Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Jeffrey P. Halka, Director

BASIC DATA REPORT NO. 23

# HYDROGEOLOGIC DATA FROM EIGHT TEST-WELL SITES ON THE MARYLAND EASTERN SHORE

by

David D. Drummond, David C. Andreasen, Andrew W. Staley, and David W. Bolton

Prepared in cooperation with the
Maryland Department of the Environment

2012

State of Maryland

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## ABSTRACT

During the summer of 2010, 18 test wells and one continuous core hole were drilled at eight sites on the Eastern Shore of Maryland. The wells were drilled as part of several investigations into the hydrogeologic characteristics of Coastal Plain aquifers on the Delmarva Peninsula. The core hole and 14 test wells were drilled at Martinak, Greensboro, Cordova, Idylwild, and Warner to assess the hydraulic connectivity of sands within the Calvert aquifer system (Miocene age). Two wells were drilled at the Church Hill site to estimate the connectivity of the Aquia and Hornerstown Formations. Single test wells were drilled at the Sassafras and LESREC sites to obtain hydrogeologic information on the Monmouth and Manokin aquifers, respectively. This report describes the construction of the test wells and provides data collected during drilling and testing of the wells and core hole.

## INTRODUCTION

During the summer of 2010, 18 test wells and one continuous core hole were drilled at eight sites on the Maryland Eastern Shore. The wells were drilled as part of an investigation into the hydrogeologic characteristics of Coastal Plain aquifers on the Delmarva Peninsula (fig. 1). The primary purpose of this investigation was to collect hydrologic data for Miocene age aquifers in the Calvert and Choptank Formations, and to test whether sandy units in this formation function as separate aquifers, or as a single aquifer system. Test sites were located at Greensboro, Cordova, Martinak State Park, Idylwild Wildlife Management Area, and the Warner Tract. Two wells at the Church Hill Park site were drilled to evaluate the connectivity of the Aquia and Hornerstown Formations, and to determine if these units function as a single aquifer or hydraulically distinct aquifers. A single well at Sassafras Natural Resources Management Area was drilled to obtain stratigraphic information for the Monmouth and Magothy aquifers. A single well at the Lower Eastern Shore Research and Education Center (LESREC) was drilled to obtain hydraulic and water-level data in the Manokin aquifer.

Construction of the test wells was contracted to A. C. Schultes of Delaware Inc[1]. Well construction and testing was carried out from May through October, 2010. The core hole at Martinak was drilled by U. S. Geological Survey (USGS) Geologic Division from May 19 to 26, 2010.

[1] The use of specific names of products or companies does not constitute endorsement by the Maryland Geological Survey.

### Location of Study Area and Hydrogeologic Setting

The study area is in the Maryland portion of the Delmarva Peninsula, commonly referred to as the Eastern Shore of the Chesapeake Bay or Maryland Eastern Shore. Test-well sites were located in Kent, Queen Anne's, Caroline, Talbot, Dorchester, and Wicomico Counties (fig. 1).

The study area lies completely within the Coastal Plain province of Maryland. The geologic formations of the Coastal Plain on the Eastern Shore consist of layers of sand, silt, clay, and gravel that generally become deeper and thicker to the southeast, and overlie a basement complex of largely crystalline bedrock (fig. 2, tab. 1). Sand and gravel layers form aquifers, which provide water to wells; clay and silt layers form confining units, which limit flow between the aquifers and provide storage for the aquifer system. Aquifers and confining units penetrated by the test wells are shown in the generalized hydrogeologic section in figure 2, and the hydrogeologic characteristics of these units are briefly described in table 1.

Aquifers penetrated by the test borings include (from shallow to deep) the Surficial, Manokin, Choptank, Calvert (including the Frederica, Federalsburg, and Cheswold subaquifers), Piney Point, Aquia, Monmouth, and Magothy aquifers. The Upper Patapsco, Lower Patapsco, and Patuxent aquifers, which comprise the Potomac Group, underlie the Magothy aquifer in most, if not all, of the study area, but were not penetrated by test wells in this study. The Pocomoke and Ocean City aquifers are present to the southeast of the study area and were not addressed in this study.

The main investigation addresses the Miocene age aquifers of the Calvert and Choptank Formations on the central Eastern Shore. Cushing and others (1973) identified three aquifers in this interval, (from shallow to deep) the Frederica, Federalsburg, and Cheswold aquifers. However, additional data collected since that study indicate that those units may not be separate, extensive aquifers on the regional scale and may not correlate with similarly named units in Delaware. Test wells at Martinak, Greensboro, Idylwild, Cordova, and Warner were drilled to determine if the Frederica, Federalsburg, and Cheswold sands function hydraulically as distinct aquifers, or as a single aquifer unit.

### Acknowledgments

Cooperative funding for this study was provided by Maryland Department of the Environment.

Field data were collected by the authors and by Michael Baird, and Heather Quinn, all of the Maryland Geological Survey. Stephen Curtin, of the U.S. Geological Survey, and Peter McLaughlin, of the Delaware Geological Survey, performed geophysical logging of some test wells. Donajean Appel of the Maryland Geological Survey assisted in preparation of the tables and other aspects of the report. The report was reviewed by Peter McLaughlin, of the Delaware Geological Survey and Michael Brayton, of the U.S. Geological Survey.

The authors wish to thank the following individuals and organizations for providing drill sites and logistical support for the test wells: John Ohler, Maryland Department of Natural Resources; Rich Covert, Greensboro Volunteer Fire Department; Mark Secrist and Thomas Diem, Cordova Volunteer Fire Department; Gary Rzepecki, Queen Anne's County Department of Parks and Recreation; David Armentrout, University of Maryland, LESREC; Mike Schofield, Chesapeake Forest Lands, Maryland Department of Natural Resources; and Larry Manokey, Wildlife and Heritage Service, Maryland Department of Natural Resources.

## DRILLING AND CONSTRUCTION

The test wells were drilled and constructed between May and October, 2010; all test wells were drilled by A. C. Schultes of Delaware, Inc. Detailed location maps for the eight test well sites are shown in figures 3a-b. Test-well borings were drilled to depths ranging up to 400 ft below land surface (tab. 2, figs 4 through 13), using the direct rotary method. Drill cuttings were collected at 10-foot intervals. Descriptions of sediments were recorded by the well drillers for inclusion in well-completion reports, based on drill cuttings and the response of the drilling rig to different sediment types. Drilling fluid was circulated to allow drill cuttings to reach the surface before proceeding to the next depth interval; however, some recirculation and mixing of sediments between intervals was unavoidable. Drill cuttings were described on site and collected by MGS geologists (tabs. 3-10). Split-spoon cores were taken using a wire-line device at selected intervals to obtain sediment samples that were not disaggregated by rotary drilling.

After the first borehole at each site was drilled to final depth, the drilling fluid was thinned and geophysical logs were run on the uncased borehole (figs. 14 through 21). Depths of screen intervals were determined based on sediment logs and geophysical logs. Screened intervals were gravel packed and the annular space outside the well casings was grouted using either cement grout or a mix of cement and bentonite. A five-foot section of blank casing was installed below the deepest screen section in each well to allow settling of sediment without clogging the well screen. The 4½-inch well casing was extended about 2 ft above land surface, except for the wells at Greensboro, which were cut off below land surface and closed-in. After the grout was properly cured, each well was developed using compressed air and high-pressure jetting to remove fine-grained material from the well casing, screen openings, and gravel pack.

Aquifer tests were performed for most wells and water samples were collected for chemical analyses during the pumping phase of each aquifer test (figs. 22 through 35). Drilling equipment was then removed and the drill site restored to previous conditions. For all sites except Greensboro, a 6-inch steel protective casing was cemented in place to protect the 4½-inch well casing from damage, and was extended about 2½ ft above land surface. At Greensboro, the wells were closed-in below land surface, and housed in man-holes with steel covers. Pressure transducers were installed in all test wells to record water levels over periods of several months (figs. 36 through 43).

The continuous core hole CO Dc 152 was drilled at Martinak State Park on May 19-26, 2010 to 400 ft below land surface, with about 76 percent recovery. The core barrel was 2 inches in diameter and 10 ft long, although some core runs were less than 10 ft. Each core was washed and scraped clean and described in detail by a site geologist. Sub-samples were taken on-site for dinoflagellates and calcareous nannofossils for later analysis by USGS. Cores were boxed, wrapped in plastic, and photographed, and are archived at MGS. After coring to final depth, geophysical logs were run and the core hole was grouted with bentonite. Subsamples of shell material were taken from the core in the laboratory for strontium isotope analysis.

## SITE DESCRIPTIONS

### Greensboro Carnival Grounds

Two test wells were drilled at the Greensboro Carnival Grounds (owned by the Greensboro Volunteer Fire Department) in the town of Greensboro in Caroline County as part of the Miocene aquifers investigation (figs. 1 and 3a). Both wells were screened in the Calvert aquifer system (tab. 2). Both wells were flowing as originally constructed with casing heights a few feet above land surface, which complicated well construction and testing. Water levels in both wells were approximately 11 ft above land surface making it necessary to add casing extensions. After testing, each well casing was cut off below land surface, closed-in within a 1-foot diameter man-hole, and secured with a steel plate. Each well was fitted with a valve and hose bib to allow for water-level measurements and future testing.

Aquifer tests (24-hour drawdown phase and 16-hour recovery phase) were performed on both wells, with casing extensions and scaffolding to provide access to the wells above land surface. Water levels were measured in both wells during each test. Water samples for chemical analysis were collected from each well during the pumping phase of each test.

Because the final wells were closed-in, water levels could not be measured using typical methods (using an electric tape to measure below the top of the well casing). Instead, levels were initially measured by fitting ½-inch clear tubing to the hose bib, extending the tube about 11 ft above land surface, and sighting the level to a stadia rod from atop a van. Subsequently, a pressure gage was fitted to the tubing, and water levels were calculated from the pressure readings.

Similarly, vented pressure transducers could not be installed in the typical manner (hanging the transducer on a vented cable from the top of the well casing). Instead, a PVC chamber was constructed for each well and attached to the hose bib. An unvented transducer was installed in each chamber, and air was purged through an outlet valve. Data were uploaded by closing the main valve, disassembling the chamber, and attaching the transducer to a data reader. Transducers were installed from March 11, 2011 through present. A tidal fluctuation of approximately 0.2 ft is shown in hydrographs of both wells, caused by tides in the Choptank River, which is about 500 ft from the test wells at its closest point. A spike in water levels of about 3 ft is seen in both wells on August 28-29, 2011, caused by flooding of the Choptank River during Hurricane Irene, which inundated the test-well site.

### Martinak State Park

Four test wells and a continuous core hole were drilled at Martinak State Park as part of the Miocene aquifers investigation. Martinak is south of Denton in central Caroline County (figs. 1 and 3b, tab. 2). The three deepest wells (CO Cd 153, 154, and 155) were screened in sands in the Calvert Formation, and the shallowest well (CO Cd 156) was screened in the Choptank Formation. The continuous core hole was drilled to the top of the Piney Point Formation to provide high-quality sediment samples for biostratigraphic analysis and to display sediment structures and features not possible in drill cuttings from rotary drilling.

A condensed geologist's lithologic log is shown in table 4. This log is more detailed than lithologic logs from other sites because the descriptions were made on high-quality core material, which shows colors, structures and spatial variation not possible in drill cuttings. The original, more detailed lithologic log is on file at MGS.

Aquifer tests were performed on wells CO Dc 153, 154, and 155 (not on CO Dc 156). Water levels were measured in the pumping wells and all observation wells during the tests, as well as in a nearby park well, CO Dc 157. All test wells show a significant tidal fluctuation caused by the Choptank River, about 300 ft from the test wells (fig. 3). The tidal fluctuation complicates the analysis of aquifer-test data in observation wells because it masks possible drawdown caused by the pumping well. Water quality samples were taken from wells CO Dc 153, 154, and 155 (not CO Dc 156) during the pumping phase of each aquifer test.

Pressure transducers were installed in all four test wells to continuously record water levels from October 18, to December 16, 2010. In addition, a tide gage was installed near the test site on the Choptank River to relate tidal fluctuations in the river with water-level fluctuations in the test wells and aid in analysis of aquifer testing. The tide gage operated from October 13 to November 30, 2010.

### Idylwild Wildlife Management Area

Three test wells were drilled at the Idylwild Wildlife Management Area, as part of the Miocene aquifers investigation (figs. 1 and 3a, tab. 2). Idylwild is just east of Federalsburg in southern Caroline County. The three wells were screened in different intervals of the Calvert Formation. An aquifer test was performed on each test well and water levels were measured in all wells for each test. In addition, water levels were measured in three existing wells at the site: USGS test wells CO Fd 36 and CO Fd 37, and a nearby supply well for the facility, CO Fd 44. Well CO Fd 36 is screened in the Choptank aquifer, CO Fd 37 is screened in the Surficial aquifer, and CO Fd 44 is screened in the Calvert aquifer, in the same approximate interval as CO Fd 43. Water-quality samples were taken from each MGS test well during the pumping phase of the aquifer test. Pressure transducers were installed in the three MGS test wells and the two USGS test wells to continuously record water levels from August 6, to October 18, 2010.

### Warner Tract

Three test wells were drilled at the Warner Tract (Chesapeake Forest Lands, MD DNR) in central Dorchester County, as part of the Miocene aquifers investigation (figs. 1 and 3b, tab. 2). Wells DO Df 12 and DO Df 13 were screened in sands within the Calvert aquifer system, and well DO Df 14 was screened in the Choptank aquifer. Aquifer tests were performed on wells DO Df 12 and DO Df 14, and water quality samples were collected during the pumping phase of each test. Well DO Df 13 did not produce enough water to warrant an aquifer test or water-quality sample. Pressure transducers were installed in all three wells from December 16, 2010 to April 25, 2011.

## Sassafras Natural Resources Management Area

One test well (KE Ae 71) was drilled at the Sassafras Natural Resources Management Area (referred to as Sassafras) in the Monmouth aquifer in north-central Kent County (figs. 1 and 3a, tab. 2). The purpose of this site was to obtain hydraulic properties of the Monmouth aquifer, and to establish long-term water-level monitoring. No aquifer test was conducted on the well; however, it was pumped using a submersible pump to obtain a water-quality sample. A pressure transducer was installed in the well to continuously record water levels from February 15 to May 26, 2011.

## Church Hill County Park

Two test wells were drilled at Church Hill County Park, just east of the town of Church Hill in northern Queen Anne's County (figs. 1 and 3a, tab. 2). Well QA Cf 78 was screened in the Aquia Formation, and well QA Cf 77 was screened in the Hornerstown Formation. The two formations have historically been considered to comprise the Aquia aquifer (Hansen, 1992; Drummond, 2001). These wells were drilled to determine if the sands in the Aquia and Hornerstown Formations act hydraulically as a single aquifer or as two separate aquifers. Aquifer tests were performed on each well, with water levels measured in both the pumped well and observation well. Water quality samples were taken from each well during the pumping phase of the aquifer test. A water-quality sample was also obtained from the park supply well QA Cf 79, which is screened in the lower part of the Aquia Formation, between the screened intervals of the two test wells. Pressure transducers were installed in the two test wells to continuously record water levels from October 22, 2010 to January 20, 2011.

## Cordova Volunteer Fire Department

Two test wells were drilled at the Cordova Volunteer Fire Department carnival grounds in northern Talbot County as part of the Miocene aquifers investigation (figs. 1 and 3a, tab. 2). Wells TA Bf 99 and TA Bf 100 were screened in sands of the Calvert aquifer system. An aquifer test was conducted on well TA Bf 100, with water levels measured in both wells. A water-quality sample was collected from TA Bf 100 during the pumping phase of the test. Well TA Bf 99 did not produce enough water to warrant an aquifer test or a water-quality sample. Pressure transducers were installed in both wells from January 20 to April 25, 2011.

## Lower Eastern Shore Research and Education Center

One test well (WI Ce 327) was drilled at the Lower Eastern Shore Research and Education Center (referred to as LESREC) in the Manokin aquifer in Wicomico County (figs. 1 and 3b, tab. 2). The purpose of this well was to obtain hydraulic properties of the Manokin aquifer and to establish long-term water-level monitoring in an area where data had previously been lacking. An aquifer test was run on the well, and water-quality sample was obtained during the pumping phase of the test. A pressure transducer was installed in the well to continuously record water levels from December 16, 2010 to February 15, 2011.

## HYDROGEOLOGIC DATA

### Lithologic Descriptions

Descriptive lithologic logs of the continuous core (at Martinak) and drill cuttings (at all other sites) were recorded by geologists on site (tabs. 3 through 10). Samples were washed using a 250-micron sieve, examined with a hand lens and described. Color designations (for instance 7.5YR 3/4) were recorded at some sites and were made on moist material using Munsell soil color charts (Munsell Color Company, 1975). Depths are in feet below land surface; dimensions of sediment grains, fossils, and rock fragments are in millimeters (mm). Formation determinations are based on lithologic data, geophysical logs, regional cross sections, and structure-contour maps. Consequently, not all formation contacts correspond to changes in lithology as noted in the on-site logs.

