Report J

FEASIBILITY OF DEEP-WELL WASTEWATER DISPOSAL AT THE SAND LAKE ROAD TREATMENT FACILITY ORANGE COUNTY, FLORIDA

EPA PROJECT No. C120314.010

prepared for

The Board of County Commissioners
and
Public Utilities Division

SEPTEMBER, 1977

IN COOPERATION WITH

VTN INC.
CONSULTING ENGINEERS
712 WEST GORE STREET
ORLANDO, FLORIDA

GERAGHTY & MILLER, INC.
CONSULTING GROUND-WATER HYDROLOGISTS AND GEOLOGISTS
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November 17, 1977

Florida Department of Environmental Regulation
2562 Executive Center Circle, East
Montgomery Building
Tallahassee, Florida 32301

Attention: Mr. Howard L. Rhodes, P.E.
Chief, Bureau of Wastewater Management and Grants

Re: EPA Project C120314.010
Orange County, Florida
Deep Well Injection Test Program (VTN File No. 2430-006)

Gentlemen:

We are transmitting to you herewith three copies of the final project report entitled, "Feasibility of Deep Well Wastewater Disposal at the Sand Lake Road Treatment Facility, Orange County, Florida." Under separate cover, three copies of the geophysical logs that were obtained during the study are also being transmitted to you. These documents were prepared primarily by our consulting groundwater hydrologists and geologists, Geraghty & Miller, Inc. of Tampa, Florida, in cooperation with VTN Inc. acting as consulting engineers to and for Orange County. We concur with the findings and the conclusions reached therefrom.

Although the findings suggest that disposal into a deep well of large volumes of treated wastewater would be uneconomical, the investigation nevertheless provided valuable geologic and hydrologic data on the area. The test hole was the deepest drilled in this part of Florida that has developed much detailed information for future reference. In addition, innovative methods of drilling and testing were utilized to collect the necessary information for evaluation.

Even though disposal of treated wastewater by deep well injection does not appear feasible at this location due to the lack of a lower zone of high transmissivity and the necessity for very high pressures to effect the injection of even small quantities, the test injection well, as constructed, could become a valuable tool for research and monitoring of the fresh water bearing Floridan aquifer at its lower level and the saline water bearing strata below 2500 feet from ground surface. Our recommendation is that the well be retained for research by either the U.S. Geological Survey or the Florida Bureau of Geology, or possibly the South Florida Water Management District, provided that any one or a combination of these agencies would be willing to accept the responsibility and cost for modifying the well for this purpose.

Specifically, a small immersible turbine pump with suitable piping and sampling points therein could be installed in the upper 4-inch section of the monitor tube, wired for both automatic time clock operation and manual operation, so that small volumes of fresh water from the monitor tube would be discharged into the test injection well to maintain a head of fresh water throughout the larger well for an indefinite period or until one of the above agencies elected to perform further research or sampling in the lower saline regions.

If the test injection well is not to be so utilized, then it may have to be plugged and the local share of its cost written off as a capital loss by Orange County, except for those portions of the facilities which can still be utilized, namely the monitor tube for monitoring the lower levels of the fresh water Floridan aquifer. We do not believe that anyone would wish to abandon this latter valuable tool. Accordingly, we ask the cooperation of your department, along with EPA and the other agencies mentioned hereinabove, in arriving at a determination of what to do with the main injection test well. Orange County has retained approximately 0.5% of the Contractor's final payment in order to keep the contract open for a possible final change order should the well have to be plugged and abandoned in accordance with the procedures outlined in Geraghty & Miller's report (pp. 75 and 76). We would like to have this decision finalized as soon as possible.

By copy of this letter, we are transmitting the only other presently available sets (report and geophysical logs) to the agencies most concerned with this project, as indicated below. We request that you review and retain one set for your records and transmit two sets to EPA in Atlanta, one each of which should be specifically marked to the attention of Mr. Gene Coker and the other to the attention of Mr. Stallings Howell. If additional copies of the report are requested, in writing, and accompanied by a check payable to VTN Inc. in the amount of $18.50 per copy (exclusive of the geophysical logs, which are not reproducible by VTN Inc.), such reproduced copies of the report only will be sent postpaid to the requestor. The agencies listed below will have copies of the geophysical logs for perusal by interested parties, and so will the firm of Geraghty & Miller, Inc. in Tampa. The originals of these documents, of course, remain with the firm who produced them (Birdwell Division, Seismograph Service Corporation, P. O. Box 1723, Clarksburg, West Virginia).

It is unfortunate and somewhat disappointing that the deep well disposal of treated wastewater at the Orange County Sand Lake Road Plant site has not been demonstrated to be feasible. However, much valuable information has been obtained for the future guidance of the several local, state and federal agencies who have been involved with this project, and all of their people should be commended for their cooperation and assistance. Orange County must now proceed to look for other means of treated effluent disposal, and it is expected that a joint venture with the City of Orlando, to address this problem and others common to both in the Southwest Orange County area, will be the subject of an application to EPA for a 201 Facilities Planning Grant.

Yours very truly,

VTN INC.

R. G. Shanklin, Jr., P.E.
Vice President

RGS/dwj

Enclosures

cc: Orange County (E. P. West, Jr.) - 2 reports, 2 geophysical logs
Florida Department of Environmental Regulation, Orlando (T. E. Hunnicutt) - 1 report, 1 geophysical log
South Florida Water Management District (C&SF-FCD, Abe Kreitman) - 1 report, 1 geophysical log
✓U. S. Geological Survey, Orlando (C. H. Tibbals) - 1 report, 1 geophysical log
Florida Bureau of Geology, Tallahassee (Thomas Scott) - 1 report, 1 geophysical log

cc: (letter only)
U. S. Environmental Protection Agency, Region IV, Atlanta (Gene Coker, Stallings Howell)
Geraghty & Miller, Inc. (P. Hackenberry)

Carrollwood Village Executive Center
13902 North Dale Mabry Highway
Suite 150
Post Office Box 17174
TAMPA, FLORIDA 33682
Telephone 813 / 961-1921

Geraghty & Miller, Inc.

CONSULTING GROUND-WATER GEOLOGISTS AND HYDROLOGISTS

October 19, 1977

Mr. R. G. Shanklin, Jr., P.E.
Vice President
VTN, Inc.
Post Office Box 5819
Orlando, Florida 32805

Re: Orange County Injection-Test Well Program, EPA Project No. C120314.010

Dear Mr. Shanklin:

We are pleased to submit herewith our final project report entitled "Feasibility of Deep-Well Wastewater Disposal at the Sand Lake Road Treatment Facility, Orange County, Florida." Copies of the geophysical logs that were obtained during the study accompany the report under separate cover.

Although the findings suggest that disposal into a deep well of large volumes of treated wastewater is uneconomical, the investigation nevertheless provided valuable geologic and hydrologic data on the area. The test hole was the deepest drilled in that part of Florida that developed detailed information for future reference. In addition, innovative methods of drilling and testing were utilized to collect the necessary information for evaluation.

We appreciate the valuable support and suggestions you provided throughout this study. It has been a pleasure working with you on this project and we sincerely hope we may be of service in the future.

Sincerely,

GERAGHTY & MILLER, INC.

James J. Geraghty
President

Enclosure

FEASIBILITY OF DEEP-WELL WASTEWATER DISPOSAL AT THE SAND LAKE ROAD TREATMENT FACILITY, ORANGE COUNTY, FLORIDA

EPA Project No. C120314.010

prepared for

THE BOARD OF COUNTY COMMISSIONERS

and

THE PUBLIC UTILITIES DIVISION

in cooperation with

VTN Inc.
Consulting Engineers
712 West Gore Street
Orlando, Florida

submitted by

GERAGHTY & MILLER, INC.
Consulting Ground-Water Hydrologists and Geologists
13902 North Dale Mabry Highway
Tampa, Florida

September, 1977

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SUMMARY

In 1976 and early 1977, an injection-test well was drilled at the Sand Lake Road Wastewater Treatment Facility in Orange County, Florida, through marine sediments composed chiefly of limestone and dolostone into metamorphic basement rock, to a final depth of 6,193 feet below land surface. The purpose of the well was to locate and test potential wastewater injection zones for the disposal of 15 mgd (million gallons per day), and to determine the presence and adequacy of overlying confining units. Originally, the proposed program was to drill through the base of the fresh-water zone of the Floridan Aquifer and to set a casing in the first underlying confining unit to protect the fresh water. Then exploratory drilling was to proceed through an anticipated high-sulfate, low-chloride, brackish-water zone to a depth where the TDS (total dissolved solids) content exceeded 10,000 mg/l (milligrams per liter). This zone was to be tested and then isolated with a liner casing.

However, the test-well program was changed because hydrogeologic conditions differed markedly from those anticipated from the initial review of available data. Based upon information obtained during this investigation, a high-sulfate, brackish-water zone was not found in the expected interval from about 1,400 to 2,100 feet. Below the 2,100-foot depth, through a limestone and dolostone of low perme-

ability, the water quality deteriorated rapidly from brackish water to brine. Therefore, the liner casing was eliminated from the design and a single 12-inch-diameter casing was set through the fresh-water zone in the brine to a depth of 2,420 feet.

An examination of the drill-cutting samples and an analysis of the response of the water level in the well during the air-reverse drilling below 2,420 feet indicated that the permeability of the rock was low. Although the original test program envisioned a series of fresh-water injection tests as drilling progressed, the low permeabilities necessitated a change in plan, and instead, short-term aquifer tests were conducted so as not to interfere unduly with the drilling operation. The data from these tests also indicated that the transmissivity of the rock penetrated by the well bore was extremely low; the first significant increase in transmissivity was found below about 5,400 feet. Based on the results obtained from these preliminary tests, a final 48-hour injection test was designed.

The final injection test was run in three steps. Initially, the injection rate was 200 gpm (gallons per minute). After a relatively short period of time, the rate was increased to 500 gpm, and finally to 700 gpm. A plot of the pressure at the wellhead after apparent stabilization versus injection rate followed a linear relationship of about 2 gpm/psi (gallons per minute per pound per square inch) or 0.9 gpm/ft of head increase. The head recovery data were used to calculate the apparent transmissivity, of the aquifer, which is a measure of the rate at which water is conveyed through the aquifer. These values ranged from 1,200 to 2,000 gpd/ft (gallons per day per foot) of head increase in the aquifer.

Calculations using the Theis nonequilibrium formula were made of pressure build-up in a single well with an injection rate of 1 mgd. These were then used to calculate pressure build-up for an assumed line of injection wells spaced 1,000 feet apart. An aquifer transmissivity of 2,000 gpd/ft and a coefficient of storage of 1×10^{-4} were used for these calculations. A very important assumption made in using this model was that there would be no long-term stabilization of pressure in the aquifer.

For a line of eight wells injecting a total of 8 mgd, the calculations show that the outermost wells would have an injection pressure of approximately 291 psi after one day, while the two wells at the center of the line would show approximately 331 psi. After one year, the respective pressures would be about 967 and 1,090 psi; and after 20 years, the respective pressures would be about 1,384 and 1,508 psi. If a continuous injection rate of 15 mgd were maintained for 20 years, the outermost wells and center wells would show pressures of about 2,170 and 2,450 psi, respectively. These are injection pressures at land surface and do not include friction loss in the well, which would be about an additional 10 psi. In essence, a zone of high transmissivity suitable for the injection of large volumes of waste water was not found at this site.

The predominant nature of the porosity of the injection zone is intergranular space and pinpoint vug openings. Because of this, any suspended solids in the injecta would tend to clog the aquifer. Also, bacterial growth within the well might constitute another potential clogging problem. Before any injection system could be planned, these problems would have to be evaluated.

CONCLUSIONS

1. Based upon the hydrogeologic findings of this investigation the disposal of treated wastewater by deep well injection does not appear feasible at this location.

2. Ultimately, 15 mgd of wastewater might be disposed of through an injection well system, but the injection system would require at least 15 wells and very high pressure, ranging from about 1,091 to 2,450 psi over the next 20 years.

3. Based on the interpretation of the pumping and injection tests, the values of the apparent transmissivity for the open hole in the interval from 2,420 to 6,193 feet ranged from 1,200 to 3,600 gpd/ft.

4. The specific capacity of the well for fresh-water injection appears to follow a linear relationship of about 2 gpm/psi or 0.9 gpm/ft of head increase.

5. The most transmissive zone in the open bore hole appears to be in the interval from approximately 5,400 to 5,900 feet.

6. Based on an inspection of the drill-cutting samples, the core from 5,584 to 5,613 feet, and the well-bore geophysical logs, the predominant porosity type appears to be intergranular space, pinpoint vugs, and fossil molds.

7. During the injection test, no change of water level in the monitor tube was observed as a result of the injection.

8. The Cedar Keys Formation, composed chiefly of interbedded anhydrite and dolostone in the interval from about 2,120 to 3,154 feet, forms a confining unit.

Jim Miller, USGS says top of Cedar Keys is at 2368'.

9. In the Cedar Keys Formation and the sediments of Cretaceous age, evaporites fill much of the available pore space and fractures.

10. A zone of predominantly fresh water was found in the interval from 1,400 to 2,100 feet, rather than the high-sulfate, brackish water that had been expected.

Jim Miller, USGS, says top of Oldsmar is at 1834'.

11. The dolostone of the Oldsmar Limestone generally appears less dense and more porous than the dolostone of the overlying Lake City and Avon Park Limestones.

12. Observed on the video tape of the well bore were numerous high-angle fractures in the Floridan Aquifer, some of which show evidence of solutional widening.

13. Analysis of water-level data from the monitor tube and the water-supply well indicated that the Floridan Aquifer acts as a single hydrologic unit to a depth of about 2,030 feet.

INTRODUCTION

During the period from September, 1975 to April 15, 1976, personnel of Geraghty & Miller, Inc., provided professional services to VTN, Inc., consulting engineers to Orange County, Florida, in connection with the planning and design of an injection-test well program to determine the feasibility of disposing of 15 mgd of treated wastewater at the Sand Lake Road Sewage Treatment Plant shown in Figure 1. Following this, Geraghty & Miller, Inc., was retained by VTN, Inc., to provide hydrologic and geologic consulting services during the drilling and the testing phase of the program, which was completed in April, 1977. Two wells were drilled on property owned by Orange County at the Sand Lake Road Treatment Facility. Initially, a water-supply well was constructed in the Floridan Aquifer to a depth of 450 feet, to furnish water for drilling operations and for the injection testing. Subsequently, an injection-test well was installed to a depth of 6,193 feet.

The concept of injecting wastes into geologic formations is an accepted disposal practice in many parts of the country. The regulations controlling such practices are generally designed to prevent contamination of the fresh ground-water resources and require that an applicant for a disposal well provide certain kinds of technical information relating to geologic requirements and ground-water quality criteria. For example, the disposal zone must have sufficient porosity

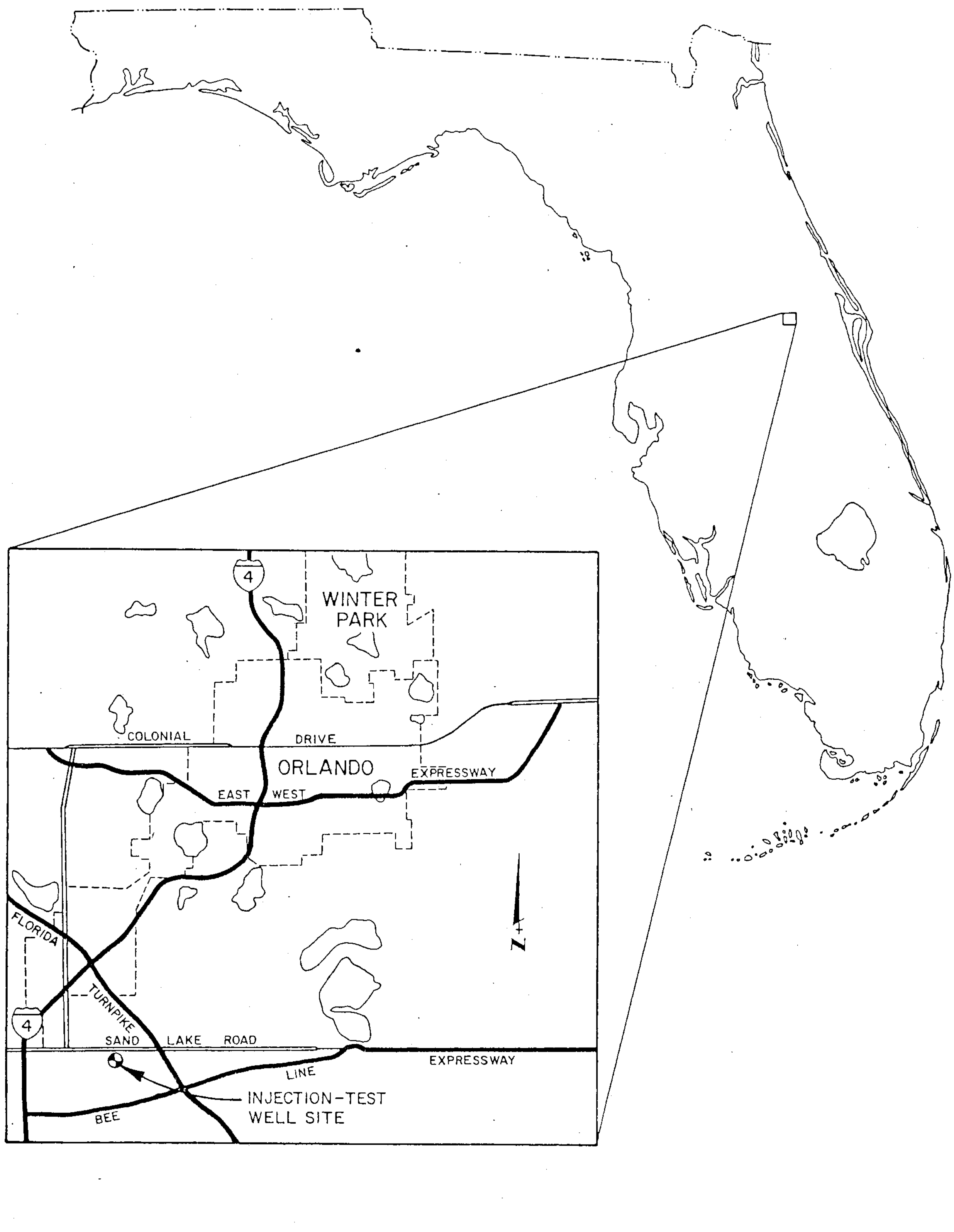

Figure 1. Injection-test well site location.

and permeability to permit the injected fluid to move through the formation, and also must be of sufficient areal extent to accept the volume of waste to be injected. The disposal zone must be confined by material of low permeability of sufficient thickness and areal extent to prevent the movement of the injected wastewater into formations containing fresh water. The proposed U.S. Environmental Protection Agency regulations specify that the formation into which disposal takes place must contain saline ground water with a TDS concentration greater than 10,000 mg/l. In addition, the State of Florida requires that the first zone of sufficient permeability containing saline water below the confining unit must be reserved for monitoring purposes and as a possible buffer zone should leakage from the injection zone occur.

The injection-test well constructed for this study was drilled to a depth of 6,193 feet below land surface to locate and test potential wastewater injection zones and to determine the presence and adequacy of overlying confining units. Basically, the initial test-well program called for drilling through the base of the fresh-water zone of the Floridan Aquifer and setting a 20-inch-diameter casing in the first underlying confining unit. Then the drilling was to proceed through an anticipated zone of high-sulfate, low-chloride, brackish water to the point where the TDS exceeded

10,000 mg/l. This zone was to be tested and then isolated with a 12-inch-diameter liner casing. However, because the field conditions differed from those anticipated from the initial review of available information, the well design and the testing program were modified to fit the site conditions. The anticipated high-sulfate, brackish-water zone, which might have been suitable for injection, was not found. Therefore, the proposed 20-inch-diameter casing was eliminated in the revised program, and the 12-inch-diameter casing was set to a depth of 2,420 feet, which placed it through the fresh water into brine with a TDS slightly in excess of 100,000 mg/l.

The data collected during drilling and testing consisted of drill-cutting samples, cores, well bore geophysical logs, water samples for chemical analyses, water levels in the wells, and injection and pumping test data. The well-construction information included drilling rates, drilling fluid density, plumbness and alignment of the well bore, casing lengths, cementing procedures, and cement slurry volumes and densities.

A slug injection test and four short-term pumping and recovery tests were conducted to develop estimates of transmissivity of the materials penetrated as the well was deepened. In the final phase of the program, a fresh-water injection test was conducted in the entire section of the well bore, during which geophysical logs were run. The analyses and interpretation of all the data formed the basis for the feasibility evaluation of injecting large volumes of treated effluent.

ACKNOWLEDGMENTS

Geraghty & Miller, Inc., extends its appreciation and thanks to the various people and organizations who provided assistance during the injection-test well program. Thanks are due to Mr. Richard G. Shanklin, Jr., P.E., of VTN, Inc., for his cooperation, advice, and assistance. The U. S. Geological Survey, Water Resources Division, furnished a number of important well bore geophysical logs to supplement the suite of geophysical logs specified in the contract documents. Messrs. Eugene Coker, of the Environmental Protection Agency, and Charles Tibbals, of the U. S. Geological Survey, provided many thoughtful discussions and gave freely of their experience. Mr. Thomas Scott of the Florida Bureau of Geology provided advice and suggestions during test-well drilling and later in the review of geologic samples. Thanks are also due to Messrs. E. P. West, Jr., P.E., Director of Utilities, and C. L. Goode, P.E., former Director of Utilities, and various members of their staff for assistance and cooperation.

INJECTION-TEST WELL DRILLING PROGRAM

Construction of the Water-Supply Well

In order to supply water for drilling operations and for the injection testing, a water well was constructed on-site as the first step in the program. In the initial attempt to drill this well, lost circulation in a cavity at 127 feet and settlement of the pit casing at the surface necessitated abandonment of the well, which was then cemented back to land surface in accordance with State requirements. After moving the drilling rig 35 feet westerly to a new location, the water well was finally constructed to a depth of 450 feet. The upper part of the well consisted of 57 feet of 26-inch-diameter pit casing cemented in place inside a 29-inch-diameter hole. Then, a 25-inch-diameter hole was drilled to 120 feet and an 18-inch-diameter casing set and cemented in place. Below this string of casing, a 17-1/2-inch-diameter hole was drilled to the depth of 450 feet. Upon completion of drilling and development, a short-term pumping and recovery test was conducted to determine the yield of the well. The aquifer transmissivity determined from the test was about 600,000 gpd/ft, which indicated that the well could easily yield the 1,000 gpm required for injection testing.

Construction of the Injection-Test Well

Drilling of the injection-test well started on April 26, 1976, and was completed on March 26, 1977, at a depth of 6,193 feet below land surface, which was approximately 60 feet into metamorphic basement rock. Essentially the drilling and testing was completed in two phases. The Layne Atlantic Company was the low bidder and prime contractor for the program and completed the first phase, which consisted of drilling and casing through the fresh-water and saline-water zones to a depth of 2,420 feet. The second phase entailed drilling to the 6,193-foot T.D. (total depth), running well bore geophysical logs, and performing hydrologic tests. About a two-month delay was experienced between the first and second phases of the program, because Layne Atlantic's intended subcontractor for the second phase was unable to fulfill its commitment. As a result, Layne Atlantic also completed the second phase by using drilling equipment and supervisory personnel from another Layne division in Texas.

Two drilling techniques were employed to construct the well. Initially, conventional mud-rotary drilling was used until a loss of drilling fluid circulation occurred at a depth of 132 feet. Then, air-reverse rotary drilling was used to complete the well. At the start of the program, it was not known if the test well could be successfully drilled to the planned depth of 6,500 feet by the air-reverse technique, because no records of wells in Florida were found to indicate that this depth could be reached by that method. Thus, the drilling procedure was, to a certain degree, experimental for the depths involved.

There were several important reasons for using this method to drill the well. The air-reverse technique has the advantage of providing a clean well bore with no mud-cake on the side-walls of the well, unlike conventional mud-rotary drilling procedures. A mud-cake results in the reduction of permeability of the well bore and the formation immediately adjacent to the well bore, which would interfere with hydrologic testing if not removed. Because there were no facilities to dispose of the salt-water or brine-contaminated drilling mud that would be produced during pretest well development, the air-reverse technique was selected to start the second phase drilling. Alternative plans for drilling were developed that could be implemented if borehole conditions necessitated them. For example, if a depth were reached that required the well to be completed by conventional fluid circulation, an organic-base fluid additive was planned for use. During well development procedures, such an additive could be broken down by chemical means, thus facilitating well development.

Initially, a 48-inch-diameter hole was drilled to 66 feet below land surface and a 42-inch O.D. (outside diameter) casing was installed and cemented in place. Construction details of the well are shown in Figure 2. Next, a 12-1/4-inch-diameter pilot hole was drilled to 132 feet, where drilling fluid circulation was lost in a cavity. Several attempts were made to regain circulation by pumping cement and gravel into the cavity, but were unsuccessful. Then, the pilot hole was reamed to 40 inches in diameter to a depth of 120 feet, and a 32-inch O.D. casing was installed and cemented in place. After this casing was installed, another attempt was made to regain circulation but was also unsuccessful. At this point, the drilling of the 12-1/4-inch-diameter pilot hole continued by the air-reverse technique to a depth of 1,461 feet.

During the drilling operation, well bore verticality surveys were run by wire-line inside the drill pipe every double random length of pipe. Several of the surveys indicated that the well bore alignment was not within the 0.5 degree design specification. In an attempt to straighten the well bore, the well was reamed with a nominal 15-inch-diameter drill bit with a drill-stem stabilizer. After one month of reaming, the well bore misalignment still remained greater than the specified 0.5 degree at several depths.

