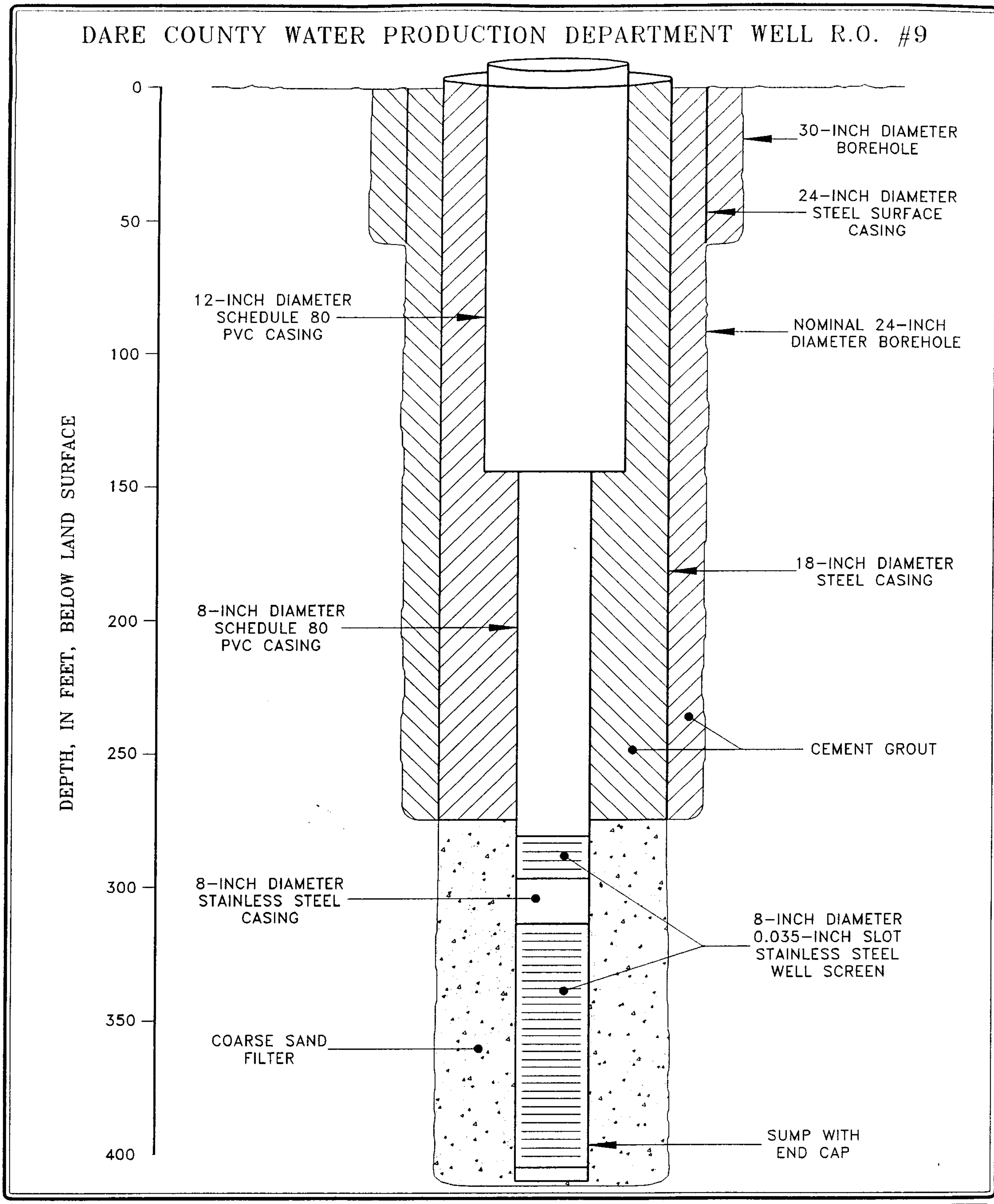

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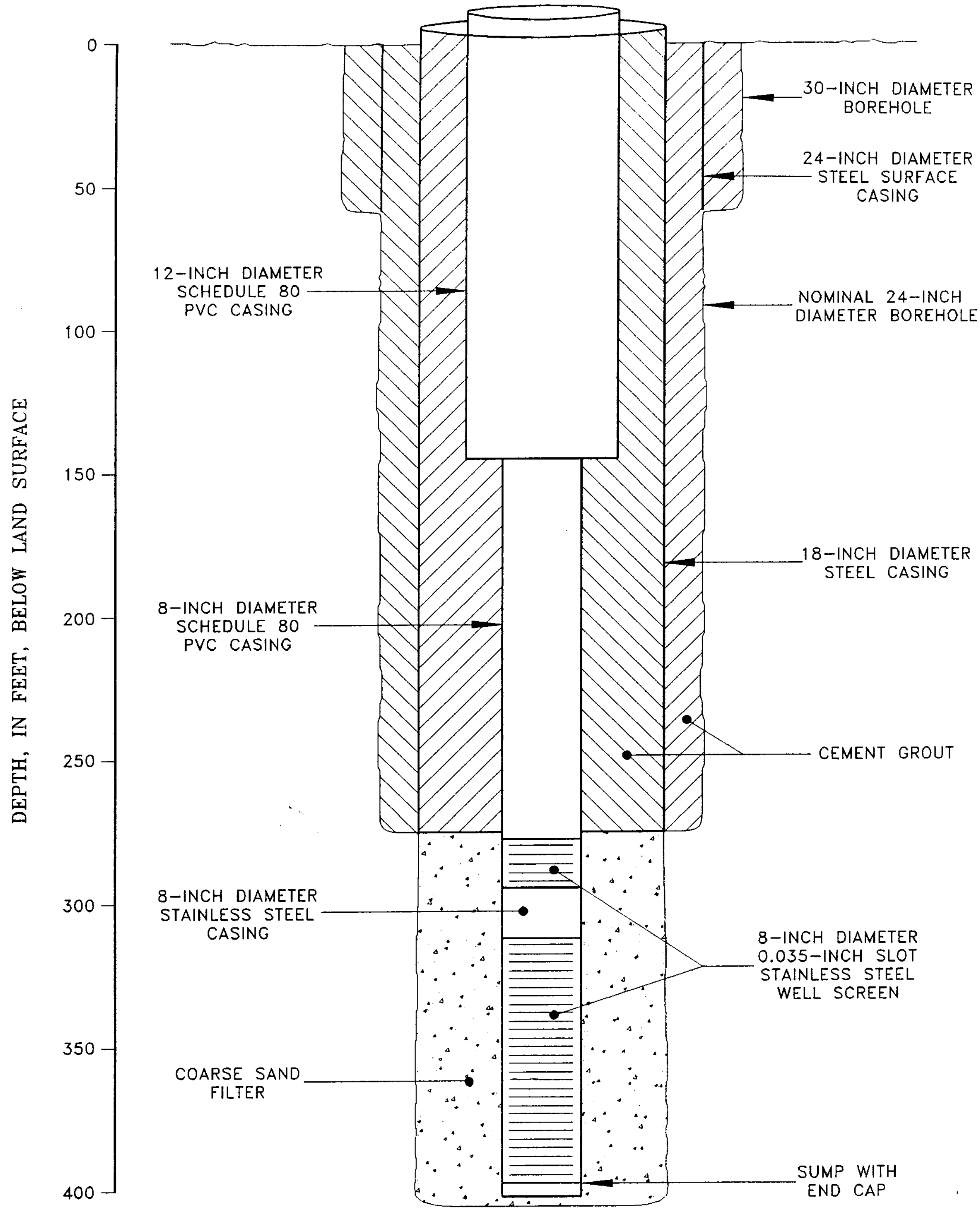
FIGURE IV-1. SCHEMATIC DIAGRAM SHOWING THE CONSTRUCTION DETAILS OF WELL R.O. #9.

DARE COUNTY WATER PRODUCTION DEPARTMENT WELL R.O. #10



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PROJECT NAME: DARE COUNTY R.O. NUMBER: 01-02737.00

FIGURE IV-2. SCHEMATIC DIAGRAM SHOWING THE CONSTRUCTION DETAILS OF WELL R.O. #10.

to obtain specific capacity values for each of the production wells. Results of the pump tests are summarized in Table IV-2.

Well yields are good with specific capacity values ranging from 19.0 gpm/ft to 38.0 gpm/ft. Plots of specific capacity vs. pumping rate for both wells are provided as Figures IV-3 and IV-4. Inspection of the figures indicates that at a production rate of 500 gpm well R.O. #9 is anticipated to have a specific capacity of approximately 35 gpm/ft and that of well R.O. #10 approximately 21 gpm/ft. Recommended production rates are 550 gpm for well R.O. #9 and 500 gpm for well R.O. #10. Higher sustained production rates are feasible from the wells but are not recommended because of the potential for accelerated water quality deterioration due to increased drawdowns. Based on the specific capacity values, proposed pumping rates, anticipated static water levels and interference drawdowns; pumping water levels of approximately 50 to 55 feet below land surface can be expected in the wells. A minimum pump setting depth of 80 feet below land surface is recommended. Setting the pumps slightly deeper than required will allow for potential well yield deterioration over time.

C. Water Quality

Water samples were obtained from production wells R.O. #9 and R.O. #10 during the step drawdown and aquifer performance tests. The samples were analyzed by Dare County Water Production Department staff for dissolved chloride concentration and total dissolved solids (TDS). Results of the water quality analyses are included in Tables IV-3 and IV-4. Total dissolved solids concentrations of the samples ranged from 1740 mg/l to 2170 mg/l which is considerably less saline than the water produced from the existing production wells at the Baum Tract wellfield. Total dissolved solids levels increased steadily in both wells during the step drawdown and aquifer performance tests, which is cause for concern. However, the rate of salinity increase in wells in this area is typically highest just after production is initiated and then it begins to taper off. Water quality in the new production wells should be

TABLE IV-2. DARE COUNTY R.O. PRODUCTION WELLS #9 AND #10
SUMMARY OF STEP DRAWDOWN TEST RESULTS

Well	Pumping Rate (GPM)	Drawdown (Feet)	Specific Capacity (GPM/Ft)
R.O. #9	400 600 800 890	10.52 18.33 27.37 33.89	38.0 32.7 29.2 26.3
R.O. #10	200 400 485 700	8.22 17.94 22.71 36.79	24.3 22.3 21.4 19.0

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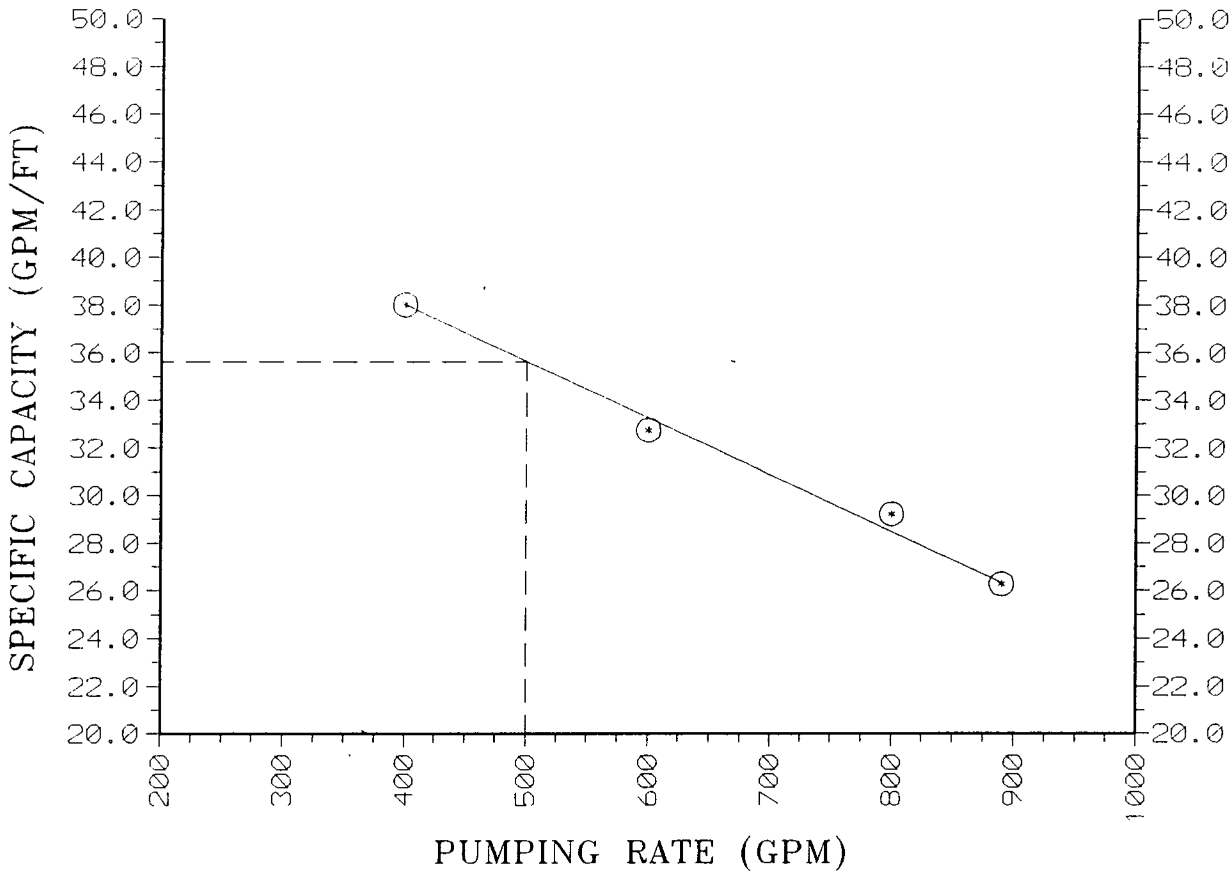

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FIGURE IV-3. GRAPH OF SPECIFIC CAPACITY vs. PUMPING RATE FOR DARE COUNTY PRODUCTION WELL R.O. #9.

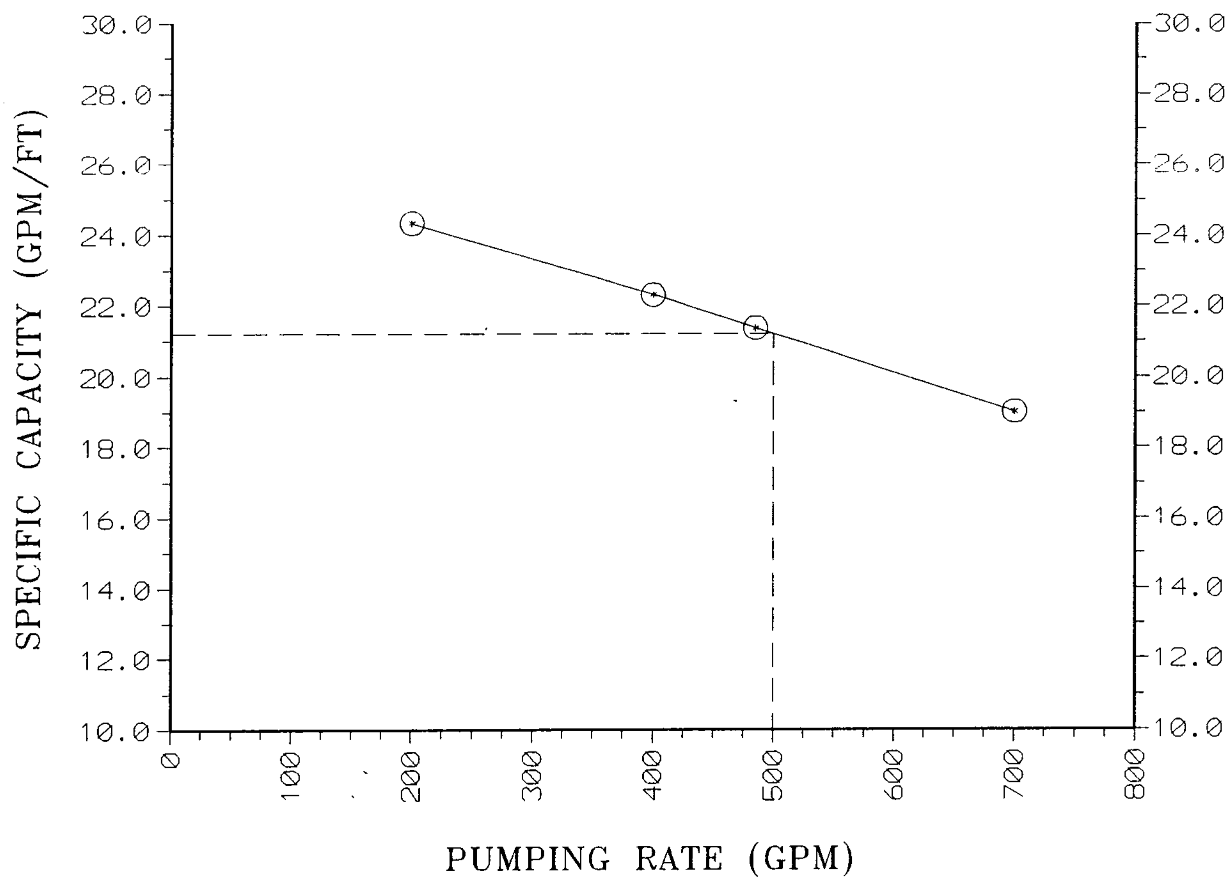

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FIGURE IV-4. GRAPH OF SPECIFIC CAPACITY vs. PUMPING RATE FOR DARE COUNTY PRODUCTION WELL R.O. #10.

TABLE IV-3. DARE COUNTY R.O. PRODUCTION WELLS #9 AND #10
STEP DRAWDOWN TEST
WATER QUALITY ANALYSES RESULTS

Time Sample Selected	Well R.O. #9		Well R.O. #10	
	Dissolved Chloride Concentration (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Chloride Concentration (mg/l)	Total Dissolved Solids (mg/l)
End Step 1	860	1760	850	1780
End Step 2	870	1760	850	1760
End Step 3	890	1770	880	1870
End Step 4	920	1780	900	1920

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

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TABLE IV-4. DARE COUNTY R.O. PRODUCTION WELLS #9 and #10
AQUIFER PERFORMANCE TEST
WATER QUALITY ANALYSES RESULTS

WELL R.O. #9 PUMPING AT 500 GPM		
Time Sample Selected (hours)	**Dissolved Chloride Concentration (mg/l)**	**Total Dissolved Solids (mg/l)**
0.25	880	1740
12	920	1780
24	940	1800
48	960	1830
68	980	1870
WELL R.O. #10 PUMPING AT 700 GPM		
Time Sample Selected (hours)	**Dissolved Chloride Concentration (mg/l)**	**Total Dissolved Solids (mg/l)**
0.75	980	1920
6	1000	1970
16	1050	2020
26	1050	2040
42	1070	2070
65	1100	2100
74	1130	2170

monitored closely after the wells are put into production. If the rate of water quality deterioration does not slow down substantially, it may become necessary to investigate the cause. Such an investigation might initially involve drilling and collection of lithologic and water quality samples from zones beneath the production zone of the Mid-Yorktown Aquifer. Drilling and testing will provide data that will assist in evaluating the degree of connection between the Mid-Yorktown and Lower Yorktown aquifers.

V. AQUIFER PERFORMANCE TESTING

A. Testing Procedures

Aquifer performance tests (APT) were conducted on the Mid-Yorktown Aquifer at both production well sites. In each case, the production well was pumped at a continuous rate while drawdowns were measured at specified time intervals in the adjacent test well. In addition, water level fluctuations in the water-table aquifer were monitored in the shallow monitor wells at each site. Time and water level data were measured and recorded by utilizing pressure transducers in the wells coupled to an electronic data logger. The time and drawdown data for each test are included in Appendix D.

An electric submersible pump powered by a generator was used to withdraw water from the production wells. The water was piped away from the test sites using a temporary discharge line. Flow rates were measured using an in-line flowmeter near the pump. The relative locations of the wells at the site shown on Figure III-1.

The initial APT was conducted at the site of R.O. #10 and started at 4:20 PM on June 24, 1994. Production well R.O. #10 was pumped at a continuous rate of 700 gpm for 73 hours. Drawdown in the Mid-Yorktown Aquifer was measured in well TW-10 located 66 feet from the pumped well. Water-Table aquifer water levels were monitored in well SW-10 approximately 75 feet from the production well. The drawdown and water level data collected for the test were transferred to a computer for plotting and the analysis was conducted as described in part B of this section of the report.

The second APT was started at 12:00 Noon on July 2, 1994. Production well R.O. #9 was pumped at a continuous rate of 500 gpm for 68 hours. Drawdown in the Mid-Yorktown Aquifer was measured in well TW-9 located 94 feet from the pumped well. Water-Table aquifer water levels were monitored in well SW-9 located approximately

90 feet from the production well. Drawdown and recovery data were again transferred to a computer for plotting and the analysis was conducted as described in part B of this section.