### Geophysical Logs

Geophysical logs were run in the deepest borehole at each site after drilling to final depth. Geophysical logs shown in figures 14 through 21 include natural gamma, multi-point resistivity (including 16-inch and 64-inch electrode spacings) and single-point resistance. Other logs were run in some wells, including spontaneous potential, 8-inch resistivity, 32-inch resistivity, and lateral resistivity, and are on file at the Maryland Geological Survey. The geophysical logs for wells CO Cd 66, CO Fd 41, DO Df 12, TA Bf 99 and WI Ce 327 were run by USGS; the log for well CO Dc 152 was run by Delaware Geological Survey; the log KE Ae 71 was run by A. C. Schultes of Delaware, Inc.; and the log for QA Cf 77 was run by Earth Data, Inc.

Geophysical logs can be used to determine generalized sediment types in boreholes. Gamma radiation generally is higher in clays and silts and lower in sands and gravels; resistivity and resistance generally are lower in clays and silts and higher in sands and gravels. The logs were used to determine optimal intervals for screening the test wells and for regional correlation of hydrostratigraphic units.

### Aquifer Tests

After each test well was constructed and developed, an aquifer test was performed which, for most wells, included a 24-hour constant-discharge pumping phase followed by a 24-hour recovery phase. The discharge rate was held constant for each test within a few gallons per minute (gpm). Discharge was monitored using an orifice meter and/or a bucket and stopwatch. Withdrawal rates in the test wells ranged from 8.6 to 118 gpm, and specific capacities ranged from 0.05 to 9.34 gallons per minute per foot (gpm/ft) (tab. 2). The aquifer test for well WI Ce 327 included an 8-hour drawdown test and 8-hour recovery test; aquifer tests were not performed on wells CO Dc 156, DO Df 13, TA Bf 99, and KE Ae 71. Graphs showing drawdown and recovery data for the aquifer tests are shown in figures 22 through 35.

Aquifer-test data are commonly displayed with a logarithmic x-axis (time scale) to facilitate calculation of transmissivity using the Cooper-Jacobs straight-line method. However, the primary purpose of aquifer tests in this investigation was to assess the hydraulic connectivity of sandy units by pumping from one unit and observing the water-level response in other units. These relations are best displayed with a linear time scale. Test data are available at the Maryland Geological Survey.

### Water Levels

Pressure transducers were installed on the test wells, which recorded water level at intervals of one to fifteen minutes (figs 36 through 43). The time periods recorded for the wells varied, because transducers were rotated between sites. Hand-held water-level measurements were recorded intermittently for the first few months after well installation, and monthly from February 2011 to January 2012.

### Water-Quality Analyses

Water samples for chemical analysis were obtained from an in-line spigot for most wells during the pumping phase of the aquifer test. MGS personnel collected the water samples and performed field tests for pH, alkalinity, dissolved oxygen, and specific conductance. Chemical analyses were performed by the USGS National Water-Quality Laboratory and their subcontracted laboratories. Results are shown in table 11. A Piper diagram shows major ion chemistry of water from the test wells in figure 44. Water-quality samples were not collected for wells CO Dc 156, DO Df 13, and TA Bf 99.

Water-quality analyses included major ions, nutrients, iron, manganese, fluoride, arsenic, radon, and selected field parameters (pH, alkalinity, dissolved oxygen, and specific conductance). Water-quality results did not exceed established Maximum Contaminant Levels (MCL) for any constituents with the exception of arsenic at well KE Ae 71, screened in the Monmouth aquifer. Secondary MCL's (established for aesthetic qualities such as taste and odor) were exceeded for iron (4 samples greater than 300 micrograms per liter [µg/L] and manganese (one sample greater than 50 µg/L).

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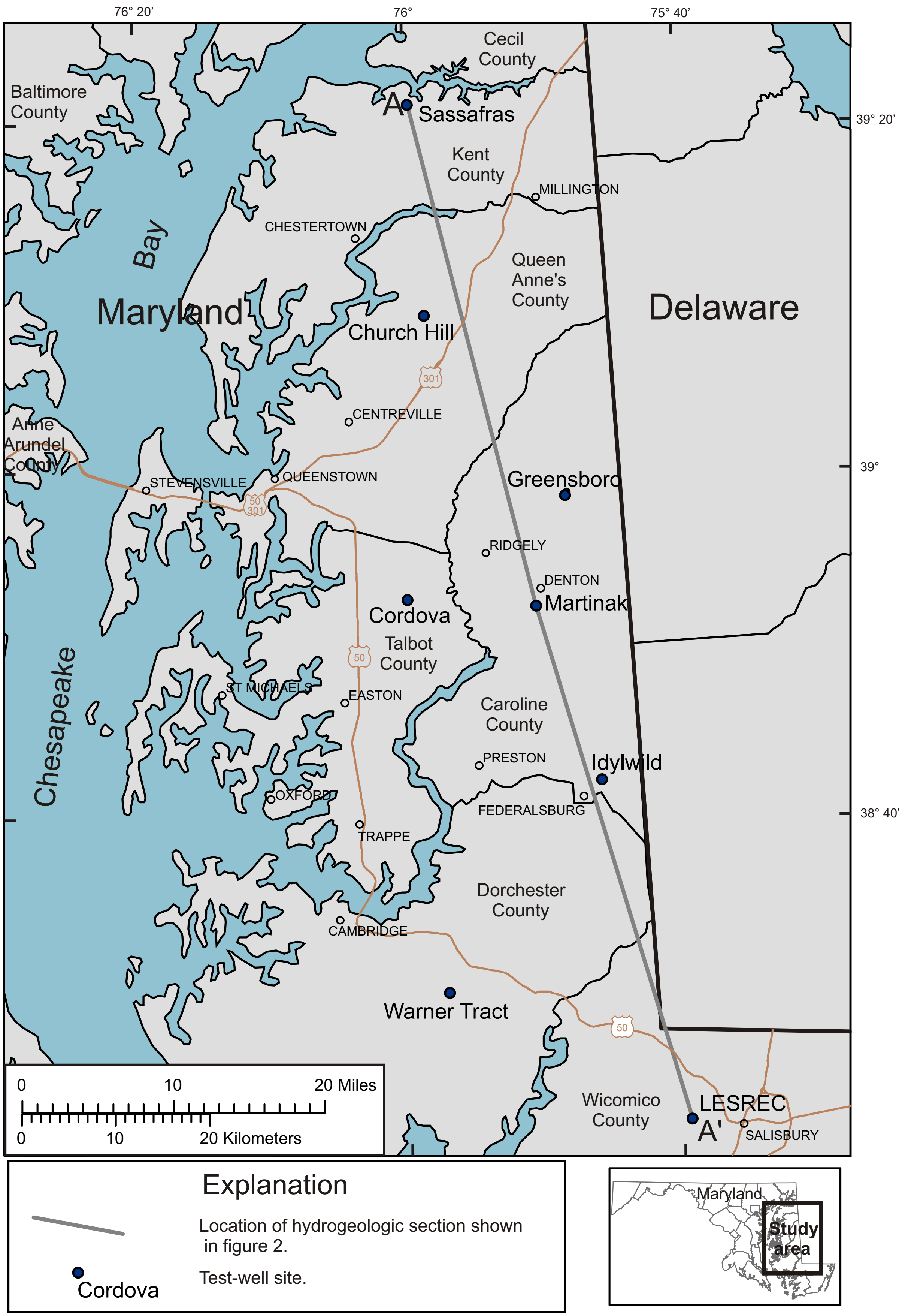



**Figure 1. Location of the study area, test-well sites, and hydrogeologic section A-A' on the Eastern Shore of Maryland.**

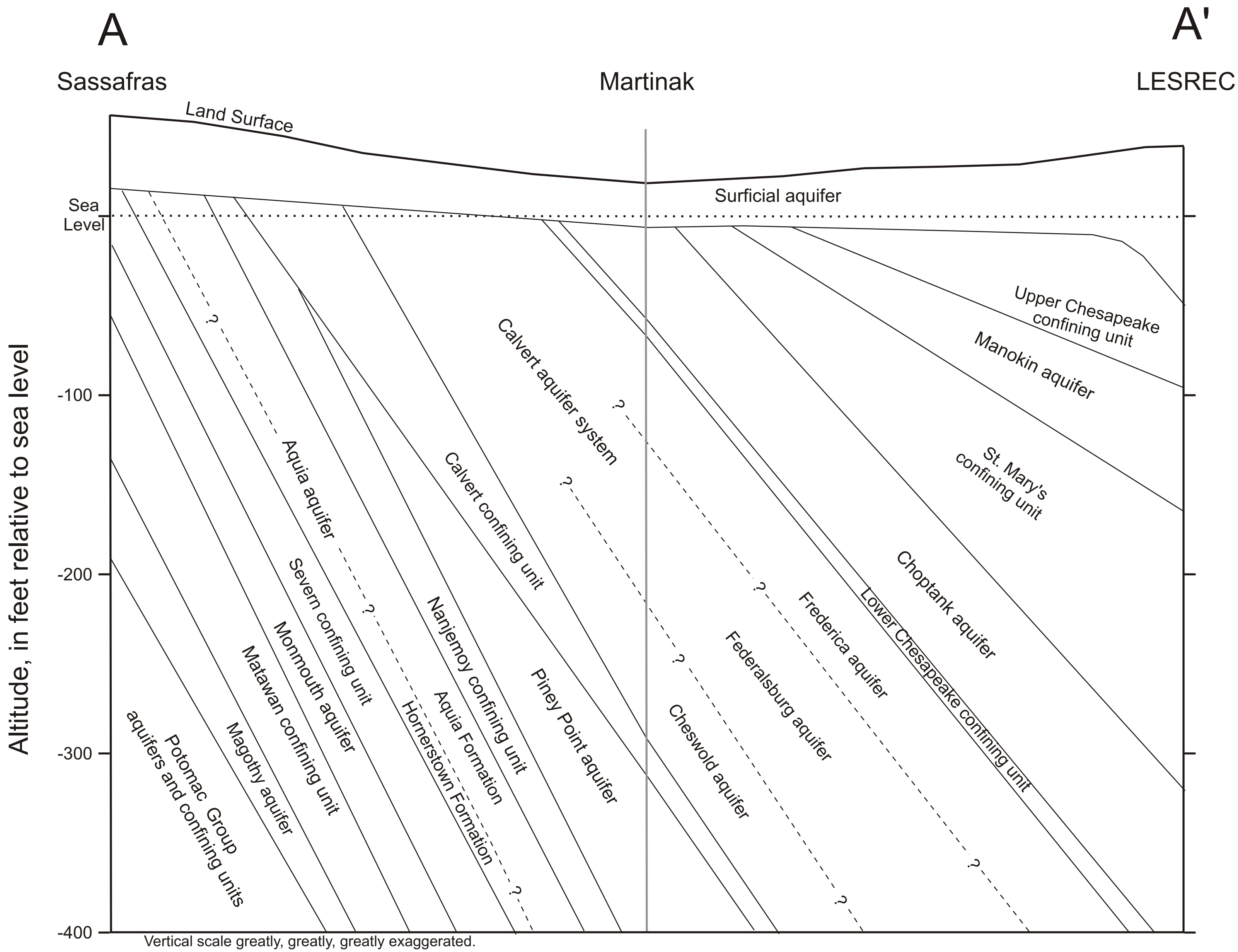



**Figure 2. Schematic cross section A-A', from Sassafras, through Martinak, to LESREC, showing hydrogeologic units on the Eastern Shore of Maryland. (See figure 1 for location of section.)**