Prior to the completion of reaming to the depth of 1,461 feet, the U.S. Environmental Protection Agency requested that a representative bottom hole water sample be collected

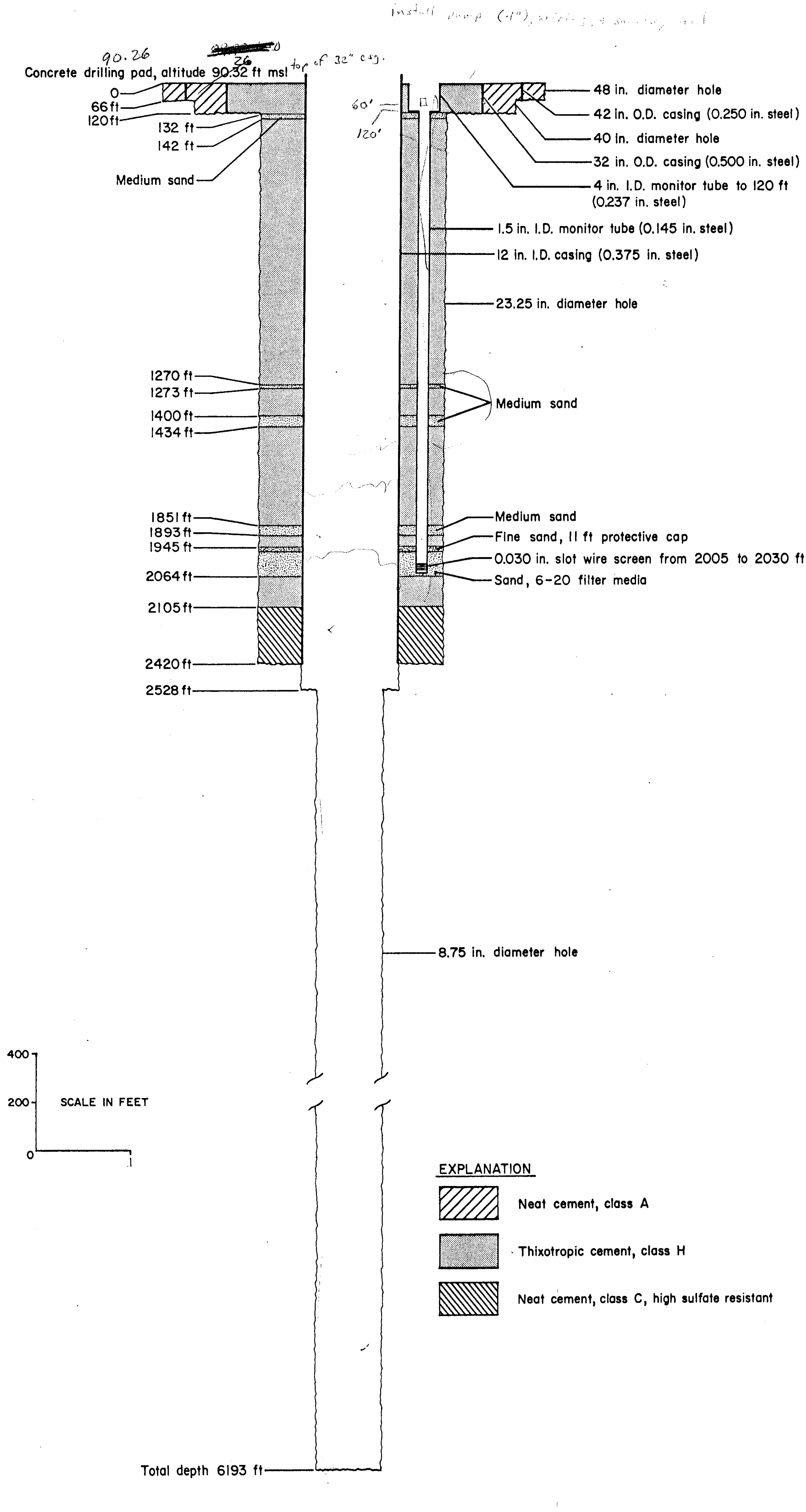

Figure 2. Construction diagram of injection-test well.

by isolating the well below 1,375 feet with a packer. Because the maximum hole diameter in which a standard packer can be set is 14 inches, the 15-inch-diameter ream was stopped at 1,350 feet. The lower section of the well was kept at the original 12-1/4-inch diameter in order to seat the packer. After the cuttings from the reaming operation were cleaned from the bottom of the well, a caliper log was run in the well. In the bottom 100 feet of the bore hole, an expanded scale caliper log was run to help locate a section to seat the packer. An expandable rubber element packer was set between the depths of 1,369 and 1,375 feet. After the packer was set and the ports opened, water levels were measured inside the drill stem and in the annulus of the well. A submersible pump was installed inside the drill pipe and water was then pumped for about 5 hours from the interval between 1,375 and 1,461 feet, after which a water sample was collected.

packer

While not releasing the contractor from the requirement of meeting verticality specifications, a decision was made to continue the pilot-hole drilling operation. The pilot-hole drilling continued to a depth of 2,528 feet. At this depth, the discharge water from the drilling operation became brackish and the drilling was stopped. A full suite of well bore geophysical logs was run and a video tape survey was made of the well bore. Based upon a review of the drill cuttings and analysis of the geophysical logs, a casing depth of 2,420 feet was selected, and the pilot hole was then reamed to 15 inches in diameter in the interval from 1,461 to 2,425 feet.

The verticality survey equipment used on the site indicated that the well bore alignment in the interval from 1,461 to 2,528 feet was greater than 1.0 degree from vertical in a number of places. Before any additional time was spent trying to straighten the hole, a well bore directional and alignment survey was run by Sperry-Sun, Inc.; the results of this survey are contained in Appendix A. This information indicated that the well appeared to be straight enough to run the casing, monitor tube, and tremie pipe without difficulty. Based on this, the well bore was reamed to 23-1/4 inches in diameter from 120 to 2,425 feet. This diameter was necessary to accommodate the 12-inch-diameter casing, the 1-1/2-inch-diameter monitor tube, and the 2-inch-diameter tremie pipe.

The 12-inch-diameter casing was installed to the depth of 2,420 feet, with the monitor tube attached so that both were emplaced simultaneously. The monitor tube was equipped with a 25-foot length of 1-1/2-inch-diameter, 0.030-inch-slot wire screen, which spanned the interval from 2,005 to 2,030 feet.

Two types of cement were used to grout the casing and monitor tube in place. Because the sulfate concentration in the ground water exceeded 5,000 mg/l below about 2,395 feet, due to the presence of brine, a class C high-sulfate resistant type cement with high early strength was used to pressure grout the bottom of the 12-inch-diameter casing in place. All other cement placed around the casing was a class H thixotropic cement.

Two stages of thixotropic cement were tremied in place to bring the grout level up to the base of the monitor zone at a depth of 2,064 feet. Then, 6-20 filter media was placed for 108 feet through the zone to be monitored. This was capped with about 11 feet of a fine sand to prevent the invasion of cement in the gravel pack; this brought the sand fill up to a depth of 1,945 feet.

About 3,860 cubic feet of thixotropic cement was placed above the monitor zone in six stages to bring the grout up to about 1,643 feet. After the setting time for the seventh stage, the top of the cement was tagged at a depth of 1,893 feet, indicating that approximately 3,500 cubic feet of cement had been lost through a vertically oriented fracture zone at a depth of about 1,887 feet. This area was then filled with sand back to 1,851 feet.

Subsequent to this, no attempts were made to cement through cavities or large fractures that could be identified on the geophysical logs or the video tape of the well bore, and instead, sand was placed in the annulus through those areas, as indicated on the construction diagram in Figure 2. Prior concurrence with this procedure was obtained from the Florida Department of Environmental Regulation. The remainder of the cementing was completed in twenty-six stages. In the course of the cementing operations, temperature logs were run inside the casing periodically to assist in locating the top of the cement as it was placed in stages. Completion of the grouting marked the end of the first phase of the project.

In preparation for the second phase of drilling, the concrete drilling pad was enlarged and equipped with curbs to reduce potential for salt-water contamination of the shallow ground water by accidental spills. A large drilling rig capable of completing the well to a depth of 6,500 feet was then set up, along with a closed circulation system.

Because the remainder of the drilling would be entirely in formations that contained brine (TDS greater than 100,000 mg/l), a closed drilling fluid circulation system was maintained. Initially, the circulation system consisted of a series of three settling tanks for solids removal, with water and cuttings from the air-reverse drilling being discharged into one tank connected by an overflow to the other two tanks. Water from the last tank was returned by gravity flow to the well bore.

The second phase began on January 26, 1977. The first step consisted of drilling out the cement plug and cleaning the hole with an 11-1/4-inch-diameter bit to the original depth of 2,528 feet. The bore hole diameter then was reduced to 8-3/4 inches and drilling was continued to a depth of 6,193 feet.

Several times during the drilling, circulation was lost due to the increased density of the drilling fluid, which was the result of both the brine density and the suspended solids load. Fresh water was periodically added to the circulation system to dilute the brine. In addition, to help alleviate the suspended solids problem, a fourth settling tank was added in series to the existing system. On two occasions after cleaning the settling tanks, fresh water was added to the system and sodium chloride was used to increase fluid density. To maintain and control circulation, the fluid density and suspended solids of the water in the last tank were measured about every four hours or as conditions warranted.

At a depth of 6,133 feet, metamorphic basement rock was encountered. Drilling continued for an additional 60 feet into the metamorphic rock, at which point the drilling was terminated. Upon completion of drilling, another full suite of well bore geophysical logs was run.

Geophysical Logging

The two complete suites of well bore geophysical logs were run in the test well by Birdwell (Birdwell Division, Seismograph Service Corporation). The suites included: induction electrical survey (IES), caliper, temperature, natural gamma ray, 3-dimensional velocity, formation density, and neutron. For the final survey, well bore fluid resistivity, fluid pressure, and three thief samples were added to the logging service.

Geophysical logs are used to provide qualitative estimates of formation water quality, identify primary and secondary porosity, define fractures, and assist in mineral identification. This information supplements the drill-cutting samples and cores in developing an understanding of the geologic and hydrologic framework of the system. The first complete suite of logs was run in the interval from 120 to 2,528 feet, and the second complete suite was run in the interval from 2,420 to 6,193 feet. Copies of the Birdwell logs accompany this report in a separate case. A summary of all geophysical logs and wire-line services run in the well is given in Table 1.

Table 1. - Summary of geophysical logging and wire-line services

Date	Well Depth Driller (ft)	Well Depth Logger (ft)	Logged Interval (ft)	Type of Log	Logged By
6- 7-76	1,461	1,465	120 to 1,461	Single-point electric; caliper; caliper (expanded scale from 1,280 to 1,461 feet); natural gamma ray	U. S. Geological Survey[1/]
7-28-76	1,938	1,948	120 to 1,938	Caliper; temperature; thief sample	U. S. Geological Survey[1/]
8-18-76	2,528	2,517	0 to 2,517	Video tape	Deep-Venture Diving Service[2/]
8-22-76	2,528	2,532	130 to 2,530	IES; caliper; temperature; formation density; neutron; 3-dimensional velocity; natural gamma ray	Birdwell[3/]
8-24-76	2,502	N.A.	120 to 2,345	Magnetic multishot directional survey	Sperry-Sun, Inc.[4/]
8-25-76	2,502	2,502	120 to 2,502	Fluid resistivity; flow meter; thief samples; natural gamma ray (from 1,478 to 2,502 feet)	U. S. Geological Survey[1/]
10-23-76	2,425	2,430	118 to 2,430	Caliper; flow meter	P. E. LaMoreaux & Associates, Inc.[5/]
3-28-77	6,193	6,210	2,400 to 6,140	Induction; caliper; temperature; formation density; neutron; 3-dimensional velocity; natural gamma ray; fluid resistivity; pressure; thief samples	Birdwell[3/]
4-18-77	6,193	N.A.	2,300 to 6,007	Flow meter; saliometer; temperature	Birdwell[3/]

Footnotes indicate where copies of the logs are located.

[1/] U.S. Geological Survey, Orlando and Geraghty & Miller, Tampa.

[2/] Orange County Public Utilities Office, Orlando and U.S. Environmental Protection Agency, Atlanta.

[3/] Accompany report in separate case.

[4/] Appendix A of report.

[5/] Geraghty & Miller, Tampa and P.E. LaMoreaux & Assoc., Lakeland.

A computer analysis was made of the geophysical logs for the interval from about 2,000 to 2,528 feet. This information was used to supplement the lithologic log and the water-quality data in selecting a seat for the 12-inch-diameter casing.

The video tape recording of the well bore provided qualitative information on cavern development and fracturing, which was used to assist in planning the cementing program for the 12-inch-diameter casing. Also, prior to installing the casing, a caliper log was used to assist in estimating the cement volumes.

Additional information was collected by the U. S. Geological Survey, including well bore geophysical logs and thief samples of water as the pilot hole drilling progressed to 2,528 feet. The logs, which are on file in the Orlando office of the Geological Survey, include: single-point resistivity, well bore fluid resistivity, caliper, temperature, natural gamma ray, and flow meter.

In addition to the geophysical formation logging, flow meter, salinometer, and temperature logs were run by Birdwell during the injection test to aid in evaluation of the test. A discussion of how these logs were run and their use is contained in the sections on the design of the injection test and the injection-test procedure.

Coring Program

The purpose of the coring program was to establish the presence of adequate confining units and to determine the nature of potential injection zones. Cores were not taken in the Floridan Aquifer at depths of less than 1,400 feet because it was felt to be reasonably certain that this section would contain only fresh water, although it was not known at what depth the water quality would deteriorate beyond 250 mg/l for sulfate and chloride, and 500 mg/l for TDS. A total of six cores were taken in the test well during the drilling operation; a log summarizing the core information is given in Table 2. Sections from all the cores, except from the third core, were sent to Florida Testing Laboratories, Inc., Clearwater, Florida, for measurements of permeability, dry unit weight, specific gravity, and porosity. A brief discussion of the test procedures and the results from these analyses are contained in Appendix B.

Vertical permeability measurements were performed from the bottom upward in the first five cores. The rock in the first core consisted of a low porosity dolostone and a high porosity limestone, and a section of each rock type was sent to the laboratory for analysis. The second core was cut in a more uniform dolostone, and one section from this core was tested for permeability. While cutting the third core, the core-barrel penetration stopped after about 9 feet and

Table 2. - Core log of the injection-test well

Core Number	Core Interval (feet below land surface)	Top of Core Section Tested (feet below land surface)	Permeability Measurement	Description
1	1,597-1,606	1,601	Vertical	Dolostone, medium gray, porosity-intercrystalline and moldic, grain size-very fine, good induration.
		1,603	Vertical	Limestone, white, porosity-intergranular, moldic, pinpoint vugs, grain size-medium, good induration.
2	1,713-1,727	1,722	Vertical	Dolostone, gray to brown, porosity-intercrystalline, moldic, grain size-microcrystalline, good induration.
3	1,919-1,928	--	None	Dolostone, gray to brown, porosity-intercrystalline, moldic, fracture, grain size-very fine, good induration, sucrosic.
4	2,140-2,160	2,151	Vertical	Dolostone, light gray, porosity-intercrystalline, pinpoint vugs, grain size-very fine, good induration.
5	2,546-2,565	2,559	Vertical	Dolostone, very light gray, porosity-intercrystalline, vugular, pinpoint vugs, grain size-very fine, good induration, anhydrite (10%).
6	5,589-5,613	5,590	Horizontal	Dolostone, light gray to brown, porosity-intercrystalline, pinpoint vugs, fracture, grain size-very fine, good induration, anhydrite (20%), fill in vugs and fractures.
		5,611	Horizontal	Dolostone, light gray to brown, porosity-intercrystalline, vugular, pinpoint vugs, moldic, grain size-very fine, good induration, anhydrite (20%), fill in vugs.

upon retrieval and examination, this core was found to be composed of a very fine grained dolostone that was highly fractured. No permeability measurements were made on this core, since a permeability measurement for the dolostone would not reflect the overall fracture permeability of this section.

Cores numbered four and five were cut in a fine grained dolostone and were tested for vertical permeability. The information from these two cores, the drill cutting samples, and the well bore geophysical logs demonstrated rather conclusively that the thick evaporite-dolostone sequence between about 2,380 and 2,970 feet constituted an effective confining unit, and it was then decided not to take additional cores in rocks of this kind.

Only one more core was taken, at a depth of from 5,589 to 5,613 feet, in a zone that appeared to be more permeable than had previously been encountered and in which a loss of drilling fluid occurred. This core was analyzed for horizontal permeability by testing two sections cut perpendicular to the vertical axis of the core.

HYDROGEOLOGIC FRAMEWORK

Geologic Conditions

As drilling of the test well progressed, cutting samples were collected and identified at regular intervals and a geologic log of the materials was maintained on-site. Duplicate samples of the cuttings were sent to Mr. Thomas Scott, at the Florida Bureau of Geology, Tallahassee, for further evaluation and identification of formation contacts. The information provided by the Bureau of Geology is preliminary, and the formation contacts below the Avon Park Limestone are tentative and subject to revision. The geologic log in Appendix C represents the combination of the two evaluations of the cutting samples. In addition, the lithologic logs were corrected by mineral identification from the well bore geophysical logs.

The site is underlain by 6,133 feet of marine sediments ranging in age from Recent and Pleistocene to Lower Cretaceous. These sediments are composed chiefly of limestone and dolostone. Below about 2,300 feet in the Cedar Keys Formation, the formations consist of dolostone and limestone interbedded with thick sequences of anhydrite. The evaporites were first encountered in the Cedar Keys Formation, and thereafter were found intermittently through the Cretaceous age limestones and dolostones to a depth of about 6,100 feet.

Sandstone, sandy shale, shale, and siltstone occurred in minor amounts in the Cedar Keys Formation and the underlying Cretaceous age sediments. Clastic deposits of Lower Cretaceous age occurred in the interval from 6,113 to 6,133 feet. The basement rock was identified as a micaceous schist.

Undifferentiated surficial deposits composed chiefly of sand, clay, limestone, and dolostone were present from land surface to a depth of 110 feet. The shallow water-table aquifer is in the uppermost 20 feet of sand above 10 feet of brown and gray clay. Below the surficial sediments lie sandy limestones and dolostones with a clay cement. The underlying Hawthorn Formation is composed of a very fine grained dolostone with clay cement. The clays in the surficial deposits and in the top of the Hawthorn Formation form a confining unit for the Floridan Aquifer.

The Floridan Aquifer at the site consists of almost 2,000 feet of limestone and dolostone, comprised of, from top to bottom, the lower Hawthorn Formation, the lower Ocala Group, the Avon Park Limestone, the Lake City Limestone, and the Oldsmar Limestone (Parker, 1955, and Stringfield, 1966). The lower Hawthorn Formation is chiefly a light gray, slightly porous to porous, crystalline dolostone. At a depth of about 132 feet, drilling fluid circulation was lost in a cavity and no samples were obtained for the next 20 feet. At 150 feet, the material encountered was a white, poorly consolidated, highly fossiliferous calcarenite, which marks the base of the Hawthorn. The well bore geophysical logs showed a distinct decrease in the natural gamma ray activity at this contact. The upper surface of the limestone of the Ocala Group has been deeply eroded in Orange County (Lichtler, et al, 1968), and only about 10 feet of the lower Ocala Group is present, in the interval from 150 to 160 feet.

Underlying the Ocala Group in the interval from 160 to 540 feet is the Avon Park Limestone. The uppermost section of this formation between 160 and 350 feet consists of a white, fine to medium grained, fossiliferous calcarenite. The lower section is composed predominantly of white, pink to gray and brown, very finely crystalline dolostone and limestone. The section contains many high-angle fractures, fossil molds, pinpoint vugs, and vugs. Overall, the formation has a high porosity and contains many solution openings.

The subjacent Lake City Limestone in the interval from 540 to 1,240 feet is composed chiefly of pink-gray to brown, finely crystalline dolostone. The formation contains some highly fractured zones, one of which showed evidence of solutional development. Porosity is also present as fossil molds and pinpoint vugs. Crystalline calcite and quartz occur in minor amounts as partial filling in vugs.

The contact between the Lake City Limestone and the underlying Oldsmar Limestone is believed to be at 1,290 feet. However, the contact is not very distinct because dolomitization has destroyed the character of many of the fossils. The Oldsmar Limestone consists predominantly of alternating layers of gray, brown and cream, porous to dense, crystalline dolostone, and soft to hard, cream to tan, fossiliferous limestone and dolomitic limestone. At its upper boundary, the formation contains one 20-foot-thick bed of light gray to brown chert. Compared with the overlying formations, this section contained fewer high-angle fractures; at three depths, these fractures showed evidence of solutional development. Porosity was present as fossil molds, pinpoint vugs, and vugs. Crystalline quartz and calcite were present, probably of secondary origin, as a lining of or a partial filling of vugs. Below the 1,400-foot depth, the drill-cutting samples and the cores from the intervals 1,597 to 1,606 feet, 1,713 to 1,727 feet, and 1,918 to 1,928 feet, were examined closely for the presence of gypsum, selenite, and anhydrite, but none was found. The formation contained many peat films on bedding planes. Numerous thin zones of porous, granular, sand-like dolomite were present. The dolostone of the Oldsmar generally appears less dense and more porous than the dolostone of the overlying Lake City and Avon Park Limestones.

The formation contact between the Oldsmar Limestone and the Cedar Keys Formation was not detected from the drill cutting samples. However, the top of the Cedar Keys generally shows a low resistivity curve on electric logs due to a distinctive lithologic change (Chen, 1965). On this basis, the formation top was tentatively picked at 2,120 feet from a low resistivity curve on the induction and short normal logs, but this pick may be somewhat low according to structural contours on the top of the formation in Chen's report. The base of the formation was established at a depth of 3,154 feet.

The Cedar Keys Formation is composed mainly of a light gray, very finely crystalline, slightly porous dolostone, interbedded with thick sequences of anhydrite. Gypsum and selenite commonly occur as fill in veinlets and vugs. Because of its density and lack of chemically bound water, the anhydrite beds show very distinctly on the geophysical logs. The interval from about 2,300 to 2,970 feet is predominantly anhydrite with interbedded dolostone. Fractures were noted in viewing the video tape, but in this section they appeared to be filled with evaporites. Two cores were taken in this formation in the intervals from 2,140 to 2,160 feet and 2,546 to 2,565 feet. A section from the second core in this interval contained a high-angle fracture filled with evaporites and large vugs also filled with evaporites. Laboratory analyses of the cores (Appendix C) indicated a very low permeability.

Dolostone, limestone, calcarenite, evaporites, and some sandstone and chalk of Cretaceous age underlie the Cedar Keys Formation, extending downward from 3,158 to 6,113 feet. The Upper Cretaceous age rocks in the interval from 3,158 to 3,568 feet are composed chiefly of dolostone, limestone, and calcarenite. The dolostone is light gray to pink-gray, slightly porous to porous, hard, and finely crystalline. Anhydrite, gypsum, and selenite occur as fillings in vugs in the dolostone. The limestone is granular, very fine to medium, white to very light gray and pink-gray, slightly porous, and medium hard. The calcarenite is white to very light gray, medium grained, fossiliferous, and chalky.

The Lower Cretaceous rocks consist of dolostone, limestone, calcarenite, sandstone, chalk, and anhydrite. The calcarenite occurs in the Lower Cretaceous to a depth of about 4,000 feet and is white to very light orange and gray, fine, chalky, and hard to soft. The limestone is white, very finely crystalline, porous, and soft. Through the interval from about 3,568 to 5,275 feet, the soft chalky limestone predominates. A light gray sandstone with glauconite and traces of pyrite, phosphorite, and mica occurs in the interval from 5,275 to 5,355 feet. Below the sandstone and to a depth of about 6,113 feet, there is a light gray to gray-brown, slightly porous to porous, hard dolostone. Interbedded with the dolostone are several lenses of anhydrite that show up distinctly on the geophysical logs. Anhydrite, gypsum, and selenite commonly occur as fillings in veinlets, vugs, and fossil molds.

The interval from 6,113 to 6,133 feet consists of a green, sandy, shale. Metamorphic basement rock occurs at 6,133 feet and was identified as a micaceous schist with some granitic rock. Exploratory drilling in this material continued for an additional 60 feet and then was terminated.

Overall, the Floridan Aquifer consists of about 2,000 feet of limestone and dolostone. The uppermost part of the aquifer is the lower Hawthorn Formation and the base of the aquifer is in the Oldsmar Limestone. The dolostones in the Avon Park and Lake City Limestones are more dense than the dolostone of the Oldsmar. The limestones and dolostones are predominantly porous and permeable throughout the section and contain no distinctive confining units. Evaporitic minerals were not found until the Cedar Keys Formation. No zones suitable for injection were found within the aquifer.

The Cedar Keys Formation consists of about 1,000 feet of alternating beds of anhydrite and gypsiferous dolostone. This formation would serve as an effective confining unit for injection into deeper sediments.

Generally, the limestones and dolostones of Cretaceous age have a fine texture. No zones of high porosity suitable for the injection of large volumes of wastewater were found in these sediments. For the most part, within and below the Cedar Keys Formation, the pore spaces were found to be filled with evaporites.

Evaluation of Ground-Water Levels

Water levels in the water-supply well were measured and recorded daily for the period beginning June 4, 1976, and ending April 18, 1977. As shown in Figure 3, the water levels gradually rose through the summer months to mid-September and then began dropping until late October. After that time, the levels rose slightly for several weeks, remaining relatively constant through winter until mid-March, and then began to sharply decline throughout the remainder of the period of record, reflecting a lack of rainfall in March and April of 1977.

Water levels in the monitor tube in the injection-test well were first recorded on January 26, 1977, and were measured intermittently from that date until the end of data collection in April, 1977. Water levels in the monitor tube prior to February 9, 1977, were 15 to 20 feet lower than levels taken later because brackish water was present initially in the monitor tube. On February 9, the monitor tube was

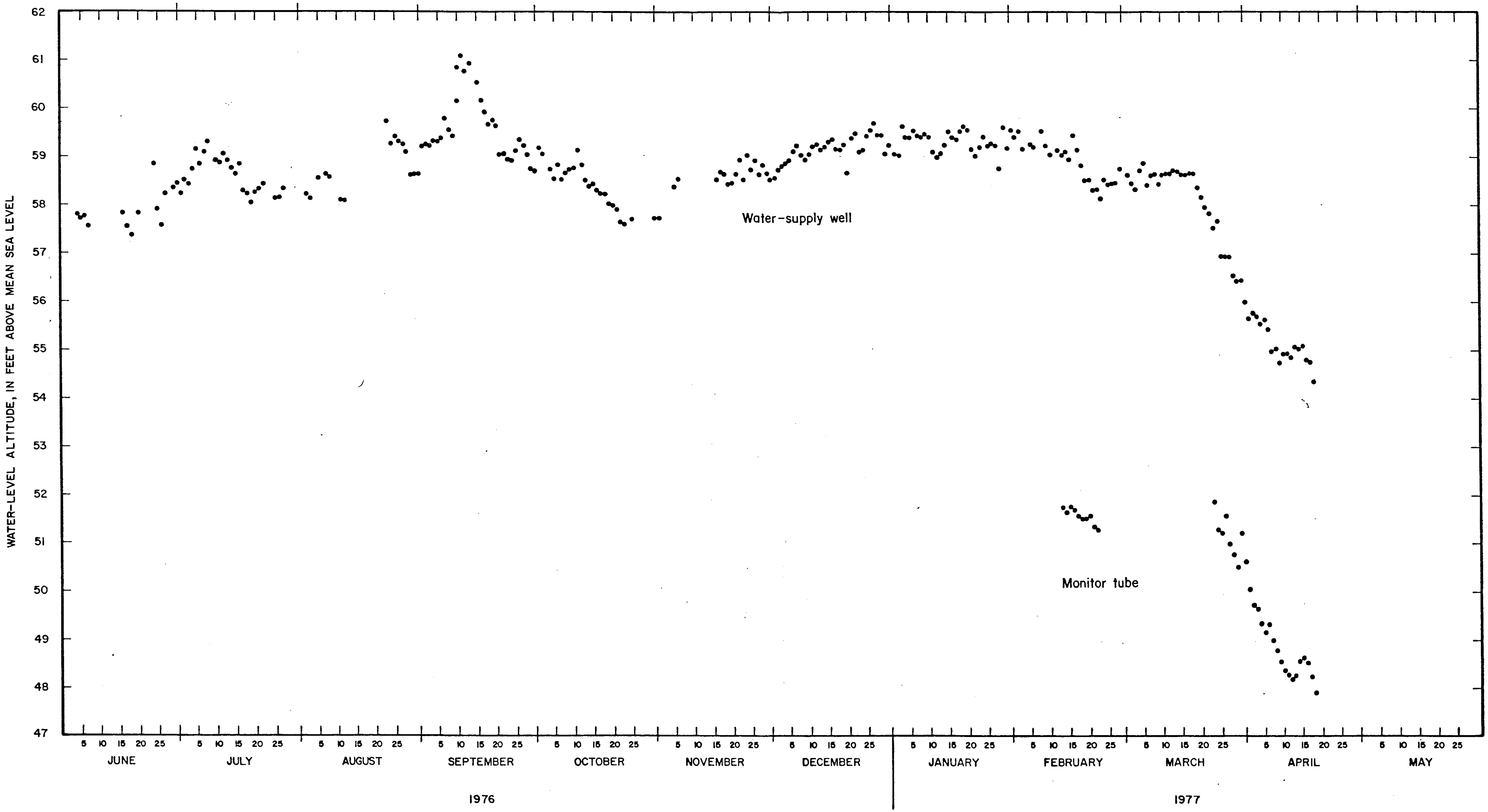

Figure 3. Hydrographs of daily measurements in the water-supply well and the monitor tube.

pumped at about 8 gpm for several hours and the specific conductance of the discharge water monitored. In a very short period of time, the conductance stabilized and indicated the presence of fresh water. Pumping was then terminated, and water levels were monitored for about 9 days more. The monitor tube was again pumped for more than 600 hours to obtain water samples. Water levels were then measured and recorded daily to establish a seasonal trend prior to the injection test; these levels are shown in Figure 3. The water levels measured in the monitor tube show a decline similar to that of the water levels in the water-supply well.