B. Data Analysis

Analysis of the data collected during the aquifer performance tests was accomplished using the method developed by Cooper (1963). Logarithmic plots of drawdown vs. time were constructed using data from the Mid-Yorktown Aquifer observation well for each test. The log-log graphs are included as Figures V-1 and V-2. 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.

$$T = \frac{114.6\ Q\ L(u,v)}{s} \qquad (1)$$

$$S = \frac{Tt}{1.87\ r^2\ (1/u)} \qquad (2)$$

$$L = \frac{T\ (r/b)^2}{r^2} \qquad (3)$$

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)
r/b = 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 which are included as Figures V-3 and

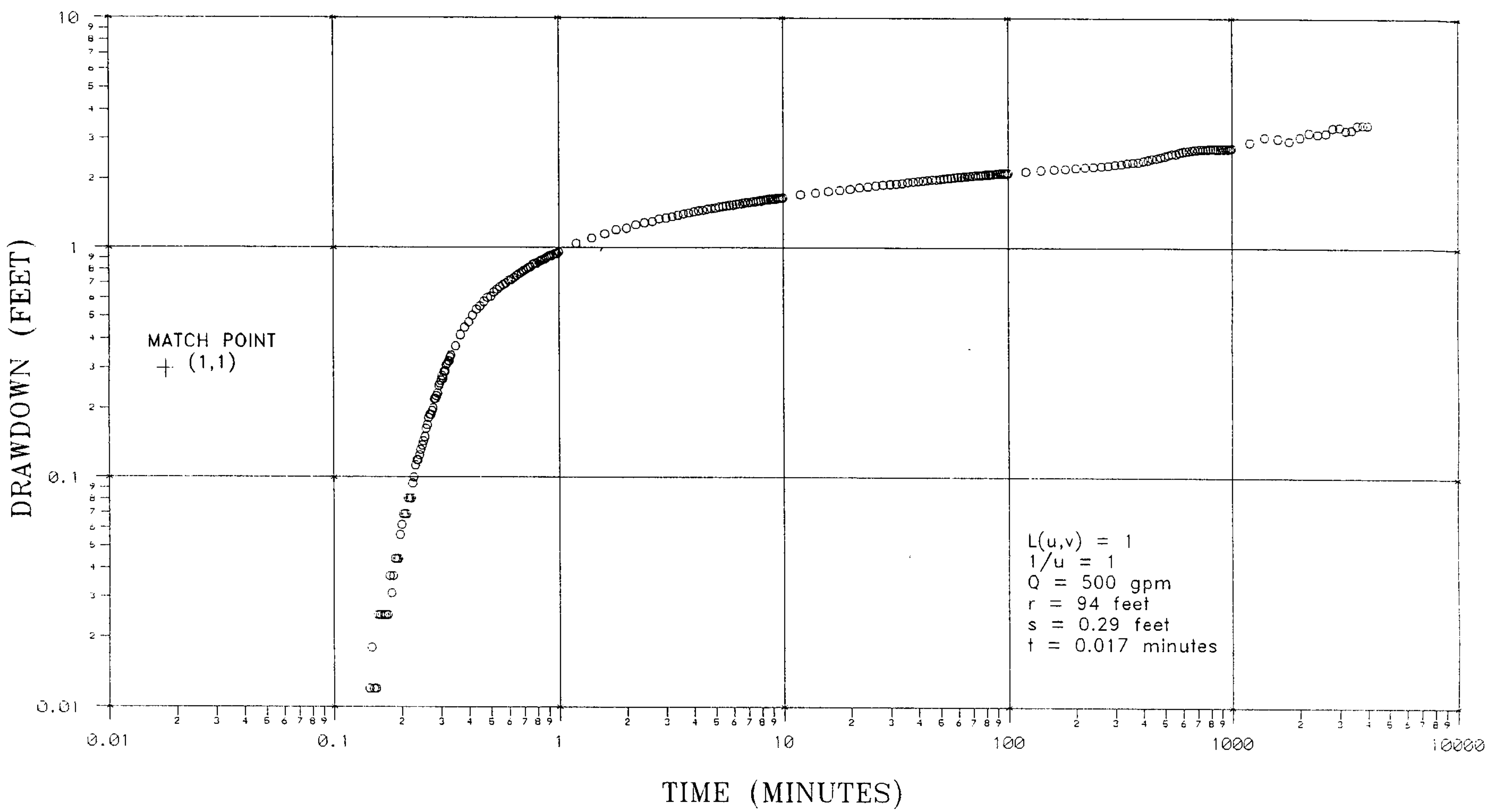

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FIGURE V-1. DRAWDOWN IN TEST WELL #9 DURING THE AQUIFER PERFORMANCE TEST ON DARE COUNTY PRODUCTION WELL R.O. #9.

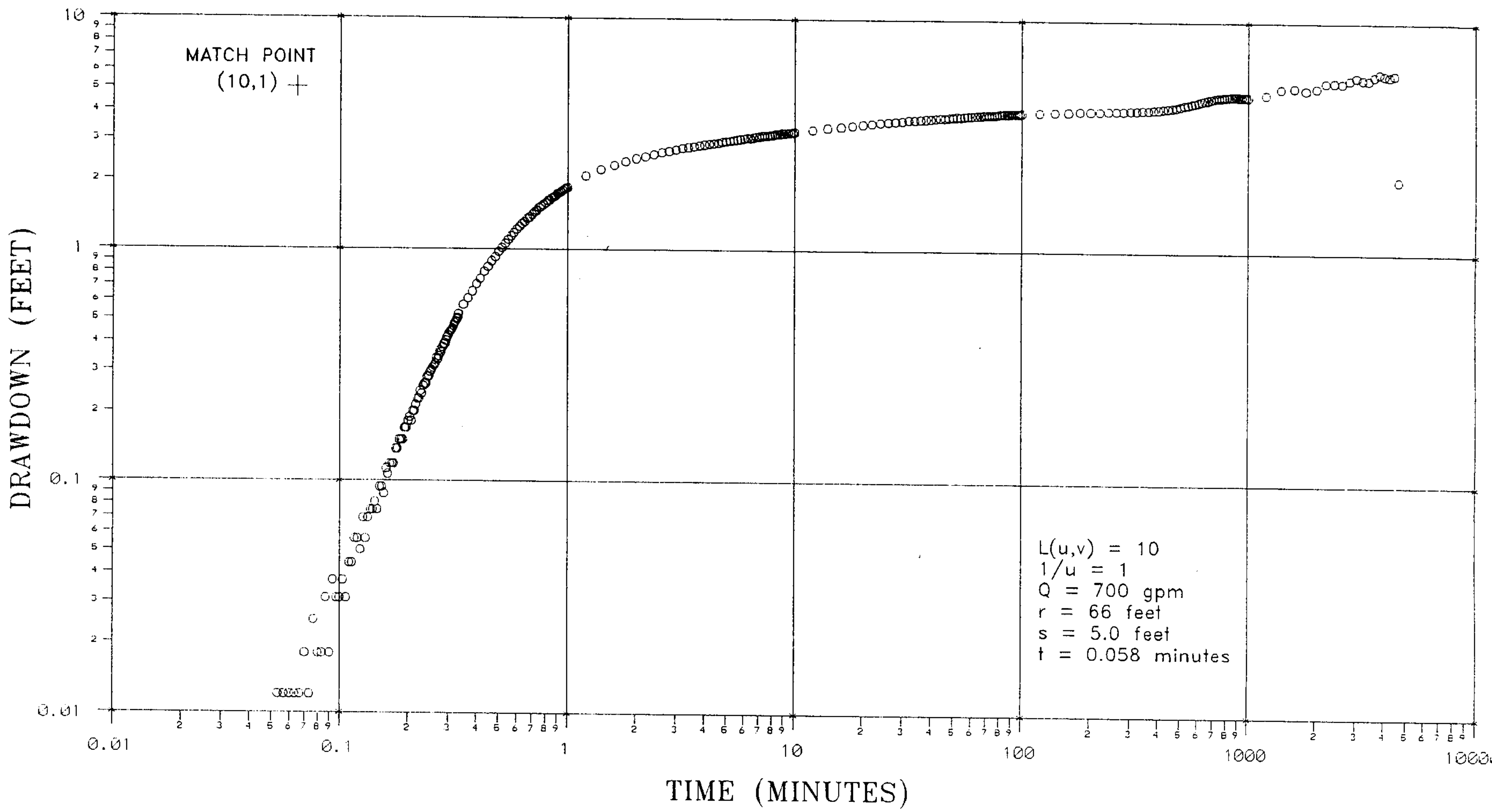

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FIGURE V-2. DRAWDOWN IN TEST WELL #10 DURING THE AQUIFER PERFORMANCE TEST ON DARE COUNTY PRODUCTION WELL R.O. #10.

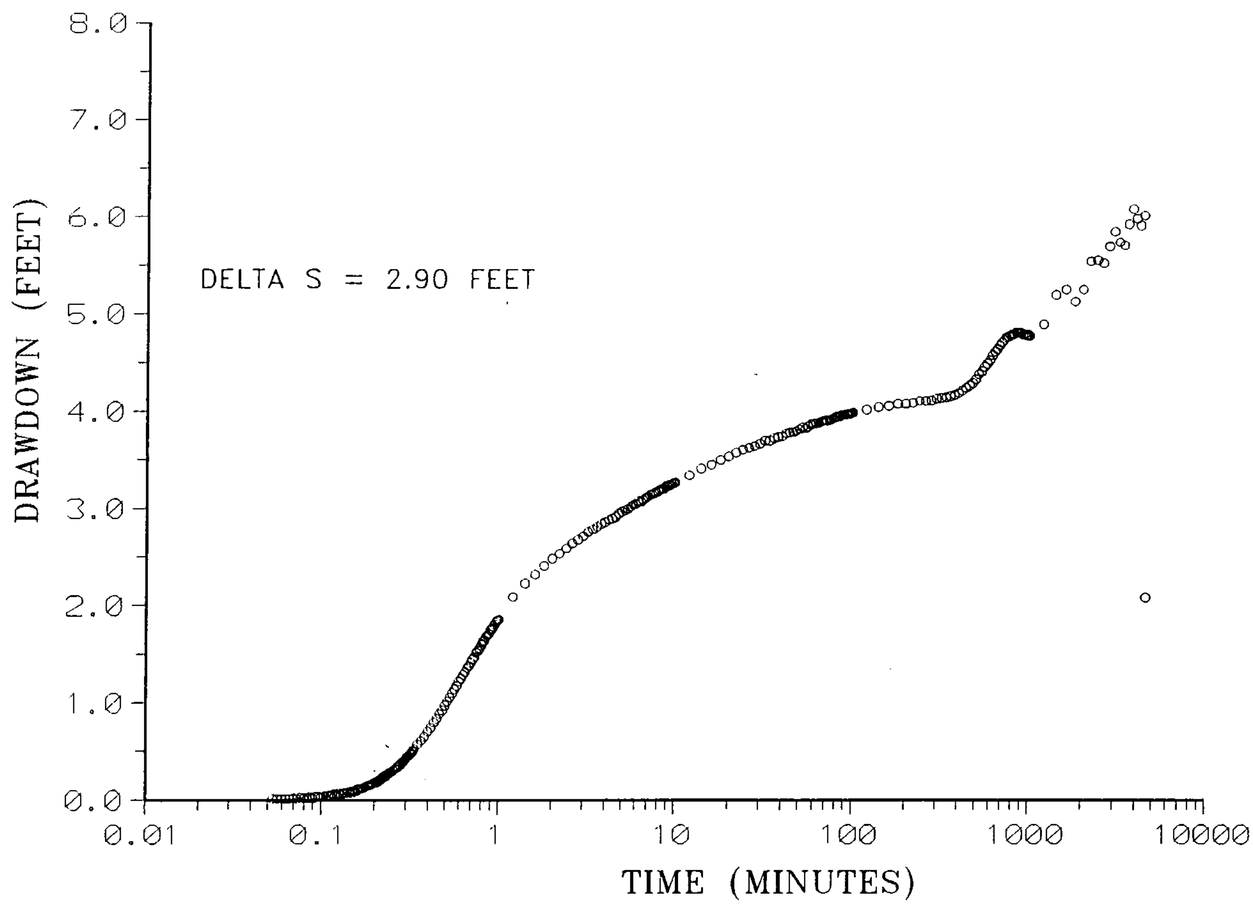

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FIGURE V-4. SEMI-LOG PLOT OF DRAWDOWN vs. TIME IN TEST WELL #10 DURING THE AQUIFER PERFORMANCE TEST ON DARE COUNTY PRODUCTION WELL R.O. #10.

V-4. A straight line segment is selected from 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 with this method.

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

$$S = \frac{Tto}{4790\ r^2} \qquad (5)$$

where,

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

A summary of the hydraulic coefficients calculated for Mid-Yorktown Aquifer at both test sites is given in Table V-1. The early data were used for the straight line analysis method which yielded transmissivity values of approximately 65,000 gpd/ft to 85,000 gpd/ft. This probably represents the hydraulic characteristics of the aquifer in the immediate vicinity of the production wells. Later data show a flattening of the drawdown response which appears to indicate that the cone of depression has encountered an area of high transmissivity. This transmissivity may be representative of the regional system. The later data indicate that the transmissivity of the regional system may range from 150,000 to 200,000 gpd/ft. It was not possible to determine the leakance values of the confining sequence based on the data obtained from the nearby monitor wells.

C. Water-Table aquifer Impacts

The production zone for the reverse osmosis feedwater wells occurs within the Mid-Yorktown aquifer which is encountered at a depth of approximately 300 feet below land surface in the Nags Head area. Immediately above the aquifer lies a sequence of very low permeability clays that form a confining unit with a thickness of approximately 170 feet. This confining unit effectively separates the production zone

TABLE V-1. AQUIFER HYDRAULIC COEFFICIENTS CALCULATED FOR THE MID-YORKTOWN AQUIFER AT THE DARE COUNTY WATER PRODUCTION DEPARTMENT FRESH POND WELLFIELD SITE

Curve Matching Method				
TEST		**TRANSMISSIVITY (gpd/ft)**	**STORAGE COEFFICIENT**	**LEAKANCE (gpd/ft^3)**
APT #1 (R.O. #10 Site)	Drawdown	160,400	7.9×10^{-4}	Not Determined
APT #2 (R.O. #9 Site)	Drawdown	197,600	1.4×10^{-4}	Not Determined
Straight-Line Method				
TEST		**TRANSMISSIVITY (gpd/ft)**	**STORAGE COEFFICIENT**	**LEAKANCE (gpd/ft^3)**
APT #1 (R.O. #10 Site)	Drawdown	63,700	6.4×10^{-4}	N/A
APT #2 (R.O. #9 Site)	Drawdown	85,700	4.1×10^{-4}	N/A

from overlying formations. A unit consisting of quartz sand and gravel termed the Principal Aquifer is present above the main confining unit. If not for the confining clays at this unit's base, leakage from the Principal Aquifer could provide substantial attenuation of hydraulic impacts of pumpage from the Mid-Yorktown aquifer. The Principal Aquifer is separated from the Water-Table aquifer by a clay layer that again has very low permeability. The geologic sequence beneath the Nags Head area is shown on Figure V-5. Based on the geology, it is apparent that the production zone is very well confined from overlying strata and there is negligible hydraulic connection to the Water-Table aquifer.

Water levels in the Water-Table aquifer were monitored in shallow wells at both test sites during the APT's. The monitoring was conducted to determine what, if any, impacts, pumpage from the Mid-Yorktown Aquifer has on the Water-Table Aquifer or surface environment. Graphs showing water levels in the shallow wells during the APT's are provided as Figures V-6 and V-7. Inspection of the figures indicates that water levels in the shallow aquifer remained relatively stable during the pump tests. The small declines in water levels noted during each test (less than 0.10 feet) are attributed to pumpage from the Fresh Pond which averaged approximately 0.6 mgd during the APT's. Withdrawals from the Fresh Pond are made for public supply purposes. Pumpage from the Mid-Yorktown Aquifer will have negligible effects on the Water-Table aquifer or surface environment.

DEPTH	SERIES	FORMATION	LITHOLOGY	AQUIFER
0, 100	HOLOCENE PLIO-PLEISTOCENE		SAND, FINE TO COARSE QUARTZ	WATER TABLE AQUIFER
	PLIOCENE	YORKTOWN	CLAY, OLIVE GRAY, STIFF	CONFINING BED
			SAND AND GRAVEL QUARTZ	PRINCIPAL AQUIFER
200, 300			CLAY, OLIVE GRAY, FINE, SANDY, SILTY, MINOR SHELL	CONFINING BEDS
400			SAND AND SHELL, FINE TO MEDIUM GRAIN SIZE	MID YORKTOWN AQUIFER
			CLAY AND SAND, OLIVE GRAY, SHELL	MID YORKTOWN AQUITARD
500			SAND, MINOR CLAY, FINE SHELL	LOWER YORKTOWN
600			SAND AND CLAY, INTERBEDDED, LIGHT OLIVE GRAY, SHELL	
700	MIOCENE	PUNGO RIVER	CLAY	PUNGO RIVER CONFINING UNIT

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FIGURE V-5. HYDROGEOLOGIC SECTION OF DARE COUNTY BAUM TRACT WELLFIELD.

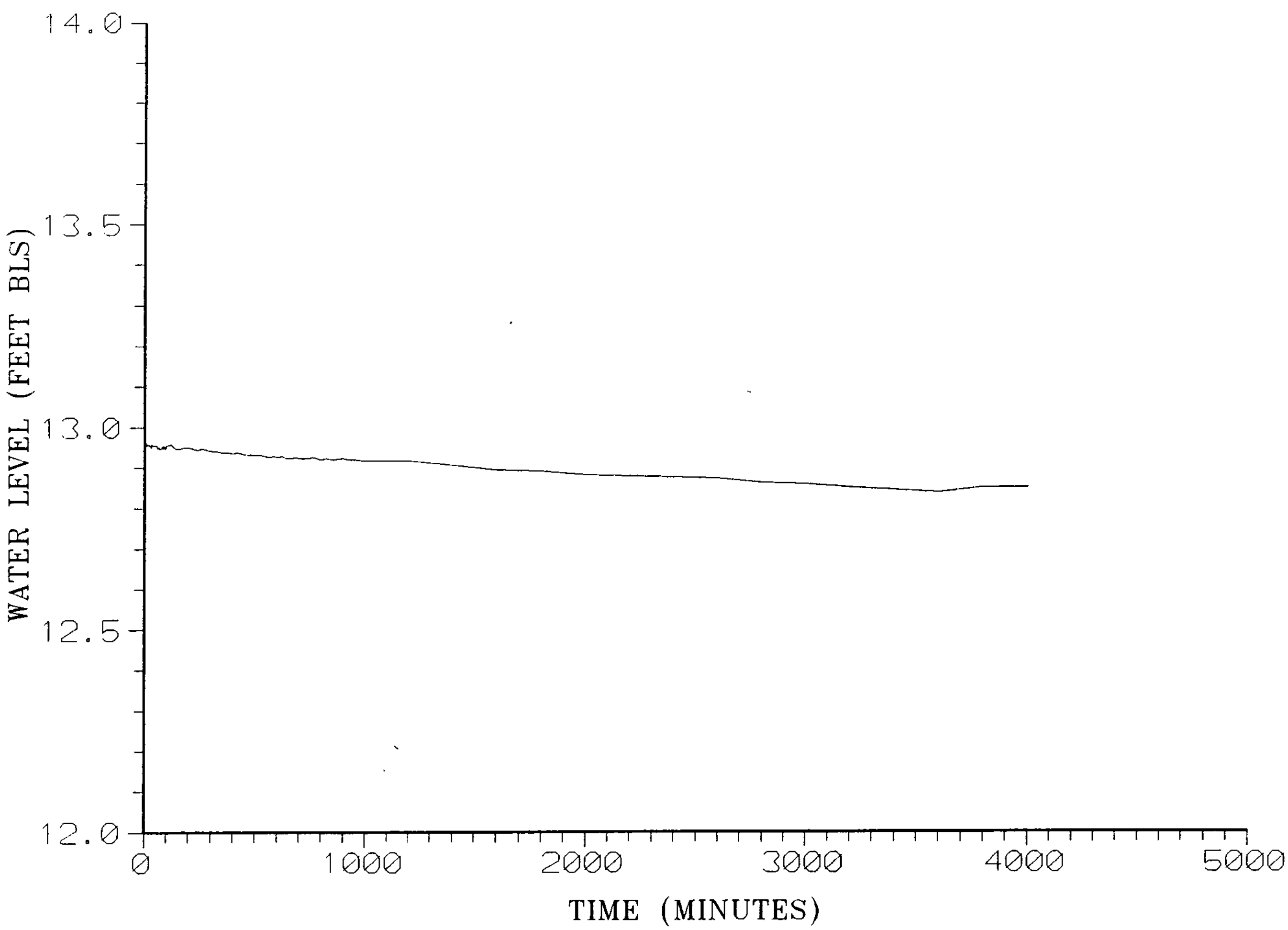

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FIGURE V-6. GRAPH SHOWING WATER LEVEL FLUCUATIONS IN THE WATER TABLE AQUIFER DURING THE AQUIFER PERFORMANCE TEST AT R.O. SITE #9.

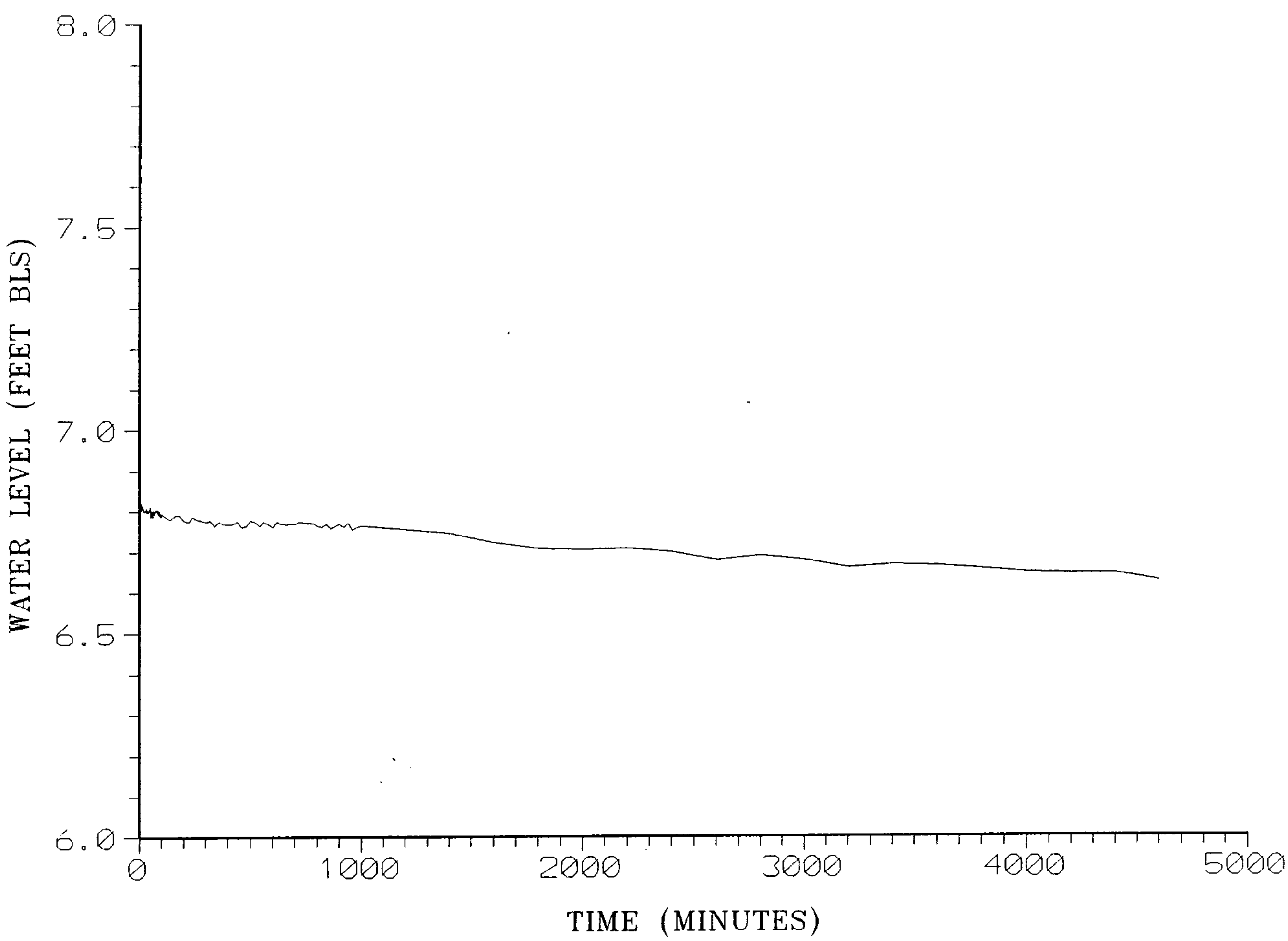

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FIGURE V-7. GRAPH SHOWING WATER LEVEL FLUCUATIONS IN THE WATER TABLE AQUIFER DURING THE AQUIFER PERFORMANCE TEST AT R.O. SITE #10.

