336025

FILE COPY

WORKPLAN

FOR

INSTALLATION OF ADDITIONAL MONITORING WELLS

General Switch Property

Located at
20 Industrial Place
City of Middletown
Orange County, New York

May 2003
(revised December 2003)

Prepared By:

ECOSYSTEMS STRATEGIES, INC.
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ESI File: LM97145.41

Ecosystems Strategies, Inc. Environmental Services and Solutions

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December 16, 2003

Mr. Paul Olivo
United States Environmental Protection Agency (USEPA)
290 Broadway
New York, New York 10007-1866

Re: General Switch Site, 20 Industrial Place, City of Middletown, Orange County, New York
ESI File LM97145.40

Dear Mr. Olivo:

Per your request, enclosed please find three (3) additional copies of the Workplan for Installation of Additional Monitoring Wells (Workplan) for the above-referenced site dated May 2003 (revised December 2003).

This Workplan incorporates all changes requested by the USEPA and your consultant at our meeting of October 2003. As stated verbally, this office is prepared to begin the installation of these additional wells within two weeks of receipt of Agency approval. Installation of these wells is weather dependent, and therefore any commitment to complete these wells within the pre-specified timetable is subject to revision.

Please review this document and call me at (845) 452-1658 should you have any questions or comments.

Sincerely,

ECOSYSTEMS STRATEGIES, INC.

Paul H. Ciminello /cpr
Paul H. Ciminello
President

PHC:cpr

enclosure

cc: file

Depth to GW = 0 - 15'
cont shallow & deep
deep wells are
200 - 300' deep
site is mostly
fill, with
wetlands
on one side

TABLE OF CONTENTS

1.0 Introduction and Objectives of Monitoring Well Installation

As previously proposed, Ecosystems Strategies, Inc. is planning to install additional monitoring wells in four locations with the following identification numbers based on existing wells (see Figure 1, Appendix A):

MW-206	Bedrock well near overburden well MW-6
MW-209	Bedrock well near overburden well MW-9
MW-219	Bedrock well farther downgradient than MW-209
MW-19	Overburden well farther downgradient than MW-9
MW-211	Bedrock well near overburden well MW-11
MW-220	Deep bedrock well to identify vertical extent of contamination

The bedrock well next to MW-11 is added to the list after the last round of sampling when MW-11 contained sufficient water for sampling and over 800 ug/L total chlorinated VOCs were detected (January 2003).

One more deep bedrock well is added to this plan to identify the vertical extent of contamination. That well will be installed within the triangular area outlined by wells MW-5, MW-203, and MW-204. That location is chosen to be down gradient of monitoring well MW-5 where the highest concentrations of PCE are found.

The plan is to install the bedrock wells first and remobilize with a soils rig to install the overburden well. Compared to the overburden well installation, the bedrock coring. drilling, testing, and well installation program is much more complicated and is the focus of this Workplan.

This plan proposes to omit the borehole geophysical logging and replace it with borehole video recording for existing wells and the new wells. The video method is far superior and is less expensive than the borehole geophysics. It will be cost effective to have a camera on site throughout the tedious drilling operations. The video recording will give much more specific information about the fractures because it is a remote means of observation.

The geophysical borehole logging is a remote means of measuring discrete geophysical properties at a series of depths without specific fracture characterization. The only information about fractures derived from logging is the depth of fracture from the caliper log.

2.0 Outline of Procedures

- Update Health and Safety Plan and conduct field meetings.
- The existing deep bedrock wells are open hole, the shallow bedrock wells are not. Record video tape of each of the four existing deep bedrock monitoring wells from top to bottom and reverse to observe if the fractures are single or multiple cut, horizontal or vertical, planar or curved, parallel or oblique to any observable bedding structure. This procedure will provide specific information about the geology that cannot be obtained with borehole geophysics and will be helpful in guiding the installation of new bedrock wells.
- Isolate the overburden from the bedrock by seating and grouting steel surface casing at least 5 feet into the bedrock.
- Core bedrock at 20-foot intervals. Preserve the core in core boxes. Describe the core and photograph.

- After each 20-feet of drilling, sample the borehole fluid and send to lab for Chlorinated VOC testing by EPA method 8060. Obtain results overnight to expedite well installation.
- Identify and characterize zones with fractures in the bedrock during drilling and prior to well installation with borehole video recording and packer tests.
- Conduct packer tests in selected depth intervals exhibiting fractures in the bedrock to identify zones of groundwater inflow, outflow and up or down vertical gradient.
- Using the contaminant, bedrock, fracture, and hydraulic information obtained during coring and testing, install wells to monitor specific depth intervals. Use either steel casing to seal off the upper bedrock interval or PVC/sand pack well construction with bentonite or grout seals depending on cost and drill rig capability.
- Collect all well and decon water on site and filter through activated carbon units, store onsite and release to storm sewer or municipal sewer with appropriate testing and permits.
- Develop the bedrock wells during drilling. Remove all fines with air pressure after coring and reaming each 20-foot depth interval.
- Decontaminate all equipment on site in designated decon area with standard procedures.
- Aquifer testing to determine hydraulic conductivity of bedrock in vicinity of wells.
- Installation of Overburden Monitoring Well (MW-19)

3.0 DESCRIPTION OF TASKS

The above listing of tasks provide an outline of the procedures necessary to accomplish the Workplan objectives. The following sections describe each task in greater detail for EPA review.

3.1 Health and Safety Preparations and Meetings

Prior to each state of the investigation, an appropriate decon pad will be prepared and containers for decon water storage placed in the area. The work zones will be established to restrict access to authorized persons and limit spread of contamination.

Prior to each stage of the investigation, the new subcontractors shall receive a copy of the Health and Safety Plan. Prior to the first day of field activity, the subcontractor and ESI personnel shall have a brief onsite Health and Safety Meeting to make sure everyone has reviewed the characteristics of chemicals of concern at the site and levels previously encountered in fieldwork at the site. The route to the nearest hospital and emergency phone numbers and procedures will be reviewed. The decontamination area and limited access danger zones will be reviewed with all personnel. Other relevant site features will be toured or pointed out. Copies of Health and Safety training certificates will be collected for each individual and placed in the health and safety records file. Each participant will sign an affidavit confirming review of the Health and Safety Plan.

3.2 Video Taping Borehole Features in Existing Wells

As mentioned above, this step would be unnecessary if the bedrock monitoring wells were not constructed with open wellbores. The Shatki "Characterization Report" (February 1994) shows the "Typical Deep Bedrock Monitoring Well Construction" (Figure 2-21 as open hole with steel casing seated and grouted 5 feet into competent bedrock. Consequently, this step of video taping the open bedrock walls of the wells will be most instructive for the drilling and installing the additional monitoring wells. Therefore, immediately prior to start of drilling, the downhole video camera will be procured in order to proceed with video tape recording. A video tape of each of the existing bedrock monitoring wells will be recorded from top to bottom and reverse to observe if the fractures are single or multiple cut, horizontal or vertical, planar or curved, parallel or oblique to any observable bedding structure. Notes will be made of the observations at different depths and still photos downloaded from the tape for documentation of borehole conditions if deemed appropriate. This procedure will provide specific information about the geology that cannot be obtained with borehole geophysics and will be helpful in guiding the installation of new bedrock wells.

The video camera equipment will be decontaminated prior to and after usage at each monitoring well.

3.3 Isolate Overburden by Grouting Steel Casing into Bedrock

Prior to drilling a drill rig decon pad will be constructed in the General Switch parking lot near the old Shatki trailer. The pad will be constructed to collect all decon water and pump into storage tanks for disposal.

In the previous drilling and installation of bedrock monitoring wells, the Shatki "Site Characterization Report" (February 1994) indicated that the top of bedrock beneath overburden was highly weathered. To keep shallow groundwater from the overburden from seeping through the weathered bedrock in to the deep well, a steel surface casing was seated and grouted at least 5 feet into competent bedrock. This same procedure will be used in drilling and installation of the new additional bedrock monitoring wells.

Drilling shall be accomplished using air rotary and/or air percussion drilling techniques. The drilling contractor shall be required to arrive at the site with all equipment decontaminated from prior jobs. Another decontamination procedure will be conducted onsite prior to commencement of drilling to remove road dirt from the drilling equipment. During drilling of the borehole through the overburden, the annulus will be monitored for Volatile Organic Compounds (VOCs) using a Photoionization Detector (PID). When bedrock is reached, a 10-inch diameter socket will be drilled into the bedrock observing the condition of cuttings, when the cuttings indicate a nonweathered condition, the socket will be drilled an additional 5 or more feet into bedrock. An 8-inch steel surface casing will be driven into the casing and grout installed between the formation and the steel casing. The grout will be allowed to set for 24 hours before, coring and drilling commences. Any grout that enters and sets up inside the steel casing will be drilled through with subsequent operations.

3.4 Core Bedrock at 20-foot Intervals

A core barrel will be used to obtain 20 feet of 2-inch diameter or greater core. The core will be wrapped in plastic, placed in wooden core boxes, and transported to the decon area. If any PID readings were detected during the coring procedure, the core will be steam cleaned. If no contamination is detected, it will be washed down at the decon area, prior to handling and study. The core lengths will be described and photographed. Indications of fractures will be noted with depth of occurrence and orientation. Consideration was given to obtaining a groundwater sample of the borehole fluid after each 20-feet of drilling and sending it to lab for overnight Chlorinated VOC testing by EPA method 8060. However, by using air rotary drilling, the air will most likely strip the volatile compounds from the groundwater in and near the well, so the sample results would not be reliable. Hence, it is concluded that during drilling, our best indicator of the presence of chlorinated VOCs will be readings on the PID.

3.5 Video Tape New Borehole Top to Temporary Total Depth

After each 20-feet of coring and drilling, the borehole video camera will be used to record images of the open bedrock borehole walls with depth. In this manner, by progressing in 20-foot intervals, the fracture characteristics of the bedrock can be identified from core and video. The identified fracture zones will then be the target of packer tests. The downhole video camera apparatus and wireline will be decontaminated between uses to avoid introduction of contamination from one level to another or from one well to another.

3.6 Packer Testing

Packer tests will be conducted over selected 10-foot depth intervals exhibiting fractures in the bedrock. The packer tests will identify zones of groundwater inflow, outflow and up or down vertical gradient. The packer tests will be conducted with a 10-foot length of Schedule 40 PVC screen containing a 2-inch diameter Grundfos Redi-flo 2 pump and pressure transducer. The screen apparatus is suspended between the upper and lower inflatable packers. This method was used in the Shakti investigations as shown in Figure 2-10 from the "Site Characterization Report" (February 1994). Pumping of the fluids from the interval will be conducted and water levels above the upper packer recorded. A second transducer will be placed above the packer to monitor water levels in that zone during pumping below the packer.

Shakti's results of this form of packer testing indicated that the bedrock is frequently fractured in a fine pervasive pattern and hydraulic connection was interpreted from above and below the packers either by packer leakage or fractures within the formation. See Shakti conclusions and recommendations relative to packer tests from pages 4-38 and 4-39 (1994, Site Characterization Report) included here as Appendix B.

The packer test downhole equipment will be decontaminated between uses to avoid introduction of contamination from one level to another or from one well to another.

3.7 Repeat Coring, Video Taping, and Packer Testing

For consecutive 20-foot intervals, the interval will be cored, video taped and packer tested. The entire openhole bedrock interval will be video taped so that the last tapes per boring will have the complete hole. PID readings will indicate the first observed zone of contamination as coring proceeds downward. However, PID readings may not be capable of identifying the downward vertical extent of contamination because groundwater from different fractures may be mixed in the borehole. However, indications and calculations of vertical gradients will at least indicate whether groundwater is moving upward or downward and thereby, the direction of movement of dissolved chlorinated VOCs will be determined. A method employed in a USGS study (Senior and Goode, 1999) will be used to measure the vertical component of groundwater flow over 10 foot intervals as indicated on their diagrams (Appendix C). If no PID readings are recorded above background and the well reaches a depth of 140 feet, drilling will stop and a monitoring well will be designed and installed. If the well reaches 100 feet and thereafter if coring does not show any fractures for an interval of 40 feet, drilling will end and a monitoring well designed and installed. If PID readings are above background and fractures are observed to a depth of 160 feet, drilling will stop and a monitoring well will be designed and installed.

For the deep well to define vertical extent of contamination, the well shall be drilled, cored, and tested as planned for the other bedrock wells. The difference is that drilling shall continue until a zone of 40 feet is encountered with no PID measurements above background. Also, the well will be purged and the rig pump used to obtain a fresh sample of formation waters from the deepest water-bearing zone for overnight laboratory analysis for VOCs.