The daily water-level measurements in the water-supply well and monitor tube were supplemented by hourly water-level readings for several periods of about two weeks' duration each, whenever the drilling schedule permitted. The hourly levels and corresponding barometric pressures are shown in Figures 4 and 5. In the water-supply well, marked fluctuations occur over short periods of time, with changes of as much as a half-foot in less than six hours. Water levels were generally highest in the early morning and lowest in the late evening. This daily fluctuation is believed to have been caused by nearby pumping, perhaps from the public water-supply well operated by the Orlando Utilities Commission less than one-half mile away.

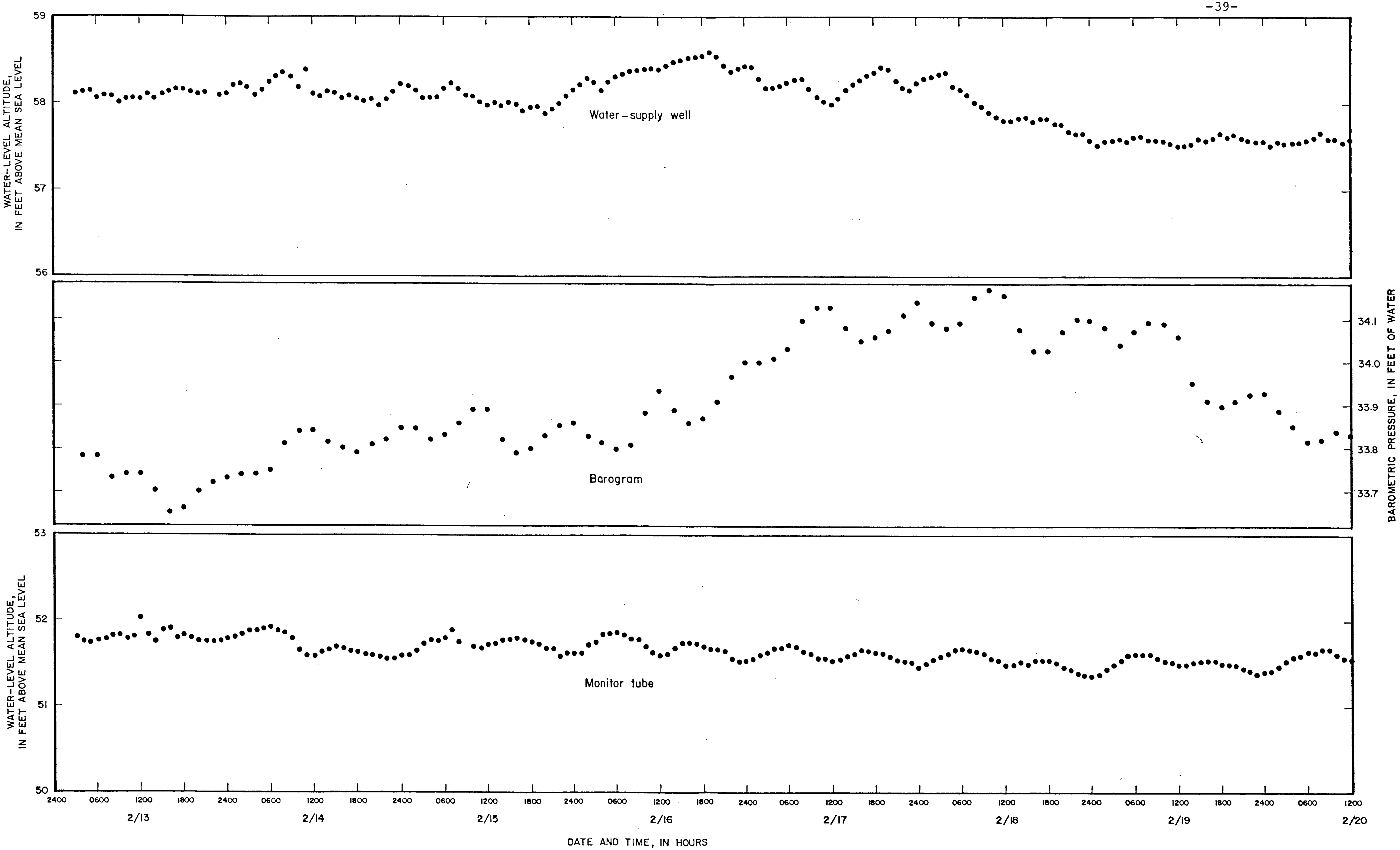

Figure 4. Hydrographs of hourly measurements in the water-supply well and the monitor tube, and barogram for the period from February 13 to February 20, 1977.

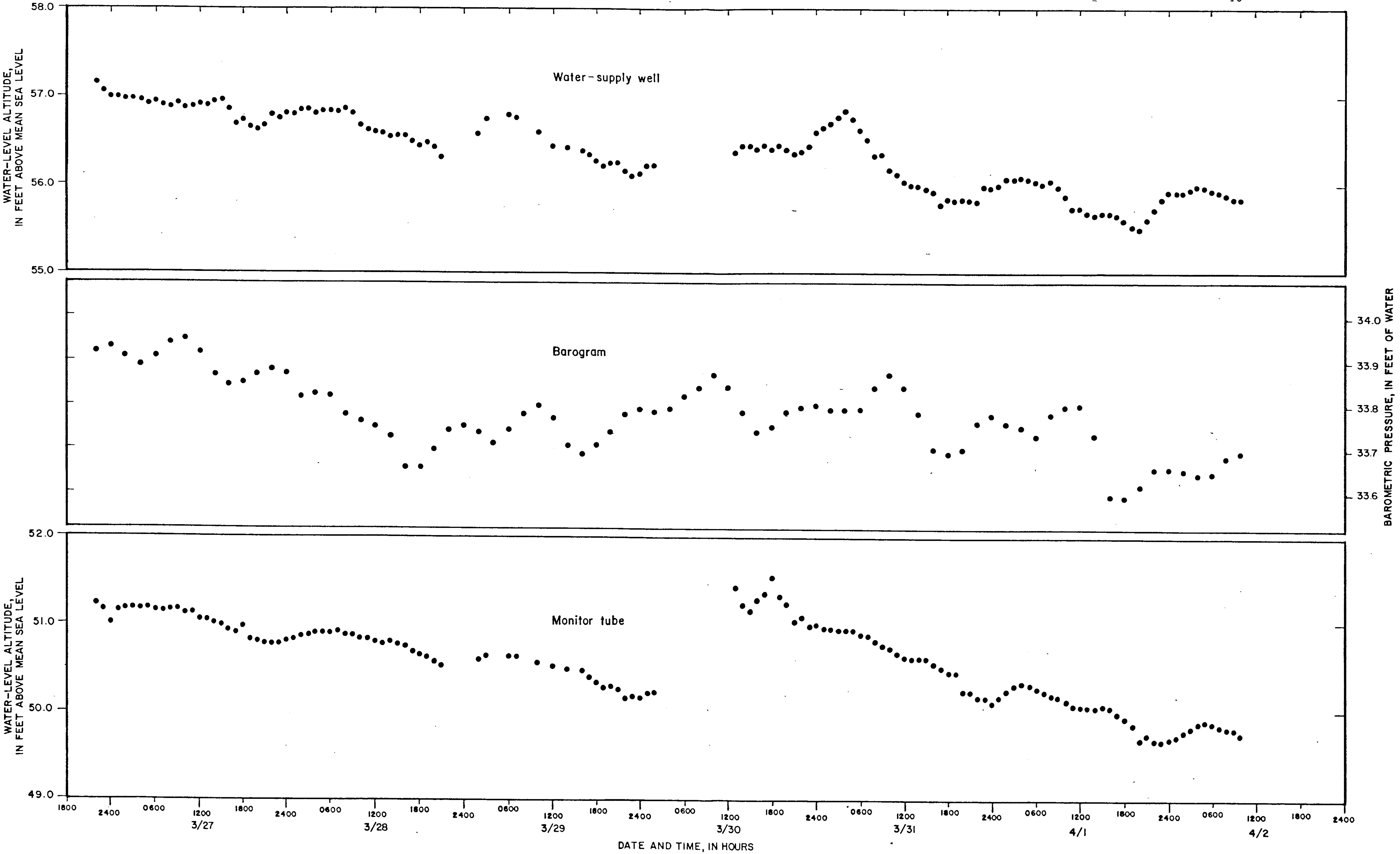

Figure 5. Hydrographs of hourly measurements in the water-supply well and the monitor tube, and barogram for the period from March 27 to April 2, 1977.

The monitor tube water-level plot in Figure 4 shows a strong semi-diurnal rise and drop, with peaks occurring around 0600 hours (6 a.m.) and 1600 hours (4 p.m.) and lows occurring around noon and midnight. As shown in Figure 5, these fluctuations are not as apparent for the period from March 26 through April 2, because of the masking effect of the pronounced water-level decline occurring at that time. Overall, the water-level barometric response in the monitor tube is more apparent than in the water-supply well, probably because pumping in the zone monitored by the water-supply well masks out these effects.

Figures 3, 4, and 5 show very similar trends in water levels in both the water-supply well and the monitor tube, with the levels in the monitor tube having a smaller amplitude. For the period of February 13 through 22, water levels in the water-supply well and monitor tube dropped 0.72 foot and 0.46 foot, respectively. Later, from March 23 through April 18, the levels dropped 4.10 and 3.98 feet respectively. One exception to the more or less similar trends shown on this figure is after the pumping and recovery test in the injection test well that ended at about noon on March 30. The behavior of the water levels in the monitor tube at that time may be a result of heat exchange, as warmer water was pumped up through the injection-test well from very deep formations.

The strong similarities in water-level changes are an indication of hydraulic connection between the zones monitored at about 450 feet and 2,000 feet below land surface, and indicate that there is no areally extensive confining unit between the two zones. This information is in agreement with observations from the geologic and geophysical logs, which show that the section is composed predominantly of porous and permeable dolostones and limestones.

During the packer test, which was designed to obtain a bottom-hole water sample, water levels were measured in the annulus above the packer in the interval from 120 to 1,369 feet and in the drill stem for the interval below the packer from 1,375 to 1,461 feet. These water levels were 57.47 and 52.40 feet msl (mean sea level), respectively, and showed a downward hydraulic gradient between the zones of 5.07 feet. Comparison of water levels between the 450-foot-deep water-supply well and the 2,000-foot-deep monitor tube in the injection test well show a downward gradient of about 7 feet. This information indicates that the site is located in or near a significant recharge area for the Floridan Aquifer. The water-level information and geologic information indicates that a relatively deep fresh-water circulation system exists at the site.

Ground-Water Quality

As part of the data collection in the first and second phases of the program, water samples were collected and analyzed for a number of chemical constituents. Starting at a depth of 900 feet, water samples were collected from the drilling discharge water at about 100-foot intervals and sent out for laboratory analysis. The discharge water from the air-reverse drilling was also field checked for specific conductance at 5-foot intervals between 1,400 and 2,528 feet. Whenever the specific conductance measurements showed an increase, a water sample was collected for laboratory analysis. During the packer test, the specific conductance of the discharge water was measured, and a water sample was collected just prior to the termination of pumping for laboratory analysis. From time to time during the drilling operation and before setting the 12-inch casing at 2,420 feet, the U. S. Geological Survey collected thief samples from the well for chemical analysis. The results of all these analyses are contained in Appendix D.

The water samples collected during the drilling operation cannot be considered true bottom-hole water samples, because water continuously moved down the well bore, as drilling proceeded, from shallower into deeper beds. A flow-meter survey and temperature log verified downward flow to a maximum depth of 2,025 feet.

Before the drilling program began, it had been theorized that a zone of high sulfate water might be present between depths of 1,400 and 2,000 feet. Such zones have been encountered elsewhere in Florida and have been attributed to the presence of sulfate-bearing minerals in the rock. The water samples collected in the injection test well at these depths showed very low concentrations of sulfate, which is supported by the absence of sulfate minerals above a depth of about 2,135 feet. However, it still cannot be ruled out that highly diluted residual sea water might be present in the same zone at depths greater than about 1,500 feet. As noted above, the continuous invasion of the zone by fresh water moving downward through the bore hole may simply have masked out the natural ground-water quality at those depths.

Throughout the interval from 1,320 to 2,134 feet, the specific conductance of the water measured at 5-foot intervals ranged from 240 to 295 μmhos/cm. At 2,135 feet, the specific conductance increased to 500 μmhos/cm and gypsum was observed for the first time in the drill cuttings. This information makes it appear almost certain that high sulfate water is present below the depth of 2,135 feet, regardless of the fact that the water analyses do not show this condition.

As a result of the formation invasion by the downward movement of fresh water in the well bore, the IES log could not be used to estimate formation water quality above a depth of about 2,025 feet. At a depth of 2,113 feet, an estimate of the TDS (as equivalent NaCl) of the formation water was about 1,000 ppm (parts per million), based upon the IES log. According to a generalized map showing the base of potable water in the Floridan Aquifer, the TDS in the study area exceeds 500 mg/l and chlorides exceed 250 mg/l at a depth of about 1,800 feet (Klein, 1971). Thus, a zone in which the TDS ranges from 500 to 1,000 mg/l could exist between about 1,800 to 2,113 feet.

The water quality estimated from the IES log at the depth of 2,133 feet is about 4,500 ppm TDS and at the depth of 2,293 feet the TDS is about 10,000 ppm. Below an anhydritic dolostone in the interval from about 2,373 to 2,387 feet, the formation contained water with an estimated TDS from the IES log of 110,000 ppm. Laboratory analysis of a thief sample collected at the depth of 2,395 feet had a TDS of about 108,000 mg/l determined by evaporation at 180°C. As would be expected, through the less permeable materials where there probably exists limited fluid circulation, the water quality deteriorates very rapidly with depth.

During the second phase of the project, the drilling fluid was recirculated down the well bore after flowing through a series of settling tanks. Conductance was monitored at 10-foot intervals and soon exceeded 80,000 µmhos/cm.

Periodically during the drilling operation, the fluid density was controlled and maintained by the addition of fresh water or salt to the circulation system. Because of the adjustments in density, water samples for chemical analysis were collected infrequently. At the completion of the well, three thief samples were collected at selected depths based upon a review of the well bore fluid resistivity log. The results of all the chemical analyses on water samples collected during this phase of drilling are listed in Appendix D. These data indicate that the TDS, and therefore the fluid density, increase with depth.

In an attempt to obtain representative formation water samples for the lower zone of the Floridan Aquifer, the monitor tube in the annulus of the injection test well was pumped for over 600 hours, removing about 288,000 gallons of water. However, since the volume of water that could have moved down the borehole is unknown, these analyses may not be truly representative of the formation water. At various times during the pumping, water samples were collected for chemical analyses; the results are contained in Appendix E. At the time pumping was stopped, the water quality was fresh, with very low chlorides and sulfates.

AQUIFER TESTING

By close examination of the drill-cutting samples and by checks on the response of the well during the air-reverse drilling, a preliminary evaluation was made indicating that the permeability of the rock below 2,420 feet was low. Therefore, although the program specifications called for a series of fresh-water injection tests as drilling progressed, short-term aquifer tests were conducted instead, which could be easily set up with minimal interference to the drilling operation. The actual aquifer tests conducted in the injection-test well included injecting a slug of brine into the well, pumping brine from the aquifer, and injecting fresh water into the aquifer.

Prior to the final fresh-water injection test, a slug injection test and four pumping and recovery tests were performed to aid in determining the hydraulic characteristics of the materials penetrated by the well bore. The pumping and recovery tests were conducted at various depths during the drilling operation and provided information about the water-transmitting characteristics of the formations as the well was deepened. Using the results obtained from these tests, a 48-hour-duration injection test was conducted to determine the hydraulic response of the receiving zones to fresh water.

Preliminary Aquifer Test Procedures

The first test involved injecting a slug of 177 gallons of brine into the well, when the well was 3,622 feet deep, and measuring the decline of the water level until near pretest levels were attained. Owing to the drilling equipment arrangement and the increasing depth to water as the well was deepened and the fluid became more dense, this method was felt to be not as practical as pumping and recovery tests and was not utilized in the deeper zones.

The next four tests were conducted by pumping brine from the well and measuring drawdowns and recoveries of water levels. The closed circulation system maintained during the second phase necessitated conducting the brine pumping tests after the settling tanks were cleaned. This was done to take advantage of the available storage for brine produced during the test. While the tanks were being cleaned, the valve on the fluid return line to the well from the last tank was closed and the water level in the well bore was monitored. For a period of about 2 to 3 hours before the drilling resumed, brine was produced from the well by air-lift pumping through the drill stem. Because of the large drawdowns that resulted, the decrease in the depth of submergence of the air-line of the pump resulted in a decreasing pumping rate. Measurements of discharge rate were made by checking the fluid rise with a staff gage in the first settling tank. Periodic checks were made by timing the fill-up of a 5-gallon container. After the pumping stopped, the water-level recovery was measured until near pretest levels were reached. Because the density of the circulation fluid had to be controlled by periodically adding fresh water to the system, absolute static water levels could not be obtained.

Analysis of Preliminary Aquifer Test

The degree to which field conditions deviate from the assumptions for the analytical models used for test analysis determines the accuracy and reliability of the results. Because some of the limiting conditions could not be met for the tests in the injection-test well, the transmissivity calculations yielded apparent values, and thus represent an approximation of the actual value. The slug injection test and the pumping and recovery tests utilized brine produced from the well bore and therefore, the information on aquifer transmissivity derived from these tests is felt to be representative of formation conditions.

The data from the slug injection test were analyzed by the method developed by Cooper, Bredehoeft and Papadopulus (1967) for the response of a well of finite-diameter to an "instantaneous slug" of water. Values of H/H_o (head in the well after injection divided by head in the well prior to injection) were plotted versus the logarithm of time in seconds, as shown in Figure 6, and analyzed by type curve solution.

During the four pumping and recovery tests, transient fluctuations of water levels occurred that were probably due to such factors as density, temperature, or inertia effects. In the first two of these tests, the water-level drawdown data were too variable for analysis, whereas in the last two tests the drawdown data, appeared to provide more reliable results. Water levels in the well were plotted versus the logarithm of time as shown in Figures 7, 8, and 9. The time-recovery data were analyzed by the technique developed by Theis as reported by Ferris, et al (1962), and the time-drawdown data were analyzed by the technique developed by Jacob (1950).

Transmissivity values calculated from the preliminary aquifer tests are summarized in Table 3. This information indicates that the transmissivities are extremely low in the Cedar Keys Formation and Upper Cretaceous age limestones. The only zone displaying any significant transmissivity is in the Lower Cretaceous age dolostones below about 5,400 feet, which is consistent with the findings from the geologic data and geophysical logs. As a result of the findings from the preliminary aquifer tests, the injection-test plan was modified as described below.

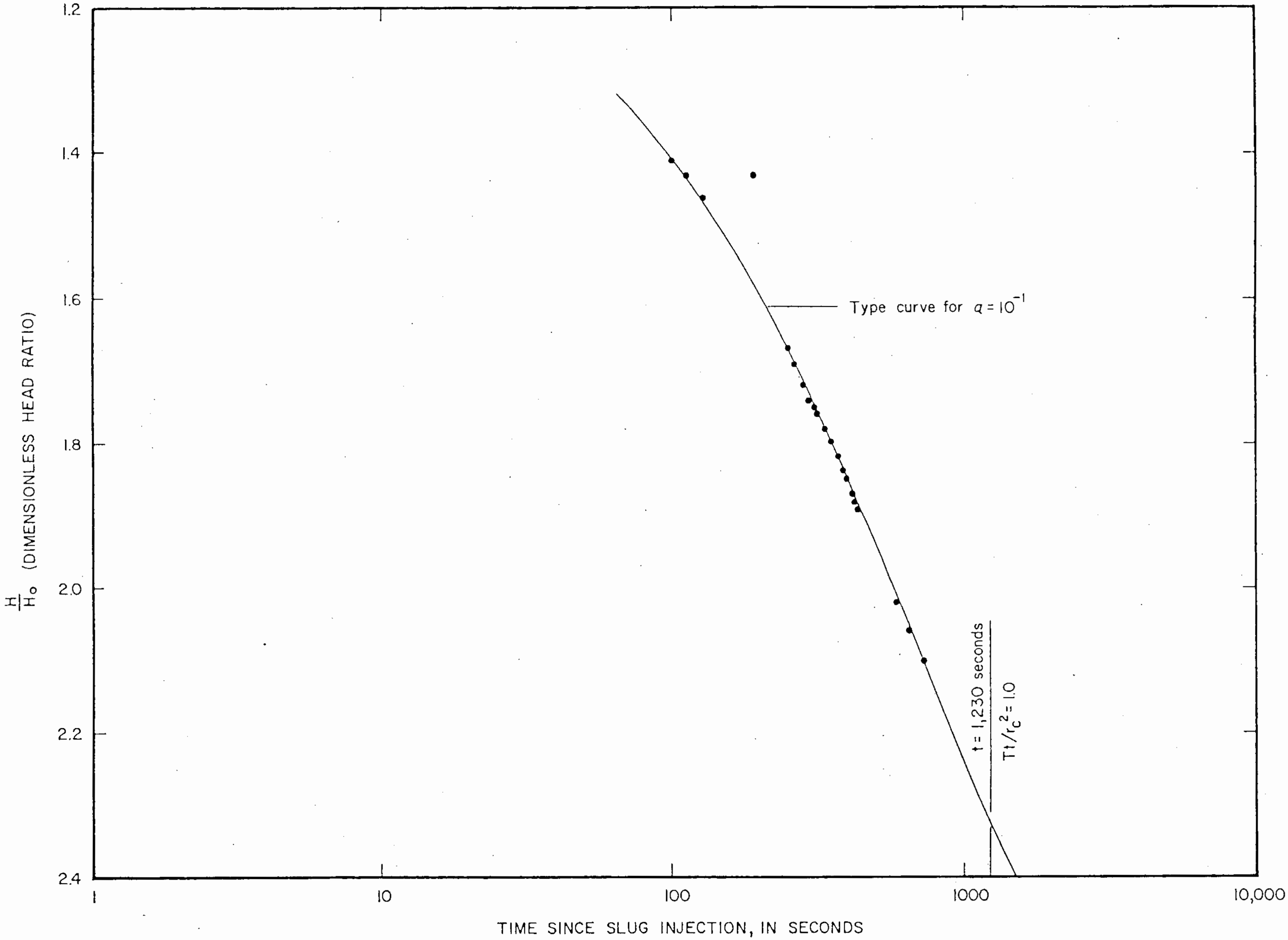

Figure 6. Plot of head ratio versus time for slug injection test on February 7, 1977.

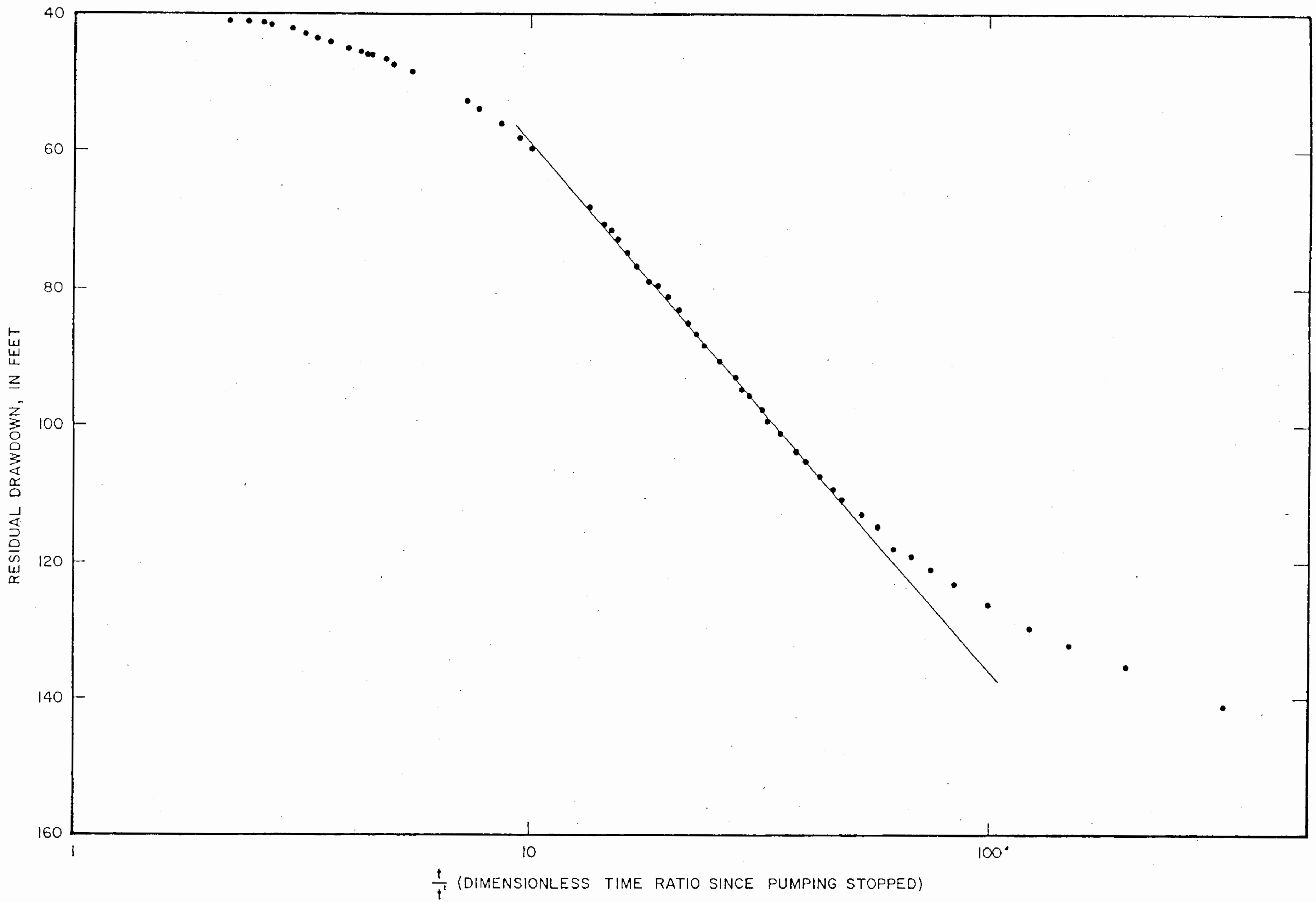

Figure 7. Plot of residual drawdown versus time ratio after pumping stopped on February 22, 1977.