VI. REFERENCES

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., 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.

APPENDIX A

GEOLOGIST'S LOGS

GEOLOGIST'S LOG OF WELL SITE #9 TEST WELL

Depth (feet)	Lithology
0 - 39	No samples.
39 - 51	Sand, light olive gray (5 Y 5/2) dark yellowish brown (10 YR 4/2) to black (N1), very fine to fine grained, moderate to well sorted, subangular to rounded, abundant organics, minor shell fragments, medium to high permeability.
51 - 68	Sand, as above, except increase in shell fragements, common reworked lithic fragments, decrease in organic material.
68 - 76	Sand, light olive gray (5Y 5/2) light gray (N7), fine to coarse grains, subrounded to rounded, poorly sorted, minor shell fragments, traces of heavy minerals and phosphate grains, medium to high permeability.
76 - 99	Sand, as above, multicolored, increase in coarse grains, high permeability.
99 - 101	Clay, moderate brown (5 YR 4/4), soft, fibered texture, minor sand, as above.
101 - 110	Sandy clay, light olive gray (5Y 5/2), moderate yellowish born (10YR 5/4), traces of light gray clay (N7), silt size material, very fine to fine quartz grain material.
110 - 125	Sand, light gray (N7) to dark gray (N3), fine to coarse grained, subrounded to well rounded, poorly sorted, traces of shell fragments, medium permeability.
125 - 133	Clay, light olive gray (5 Y 6/1), medium gray (N5), stiff, common soft layers, minor phosphorite grains and shell fragments, low permeability.
151 - 160	Clay, as above and increase in fine to medium quartz sand with depth.

GEOLOGIST'S LOG OF WELL SITE #9 TEST WELL

Continued:

Depth (feet)	Lithology
160 - 168	Sand, multicolored, very fine grained to coarse sizes, subangular to rounded, poorly sorted, occasional shell, unconsolidated dark minerals 5 - 10%, medium to high permeability.
168 - 176	Sand, light olive gray (5 Y 6/1), very fine to fine grained, minor silt size sediment, rounded, well sorted, medium permeability.
176 - 195	Sand, as above, and medium to coarse sand size quartz.
195 - 201	Clay and sand, olive gray (5 Y 4/1), clay is unlithified, dense, silty, well sorted, minor dark minerals occasional shell fragments, low permeability.
201 - 226	Sand, light gray (N7) to light olive gray (5 Y 6/1), very fine grained to fine grained, rounded, well sorted, abundant shells and shell fragments, interbedded thin soft clay layers, low to medium permeability.
226 - 240	Sand, as above, and increase in clay layers.
240 - 251	Sandy clay, olive gray (5 Y 4/1), unlithified, loose, abundant silt and very fine sand, very fine shell fragments, dark minerals, mica, and other dark grains, low permeability.
251 - 278	Clay, olive gray (5 Y 4/1), soft, gummy texture, mostly lithified clay, occasional shell fragments, low permeability.
278 - 301	Sand, light gray (N7) to medium gray (N5), fine grained, minor coarse grains, moderately sorted, abundant shells and shell fragments.
301 - 305	Sand, as above, and thin layers of soft lithified clay.

GEOLOGIST'S LOG OF WELL SITE #9 TEST WELL

Continued:

Depth (feet)	Lithology
305 - 315	Clayey sand, light olive gray (5 Y 6/1), very fine to fine grained, dark minerals, minor lithified clay layers, low to medium permeability.
315 - 335	Sand, as above, increasing to fine to medium quartz grains, and dark minerals, phosphorite, mica, minor fine shell fragments, medium permeability.
335 - 350	Sand, medium gray (N5), yellowish gray (5 Y 8/1), light olive gray (5 Y 6/1), fine grained, minor medium grains, subangular to subrounded, moderately sorted, dark minerals, phosphorite, shell fragments, medium to high permeability.
350 - 362	Sand, multicolored, fine to medium grained, very phosphatic, dark minerals, traces of coarse to gravel quartz sand, high permeability.
362 - 376	Sand, as above, and increase in medium to coarse grains, subangular to rounded, poor to moderately sorted, high permeability.
376 - 401	Sand, light olive gray (5 Y 6/1), fine to medium, and minor coarse grains, subangular to subrounded, abundant shell fragments, minor dark minerals, phosphorite, medium to high permeability.
401 - 426	Sand, as above and increase in coarse size sediment.
426 - 476	Sand, light olive gray (5 Y 6/1), yellowish gray (5 Y 8/1), very fine to coarse quartz grains, abundant shell fragments, phosphorite, dark minerals, traces of soft, thin, lithified clay between 468 to 470.

GEOLOGIST'S LOG OF WELL SITE #10 TEST WELL

Depth (feet)	Lithology
0 - 40	No Samples.
40 - 50	Clayey sand, light olive gray (5 Y 6/1) to medium gray N6), very fine grained, well rounded, well sorted, minor shell and shell fragments; clay is soft, light olive, gummy texture, traces of phosphorite grains.
50 - 58	Clayey sand, as above and increase in sand and phosphorite grains.
58 - 60	Clay, light gray (N7) to medium gray (N6), soft, gummy texture minor phosphorite grains, traces of shell fragements and very fine sand.
60 - 70	Sandy clay, light olive gray (5 Y 6/1), as above and sand content is approximately 40%.
70 - 80	Sand, light olive gray (5 Y 6/1), very fine to fine grained, subrounded to rounded, well sorted, abundant fine phosphorite grains, interbedded clay and shell layers at depths of 68 to 70 feet and 78 to 79 feet, medium permeability.
80 - 85	Sand, light olive gray (5 Y 6/1), fine to coarse grains, angular to sub-rounded, poorly sorted, minor phosphorite grains, traces of tiny shell fragments and black minerals, medium to high permeability.
85 - 90	Sand, as above and increase in very fine to fine sand content.
90 - 95	Sand, medium gray (N6), light olive gray (5 Y 6/1), very fine to fine grained, subangular to subrounded, well sorted, common shells and shell fragments, traces of dark minerals.

GEOLOGIST'S LOG OF WELL SITE #10 TEST WELL

Continued:

Depth (feet)	Lithology
95 - 97	Clay, grayish brown (5 Y 3/2), very soft, fibered texture, common fine phosphorite grains, monitor shell fragments, traces of dark minerals.
97 - 98	Clay, as above and increasing to medium gray (N6), gummy texture, minor fine grained quartz sand.
98 - 113	Sand, light olive gray, (5 Y 6/1), fine to coarse grained, traces of pebble sizes, subangular to rounded, poorly sorted, minor shell fragements, traces of phosphorite and dark minerals, medium to high permeability.
113 - 118	Clay, light gray (N7) to medium gray (N6), soft, gummy texture, minor sand content, as above.
118 - 123	Sand, light olive gray (5 Y 6/1), fine to medium grained, common shell fragements, phosphorite, and dark minerals.
123 - 126	Clay, light gray (N7) to medium gray (N6), soft, gummy texture, minor unlithified layers, traces of silt size material and very fine quartz sand.
126 - 136	Sand, light gray (N7), very fine to fine grained, rounded, well sorted, minor interbedded clay layers, as above, poor to medium permeability.
136 - 148	Sand, as above and increase in medium grains of quartz sand, medium permeability.
148 - 153	Sand, light olive gray (5 Y 6/1), very fine to coarse grained, increase in coarse grains with depth, subangular to well rounded, poorly sorted, traces of shells and shell fragments, traces of dark minerals, high permeability.
153 - 154	Clay, medium gray (N6) soft, gummy texture, abundant phosphorite and dark minerals.

GEOLOGIST'S LOG OF WELL SITE #10 TEST WELL

Continued:

Depth (feet)	Lithology
154 - 163	Sand, light olive gray (5 Y 6/1), light gray (N7) to medium gray (N6), fine to medium grained, subangular to subrounded, occasional shells, monitor dark minerals, moderately sorted, medium permeability.
165 - 170	Clay, light olive gray (5 Y 6/1), soft, mostly unlithified, interbedded sand layers increasing with depth, as above.
170 - 176	Sand, as above and decreasing clay content with depth.
176 - 201	Sand, light gray (N7), light olive gray (5 Y 6/1), very fine grained, common silt size particles, rounded to well rounded, well sorted, minor dark minerals, occasional shell fragements, low permeability.
201 - 226	Silty clay, soft, unlithified, minor soft layers, very fast drilling, low permeability.
226 - 251	Clay, light gray (N7) to medium gray (N6), unlithified, minor soft layers, common fine phosphorite and dark mineral content.
251 - 270	Clay, as above and increase in stiff layers with depth.
270 - 295	Sand, light olive gray (5 Y 6/1), very fine to fine grained, increasing medium grains with depth, subrounded to well rounded, moderately sorted, abundant shells and shell fragments, large phosphatic grains, minor dark minerals, medium to high permeability.
295 - 300	Clay, light gray (N7) to medium gray (N6), soft, cohesive, minor interbedded quartz sand, as above.
300 - 311	Clay, light gray (N7), soft, unlithified layers with depth, minor shells and shell fragments, increasing shells with depth.

Continued:

Depth (feet)	Lithology
311 - 320	Sand, light gray (N7) to medium gray (N6), fine to medium grained, mostly fine grained, common phosphorite, minor dark minerals, medium permeability.
320 - 326	Sand, as above and interbedded clayey sand layers between 324 to 326 feet.
326 - 331	Sand, light gray (N7), very fine to fine grained, minor medium grains, subrounded to rounded, moderately sorted, interbedded clay layers between 328 and 330 feet, minor phosphorite grains, traces of dark minerals, medium permeability.
331 - 336	Sand, as above and increase in medium grained quartz sand, common shells and shell fragments.
336 - 341	Sand, light gray (N7), light olive gray (5 Y 6/1), fine to medium grained, subrounded to rounded, moderately sorted.
341 - 346	Sand, light gray (N7) to medium gray (N6), fine grained quartz sand, minor medium grains, subrounded to rounded, well sorted, abundant shell fragments, minor phosphorite and dark minerals.
346 - 351	Sand, as above and increase in medium grained quartz sand, and shell fragments.
351 - 356	Sand, light olive gray (5 Y 6/1), medium to coarse grains, minor fine grains, subangular to subrounded, moderately sorted, minor phosphorite and shell fragments, traces of dark minerals.
356 - 376	Sand, as above and traces of yellowish gray gravel size quartz sand.
376 - 391	Sand, light gray (N7), light olive gray (5 Y 6/1), fine to medium grained, mostly medium grains, traces of coarse

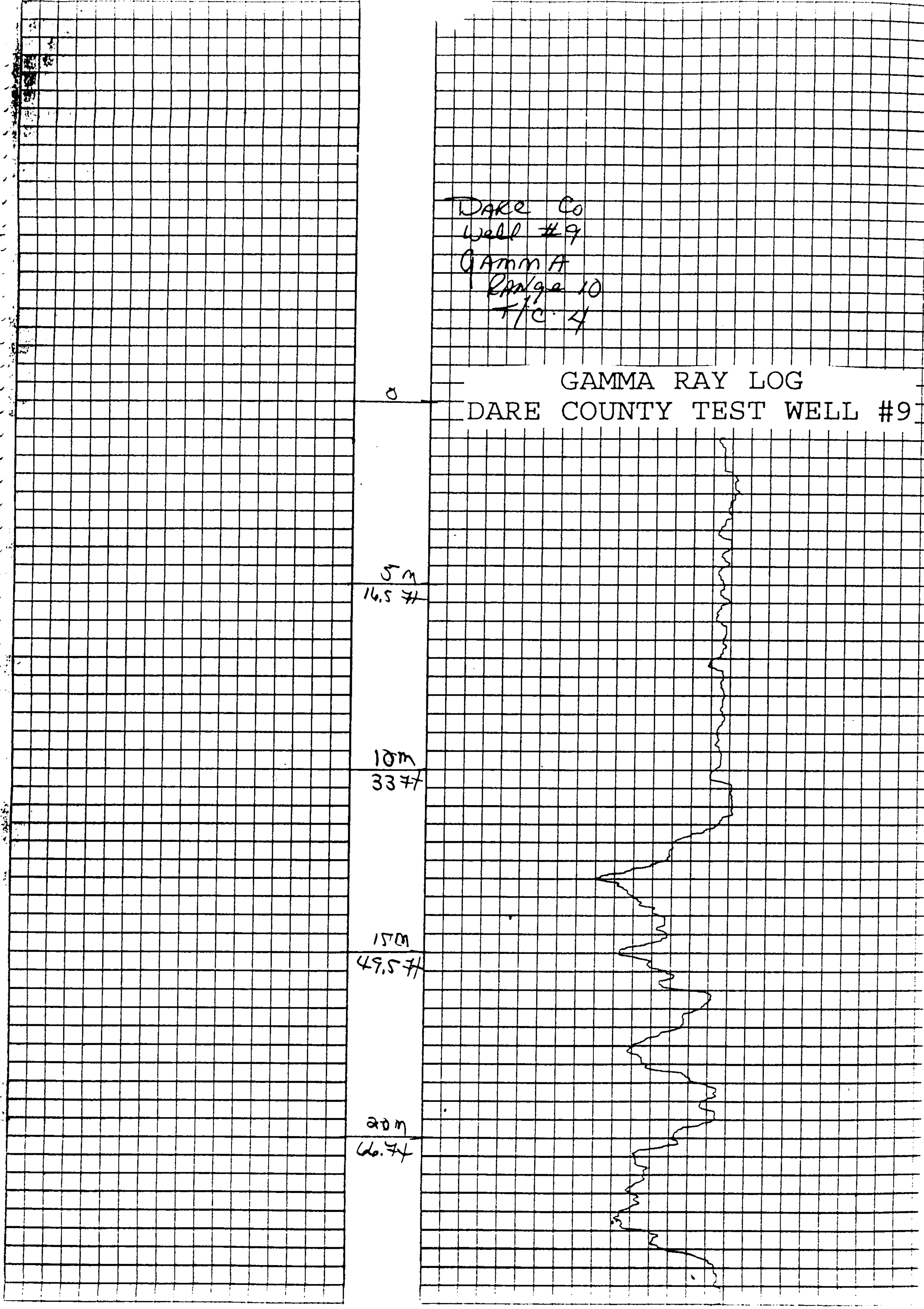
Continued:

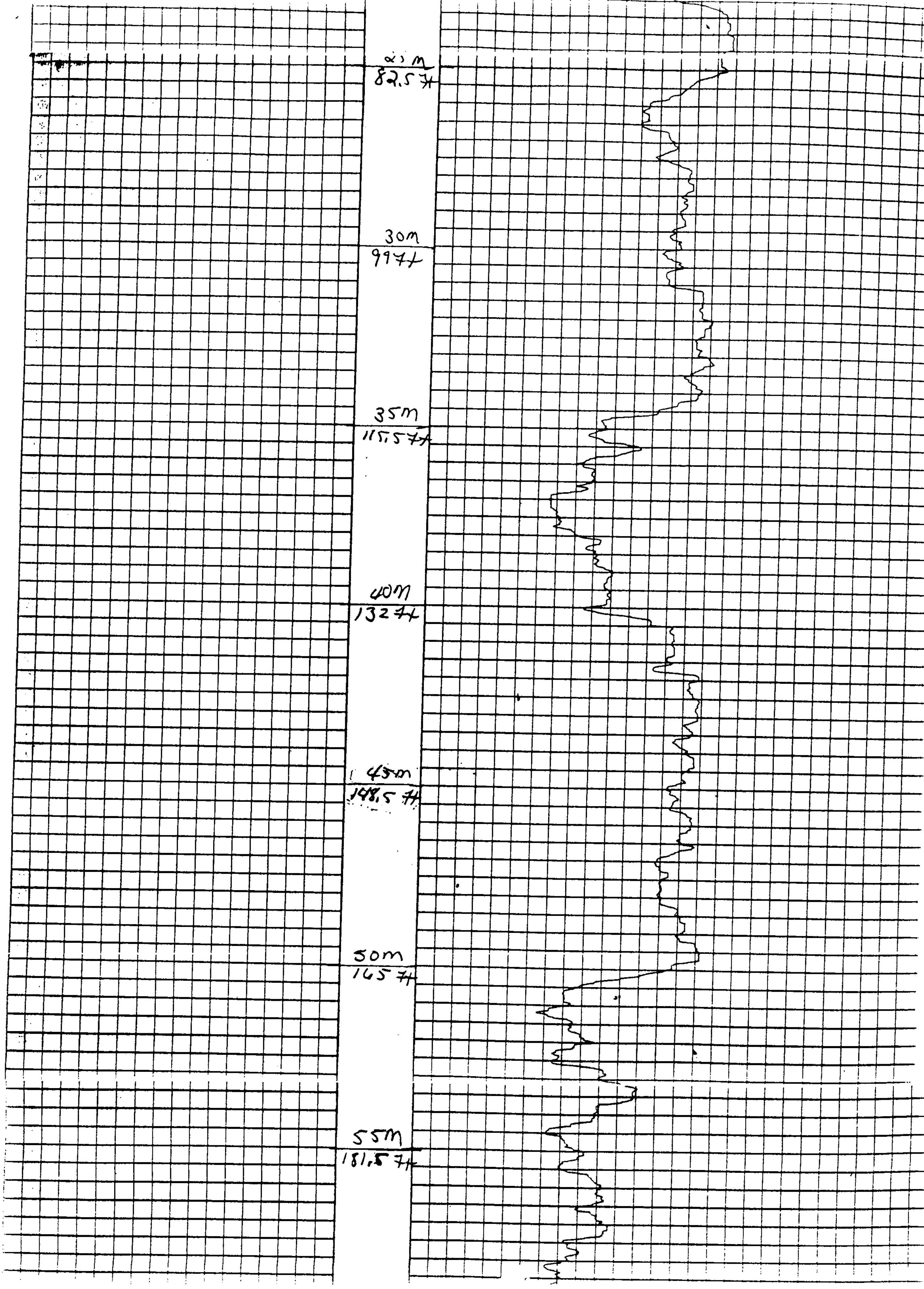
Depth (feet)	Lithology
	material, abundant shell fragments, common phosphorite grains, traces of dark minerals, medium to high permeability.
391 - 406	Sand, as above and increase in greenish gray color.
406 - 416	Sand, greenish gray (5 GY 6/1), light olive gray, fine to medium grained, minor very fine grains, subangular to subrounded, moderately sorted, abundant shell fragments, minor dark minerals and phosphorite, medium permeability.
416 - 421	Sand, as above, becoming finer grained with depth, minor shell fragments, medium to low permeability.
421 - 436	Clayey sand, as above, and minor interbedded layers of soft and unlithified clay layers, medium to low permeability.
436 - 441	Sand and interbedded clay, light olive gray (5 Y 6/1), very fine grained, traces of medium grains, minor phosphorite and dark minerals, abundant shell fragments, clay (30%) unlithified traces of soft, gummy clay which contain silt and fine sand.
441 - 461	Sandy clay, as above, clay constitutes approximately 70 to 80%.
461 - 475	Clay, light gray (N7) to medium gray (N6), soft, loose, and silty, common shell fragments, minor phosphorite and dark minerals, low permeability.