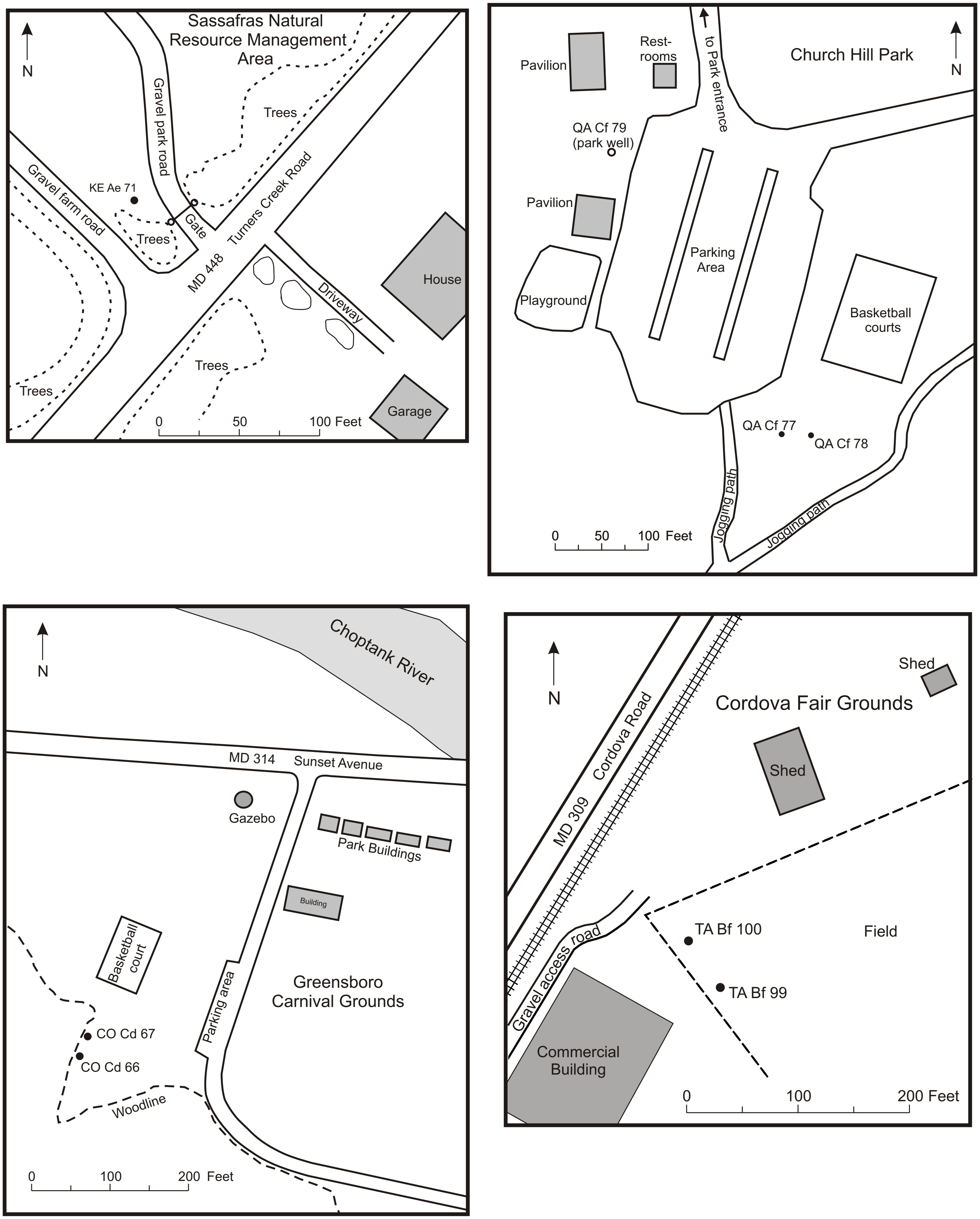



**Figure 3a. Site maps for test-well sites at Sassafras, Church Hill, Greensboro, and Cordova.**

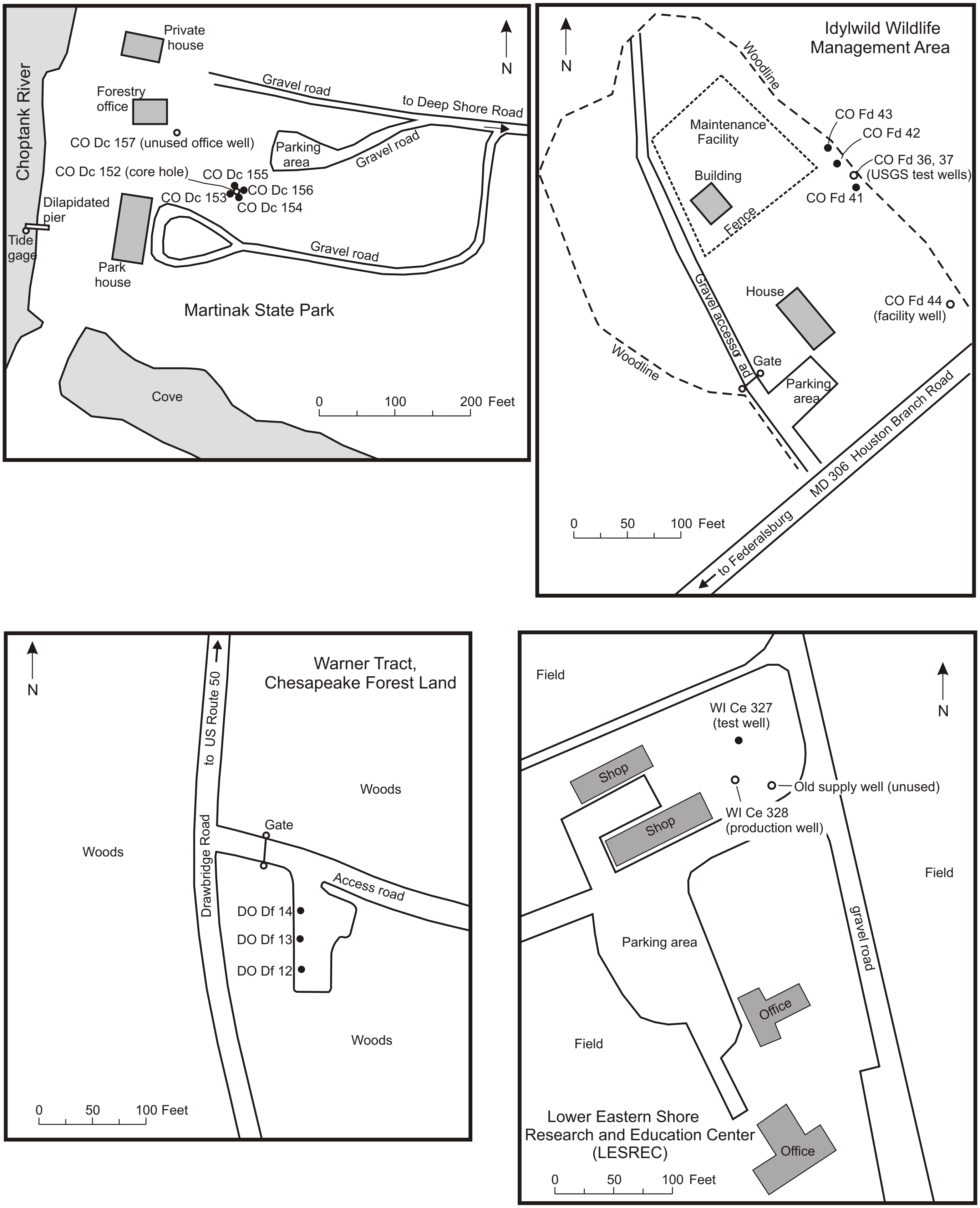
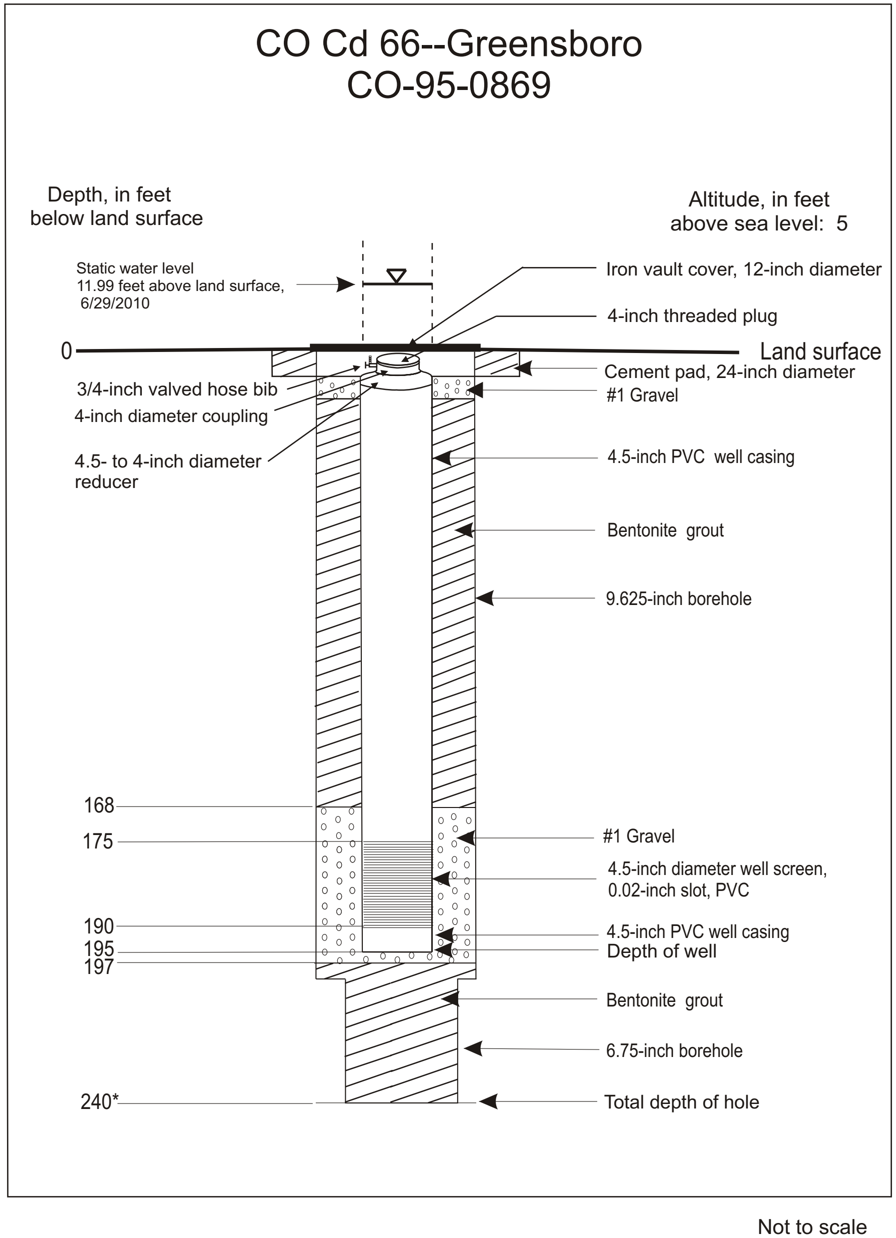



**Figure 3b. Site maps for test-well sites at Martinak, Idylwild, Warner, and LESREC .**



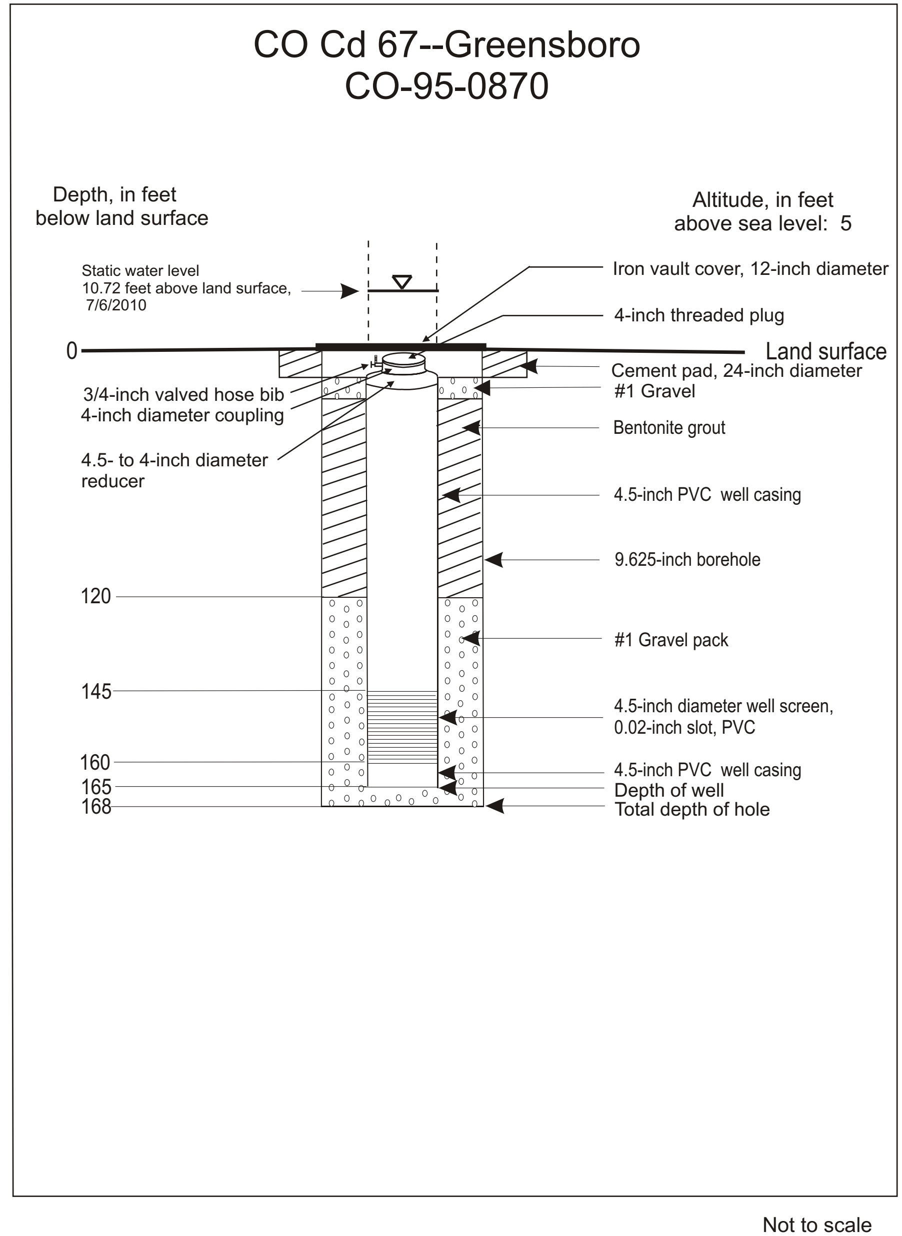
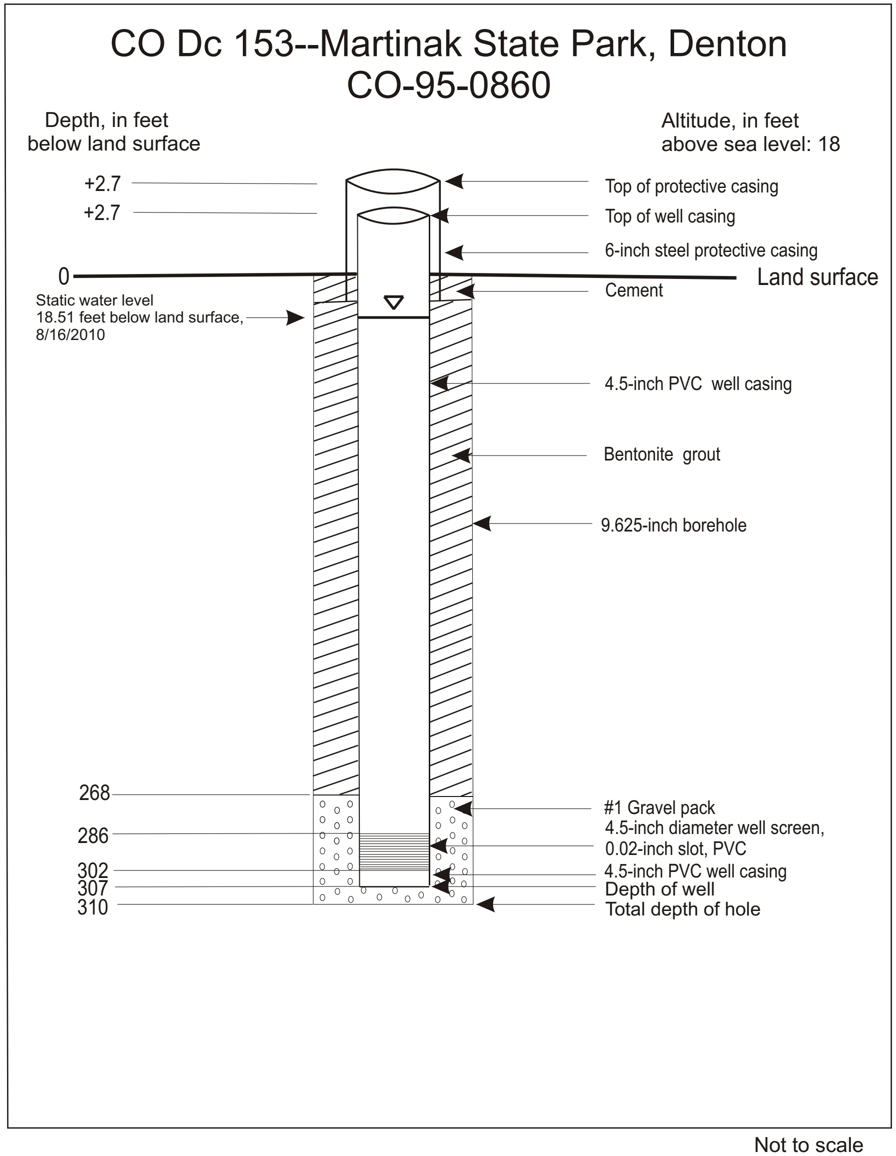




**Figure 4. Diagrams showing construction features of wells CO Cd 66 and CO Cd 67.**



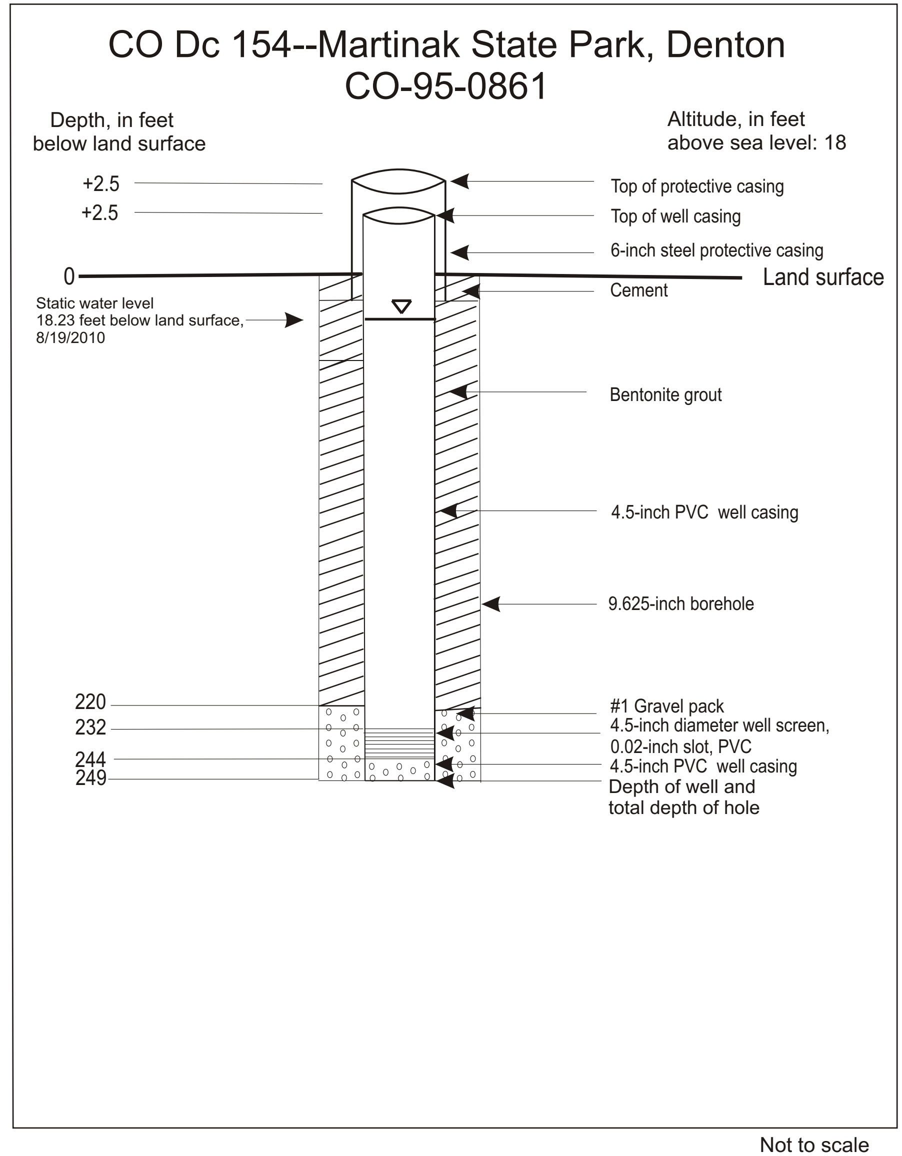
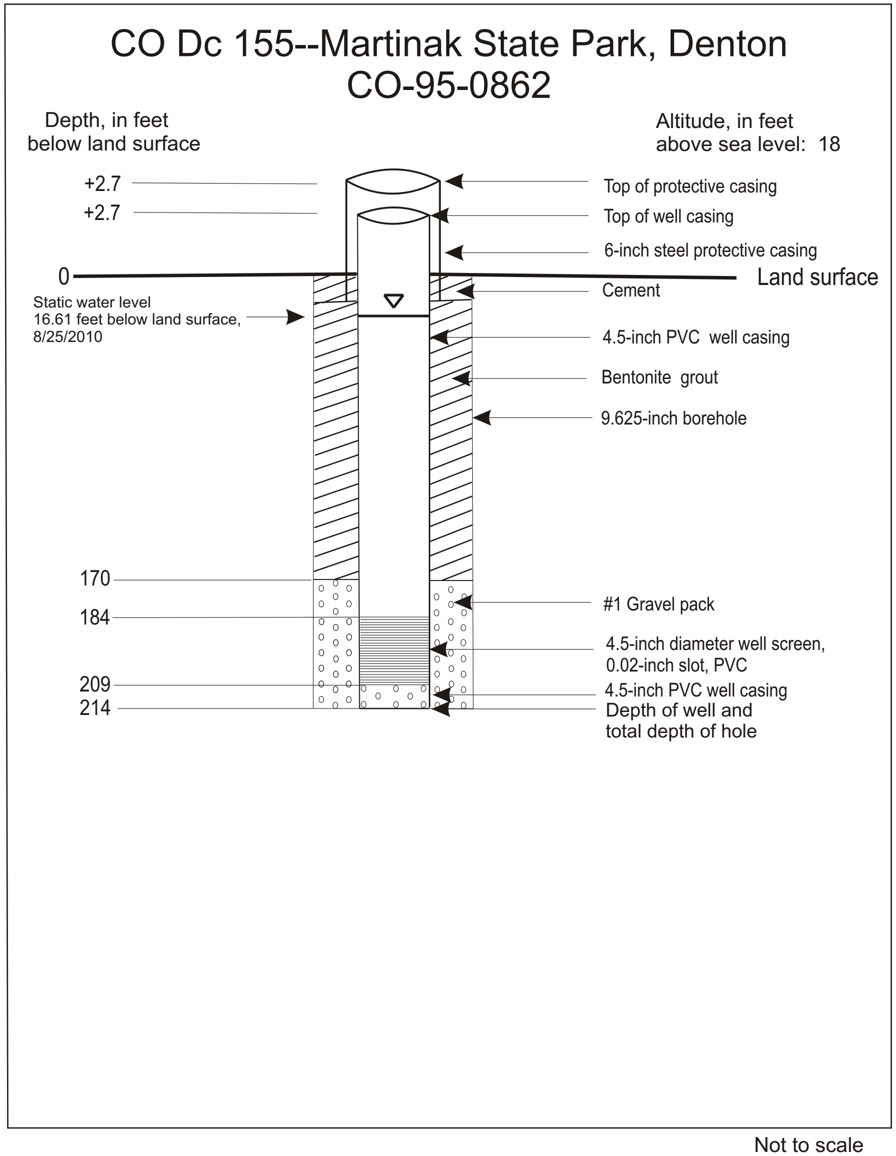