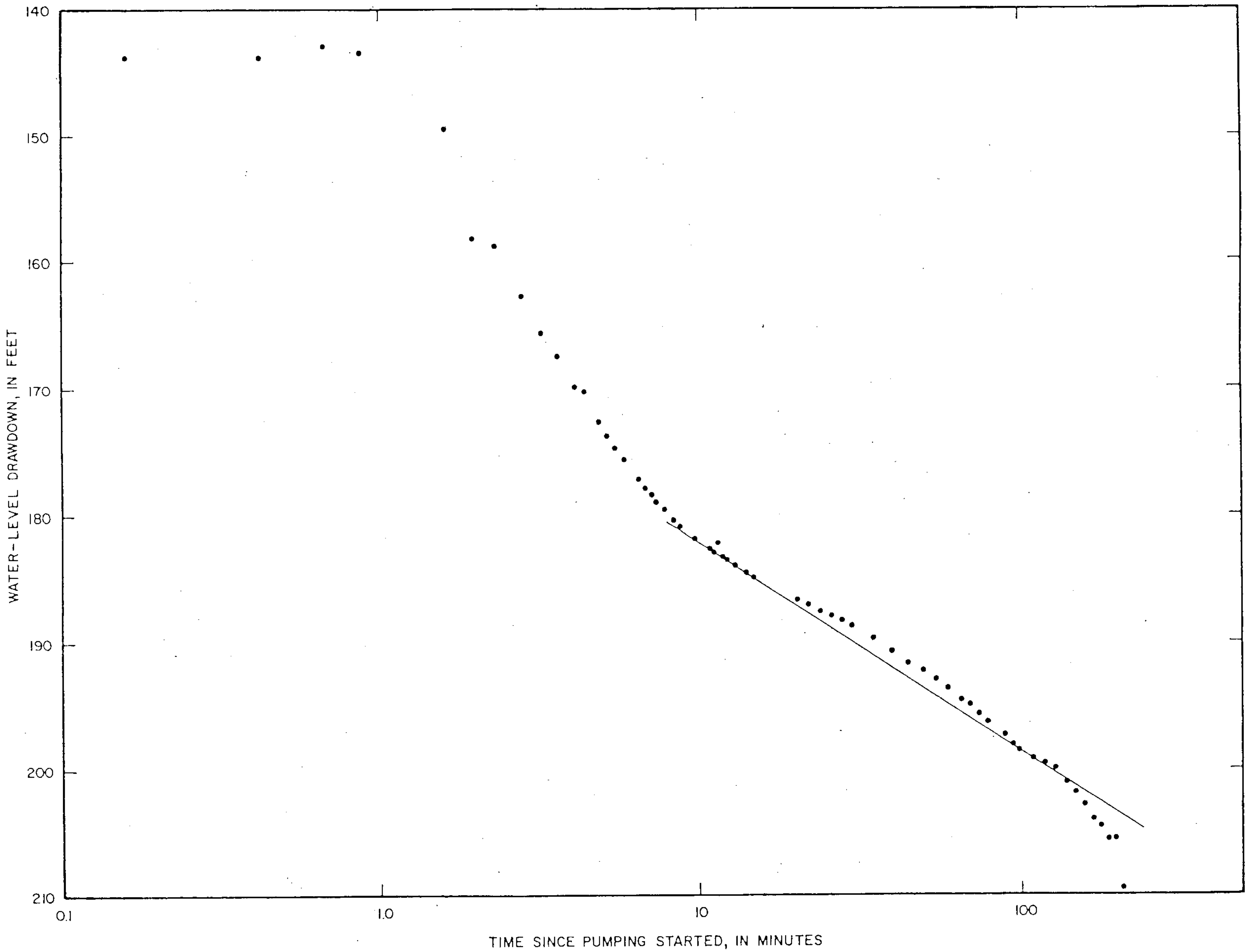

Figure 8. Plot of drawdown versus time during pumping test on March 18, 1977.

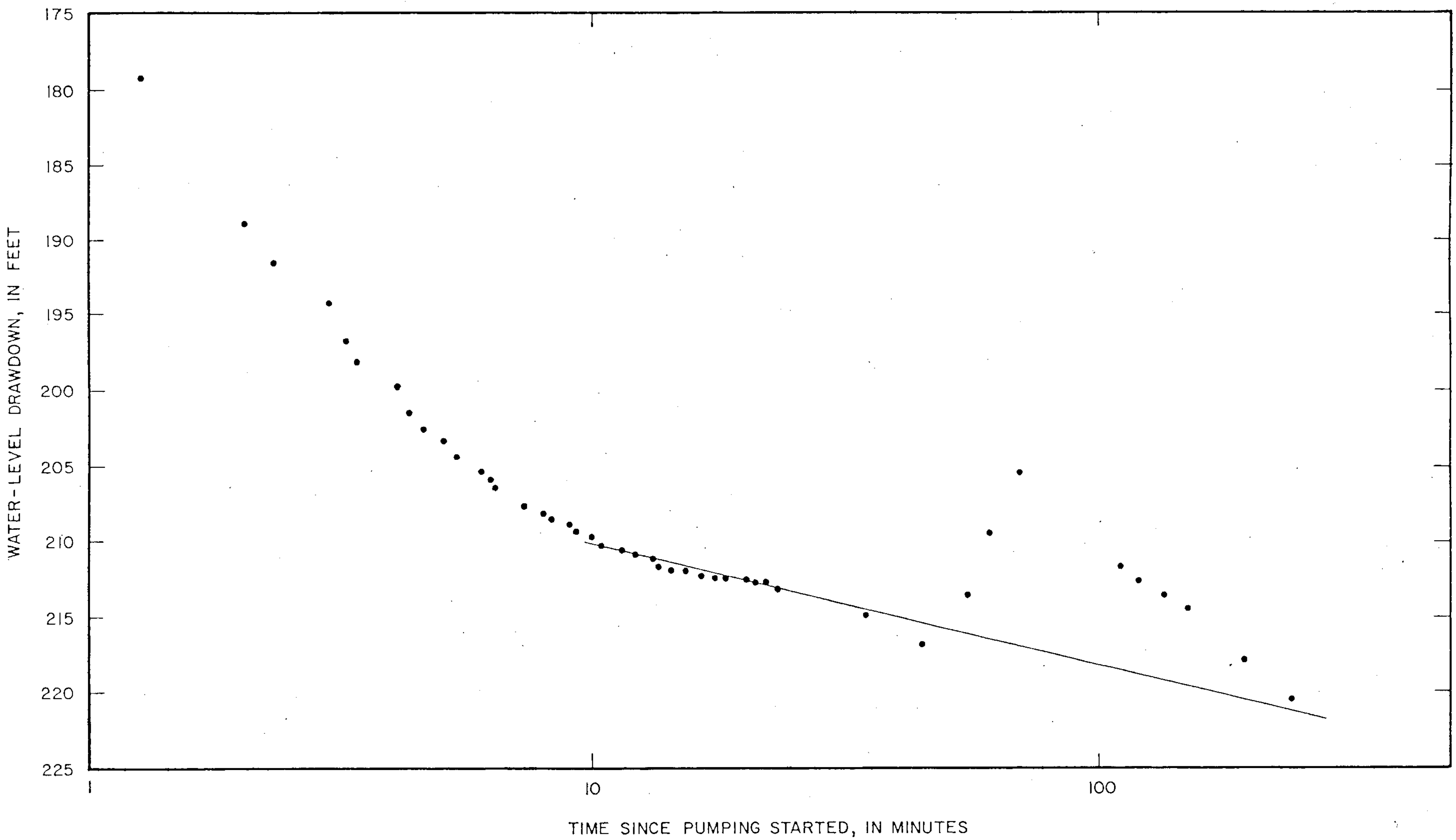

Figure 9. Plot of drawdown versus time during pumping test on March 30, 1977.

Table 3. - Summary of apparent transmissivities computed from the preliminary aquifer tests

Date	Well Bore Open Interval (ft)	Transmissivity (gpd/ft)	Method of Determination
2- 7-77	2,420-3,622	130	Cooper, et al, slug injection
2-22-77	2,420-4,195	160	Theis, recovery (Ferris, et al)
3-18-77	2,420-5,594	1,800	Jacob, drawdown
3-30-77	2,420-6,193	3,600	Jacob, drawdown

Design of the Injection System

The injection system shown in Figure 10 was designed to allow the injection rate to be increased by steps to a maximum of 1,000 gpm and to provide access through the wellhead for geophysical logging. The system as planned was to provide both low flow rates against low wellhead pressures and high flow rates against high wellhead pressures.

In order to achieve this flexibility, two pumps were placed in series with the first pump having the capability of pumping at a maximum rate of 1,000 gpm against a wellhead pressure of approximately 118 psi, and the second pump, a booster pump, having a pumping rate capability of 1,000 gpm against a wellhead pressure of approximately 325 psi. By operating in series, this system was designed to provide for a maximum flow rate of 1,000 gpm against a wellhead pressure

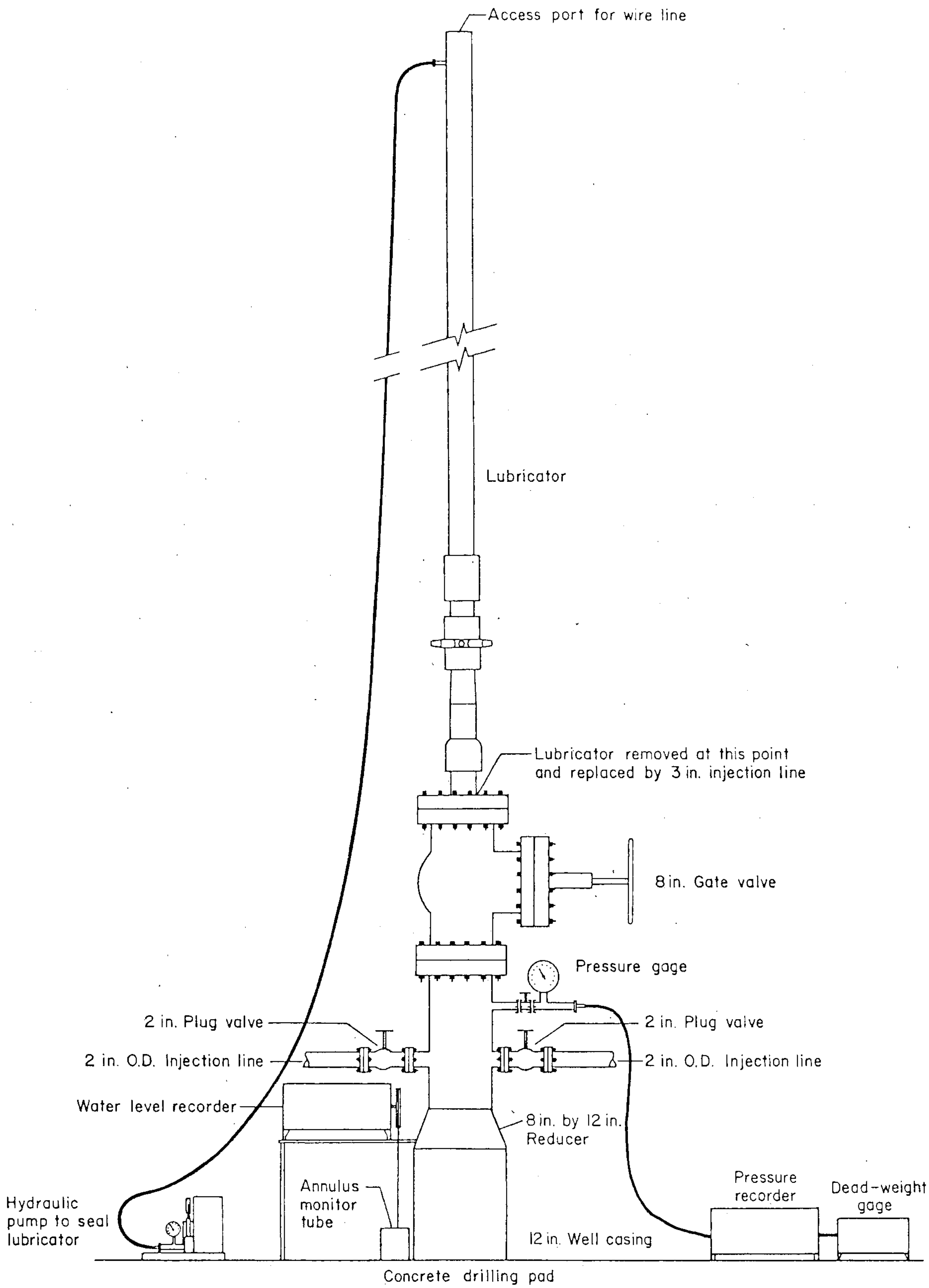

Figure 10. Schematic diagram of the injection wellhead equipment.

of 425 psi. Layne Atlantic installed and maintained throughout the injection test an electrically powered turbine pump in the water-supply well. L and L Hydrotest, Inc., specialists in testing high pressure pipelines, supplied and maintained the diesel powered booster pump.

In order to measure the injection rates, two in-line totalizing flow meters were installed between the first and second pumps. This location was chosen to prevent excessive back pressures on the flow meters. Water was discharged from the first pump into the second pump and initially through two 2-inch O.D. high pressure hoses into the well. The flow rate was controlled by means of two 2-inch-diameter high pressure plug valves located at the wellhead as shown in Figure 10.

Installed on the wellhead above the 2-inch-diameter injection lines was an 8-inch gate valve and a wire-line lubricator, as shown on Figure 10. With the gate valve closed, the lubricator could be opened and a logging probe installed. Then the lubricator could be closed, sealed by a hydraulic pump, and the gate valve opened to begin a logging run. Upon completion of a log, the probe was pulled back up inside the lubricator and the gate valve again closed. Using both the valve and wire-line lubricator in this manner, geophysical logging probes were interchanged and continuous well bore logs run with the wellhead under pressure. The geophysical services were provided by Birdwell, and included salinometer, temperature, and flow meter surveys. Copies of these logs accompany this report under separate cover. These surveys were used to obtain information on the location of the fresh-water-brine interface as it moved down the well bore and to aid in delineating zones taking the injected fresh water. Because the interface between the fresh water and brine in the well bore was a transitional zone several hundred feet thick, a point of departure of 10,000 ppm TDS was used since it could be identified on all the salinometer runs. Although this value was arbitrary, it provided a means to follow the progress of the injecta and to determine the maximum depth of fluid movement in the well bore.

Pressure build-up in the well during the injection test was measured with a dead-weight gage and recorded by a continuous pressure recorder. The dead-weight gage, accurate to within one psi, was the primary means of measuring the injection pressure. In addition to measuring wellhead pressures, water levels in the monitor tube installed in the annulus of the test well were recorded on a continuous basis with a Stevens Type F recorder for the duration of the test.

Injection Test

On April 18, at 1625 hours, the fresh-water injection test was begun. The water level in the 12-inch casing of the injection well prior to the test was approximately 156 feet below land surface. The initial stage of the test consisted of filling the well with water to land surface in order to remove all air from the well. This was accomplished by injecting water at an initial rate of about 300 gpm and gradually decreasing to about 34 gpm as the water level in the well approached land surface. The air in the well was allowed to escape through the lubricator. During this stage of the test, salinity profiles of the water in the cased portion of the well were run at three different time intervals (profiles numbered 1 through 3 on the salinometer log) to locate the fresh-brine interface. Prior to closing-in the system, the interface was approximately 2,078 feet below land surface. No water levels were measured in the well during this stage of the test.

After pumping for 161 minutes, the water level in the well was back to land surface, and the valve that allowed the air to escape through the lubricator was closed. Approximately 0.63 minutes (38 seconds) after closing-in the wellhead, on April 18, the pressure was 52 psi. During the first few minutes after shut-in, the rate was adjusted until a flow of 200 gpm was established. The flow was maintained at a relatively constant rate for 318 minutes after shut-in. During this interval, salinity profiles numbered 3 through 9 on the salinometer log were run to locate the fresh-brine interface as it moved down the bore hole. The last profile of this series ended 301 minutes after shut-in, on April 19, and detected the interface at a depth of approximately 5,780 feet.

Initially, the first pump was used alone to provide the force to inject the water into the well. At 37 minutes after shut-in, on April 18, the wellhead pressure had increased to 90 psi, which was approaching the maximum pressure limit of the first pump. Then the booster pump was started and used in series to provide the necessary force to continue pumping at the rate of 200 gpm.

At 318 minutes after shut-in, on April 19, the injection pressures appeared to have stabilized, and the injection rate was increased to 500 gpm. Twenty minutes later, the salinity profile numbered 10 on the salinometer log was run, which indicated that the fresh-brine interface was located at a depth of about 5,910 feet. This last salinity profile showed a much steeper gradient at the interface than that detected before, indicating that the predominant flow was above this depth and that no significant permeable zones were present below. To help verify this, a temperature survey was run from a depth of 1,990 feet to about 5,940 feet, which reinforced the findings from the salinity survey.

After increasing the injection rate from 200 to 500 gpm, the wellhead pressures increased to approximately 272 psi and appeared to stabilize within several hours. At 724 minutes after shut-in, on April 19, the pumping rate was again increased but the next desired injection rate of 750 gpm could not be attained. The flow rate initially increased to about 600 gpm but quickly decreased to less than 550 gpm with a wellhead pressure of 294 psi. At 738 minutes after shut-in the flow was reduced to 500 gpm and held constant for the next 666 minutes. After the flow rate was reduced to 500 gpm, the wellhead pressure reached an apparent stabilization of about 266 psi.

During the morning of April 19, a down-the-hole flow meter survey was conducted. The flow rate was insufficient to show percentages of water leaving the bore hole at different depths. However, the data were adequate to indicate that the primary injection zone was between depths of 5,565 feet and 5,890 feet.

As originally planned, the injection test was to be run by increasing the flow rate in at least three steps to a maximum of 1,000 gpm. Injection rates of 200 and 500 gpm were maintained for the first two steps. Because of high frictional losses in the two 2-inch O.D. hoses, the maximum rate was slightly less than 500 gpm. Although the data collected at the injection rates of 200 and 500 gpm were felt to be adequate for determining the hydraulics of the injection zone, a decision was made to inject at a higher rate to verify the first findings. Thus, after the geophysical logging services had been completed, the lubricator was removed and a 3-inch O.D. high pressure hose added to the system at the point where the lubricator was connected, as shown in Figure 10. This enabled the injection rate to be increased to about 700 gpm. The final injection system configuration is shown in Figure 11.

On April 19 at 1,404 minutes after shut-in, the injection was halted. The 3-inch O.D. hose was then added and the test was resumed 30 minutes later at a rate of about 700 gpm. The wellhead pressure increased to 358 psi after 44 minutes of injection and then gradually decreased to a minimum of 350 psi over the next 20 hours of injection. At 1600 hours on April 20, immediately before the injection test was terminated, the wellhead pressure was 352 psi. Slightly more than 1.5 million gallons of water had been injected during the test.

Upon terminating the injection, the decline of the wellhead pressure was measured and recorded. After one and one-half minutes, the pressure had decreased to 160 psi, and

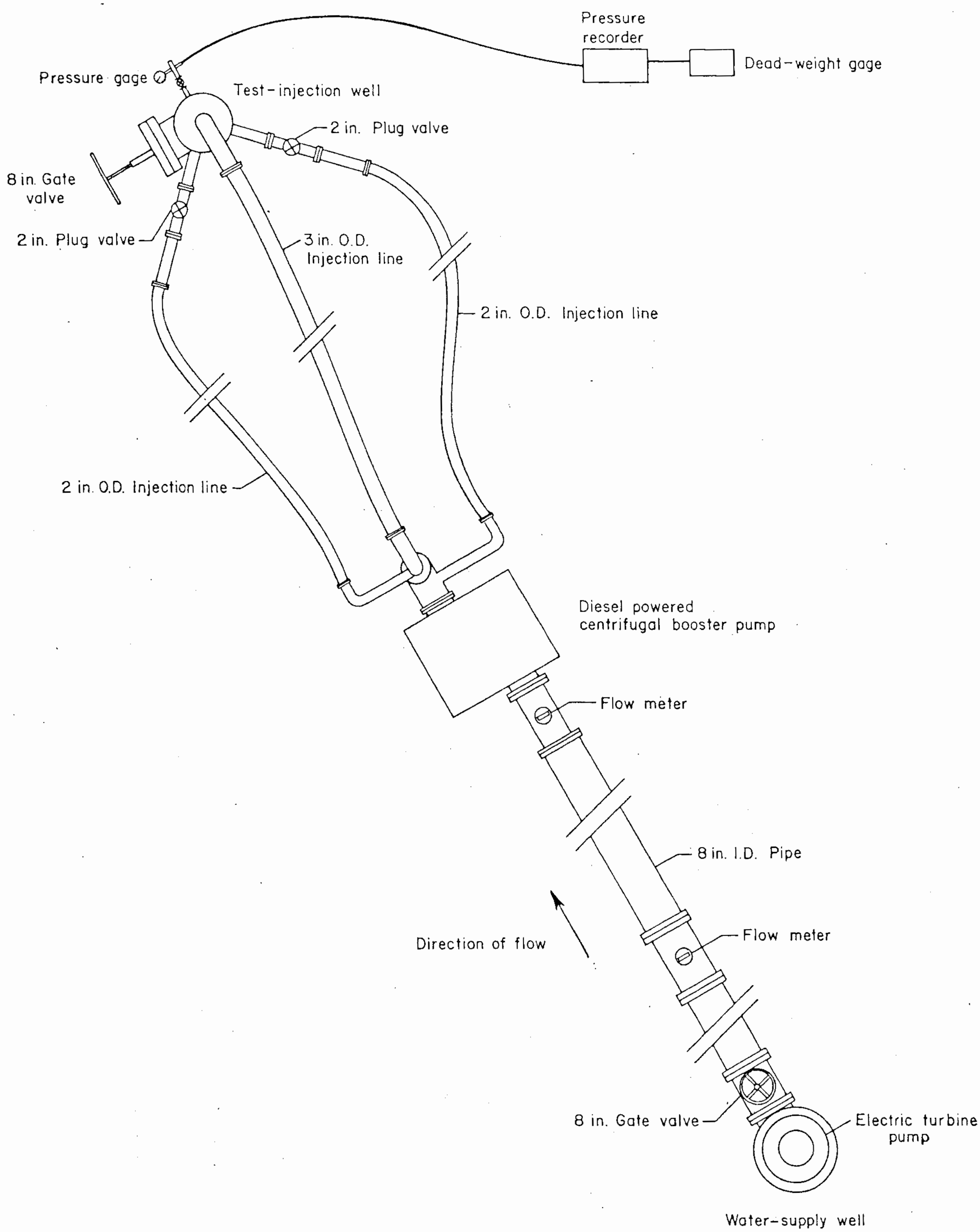

Figure 11. Plan view of the injection-test equipment.

after one day, it had decreased to 57 psi on April 21, 1977. Five days later, on April 26, at 0925 hours, the pressure at the wellhead had decreased to 24 psi. At that time, the pressure was bled-off by allowing the well to flow. After 9 hours, the flow rate had decreased to less than 1 gpm and the NaCl concentration was about 25 mg/l. The well was then shut-in. The next morning, the water level in the well was below the discharge pipe. Following the injection test, the wellhead equipment above the 12-inch-diameter well casing shown in Figure 10, was removed and a 12-inch-diameter blind flange was welded to the top of the casing.

Analysis of Injection-Test Data

To evaluate in great detail the process of injecting fresh water into a brine receiving zone would require a complicated analysis to correct the test data for temperature, viscosity, and density differences. The corrections would have to be made for different times as well as for different depths in the well. In addition, the injected fresh water would tend to dissolve the sulfate minerals exposed in the well bore and in the zones taking the injected water, which would result in a slight increase in aquifer transmissivity and storage capacity with time. Because all computed values of transmissivity for the injection tests at the site were very low, it was decided not to bother correcting the raw data for these various factors, because this would not result in any significant change of the apparent transmissivity values. Therefore, only the uncorrected values are reported herein.

Pressure build-up at the start of the test and after each increase in pumping rate occurred rapidly, followed by essential stabilization. These pressure data could not be used for the computation of aquifer transmissivity. The apparent pressure stabilization for each step was plotted versus time and followed a linear relationship as shown in Figure 12. The specific capacity data for the well, computed from these data, gave a value of about 2 gpm/psi or about 0.9 gpm/ft.

After injection was stopped, the decline of pressure in the injection well was measured. A plot of the pressure decline does not show the step increases noted during the injection test, because the rate of decline is related only to the average rate of injection. The pressure-decline data were plotted versus a dimensionless time ratio as shown in Figure 13, and analyzed by techniques developed by Theis as previously discussed. In addition, the pressure-decline data were analyzed with the Theis nonequilibrium-type curve and the nonsteady-state type curve for leaky aquifers developed by Hantush (Walton, 1962), as shown in Figure 14.

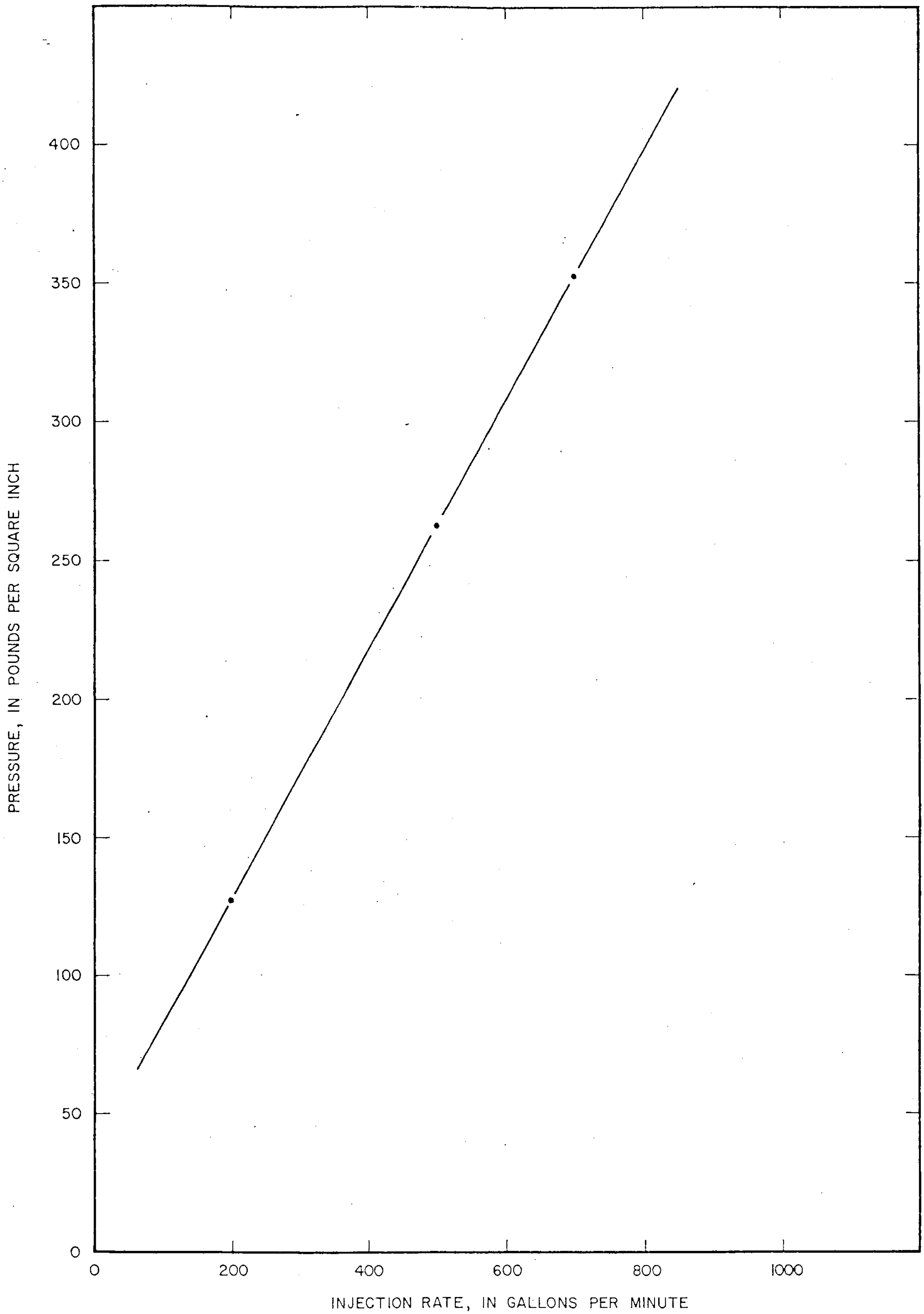

Figure 12. Injection rate versus pressure at land surface during injection test.