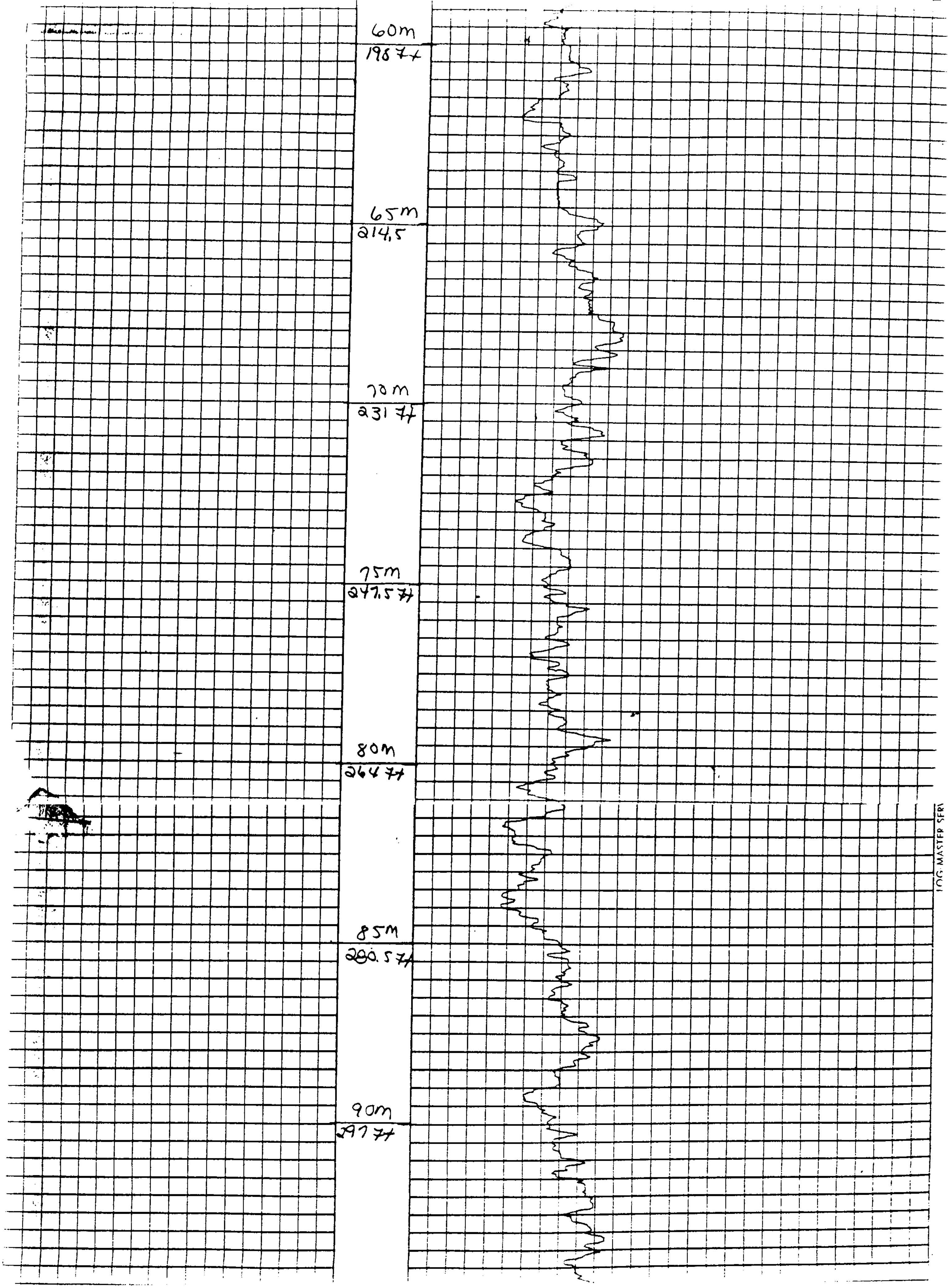
APPENDIX B

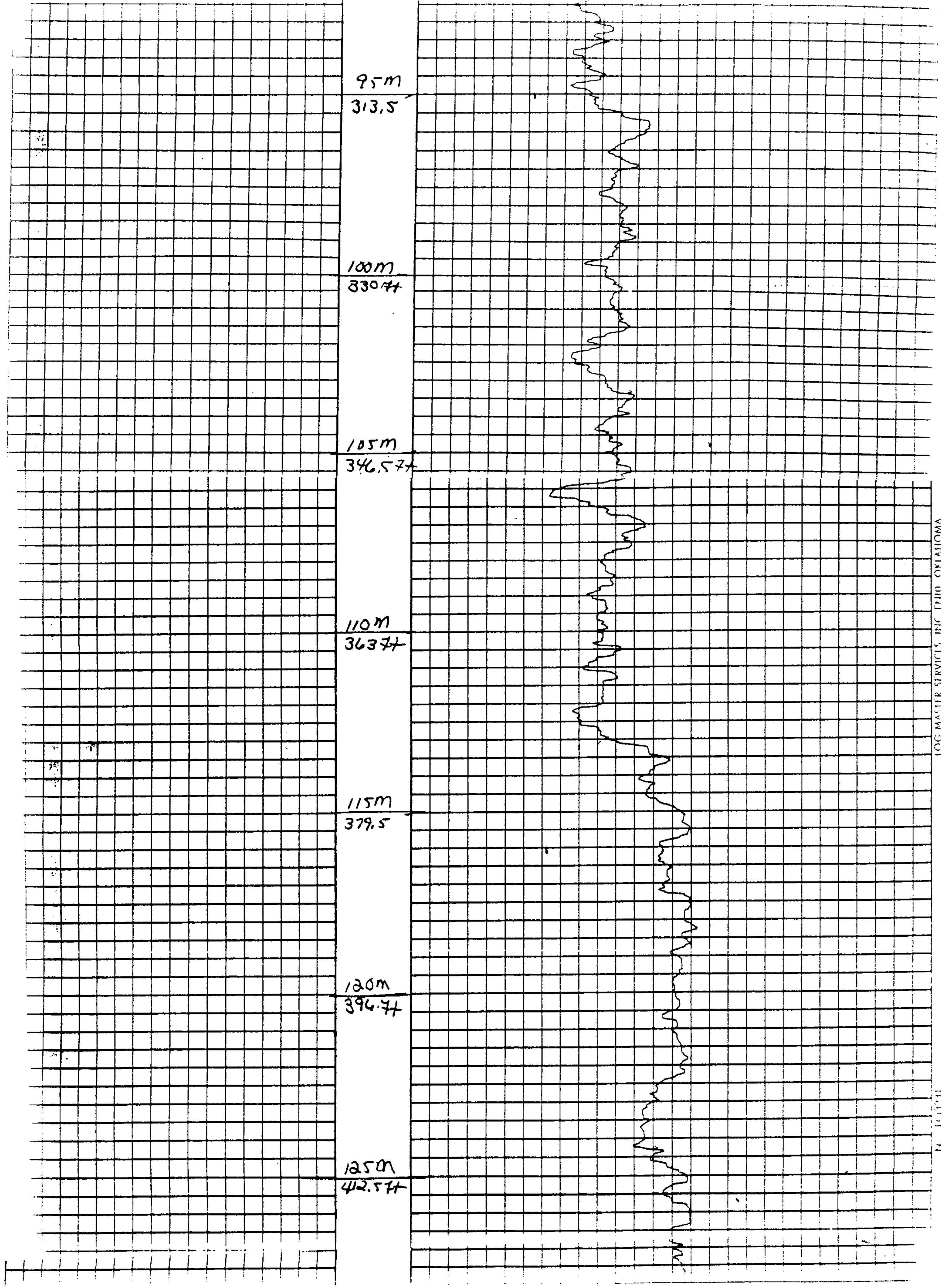
GEOPHYSICAL LOGS

GAMMA RAY LOG
DARE COUNTY TEST WELL #9

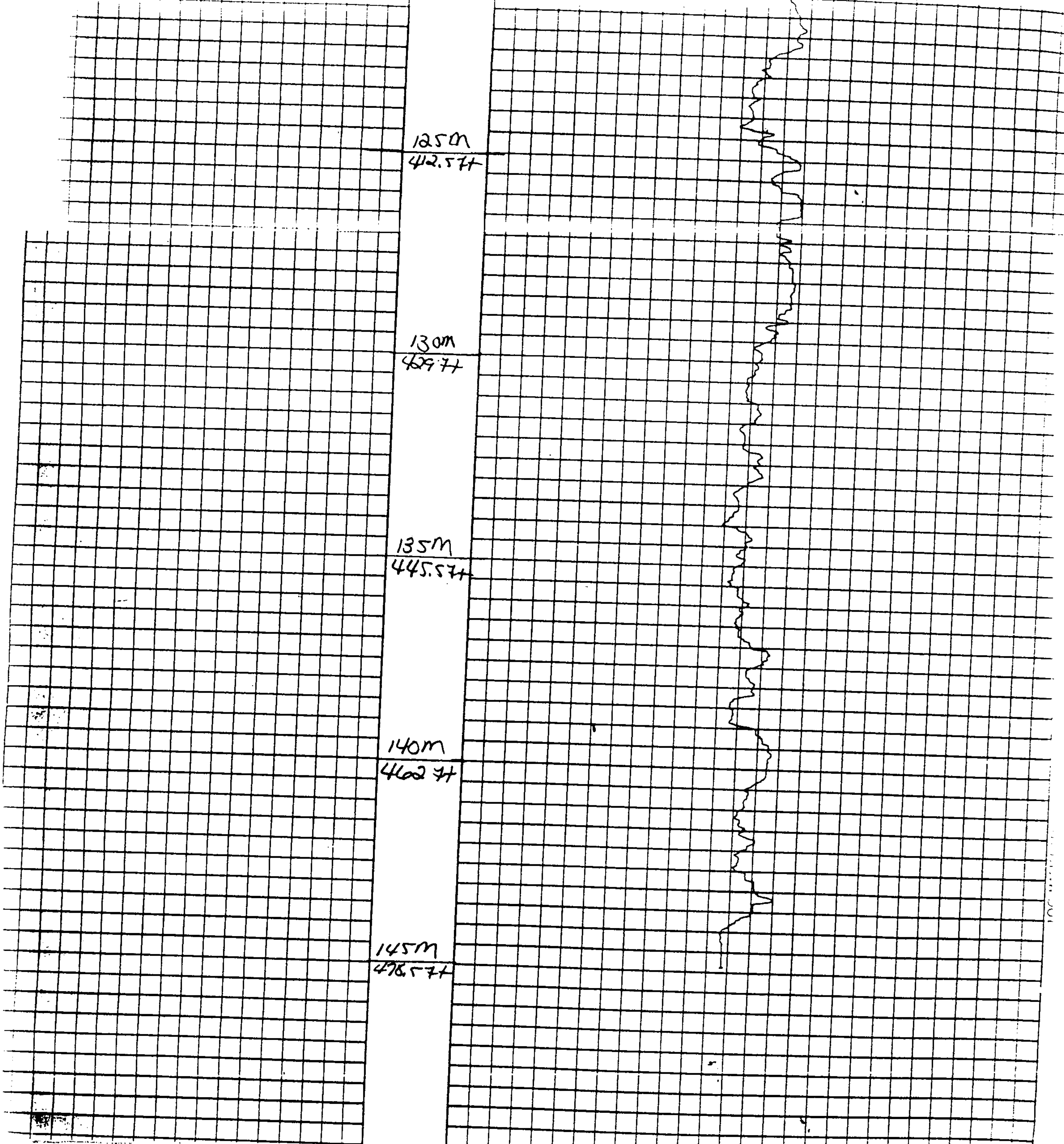



25m
82.5 ft
30m
99ft
35m
115.5ft
40m
132ft
45m
148.5 ft
50m
165 ft
55m
181.5 ft

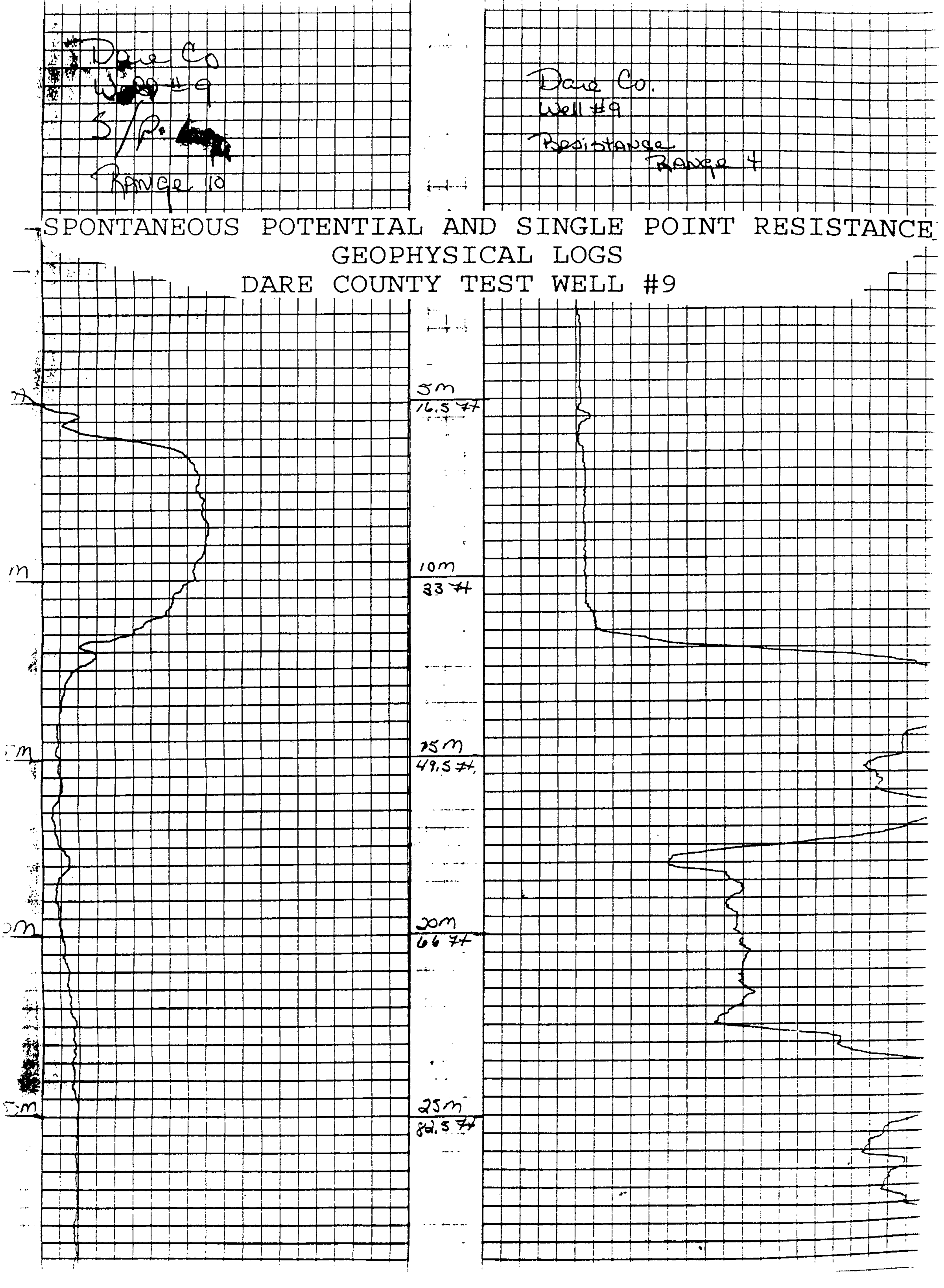

60m
198 ft
65m
214.5
70m
231 ft
75m
247.5 ft
80m
264 ft
85m
280.5 ft
90m
297 ft
LOG MASTER SERV