**Figure 5. Diagrams showing construction features of wells CO Dc 153 and CO Dc 154.**



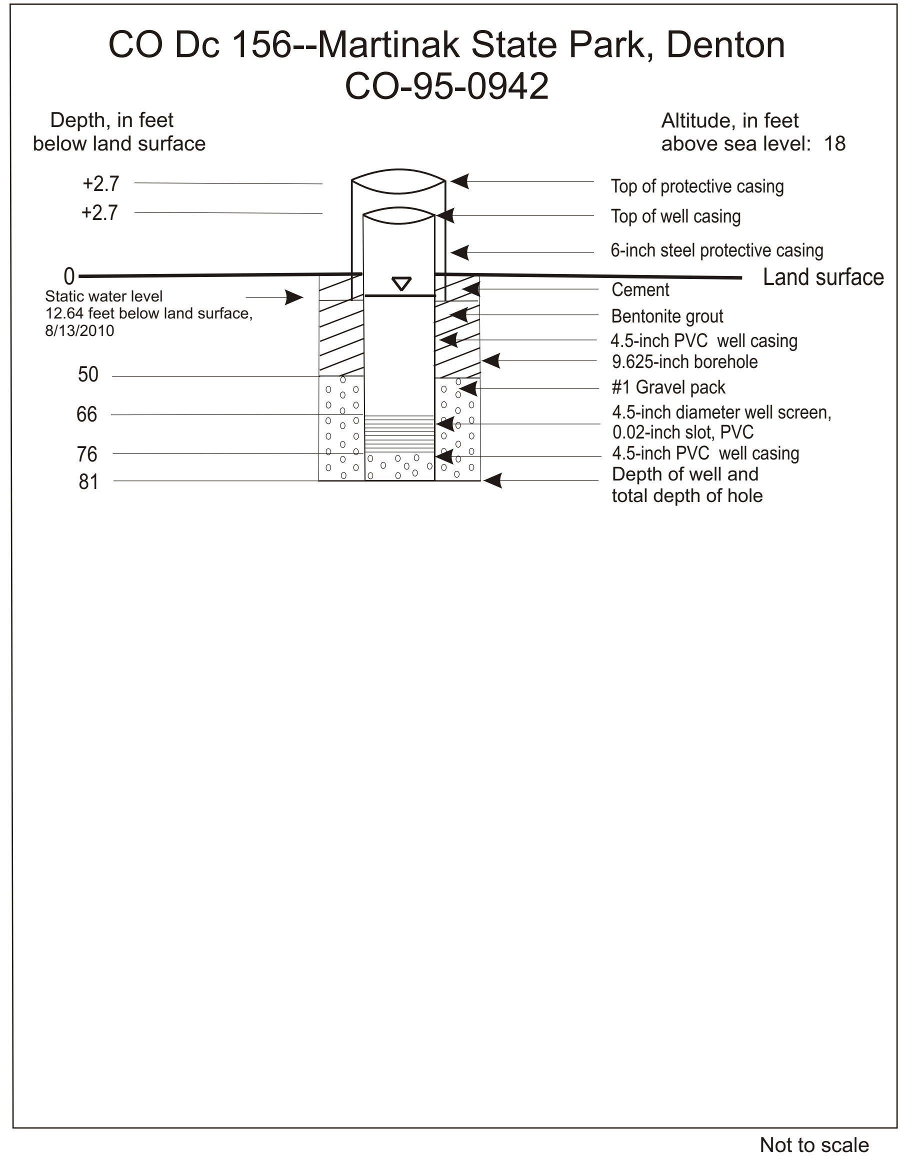
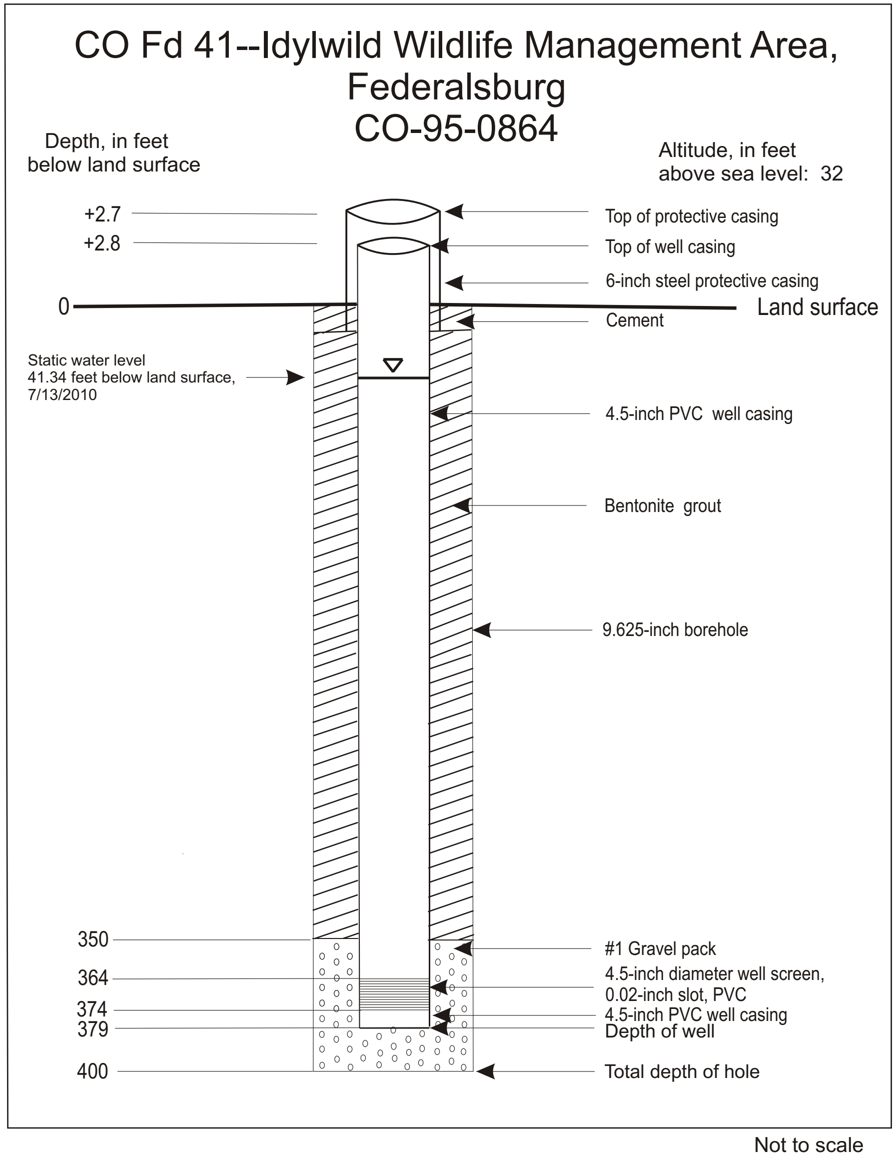




**Figure 6. Diagrams showing construction features of wells CO Dc 155 and CO Dc 156.**



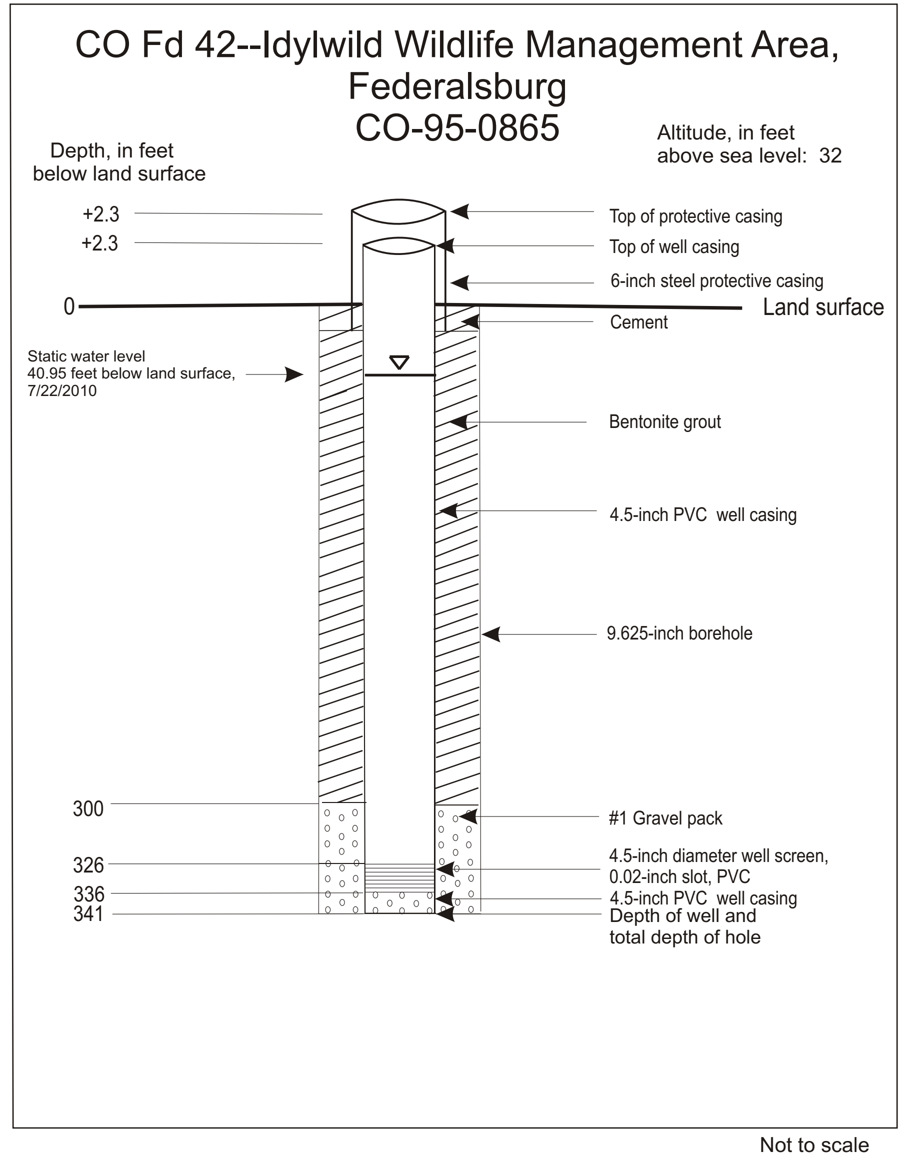




**Figure 7. Diagrams showing construction features of wells CO Fd 41 and CO Fd 42.**

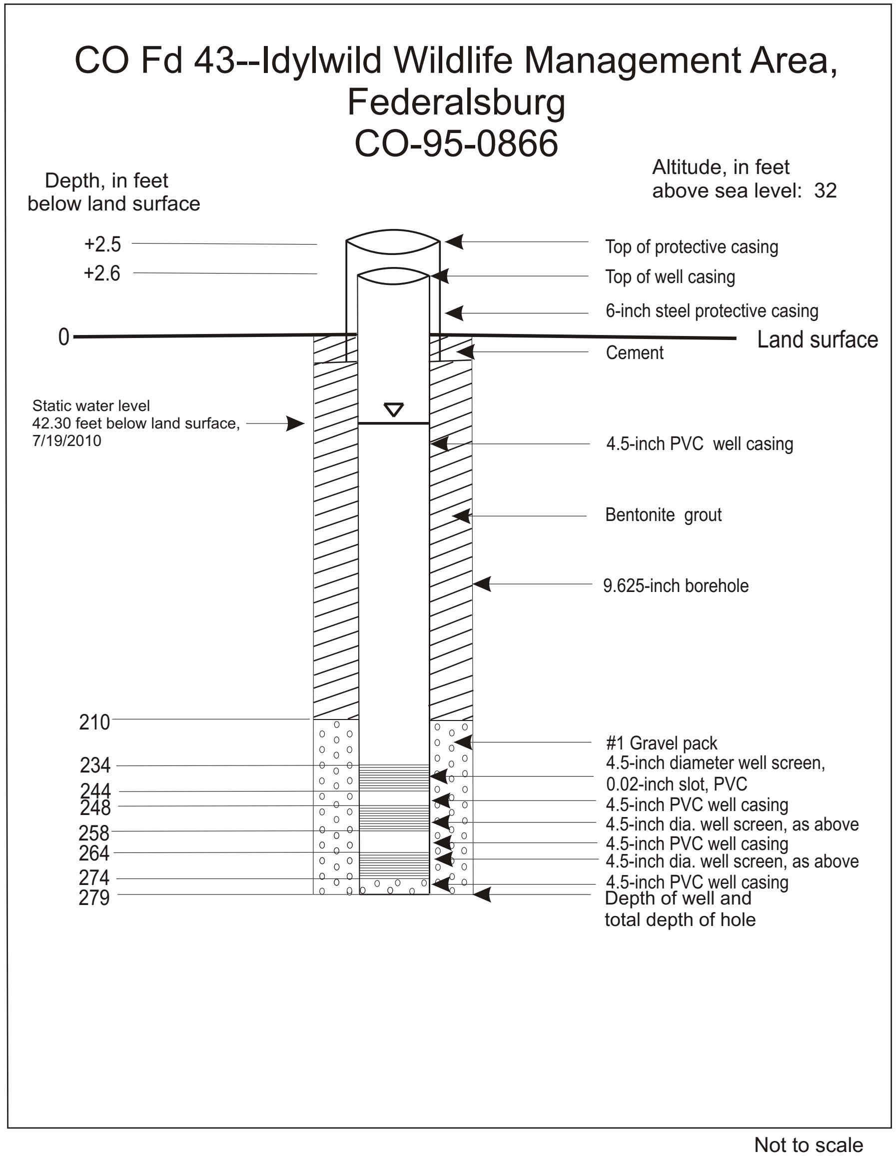
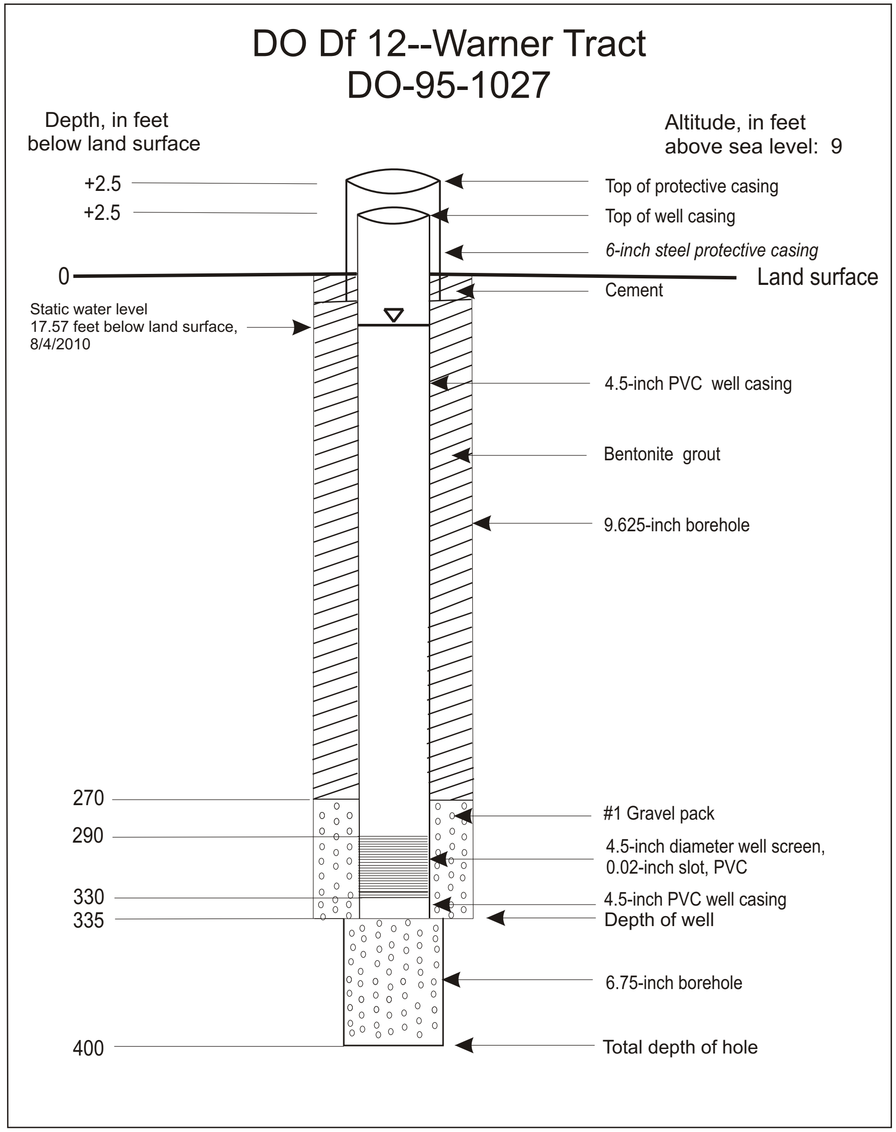