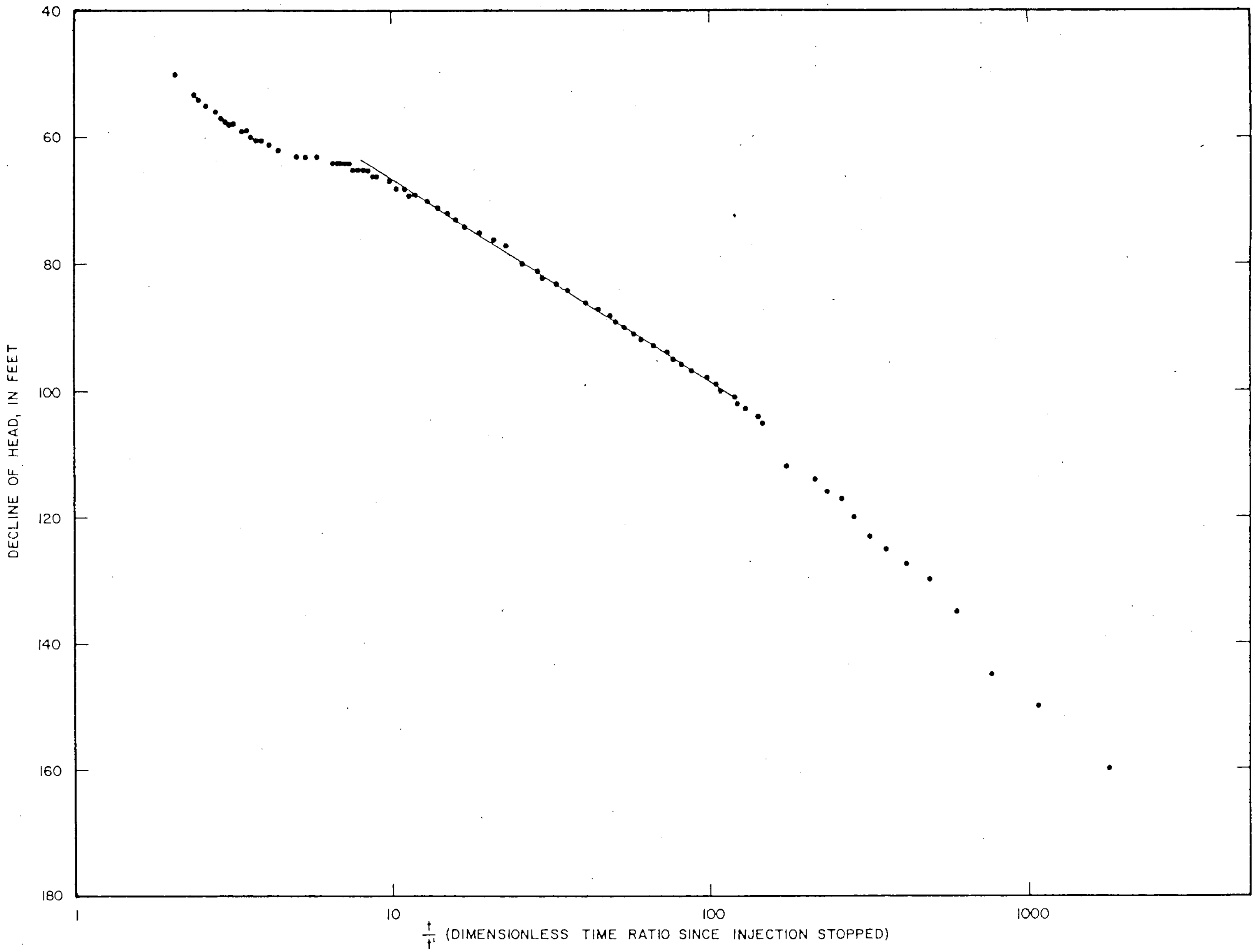

Figure 13. Plot of head decline versus time ratio after injection stopped.

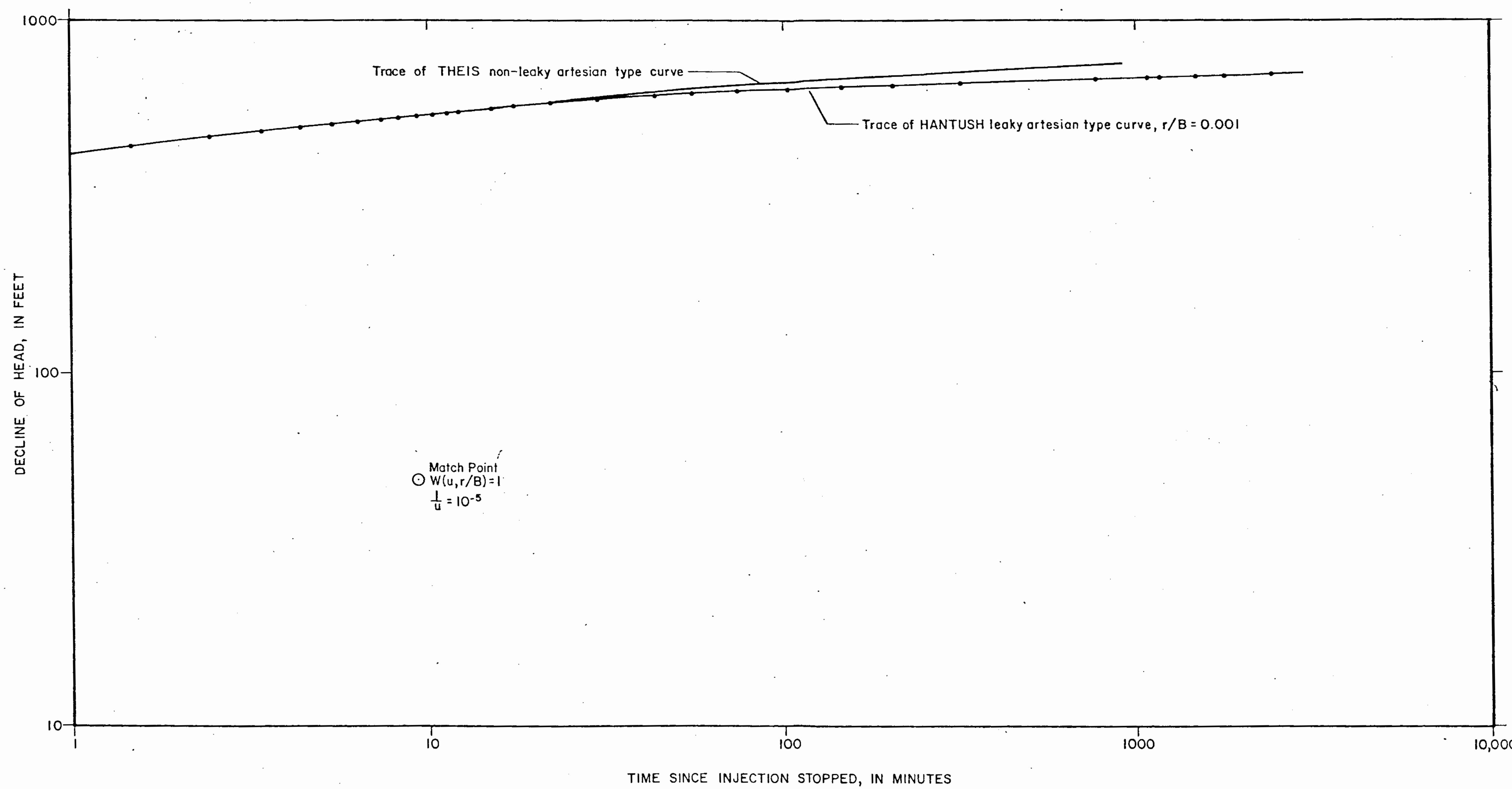

Figure 14. Plot of head recovery versus time and matching-type curves for injection test.

By the first method of analysis, the aquifer transmissivity was estimated at about 2,000 gpd/ft. Using the type curve method, a fit to the Theis nonleaky curve was obtained for the first 35 minutes of pressure decline; after that time, the data fit the Hantush leaky artesian curve for r/B = 0.001. The estimate of transmissivity obtained using the type curve method was about 1,200 gpd/ft. The apparent departure from a nonleaky to a leaky artesian type curve could be a result of the increasing transmissivity due to the dissolution of minerals exposed to the injecta or could have resulted from a change in density and temperature because the injected fresh water would tend to approach an equilibrium with the native fluid.

As previously mentioned, the water level in the monitor tube in the annulus of the injection-test well was monitored with a water-level recording instrument during the test. Throughout the test, the water level in the monitor tube declined more or less in accordance with the seasonal trend established prior to the test. Semi-diurnal fluctuations also were observed, as had been noted in earlier monitoring. Although the injection pressures at land surface reached 358 psi, no response to the injection occurred in the monitor tube.

ESTIMATES OF PRESSURE BUILD-UP FOR AN INJECTION-WELL PROGRAM

In order to estimate long-term pressure changes in the aquifer if an injection facility were to be constructed at the site, two preliminary sets of calculations were made, one using the Theis non-equilibrium formula and the second the Hantush nonsteady-state formula. The former method of analysis would show the worst condition, because it assumes that pressures would continue to build up logarithmically with time and would never stabilize. The latter method incorporates eventual stabilization of pressures. The preliminary calculations showed that there were no significant differences between the two methods, and therefore only the Theis analysis was used to predict pressure changes with time.

Present plans are for the disposal of about 8 mgd of wastewater, with an expected eventual increase to 15 mgd. The timing of the rate of increase is not known. Therefore, to simplify the computations and to satisfy the constant rate assumption of the Theis formula, the minimum and maximum rates were used to compute the lower and upper limits of the pressure build-up. In other words, calculations were first made on the assumption that the disposal volume would remain at a constant rate of 8 mgd for 20 years. Then, a second set of calculations was made for a total of 15 mgd for 20 years.

For the purpose of the computations, an apparent aquifer transmissivity of 2,000 gpd/ft and a storage coefficient of 1×10^{-4} were used.

Computations first were made of head build-up in feet in a single well with an injection rate of 1 mgd, as shown in Figure 15. Pressure or head resulting from injection into a well dissipates logarithmically with distance from the well. However, when more than one well is used for disposal and the wells are relatively closely spaced, the hydraulic heads interfere with each other and the effects are additive. Thus, well spacing and interference effects between wells would have to be considered for an injection-well system. In the present instance, it has been assumed that a line of wells spaced 1,000 feet apart would be needed to handle the wastewater.

Considering an operational system starting with a volume of 8 mgd, calculations were made for the interference effects among 8 wells, each disposing of 1 mgd. The outermost wells would have an injection pressure of approximately 291 psi after one day of operation, while the center two wells would show approximately 331 psi. After one year, the respective pressures would be about 967 and 1,091 psi; and after 20 years of continuous operation at 8 mgd, the respective pressures would be about 1,384 and 1,508 psi. If a continuous

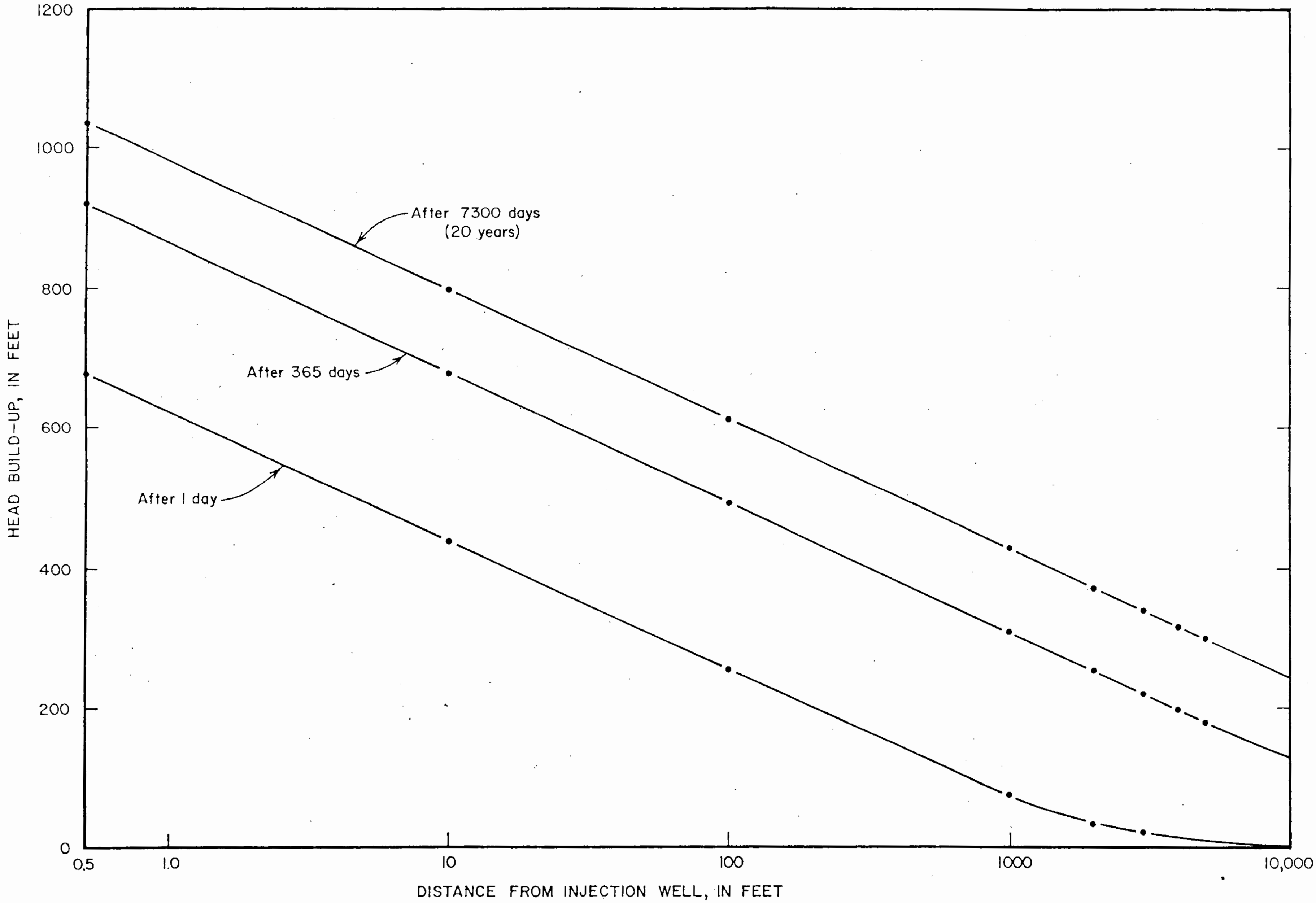

Figure 15. Predicted head decrease with distance from an injection well assuming Theis nonequilibrium conditions.

injection rate of 15 mgd were maintained for 20 years, the outermost wells and center wells would show pressures of about 2,170 and 2,450 psi, respectively. These are injection pressures at land surface due to the transmissivity of the aquifer and corrected for the initial depth of fluid in the well bore. The computations do not include friction loss in the casing and well bore, which would be only about 10 psi.

If the assumption is correct that the fluid pressure in the formation would increase continually with time, a critical value ultimately could be reached at which hydraulic fracturing might occur. An accepted regulatory limit for injection pressure to prevent hydraulic fracturing is 0.5 psi per foot of depth. Figuring a casing depth of about 5,400 feet (which is the greatest depth to which casing could be set in order to leave the most transmissive zone exposed), the allowable regulatory pressure would be 2,700 psi. The maximum calculated injection pressure, which is that for the center two wells after 20 years of continuous injection at a rate of 15 mgd, falls just below this limit.

The estimated cost for construction of a single injection well with a 12-inch-diameter casing set to about 5,400 feet would be approximately $1.2 million. If the need were to dispose of 15 mgd, the injection well system as outlined herein would require at least 15 wells with possibly

2 wells for emergency backup. Because of the low transmissivity and the resultant large pressure effects between wells, the system would have to be designed with very high pressure pipe, fittings, and pumps. Also, enormous amounts of energy would be needed to operate the system, and taking everything into account, including the hydrological implications, the disposal of the wastewater by deep-well injection does not appear to be a practicable solution at this site.

DISPOSITION OF THE INJECTION-TEST WELL

If the injection-test well is not to be used for subsurface disposal of wastes, it could either be adapted for research or plugged and abandoned. If the well were to be used for research, a corrosion resistant liner casing would have to be emplaced in it in order to protect the Floridan Aquifer from possible contamination by brine. The liner would have to be sealed on the bottom and the brine in the annulus between the 12-inch casing and the liner would have to be replaced with a corrosion inhibiting fluid. Some governmental entity other than Orange County might be willing to accept the responsibility and cost for modifying the well for this purpose.

On the other hand, if it is decided to plug and abandon the well the principal requirement of the State of Florida is to fill the well entirely with neat cement up to the land surface. This would be a very expensive procedure, and if the State would agree, it would seem more reasonable to adopt procedures similar to those used for abandonment of oil-test wells. The State has allowed such a variation in other cases.

Briefly, the modified procedure should be to place a plug or cement basket in the well bore at a depth of about 2,520 feet, which is about 100 feet below the bottom of the

12-inch-diameter casing. Class B or H densified, neat cement should then be placed in the well back to about 2,000 feet. Crushed limestone or gravel and clay should be emplaced from 2,000 feet back up to 100 feet below land surface. The volume of mud used should be sufficient to fill the theoretical void space in the fill material. Finally, the fill material should be capped with approximately 100 feet of neat cement and the 12-inch-diameter casing cut off about 4 to 6 feet below land surface. During the back-filling operation, any brackish water displaced from the well could be routed through the wastewater treatment facility. A record of the plugging must be filed with the State Department of Environmental Regulation after the well has been abandoned. The monitor tube could still be maintained for water level and water quality, monitoring by another governmental entity.

Respectfully submitted

GERAGHTY & MILLER, INC.

Paul S. Hackenberry
Senior Scientist

Peter L. Palmer
Senior Hydrogeologist

September, 1977

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APPENDIX A

SPERRY-SUN, INC., DIRECTIONAL SURVEY REPORT

SPERRY-SUN

DIRECTIONAL SURVEY REPORT

FOR

Layne Atlantic Co.

TYPE OF SURVEY: Magnetic Multishot

SURVEY DEPTH: FROM 120 FT. TO 2395 FT.

Injection-Test Well Program WELL NO. 1

FIELD: Location: T23S, R29E, Sec. 32AA

COUNTY/~~PARISH~~ XXXX Orange STATE Florida

DATE OF SURVEY 8-24-76 JOB NO. MS-3772

OFFICE: New Orleans, La.

LAYNE ATLANTIC COMPANY
DEEP TEST, WELL NO. 1 — DATE OF SURVEY AUGUST 24, 1[illegible]7
VERTICAL SECTION DIRECTION CLOSURE
ORANGE COUNTY, FLORIDA — 1 DEG WEST CORRECTION APPLIED
MAGNETIC MULTISHOT DIRECTIONAL SURVEY — MS-3772

SPERRY-SUN, INC.
RECORD OF SURVEY

MEASURED DEPTH	TRUE VERTICAL DEPTH	SUB SEA TVD	COURSE INCLINATION DEG MIN	COURSE DIRECTION DEG	DOG-LEG SEV DEG/100	TOTAL RECTANGULAR COORDINATES NORTH/SOUTH	TOTAL RECTANGULAR COORDINATES EAST/WEST	VERTICAL SECTION
120	120.00	120.00	ASSUMED VERTICAL TO 120 FEET			0.00 N	0.00 E	0.00
156	156.00	156.00	0 7	N 63 W	0.32	0.02 N	0.03 W	0.03
218	218.00	218.00	0 14	N 30 E	0.43	0.15 N	0.05 W	0.15
279	279.00	279.00	0 12	N 37 E	0.07	0.35 N	0.10 E	0.26
340	340.00	340.00	0 21	N 29 E	0.25	0.60 N	0.25 E	0.40
400	400.00	400.00	0 20	N 29 E	0.03	0.91 N	0.43 E	0.59
460	460.00	460.00	0 22	N 26 E	0.06	1.23 N	0.60 E	0.80
521	521.00	521.00	0 7	S 57 E	0.65	1.37 N	0.73 E	0.85
582	582.00	582.00	0 8	S 5 E	0.18	1.27 N	0.79 E	0.73
643	643.00	643.00	0 8	S 43 E	0.14	1.15 N	0.85 E	0.60
705	705.00	705.00	0 7	S 46 E	0.03	1.05 N	0.94 E	0.47
766	765.99	765.99	0 4	N 86 E	0.14	1.01 N	1.02 E	0.40
827	826.99	826.99	0 2	N 54 E	0.07	1.02 N	1.07 E	0.38
888	887.99	887.99	0 8	S 21 W	0.27	0.97 N	1.06 E	0.34
949	948.99	948.99	0 10	N 35 W	0.44	0.97 N	0.98 E	0.36
1009	1008.99	1008.99	0 11	N 56 W	0.11	1.10 N	0.85 E	0.59
1070	1069.99	1069.99	0 18	N 36 W	0.23	1.28 N	0.68 E	0.80
1131	1130.99	1130.99	0 17	N 22 W	0.12	1.55 N	0.53 E	1.11
1190	1189.99	1189.99	0 20	N 21 W	0.09	1.85 N	0.41 E	1.42
1251	1250.99	1250.99	0 30	N 25 W	0.28	2.25 N	0.24 E	1.85
1311	1310.99	1310.99	0 42	N 25 W	0.33	2.82 N	0.03 W	2.49
1372	1371.98	1371.98	0 45	N 25 W	0.08	3.52 N	0.35 W	3.28
1433	1432.98	1432.98	0 51	N 22 W	0.18	4.30 N	0.69 W	4.11
1494	1493.97	1493.97	0 46	N 1 W	0.50	5.13 N	0.87 W	4.92
1555	1554.97	1554.97	0 42	N 13 E	0.31	5.90 N	0.79 W	5.56
1616	1615.96	1615.96	0 45	N 15 E	0.09	6.65 N	0.61 W	6.13
1677	1676.96	1676.96	0 43	N 15 E	0.06	7.41 N	0.40 W	6.69
1737	1736.95	1736.95	0 41	N 9 E	0.14	8.12 N	0.25 W	7.24
1797	1796.95	1796.95	0 30	N 9 E	0.31	8.73 N	0.15 W	7.73
1857	1856.95	1856.95	0 30	N 14 E	0.07	9.25 N	0.05 W	8.13

LAYNE ATLANTIC COMPANY

DEEP TEST, WELL NO. 1 DATE OF SURVEY AUGUST 24, 197[illegible]

VERTICAL SECTION DIRECTION CLOSURE

ORANGE COUNTY, FLORIDA 1 DEG WEST CORRECTION APPLIED

MAGNETIC MULTISHOT DIRECTIONAL SURVEY MS-3772

SPERRY-SUN, INC.

RECORD OF SURVEY

MEASURED DEPTH	TRUE VERTICAL DEPTH	SUB SEA TVD	COURSE INCLINATION DEG MIN	COURSE DIRECTION DEG	DOG-LEG SEV DEG/100	TOTAL RECTANGULAR NORTH/SOUTH	COORDINATES EAST/WEST	VERTICAL SECTION
1918	1917.94	1917.94	0 16	N 46 W	0.71	9.60 N	[illegible] W	8.47
1976	1975.94	1975.94	0 17	N 57 W	0.10	9.78 N	0.30 W	8.72
2036	2035.94	2035.94	0 21	S 79 W	0.41	9.82 N	[illegible] W	8.91
2097	2096.94	2096.94	0 28	S 84 W	0.20	9.76 N	1.04 W	9.0[illegible]
2158	2157.94	2157.94	0 37	S 74 W	0.29	9.64 N	1.60 W	9.23
2218	2217.93	2217.93	0 44	S 74 W	0.20	9.45 N	2.26 W	9.3[illegible]
2277	2276.93	2276.93	0 48	S 79 W	0.16	9.27 N	3.05 W	9.59
2339	2338.92	2338.92	0 55	S 75 W	0.21	9.05 N	3.95 W	9.84
2395	2394.91	2394.91	0 55	S 66 W	0.26	8.76 N	4.79 W	[illegible]

** THE CALCULATIONS ARE BASED ON THE MINIMUM RADIUS OF CURVATURE METHOD **

HORIZONTAL DISPLACEMENT = 9.98 FEET AT NORTH 28 DEG. 42 MIN. WEST (TRUE)

STATE OF Florida
COUNTY/~~PARISH~~ OF Orange

I/~~We~~, Chester R. Peck

____

____

____________________, in the employ of the Directional Surveying Department of Sperry-Sun Well Surveying Company, did on the 24th day of August 1976
and the ____ day of ________ 19__
and the ____ day of ________ 19__
and the ____ day of ________ 19__
respectively conduct or supervise the taking of a Multi-shot/~~Single Shot~~ Directional survey by method indicated:
from a depth of 120 feet to 2395 feet by ~~Gyroscopic~~/Magnetic/~~Oriented~~ Survey
depth of ____ feet to ____ feet by Gyroscopic/Magnetic/Oriented Survey
depth of ____ feet to ____ feet by Gyroscopic/Magnetic/Oriented Survey
depth of ____ feet to ____ feet by Gyroscopic/Magnetic/Oriented Survey
with records of inclination and direction of inclination being taken at approximately every 60 feet.

This survey was conducted at the request of Layne Atlantic Co.,

for their Orange County Deep Injection Well Test Project Well No. ____,

____________ Survey, Orange County/~~Parish~~,

State of ________, in the ------------- Field.

I/~~We~~ certify that this is a true and correct report of such survey and that it affords a true and correct representation of our findings as to the nature and conditions of the well at the time the survey was/~~surveys were~~ made.