3.8 Design and Install Monitoring Well

Using the contaminant, bedrock, fracture, and hydraulic information obtained during rock coring, video taping, and packer testing, wells will be designed to monitor specific depth intervals. Use either steel casing to seal of the upper bedrock interval or PVC/sand pack well construction with bentonite or grout seals depending on cost and drill rig capability. Open borehole completion is the preferred method because it allows access to a large diameter wellbore for future use. Prior to well installation, the bottom of the well will be tested for dnapl with a product interface meter. Any dnapl will be pumped out and containerized with the decon water on site. If the boring has to be plugged back, grout will be used to seal the bottom interval. Bottom grout will be pumped into place using a long tremie tube to reach the desired depth. Well construction diagrams from Shatki (1994) are shown for typical shallow and deep bedrock monitoring wells in Appendix B (Figures 2-20 and 2-21). All wells are in locations where "stickup" construction is appropriate.

All well construction tools will be decontaminated prior after each day's use and prior to use on another monitoring well location.

3.9 Treatment and Discharge of Purge and Decon Water

All well and decon water will be collected onsite and filter through activated carbon units, stored on-site and release to storm sewer or municipal sewer with appropriate testing and permits.

3.10 Well Development

The bedrock wells will be developed during drilling using the air pressure on the drilling rig to clean out the borehole after coring and drilling each 20 foot section of borehole and before each of the borehole video taping and packer test procedures. This method is far more effective than any post drilling method.

3.11 Decontamination Procedures

Decontamination of all equipment on site in designated decon area will be performed in the following manner: All drilling equipment in contact with soils will be steam cleaned at the beginning of each day and between wells. Sampling pumps will be decontaminated in accordance with the procedures outlined in the USEPA Region 2 Groundwater Sampling Procedures, including in Appendix G of the ESI Interim Workplan for previous work. Other reusable sampling or testing equipment will be decontaminated in the following manner:

- Pressure wash with water and a designated brush to remove any visible dirt.
- Wash and scrub in a mild detergent (e.g. Alconox) and de-ionized water using a designated brush.
- Rinse with de-ionized water.
- Rinse with 10% Nitric Acid solution.
- Rinse with de-ionized water.
- Rinse with methanol.
- Rinse with de-ionized water.
- Allow to air dry and use immediately or wrap in aluminum foil (Shiny side out).

3.12 Aquifer Testing

Aquifer testing to determine hydraulic conductivity, transmissivity, and storativity of bedrock in vicinity of wells. Step drawdown tests will be conducted in each of the new deep bedrock monitoring wells. During the test, water levels will be monitored in the pumping well with a pressure transducer and data logger and in nearby monitoring wells with a water level indicator. A Grundfos Redi-flo pump will be used with a controller to regulate the flow and increase the pumping rate in regular steps to identify the maximum pumping capacity of the well. Recovery data will be collected from all of the wells for hydraulic calculations. Additional aquifer hydraulic data will be incorporated from the packer tests. Hydraulic parameters from this testing program will be used in analytical computer program models to plan and predict pumping rates and capture zones for remedial action.

3.13 Installation of Overburden Monitoring Well

A soils rig will be mobilized and deconed for the drilling and installation of shallow overburden monitoring well MW-19. Split spoon and hollow stem auger will be used to reach the top of bedrock. Split spoon samples will be taken at 5-foot intervals. During drilling activities, the annulus will be monitored for VOCs with a PID. If PID readings are above background, the soil samples placed in laboratory containers, packed in cooler with ice and sent under chain of custody to a certified lab for VOC analysis.

The Shakti "Site Characterization Report" (1994) is unclear about them materials used in previous overburden monitoring well construction. On page 2-18 (Appendix B), a statement is made: "The wells were constructed of galvanized steel riser pipes with stainless steel screens." However, Figure 2-18 (Appendix B) shows PVC riser and screen. The diameter of riser and screen is recorded as 4-inch. If EPA requests steel construction, it will be used; otherwise, PVC will be used. The well will be constructed with "stickup" and 6-inch outer steel casing and locking cap.

The overburden well will be developed with surging and pumping with the soils rig. Prior to development, the bottom of the well will be tested for dnapl with a product interface meter. Drilling fluid will be evacuated form the well and containerized onsite with decon water. Development will proceed until the water exhibits turbidity of less than 200 ntu or the water is clear .

After well completion and development, slug tests will be conducted to estimate the hydraulic conductivity of the overburden materials surrounding the new monitoring well.

3.14 Final Report of Drilling, Installation and Testing of Additional Monitoring Wells

A report will be prepared documenting the above-described activities. The conclusions and recommendations of the report will focus on relevance of the investigation activities to remedial action.

4.0 References

Aller, Linda, et al, 1991, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA160014-891034.

Bardenhagen, Ingo and Jorg Goedicke, Investigation Methods for Contaminated Fractured Aquifer

Cohen, Andrew J. et al, 1996, Hydrogeologic Characterization of Fractured Rock Formations: A Guide for Groundwater Remediators, EPA Project Summary, EPA/800/S-96/001.

The Coalition Opposed to PCB Ash in Monroe County, Indiana (COPA), 2002, Test Report for MW-1 Packer/Pump Test of June 4, 2002, Http://www.copa.org/2002/lemonlane/4i/4l-testreport.html.

Pulido-Silva, Gonzalo and Thomas P. Ballestero, Hydraulic Tests in Fractured Bedrock Formation,

Rowe, Clem, Inflatable Packer Applications, Age Developments Pty. Ltd.

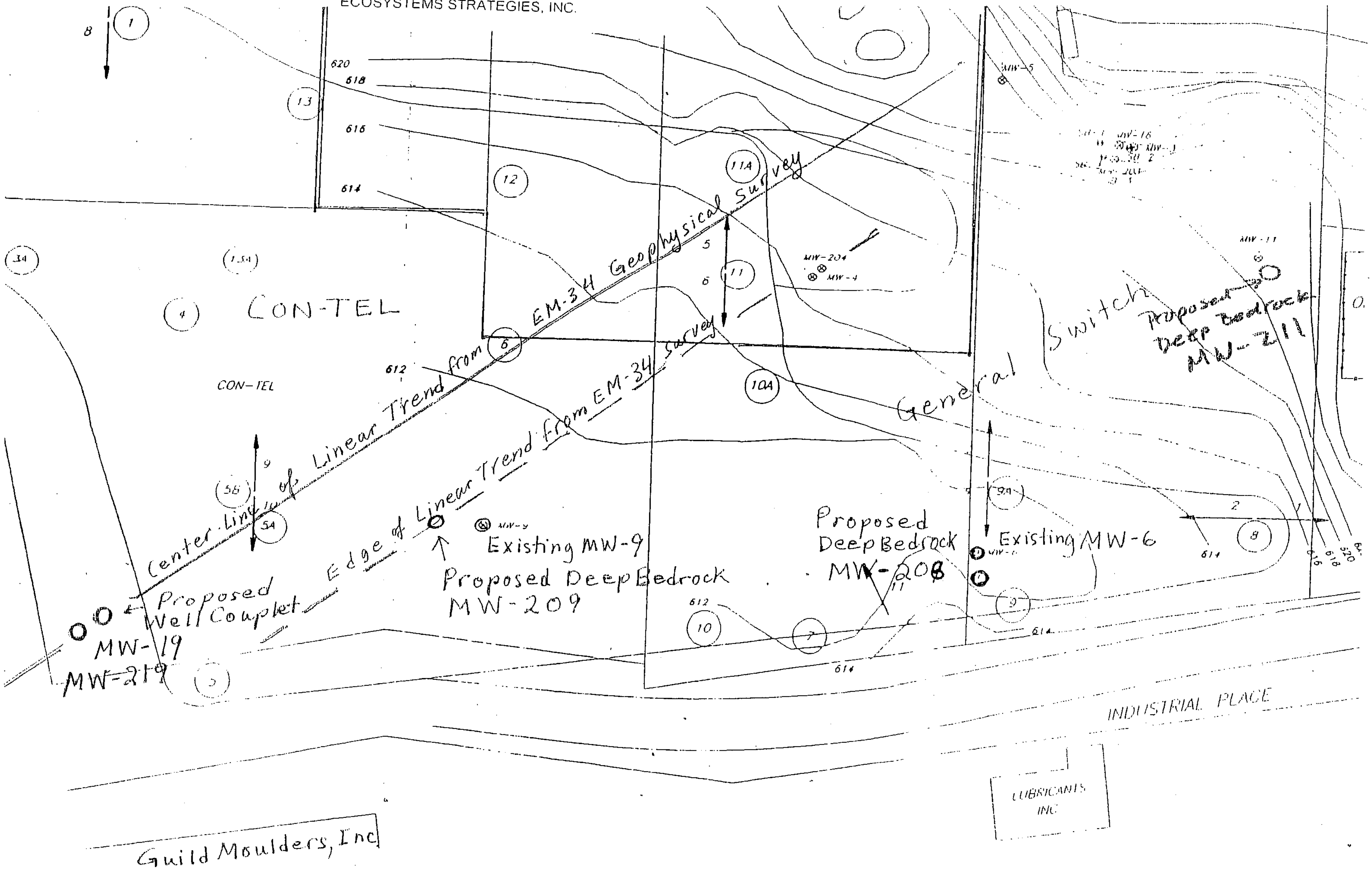
Royle, Michael, Standard Operating Procedures for Borehole Packer Testing,

Senior, Lisa A. and Daniel J. Goode, 1999, Ground-Water System, Estimation of Aquifer Hydraulic Properties, and Effects of Pumping on Ground-Water Flow in Triassic Sedimentary Rocks in and near Lansdale, Pennsylvania, USGS, Water-Resources Investigations Report 99-4228.

APPENDIX A

Figure 1 – Proposed Locations of Additional Monitoring Wells

Figure 1 - Proposed Locations of Additional Monitoring Wells
Source Map: Original Topographic Map 2-1 (1994)
ESI File: LM97145.41, May 2003
ECOSYSTEMS STRATEGIES, INC.



APPENDIX B

Pertinent Pages and Figures from Shakti
"Site Characterization Report" February 1994

SITE CHARACTERIZATION REPORT

VOLUME I
(Report)

for

General Switch Site
Middletown, New York

February 18, 1994
Submission

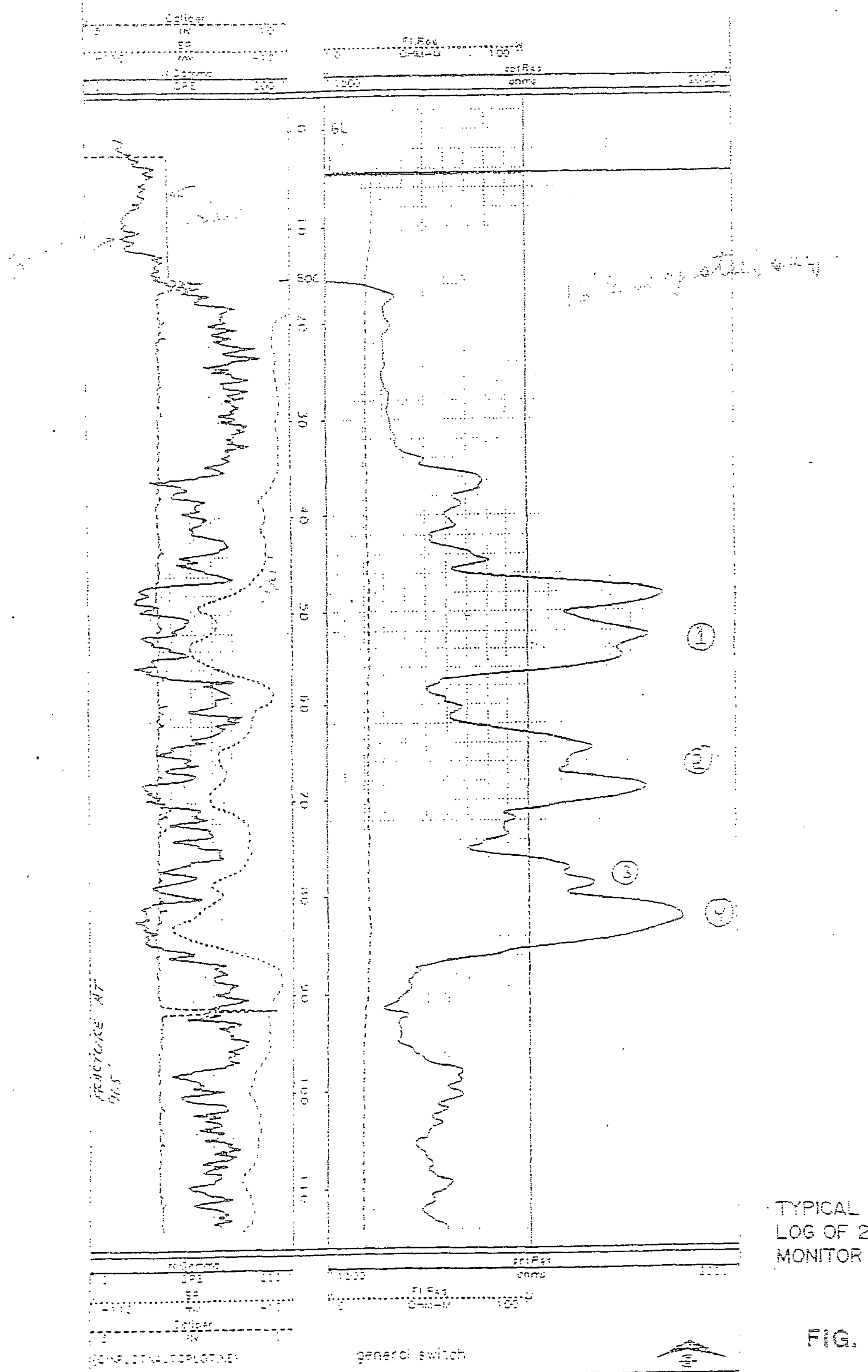
Prepared by:

Jacobs Environmental, Inc.
120 Centennial Avenue, Piscataway, New Jersey

Shakti Consultants, Inc.
185 Gatzmer Avenue, Jamesburg, New Jersey

and

Sadat Associates, Inc.
116 Village Boulevard, Princeton, New Jersey



TYPICAL GEOPHYSICAL
LOG OF 200 SERIES
MONITOR WELL

FIG. 2-9

packers. The dye was observed in the water discharged from the pump within the packers. This indicates that there is leakage occurring around the packers. Robert Marshalk, the manufacturer of the packers was contacted by Shakti to confirm that the packers were being used in accordance with design specifications. Marshalk indicated that Shakti was in fact using the packers properly and that the design of the packers would prevent water from leaking between the packers and the well hole wall. Based on this, it is apparent that the leakage is occurring through interconnected vertical and horizontal fractures in the formation.

4.4.2.4 MW-207 Packer Test

In order to confirm the conclusions drawn during the packer test of MW-203 regarding the suitability of performing packer tests, Shakti performed additional packer tests on MW-207 and W-33 (Contel). The packer test of MW-203 was conducted on May 20, 1993. The well was packed below the bottom of the steel casing at a depth of 32-44' and pumped at ½, 1, 1½, 2, 3 and 4 gpm. During the pumping of the 32-44' interval at 4 gpm, dye was placed in the water in the zone immediately above the packers. Within 7 minutes the dye was observed in the discharge water. The observation of the dye indicated that there is leakage in the well and therefore further packer testing of MW-207 would not yield useful data.

4.4.2.5 W-33 (Contel Well) Packer Test

As with the packer test of MW-207, the packer test of W-33 (Contel well) was performed in order to confirm the conclusions drawn regarding the reliability of packer tests data. The packer test of W-33 (Contel) was conducted on May 21, 1993. W-33 was packed below the steel casing at a depth of 62-74' and pumped at 1, 2 and 3 gpm. During the pumping of this interval at 3 gpm, dye was injected into the water in the zone immediately above the packers. Within 12 minutes the dye was observed in the discharge water. Like the packer tests of MW-203 and MW-207, the observation of the dye indicated that there is leakage through the formation and therefore no further packer testing of W-33 was performed.

4.4.3 Conclusions and Recommendations

In light of the foregoing, General Switch has re-evaluated the reliability of data obtained from the packer testing. Since evidence of leakage was observed in all of the wells that were packer tested, it is apparent that packer testing does not provide data regarding the extent of fracture zones, the amount of water yielded by specific fracture zones or the concentrations of contamination travelling through the fractures.

The packer tests, although not providing data about specific fracture zones, do provide useful information regarding the overall site geology; namely, that the shale bedrock is highly fractured in both the horizontal and vertical directions. Upon review of the caliper logs of the deep residential wells, it is clear that the older residential wells are degraded. The rock cores for the deep bedrock monitoring wells and the outcrop strike and dip analysis were reviewed and the fracturing observed in the cores for each of the bedrock wells and at the outcrop was in both the horizontal and vertical planes. These observations are consistent with the nature of the bedrock - it is a shale that is highly fractured in many directions.

The results of the packer tests indicate that there may be vertical leakage in all of the well tested. This fact combined with the caliper log data, the rock core analysis and outcrop analysis indicates that regardless of whether the packer is able to obtain a good seal, complete isolation of the suspected fracture zone will not be possible due to vertical leakage.

In light of the foregoing, one additional conclusion that can be drawn is that groundwater flow in the bedrock is most likely through numerous minor fractures instead of several major fractures. This conclusion is supported by the evaluation of the W-30 (Parella) bedrock well pump test data. A radial flow method for data evaluation was employed instead of a linear flow method, which indicates that the flow is probably through numerous interconnected minor fractures and not only major fractures.