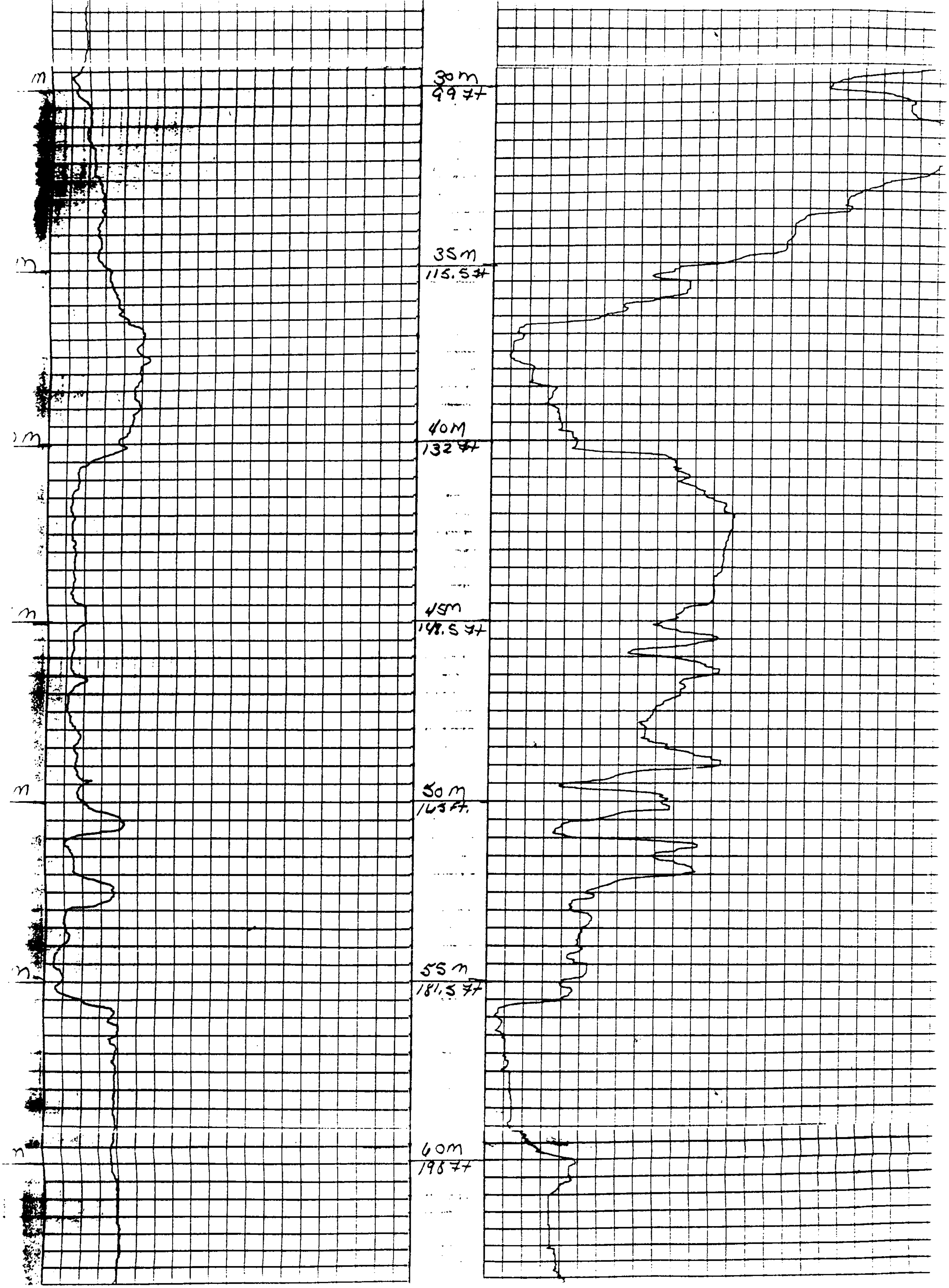


95m
313,5
100m
330ft
105m
346.5ft
110m
363ft
115m
379.5
120m
396.ft
125m
412.5ft

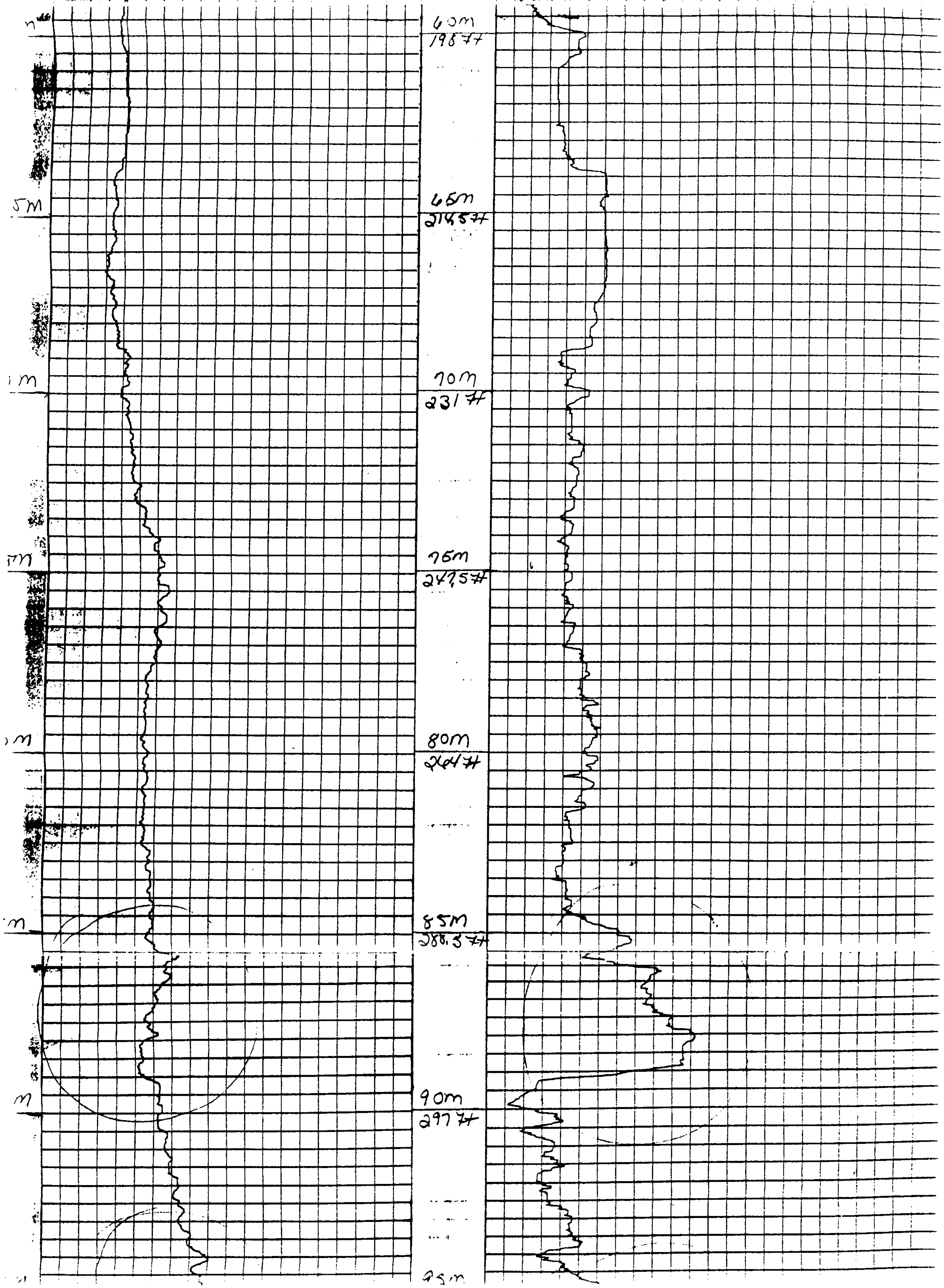

125m
412.5ft
130m
429ft
135m
445.5ft
140m
462ft
145m
478.5ft

SPONTANEOUS POTENTIAL AND SINGLE POINT RESISTANCE
GEOPHYSICAL LOGS
DARE COUNTY TEST WELL #9

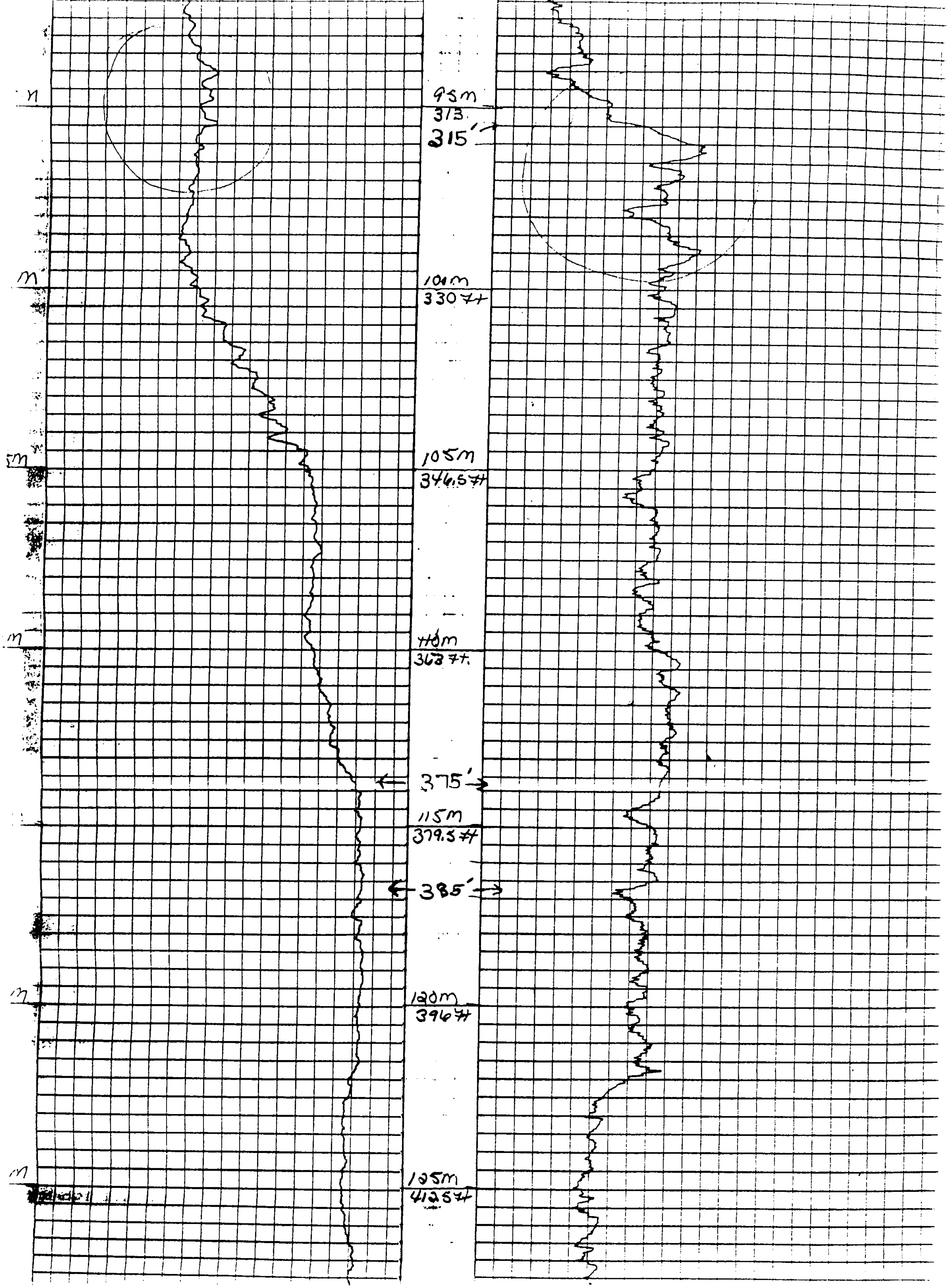


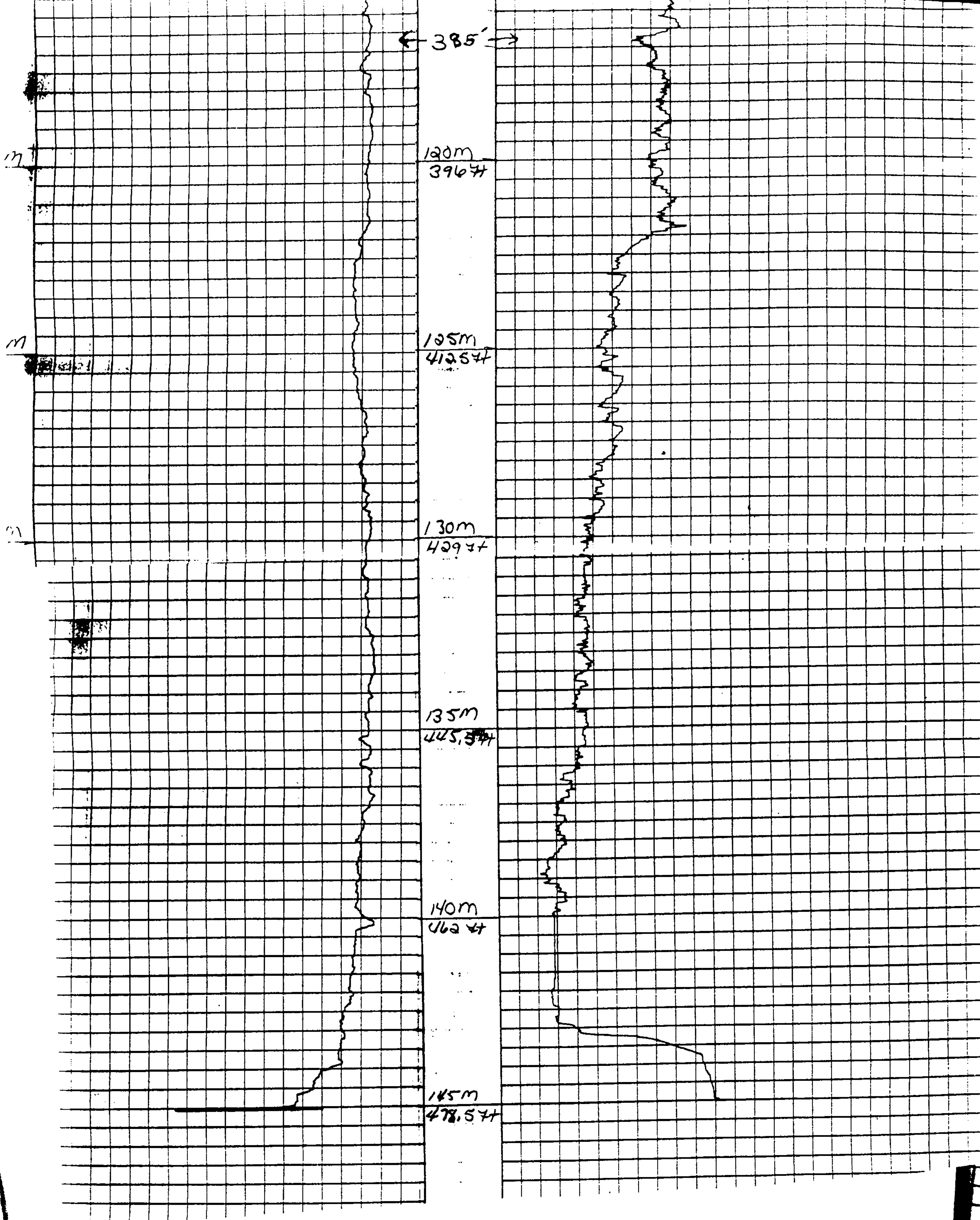


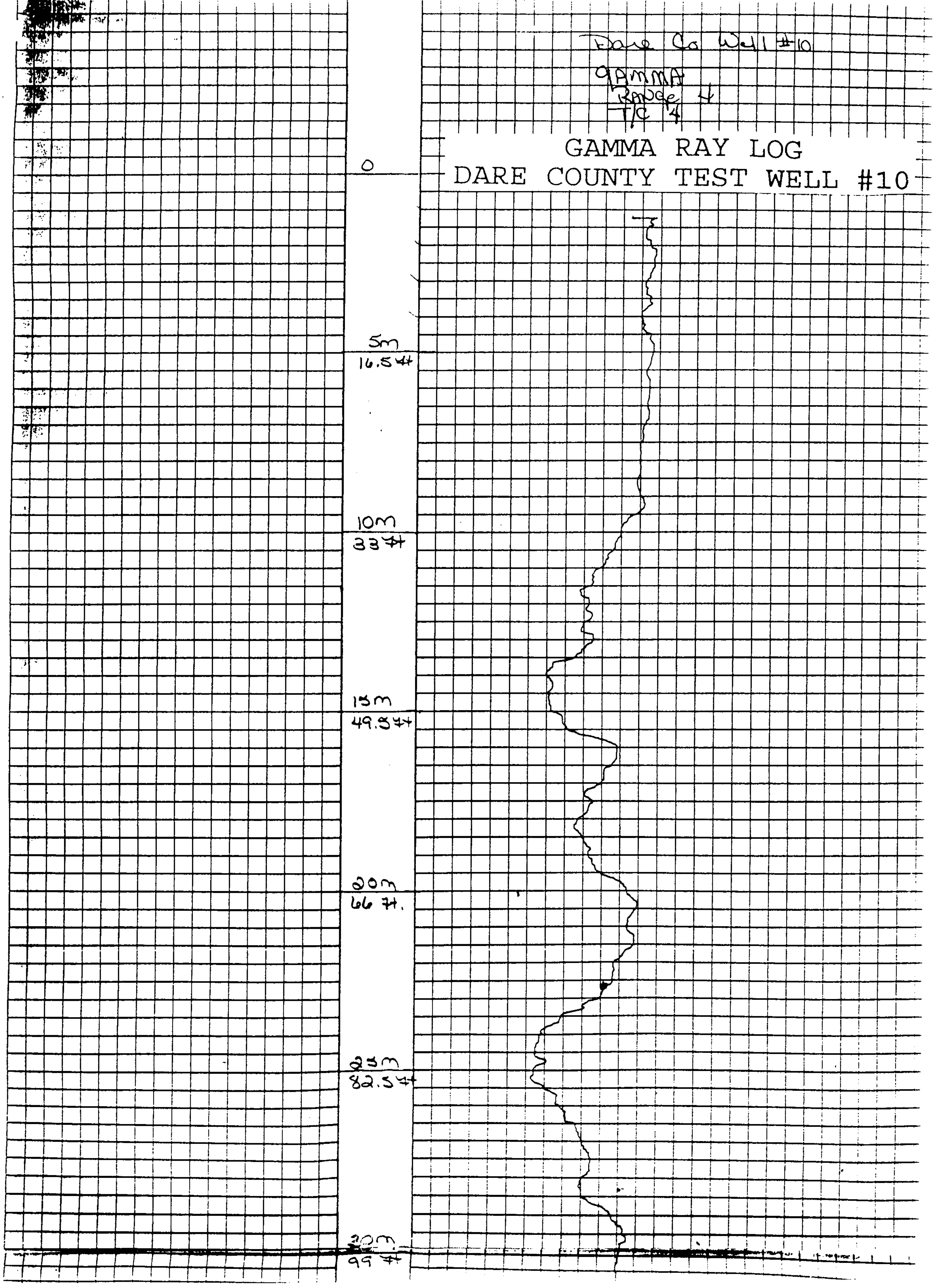
30 m
99 ft
35 m
115.5 ft
40 M
132 ft
45 m
148.5 ft
50 m
165 ft.
55 m
181.5 ft
60 m
198 ft

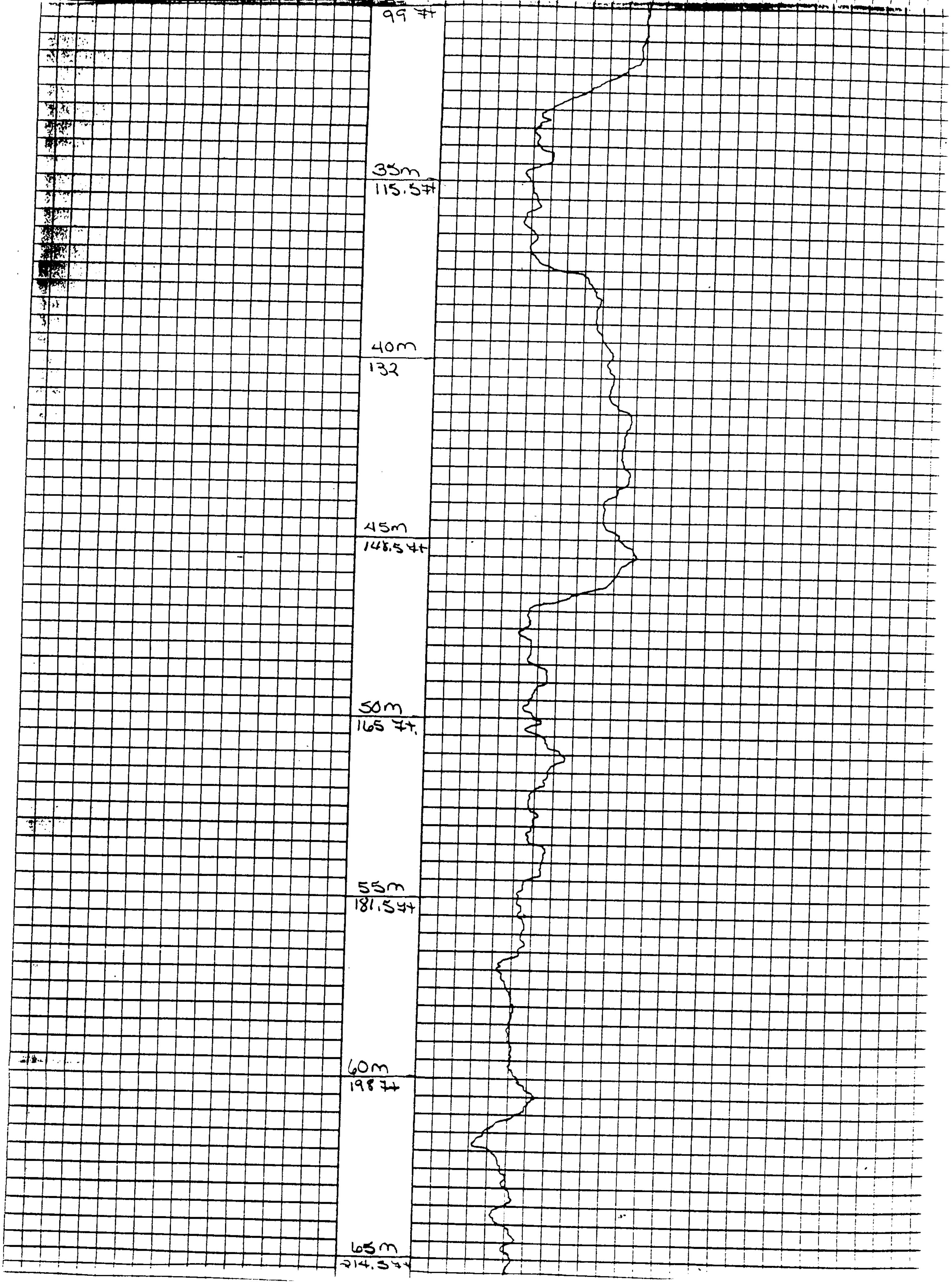


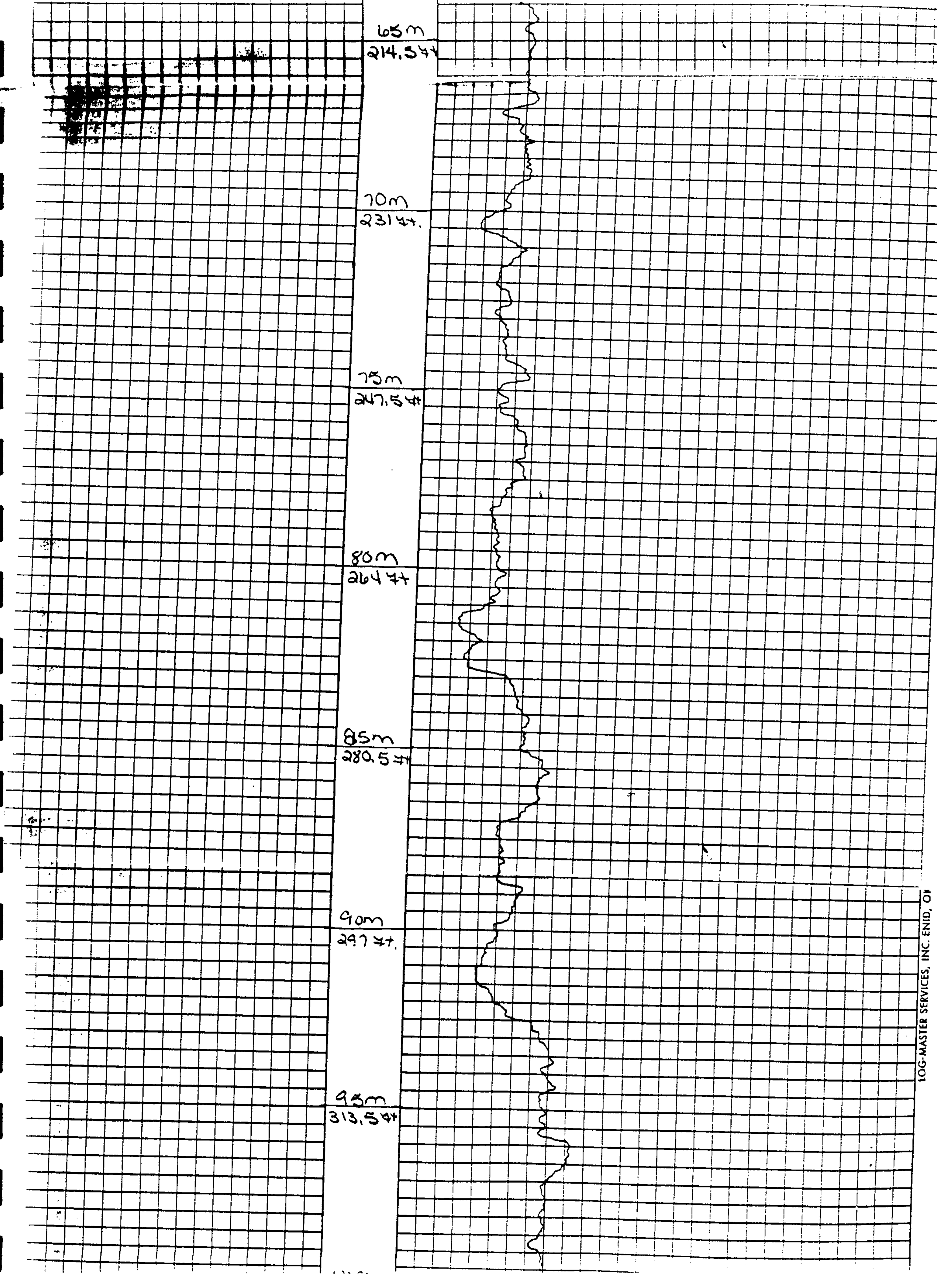
5M
60m
198 ft
65m
214.5 ft
70m
231 ft
75m
247.5 ft
80m
264 ft
85m
280.5 ft
90m
297 ft
95m


95m
313
315'
100m
330 ft
105m
346.5 ft
110m
363 ft.
375'
115m
379.5 ft
385'
120m
396 ft
125m
412.5 ft

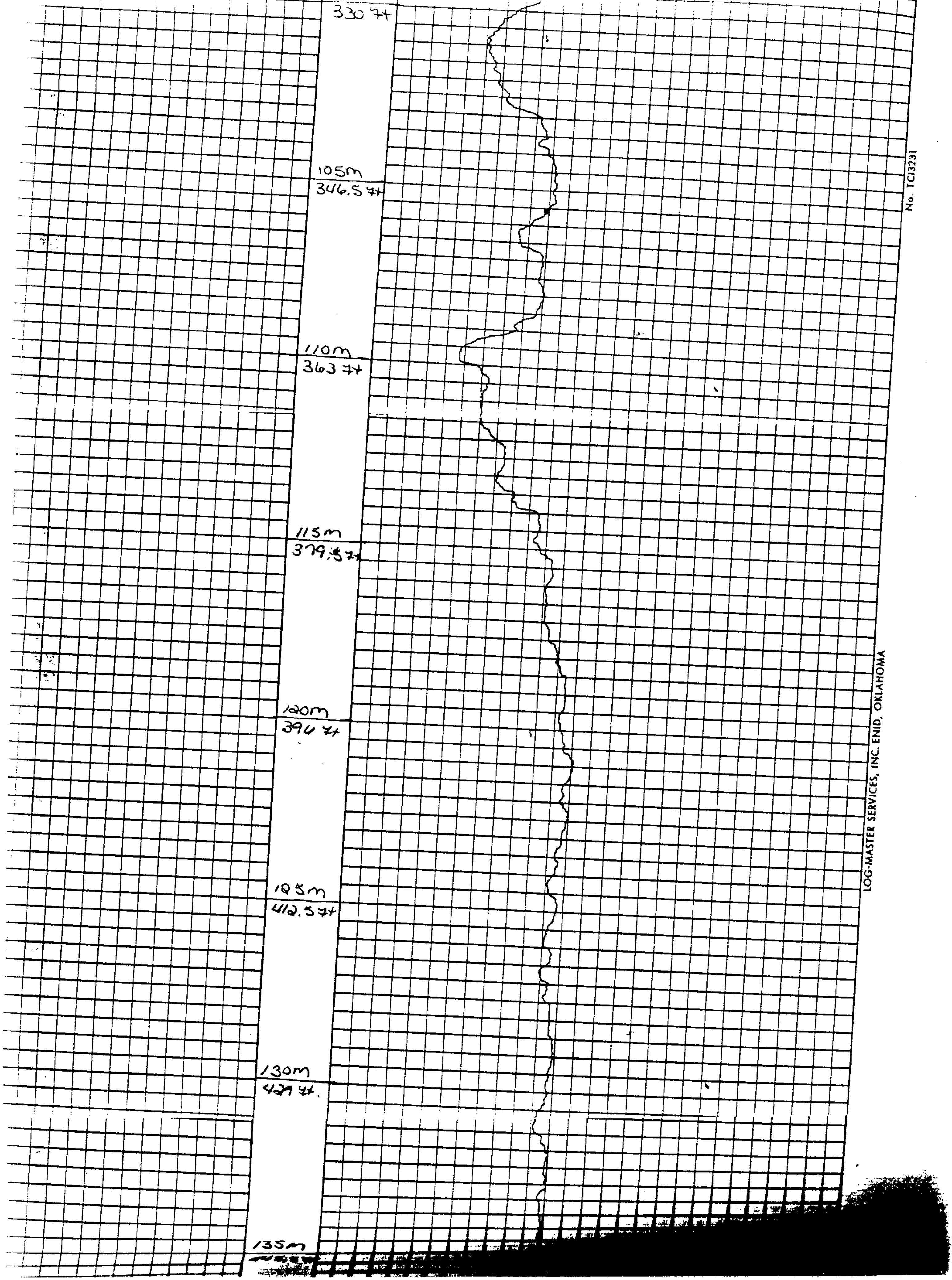

← 385' →
120m
396ft
125m
412.5ft
130m
429ft
135m
445.5ft
140m
462ft
145m
478.5ft

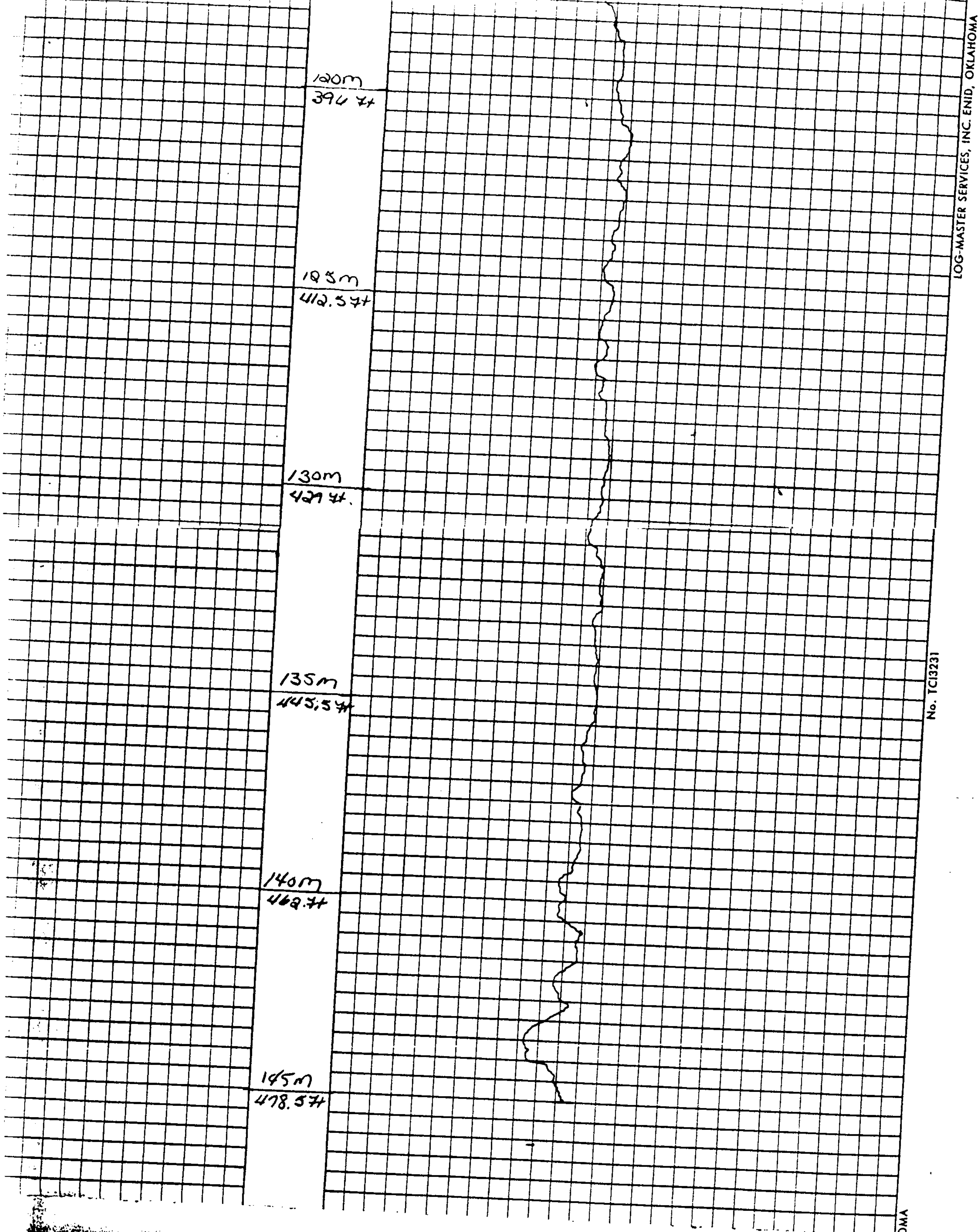

Dare Co Well #10
GAMMA
Range 4
T/C 4
GAMMA RAY LOG
DARE COUNTY TEST WELL #10
0
5m
16.5 ft
10m
33 ft
15m
49.5 ft
20m
66 ft.
25m
82.5 ft
30m
99 ft