Chester R Peck
Chester R. Peck

STATE OF Louisiana
~~COUNTY~~/PARISH OF Jefferson

Before me the undersigned authority/~~authorities~~, on this day personally appeared CHESTER R. PECK, ____, ____, ____,
known to me to be the person/~~persons~~ whose name is/~~names are~~ subscribed to this instrument, who after being by me duly sworn on oath, states that he has/~~they have~~ knowledge of all the facts stated above and that the same is a true and correct statement of the facts therein recited.

Subscribed and sworn to before me this the 26 day of August 1976

____

Notary Public in and for JEFFERSON

FORM SP-220 (REV. 3) (2M-50) 12/74

APPENDIX B

Laboratory Testing Reports
By
Florida Testing Laboratories, Inc.,
For Core Samples

FLORIDA TESTING LABORATORIES, INC.
Geotechnical Engineering and Construction Materials Testing
P.O. BOX 11064 • ST. PETERSBURG, FLORIDA 33733 • 813/531-1446 • TAMPA LINE 229-2119
9000 N. NEBRASKA AVE • TAMPA, FLORIDA 33604 • 813/935-8585
4279 S.R. 52 • NEW PORT RICHEY, FLORIDA 33552 • 813/586-1425

May 25, 1977

Geraghty & Miller, Inc.
P. O. Box 17174
Tampa, Florida 33682

Attention: Mr. Paul Hackenberry

Re: Orange County Injection Test Well Program
E.P.A. Project #C-120314.010
Florida Testing Laboratories, Inc. Lab. #35674,35817 & 39988

Gentlemen:

Attached herewith please find results of tests performed by this office on rock core samples submitted to this laboratory by Geraghty & Miller.

Testing was performed on samples as received commencing on July 20, 1976 and completed May 24, 1977. Individual test procedures are as indicated on report sheets. Permeability test set-up is shown on Plate A attached.

Unit Weight

Dry unit weight of specimens were determined by either the weight and measured dimensions of the test specimen or by the bulk-specific gravity method (ASTM C-127) of the specimen after testing.

Measured specimens were measured to the nearest .001 inch and weights recorded to the nearest .05 gram.

Specific Gravity (Apparent)

G_s performed on permeability specimens in accordance with ASTM C-127 except as noted in remarks on report sheets. G_s performed on Core #1 (1603.5') in accordance with ASTM D 854, 68^{o}F.

Porosity

Porosity determined from the following formula:

$$P = 1 - \frac{\text{dry unit weight } (\#/ft^3)}{G_s \times 62.36} \times 100\%$$

Permeability

Specimens trimmed to dimensions indicated on report sheets. Samples inserted into a 6.35 cm diameter X 2.54 cm high ring and sealed around vertical edges between specimen and ring. Specimens were allowed to soak a minimum of 24 hours before testing. Plate A diagrams the set-up procedure and formula for computing the coefficient of permeability.

In all tests performed, demineralized water was utilized for saturation and permeability determination. *No allowance has been applied to the permeability rate for variations in ground water viscosity.

Florida Testing Laboratories, Inc., appreciates the opportunity to provide this service to you. If there are any questions regarding the test results or procedures, please contact this office at your convenience.

Very truly yours,

FLORIDA TESTING LABORATORIES, INC.

Robert T. Smith, S.E.T.

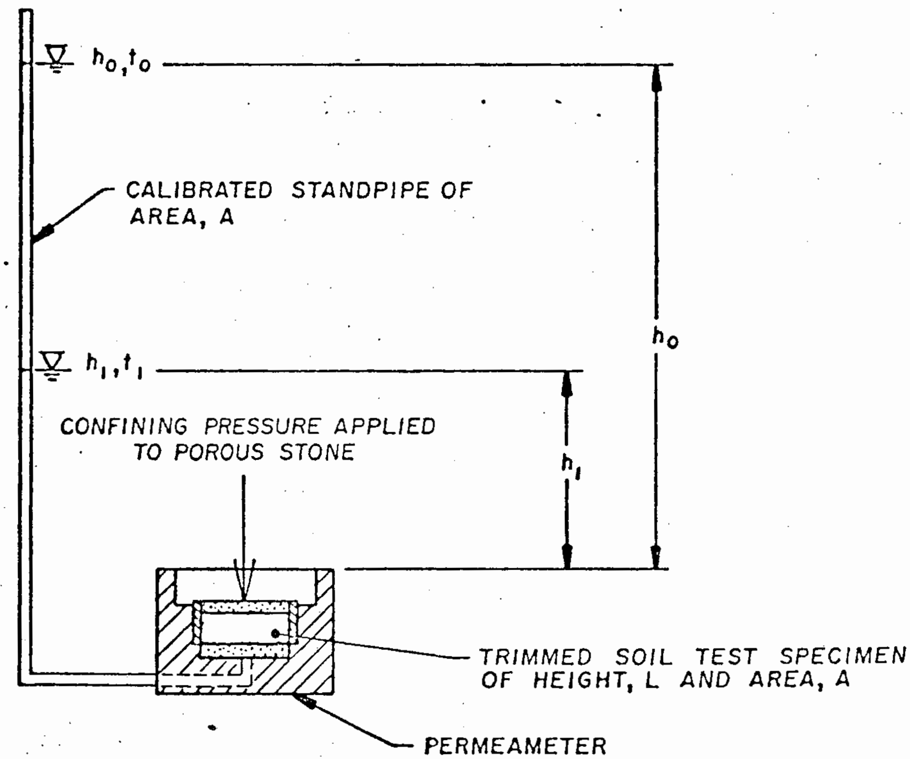
F. Jaime Driggers, P.E.

RTS/FJD/fh

Enclosures

* Approximate temperature of water at time of test ranged from 72^{o}F to a maximum of 76^{o}F.

SCHEMATIC OF PERMEAMETER



CALCULATIONS:

Falling Head: $K = 2.3 \frac{aL}{A(t_1 - t_0)} \text{ Log } \frac{h_0}{h_1}$ (cm/sec)

PLATE A

FLORIDA TESTING LABORATORIES

PROJECT: E.P.A. Proj.#C-120314.010
Orange County Injection Well Program

CLIENT: Geraghty & Miller

BY: R. J. Smith

LAB. NO.: 35674,35817,39988

DATE: 7-30-76 to 5-24-77

BY____ DATE____
CHKD. BY____ DATE____
SUBJECT____
SHEET NO. 1 OF 3
JOB NO.____

Core #	(ft) Core Depth	Core Description	Perm. Rate	Dry Unit wt-PCF	Gs	Porosity %	Perm. Surcharge	Remarks
1	1601	Light gray,hard,dense well cemented dolostone	4.497 x10-8 cm/sec	153.1	2.697	9.0	3 KSF	1. Unit weight & G_S performed on permeameter specimen in accordance with ASTM C 127 with the addition of 15" Mercury vacuum on submerged specimen for de-airing 2. Permeameter test dimensions D=2.335" Ht=0.999" 3. Water flow from bottom thru top as marked on core box-falling head method
1	1601	Light gray, hard, dense, well cemented, slightly vuggy dolostone	-	153.2	2.646	7.2	-	1. Unit weight & G_S performed on full core diameter sample adjacent to permeameter specimen 2. U.W. & G_S performed in accordance with ASTM C 127
1	1603.5	Light tan cemented, vuggy, fossiliferous limestone	2.017 x10-4 cm/sec	104.5	2.695	37.8	3 KSF	1. Unit weight determined from trimmed permeameter dimensions D=2.320" Ht= 0.987" 2. G_S performed in accordance with ASTM D854 on oven dried trimmings from permeameter 3. Water flow from bottom thru top as marked on core box in falling-head method

FLORIDA TESTING LABORATORIES

PROJECT: E.P.A. Proj.#C-120314.010
Orange County Injection Well Program

CLIENT: Geraghty & Miller, Inc.

LAB. NO.: 35674,35817,39988

DATE: 7-30-76 to 5-24-77

BY: R. J. Smith

BY______ DATE______

CHKD. BY______ DATE______

SUBJECT______

SHEET NO. 2 OF 3

JOB NO.______

Core #	(ft) Core Depth	Core Description	Perm. Rate	Dry Unit wt-PCF	Gs	Porosity %	Perm. Surcharge	Remarks
2	1722	Light brown, hard very dense well cemented dolostone	2.13 x10-9 cm/sec	164.7	2.850	7.3	3 KSF	1. Unit weight & G_s performed on permeameter specimen in accordance with ASTM C 127 with the addition of 15" mercury vacuum on submerged specimen for de-airing 2. Permeameter test dimensions D=2.321" Ht=0.995" 3. Water flow from bottom thru top as marked on core box-falling-head method
4	2151.4	Medium gray very dense dolostone	5.048x 10-9 cm/sec	137.0	2.650	17.2	3 KSF	1. Unit weight & G_s performed on permeameter specimen in accordance with ASTM C127 with the addition of 15" mercury vacuum on submerged specimen for de-airing 2. Permeameter test dimensions D=2.360" Ht=.9947" 3. Water flow from bottom thru top as marked on core box. Falling head method
5	2558.85 2559.10	Light gray, medium dense, well cemented, slightly vuggy dolostone	1.193 x10-7 cm/sec 74.8°F	120.6	2.790	30.7	3 KSF	1. Unit weight & G_s performed on permeameter specimen in accordance with ASTM C127 with the addition of 15" mercury vacuum on submerged specimen for de-airing 2. Permeameter test dimensions D=2.361" Ht=0.924" 3. Water flow from bottom thru top as marked on core Falling head method.

FLORIDA TESTING LABORATORIES

PROJECT: E.P.A. Proj.#C-120314.010
Orange County Injection Well Program
CLIENT: Geraghty & Miller, Inc.

LAB. NO.: 35674,35817,39988
DATE: 7-30-76 to 5-24-77

BY: R. T. Smith

Core #	(ft) Core Depth	Core Description	Perm. Rate	Dry Unit wt-PCF	Gs	Porosity %	Perm. Surcharge	Remarks
6	5590.28 to 5590.61	Light gray, hard, dense dolostone	1.077 x10-7 cm/sec Horizontal permeameter orientation 74.8°F	133.41	2.382	10.2	3 KSF	1. Unit weight & G_s performed on permeameter specimen in accordance with ASTM C127 with the addition of 15" mercury vacuum on submerged specimen for de-airing 2. Specimen trimmed parallel to vertical axis of core as received. 3. Permeameter test dimensions D=2.354" Ht=0.9996" 4. Water flow vertically thru horizontal axis of core. Falling head method.
6	5611.34 to 5612.51	Gray, very hard, well cemented vuggy dolostone	2.720 x10-7 cm/sec Horizontal permeameter orientation 74.6°F	155.9	2.729	8.1	3 KSF	1. Unit weight & G_s performed on permeameter specimen in accordance with ASTM C127 with the addition of 15" mercury vacuum on submerged specimen for de-airing 2. Specimen trimmed parallel to vertical axis of core as received. 3. Permeameter test dimensions D=2.401" Ht=1.0076" 4. Water flow vertically thru horizontal axis of core. Falling head method.

BY: Robert T. Smith
Robert T. Smith, S.E.T.

BY: F. Jaime Driggers
F. Jaime Driggers, P.E.

BY___ DATE___ CHKD. BY___ DATE___ SUBJECT___ JOB NO.___

APPENDIX C

Geologic Log of the Injection-Test Well

Sample Description	Depth (feet)	Thickness (feet)
Sand, transparent to very light gray, porosity - intergranular, grain size - fine, range - fine to medium, angular and subangular, non-indurated; minor organic matter.	0- 20	20
Sand, transparent to gray brown, porosity - intergranular, moldic, pinpoint vugs, grain size - fine, range - fine to medium; angular, subangular, poor induration, clay cement; heavy minerals (1%); clay, brown, gray (5%); silt; limonite.	20- 30	10
Clay, light-olive-gray, porosity - intergranular, moldic, pinpoint vugs, moderate induration, clay cement, phosphorite grains; sand, quartz (3%); silt (1%).	30- 50	20
Clay, olive gray, light-olive-gray, porosity - intergranular, pinpoint vugs, moderate induration, clay cement; sand, quartz (30%); silt.	50- 60	10
Limestone, light gray, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - micritic, skeletal, moderate induration, micritic cement, mollusk; sand, quartz (20%); silt.	60- 90	30
Limestone, light gray, very light gray, porosity - intergranular, moldic, intercrystalline, pinpoint vugs, grain type - micritic, skeletal, moderately indurated, micritic cement; sand, quartz (20%); silt (1%); phosphatic sand (1%); shell fragments; mollusk.	90- 100	10
Dolostone, green gray, porosity - intergranular, moldic, altered (50-90%), subhedral, gran size - very fine, range - microcrystalline to very fine, moderate induration, dolomitic cement, clay cement; sand, quartz (30%); phosphatic sand (2%); silt (trace); clay (trace).	100- 110	10
Dolostone, light gray, porosity - intercrystalline, moldic, crystalline, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; sand, quartz (10%); phosphatic sand (1%).	110- 120	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, light gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; sand, quartz (10%); phosphatic sand (3%).	120- 130	10
Cavity.	130- 150	20
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (95%), grain size - medium, range - fine to coarse, moderate induration, siliceous cement; foraminifer; echinoid; mollusk.	150- 160	10
Calcarenite, white, porosity - intergranular, moldic, grain type - skeletal, biogenic, micritic, allochems (85%), grain size - medium, range - fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer; echinoid.	160- 180	20
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (80%), grain size - fine, range - fine to medium; moderate induration, silicious cement, micritic cement; foraminifer; echinoid; mollusk.	180- 190	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (75%), grain size - fine, range - fine to medium, moderate induration siliceous cement, micritic cement; foraminifer; echinoid, C.F. Peronella dalli; mollusk.	190- 200	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - fine, range - very fine to medium; moderate induration, siliceous cement, micritic cement; foraminifer.	200- 210	10

Sample Description	Depth (feet)	Thickness (feet)
Calcarenite, white, porosity - intergranular, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (80%), grain size - fine, range - fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer; fossil molds; mollusk.	210- 220	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (75%), grain size - fine, range - fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer; mollusk.	220- 230	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (80%), grain size - fine, range - fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer; mollusk; echinoid.	230- 240	10
Calcarenite, white, porosity - intergranular pinpoint vugs, moldic, grain type - skeletal, biogenic, micritic, allochems (85%), grain size - fine, range - fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer; mollusk.	240- 250	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - fine, range - fine to coarse, moderate induration, siliceous cement; foraminifer; mollusk; echinoid.	250- 260	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - fine, range - fine to coarse, moderate induration, siliceous cement; foraminifer; mollusk.	260- 270	10
Calcarenite, white, porosity - intergranular, moldic pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - medium, range - fine to coarse, moderate induration, siliceous cement; foraminifer; mollusk.	270- 300	30

Sample Description	Depth (feet)	Thickness (feet)
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (95%), grain size - medium, range - fine to coarse, moderate induration, siliceous cement; foraminifer; echinoid.	300- 320	20
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (95%), grain size - medium, range - fine to coarse, moderate induration, siliceous cement; foraminifer; echinoid.	320- 330	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - medium, range - fine to coarse, moderate induration, siliceous cement; foraminifer; echinoid.	330- 340	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - medium, range - fine to medium, moderate induration, siliceous cement; dolomite (5%); foraminifer; echinoid.	340- 350	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - medium, range - fine to medium, moderate induration, siliceous cement, dolomite (5%); foraminifer; echinoid; dolostone, gray brown, moldic, altered (50-90%), subhedral, size - microcrystalline, range - cryptocrystalline to very fine crystalline, good induration, dolomitic cement.	350- 360	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (85%), grain size - fine, range - medium to fine, moderate induration, siliceous cement, micritic cement; foraminifer; echinoid; mollusk.	360- 370	10
Dolostone, pink gray, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	370- 380	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, pink gray, gray brown, porosity - inter-crystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	380- 390	10
Dolostone, pink gray, gray brown, porosity - inter-crystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - cryptocrystalline to very fine, good induration, dolomitic cement, sucrosic.	390- 400	10
Dolostone, pink gray, gray brown, porosity - inter-crystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - cryptocrystalline to microcrystalline, good induration, dolomitic cement, sucrosic.	400- 410	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (85%), grain size - medium, range - fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer; echinoid.	410- 420	10
Dolostone, gray brown, pink gray, porosity - inter-crystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	420- 440	20
Dolostone, dark-yellow-brown, gray brown, inter-crystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - cryptocrystalline to microcrystalline, good induration, dolomitic cement, sucrosic.	440- 450	10
Dolostone, dark-yellow-brown, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	450- 460	10
Dolostone, gray brown, dark-yellow-brown, inter-crystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - cryptocrystalline to microcrystalline, good induration, dolomitic cement.	460- 470	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, gray brown, porosity - vulgular, intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	470- 490	20
Dolostone, gray brown, porosity - vulgular, intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	490- 500	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (10-50%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, calcareous; foraminifer.	500- 510	10
Limestone, pink gray, porosity - intergranular, moldic, vugular, grain type - skeletal, biogenic, oolitic casts, good induration, siliceous cement, organic cement, sample dolomitic.	510- 520	10
Limestone, pink gray, white, porosity - intercrystalline, moldic, vugular, grain type - oolitic casts, grain size - very fine, range - microcrystalline to very fine, good induration, siliceous cement, organic cement, sample dolomitic.	520- 530	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (10-50%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, calcareous.	530- 540	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (10-50%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; plant remains.	540- 550	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (10-50%), subhedral, grain size - very fine, range microcrystalline to very fine, good induration; quartz, crystals, very fine; plant remains.	550- 560	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz, very fine; plant remains.	560- 570	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (10-50%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; phosphorite, very fine grains; plant remains.	570- 580	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz, crystals, very fine; plant remains.	580- 590	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; quartz, crystals, very fine; plant remains.	590- 640	50
Dolostone, pink gray, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	640- 650	10
Dolostone, pink gray, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhederal, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; quartz; phosphorite; foraminifer.	650-680	30
Dolostone, pink gray, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhederal, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; bryozoan.	680- 690	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, pink gray, porosity - intercrystalline, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, fossil molds.	690- 700	10
Dolostone, pink gray, porosity - intercrystalline, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz (trace).	700- 710	10
Dolostone, pink gray, porosity - intercrystalline, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; quartz, minor amounts; fossil molds.	710- 720	10
Dolostone, pink gray, porosity - intercrystalline, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; foraminifer.	720- 730	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz, minor amount.	730- 750	20
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement.	750- 760	10
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; plant remains.	760- 790	30
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; quartz, fine grains; plant remains; shell fragments.	790- 820	30

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; marl, gray, silty, calcitic.	820- 830	10
Dolostone, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), euhedral, grain size - fine, range - very fine to medium, moderate induration, dolomitic cement, sucrosic; marl, gray, calcitic, phosphatic.	830- 840	10
Dolostone, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; marl (trace), gray, calcitic, phosphatic; quartz (trace).	840- 850	10
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; marl (trace), gray, calcitic, phosphatic; quartz (trace).	840- 850	10
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz (trace).	850- 860	10
Dolostone, pink gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; quartz (trace); marl (trace), gray, calcitic.	860- 870	10
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz (trace); marl (trace), gray, calcitic.	870- 880	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement.	880- 890	10
Dolostone, very light orange, porosity - moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement.	880- 890	10
Dolostone, very light orange, porosity - moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; quartz (trace); marl (trace), gray, calcitic.	890- 910	20
Dolostone, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; quartz (trace).	910- 920	10
Dolostone, very light orange, light-brown-gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - cryptocrystalline to microcrystalline, good induration, dolomitic cement; calcite, crystals.	920- 960	40
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; calcite, white to opaque, crystals.	960- 990	30
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; calcite, white to smokey opaque, crystals.	990-1040	50

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement; calcite, clear to amber, crystals; plant remains.	1040-1070	30
Dolostone, very light orange, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; calcite, crystals.	1070-1100	30
Dolostone, gray brown, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; quartz.	1100-1110	10
Dolostone, light brown, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; calcite; quartz, grains; phosphorite, black, grains.	1110-1120	10
Dolostone, gray brown, white, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; quartz, grains.	1120-1130	10
Dolostone, pink gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; marl, gray to black laminated, calcitic.	1130-1140	10
Dolostone, gray brown, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; quartz, grains; marl, calcitic; phosphorite.	1140-1160	20
Dolostone, pink gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; quartz; marl, calcitic.	1160-1170	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, gray brown, very light orange, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement; marl, gray to black, calcitic; quartz, grains.	1170-1210	40
Dolostone, gray brown, very light orange, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - very fine to medium, good induration, dolomitic cement; marl, calcitic; plant remains.	1210-1240	30
Dolostone, gray brown, dark-yellow-brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - very fine to medium, good induration, dolomitic cement, calcareous; plant remains.	1240-1260	20
Dolostone, gray brown, dark-yellow-brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement; quartz, grains; calcite, crystals; phosphorite; plant remains.	1260-1280	20
Dolostone, gray brown, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - very fine to fine, good induration, dolomitic cement; plant remains.	1280-1290	10
Chert, brown gray, medium-light-gray, porosity - intercrystalline, very fine grained, good induration, siliceous cement.	1290-1310	20
Dolostone, very light orange, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement; chert, milky white to dark brown.	1310-1330	20

Sample Description	Depth (feet)	Thickness (feet)
Calcarenite, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - fine, range - very fine to medium, moderate induration, siliceous cement, micritic cement; foraminifer.	1330-1340	10
Dolostone, gray brown, very light orange, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement; calcite, crystals; plant remains.	1340-1350	10
Dolostone, very light orange, white, porosity - intercrystalline, moldic, altered (50-90%), subhederal, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement.	1350-1360	10
Dolostone, brown gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement; phosphorite, grains.	1360-1370	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (85%), grain size - fine, range - very fine to medium, moderate induration siliceous cement, micritic cement, dolomitic, moderate recrystallization; foraminifer.	1370-1374	5
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement.	1374-1380	6
Dolostone, gray brown, yellow gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to coarse, good induration, dolomitic cement; quartz, grains.	1380-1410	30
Dolostone, light brown, light tan, porosity - intercrystalline, vugular, altered (50-90%), grain size - fine, range - very fine to coarse; quartz, secondary, microcrystalline; phosphorite.	1410-1420	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, tan, light brown, cream, porosity - intercrystalline, altered (50-90%), grain size - medium coarse, range - medium coarse to coarse; phosphorite; quartz, milky white, secondary, microcrystalline.	1420-1430	10
Dolostone, gray brown, porosity - vugular, altered (50-90%), coarse crystalline; phosphorite.	1430-1440	10
Dolostone, gray brown, porosity - vugular, altered (50-90%), coarse crystalline; quartz, milky white, secondary, microcrystalline; phosphorite.	1440-1450	10
Limestone, light tan, very fine grained, lime sand; quartz, grains.	1450-1453	3
Dolostone, light brown, light gray, porosity - intercrystalline, coarse crystalline, sucrosic.	1453-1457	5
Dolostone, light tan, gray, buff, porosity - vugular, range - very fine to coarse.	1457-1465	8
Dolostone, light tan, light brown; calcite; quartz.	1465-1480	15
Dolostone, light tan, light brown; quartz, milky white, secondary, microcrystalline.	1480-1490	10
Dolostone, tan, cream, good induration; chert, dark brown; marl, brown to cream, laminated; quartz, milky white, secondary, microcrystalline.	1490-1500	10
Dolostone, very light orange, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement.	1500-1525	25
Dolostone, very light orange, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, calcareous.	1525-1540	15

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light orange, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; quartz (1%), crystalline clusters.	1540-1550	10
Dolostone, gray brown, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement; quartz (1%).	1550-1570	20
Limestone, very light gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - skeletal, biogenic, allochems (90%), grain size - medium, range - fine to coarse, good induration, siliceous cement, dolomitic, medium recrystallization.	1570-1580	10
Dolostone, medium gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - cryptocrystalline to very fine, good induration, dolomitic cement.	1580-1585	5
Dolostone, medium gray, very light orange, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - cryptocrystalline to very fine, good induration, dolomitic cement, calcareous.	1585-1600	15
FIRST CORE.	1597-1607	10
Limestone, very light orange, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (95%), grain size - medium, range - fine to medium, good induration, siliceous cement; foraminifer.	1600-1621	21
Limestone, very light orange, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - fine, range - fine to medium, good induration, siliceous cement, micritic cement; foraminifer.	1621-1631	10

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - medium, range - fine to medium, good induration, siliceous cement, micritic cement, low recrystallization; chert (trace); marl, cream, gray, calcitic; foraminifer.	1631-1640	9
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - medium, range - fine to medium, good induration, siliceous cement, micritic cement, medium recrystallization; quartz; chert (trace); marl, gray, calcitic; foraminifer.	1640-1649	9
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (95%), grain size - medium, range - fine to medium, good induration, siliceous cement, micritic cement, low recrystallization; quartz; chert; foraminifer.	1649-1693	44
Dolostone, gray brown, very light orange, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; quartz, milky white, sand size crystals; chert (trace).	1693-1701	8
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (80%), grain size - fine, range - very fine to medium, moderate induration, siliceous cement, micritic cement, dolomitic; quartz; milky, secondary, microcrystalline; phosphate; foraminifer.	1701-1707	6
SECOND CORE.	1713-1727	14
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; quartz, milky white, secondary, microcrystalline; marl, with calcite crystals.	1707-1725	18

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light orange, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic; quartz; calcite; marl.	1725-1735	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - fine, range - fine to medium, good induration, siliceous cement, micritic cement; quartz; marl, phosphatic; foraminifer.	1735-1741	6
Dolostone, light gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - fine, range - very fine to fine, good induration, dolomitic cement, micritic cement; limestone (10%); dolomite, crystals in calcareous matrix.	1741-1751	10
Calcarenite, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - medium, range - fine to medium, good induration, siliceous cement, micritic cement, medium recrystallization; foraminifer.	1751-1761	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (75%), grain size - very fine, range - very fine to fine, good induration, siliceous cement, micritic cement, dolomitic cement; dolomite (30%), crystalline, calcareous matrix; quartz (trace), milky white, secondary, microcrystalline; foraminifer.	1761-1771	10
Dolostone, gray brown, light gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - fine, range - fine to medium, good induration, dolomitic cement, micritic cement; limestone (10%); quartz (trace), milky white, secondary, microcrystalline; calcite, crystals.	1771-1780	9

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, good induration, siliceous cement, micritic cement, dolomitic cement; dolomite (25%); quartz, milky white, secondary, microcrystalline; marl, laminated; chert, light tan.	1780-1796	16
Dolostone, light gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - very fine to fine, good induration, dolomitic cement, micritic cement; limestone (10%); calcite, coarse crystalline, in dolostone matrix.	1796-1806	10
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic; quartz; chert.	1806-1810	4
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, good induration, siliceous cement, micritic cement, dolomitic cement; dolomite (20%); calcite, crystals; chert, tan; foraminifer.	1810-1812	2
Dolostone, gray brown, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - fine, range - fine to medium, good induration, dolomitic cement, micritic cement; limestone (10%); calcite, opaque crystals, in dolostone matrix.	1812-1817	5
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, good induration, siliceous cement, micritic cement, dolomitic cement; dolomite (10%); foraminifer.	1917-1830	13
Dolostone, medium gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement, sucrosic.	1830-1846	16

Jim Miller, USGS
says top of Oldsmar is
at 1834'