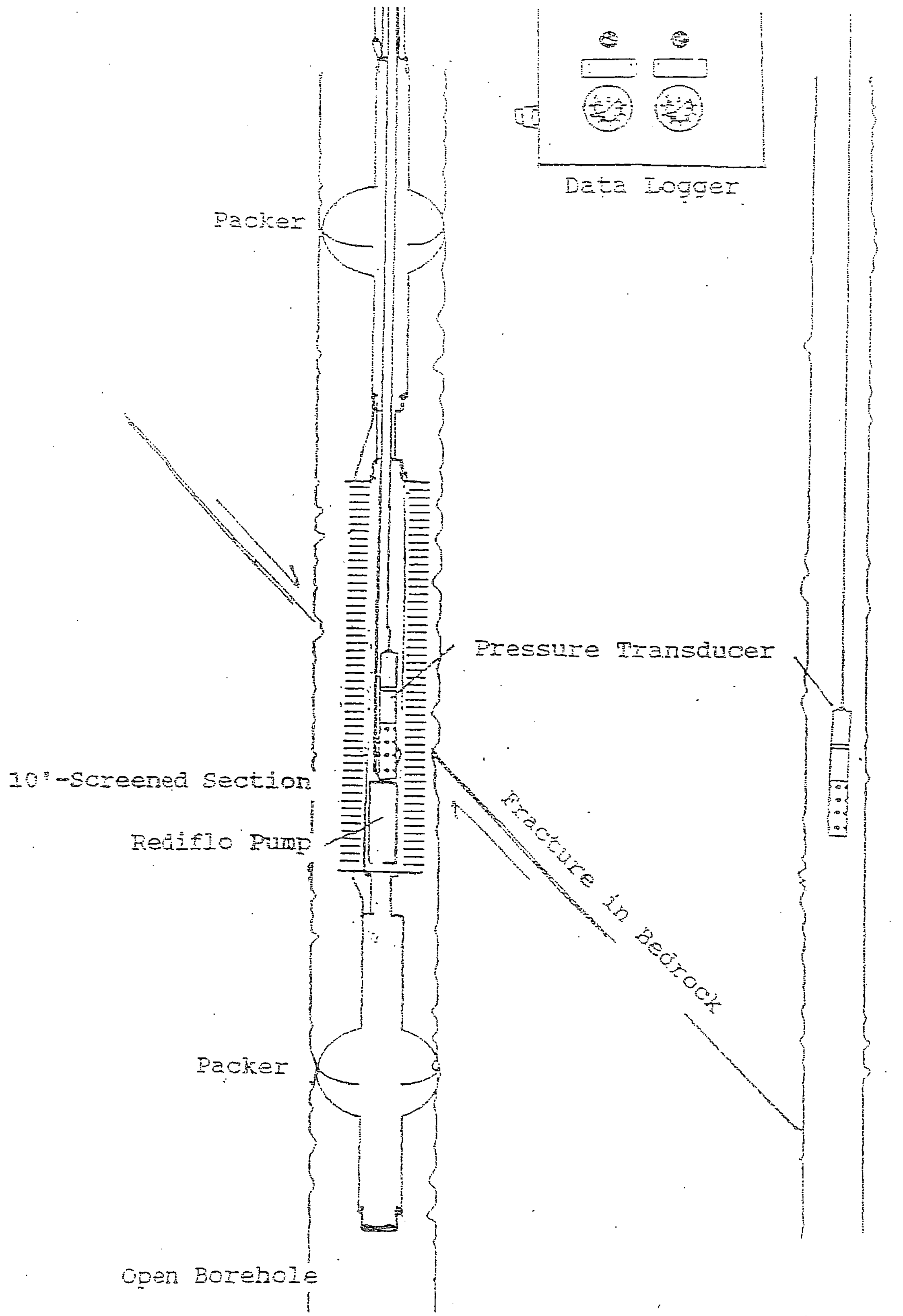


FIG. 2-10

nakti Consultants
65 Gatzmer Avenue
amesburg, NJ 08831

Packer and Pressure Transducer Array in Bedrock Wells

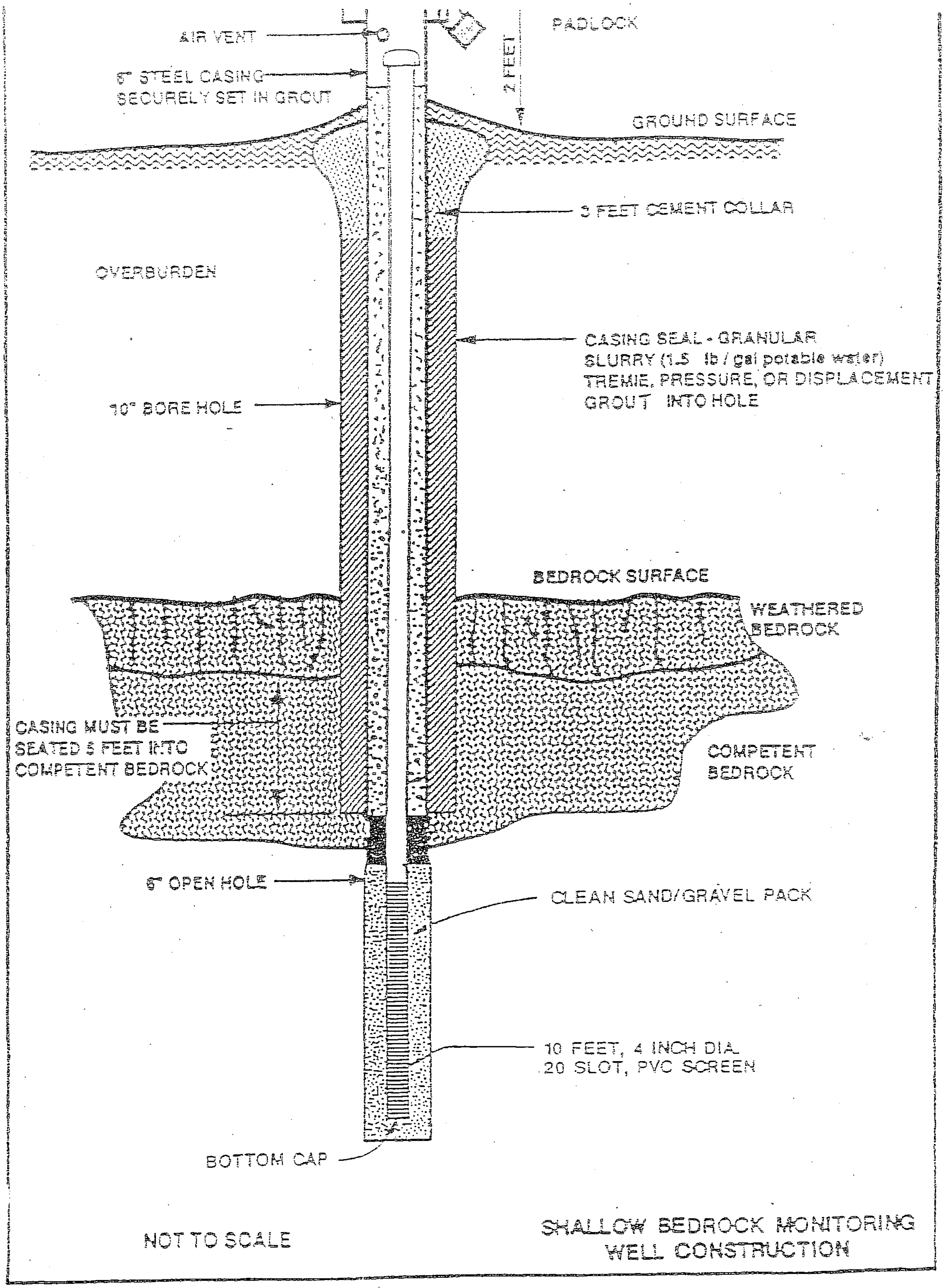
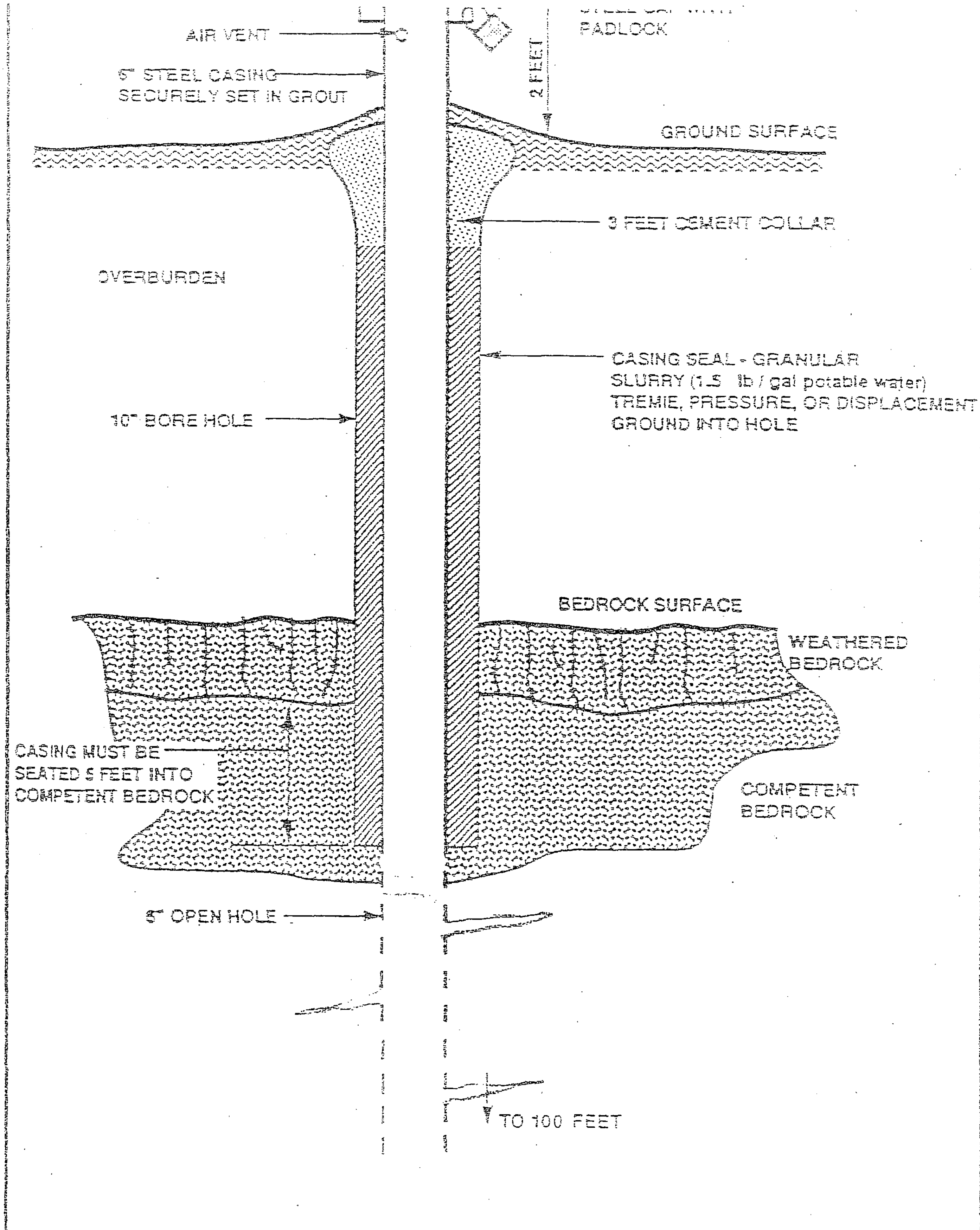

PADLOCK
AIR VENT
6" STEEL CASING
SECURELY SET IN GROUT
2 FEET
GROUND SURFACE
3 FEET CEMENT COLLAR
OVERBURDEN
CASING SEAL - GRANULAR
SLURRY (1.5 lb / gal potable water)
TREMIE, PRESSURE, OR DISPLACEMENT
GROUT INTO HOLE
10" BORE HOLE
BEDROCK SURFACE
WEATHERED
BEDROCK
CASING MUST BE
SEATED 5 FEET INTO
COMPETENT BEDROCK
COMPETENT
BEDROCK
6" OPEN HOLE
CLEAN SAND/GRAVEL PACK
10 FEET, 4 INCH DIA
20 SLOT, PVC SCREEN
BOTTOM CAP
NOT TO SCALE
SHALLOW BEDROCK MONITORING
WELL CONSTRUCTION

FIG. 2-19



NOT TO SCALE

TYPICAL "DEEP" BEDROCK MONITORING
WELL CONSTRUCTION

measured and plotted to indicate the piezometric head in the shale aquifer and groundwater piezometric gradients that determine the horizontal and vertical direction of groundwater flow.

2.6.1 Installation of Monitoring Wells, 1992

There were eight existing groundwater monitoring wells at the site, MW-1 through MW-8, which were installed in 1984-85 by Fred C. Hart, as depicted in Figure 2-15. In order to more fully define the extent of groundwater contamination, a total of 14 additional soil borings and eight shallow unconsolidated monitoring wells were installed at the site during the RSAMP site investigation, as depicted in Figure 2-15.

Only flush threaded joints were used for the casing, screen and riser pipe. Field welds are prone to leakage and were not used. No glues or oils were allowed during the drilling and installation of the wells. The riser pipes were permanently marked at the survey reference points for accurate and consistent water level measurements. The wells were numbered clearly on the outer casing for easy identification. A diagram of the rock well locations and details are presented in Figure 2-16. A detailed site map of the well locations is presented in Appendix 2.

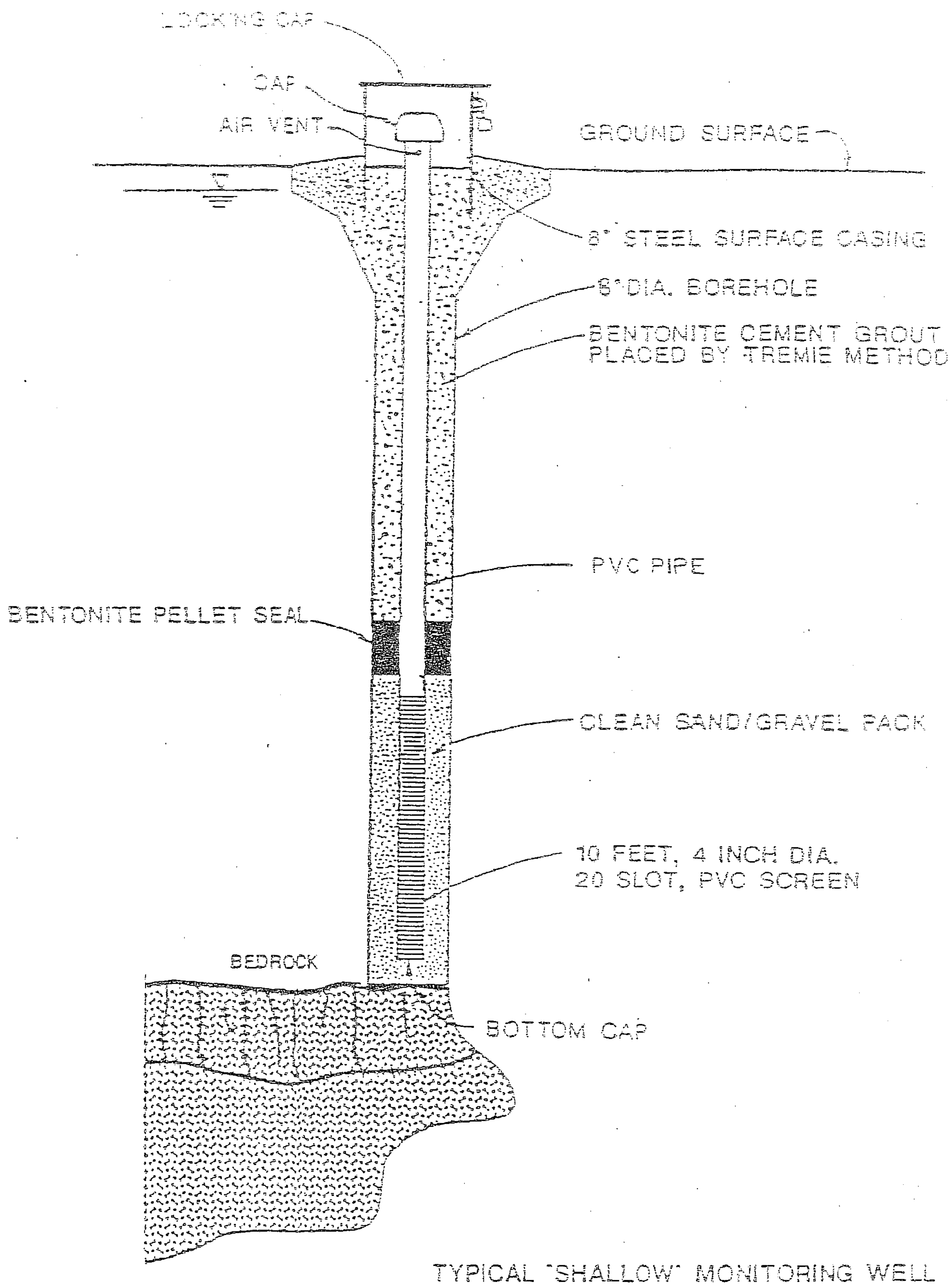
2.6.1.1 Shallow Overburden Wells

The shallow overburden wells MW-1 through MW-8 were installed in or near the soil contamination hot spots at the General Switch site and at upgradient or sidegradient locations. In some cases the wells were installed to the interface of the base of the overburden and top of bedrock, encountered between 10 and 66 feet, to monitor the groundwater quality and flow at the overburden/bedrock disconformity. The wells were constructed of galvanized steel riser pipes with stainless steel screens. These wells did not penetrate the bedrock to avoid introducing any contaminants from the overburden into the shale aquifer.

Three monitoring wells were installed during the RSAMP site investigation down-gradient of existing wells MW-3 and MW-4 and south of well W-30 (Parella). These wells were installed to the top of the bedrock at a depth of between 10 and 15 feet below the existing grade and were designated MW-9, MW-10 and MW-11.

Three monitoring wells were installed at a depth of between 15 and 23 feet, at the base of the overburden in the hot spots TP-6, TP-A and TP-D on the General Switch property and were designated MW-16, MW-17 and MW-18, respectively.

The shallow, 4-inch-diameter monitoring wells were installed to a depth of between 5 and 35 feet screened across first water at the locations indicated in Figure 2-17 in accordance with Section 4



TYPICAL "SHALLOW" MONITORING WELL
CONSTRUCTION AT BASE OF GLACIAL TILL

FIG. 2-18

APPENDIX C

Relevant Pages from Reference: Senior, Lisa A. and Daniel J. Goode, 1999, Ground-Water System, Estimation of Aquifer Hydraulic Properties, and Effects of Plumbing on Ground-Water Flow in Triassic Sedimentary Rocks in and near Lansdale, Pennsylvania, USGS Water-Resources Investigations Report 99-4228

U.S. Department of the Interior
U.S. Geological Survey

Ground-Water System, Estimation of Aquifer Hydraulic Properties, and Effects of Pumping on Ground-Water Flow in Triassic Sedimentary Rocks in and near Lansdale, Pennsylvania

by Lisa A. Senior and Daniel J. Goode

Water-Resources Investigations Report 99-4228

prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

Lemoyne, Pennsylvania
1999

were measured during pumping by use of pressure transducers: drawdowns were recorded at a specified change in water level [0.1 ft (.03 m)]. Pumping duration was approximately 1 to 2 hours: rates ranged from about 0.2 to 4 gal/min (0.76 to 15 L/min) for each test.

Specific capacity and transmissivity for each isolated zone were calculated. These results are compared to additional data, where available, on specific capacities of the open-hole wells determined from pumping rates and drawdowns during pumping for open-hole tests (Conger, 1999; Black & Veatch Waste Science Inc., 1998). The transmissivity (T) was calculated by use of the Thiem equation (Bear, 1979), assuming steady-state conditions, as follows:

$$T = \frac{Q}{2\pi\Delta h}\ln\frac{R}{r_w}, \qquad (1)$$

where Q is pumping rate.

Δh is change in head.

R is radius of influence of pumping, and

r_w is radius of well.