99 ft
35m
115.5ft
40m
132
45m
148.5ft
50m
165 ft.
55m
181.5ft
60m
198 ft
65m
214.5ft

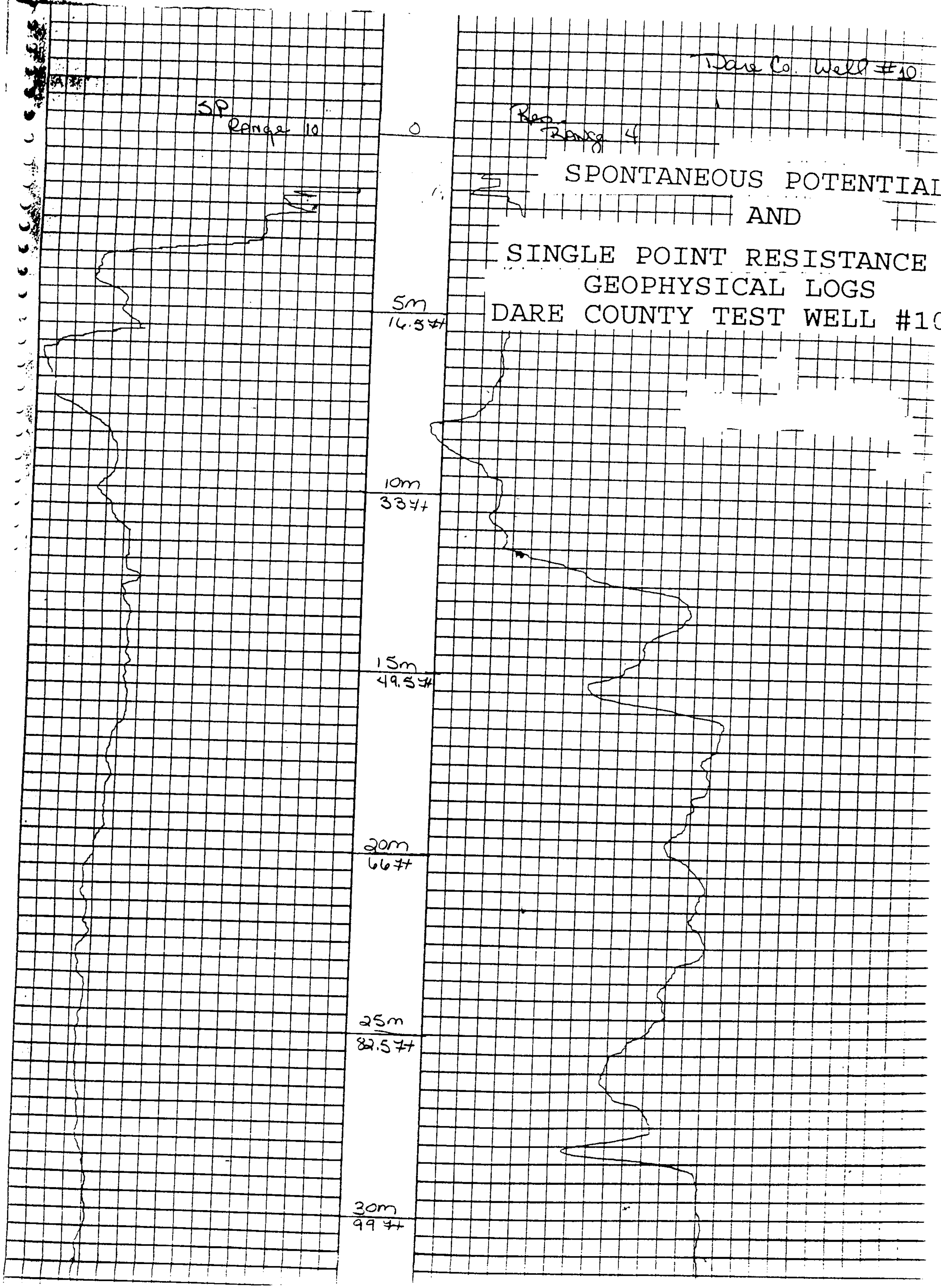


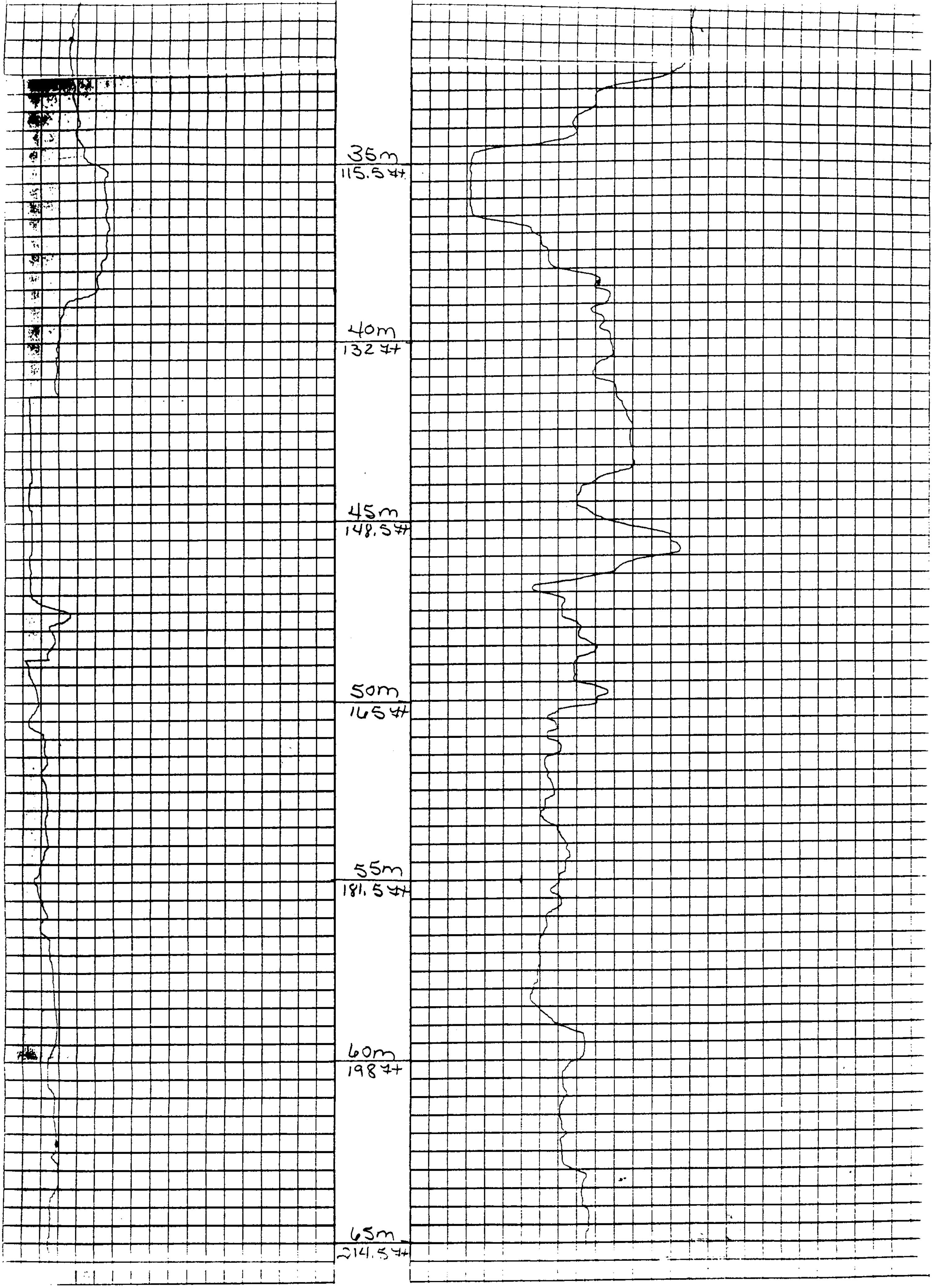
65m
214.5ft
70m
231ft.
75m
247.5ft
80m
264ft
85m
280.5ft
90m
297ft.
95m
313.5ft
LOG-MASTER SERVICES, INC. ENID, OK

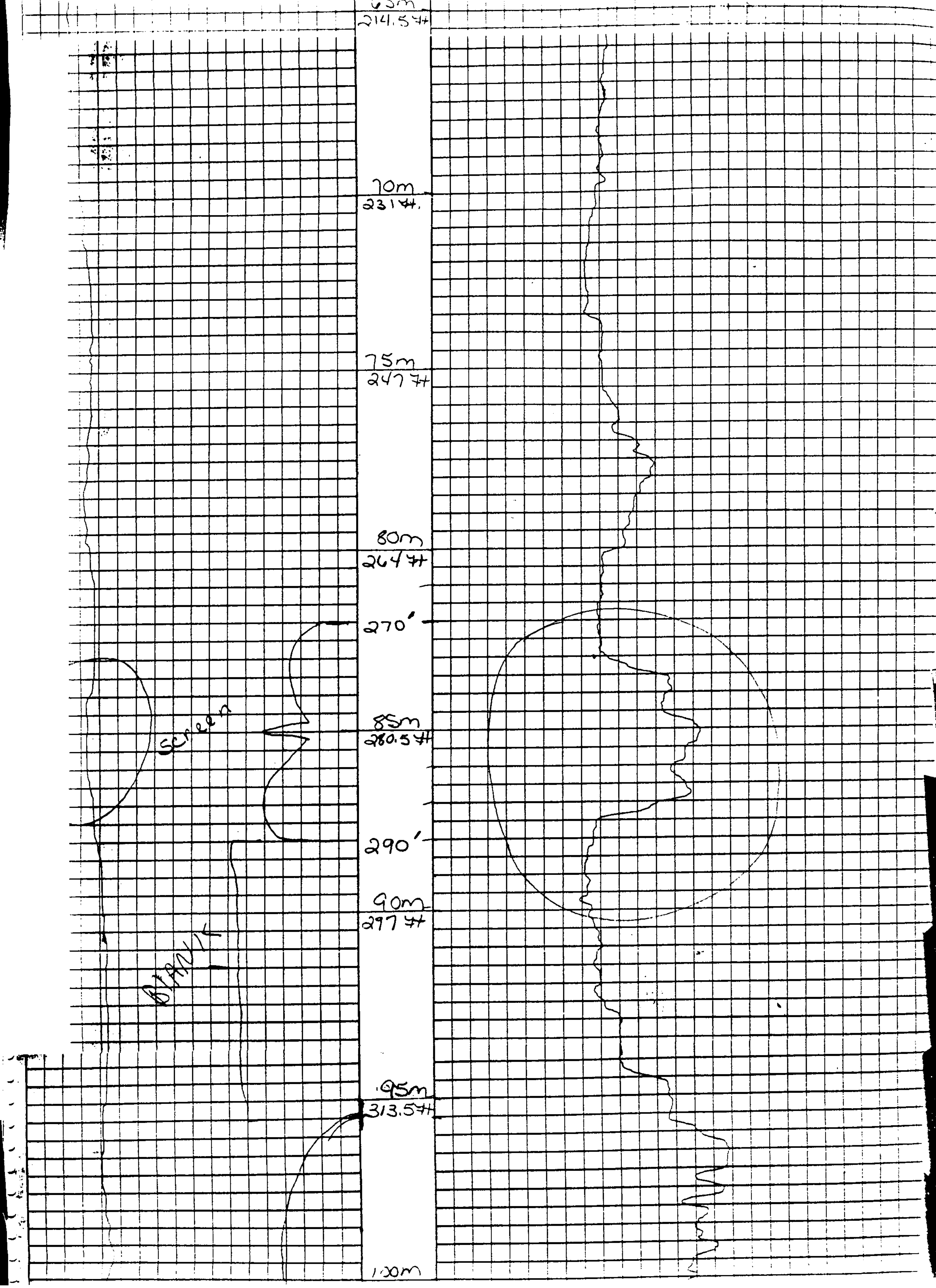

330 ft
105m
346.5 ft
110m
363 ft
115m
379.5 ft
120m
396 ft
125m
412.5 ft
130m
429 ft.
135m
No. TC13231
LOG-MASTER SERVICES, INC. ENID, OKLAHOMA



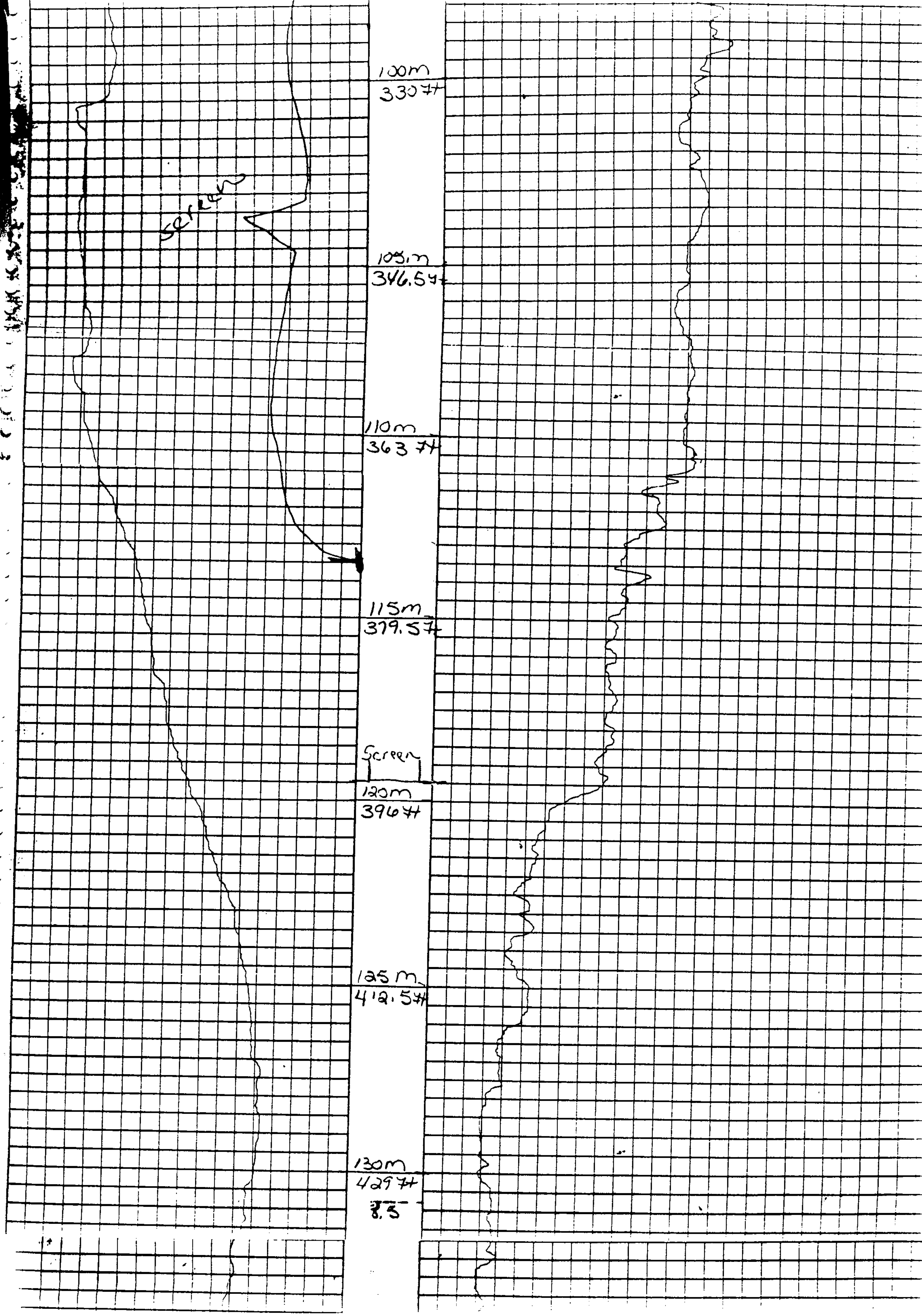
120m
394 ft
125m
412.5 ft
130m
427 ft.
135m
445.5 ft
140m
462 ft
145m
478.5 ft
LOG-MASTER SERVICES, INC. ENID, OKLAHOMA
No. TC13231

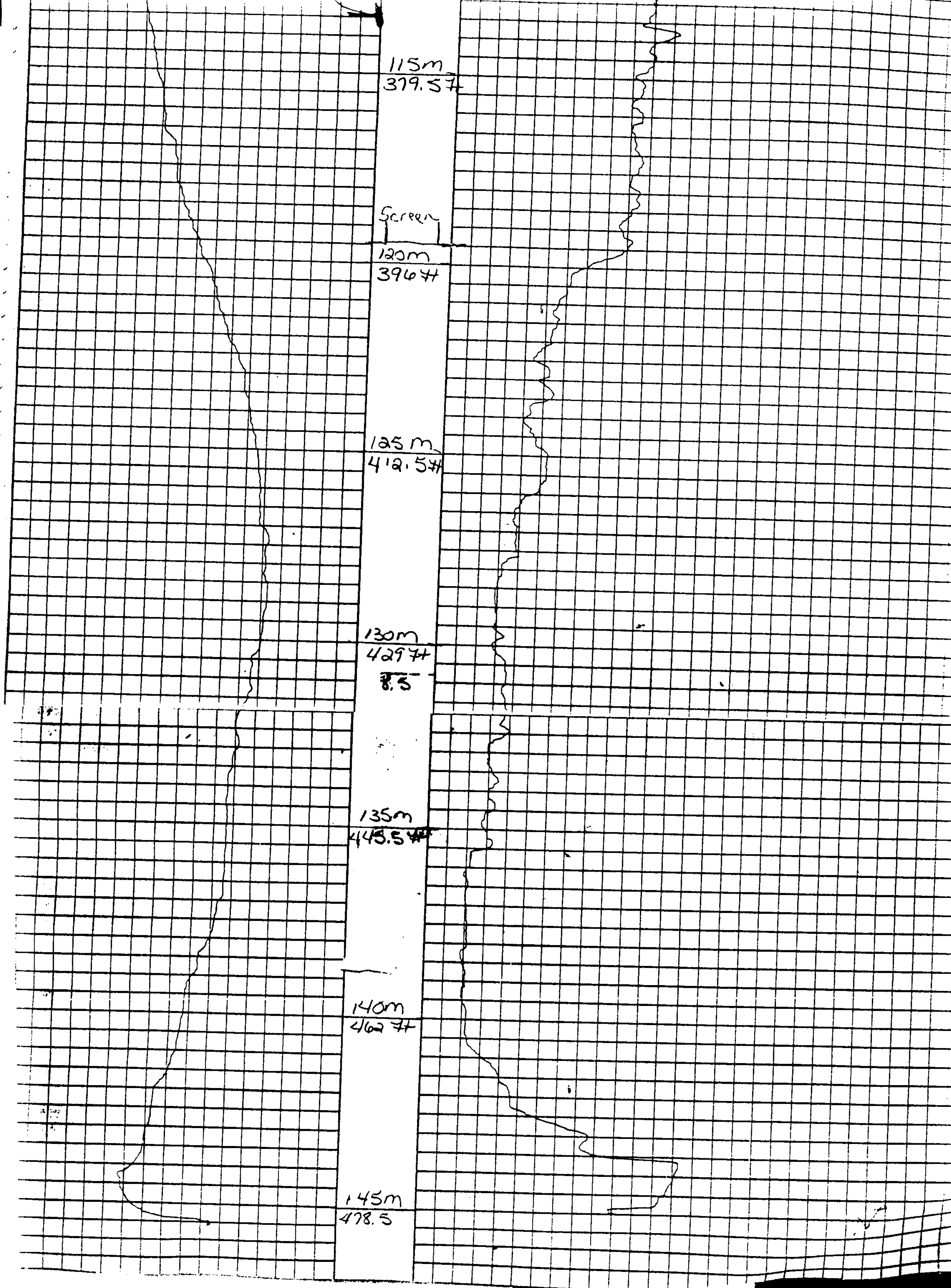

Dare Co. Well #10
SP Range 10
0
Res. Range 4
SPONTANEOUS POTENTIAL
AND
SINGLE POINT RESISTANCE
GEOPHYSICAL LOGS
DARE COUNTY TEST WELL #10
5m
16.5 ft
10m
33 ft
15m
49.5 ft
20m
66 ft
25m
82.5 ft
30m
99 ft


35m
115.5 ft
40m
132 ft
45m
148.5 ft
50m
165 ft
55m
181.5 ft
60m
198 ft
65m
214.5 ft



214.5 ft
70m
231 ft.
75m
247 ft
80m
264 ft
270'
85m
280.5 ft
screen
290'
90m
297 ft
95m
313.5 ft
100m