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - fine, range - fine to medium, good induration, siliceous cement.	1846-1865	19
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (90%), grain size - fine, range - fine to medium, good induration, siliceous cement, micritic cement; foraminifer.	1865-1875	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (65%), grain size - fine, range - very fine to medium, good induration, micritic cement, dolomitic cement; dolomite (15%); calcite, amber, crystals; foraminifer.	1875-1883	8
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement.	1883-1884	1
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - very fine to medium, good induration, dolomitic cement.	1884-1892	8
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - medium, range - fine to coarse, good induration, dolomitic cement.	1892-1902	10
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	1902-1907	5
Dolostone, light gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; calcite, crystals.	1907-1911	5

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement, sucrosic.	1911-1923	12
Dolostone, light gray, medium light gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement, sucrosic.	1923-1951	28
THIRD CORE.	1928-1938	10
Dolostone, light gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement; peat (trace), black.	1951-1954	3
Dolostone, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement; quartz, subangular grains; phosphorite.	1954-1959	5
Dolostone, light gray, very light orange, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement.	1959-1965	6
Dolostone, very light orange, gray brown, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement.	1965-1974	9
Dolostone, white, porosity - intercrystalline, moldic, altered (50-90%), subhedral, size - microcrystalline, range - microcrystalline to very fine, dolomitic cement.	1974-1977	3
Dolostone, brown gray, medium dark gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - fine, range - microcrystalline to medium, good induration, dolomitic cement.	1977-1981	5

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, light gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to fine, good induration, dolomitic cement.	1981-1984	3
Dolostone, light gray, porosity - intercrystalline, moldic, vugular, altered (50-90%), subhedral, grain size - very fine, range - very fine to fine, good induration, dolomitic cement; dolostone, light brown gray, brown gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral moderate induration, dolomitic cement, laminated.	1984-1987	3
Dolostone, light gray, porosity - intercrystalline, moldic, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement, peat (trace), black.	1987-2003	16
Dolostone, medium gray, medium light gray, porosity - intercrystalline, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range cryptocrystalline to very fine, good induration, dolomitic cement; mudstone, buff, low porosity; peat, black; fossil molds.	2003-2010	7
Dolostone, medium gray, medium dark gray, porosity - intercrystalline, pinpoint vugs, altered (50-90%), subhedral, grain size - cryptocrystalline to very fine, good induration, dolomitic cement.	2010-2022	12
Dolostone, medium light gray, medium gray, porosity - intercrystalline, pinpoint vugs, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; fossil molds.	2022-2031	9
Dolostone, medium gray, medium dark gray, porosity - intercrystalline, pinpoint vugs, vugular, altered (50-90%), grain size - very fine, range - microcrystalline to medium, good induration, dolomitic cement; shell fragments.	2031-2038	7

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light gray to light gray, porosity - intercrystalline, pinpoint vugs, vugular, altered (50-90%), euhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; peat, black.	2038-2082	44
Dolostone, medium gray, light brown gray, porosity - intercrystalline, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement.	2082-2092	10
Dolostone, medium gray, light brown gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement.	2092-2099	7
Dolostone, very light orange, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), euhedral, grain size - very fine, range - very fine to fine, good induration, dolomitic cement.	2099-2110	11
Dolostone, medium dark gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), euhedral, grain size - very fine, range - microcrystalline to fine, moderate induration, dolomitic cement.	2110-2119	8
Clay, dark gray, medium dark gray, porosity - intergranular, moderate induration, clay cement, dolomitic cement, dolomitic; quartz, milky white, secondary, microcrystalline.	2119-2123	4
Dolostone, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement; quartz, milky white, secondary, microcrystalline; gypsum (1%), white, vitreous.	2123-2140	17
Dolostone, very light gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - microcrystalline to very fine, good induration, dolomitic cement, calcareous; fossil fragments.	2140-2150	10

Sample Description	Depth (feet)	Thickness (feet)
FOURTH CORE.	2140-2160	20
Limestone, light gray, very light gray, porosity - intercrystalline, moldic, pinpoint vugs, grain type - biogenic, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic, high recrystalization; quartz, milky white, secondary, microcrystalline; foraminifer; organics.	2150-2195	45
Limestone, white, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, crystalline, 90% allochems, grain size - medium, good induration, siliceous cement, medium recrystallization, dolomitic; gypsum, milky white, vitreous; foraminifer; organics.	2195-2205	10
Calcarenite, white, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, good induration, siliceous cement, medium recrystallization, dolomitic; selenite, transparent, translucent, basal plane cleavage; foraminifer; fossil fragments.	2205-2214	9
Dolostone, very light gray, porosity - intercrystalline, pinpoint vugs, vugular, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; gypsum, white, translucent, vitreous, soft; fossil fragments.	2214-2222	8
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (10-50%), subhedral, good induration, dolomitic, cement, siliceous cement, calcareous; foraminifer.	2222-2232	10
Limestone, very light gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - skeletal, biogenic, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic; gypsum, white, opaque, microcrystalline; foraminifer; fossil molds; organics.	2232-2240	8

Sample Description	Depth (feet)	Thickness (feet)
Limestone, very light gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - skeletal, biogenic, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic; gypsum, white, microcrystalline; selenite, transparent to translucent, basal plane cleavage; foraminifer; fossil molds; organics.	2240-2250	10
Limestone, very light gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - skeletal, biogenic, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic; gypsum, white, vitreous; foraminifer; fossil molds; organics.	2250-2291	41
Limestone, very light gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - skeletal, biogenic, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic; gypsum, white, vitreous; selenite, clear, basal plane cleavage; foraminifer; fossil molds; organics.	2291-2306	15
Limestone, very light gray, white, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - biogenic, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic; gypsum (trace), white, fibrous; selenite, clear, basal plane cleavage.	2306-2336	30
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement; gypsum, white, fills vugs; selenite, clear, basal plane cleavage.	2336-2362	26
Gypsum, white, good induration, anhydritic cement; dolostone (25%); selenite (trace), transparent, basal plane cleavage.	2362-2363	1
Gypsum, white, good induration, anhydritic cement; dolostone (45%), light gray, fine grain, medium induration; selenite, transparent, basal plane cleavage.	2363-2373	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, white, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, anhydritic cement; gypsum (15%), white, microcrystalline; selenite (trace), foraminifer; fossil molds.	2373-2387	14
Anhydrite, white, anhydritic cement.	2387-2399	12
Dolostone, very light gray, white, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, anhydritic cement; gypsum (7%), white, amorphous; selenite (trace).	2399-2407	8
Anhydrite, light blue gray; gypsum, white, amorphous; selenite; white, opaque, basal cleavage; dolostone, gray.	2407-2451	44
Dolostone, light gray, porosity - intercrystalline, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - cryptocrystalline to microcrystalline, good induration; dolomitic cement, anhydritic cement; gypsum (1%), pearly white.	2451-2460	9
Anhydrite, white, good induration, anhydritic cement; dolostone (40%), light gray, fine crystalline, vugular, high secondary mineralization; selenite (trace), pearly white, basal plane cleavage.	2460-2469	9
Dolostone, light gray, white, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, anhydritic cement; gypsum (10%), white, vitreous; foraminifer; fossil molds.	2469-2500	31
Anhydrite, white, good induration, anhydrite cement.	2500-2507	7

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, white, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to very fine, good induration, dolomitic cement, anhydritic cement, organics, fossil molds; gypsum, white, microcrystalline, in vugs and fractures; anhydrite, dull gray, microcrystalline.	2507-2513	6
Anhydrite, white, good induration, anhydritic cement; selenite, low luster, in vugs and fractures; marl (trace), brown and cream, laminated, gypsiferous.	2513-2519	6
Dolostone, very light gray, white, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement; anhydrite (10%).	2519-2535	16
Anhydrite, white, cryptocrystalline, good induration, anhydritic cement.	2535-2542	7
Dolostone, white, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline; good induration, dolomitic cement, anhydritic cement; anhydrite (10%); selenite, transparent, basal plane cleavage; foraminifer; fossil molds.	2542-2587	45
FIFTH CORE.	2546-2565	19
Anhydrite, white, good induration, anhydritic cement.	2587-2610	23
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement, anhydrite (15%); fossil molds.	2610-2633	23
Anhydrite, white, very light gray, good induration, anhydritic cement.	2633-2661	28

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine - microcrystalline, good induration, dolomitic cement, anhydritic cement, anhydrite (15%).	2661-2674	13
Anhydrite, white, good induration, anhydritic cement, dolomitic cement, dolomite (35%).	2674-2692	18
Dolostone, very light gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine - microcrystalline, good induration, dolomitic cement, anhydrite (10%), fossil molds.	2692-2704	12
Anhydrite, white, good induration, anhydritic cement	2704-2778	74
Dolostone, very light gray, porosity - intercrystalline vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement; anhydrite (10%).	2778-2791	13
Anhydrite, very light gray, light brown, good induration, anhydritic cement, dolomitic cement.	2791-2838	47
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine - microcrystalline, good induration, dolomitic cement, anhydritic cement; selenite, transparent, basal plane cleavage; anhydrite; fossil molds.	2838-2844	6
Anhydrite, very light gray, light brown, good induration, anhydritic cement, dolomitic cement; dolomite, very light gray, crystalline.	2844-2849	5
Dolostone, very light gray, light brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement; anhydrite (25%); fossil molds.	2849-2860	11

Sample Description	Depth (feet)	Thickness (feet)
Anhydrite, light brown, very light gray, good induration, anhydritic cement, dolomitic cement; gypsum, blue white, white, microcrystalline.	2860-2903	43
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (10-50%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement, anhydrite (40%); gypsum, white, microcrystalline.	2903-2910	7
Dolostone, very light gray, light brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (10-50%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement, anhydrite (20-40%); gypsum; foraminifer in anhydrite/gypsum matrix, forams appear dolomitic.	2910-2938	38
Anhydrite, very light gray, light brown, good induration, anhydritic cement, dolomitic cement, dolomite (10%).	2938-2960	22
Dolostone, medium light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement; anhydrite (7%) white, very light gray.	2960-2968	8
Dolostone, very light gray, light brown, porosity - intercrystalline vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement, calcareous; anhydrite (45%), white, light gray, microcrystalline; gypsum; selenite, transparent, in vugs; foraminifer; fossil molds.	2968-2978	10
Dolostone, medium light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement; anhydrite (3%), white, vitreous.	2978-2988	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement, calcareous; gypsum (5%), white, massive; selenite, transparent, in vugs and fractures; foraminifer; fossil molds.	2988-3038	50
Dolostone, light gray, medium light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement; selenite, transparent, in vugs and fractures.	3038-3048	10
Dolostone, very light gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement; gypsum (trace); selenite (trace); foraminifer; fossil molds.	3048-3068	20
Dolostone, very light gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine range - very fine to microcrystalline, good induration, dolomitic cement; selenite (trace); gypsum (trace).	3068-3098	30
Anhydrite, white, good induration, anhydritic cement; gypsum (10%), white, microcrystalline.	3098-3105	7
Dolostone, very light gray, white, altered (50-90%), grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement, gypsum (trace); fossil molds.	3105-3108	3
Dolostone, white, very light gray, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement; anhydrite (45%), white, vitreous; gypsum, white, microcrystalline; selenite, in vugs; foraminifer; fossil molds.	3108-3128	20

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (10-50%), grain subhedral, size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, anhydritic cement; anhydrite (25%), white, vitreous; gypsum (trace), white, vitreous; foraminifer; fossil molds.	3128-3158	30
Dolostone, pink gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), grain size - fine, range - medium to very fine, good induration, dolomitic cement; anhydrite (10%), white, vitreous; gypsum (trace); foraminifer; fossil molds.	3158-3178	20
Dolostone, pink gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, subhedral, altered (50-90%), grain size - fine, range - medium to very fine, good induration, dolomitic cement; gypsum, blue, white.	3178-3206	28
Dolostone, light brown gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; anhydrite (5%), white, vitreous; gypsum (trace).	3206-3216	10
Dolostone, light gray, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; gypsum (5%), white, vitreous; selenite (trace).	3216-3276	70
Calcarenite, very light gray, porosity - intercrystalline, intergranular, pinpoint vugs, grain type - biogenic, skeletal, crystalline, allochems (90%), good induration, siliceous cement, dolomitic; gypsum (3%), white, vitreous; selenite (trace).	3276-3288	12
Dolostone, light gray, medium light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to very fine, good induration, dolomitic cement; gypsum, white, vitreous.	3288-3298	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, light gray, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; anhydrite, brown; gypsum, white.	3298-3308	10
Dolostone, light gray, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - medium, range - medium to very fine, good induration, dolomitic cement; anhydrite (2%), white, vitreous; gypsum (2%), white, microcrystalline.	3308-3348	40
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - biogenic, skeletal, crystalline, allochems (80%), good induration, siliceous cement, medium recrystallization, dolomitic; gypsum (trace), white, massive; foraminifer; fossil molds.	3348-3438	90
Limestone, pink gray, very light gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - biogenic, skeletal, crystalline, allochems (85%), grain size - fine, range - medium to very fine, good induration, siliceous cement, high recrystallization, dolomitic; foraminifer, fossil molds.	3438-3448	10
Dolostone, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (10-50%), subhedral, grain size - fine, range - fine to very fine, good induration, dolomitic cement, siliceous cement, calcareous; foraminifer; fossil molds.	3448-3468	20
Calcarenite, very light gray, pink gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - biogenic, skeletal, crystalline, allochems (90%), grain size - medium, range - medium to fine, good induration, siliceous cement, low recrystallization; foraminifer; fossil molds.	3468-3488	20
Dolostone, gray orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to very fine, good induration, dolomitic cement.	3488-3498	10

Sample Description	Depth (feet)	Thickness (feet)
Calcarenite, very light gray, pink gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - biogenic, skeletal, crystalline, good induration, siliceous cement, dolomitic cement, dolomitic, medium recrystallization; foraminifer; fossil molds; echinoid.	3498-3508	10
Calcarenite, very light gray, pink gray, porosity - intergranular, moldic, pinpoint vugs, grain type - biogenic, skeletal, crystalline, allochems (85%), grain size - medium, range - medium to very fine, good induration, siliceous cement, low recrystallization; foraminifer; echinoid.	3508-3548	40
Calcarenite, very light gray, pink gray, porosity - intergranular, intercrystalline, pinpoint vugs, grain type - skeletal, biogenic, crystalline, allochems (85%), grain size - medium, range - medium to very fine, good induration, siliceous cement, medium recrystallization, dolomitic; foraminifer; brachiopod.	3548-3558	10
Dolostone, gray brown, gray-orange-pink, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to very fine, good induration, dolomitic cement, siliceous cement, high recrystallization, calcareous; foraminifer; mollusk.	3558-3568	10
Calcarenite, very light gray, pink gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, crystalline, allochems (80%), grain size - medium, range - medium to very fine, good induration, siliceous cement, low recrystallization, chalky; foraminifer; mollusk.	3568-3618	50
Dolostone, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to very fine, good induration, dolomitic cement, calcareous; foraminifer; fossil molds.	3618-3646	28
Limestone, white, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (60%), good induration, siliceous cement, micritic cement, chalky; foraminifer; fossil molds.	3646-3657	11

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, gray brown, gray orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (10%), white, very light blue, massive, vitreous.	3657-3685	28
Calcarenite, white, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, allochems (80%), grain size - fine, range - medium to very fine, good induration, siliceous cement, micritic cement, chalky; anhydrite (trace); selenite (trace); foraminifer; mollusk; echinoid.	3685-3757	72
Calcarenite, white, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - fine, range - medium to very fine, poor induration, micritic cement, chalky; foraminifer; mollusk.	3844-3954	110
Calcarenite, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micrite, grain size - fine, range - fine to very fine, poor induration, micritic cement, chalky; foraminifer; mollusk; fossil molds.	3954-3964	10
Calcarenite, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - very fine, range - very fine to fine, moderate induration, micritic cement, chalky; foraminifer; echinoid.	3964-3974	10
Dolostone, very light orange, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to very fine, good induration, dolomitic cement, micritic cement, chalky, calcareous.	3974-3984	10
Calcarenite, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - fine, range - fine to very fine, poor induration, micritic cement, chalky, low recrystallization; dolomite (1%); foraminifer.	3984-4074	90

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, moderate induration, micritic cement, siliceous cement, chalky, moderate recrystallization; fossil molds.	4074-4094	20
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, poor induration, micritic cement, chalky; foraminifer.	4094-4114	20
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, micritic, poor induration, micritic cement, chalky; foraminifer.	4014-4024	10
Dolostone, gray brown, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, calcareous; anhydrite (trace).	4124-4150	26
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, crystalline, poor induration, micritic cement, chalky; foraminifer.	4150-4240	90
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, micritic, moderate induration, micritic cement, chalky; foraminifer.	4240-4268	28
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, micritic, crystalline, grain size - fine, range - fine to very fine, poor induration, micritic cement, chalky; foraminifer.	4268-4338	70
Chalk, white, porosity - intergranular, moldic, pinpoint vugs, moderate induration, micritic cement, chalky.	4338-4348	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, micritic, crystalline, grain size - fine, range - fine to very fine, poor induration, micritic cement, chalky; foraminifer.	4348-4368	20

Sample Description	Depth (feet)	Thickness (feet)
Calcite, transparent, amber, light brown, crystalline, rhombohedral habit, dolomitic; dolostone matrix; dolostone, white, porosity - intercrystalline, moldic, pinpoint vugs, poor induration, dolomitic cement; anhydrite (trace); gypsum (trace).	4368-4398	30
Dolostone, white, very light orange, altered (50-90%), subhedral, grain size - fine, range - fine to very fine, good induration, dolomitic cement.	4398-4428	30
Dolostone, white, very light orange, porosity - intercrystalline, moldic, pinpoint vugs, altered (50-90%), grain size - fine, range - fine to very fine, poor induration, dolomitic cement; anhydrite (trace), gypsum (trace); selenite (trace).	4428-4458	30
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - fine, range - medium to very fine, poor induration, micritic cement, chalky; dolomite (2%), brown, very fine crystalline clusters; gypsum (trace); anhydrite (trace), selenite (trace), foraminifer.	4458-4478	20
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, siliceous cement, chalky; dolomite (2%), light brown, amber; selenite, translucent, basal plane cleavage; gypsum, white, vitreous; foraminifer; mollusk; echinoid.	4478-4498	20
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (40%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, chalky; dolomite, gray; foraminifer; mollusk.	4498-4528	30
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (40%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, chalky; dolomite (2%); foraminifer.	4528-4548	20

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, crystalline, poor induration, siliceous cement, micritic cement, chalky; dolomite (20%), calcareous; foraminifer.	4548-4568	20
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (35%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, chalky; dolomite (3%), calcareous; foraminifer.	4568-4598	30
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (30%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, chalky; dolomite (2%); pyrite (1%); spar (1%); selenite (trace); foraminifer.	4598-4708	110
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - very fine, range - very fine to microcrystalline, moderate induration, micritic cement; dolomite (1%); spar (1%); foraminifer.	4708-4758	50
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, crystalline, grain size - fine, range - medium to very fine, poor induration, micritic cement, siliceous cement, chalky; dolomite (trace); spar (trace); foraminifer.	4758-4768	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, crystalline, grain size - fine, range - medium to very fine, poor induration, micritic cement, siliceous cement, chalky; dolomite (1-2%), brown, black, microcrystalline; spar (trace); foraminifer.	4768-4828	60
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, micritic, biogenic, allochems (20%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, siliceous cement, low recrystallization, chalky; dolomite (1%), brown, black, microcrystalline; pyrite (1%); spar (1%); foraminifer.	4838-4875	37

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - very fine, range - fine to microcrystalline, poor induration, micritic cement, chalky, dolomite (1%), brown, black, microcrystalline; foraminifer.	4875-4908	33
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (35%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, siliceous cement, chalky, low recrystallization; organics.	4908-4928	20
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (30%), grain size - very fine, range - fine to microcrystalline.	4928-4938	10
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - very fine, range - fine to microcrystalline, poor induration, micritic cement, chalky; foraminifer.	4938-4968	30
Limestone, white, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (30%), grain size - very fine, range, - fine to microcrystalline, moderate induration, micritic cement, siliceous cement, chalky, medium recrystallization.	4968-5068	100
Limestone, white, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (30%), grain size - very fine, range - fine to microcrystalline, moderate induration, micritic cement, siliceous cement, chalky, medium recrystallization; organics.	5068-5086	18
Limestone, light gray, medium gray, porosity - intergranular, moldic, pinpoint vugs, moderate induration, micritic cement, siliceous cement, clay cement, dolomitic; clay (5%); quartz (1%), sand; organics.	5086-5093	7

Sample Description	Depth (feet)	Thickness (feet)
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (30%), grain size - fine, range - fine to microcrystalline, poor induration, micritic cement, siliceous cement, chalky; foraminifer.	5093-5102	9
Dolostone, light gray, medium gray, porosity - intercrystalline, moldic, pinpoint vugs, altered (10-50%), subhedral, moderate induration, dolomitic cement, micritic cement, calcareous; clay (5%); quartz (1%), sand.	5102-5132	30
Limestone, white, very light orange, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, grain size - very fine, range - fine to microcrystalline, poor induration, micritic cement, chalky.	5132-5152	20
Limestone, very light gray, light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (25%), grain size - very fine, range - fine to micro-crystalline, good induration, micritic cement, siliceous cement, chalky, medium recrystallization, dolomitic.	5152-5162	10
Dolostone, very light gray, light gray, porosity - intercrystalline, moldic, pinpoint vugs, altered (10-50%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement, micritic cement, siliceous cement, chalky, calcareous.	5162-5182	20
Limestone, very light gray, porosity - intergranular, moldic, pinpoint vugs, grain type - skeletal, biogenic, micritic, allochems (25%), grain size - very fine, range - fine to microcrystalline, good induration, micritic cement, siliceous cement, dolomitic cement, chalky, dolomitic, medium recrystallization.	5182-5212	30
Dolostone, light gray, medium light gray, porosity - intercrystalline, moldic, pinpoint vugs, altered (10-50%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement, siliceous cement, calcareous.	5212-5275	63

Sample Description	Depth (feet)	Thickness (feet)
Sandstone, light olive gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, good induration, dolomitic cement; glauconite (1%), green; phosphatic sand (1%).	5275-5285	10
Sandstone, light gray, medium light gray, porosity - intercrystalline, vugular, pinpoint vugs, good induration, dolomitic cement, calcareous; glauconite (5%), green; pyrite (1%), cubic habit, amorphous; silt (trace); phosphatic sand (trace).	5285-5305	20
Sandstone, light gray, medium light gray, porosity - intercrystalline, vugular, pinpoint vugs, good induration, micritic cement, siliceous cement, dolomitic cement; silt; glauconite, green; mica (trace); pyrite (trace).	5305-5355	50
Limestone, very light gray, white, porosity - intercrystalline, vugular, pinpoint vugs, grain type - crystalline, good induration, siliceous cement, high recrystallization, dolomitic; calcite, white, translucent, massive; pyrite (trace).	5355-5375	20
Dolostone, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - fine to gravel, good induration, dolomitic cement; pyrite (trace), cubic habit.	5375-5400	25
Dolostone, very light orange, gray orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement.	5400-5423	23
Dolostone, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; anhydrite (2%) white, vitreous.	5423-5456	33
Dolostone, very light orange, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; gypsum (2%), white, massive; quartz (trace), clear grains; anhydrite, white, vitreous; fossil molds.	5456-5484	28

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, gray brown, very light orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - fine to microcrystalline, good induration, dolomitic cement, anhydrite, white, massive; selenite, clear, in vugs; fossil molds.	5484-5494	10
Dolostone, very light orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - fine to microcrystalline, good induration, dolomitic cement; gypsum (trace); selenite (trace); anhydrite (trace); fossil molds.	5494-5504	10
Dolostone, white, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (trace); fossil molds.	5504-5510	6
Dolostone, very light orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - fine to microcrystalline, good induration, dolomitic cement; selenite (trace); anhydrite (trace); fossil molds.	5510-5540	30
Dolostone, light gray, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (10%), white, vitreous; fossil molds.	5540-5558	18
Anhydrite, white, good induration, anhydritic cement; dolostone (30%), gray, microcrystalline.	5558-5561	3
Dolostone, very light orange, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - medium to microcrystalline, good induration, dolomitic cement; anhydrite (10%), white, vitreous; gypsum (trace), transparent; mudstone (trace), dark gray, very fine grain; pyrite, metallic luster, cubic habit, massive.	5561-5591	30

Sample Description	Depth (feet)	Thickness (feet)
SIXTH CORE.	5589-5613	24
Dolostone, pink gray, porosity - intercrystalline, vugular, fracture, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement; anhydrite (20%) white, massive; gypsum, white, vitreous.	5591-5627	36
Dolostone, very light gray, altered (50-90%), subhedral, grain size - microcrystalline, range - very fine to microcrystalline, good induration, dolomitic cement; selenite, transparent, in vugs and fractures; anhydrite, white, vitreous.	5627-5633	6
Anhydrite, white, good induration, anhydritic cement; dolostone (10-15%), gray, altered (50-90%), subhedral, grain size - microcrystalline, good induration, dolomitic cement; gypsum (trace).	5633-5640	7
Dolostone, very light orange, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (1%), light tan; calcite, white, amber, crystalline masses.	5640-5710	70
Dolostone, medium light gray, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement; calcite (trace); selenite (trace).	5710-5715	5
Dolostone, very light orange, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to microcrystalline, good induration, dolomitic cement, anhydrite (trace); selenite (trace); fossil molds.	5715-5730	15
Dolostone, pink gray, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to microcrystalline, good induration, dolomitic cement; anhydrite (trace); white; fossil molds.	5730-5756	26

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, pink gray, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; selenite (trace); fossil molds.	5756-5766	10
Dolostone, pink gray, very light orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to microcrystalline, good induration, dolomitic cement; fossil molds.	5766-5784	18
Dolostone, light brown gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, good induration; anhydrite (40%), tan, white, massive; organics.	5784-5792	8
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - very fine to microcrystalline, good induration, dolomitic cement; anhydrite (2%), white, massive; selenite, transparent, basal plane cleavage.	5792-5801	9
Dolostone, very light orange, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - medium to microcrystalline, good induration, dolomitic cement; anhydrite (1%), white, massive; gypsum (trace); fossil molds.	5801-5809	8
Dolostone, very light gray, pink gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; selenite (trace); fossil molds.	5809-5819	10
Dolostone, pink gray, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (1%) white, massive; selenite (trace), fossil molds.	5819-5839	20

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, yellow gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (trace); selenite (trace); fossil molds; organics.	5839-5874	35
Dolostone, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - medium to microcrystalline, good induration, dolomitic; selenite, transparent, fills vugs and fractures; fossil molds.	5874-5884	10
Dolostone, gray brown, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to microcrystalline, good induration, dolomitic cement; anhydrite (trace); fossil molds.	5884-5894	10
Dolostone, yellow gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - medium, range - medium to very fine, good induration, dolomitic cement; glauconite (trace); selenite (trace), anhydrite (trace); fossil molds.	5894-5935	41
Dolostone, yellow gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - medium to very fine, good induration, dolomitic cement; selenite, white, translucent, basal plane cleavage, in vugs and fractures; quartz (trace); fossil molds.	5935-5977	42
Dolostone, light gray, yellow gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement; selenite, translucent, basal plane cleavage; fossil molds.	5977-6010	33
Dolostone, light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, dolomitic cement; calcite, opaque, light yellow, massive, rhombohedral habit, fills vugs; anhydrite (1%), white, massive; glauconite (trace); fossil molds.	6010-6020	10