**Figure 8. Diagram showing construction features of well CO Fd 43.**

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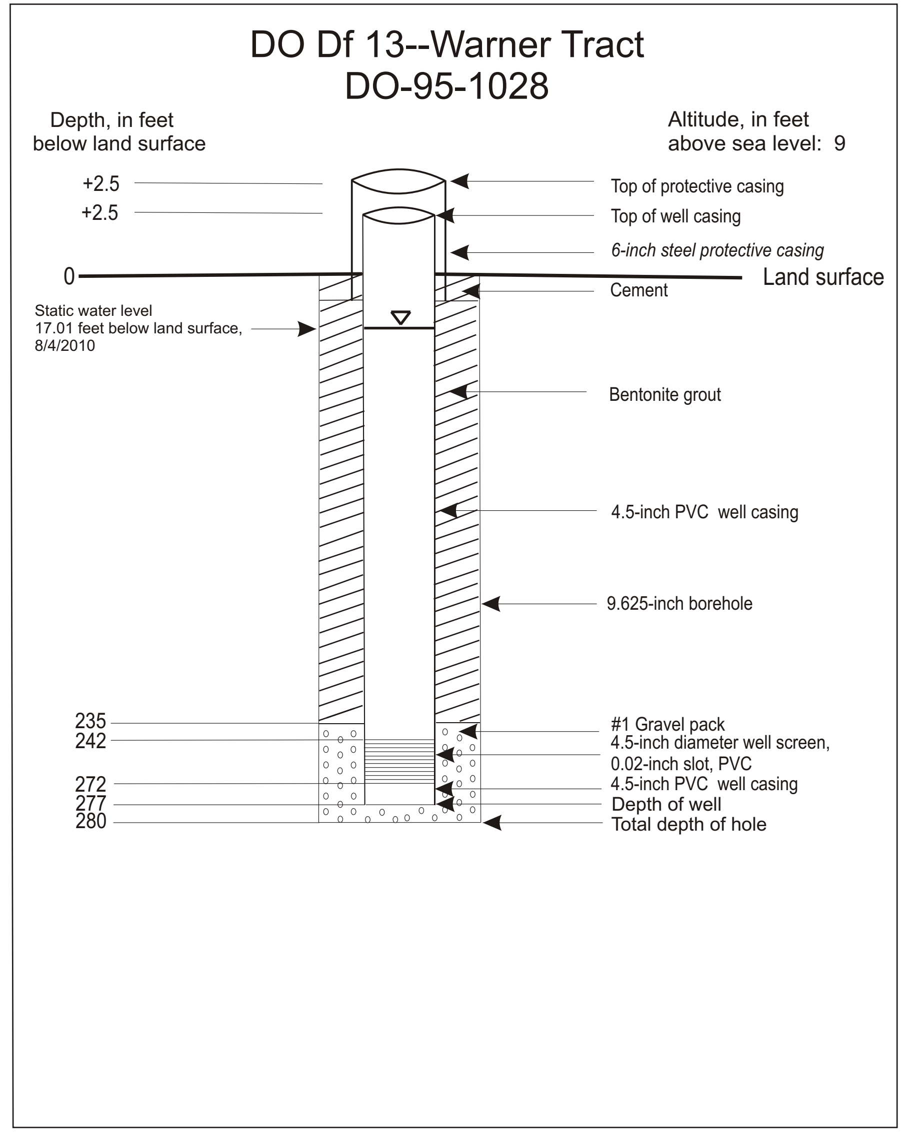


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**Figure 9. Diagrams showing construction features of wells DO Df 12 and DO Df 13.**

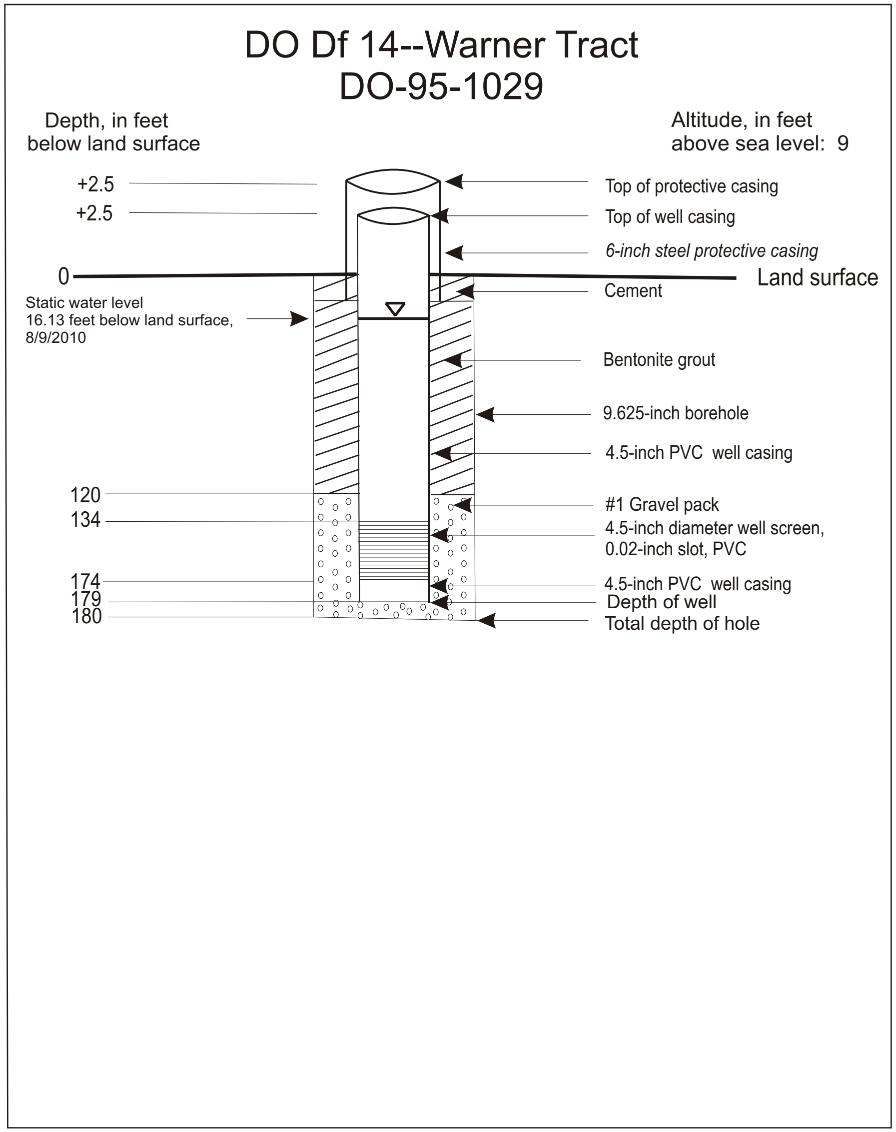


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**Figure 10. Diagram showing construction features of well DO Df 14.**

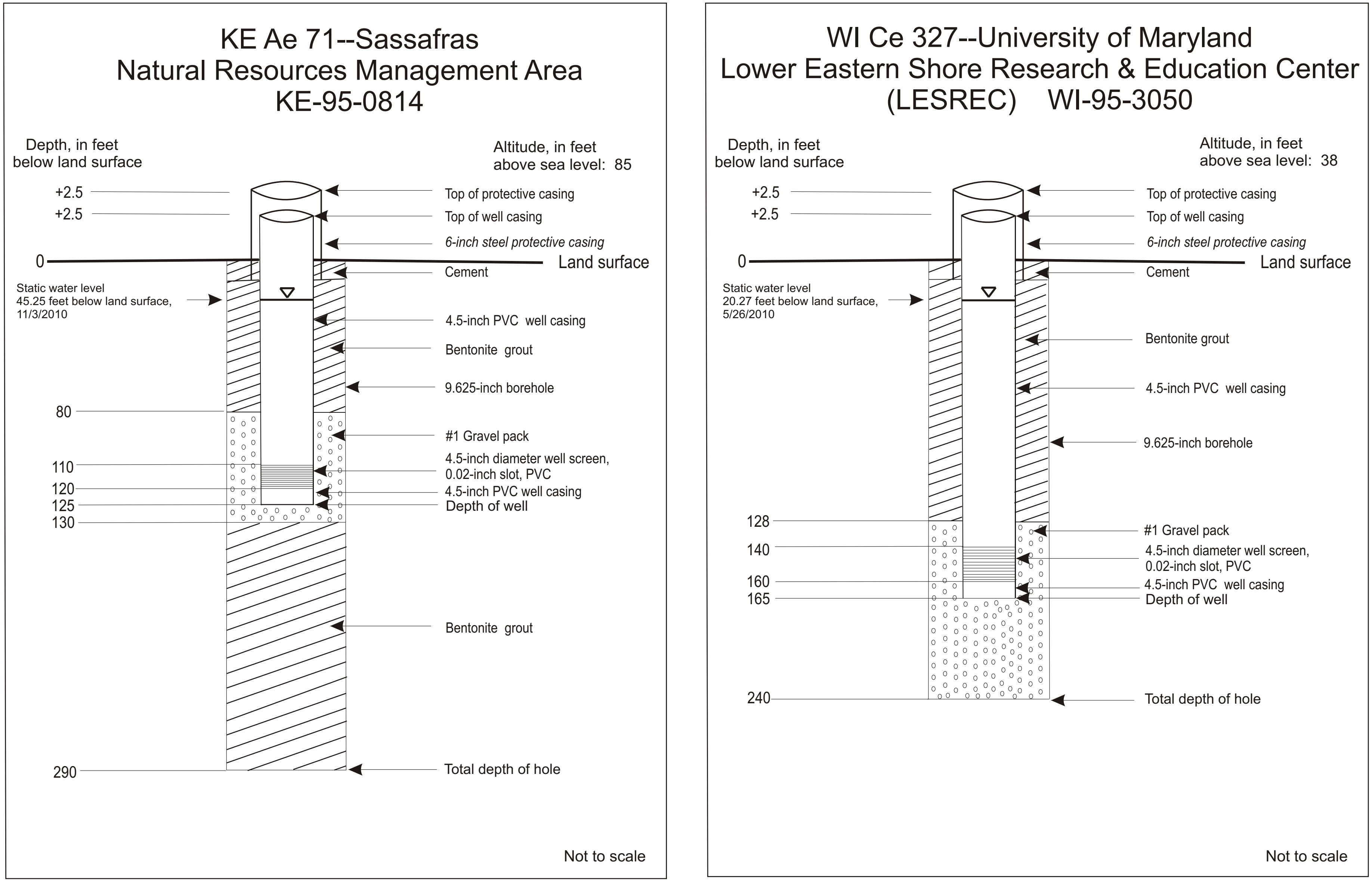
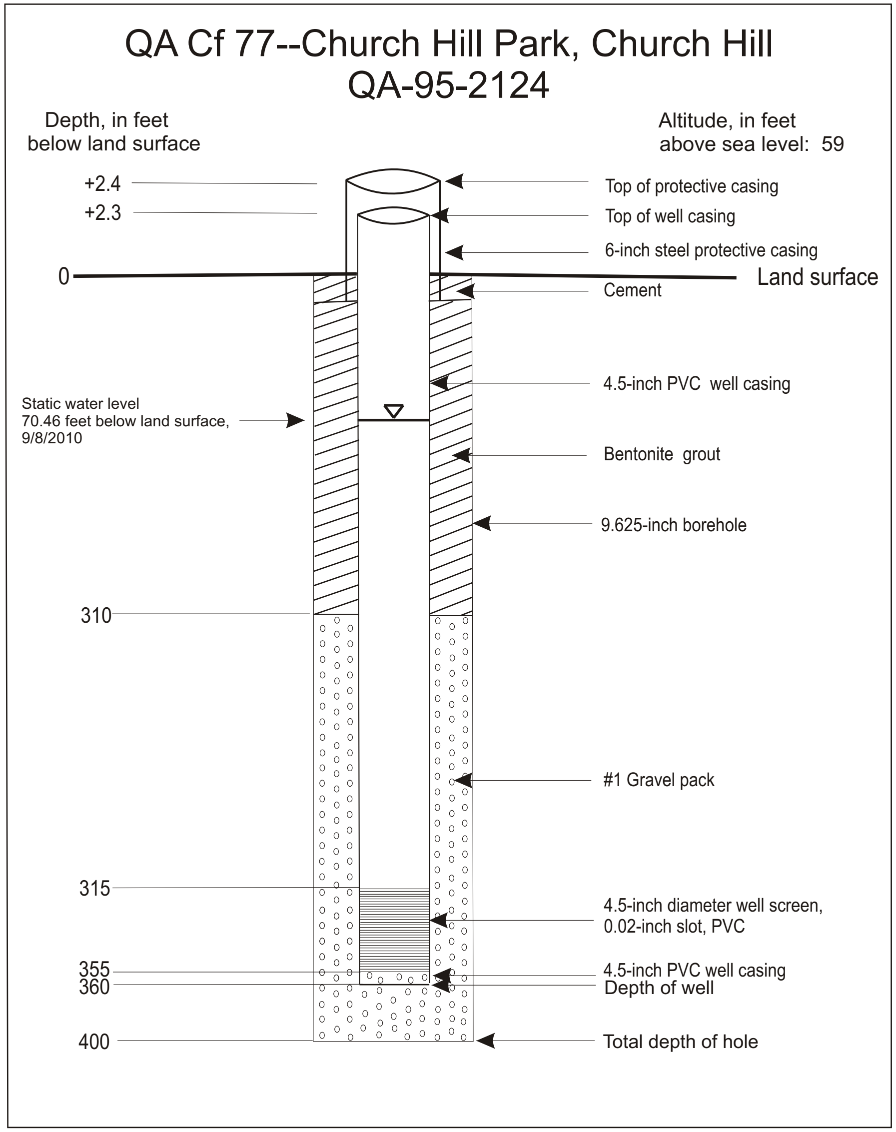