For analysis of data from single-well, interval-isolation tests at the three wells (Mg-80, Mg-1443, and Mg-1444), R was assumed to equal 328 ft (100 m). This method of estimating transmissivity is similar to that used by Shapiro and Hsieh (1998) for short-term, low-injection-rate, single-well, interval-isolation tests in low-permeability fractured rocks. For the tests by Shapiro and Hsieh (1998), R was assumed to equal 9.8 ft (3 m). The rate and duration of pumping of tests for the present study were greater than in the tests by Shapiro and Hsieh (1998), and it is reasonable to assume that R would be greater than 9.8 ft (3 m).

Single-well, interval-isolation aquifer tests at three wells in Lansdale (Mg-80, Mg-1444, Mg-1443) generally indicate that (1) discrete water-bearing openings are not well connected in the vertical direction and (2) specific capacity and estimated transmissivity ranged over two to three orders of magnitude in the water-bearing zones tested. No relation between depth and specific capacity or estimated transmissivity was noted in the results of tests of isolated zones in the three wells. Evidence for limited vertical hydraulic connection between water-bearing openings includes differences in static potentiometric head up to 15 ft (46 m) over 300 vertical ft (91 m) and typically small drawdown in zones adjacent to the isolated pumped zone.

The chemical and physical properties of borehole discharge were measured at various times during pumping by the USGS by the use of temperature-compensated pH and specific-conductance meters. After physical and chemical properties stabilized or after three test-interval volumes of borehole water were pumped, water samples for measurement of pH, specific conductance, temperature, and dissolved oxygen concentration were collected. Samples for VOC analysis then were collected by the USGS and forwarded to USEPA's contractor, B&V, for analysis. In single-well, aquifer-interval-isolation tests by QST Environmental, Inc., in wells Mg-624 and Mg-1639, the USGS measured chemical and physical properties and QST Environmental, Inc., collected samples for VOC analysis. The pH and specific conductance were measured by methods outlined in Wood (1976). Dissolved oxygen was measured by use of the azide modification of the Winkler titration method (American Public Health Association and others, 1976).

Well Mg-80

The open-hole well is about 270 ft (82.3 m) in depth with a few feet of soft sediment at the bottom of the well. An 8-in. (0.2-m) diameter casing extends to a depth of 138 ft bls (42.1 m). Geophysical logging (Conger, 1999) indicated water-bearing zones at 144-154 ft bls (43.4-46.9 m) and 253-258 ft bls (77.1-78.6 m) (fig. 24). Under non-pumping conditions, upward flow in the borehole was measured with inflow from fractures at 253-258 ft bls (77.1-78.6 m) and outflow through fractures at 144-154 ft bls (43.4-46.9 m). The flow pattern indicated a difference in hydraulic heads in the well. When the open-hole well was pumped at a rate of about 1 gal/min (3.785 L/min) in summer 1996, the fractures at 144-154 ft bls (43.4-46.9 m) produced most of the fluid.

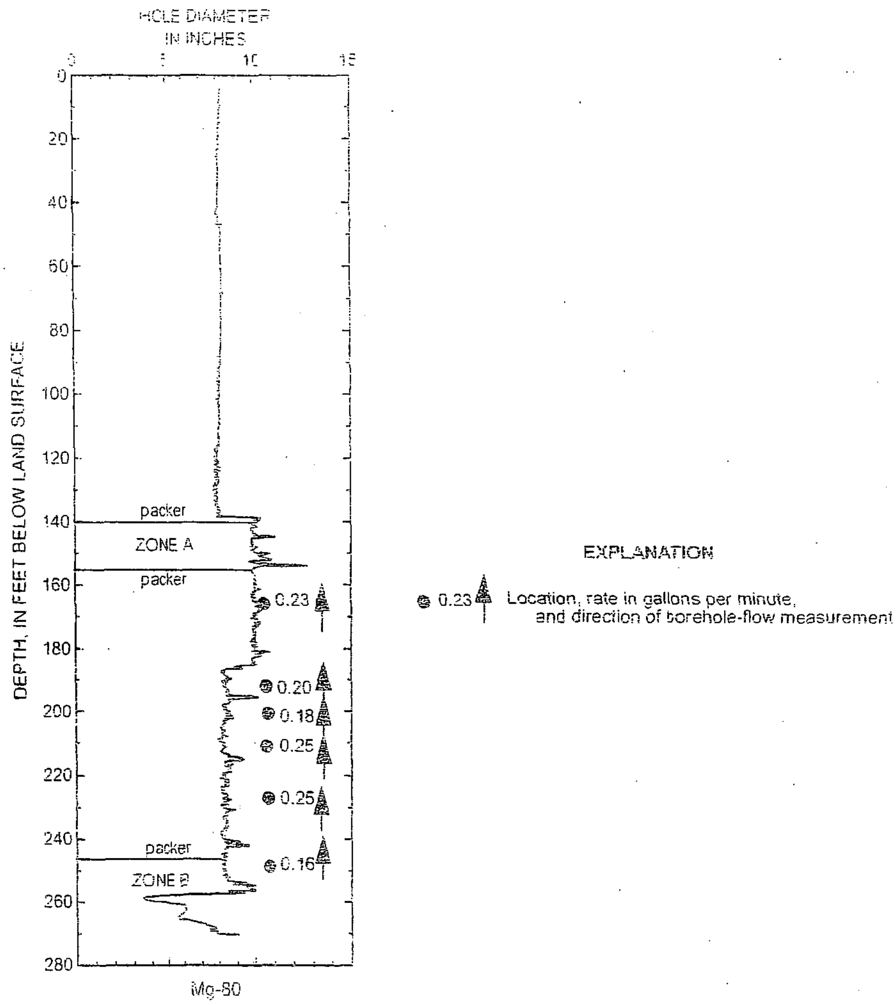


Figure 24. Depth of packers for aquifer-interval-isolation tests and direction of nonpumping flow in well Mg-80 in Lansdale, Pa.

Tests in well Mg-80 were conducted on March 24-27, 1997. Packers isolated two intervals (fig. 24) for testing, including below 246 ft bls (75 m) (zone B) and 142-157 ft bls (43.3-47.8 m) (zone A). Depth to water in the open borehole was 12.43 ft bls (3.79 m). After packer inflation, water levels were measured above, in, and for zone A below the isolated intervals. Water levels in isolated intervals stabilized in about 15 minutes after packer inflation. In test of zone A, the isolated interval was pumped at about 2 gal/min (7.6 L/min), and drawdown was observed in all three intervals (fig. 25, table 7). The observed drawdowns indicate either the packers did not isolate the interval (seal the borehole) effectively or the intervals are connected outside of the well. In the test of zone B, a single packer was placed at 246 ft bls (75 m) and the pump was placed below the packer. Drawdown was observed only in the pumped zone (fig. 26, table 7). These results indicate that the zone below 246 ft bls (75 m) is hydraulically isolated from water-bearing zones above that depth. In the test of zone A, a straddle packer with a 15-ft (4.6-m) spacing between center of packers was used to isolate the interval of 142-157 ft bls (43.3-47.8 m). The water level in the isolated interval was slightly higher than in the upper or lower intervals after packer inflation (table 7).

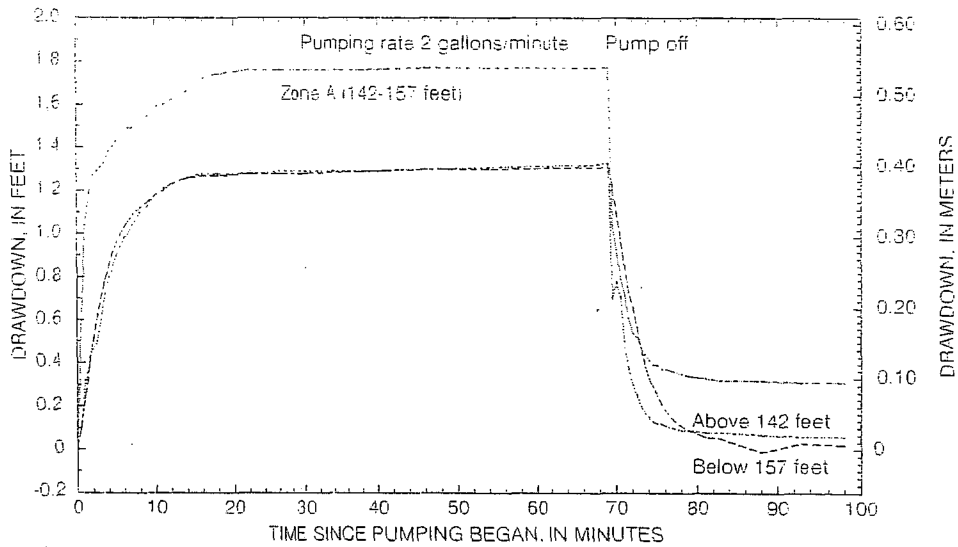


Figure 25. Drawdown as a function of time in aquifer-interval-isolation test of zone A in well Mg-80 in Lansdale, Pa., March 26, 1997.

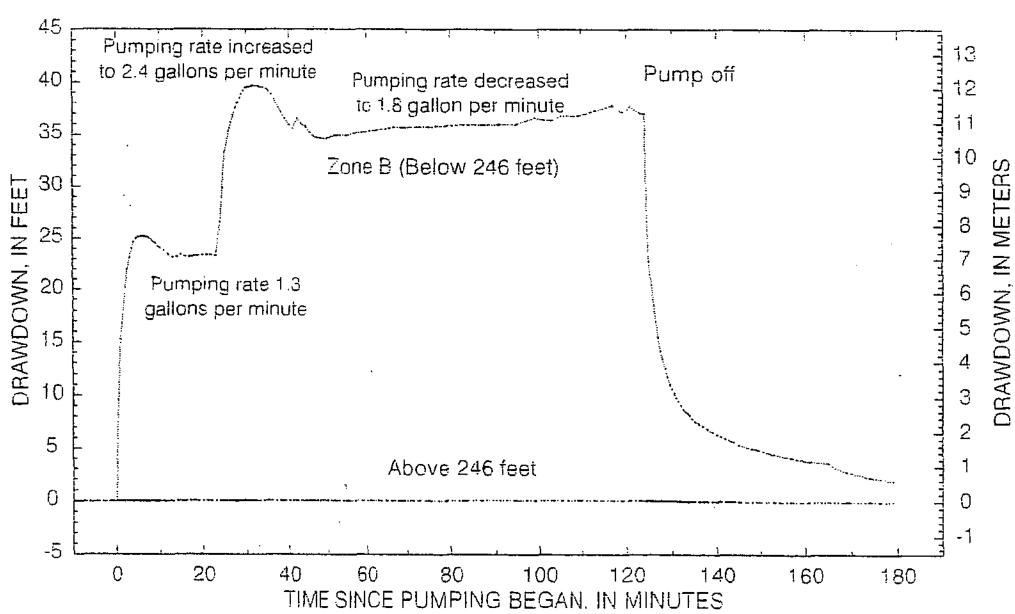


Figure 26. Drawdown as a function of time in aquifer-interval-isolation test of zone B in well Mg-80 in Lansdale, Pa., March 27, 1997.

The interval between 142-157 ft bls (43.3-47.8 m) has a greater specific capacity than the interval below 246 ft bls (75 m). These specific-capacity measurements are consistent with the heatpulse-flowmeter measurements that indicated fractures in the upper zone produced most water when the open well was pumped (Conger, 1999). The calculated specific capacity for the zone A (table 7) in this borehole probably is greater than actual specific capacity for the zone because of contribution from other intervals. The sum of specific capacities determined for isolated zones A and B is similar or somewhat less than the specific capacity determined for the open-hole tests (table 7).