Sample Description	Depth (feet)	Thickness (feet)
Dolostone, light gray, yellow gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - fine to microcrystalline, good induration, dolomitic cement; anhydrite (2%), white massive; glauconite (1%), green; calcite, transparent to light yellow, massive, crystalline, rhombohedral habit; selenite (trace).	6020-6040	20
Dolostone, light gray, yellow gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, good induration, dolomitic cement; anhydrite (1%) white; fossil molds.	6040-6070	30
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - very fine, range - microcrystalline to fine, dolomitic cement; anhydrite (1%) white, massive; selenite (trace), quartz (trace).	6070-6090	20
Dolostone, very light gray, porosity - intercrystalline, vugular, pinpoint vugs, altered (50-90%), subhedral, grain size - fine, range - very fine to fine, good induration, dolomitic cement; sand (40%), quartz.	6090-6100	10
Clastics, very light gray, porosity - intergranular, moldic, pinpoint vugs, good induration, dolomitic cement; silt, green gray, porosity - intergranular, moldic, pinpoint vugs, moderate induration, clay cement, micritic cement; quartz (20%), transparent, amber, rose, angular, slightly subangular.	6100-6123	23
Micaceous schist, very light gray, medium dark gray, crystalline, angular, subangular; muscovite, brown, foliated; biotite, black, foliated, pyrite, gold metallic luster, cubic habit, quartz (trace), amber, rose.	6123-6133	10
Micaceous schist, gray, dark gray, crystalline, hard; muscovite, brown, foliated; biotite, black, foliated; quartz, transparent, amber, rose, angular, vein quartz common.	6133-6192	59

APPENDIX D

Chemical Analyses of Water Samples Collected During Drilling and Testing in the Injection-Test Well

APPENDIX D. CHEMICAL ANALYSES OF WATER SAMPLES COLLECTED DURING DRILLING AND TESTING IN THE INJECTION-TEST WELL[1]

Date	5/5/76	5/5/76	5/6/76	5/8/76	5/11/76	5/14/76	5/15/76	5/15/76
Sample Depth (ft)[2]	900	1,000	1,100	1,200	1,300	1,365	1,400	1,400
Well Bore Interval Open (ft)[2]	120-900	120-1,000	120-1,100	120-1,200	120-1,300	120-1,365	120-1,400	120-1,400
Sampling Method	D.S.[3,4]	D.S.[4]	D.S.	D.S.	D.S.	D.S.[4]	D.S.	D.S.[4]
Temperature (°C), field	--	--	--	22.0	--	--	--	--
Silica (SiO_2)	10.0	11.0	5	5	5	9.5	5	10.0
Calcium (Ca)	35.0	35.0	38	38	38	36.0	40	37.0
Magnesium (Mg)	5.4	5.6	11	5.8	4.9	5.5	5.8	6.4
Sodium (Na)	7.7	9.6	9.2	7.2	6.9	7.5	6.2	7.0
Potassium (K)	0.9	1.0	--	--	--	0.9	--	0.9
Bicarbonate (HCO_3)	135.0	138.0	161	146	142	139.0	151	146.0
Carbonate (CO_3)	0.0	0.0	0	0	0	0	0	0.0
Hydroxide (OH)	--	--	0	0	0	--	0	--
Sulfate (SO_4)	3.2	4.2	16	6	2	3.0	3	4.8
Chloride (Cl)	8.3	9.5	8	7	6	8.4	7	9.4
Fluoride (F)	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1
Nitrate (NO_3)	--	--	--	--	--	--	--	--
Phosphate (PO_4)	--	--	0.1	0.1	0.1	--	0.1	--
Total Dissolved Solids								
Calculated	140.0	140.0	212	187	178	140.0	188	150.0
Residue by Evaporation @ 180°C	147.0	145.0	--	--	--	141.0	--	148.0
Phenolphthalein Alkalinity ($CaCO_3$)	--	--	0	0	0	--	0	--
Total Alkalinity ($CaCO_3$)	111.0	113.0	132	120	116	114.0	124	119.0
Hardness as $CaCO_3$ (Ca, Mg)	110.0	110.0	140	120	116	110	124	120.0
Specific Conductance								
(µmhos/cm @ 25°C)	240	247	--	--	--	242	--	262
pH, laboratory	8.30	8.30	8.1	8.0	8.0	8.1	8.1	8.2
pH, field	--	--	--	--	--	--	--	--
pHs	--	--	7.9	7.9	7.9	--	7.9	--
Density @ 15°C (gm/ml)	--	--	--	--	--	--	--	--
Arsenic (As)	--	--	--	--	--	--	--	--
Copper (Cu)	--	--	<0.1	<0.1	<0.1	--	<0.1	--
Iron (Fe)	--	--	<0.1	<0.1	<0.1	--	<0.1	--
Lead (Pb)	--	--	--	--	--	--	--	--
Manganese (Mn)	--	--	<0.05	<0.05	<0.05	--	<0.05	--
Mercury (Hg)	--	--	--	--	--	--	--	--
Silver (Ag)	--	--	--	--	--	--	--	--
Strontium (Sr), (µgm/l)	190.0	220.0	--	--	--	220.0	--	220.0
Zinc (Zn)	--	--	--	--	--	--	--	--

Date	5/18/76	6/16/76	6/8/76	6/8/76	7/2/76	7/9/76	7/14/76	7/18/76
Sample Depth (ft)[2/]	1,450	1,460	1,461	1,461	1,500	1,597	1,700	1,800
Well Bore Interval Open (ft)[2/]	120-1,450	120-1,460	1,375-1,461	1,375-1,461	120-1,500	120-1,597	120-1,700	120-1,800
Sampling Method	D.S.[4/]	D.S.	P.T.[5/]	P.T.[4/]	D.S.	D.S.	D.S.	D.S.
Temperature (°C), field	--	23.5	23.5	23.5	23.0	23.5	23.0	23.0
Silica (SiO_2)	10.0	5.0	5	11	4.1	5.8	5.0	4.5
Calcium (Ca)	35.0	38	38	36	42	37	41	37
Magnesium (Mg)	5.6	4.9	5.8	5.9	5.8	5.1	6.8	6.8
Sodium (Na)	7.0	6.6	7.5	6.3	6.8	7.4	7.8	7.6
Potassium (K)	0.8	--	--	0.9	--	--	--	--
Bicarbonate (HCO_3)	139.0	142	146	139	144	150	139	139
Carbonate (CO_3)	0.0	0	0	0	0	0	0	0
Hydroxide (OH)	--	0	0	--	0	0	0	0
Sulfate (SO_4)	2.4	2	1	2.9	2.5	2	3	2
Chloride (Cl)	8.9	4	3	8.4	6	3	6	3
Fluoride (F)	0.1	0.2	0.1	0.2	0.1	0.15	0.18	0.15
Nitrate (NO_3)	--	--	--	0.04	--	--	--	--
Phosphate (PO_4)	--	0.2	0.6	--	0.06	0.1	0.11	0.10
Total Dissolved Solids								
Calculated	140.0	173	175	--	195	175	188	178
Residue by Evaporation @ 180°C	136.0	--	--	114	--	--	--	--
Phenolphthalein Alkalinity ($CaCO_3$)	--	0	0	--	0	0	0	0
Total Alkalinity ($CaCO_3$)	114.0	116	120	114	118	123	114	114
Hardness as $CaCO_3$ (Ca, Mg)	110.0	116	120	110	130	114	130	120
Specific Conductance (μmhos/cm @ 25°C)	244	--	205	205	278	245	262	250
pH, laboratory	8.2	8.0	8.1	7.8	7.2	8.0	6.6	7.3
pH, field	--	--	--	--	--	--	--	--
pHs	--	8.0	7.9	--	7.9	7.9	7.9	8.0
Density @ 15°C (gm/ml)	--	--	--	0.9985[a/]	--	--	--	--
Arsenic (As)	--	--	--	--	--	--	--	--
Copper (Cu)	--	<0.1	<0.1	0.003	<0.01	<0.1	<0.1	<0.1
Iron (Fe)	--	0.5	0.5	1.1	0.05	<0.1	0.04	0.05
Lead (Pb)	--	--	--	0.017	--	--	--	--
Manganese (Mn)	--	<0.05	<0.05	0.03	<0.05	<0.05	<0.05	<0.05
Mercury (Hg)	--	--	--	--	--	--	--	--
Silver (Ag)	--	--	--	--	--	--	--	--
Strontium (Sr), (μgm/l)	220.0	--	--	200	--	--	--	--
Zinc (Zn)	--	--	--	0.01	--	--	--	--

Date	7/23/76	7/23/76	7/21/76	7/31/76	8/25/76	8/25/76	8/2/76	8/3/76
Sample Depth (ft)[2/]	1,890	1,890	1,898	2,000	2,075	2,075	2,100	2,136
Well Bore Interval Open (ft)[2/]	120-1,898	120-1,898	120-1,898	120-2,000	120-2,528	120-2,528	120-2,100	120-2,136
Sampling Method	T.S.[6/]	T.S.[4/]	D.S.	D.S.	T.S.	T.S.[4/]	D.S.	D.S.
Temperature (°C), field	--	--	23.5	23.0	--	--	23.5	--
Silica (SiO_2)	4.2	10.0	3.0	4.8	5.6	11.0	4.8	5.5
Calcium (Ca)	36	35.0	36	38	38	38.0	38	161
Magnesium (Mg)	5.8	5.4	6.6	5.8	5.8	5.8	5.8	8.7
Sodium (Na)	6.8	6.4	7.6	8.4	8.3	9.0	8.4	9.4
Potassium (K)	--	0.8	--	--	--	2.0	--	--
Bicarbonate (HCO_3)	144	132.0	151	154	149	148.0	154	154
Carbonate (CO_3)	0	0.0	0	0	0	0.0	0	0
Hydroxide (OH)	0	--	0	0	0	--	0	0
Sulfate (SO_4)	2	2.4	1	2	3	6.0	2	312
Chloride (Cl)	4	9.4	3	3	9	9.3	3	3
Fluoride (F)	0.10	0.2	0.10	0.2	0.18	0.2	0.2	0.5
Nitrate (NO_3)	--	--	--	--	--	--	--	--
Phosphate (PO_4)	0.3	--	0.15	<0.1	0.15	--	<0.1	0.1
Total Dissolved Solids								
Calculated	178	140.0	175	185	154	150.0	183	565
Residue by Evaporation @ 180°C	--	140.0	--	--	--	146.0	--	--
Phenolphthalein Alkalinity ($CaCO_3$)	0	--	0	0	0	--	0	0
Total Alkalinity ($CaCO_3$)	118	108.0	124	126	122	121.0	126	126
Hardness as $CaCO_3$ (Ca, Mg)	114	110.0	117	120	120	120.0	120	438
Specific Conductance (µmhos/cm @ 25°C)	--	275	240	250	--	256	260	--
pH, laboratory	7.7	7.8	8.0	6.4	7.8	8.0	8.0	8.0
pH, field	--	--	--	--	--	--	--	--
pHs	8.0	--	7.9	7.9	7.9	--	7.9	7.3
Density @ 15°C (gm/ml)	--	--	--	--	--	0.9980[a/]	--	--
Arsenic (As)	--	--	--	--	--	--	--	--
Copper (Cu)	<0.1	--	<0.1	<0.1	<0.1	--	<0.1	<0.1
Iron (Fe)	0.08	--	0.1	0.05	0.3	--	0.05	0.1
Lead (Pb)	--	--	--	--	--	--	--	--
Manganese (Mn)	<0.05	--	<0.05	<0.05	<0.05	--	<0.05	<0.05
Mercury (Hg)	--	--	--	--	--	--	--	--
Silver (Ag)	--	--	--	--	--	--	--	--
Strontium (Sr), (µgm/l)	--	160	--	--	--	200	--	--
Zinc (Zn)	--	--	--	--	--	--	--	--

Date	8/6/76	8/7/76	8/25/76	8/25/76	8/7/76	8/25/76	8/25/76	8/25/76
Sample Depth (ft)[2/]	2,200	2,300	2,310	2,310	2,325	2,350	2,350	2,395
Well Bore Interval Open (ft)[2/]	120-2,200	120-2,300	120-2,528	120-2,528	120-2,325	120-2,528	120-2,528	120-2,528
Sampling Method	D.S.	D.S.	T.S.	T.S.[4/]	D.S.	T.S.	T.S.[4/]	T.S.
Temperature (°C), field	--	23.5	--	--	24.0	--	--	--
Silica (SiO_2)	4.0	5.0	5.0	10.0	5.0	4.8	10.0	4.3
Calcium (Ca)	41	46	72	72.0	127	133	140.0	2,100
Magnesium (Mg)	6.8	6.3	6.8	7.2	8.7	2.9	8.0	2,831
Sodium (Na)	8.0	11	12	11.0	9.9	5.0	28.0	36,000
Potassium (K)	--	--	--	1.1	--	--	1.7	--
Bicarbonate (HCO_3)	139	154	137	138.0	146	142	138.0	239
Carbonate (CO_3)	0	0	0	0.0	0	0	0.0	0
Hydroxide (OH)	0	0	0	--	0	0	--	0
Sulfate (SO_4)	13	27	105	110.0	240	245	250.0	6,400
Chloride (Cl)	12	9	14	15.0	3	55	49.0	65,000
Fluoride (F)	0.26	0.20	0.31	0.2	0.42	0.42	0.4	9.6
Nitrate (NO_3)	--	--	--	--	--	--	--	--
Phosphate (PO_4)	<0.1	<0.1	<0.10	--	<0.1	<0.10	--	0.2
Total Dissolved Solids								
Calculated	198	--	--	300.0	--	--	558.0	--
Residue by Evaporation @ 180°C	--	368	296	291.0	640	582	559.0	108,500
Phenolphthalein Alkalinity ($CaCO_3$)	0	0	0	--	0	0	--	0
Total Alkalinity ($CaCO_3$)	114	126	112	113.0	120	116	113.0	196
Hardness as $CaCO_3$ (Ca, Mg)	130	140	208	210.0	354	344	390.0	16,900
Specific Conductance (µmhos/cm @ 25°C)	--	310	--	496	990	--	818	--
pH, laboratory	8.0	7.9	7.7	7.6	7.9	7.7	7.65	6.9
pH, field	--	--	--	--	--	--	--	--
pHs	7.9	7.8	7.7	--	7.4	7.4	--	6.0
Density @ 15°C (gm/ml)	--	--	--	0.998[a/]	--	--	0.999[a/]	--
Arsenic (As)	--	--	--	--	--	--	--	--
Copper (Cu)	<0.1	<0.1	<0.1	--	<0.1	<0.1	--	<0.1
Iron (Fe)	0.05	0.05	0.5	--	0.1	0.7	--	0.5
Lead (Pb)	--	--	--	--	--	--	--	--
Manganese (Mn)	<0.05	<0.05	<0.05	--	<0.05	<0.05	--	<0.05
Mercury (Hg)	--	--	--	--	--	--	--	--
Silver (Ag)	--	--	--	--	--	--	--	--
Strontium (Sr), (µgm/l)	--	--	--	1,300	--	--	2,600	--
Zinc (Zn)	--	--	--	--	--	--	--	--

Date	8/25/76	8/10/76	8/10/76	8/12/76	8/12/76	8/12/76	8/13/76	8/19/76
Sample Depth (ft)[2/]	2,395	2,400	2,430	2,483	2,486	2,486	2,500	2,525
Well Bore Interval Open (ft)[2/]	120-2,528	120-2,400	120-2,430	120-2,483	120-2,486	120-2,528	120-2,500	120-2,528
Sampling Method	T.S.[4/]	D.S.	D.S.	D.S.	D.S.	T.S.[4/]	D.S.	T.S.
Temperature (°C), field	--	23.5	23.5	22.5	23.5	--	24.0	24.5
Silica (SiO_2)	8.5	4.5	--	3.0	4.5	10.0	2.8	3.6
Calcium (Ca)	2,000	290	--	296	200	250.0	288	2,000
Magnesium (Mg)	2,900	11	--	28	108	130.0	9.7	3,086
Sodium (Na)	31,000	42	--	300	1,160	1,400	48	34,000
Potassium (K)	1,200	--	--	--	--	52.0	--	--
Bicarbonate (HCO_3)	236.0	154	--	146	107	140.0	142	161
Carbonate (CO_3)	0.0	0	--	0	0	0.0	0	0
Hydroxide (OH)	--	0	--	0	0	--	0	0
Sulfate (SO_4)	6,900	560	--	738	475	540.0	610	7,250
Chloride (Cl)	57,000	105	--	445	2,075	2,500	86	63,000
Fluoride (F)	4.9	0.7	--	0.85	0.74	0.5	0.74	10.0
Nitrate (NO_3)	--	--	--	--	--	--	--	--
Phosphate (PO_4)	--	<0.1	--	<0.1	<0.1	--	<0.1	0.2
Total Dissolved Solids								
Calculated	101,200	--	--	--	--	4,900	--	--
Residue by Evaporation @ 180°C	104,000	1,316	1,070	1,924	4,356	4,890	1,220	108,000
Phenolphthalein Alkalinity ($CaCO_3$)	--	0	--	0	0	--	0	0
Total Alkalinity ($CaCO_3$)	194	126	--	120	88	115.0	116	132
Hardness as $CaCO_3$ (Ca, Mg)	17,000	768	--	855	940	1,200	760	17,700
Specific Conductance (µmhos/cm @ 25°C)	121,000	1,500	1,175	2,700	9,900	10,400	1,400	--
pH, laboratory	7.1	7.7	--	6.9	6.5	7.95	7.7	6.8
pH, field	--	--	--	--	--	--	--	--
pHs	--	7.1	--	7.0	7.3	--	7.1	5.4
Density @ 15°C (gm/ml)	1.071[a/]	--	--	--	--	1.002[a/]	--	--
Arsenic (As)	--	--	--	--	--	--	--	--
Copper (Cu)	--	<0.1	--	<0.1	<0.1	--	<0.1	<0.1
Iron (Fe)	0.300	0.05	--	<0.1	0.1	0.010	<0.1	0.3
Lead (Pb)	--	--	--	--	--	--	--	--
Manganese (Mn)	--	<0.05	--	<0.05	<0.05	--	<0.05	<0.05
Mercury (Hg)	--	--	--	--	--	--	--	--
Silver (Ag)	--	--	--	--	--	--	--	--
Strontium (Sr), (µgm/l)	36,000	--	--	--	--	3,100	--	--
Zinc (Zn)	--	--	--	--	--	--	--	--

Date	10/18/76	8/13/76	3/29/77	3/29/77	2/4/77	2/7/77	2/23/77	3/29/77
Sample Depth (ft)[2/]	2,525	2,528	2,900	2,900	2,984	3,622	3,775	4,450
Well Bore Interval Open (ft)[2/]	120-2,528	120-2,528	2,420-6,192	2,420-6,192	2,420-2,984	2,420-3,622	2,420-3,775	2,420-6,192
Sampling Method	T.S.[4/]	D.S.	T.S.	T.S.[4/]	D.S.	D.S.	D.S.	T.S.
Temperature (°C), field	--	23.5	--	--	22.0	--	19.5	--
Silica (SiO_2)	8.5	4.3	5.9	--	3.9	3.0	3.5	3.9
Calcium (Ca)	1,900	332	3,920	3,800	2,360	2,440	2,240	4,400
Magnesium (Mg)	3,100	299	1,968	2,000	1,434	948	826	1,215
Sodium (Na)	32,000	3,500	39,000	38,000	21,000	18,000	19,500	30,000
Potassium (K)	1,300	--	--	1,200	--	--	--	--
Bicarbonate (HCO_3)	164.0	146	132	120.0	132	137	127	185
Carbonate (CO_3)	0.0	0	0	0.0	0	0	0	0
Hydroxide (OH)	--	0	0	--	0	0	0	0
Sulfate (SO_4)	6,800	950	2,700	3,200	3,900	3,300	6,600	2,400
Chloride (Cl)	58,000	6,100	68,000	71,000	38,000	32,000	31,500	53,000
Fluoride (F)	6.3	1.2	6.9	2.9	6.0	5.7	6.1	6.2
Nitrate (NO_3)	--	--	2.48	5.3	--	--	--	2.17
Phosphate (PO_4)	--	<0.1	1.55	--	<0.1	<0.1	<0.1	1.71
Total Dissolved Solids								
Calculated	103,200	--	--	--	--	--	--	--
Residue by Evaporation @ 180°C	108,000	11,530	133,300	134,000	69,000	59,000	61,750	106,380
Phenolphthalein Alkalinity ($CaCO_3$)	--	0	0	--	0	0	0	0
Total Alkalinity ($CaCO_3$)	134.0	120	108	98.0	108	112	104	152
Hardness as $CaCO_3$ (Ca, Mg)	17,500	2,060	17,900	17,800	11,800	10,000	9,000	16,000
Specific Conductance								
(µmhos/cm @ 25°C)	123,000	16,000	--	138,000	>80,000	--	>80,000	--
pH, laboratory	7.0	7.5	6.3	6.65	6.4	5.7	6.6	6.9
pH, field	--	--	6.65	--	--	--	--	6.2
pHs	--	7.0	6.0	--	6.2	6.2	6.2	5.6
Density @ 15°C (gm/ml)	1.073[a/]	--	1.0865	1.08371[a/]	1.060	1.049	--	1.0710
Arsenic (As)	--	--	<0.01	--	--	--	--	<0.01
Copper (Cu)	--	<0.1	0.38	--	<0.1	<0.1	<0.1	0.25
Iron (Fe)	0.480	0.5	6.67	--	9.0	4.8	1.7	9.58
Lead (Pb)	--	--	1.00	--	--	--	--	0.58
Manganese (Mn)	--	<0.05	1.33	--	0.71	0.76	0.92	1.25
Mercury (Hg)	--	--	0.002	--	--	--	--	0.002
Silver (Ag)	--	--	<0.01	--	--	--	--	<0.01
Strontium (Sr), (µgm/l)	31,000	--	--	90,000	--	--	--	--
Zinc (Zn)	--	--	0.55	--	--	--	--	2.14

Date	3/17/77	3/21/77	3/29/77	3/29/77
Sample Depth (ft)[2/]	5,568	5,778	5,800	5,800
Well Bore Interval Open (ft)[2/]	2,420-5,568	2,420-5,778	2,420-6,192	2,420-6,192
Sampling Method	D.S.	D.S.	T.S.	T.S.[4/]
Temperature (°C), field	24.0	27.5	--	--
Silica (SiO_2)	--	1.9	11.3	--
Calcium (Ca)	--	3,200	6,640	6,800
Magnesium (Mg)	--	948	1,507	1,700
Sodium (Na)	--	21,000	42,000	42,000
Potassium (K)	--	--	--	850
Bicarbonate (HCO_3)	--	98	127	86.0
Carbonate (CO_3)	--	0	0	0.0
Hydroxide (OH)	--	0	0	--
Sulfate (SO_4)	--	3,800	1,900	2,100
Chloride (Cl)	--	37,000	78,000	85,000
Fluoride (F)	--	4.8	7.2	3.3
Nitrate (NO_3)	--	--	1.28	10.2
Phosphate (PO_4)	--	<0.1	2.95	--
Total Dissolved Solids				
Calculated	--	--	--	--
Residue by Evaporation @ 180°C	74,240	73,100	159,130	152,000
Phenolphthalein Alkalinity ($CaCO_3$)	--	0	0	--
Total Alkalinity ($CaCO_3$)	--	80	104	71.0
Hardness as $CaCO_3$ (Ca, Mg)	--	11,900	22,800	24,200
Specific Conductance (µmhos/cm @ 25°C)	>80,000	>80,000	--	150,000
pH, laboratory	--	6.6	6.4	6.2
pH, field	--	--	6.2	--
pHs	--	6.2	5.7	--
Density @ 15°C (gm/ml)	--	--	1.0960	1.09478[a/]
Arsenic (As)	--	--	<0.01	--
Copper (Cu)	--	0.88	0.38	--
Iron (Fe)	--	1.30	1.00	--
Lead (Pb)	--	--	1.17	--
Manganese (Mn)	--	1.66	0.66	--
Mercury (Hg)	--	--	0.002	--
Silver (Ag)	--	--	<0.01	--
Strontium (Sr), (µgm/l)	--	--	--	170,000
Zinc (Zn)	--	--	1.00	--

[1/] All chemical analyses by Orlando Laboratories, Inc. and reported in milligrams per liter, except as noted.

[2/] Depths given in feet below land surface.

[3/] Drill stem sample.

[4/] Chemical analysis by U.S. Geological Survey.

[5/] Packer test sample.

[6/] Thief sample.

[a/] Density @ 20°C (gm/ml).

APPENDIX E

CHEMICAL ANALYSES OF WATER SAMPLES COLLECTED FROM THE MONITOR TUBE DURING PUMPING

APPENDIX E. CHEMICAL ANALYSES OF WATER SAMPLES COLLECTED FROM FROM THE MONITOR TUBE DURING PUMPING[1,2]

Date	2/10/77	2/13/77	3/2/77	3/6/77	3/16/77	3/21/77	4/28/77
Cumulative Time (hr)	40	89	150	250	500	604	N.A.[3]
Cumulative Volume (gal)	19,200	42,720	72,000	120,000	240,000	289,992	N.A.
Temperature (°C), field	23.0	23.0	20.0	24.5	26.0	26.5	--
Silica (SiO_2)	6.0	7.0	--	--	--	9.2	10
Calcium (Ca)	36	34	--	--	--	32	32
Magnesium (Mg)	5.8	4.4	--	--	--	5.8	4.9
Sodium (Na)	7.2	7.2	--	--	--	8.4	7.1
Bicarbonate (HCO_3)	132	115	--	--	--	129	107
Carbonate (CO_3)	0	4.9	--	--	--	0	7.3
Hydroxide (OH)	0	0	--	--	--	0	0
Sulfate (SO_4)	6	4	2	--	--	4	3
Chloride (Cl)	1	1	1.0	--	--	<1.0	1.0
Fluoride (F)	0.2	0.2	--	--	--	0.2	0.2
Nitrate (NO_3)	<0.044	0.044	0.044	--	--	--	--
Phosphate (PO_4)	0.28	0.28	--	--	--	0.28	0.25
Total Dissolved Solids							
Residue by Evaporation @ 180°C	172	168	172	164	212	168	158
Phenolphthalein Alkalinity ($CaCO_3$)	0	4	--	--	--	0	6
Total Alkalinity ($CaCO_3$)	108	102	--	--	--	106	100
Hardness as $CaCO_3$ (Ca, Mg)	114	102	--	--	--	104	100
Specific Conductance							
(µmhos/cm @ 25°C), field	--	255	240	240	240	240	--
pH, laboratory	7.2	8.3	--	--	--	8.1	8.4
pHs	8.0	8.1	--	--	--	8.1	8.1
Copper (Cu)	<0.1	<0.1	--	--	--	<0.1	<0.1
Iron (Fe)	0.1	0.04	--	--	--	0.29	0.04
Manganese (Mn)	<0.05	<0.05	--	--	--	<0.05	<0.05

[1] All chemical analyses by Orlando Laboratories, Inc. and reported in milligrams per liter, except as noted.
[2] Monitor zone gravel packed in the interval from 1,956 to 2,064 feet and screened in the interval from 2,005 to 2,030 feet.
[3] Sample collected from pump discharge after 2 hours pumping following the injection test.