Screen
100m
330ft
105m
346.5ft
110m
363 ft
115m
379.5ft
Screen
120m
396ft
125m
412.5ft
130m
429ft
8.5



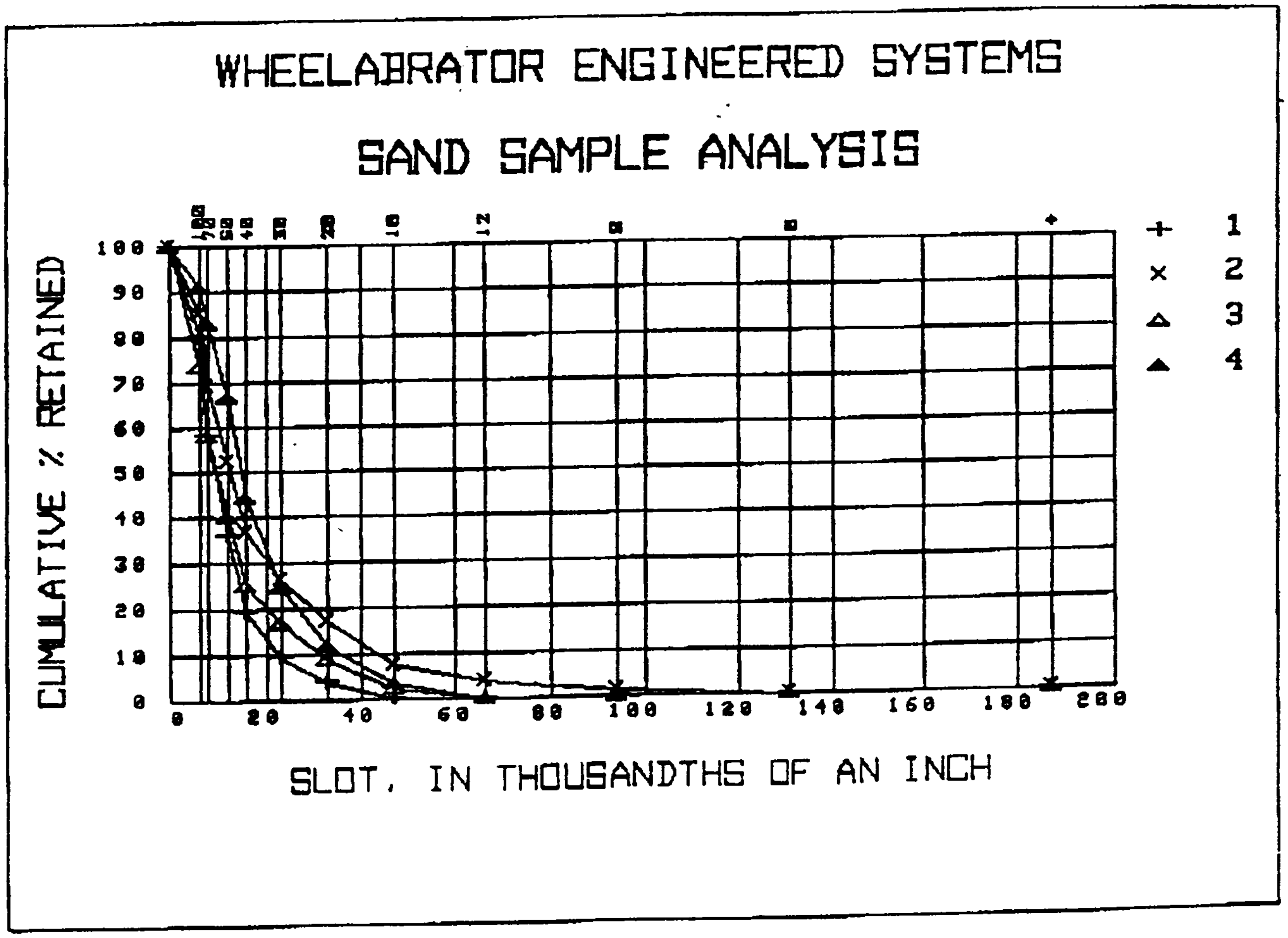
115m
379.5ft
Screen
120m
396ft
125 m
412.5ft
130m
429ft
8.5
135m
445.5ft
140m
462ft
145m
478.5

APPENDIX C

SIEVE ANALYSES RESULTS

WHEELABRATOR ENGINEERED SYSTEMS, JOHNSON SCREENS
SAND ANALYSIS REPORT

Johnson ID No.: 94123-1B
Job Name......: DARE COUNTY - WELL #10
Driller.......:
:
Engineer......:
:
Sample Sent by: SKIPPERS WELL DRILLING
Analysis by...: STEVE TUPY
Date..........: May 3, 1994



WHEELABRATOR ENGINEERED SYSTEMS, JOHNSON SCREENS
SAND ANALYSIS REPORT

Johnson ID No.: 94123-1B
Job Name......: DARE COUNTY - WELL #10

TEST HOLE DATA
****
Diameter: 0.000
Depth: 0
Drilling Method...:
Static Water Level: 0

WELL DATA
****
Casing Diameter: 8.000
Desired Yield: 500
Well App'n: PRODUCTION

PHYSICAL SAMPLE DESCRIPTION

No.	Depth	Description
**	***************	***
01	280-290	SILT TO COARSE SAND REPRESENTS 270-295
02	330-340	SILT TO COARSE SAND REPRESENTS 310-350
03	360-370	SILT TO COARSE SAND REPRESENTS 350-380
04	390-400	SILT TO COARSE SAND REPRESENTS 380-400

CUMULATIVE PERCENT RETAINED

mm	4.76	3.36	2.38	1.68	1.19	.840	.590	.420	.297	.210	.149
Inches	.187	.131	.094	.066	.047	.033	.023	.016	.012	.008	.006
US Sieve #	4	6	8	12	16	20	30	40	50	70	100
01	0.0	0.0	0.0	0.0	0.0	3.6	9.0	18.9	36.0	57.7	80.2
02	0.0	0.0	0.9	3.8	7.5	17.0	26.4	36.8	51.9	68.9	84.9
03	0.0	0.0	0.0	0.0	1.7	8.6	16.4	25.0	39.7	57.8	73.3
04	0.0	0.0	0.0	0.0	3.2	11.5	24.4	44.2	66.7	82.7	91.0

SCREEN RECOMMENDATIONS

Diameter: 8.000 in.

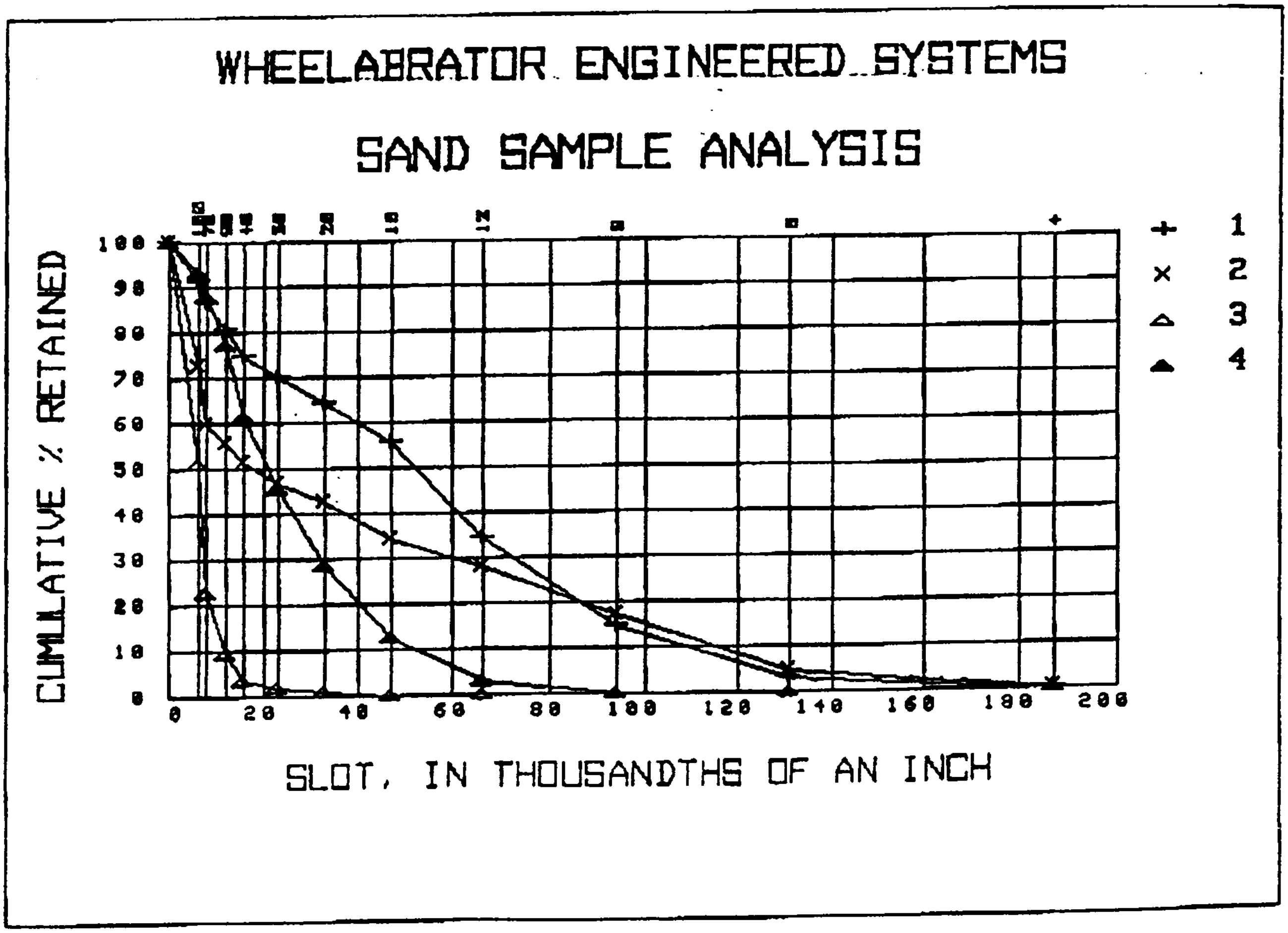
No.	Slot	Length	Setting
**	*****	*****	***************
01	0.000	0.0	
02	0.000	0.0	
03	0.000	0.0	
04	0.000	0.0	

COMMENTS
****

DESIGN RECOMMENDATIONS
****
16/30 GRAVEL PACK
SCREEN SLOT .020

WHEELABRATOR ENGINEERED SYSTEMS, JOHNSON SCREENS
SAND ANALYSIS REPORT

Johnson ID No.: 94123-1A
Job Name......: DARE COUNTY - WELL #9
Driller.......:
:
Engineer......:
:
Sample Sent by: SKIPPERS WELL DRILLING
Analysis by...: STEVE TUPY
Date..........: May 3, 1994



WHEELABRATOR ENGINEERED SYSTEMS, JOHNSON SCREENS
SAND ANALYSIS REPORT

Johnson ID No.: 94123-1A
Job Name......: DARE COUNTY - WELL #9

TEST HOLE DATA
****
Diameter: 0.000
Depth: 0
Drilling Method...:
Static Water Level: 0

WELL DATA
****
Casing Diameter: 8.000
Desired Yield: 500
Well App'n: PRODUCTION

PHYSICAL SAMPLE DESCRIPTION

No.	Depth	Description
01	280-300	SILT TO VERY FINE GRAVEL
02	310-320	SILT TO VERY FINE GRAVEL REPRESENTS 300-330
03	340-350	SILT TO MEDIUM SAND REPRESENTS 330-360
04	370-380	SILT TO VERY COARSE SAND REPRESENTS 360-400

CUMULATIVE PERCENT RETAINED

mm	4.76	3.36	2.38	1.68	1.19	.840	.590	.420	.297	.210	.149
Inches	.187	.131	.094	.066	.047	.033	.023	.016	.012	.008	.006
US Sieve #	4	6	8	12	16	20	30	40	50	70	100
01	0.0	2.9	14.6	34.0	55.3	64.1	69.9	74.8	80.6	86.4	91.3
02	0.0	4.3	17.0	27.7	34.0	42.6	46.8	51.1	55.3	59.6	72.3
03	0.0	0.0	0.0	0.0	0.0	0.8	1.6	3.2	8.9	22.6	50.8
04	0.0	0.0	0.0	2.7	12.6	28.4	45.4	61.2	77.0	88.0	93.4

SCREEN RECOMMENDATIONS

Diameter: 8.000 in.

No.	Slot	Length	Setting
01	0.000	0.0	
02	0.000	0.0	
03	0.000	0.0	
04	0.000	0.0	

COMMENTS
****

DESIGN RECOMMENDATIONS
****
20/40 GRAVEL PACK
SCREEN SLOT .015

APPENDIX D

AQUIFER TEST DATA

APT DATA FROM R.O.#9
TEST SITE

TIME (MINUTES)	DRAWDOWN (FEET)	TIME (MINUTES)	DRAWDOWN (FEET)	TIME (MINUTES)	DRAWDOWN (FEET)
0.1366	0.006	0.29	0.232	0.8833	0.905
0.14	0.006	0.2933	0.251	0.9	0.918
0.1433	0.012	0.2966	0.257	0.9166	0.924
0.1466	0.018	0.3	0.264	0.9333	0.924
0.15	0.012	0.3033	0.276	0.95	0.936
0.1533	0.012	0.3066	0.27	0.9666	0.943
0.1566	0.025	0.31	0.289	0.9833	0.943
0.16	0.025	0.3133	0.289	1	0.955
0.1633	0.025	0.3166	0.308	1.2	1.043
0.1666	0.025	0.32	0.314	1.4	1.1
0.17	0.025	0.3233	0.32	1.6	1.15
0.1733	0.025	0.3266	0.32	1.8	1.2
0.1766	0.037	0.33	0.333	2	1.219
0.18	0.031	0.3333	0.339	2.2	1.263
0.1833	0.037	0.35	0.371	2.4	1.288
0.1866	0.044	0.3666	0.415	2.6	1.307
0.19	0.044	0.3833	0.446	2.8	1.339
0.1933	0.044	0.4	0.471	3	1.351
0.1966	0.056	0.4166	0.503	3.2	1.37
0.2	0.062	0.4333	0.534	3.4	1.389
0.2033	0.069	0.45	0.553	3.6	1.408
0.2066	0.069	0.4666	0.578	3.8	1.42
0.21	0.069	0.4833	0.603	4	1.439
0.2133	0.081	0.5	0.609	4.2	1.452
0.2166	0.081	0.5166	0.635	4.4	1.464
0.22	0.081	0.5333	0.653	4.6	1.477
0.2233	0.094	0.55	0.672	4.8	1.49
0.2266	0.1	0.5666	0.685	5	1.496
0.23	0.113	0.5833	0.698	5.2	1.508
0.2333	0.119	0.6	0.716	5.4	1.521
0.2366	0.119	0.6166	0.723	5.6	1.527
0.24	0.125	0.6333	0.735	5.8	1.54
0.2433	0.132	0.65	0.754	6	1.54
0.2466	0.138	0.6666	0.767	6.2	1.552
0.25	0.144	0.6833	0.779	6.4	1.559
0.2533	0.15	0.7	0.792	6.6	1.565
0.2566	0.163	0.7166	0.804	6.8	1.578
0.26	0.169	0.7333	0.817	7	1.578
0.2633	0.182	0.75	0.823	7.2	1.584
0.2666	0.188	0.7666	0.842	7.4	1.59
0.27	0.188	0.7833	0.855	7.6	1.596
0.2733	0.195	0.8	0.855	7.8	1.615
0.2766	0.201	0.8166	0.867	8	1.609
0.28	0.22	0.8333	0.88	8.2	1.622
0.2833	0.22	0.85	0.886	8.4	1.628
0.2866	0.226	0.8666	0.892	8.6	1.634

APT DATA FROM R.O.#9
TEST SITE
- CONTINUED -

TIME (MINUTES)	DRAWDOWN (FEET)	TIME (MINUTES)	DRAWDOWN (FEET)	TIME (MINUTES)	DRAWDOWN (FEET)
8.8	1.634	88	2.112	880	2.728
9	1.64	90	2.118	900	2.734
9.2	1.634	92	2.124	920	2.728
9.4	1.653	94	2.124	940	2.734
9.6	1.647	96	2.124	960	2.728
9.8	1.653	98	2.124	980	2.74
10	1.659	100	2.131	1000	2.747
12	1.71	120	2.162	1200	2.91
14	1.741	140	2.194	1400	3.067
16	1.766	160	2.212	1600	3.023
18	1.791	180	2.225	1800	2.954
20	1.81	200	2.244	2000	3.073
22	1.835	220	2.256	2200	3.211
24	1.854	240	2.269	2400	3.168
26	1.873	260	2.281	2600	3.205
28	1.892	280	2.3	2800	3.381
30	1.904	300	2.319	3000	3.4
32	1.911	320	2.332	3200	3.287
34	1.923	340	2.357	3400	3.312
36	1.942	360	2.37	3600	3.463
38	1.948	380	2.382	3800	3.475
40	1.961	400	2.407	4000	3.469
42	1.974	420	2.432		
44	1.98	440	2.464		
46	1.992	460	2.476		
48	1.992	480	2.508		
50	2.005	500	2.527		
52	2.018	520	2.558		
54	2.024	540	2.589		
56	2.03	560	2.596		
58	2.043	580	2.627		
60	2.049	600	2.652		
62	2.049	620	2.665		
64	2.055	640	2.677		
66	2.062	660	2.69		
68	2.068	680	2.703		
70	2.068	700	2.709		
72	2.08	720	2.721		
74	2.08	740	2.715		
76	2.087	760	2.721		
78	2.093	780	2.728		
80	2.099	800	2.734		
82	2.099	820	2.734		
84	2.106	840	2.728		
86	2.106	860	2.728		

APT DATA FROM R.O.#10
TEST SITE

TIME (MINUTES)	DRAWDOWN (FEET)	TIME (MINUTES)	DRAWDOWN (FEET)	TIME (MINUTES)	DRAWDOWN (FEET)
0.0533	0.012	0.2066	0.182	0.4666	0.889
0.0566	0.012	0.21	0.201	0.4833	0.926
0.06	0.012	0.2133	0.201	0.5	0.977
0.0633	0.012	0.2166	0.214	0.5166	1.015
0.0666	0.012	0.22	0.227	0.5333	1.059
0.07	0.018	0.2233	0.227	0.55	1.103
0.0733	0.012	0.2266	0.245	0.5666	1.141
0.0766	0.025	0.23	0.239	0.5833	1.179
0.08	0.018	0.2333	0.258	0.6	1.223
0.0833	0.018	0.2366	0.264	0.6166	1.254
0.0866	0.031	0.24	0.264	0.6333	1.292
0.09	0.018	0.2433	0.283	0.65	1.317
0.0933	0.037	0.2466	0.283	0.6666	1.361
0.0966	0.031	0.25	0.296	0.6833	1.38
0.1	0.031	0.2533	0.302	0.7	1.418
0.1033	0.037	0.2566	0.309	0.7166	1.45
0.1066	0.031	0.26	0.315	0.7333	1.475
0.11	0.044	0.2633	0.321	0.75	1.519
0.1133	0.044	0.2666	0.34	0.7666	1.538
0.1166	0.056	0.27	0.334	0.7833	1.563
0.12	0.056	0.2733	0.346	0.8	1.595
0.1233	0.05	0.2766	0.365	0.8166	1.626
0.1266	0.069	0.28	0.359	0.8333	1.639
0.13	0.056	0.2833	0.378	0.85	1.676
0.1333	0.069	0.2866	0.39	0.8666	1.695
0.1366	0.075	0.29	0.39	0.8833	1.708
0.14	0.075	0.2933	0.403	0.9	1.746
0.1433	0.081	0.2966	0.416	0.9166	1.758
0.1466	0.075	0.3	0.422	0.9333	1.784
0.15	0.094	0.3033	0.435	0.95	1.803
0.1533	0.094	0.3066	0.441	0.9666	1.828
0.1566	0.088	0.31	0.447	0.9833	1.847
0.16	0.113	0.3133	0.454	1	1.853
0.1633	0.107	0.3166	0.466	1.2	2.086
0.1666	0.119	0.32	0.479	1.4	2.225
0.17	0.119	0.3233	0.485	1.6	2.319
0.1733	0.119	0.3266	0.498	1.8	2.408
0.1766	0.138	0.33	0.504	2	2.483
0.18	0.138	0.3333	0.523	2.2	2.534
0.1833	0.151	0.35	0.573	2.4	2.59
0.1866	0.151	0.3666	0.611	2.6	2.641
0.19	0.151	0.3833	0.655	2.8	2.679
0.1933	0.17	0.4	0.706	3	2.716
0.1966	0.17	0.4166	0.744	3.2	2.76
0.2	0.182	0.4333	0.8	3.4	2.786
0.2033	0.189	0.45	0.838	3.6	2.811

APT DATA FROM R.O.#10
TEST SITE
- CONTINUED -

TIME (MINUTES)	DRAWDOWN (FEET)
3.8	2.842
4	2.861
4.2	2.887
4.4	2.899
4.6	2.918
4.8	2.949
5	2.968
5.2	2.981
5.4	2.994
5.6	3.019
5.8	3.038
6	3.044
6.2	3.076
6.4	3.069
6.6	3.088
6.8	3.107
7	3.12
7.2	3.139
7.4	3.145
7.6	3.151
7.8	3.164
8	3.17
8.2	3.195
8.4	3.202
8.6	3.202
8.8	3.227
9	3.227
9.2	3.239
9.4	3.239
9.6	3.252
9.8	3.258
10	3.265
12	3.34
14	3.409
16	3.447
18	3.498
20	3.535
22	3.573
24	3.605
26	3.624
28	3.643
30	3.668
32	3.699
34	3.699
36	3.724
38	3.737
40	3.743
42	3.775
44	3.787
46	3.787
48	3.8
50	3.819
52	3.838
54	3.825
56	3.85
58	3.869
60	3.876
62	3.882
64	3.882
66	3.894
68	3.907
70	3.913
72	3.907
74	3.913
76	3.92
78	3.932
80	3.951
82	3.945
84	3.951
86	3.964
88	3.964
90	3.97
92	3.976
94	3.976
96	3.976
98	3.983
100	3.989
120	4.02
140	4.046
160	4.058
180	4.083
200	4.083
220	4.09
240	4.109
260	4.109
280	4.115
300	4.134
320	4.14
340	4.146
360	4.159
380	4.172
400	4.191
420	4.216
440	4.247
460	4.272
480	4.298
500	4.335
520	4.386
540	4.417
560	4.461
580	4.493
600	4.531
620	4.581
640	4.619
660	4.644
680	4.682
700	4.713
720	4.739
740	4.764
760	4.77
780	4.783
800	4.795
820	4.795
840	4.814
860	4.808
880	4.814
900	4.801
920	4.789
940	4.795
960	4.783
980	4.789
1000	4.776
1200	4.896
1400	5.198
1600	5.255
1800	5.129
2000	5.255
2200	5.545
2400	5.557
2600	5.526
2800	5.696
3000	5.853
3200	5.74
3400	5.708
3600	5.929
3800	6.086
4000	5.985
4200	5.916
4400	6.017