Table 7. Depths, water levels, specific capacity, and transmissivity of aquifer intervals isolated by packers and of the open hole for well Mg-80 in Lansdale, Pa., March 1997, May 1996, and September 1997

[ft bls, feet below land surface; ft, feet; gal/min, gallons per minute; min, minutes; (gal/min)/ft, gallons per minute per foot; ft^2/d, square feet per day; NA, not applicable]

Depth of isolated intervals (ft bls)	Date of test	Pre-pumping depth to water in interval[1] (ft bls)	Depth to water in interval at end of test[2] (ft bls)	Drawdown at end of test (ft)	Pumping rate (gal/min)	Pumping duration (min)	Specific capacity [(gal/min)/ft]	Transmissivity[3] (ft^2/d)
			Zone A (142-157 ft bls)					
Open hole	3-26-97	12.43	NA	NA	NA	NA	NA	NA
Above 142	3-26-97	11.93	13.26	1.33	NA	NA	NA	NA
142-157 (pumped)	3-26-97	11.88	13.65	1.77	2	69	[4] 1.13	[5] 238
Below 157	3-26-97	12.03	13.34	1.31	NA	NA	NA	NA
			Zone B (below 246 ft bls)					
Above 246	3-27-97	12.11	12.19	.08	NA	NA	NA	NA
Below 246 (pumped)	3-27-97	12.07	49.10	37.03	1.8	124	.037	10.2
Sum of specific capacities or transmissivities for intervals tested							1.17	248
			Open-hole tests					
Open hole	5-23-97	13.29	13.8	.51	1	79	1.96	413
Open hole	9-30-97	15.2	25.78	10.58	12	65	1.13	239

[1] Stabilized water levels after packers were inflated.
[2] Depth to water at end of pumping at a constant rate before the pump was shut off.
[3] Calculated using Thiem equation, assuming a radius of influence, r_0, of 328 feet (100 meters).
[4] Measured specific capacity for zone greater than actual specific capacity because of contributions of flow from other intervals.
[5] Calculated transmissivity for zone greater than actual transmissivity because of contributions of flow from other intervals.

Well Mg-1443

The caliper log indicated fractures at 35-41 ft bls (10.7-12.5 m), 104-106 ft bls (31.7-32.3 m), 175-178 ft bls (53.3-54.3 m), and 289-291 ft bls (88.1-88.7 m) in the 339-ft (103.3-m) deep, 8-in.- (0.2 m) diameter borehole (fig. 27). When the open-hole well was pumped at a rate of about 1 gal/min (3.785 L/min) in summer 1996, the fractures at 289-291 ft bls (88.1-88.7 m) appeared to produce most of the water and fractures at 104-106 ft bls (31.7-32.3 m) produced the second greatest amount (Conger, 1999). Under nonpumping conditions in summer 1996, minor upward flow was measured between the depths of 332 ft bls (101.2 m) and 68 ft bls (20.7 m) (Conger, 1999). This flow pattern indicates a difference in hydraulic heads between water-bearing zones in the borehole.

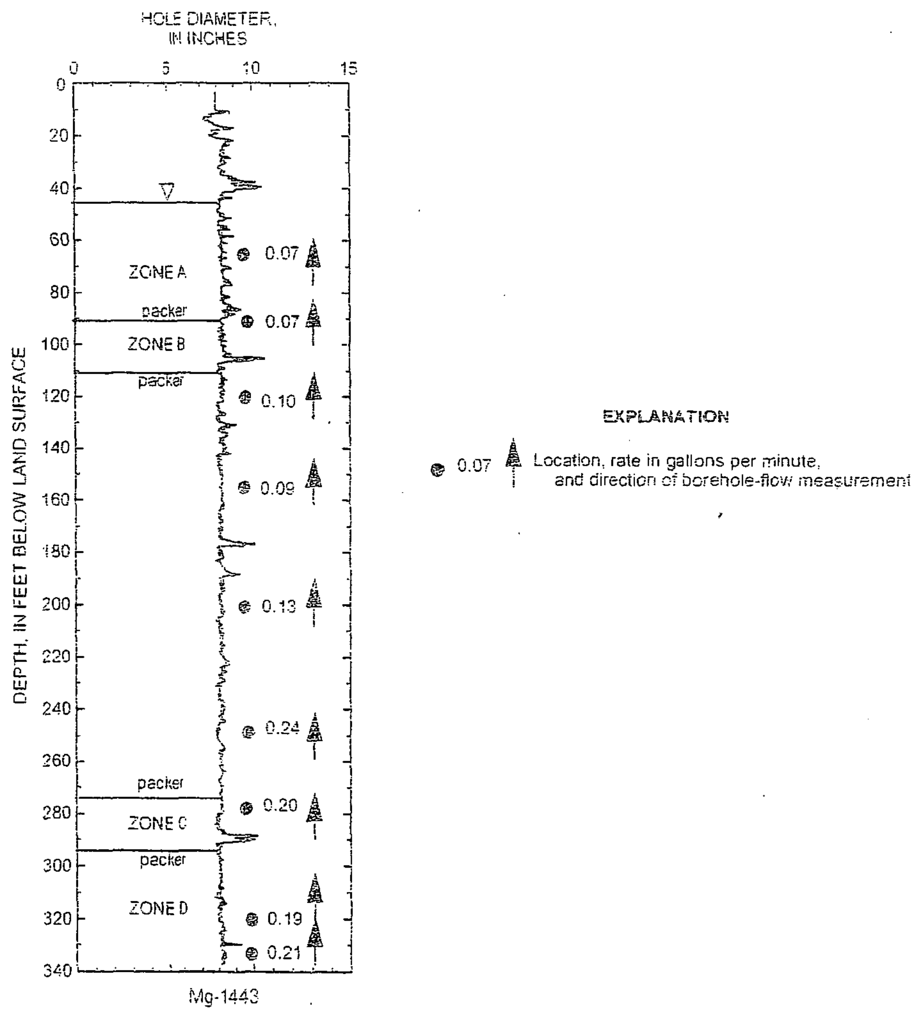


Figure 27. Depth of packers for aquifer-interval-isolation tests and direction of nonpumping flow in well Mg-1443 in Lansdale, Pa.

Tests in well Mg-1443 were conducted on April 9-11, 1997. On the basis of results of geophysical logging, four intervals were selected for testing (fig. 27) including below 296 ft bls (90.2 m) (zone D); 276-296 ft bls (84.1-90.2 m) (zone C); 90.5-110.5 ft bls (27.6-33.7 m) (zone B); and above 90.5 ft bls (27.6 m) (zone A).

In the test of zone A, the pre-pumping level in the pumped zone was about 2.4 ft (0.73 m) higher than the level in the interval immediately below (90.5-110.5 ft), indicating a downward vertical gradient between these intervals. The pre-pumping level in zone A was about 1 ft (0.3 m) lower than the interval below 110.5 ft, indicating an upward gradient between these intervals. Because testing of zone A was done soon after testing of zone B, water levels may not have fully recovered from the test of zone B. When zone A was pumped, drawdown was measured in the interval between 90.5 and 110.5 ft (27.6-33.7 m) but not in the interval below 110.5 ft (33.7 m) (fig. 28).

In the test of zone B, the pre-pumping water level in the isolated interval was almost equal to the level in the overlying interval and 0.52 ft (0.16 m) lower than the level in the underlying interval zone; the latter head difference was similar to the head difference [0.36 ft (0.11 m)] between the isolated zone C and the interval above zone C (table 8). When zone B was pumped, no drawdown was measured in the underlying interval, and about 1 ft (0.3 m) of drawdown was measured in the overlying interval (fig. 29), indicating some hydraulic connection between zone B and the interval above zone B.

In the test of zone C, the water level in the isolated interval before pumping was 4.79 ft (1.46 m) lower than the level in the underlying interval and 0.56 ft (0.17 m) higher than the level in the overlying interval, also indicating an upward vertical gradient. When pumped, small but measurable drawdown in intervals above and below zone C were observed (fig. 30), suggesting an incomplete seal by packers or hydraulic connection outside the borehole.

In the test of zone D, the water level in the isolated interval before pumping was 9.07 ft (2.76 m) higher than in the interval above 296 ft bls (90.2 m), indicating an upward vertical gradient. When zone D was pumped at a rate of about 0.2 gal/min (0.76 L/min), a large drawdown was observed in the pumped interval and very little drawdown was observed in the overlying interval (fig. 31). Zone D appeared to be hydraulically isolated from other intervals and to produce little water. Thus, water-bearing zones near the bottom of the well appear hydraulically isolated from the water-bearing zones near the top of the well.

The calculated specific capacities for zones A and C are lower than the specific capacity of zone B (table 8), which is consistent with the relative yields of these zones determined by heatpulse-flowmeter measurements while pumping (Conger, 1999). The specific capacity of zone D determined from the isolated-interval tests is probably higher than the actual specific capacity. In addition to the apparent hydraulic connection between zone D and adjacent intervals, the short duration of pumping and variable pumping rates may have affected the test. Specific capacity commonly tends to decrease with increases in pumping time. The sum of specific capacities of individual isolated zones is greater than the specific capacity determined for the open borehole in summer 1996 (Conger, 1999), possibly because of the over-estimated specific capacity of zone D (table 8).

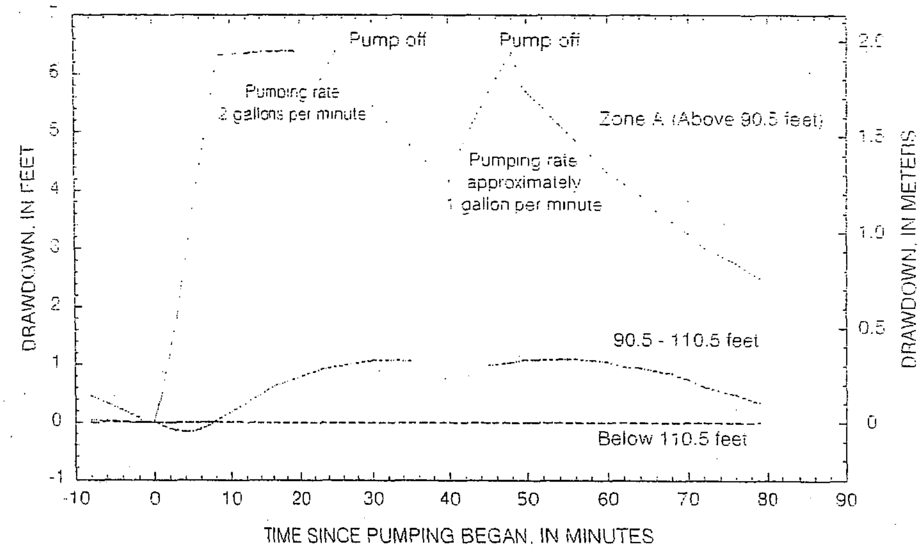


Figure 28. Drawdown as a function of time in aquifer-interval-isolation test of zone A of borehole Mg-1443 in Lansdale, Pa., April 11, 1997.

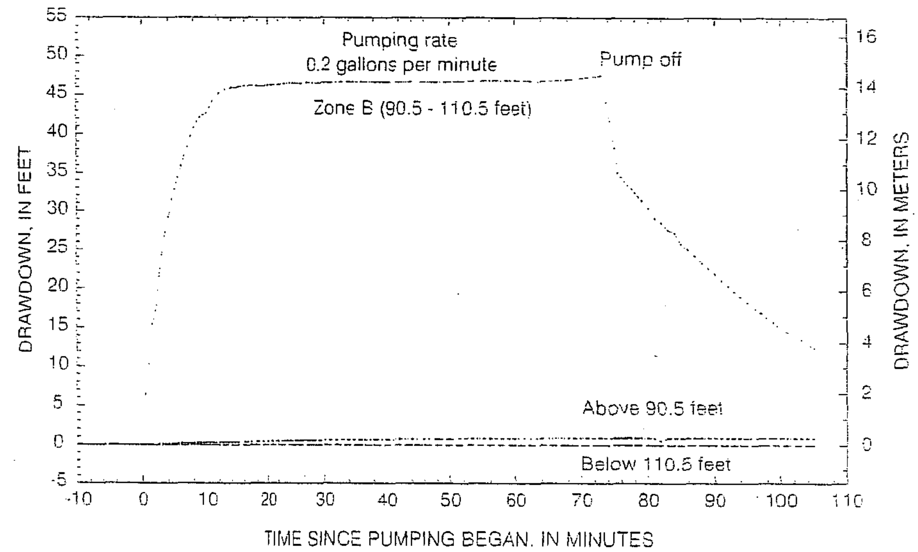


Figure 29. Drawdown as a function of time in aquifer interval-isolation test of zone B of borehole Mg-1443 in Lansdale, Pa., April 11, 1997.

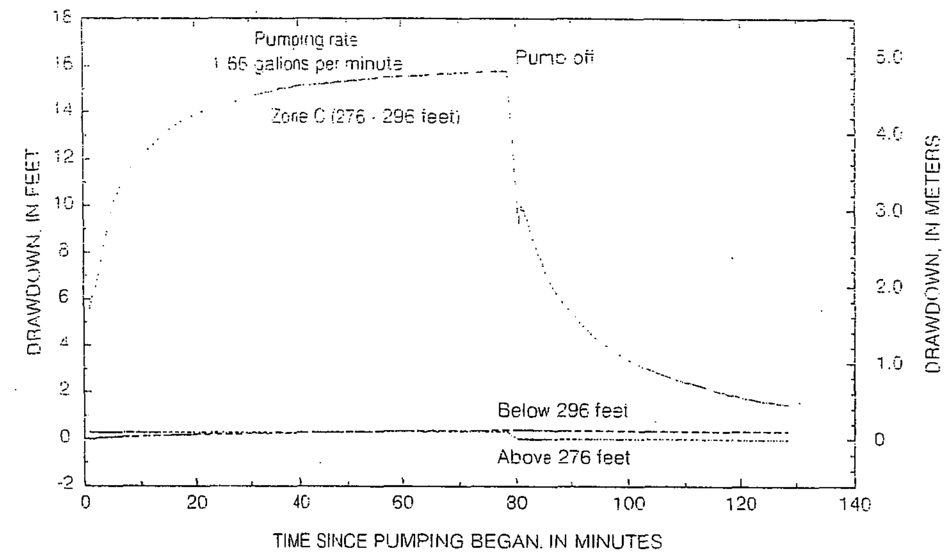


Figure 30. Drawdown as a function of time in aquifer-interval-isolation test of zone C of borehole Mg-1443 in Lansdale, Pa., April 10, 1997.