**Figure 11. Diagrams showing construction features of wells KE Ae 71 and WI Ce 327.**



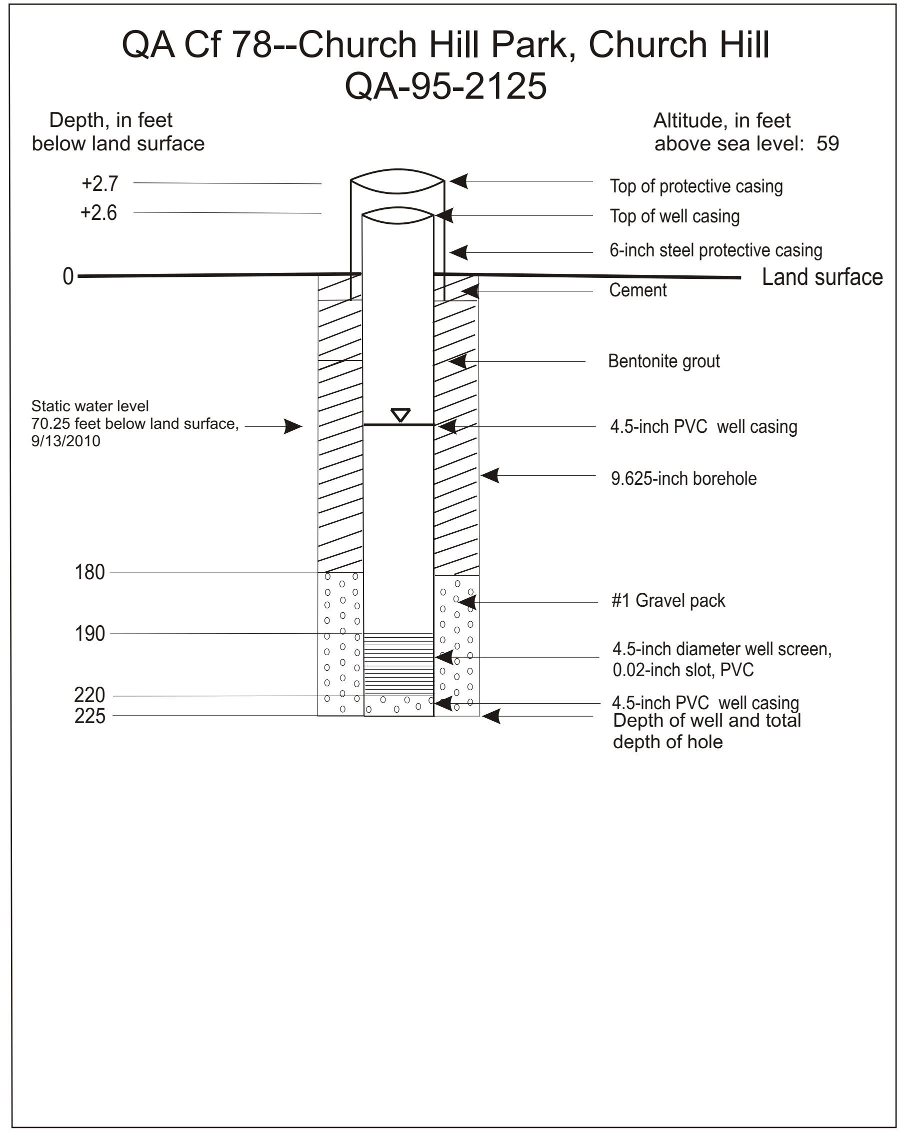
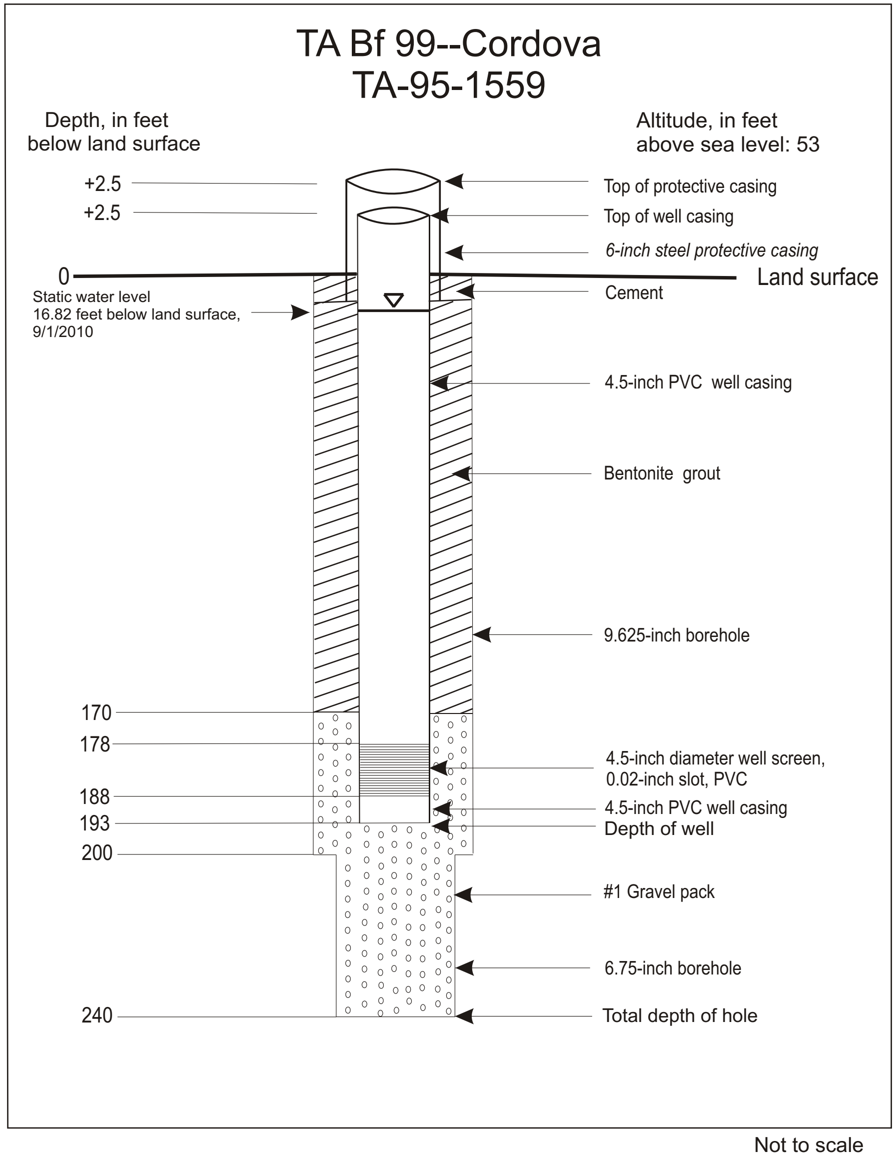