WATER LEVELS IN THE
WATER-TABLE AQUIFER
DURING THE APT AT
R.O. #9

TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)
-------	-------	-------	-------	-------	-------
0	12.95	0.1466	12.954	0.2933	12.954
0.0033	12.954	0.15	12.954	0.2966	12.954
0.0066	12.954	0.1533	12.954	0.3	12.954
0.01	12.954	0.1566	12.954	0.3033	12.957
0.0133	12.954	0.16	12.954	0.3066	12.954
0.0166	12.954	0.1633	12.954	0.31	12.954
0.02	12.957	0.1666	12.957	0.3133	12.957
0.0233	12.954	0.17	12.954	0.3166	12.954
0.0266	12.954	0.1733	12.954	0.32	12.954
0.03	12.954	0.1766	12.954	0.3233	12.954
0.0333	12.954	0.18	12.957	0.3266	12.954
0.0366	12.954	0.1833	12.954	0.33	12.954
0.04	12.954	0.1866	12.954	0.3333	12.954
0.0433	12.954	0.19	12.954	0.35	12.954
0.0466	12.957	0.1933	12.954	0.3666	12.954
0.05	12.954	0.1966	12.954	0.3833	12.95
0.0533	12.954	0.2	12.954	0.4	12.954
0.0566	12.957	0.2033	12.954	0.4166	12.954
0.06	12.954	0.2066	12.957	0.4333	12.957
0.0633	12.954	0.21	12.954	0.45	12.954
0.0666	12.954	0.2133	12.954	0.4666	12.954
0.07	12.957	0.2166	12.957	0.4833	12.954
0.0733	12.954	0.22	12.954	0.5	12.954
0.0766	12.954	0.2233	12.954	0.5166	12.954
0.08	12.957	0.2266	12.954	0.5333	12.954
0.0833	12.954	0.23	12.954	0.55	12.957
0.0866	12.954	0.2333	12.954	0.5666	12.957
0.09	12.954	0.2366	12.954	0.5833	12.954
0.0933	12.954	0.24	12.957	0.6	12.957
0.0966	12.95	0.2433	12.957	0.6166	12.957
0.1	12.954	0.2466	12.95	0.6333	12.954
0.1033	12.954	0.25	12.954	0.65	12.954
0.1066	12.957	0.2533	12.957	0.6666	12.957
0.11	12.954	0.2566	12.954	0.6833	12.957
0.1133	12.954	0.26	12.954	0.7	12.954
0.1166	12.957	0.2633	12.954	0.7166	12.957
0.12	12.954	0.2666	12.954	0.7333	12.957
0.1233	12.95	0.27	12.954	0.75	12.954
0.1266	12.954	0.2733	12.954	0.7666	12.957
0.13	12.954	0.2766	12.957	0.7833	12.957
0.1333	12.954	0.28	12.957	0.8	12.957
0.1366	12.954	0.2833	12.954	0.8166	12.957
0.14	12.954	0.2866	12.954	0.8333	12.957
0.1433	12.957	0.29	12.954	0.85	12.957

WATER LEVELS IN THE
WATER-TABLE AQUIFER
DURING THE APT AT
R.O. #9
- CONTINUED -

TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)
-------	-------	-------	-------	-------	-------
0.8666	12.957	8.2	12.957	80	12.95
0.8833	12.957	8.4	12.954	82	12.954
0.9	12.957	8.6	12.954	84	12.947
0.9166	12.957	8.8	12.957	86	12.95
0.9333	12.957	9	12.957	88	12.954
0.95	12.957	9.2	12.957	90	12.95
0.9666	12.96	9.4	12.96	92	12.95
0.9833	12.957	9.6	12.96	94	12.947
1	12.957	9.8	12.957	96	12.95
1.2	12.957	10	12.957	98	12.954
1.4	12.963	12	12.957	100	12.954
1.6	12.96	14	12.954	120	12.957
1.8	12.96	16	12.957	140	12.947
2	12.96	18	12.957	160	12.947
2.2	12.957	20	12.957	180	12.95
2.4	12.96	22	12.954	200	12.95
2.6	12.96	24	12.954	220	12.947
2.8	12.96	26	12.954	240	12.944
3	12.963	28	12.95	260	12.947
3.2	12.963	30	12.957	280	12.944
3.4	12.96	32	12.957	300	12.941
3.6	12.96	34	12.954	320	12.941
3.8	12.96	36	12.954	340	12.938
4	12.96	38	12.954	360	12.938
4.2	12.957	40	12.954	380	12.938
4.4	12.96	42	12.954	400	12.935
4.6	12.96	44	12.954	420	12.938
4.8	12.96	46	12.954	440	12.935
5	12.957	48	12.954	460	12.932
5.2	12.957	50	12.954	480	12.932
5.4	12.96	52	12.954	500	12.932
5.6	12.957	54	12.954	520	12.932
5.8	12.957	56	12.95	540	12.928
6	12.954	58	12.95	560	12.925
6.2	12.957	60	12.947	580	12.928
6.4	12.957	62	12.95	600	12.925
6.6	12.957	64	12.95	620	12.928
6.8	12.96	66	12.95	640	12.922
7	12.957	68	12.947	660	12.922
7.2	12.96	70	12.947	680	12.925
7.4	12.96	72	12.947	700	12.922
7.6	12.96	74	12.947	720	12.922
7.8	12.957	76	12.95	740	12.922
8	12.96	78	12.95	760	12.925

WATER LEVELS IN THE
WATER-TABLE AQUIFER
DURING THE APT AT
R.O. #9
- CONTINUED -

Below land surface

TIME (MINUTES)	WATER LEVEL (FEET BLS)
780	12.922
800	12.919
820	12.922
840	12.919
860	12.919
880	12.922
900	12.922
920	12.919
940	12.919
960	12.919
980	12.916
1000	12.916
1200	12.916
1400	12.906
1600	12.894
1800	12.891
2000	12.881
2200	12.878
2400	12.875
2600	12.872
2800	12.862
3000	12.859
3200	12.85
3400	12.844
3600	12.838
3800	12.85
4000	12.85

1.78" ↓ after 66.67 hrs.

2.78 days
18 hours
40 minutes

WATER-TABLE AQUIFER
WATER LEVELS DURING
THE APT AT R.O.#10

TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)
0	6.815	0.15	6.802	0.3	6.802
0.0033	6.793	0.1533	6.802	0.3033	6.805
0.0066	6.809	0.1566	6.809	0.3066	6.805
0.01	6.802	0.16	6.799	0.31	6.802
0.0133	6.796	0.1633	6.809	0.3133	6.805
0.0166	6.815	0.1666	6.802	0.3166	6.802
0.02	6.79	0.17	6.802	0.32	6.805
0.0233	6.815	0.1733	6.805	0.3233	6.805
0.0266	6.799	0.1766	6.799	0.3266	6.802
0.03	6.799	0.18	6.809	0.33	6.805
0.0333	6.812	0.1833	6.802	0.3333	6.805
0.0366	6.793	0.1866	6.805	0.35	6.799
0.04	6.812	0.19	6.805	0.3666	6.805
0.0433	6.799	0.1933	6.799	0.3833	6.802
0.0466	6.802	0.1966	6.809	0.4	6.805
0.05	6.805	0.2	6.799	0.4166	6.805
0.0533	6.799	0.2033	6.805	0.4333	6.799
0.0566	6.809	0.2066	6.802	0.45	6.809
0.06	6.799	0.21	6.802	0.4666	6.802
0.0633	6.802	0.2133	6.805	0.4833	6.805
0.0666	6.805	0.2166	6.802	0.5	6.805
0.07	6.799	0.22	6.802	0.5166	6.802
0.0733	6.805	0.2233	6.805	0.5333	6.805
0.0766	6.799	0.2266	6.802	0.55	6.802
0.08	6.805	0.23	6.805	0.5666	6.805
0.0833	6.805	0.2333	6.802	0.5833	6.802
0.0866	6.802	0.2366	6.802	0.6	6.805
0.09	6.805	0.24	6.805	0.6166	6.805
0.0933	6.799	0.2433	6.799	0.6333	6.802
0.0966	6.805	0.2466	6.805	0.65	6.805
0.1	6.805	0.25	6.802	0.6666	6.802
0.1033	6.802	0.2533	6.802	0.6833	6.805
0.1066	6.805	0.2566	6.805	0.7	6.802
0.11	6.799	0.26	6.799	0.7166	6.802
0.1133	6.805	0.2633	6.809	0.7333	6.805
0.1166	6.805	0.2666	6.802	0.75	6.799
0.12	6.802	0.27	6.802	0.7666	6.805
0.1233	6.809	0.2733	6.805	0.7833	6.802
0.1266	6.799	0.2766	6.799	0.8	6.805
0.13	6.809	0.28	6.809	0.8166	6.802
0.1333	6.802	0.2833	6.802	0.8333	6.802
0.1366	6.802	0.2866	6.805	0.85	6.805
0.14	6.809	0.29	6.805	0.8666	6.799
0.1433	6.799	0.2933	6.799	0.8833	6.805
0.1466	6.809	0.2966	6.805	0.9	6.802

WATER-TABLE AQUIFER
WATER LEVELS DURING
THE APT AT R.O.#10
- CONTINUED -

TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)	TIME (MINUTES)	WATER LEVEL (FEET BLS)
-------	------	-------	------	-------	------
0.9166	6.805	8.8	6.812	86	6.799
0.9333	6.802	9	6.815	88	6.79
0.95	6.805	9.2	6.802	90	6.793
0.9666	6.802	9.4	6.815	92	6.799
0.9833	6.799	9.6	6.812	94	6.79
1	6.809	9.8	6.805	96	6.786
1.2	6.805	10	6.815	98	6.793
1.4	6.802	12	6.815	100	6.793
1.6	6.812	14	6.812	120	6.786
1.8	6.805	16	6.809	140	6.78
2	6.818	18	6.799	160	6.79
2.2	6.812	20	6.799	180	6.79
2.4	6.809	22	6.799	200	6.777
2.6	6.818	24	6.799	220	6.774
2.8	6.809	26	6.805	240	6.786
3	6.812	28	6.805	260	6.78
3.2	6.809	30	6.796	280	6.777
3.4	6.805	32	6.809	300	6.774
3.6	6.818	34	6.796	320	6.777
3.8	6.805	36	6.799	340	6.764
4	6.818	38	6.805	360	6.774
4.2	6.818	40	6.796	380	6.768
4.4	6.812	42	6.802	400	6.768
4.6	6.821	44	6.802	420	6.768
4.8	6.815	46	6.802	440	6.774
5	6.818	48	6.812	460	6.761
5.2	6.818	50	6.786	480	6.764
5.4	6.809	52	6.796	500	6.777
5.6	6.815	54	6.802	520	6.774
5.8	6.815	56	6.799	540	6.764
6	6.805	58	6.786	560	6.774
6.2	6.818	60	6.799	580	6.768
6.4	6.812	62	6.802	600	6.761
6.6	6.809	64	6.805	620	6.774
6.8	6.812	66	6.793	640	6.768
7	6.809	68	6.793	660	6.768
7.2	6.805	70	6.802	680	6.768
7.4	6.809	72	6.799	700	6.768
7.6	6.805	74	6.805	720	6.774
7.8	6.812	76	6.802	740	6.771
8	6.809	78	6.805	760	6.771
8.2	6.802	80	6.796	780	6.771
8.4	6.812	82	6.802	800	6.764
8.6	6.809	84	6.802	820	6.761

WATER-TABLE AQUIFER
WATER LEVELS DURING
THE APT AT R.O.#10
- CONTINUED -

TIME (MINUTES)	WATER LEVEL (FEET BLS)
840	6.768
860	6.758
880	6.764
900	6.768
920	6.761
940	6.771
960	6.755
980	6.761
1000	6.764
1200	6.755
1400	6.745
1600	6.723
1800	6.708
2000	6.704
2200	6.708
2400	6.698
2600	6.679
2800	6.689
3000	6.679
3200	6.66
3400	6.667
3600	6.664
3800	6.657
4000	6.648
4200	6.645
4400	6.645
4600	6.626

7.768" ↓ after 76.67 hrs.
3 days
4 hrs.
40 minutes.

APPENDIX E

STEP DRAWDOWN TEST TABLES

TABLE A-1.

DARE COUNTY R.O. - TEST WELL #9
STEP DRAWDOWN TEST

Test Date: 4/27/94
Recorded by: Jack Breland
Static Water Level: 30.39 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
100	5	35.45	5.06	
	10	35.23	4.84	
	15	35.28	4.89	
	20	35.29	4.90	
	30	35.25	4.86	
	40	35.22	4.83	
	50	35.58	5.19	
	60	35.62	5.23	
	70	35.67	5.28	
	80	35.62	5.23	
	90	35.66	5.27	
	100	35.67	5.28	
	110	35.65	5.26	
	120	35.66	5.27	19.0
200	5	41.31	10.92	
	10	41.32	10.93	
	15	41.31	10.92	
	20	41.37	10.98	
	30	41.40	11.01	
	40	41.41	11.02	
	50	41.41	11.02	
	60	41.45	11.06	
	70	41.49	11.11	
	80	41.52	11.13	
	90	41.54	11.15	
	100	41.56	11.17	
	110	41.58	11.19	
	120	41.58	11.19	17.9
350	5	51.19	20.80	
	10	51.35	20.96	
	20	51.42	21.02	
	30	51.57	21.12	
	40	51.61	21.22	
	50	51.63	21.24	
	60	51.66	21.37	
	70	51.72	21.33	
	80	51.77	21.48	
	90	51.81	21.42	
	100	51.82	21.43	
	110	51.85	21.46	
	120	51.89	21.50	
	130	51.92	21.53	
	140	51.95	21.56	
	150	51.96	21.57	
	160	51.99	21.60	
	170	52.03	21.64	
	180	52.04	21.65	16.2

TABLE A-1. DARE COUNTY R.O. - TEST WELL #9
STEP DRAWDOWN TEST
- CONTINUED -

Test Date: 4/27/94
Recorded by: Jack Breland
Static Water Level: 30.39 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
480	5	59.63	29.24	
	10	59.75	29.36	
	20	59.87	29.48	
	30	59.94	29.55	
	40	61.07	30.68	
	50	61.24	30.85	
	60	61.43	31.04	
	70	61.50	31.11	
	80	61.60	31.21	
	90	61.70	31.31	
	100	61.74	31.35	
	110	61.77	31.38	
	120	61.82	31.43	
	140	61.89	31.50	
	160	61.96	31.57	
	180	62.07	31.68	
	200	62.16	31.77	
	220	62.19	31.80	
	240	62.22	31.83	15.1

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

TABLE A-2. DARE COUNTY R.O. - TEST WELL #10
STEP DRAWDOWN TEST

Test Date: 5/04/94
Recorded by: Jack Breland
Static Water Level: 21.73 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
100	5	28.83	7.10	
	10	28.85	7.12	
	15	28.86	7.13	
	20	28.86	7.13	
	30	28.87	7.14	
	40	28.89	7.16	
	50	28.89	7.16	
	60	28.90	7.17	
	70	28.91	7.18	
	80	28.91	7.18	
	90	28.92	7.19	
	100	28.93	7.20	
	110	28.93	7.20	
	120	28.93	7.20	13.9
200	5	36.80	15.07	
	10	36.87	15.14	
	15	36.90	15.17	
	20	36.98	15.17	
	30	36.88	15.15	
	40	36.80	15.15	
	50	36.90	15.17	
	60	36.92	15.19	
	70	36.94	15.21	
	80	36.07	15.24	
	90	37.00	15.27	
	100	37.01	15.28	
	110	37.02	15.29	
	120	37.03	15.30	13.1
350	5	50.68	28.95	
	10	50.87	29.14	
	20	51.13	29.40	
	30	51.10	29.37	
	40	51.18	29.45	
	50	51.23	29.50	
	60	51.33	29.60	
	70	51.41	29.68	
	80	51.43	29.70	
	90	51.45	29.72	
	100	51.49	29.76	
	110	51.52	29.79	
	120	51.57	29.84	
	130	51.60	29.87	
	140	51.63	29.90	
	150	51.66	29.93	
	160	51.68	29.95	
	170	52.69	29.96	
	180	52.70	29.97	11.7

TABLE A-2. DARE COUNTY R.O. - TEST WELL #10
STEP DRAWDOWN TEST
- CONTINUED -

Test Date: 5/04/94
Recorded by: Jack Breland
Static Water Level: 21.73 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
470	5	63.33	41.60	
	10	63.62	41.89	
	20	63.83	42.10	
	30	63.98	42.25	
	40	64.25	42.52	
	50	64.33	42.62	
	60	64.45	42.72	
	70	64.56	42.83	
	80	64.67	42.94	
	90	64.78	43.05	
	100	64.88	43.15	
	110	65.01	43.28	
	120	65.09	43.36	
	130	65.15	43.42	
	140	65.18	43.45	
	150	65.20	43.47	
	160	65.24	43.51	
	170	65.29	43.56	
	180	65.32	43.59	
	190	65.36	43.63	
	200	65.38	43.65	
	220	65.42	43.69	
	240	65.45	43.72	10.8

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

TABLE A-3. DARE COUNTY R.O. - PRODUCTION WELL #9
STEP DRAWDOWN TEST

Test Date: 6/31/94
Recorded by: Jack Breland
Static Water Level: 33.65 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
400	5	43.68	10.03	
	10	43.76	10.11	
	20	43.83	10.18	
	30	43.88	10.23	
	40	43.97	10.32	
	50	43.99	10.34	
	60	44.02	10.37	
	70	44.05	10.40	
	80	44.09	10.44	
	90	44.12	10.47	
	100	44.14	10.49	
	110	44.16	10.51	
	120	44.17	10.52	38.0
600	5	51.32	17.67	
	10	51.57	17.92	
	20	51.68	18.03	
	30	51.79	18.14	
	40	51.79	18.14	
	50	51.81	18.16	
	60	51.84	18.19	
	70	51.87	18.22	
	80	51.81	18.26	
	90	51.83	18.28	
	100	51.83	18.29	
	110	51.85	18.31	
	120	51.87	18.33	32.7
800	5	59.35	25.70	
	10	59.47	25.82	
	20	59.70	26.05	
	30	59.81	26.16	
	40	59.92	26.27	
	50	60.04	26.39	
	60	60.16	26.51	
	70	60.27	26.62	
	80	60.39	26.74	
	90	60.48	26.83	
	100	60.58	26.93	
	110	60.67	27.02	
	120	60.75	27.10	
	130	60.81	27.16	
	140	60.87	27.22	
	150	60.92	27.27	
	160	60.96	27.31	
	170	60.99	27.34	
	180	61.02	27.37	
				29.2

TABLE A-3. DARE COUNTY R.O. - PRODUCTION WELL #9
STEP DRAWDOWN TEST (CONTINUED)

Test Date: 6/31/94
Recorded by: Jack Breland
Static Water Level: 33.65 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
890	5	63.43	29.78	
	10	63.54	29.99	
	20	63.72	30.07	
	30	63.94	30.29	
	40	64.09	30.44	
	50	64.23	30.58	
	60	64.35	30.70	
	70	64.49	30.84	
	80	64.62	30.97	
	90	64.78	31.13	
	100	64.94	31.29	
	110	65.07	31.42	
	120	65.24	31.59	
	130	65.48	31.83	
	140	65.62	31.97	
	150	65.81	32.16	
	160	65.97	32.32	
	170	65.09	32.44	
	180	66.27	32.62	
	190	66.45	32.80	
	200	66.62	32.97	
	210	66.80	33.15	
	220	66.92	33.27	
	230	66.99	33.34	
	240	67.08	33.43	
	250	67.17	33.52	
	260	67.25	33.60	
	270	67.32	33.67	
	280	67.41	33.76	
	290	67.49	33.84	
	300	67.54	33.89	26.3

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

TABLE A-4.

DARE COUNTY R.O. - PRODUCTION WELL #10
STEP DRAWDOWN TEST

Test Date: 6/24/94
Recorded by: Jack Breland
Static Water Level: 26.15 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
200	5	34.23	8.08	
	10	34.22	8.07	
	20	34.23	8.08	
	30	34.26	8.11	
	40	34.28	8.13	
	50	34.29	8.14	
	60	34.20	8.15	
	70	34.31	8.16	
	80	34.33	8.18	
	90	34.34	8.19	
	100	34.35	8.20	
	110	34.36	8.21	
	120	34.37	8.22	24.3
400	5	44.11	17.96	
	10	43.95	17.80	
	20	44.00	17.85	
	30	44.03	17.88	
	40	44.05	17.90	
	50	44.07	17.92	
	60	44.09	17.94	
	70	44.12	17.97	
	80	44.14	17.99	
	90	44.16	17.91	
	100	44.17	17.92	
	110	44.18	17.93	
	120	44.19	17.94	22.3
485	5	48.01	21.86	
	10	47.92	21.77	
	20	48.09	21.94	
	30	48.21	22.06	
	40	48.33	22.18	
	50	48.42	22.27	
	60	48.56	22.41	
	70	48.68	22.53	
	80	48.75	22.60	
	90	48.77	22.62	
	100	48.79	22.64	
	110	48.81	22.66	
	120	48.82	22.67	
	130	48.83	22.68	
	140	48.84	22.69	
	150	48.84	22.69	
	160	48.85	22.70	
	170	48.86	22.71	
	180	48.86	22.71	21.4

TABLE A-4.

DARE COUNTY R.O. - PRODUCTION WELL #10
STEP DRAWDOWN TEST (CONTINUED)

Test Date: 6/24/94
Recorded by: Jack Breland
Static Water Level: 26.15 feet below measuring point (ft. BMP)

PUMPING RATE (GPM)	TIME (MIN.)	PUMPING WATER LEVEL (BMP)	DRAWDOWN (FT. BMP)	SPECIFIC CAPACITY (GPM/FT)
700	5	61.49	35.34	
	10	61.89	35.74	
	20	62.03	35.88	
	30	62.12	35.97	
	40	62.23	36.08	
	50	62.34	36.19	
	60	62.38	36.23	
	70	62.41	36.26	
	80	62.45	36.30	
	90	62.49	36.34	
	100	62.52	36.37	
	110	62.55	36.40	
	120	62.59	36.44	
	130	62.62	36.47	
	140	62.69	36.54	
	150	62.74	36.59	
	160	62.78	36.63	
	170	62.81	36.66	
	180	62.85	36.70	
	190	62.87	36.72	
	200	62.89	36.74	
	220	62.92	36.77	
	240	62.94	36.79	19.0

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