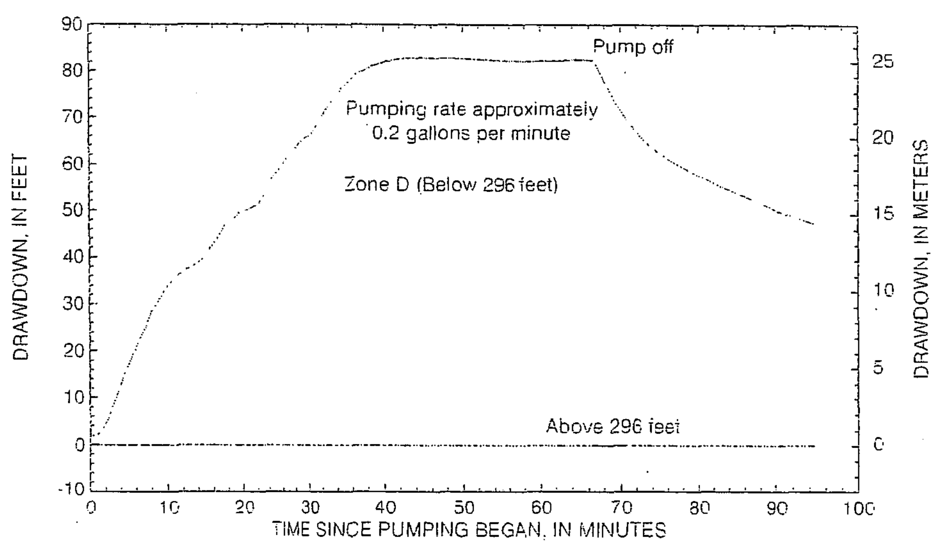


Figure 31. Drawdown as a function of time in aquifer-interval-isolation test of zone D of borehole Mg-1443 in Lansdale, Pa., April 9, 1997.

Table 8. Depths, water levels, specific capacity, and transmissivity of aquifer intervals isolated by packers and of the open hole for well Mg-1443 in Lansdale, Pa., April 1997, May 1998, and October 1997

[ft bls, feet below land surface; ft, feet; gal/min, gallons per minute; min, minutes; (gal/min)/ft, gallons per minute per foot; NA, not applicable]

Depth of isolated interval (ft bls)	Date of test	Pre-pumping depth to water in zone[1] (ft bls)	Depth to water in zone at end of test[2] (ft bls)	Drawdown at end of test (ft)	Pumping rate (gal/min)	Pumping duration (min)	Specific capacity [(gal/min/ft)]	Trans-missivity[3] (ft^2/d)
			Zone A (above 90.5 ft bls)					
Above 90.5 (pumped)	4-11-97	42.90	49.27	6.37	[4] 1	21	[5] 0.16	[6] 34.4
90.5 - 110.5	4-11-97	45.29	46.34	1.05	NA	NA	NA	NA
Below 110.5	4-11-97	41.91	41.91	0	NA	NA	NA	NA
			Zone B (90.5-110.5 ft bls)					
Above 90.5	4-11-97	42.39	43.32	.93	NA	NA	NA	NA
90.5 - 110.5 (pumped)	4-11-97	42.41	89.95	47.54	.2	73	.004	.86
Below 110.5	4-11-97	41.89	41.91	.02	NA	NA	NA	NA
			Zone C (276-296 ft bls)					
Above 276	4-10-97	42.40	42.72	.32	NA	NA	NA	NA
276 - 296 (pumped)	4-10-97	42.04	57.80	15.76	1.7	78.5	.108	22.6
Below 296	4-10-97	37.25	37.65	.40	NA	NA	NA	NA
			Zone D (below 296 ft bls)					
Above 296	4-9-97	41.95	42.00	.05	NA	NA	NA	NA
Below 296 (pumped)	4-9-97	32.88	115.43	82.55	.2	65	.002	.54
Sum of specific capacities or transmissivities for zones tested							.274	58.4
			Open hole tests					
Open hole	5-22-97	42.09	47.35	[7] 5.26	1	98	.19	39.8
Open hole	10-23-97	51.61	94.2	42.59	5.5	150	.13	26.9

[1] Stabilized water levels after packers were inflated.
[2] Depth to water at end of pumping at a constant rate before pump was shut off.
[3] Calculated using Thiem equation, assuming radius of influence, r_0, is 328 feet (100 meters).
[4] Estimated time-weighted average of variable pumping rates ranging from 0.18 to 2.2 gallons/minute.
[5] Calculated specific capacity for zone greater than actual specific capacity because of contributions of flow from other intervals, short duration of pumping, and variable pumping rates.
[6] Calculated transmissivity for zone greater than actual transmissivity because of contributions of flow from other intervals, short duration of pumping, and variable pumping rates.
[7] Drawdown did not stabilize during this test.

Well Mg-1444

Logging of well Mg-1444 identified producing fractures and vertical hydraulic head differences (Conger, 1999). The caliper log indicated major fractures at 70-72 ft bls (21.3-21.9 m), 138-141 ft bls (42.1-43 m), 153 ft bls (46.6 m), 260-265 ft bls (79.2-80.8 m) and numerous minor fractures along the open interval of the 294-ft (89.6-m) deep, 6-in.- (0.15 m) diameter borehole (fig. 32). During heatpulse-flowmeter measurements of the borehole under nonpumping conditions in summer 1996, upward borehole flow of about 1 gal/min (3.785 L/min) was measured, with inflow through fractures below 270 ft bls (82.3 m), at 260-265 ft bls (79.2-80.8 m), and possibly at 138-141 ft bls (42.1-43 m), and outflow through fractures at 70-72 ft bls (21.3-21.9 m). The observed upward flow indicated a difference in hydraulic heads in the borehole.

Tests in well Mg-1444 were conducted on April 3-7, 1997. On the basis of results of geophysical logging, five intervals were selected for testing (fig. 32) including below 268 ft bls (81.7 m) (zone E); 248-269 ft bls (75.6-82 m) (zone D); 136.5-157.5 ft bls (41.6-48 m) (zone C); 64-85 ft bls (19.5-25.9 m) (zone B); and above 64 ft bls (19.5 m) (zone A).

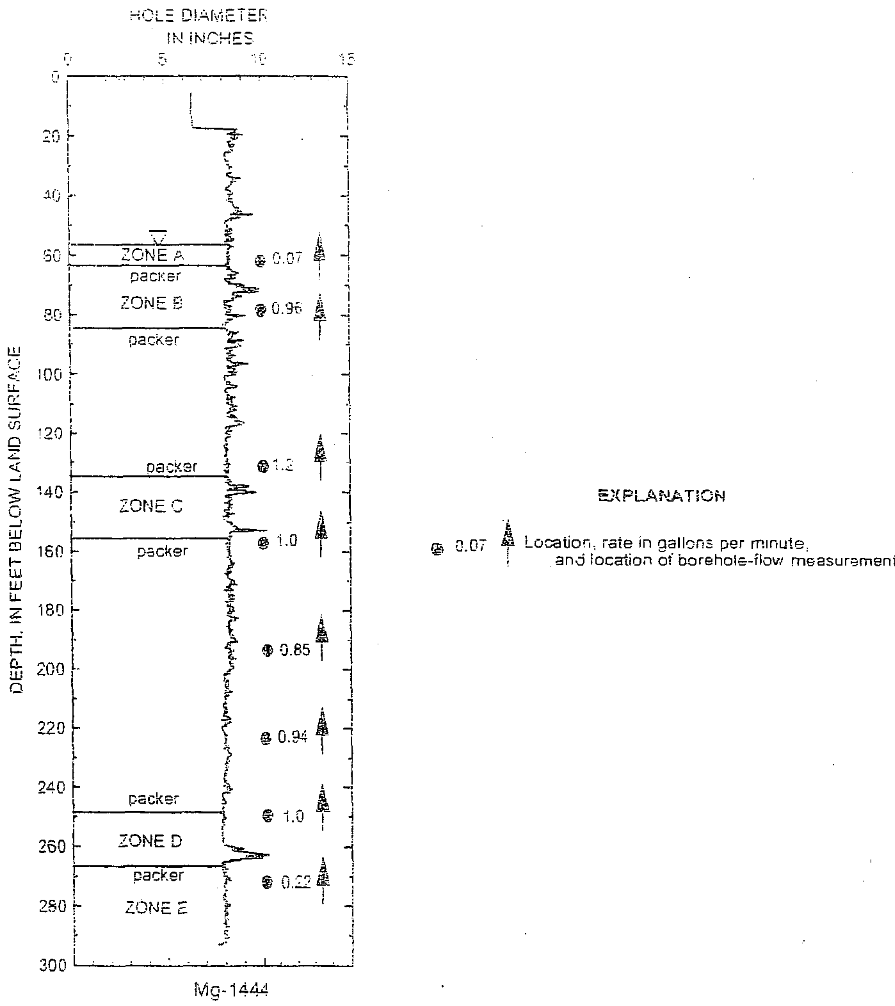


Figure 32. Depth of packers for aquifer-interval-isolation tests and direction of nonpumping flow in well Mg-1444 in Lansdale, Pa.

In the test of zone A, the pre-pumping water level in zone A was 0.28 ft (0.9 m) above the level in the interval between 64-85 ft bls (19.5-25.9 m) and 14.1 ft bls (4.30 m) lower than in the interval below 85 ft bls (25.9 m), similar to head differences measured in the test of zone B. Pumping of zone E was short in duration and at small, variable rates because the zone produced little water and dewatered rapidly. Little drawdown was measured in the interval immediately underlying zone E, and no drawdown was measured in the interval below 85 ft bls (25.9 m) (**fig. 33**).

In the test of zone B, the pre-pumping water level in zone B was 1.01 ft (0.31 m) lower than the level in the overlying interval and 12.12 ft (3.69 m) lower than the level in the underlying interval; these head differences indicate a downward vertical gradient from above and upward vertical gradient from below the isolated interval. Geophysical logging indicated fractures at 70-72 ft bls (21.3-21.9 m) were receiving, consistent with the lower heads measured in zone B compared to adjacent intervals. When zone B was pumped, gradual drawdown of up to 3 ft (0.91 m) in the interval above zone B and minor drawdown in the interval below zone B were measured (**fig. 34**). These results indicate leakage around packers or hydraulic connection outside the borehole between the zone B and the overlying interval and near hydraulic isolation between zone B and the underlying interval.

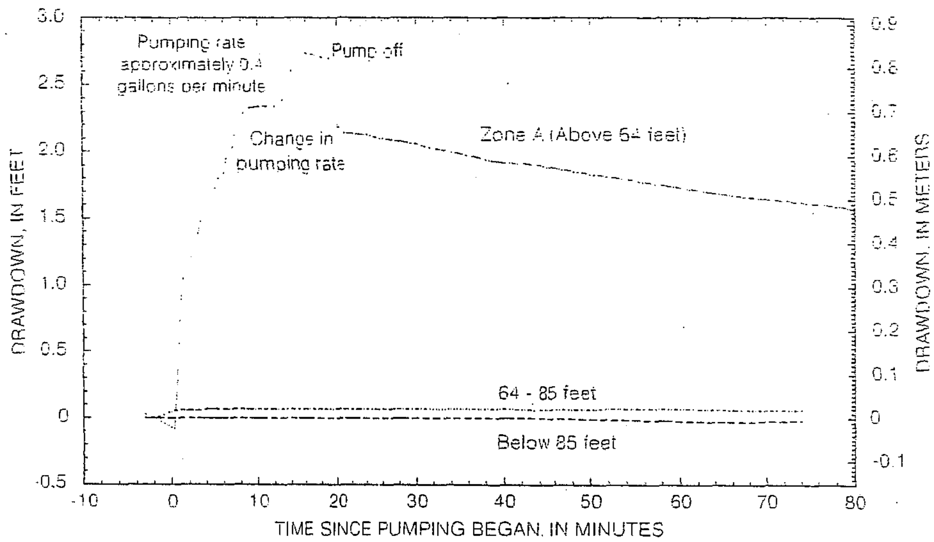


Figure 33. Drawdown as a function of time in aquifer-interval isolation test of zone A of borehole Mg-1444 in Lansdale, Pa., April 7, 1997.