**Figure 12. Diagrams showing construction features of wells QA Cf 77 and QA Cf 78.**



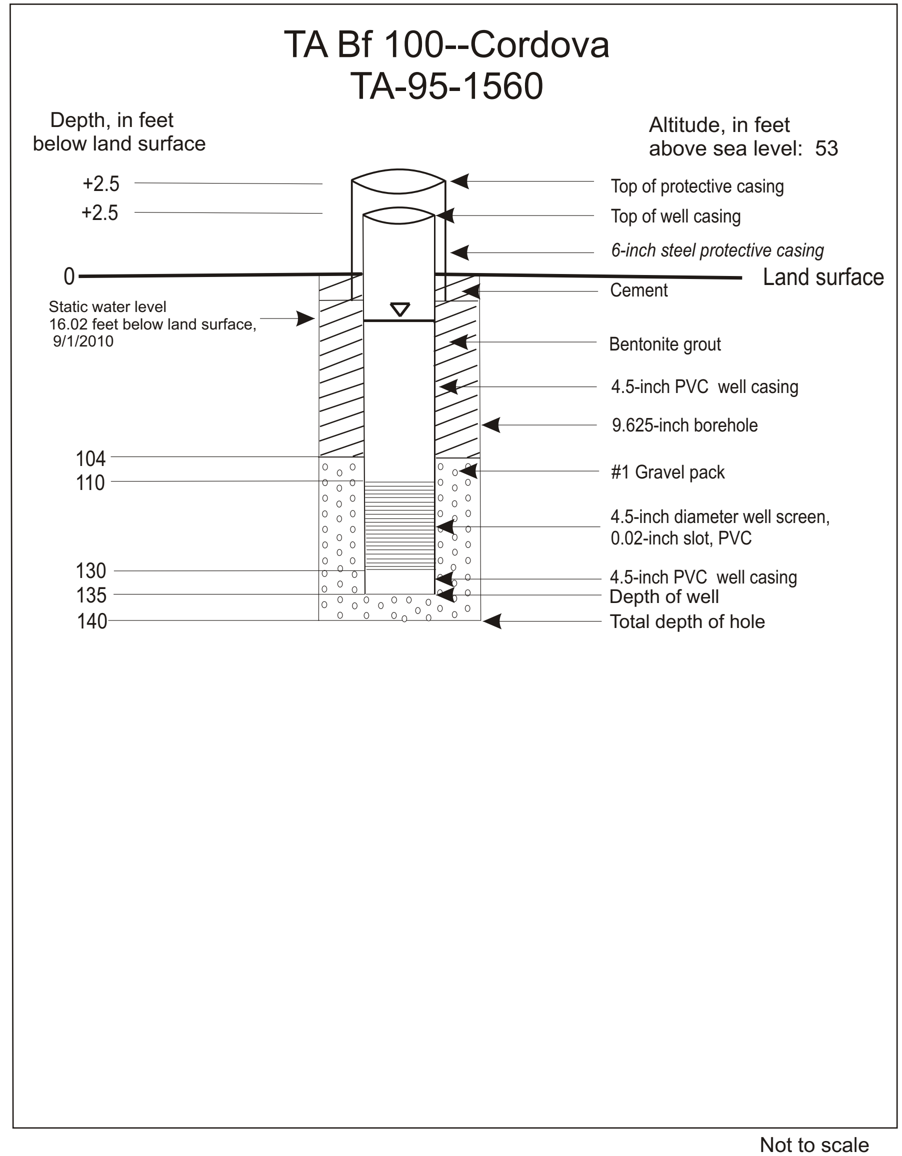




**Figure 13. Diagrams showing construction features of wells TA Bf 99 and TA Bf 100.**

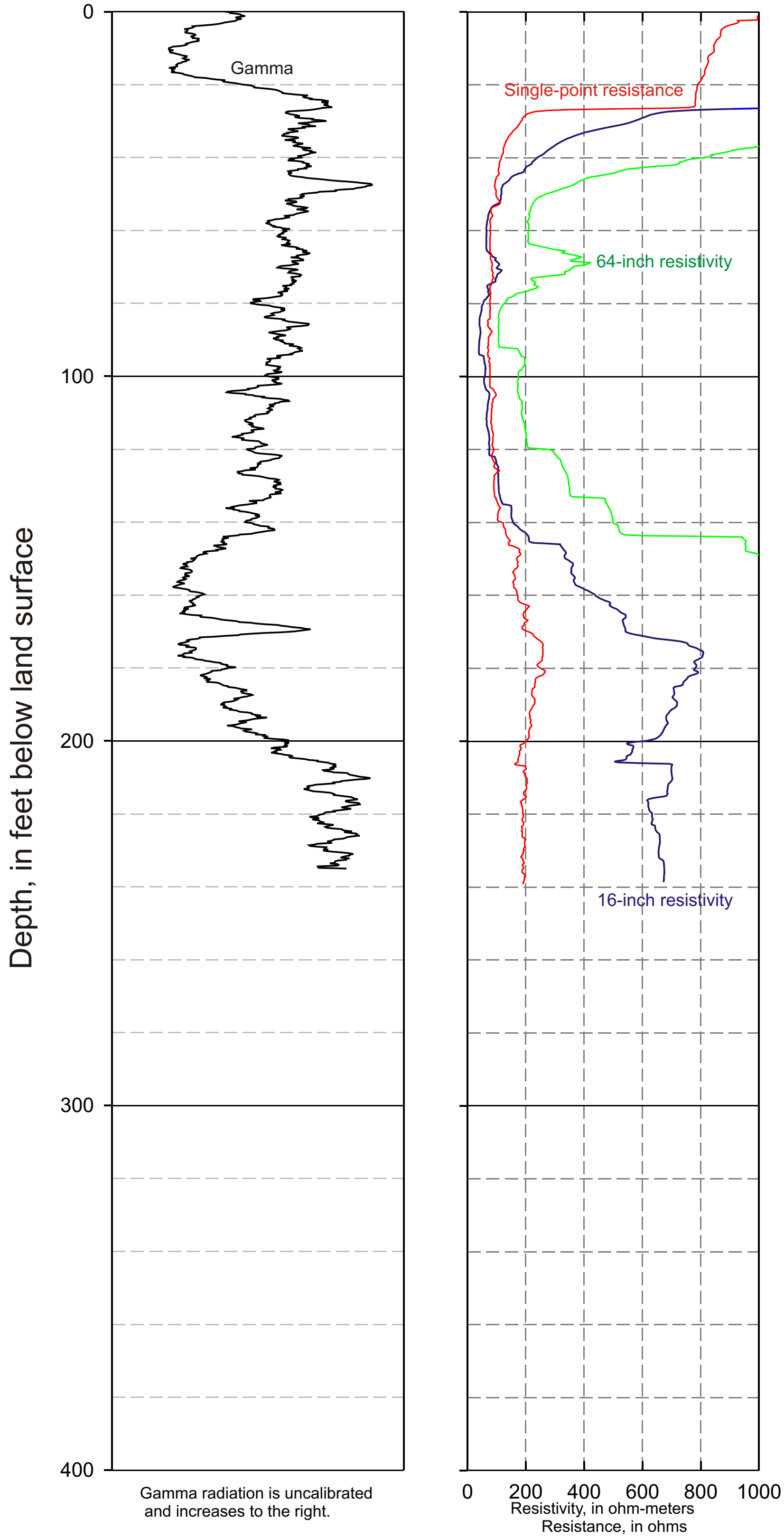



**Figure 14. Geophysical logs for test well CO Cd 66 at Greensboro.**

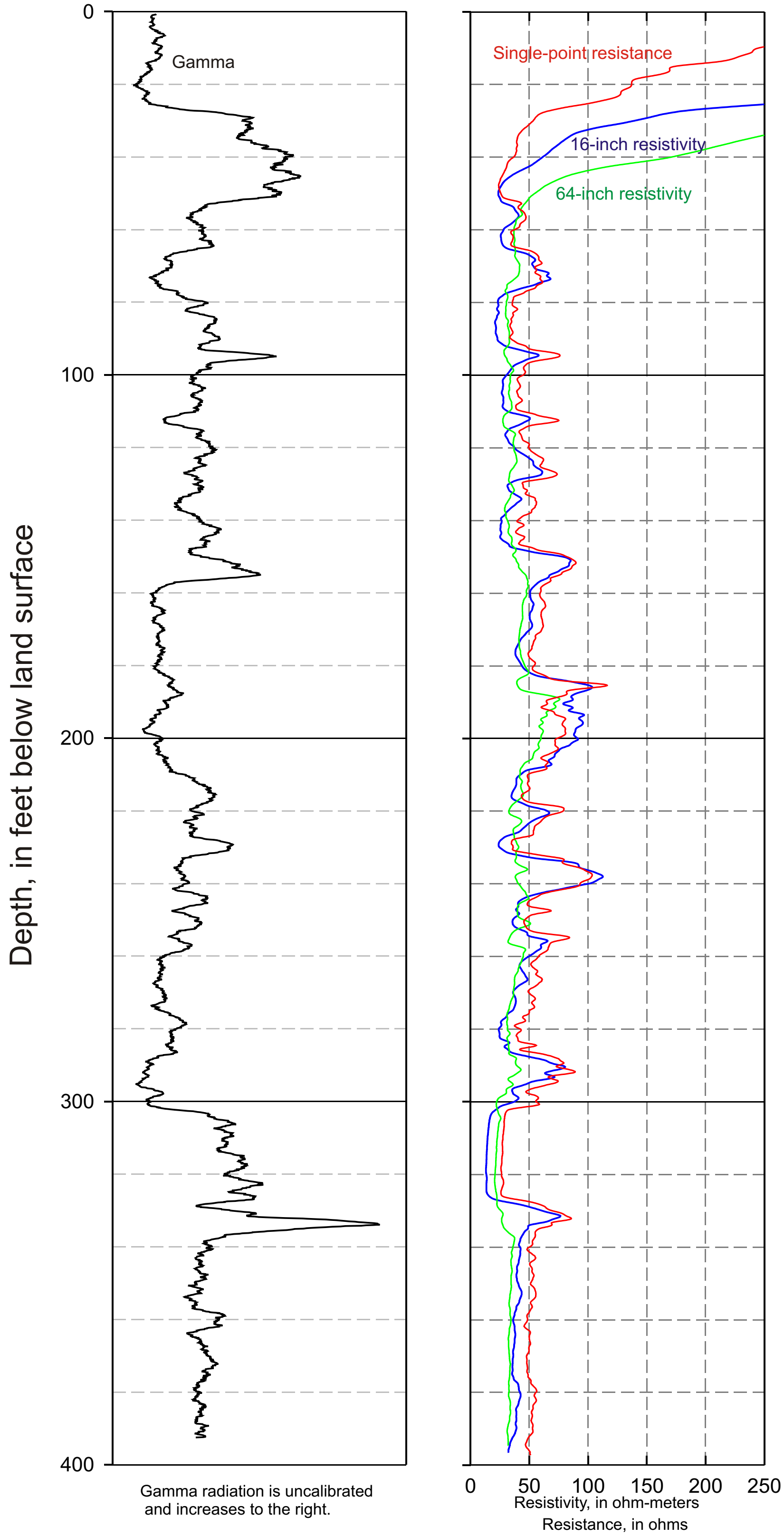



**Figure 15. Geophysical logs for test well CO Dc 152 at Martinak.**

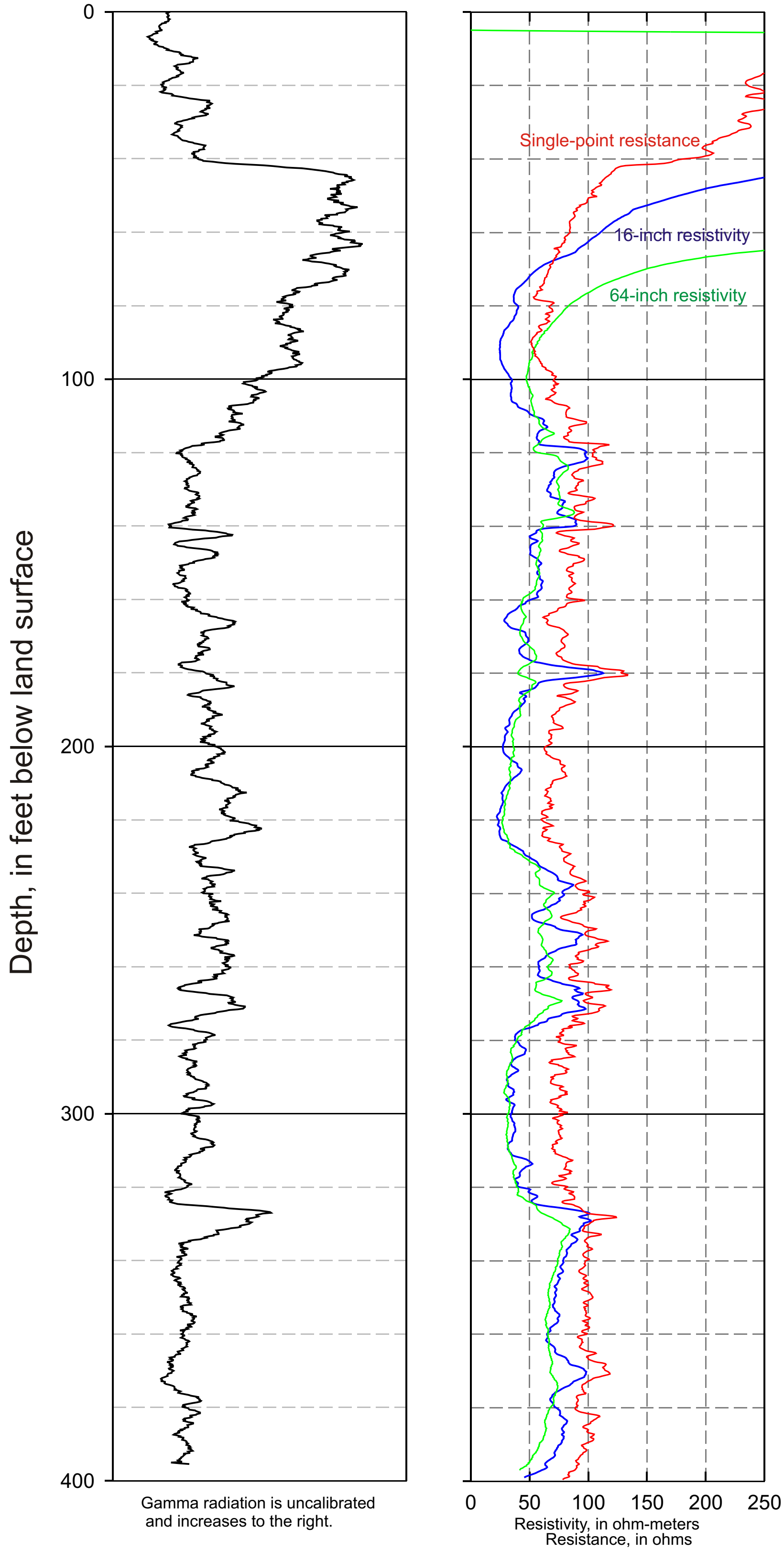



**Figure 16. Geophysical logs for test well CO Fd 41 at Idylwild.**

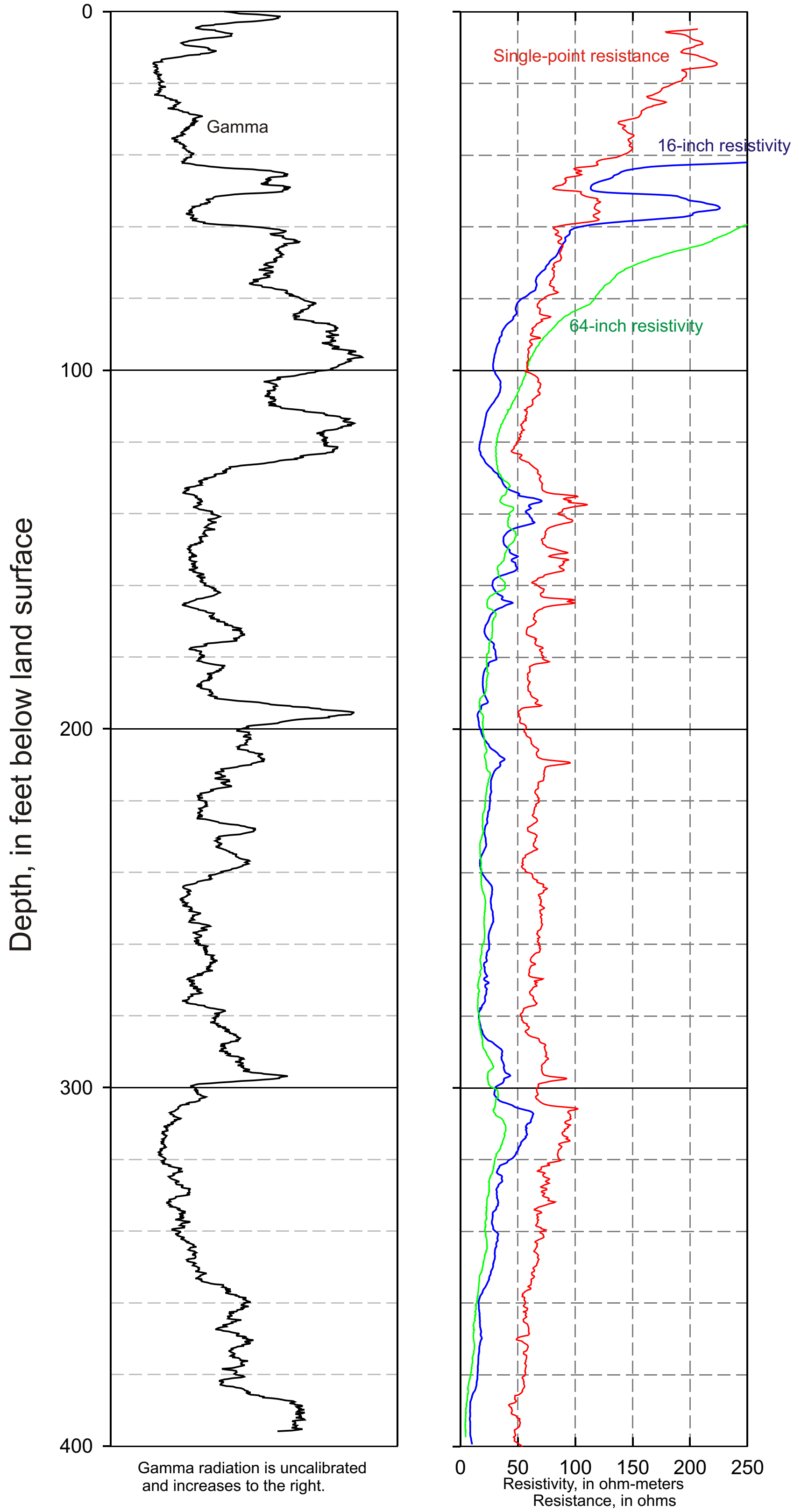



**Figure 17. Geophysical logs for test well DO Df 12 at Warner.**

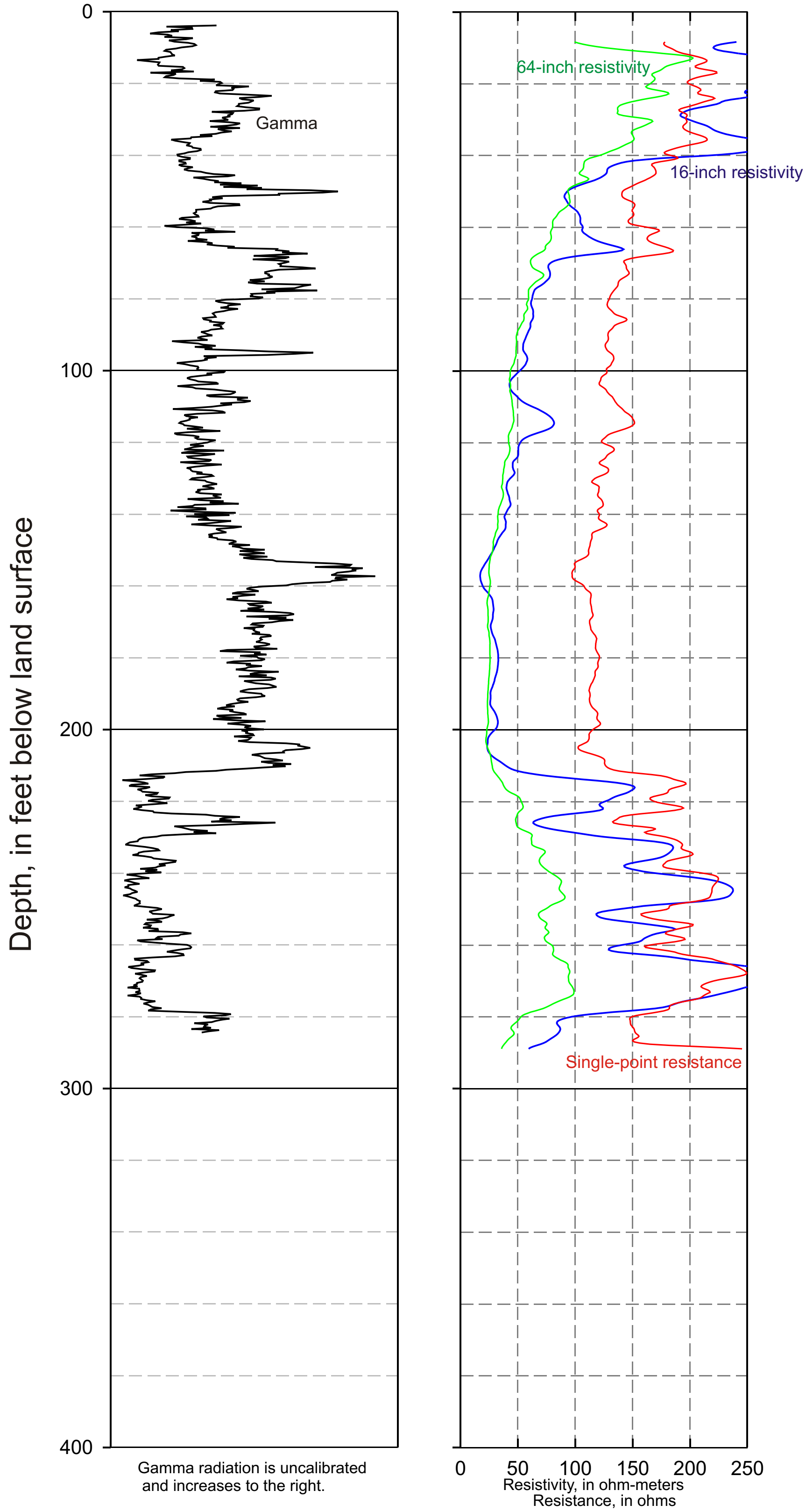