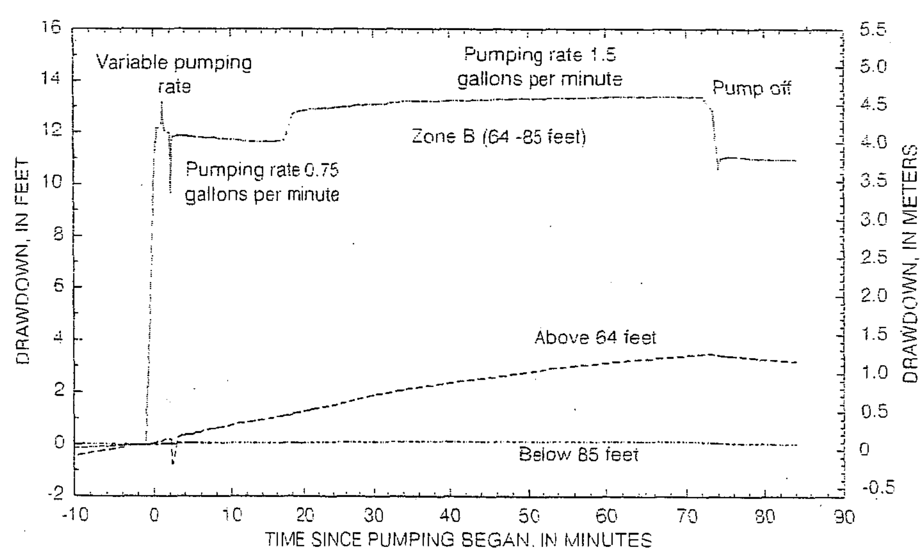


Figure 34. Drawdown as a function of time in aquifer-interval isolation test of zone B of borehole Mg-1444 in Lansdale, Pa., April 4, 1997.

In the test of zone C, the pre-pumping water level in zone C was 16.71 ft (5.09 m) higher than the level in the overlying interval and 1.06 ft (0.32 m) lower than the level in the underlying interval. These head differences are consistent with the upward flow measured with the heatpulse-flowmeter at 160 ft bls (48.8 m) and 130 ft bls (39.6 m) in summer 1996 (Conger, 1999). When zone C was pumped, very little drawdown was measured in the interval above zone C and virtually no drawdown was measured in the interval below zone C (fig. 35), suggesting hydraulic isolation between these intervals.

In the test of zone D, the pre-pumping water level in the isolated interval was 15.35 ft (4.68 m) higher than in the level in the overlying interval and 0.88 ft (0.27 m) higher than the level in the underlying interval. These head differences indicate upward and downward vertical gradients between zone D and adjacent intervals. The upward vertical gradient is consistent with the upward flow measured earlier with the heatpulse flowmeter at and above 256 ft bls (78 m) (Conger, 1999). Drawdown of more than 2 ft (0.61 m) was measured in the interval below zone D when zone D was pumped (fig. 36). These results suggest leakage around packers or a hydraulic connection outside the borehole between the isolated zone D and the underlying interval. In the test of zone D, little drawdown measured in the overlying interval indicates that zone D and the overlying interval were hydraulically isolated.

In the test of zone E, the pre-pumping water level in zone E was 6.45 ft (1.97 m) lower than the level in the overlying interval. Although upward flow was observed during heatpulse-flowmeter measurements in summer 1996, the observed head differences for zone E in April 1997 indicate a downward vertical gradient between the isolated interval and the overlying interval. Drawdown of less than 1 ft was measured in the interval above zone E during pumping of zone E (fig. 37, table 9), suggesting either leakage around packers or a hydraulic connection outside the borehole similar to the test results of zone D.

The total specific capacity of 0.89 (gal/min)/ft [11.1 (L/min)/m] determined from the interval-isolation tests was less than the specific capacity of 1.56 (gal/min)/ft [19.4 (L/min)/m] determined from an open-hole test (table 9). Results of heatpulse-flowmeter measurements in summer 1996 suggest that the zone between 248-269 ft bls (75.6-82 m) is the most productive (Conger, 1999), which is consistent with the results of the interval-isolation tests.

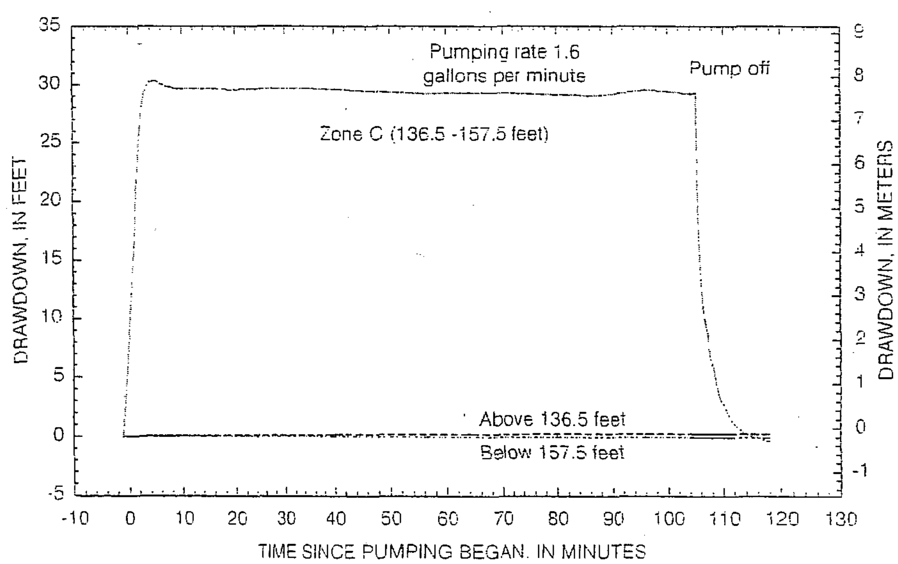


Figure 35. Drawdown as a function of time in aquifer-interval-isolation test of zone C of borehole Mg-1444 in Lansdale, Pa., April 4, 1997.

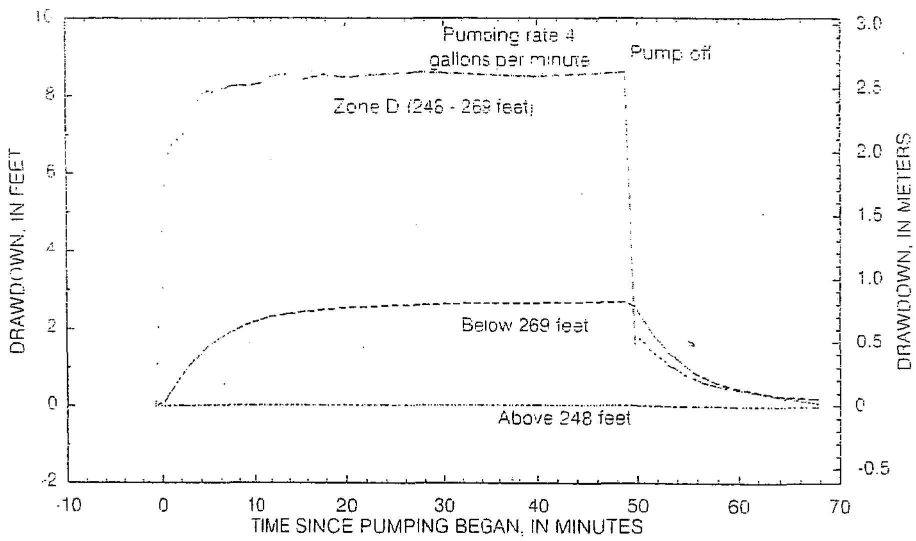


Figure 36. Drawdown as a function of time in aquifer-interval-isolation test of zone D of borehole Mg-1444 in Lansdale, Pa., April 3, 1997.

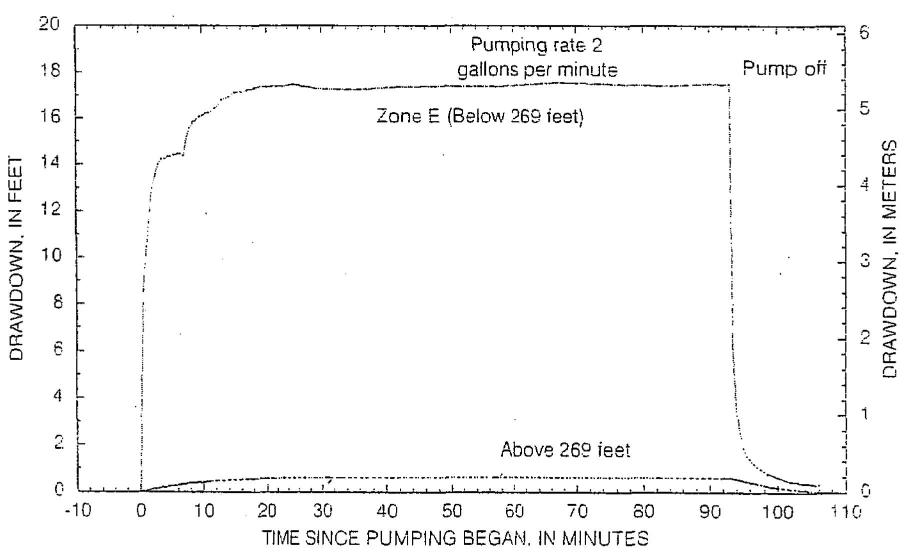


Figure 37. Drawdown as a function of time in aquifer-interval-isolation test of zone E of borehole Mg-1444 in Lansdale, Pa., April 3, 1997.

Table 8. Depths, water levels, specific capacity, and transmissivity of aquifer intervals isolated by packers and of the open hole for well Mg-1444 in Lansdale, Pa., April 1997 and October 1997

[ft bls, feet below land surface; ft, feet; gal/min, gallons per minute; min, minutes; (gal/min)/ft, gallons per minute per foot; ft^2/d, square feet per day; NA, not applicable]

Depth of isolated zone in borehole (ft bls)	Date of test	Pre-pumping depth to water in interval[1] (ft bls)	Depth to water in interval at end of test[2] (ft bls)	Drawdown (ft)	Pumping rate (gal/min)	Pumping duration (min)	Specific capacity [(gal/min)/ft]	Transmissivity[3] (ft^2/d)
Zone A (above 64 ft bls)								
Above 64 (pumped)	4-7-97	56.34	59.04	2.7	0.4	19	0.15	32.5
64-85	4-7-97	56.62	57.32	.7	NA	NA	NA	NA
Below 64	4-7-97	42.52	42.52	0	NA	NA	NA	NA
Zone B (64-85 ft bls)								
Above 64	4-4-97	54.31	57.78	3.47	NA	NA	NA	NA
64-85 (pumped)	4-4-97	55.32	68.72	13.40	1.5	72	[4] .11	[5] 24.1
Below 85	4-4-97	43.20	43.31	.11	NA	NA	NA	NA
Zone C (136.5-157.5 ft bls)								
Above 136.5	4-4-97	58.15	58.38	.24	NA	NA	NA	NA
136.5-157.5 (pumped)	4-4-97	41.44	70.73	29.29	1.67	105	.057	12.5
Below 157.5	4-4-97	40.38	40.36	-.02	NA	NA	NA	NA
Zone D (248-269 ft bls)								
Above 248	4-3-97	54.58	54.60	.02	NA	NA	NA	NA
248 - 269 (pumped)	4-3-97	39.23	47.85	8.62	4	49	.46	102
Below 269	4-3-97	40.11	42.81	2.7	NA	n	NA	NA
Zone E (below 268 ft bls)								
Above 268	4-3-97	41.54	42.12	.61	NA	NA	NA	NA
Below 268 (pumped)	4-3-97	47.99	65.50	17.51	2	93	.11	25.1
Sum of specific capacities or transmissivities for zones tested							.89	196
Open-hole tests								
Open hole	10-1-97	58.8	65.85	7.05	11	130	1.56	342

[1] Stabilized water levels after packers were inflated.

[2] Depth to water at end of pumping at a constant rate before pump was shut off.

[3] Calculated using Thiem equation, assuming radius of influence, r_0, is 328 feet (100 meters).

[4] Calculated specific capacity for zone greater than actual specific capacity because of contributions of flow from other intervals.

[5] Calculated transmissivity for zone greater than actual transmissivity because of contributions of flow from other intervals.