**Figure 18. Geophysical logs for test well KE Ae 71 at Sassafras.**

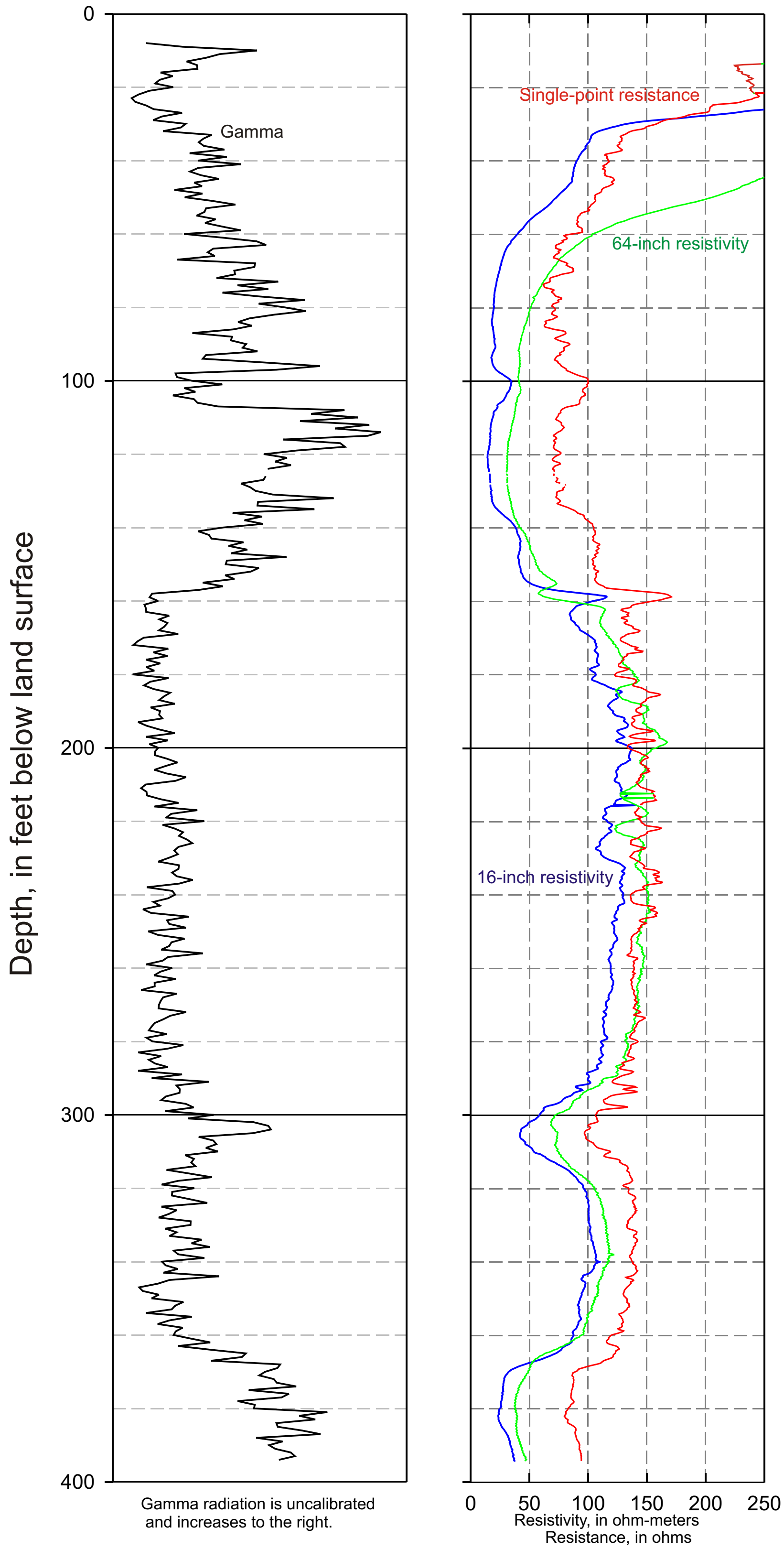



**Figure 19. Geophysical logs for test well QA Cf 77 at Church Hill.**

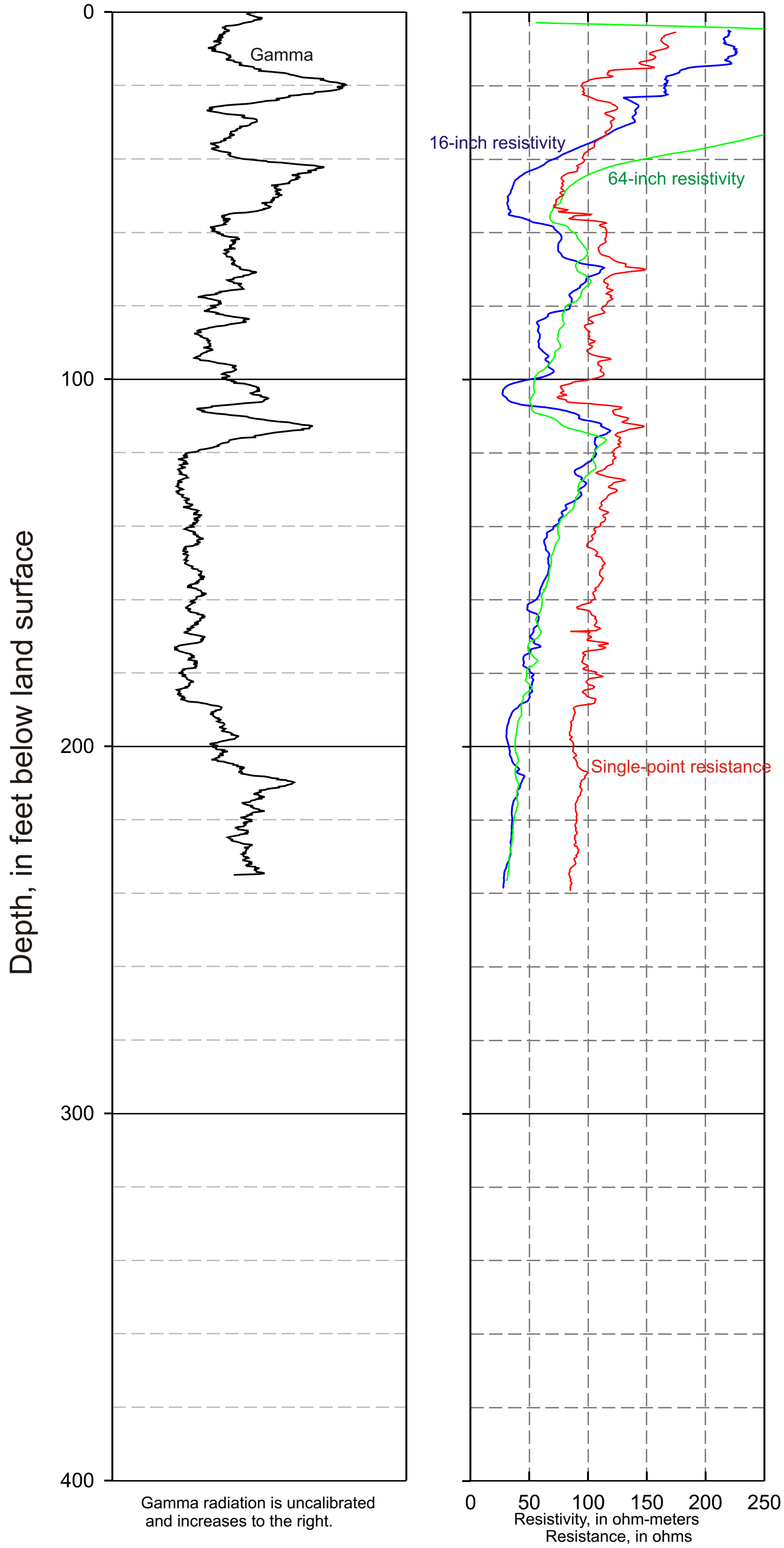



**Figure 20. Geophysical logs for test well TA Bf 99 at Cordova.**

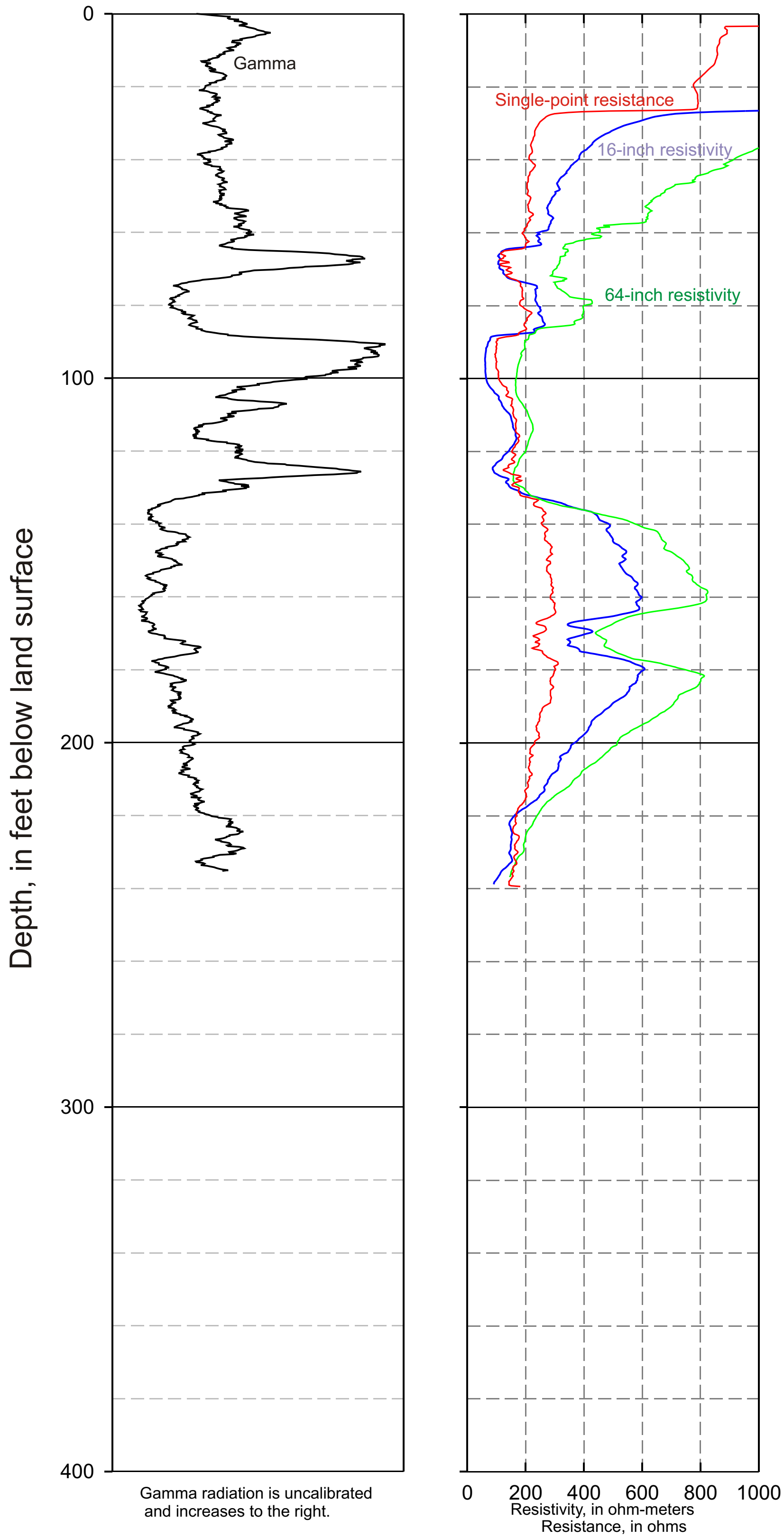
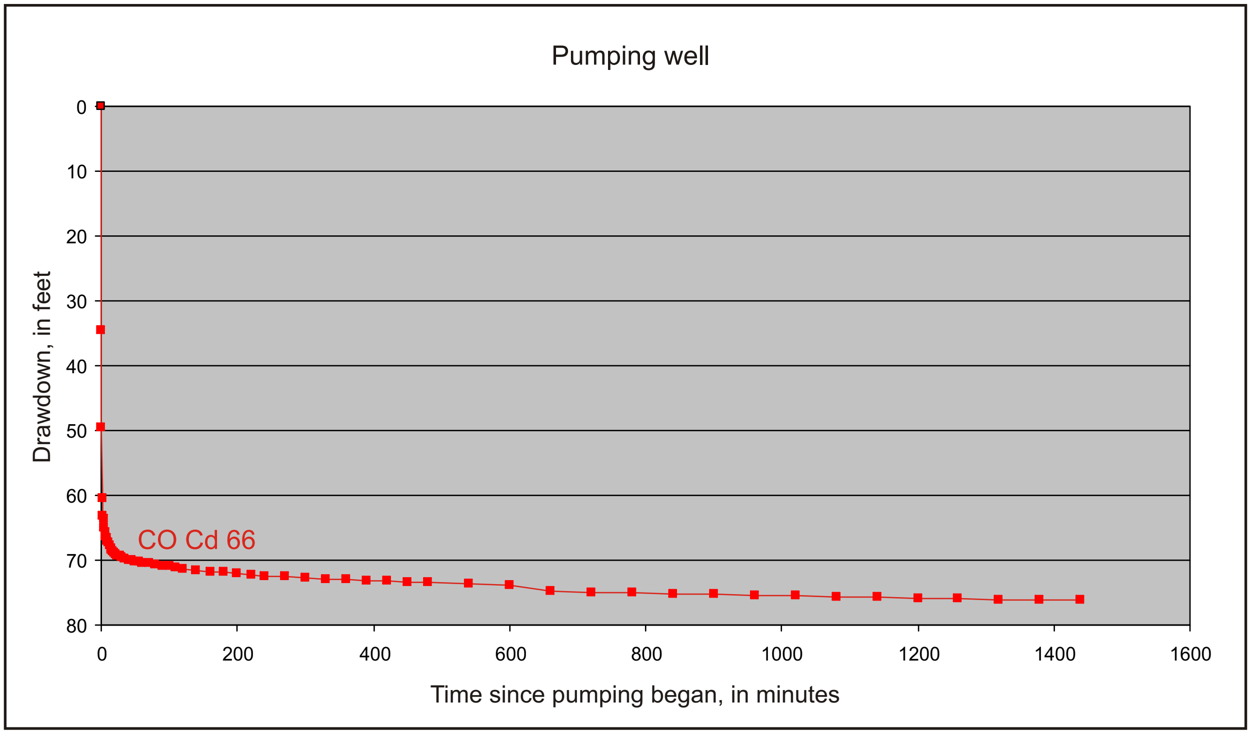



**Figure 21. Geophysical logs for test well WI Ce 327 at LESREC.**



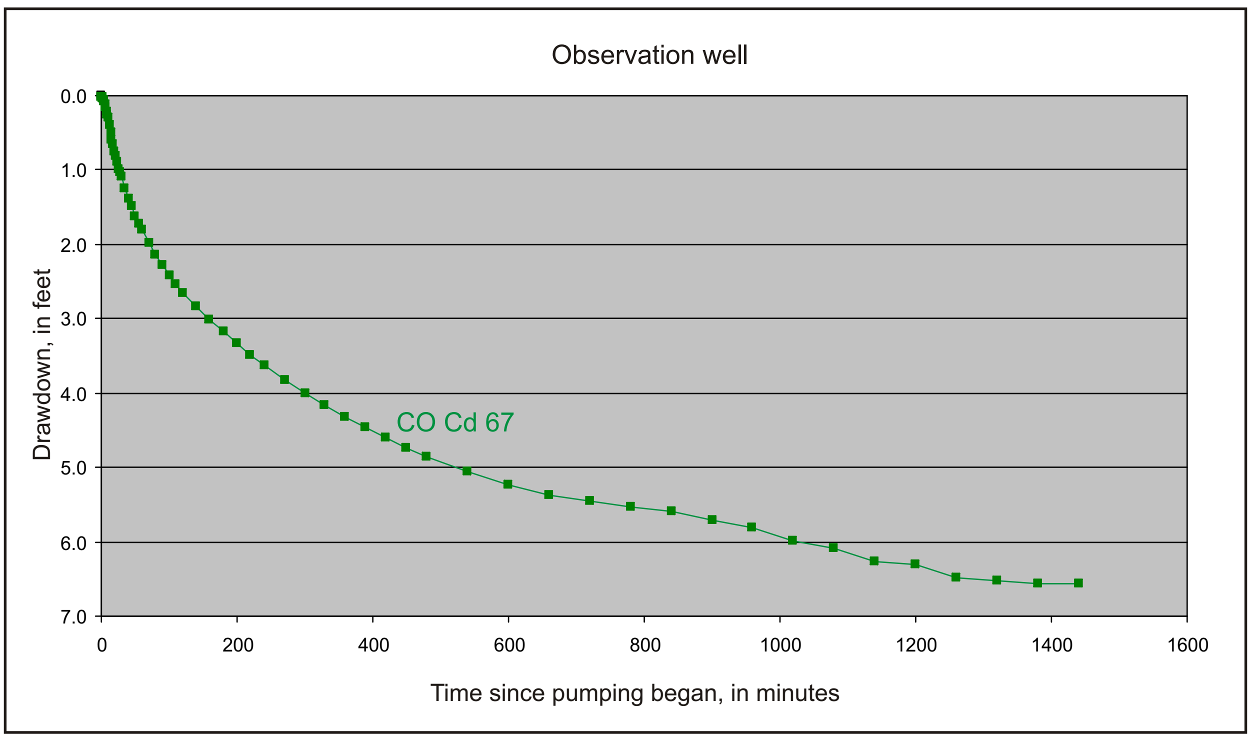
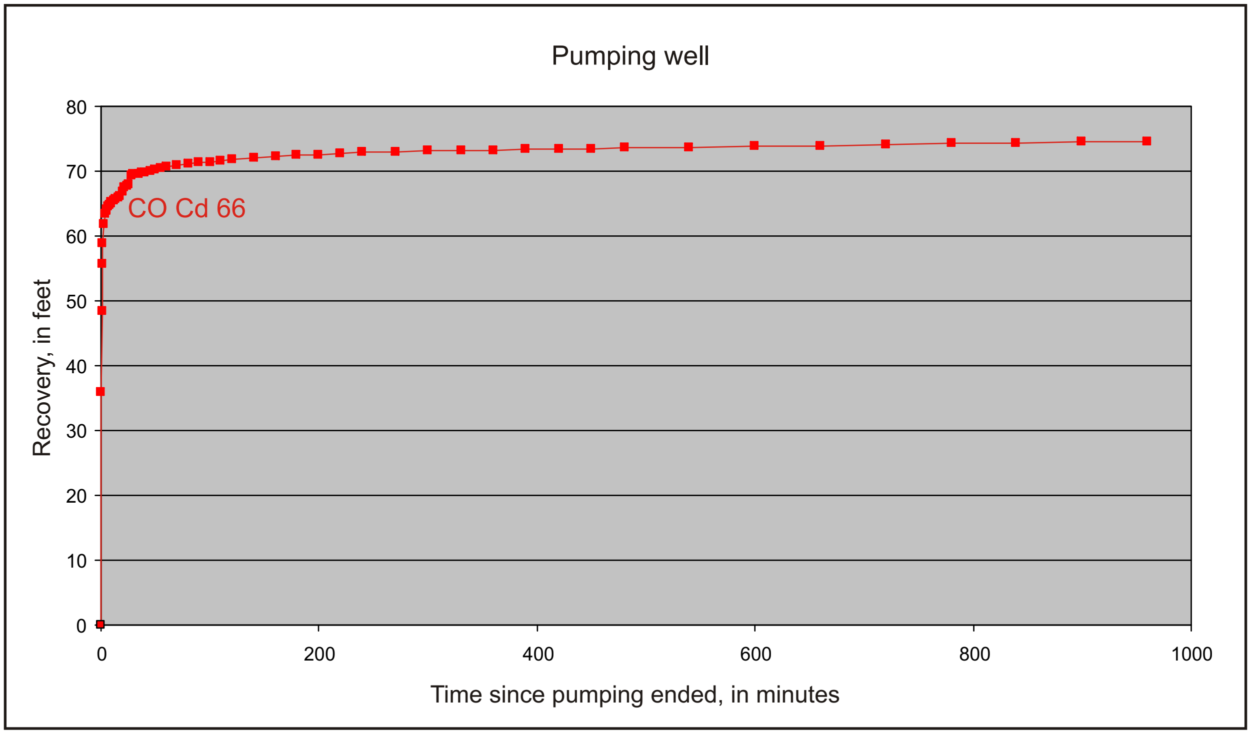




**Figure 22a. Aquifer test data for test well CO Cd 66 at Greensboro -- drawdown phase.**



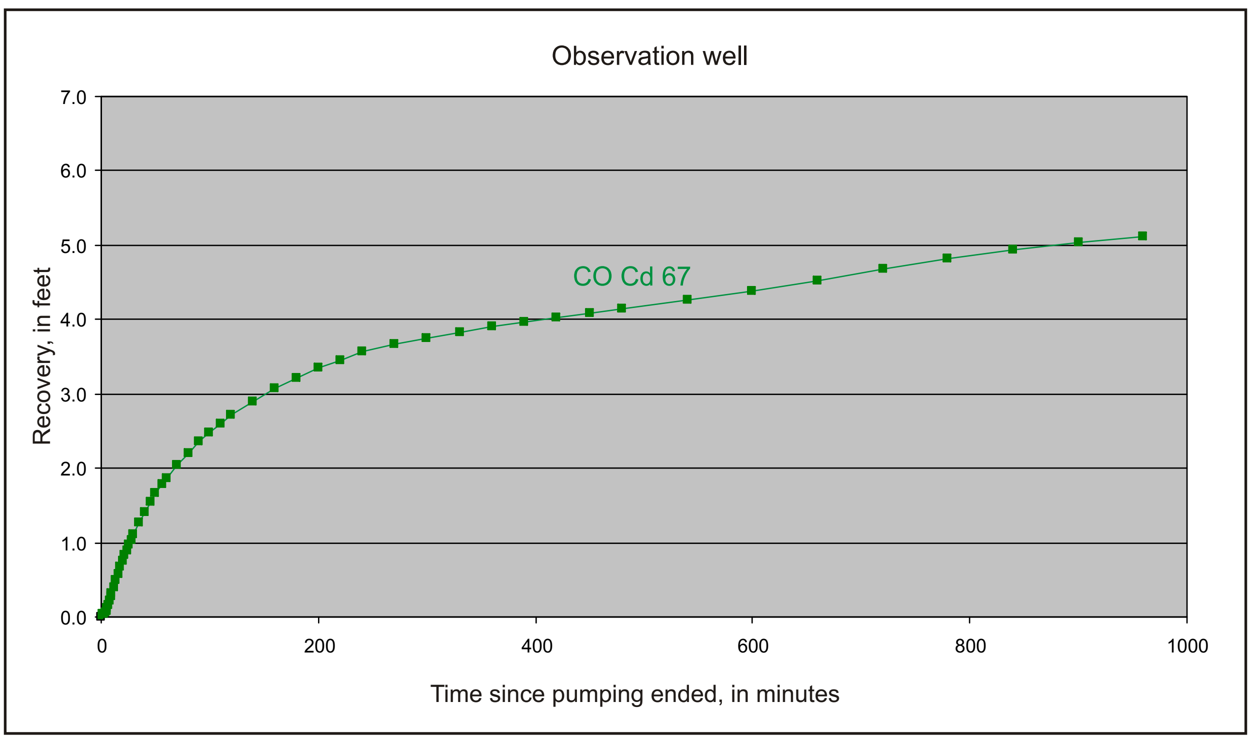
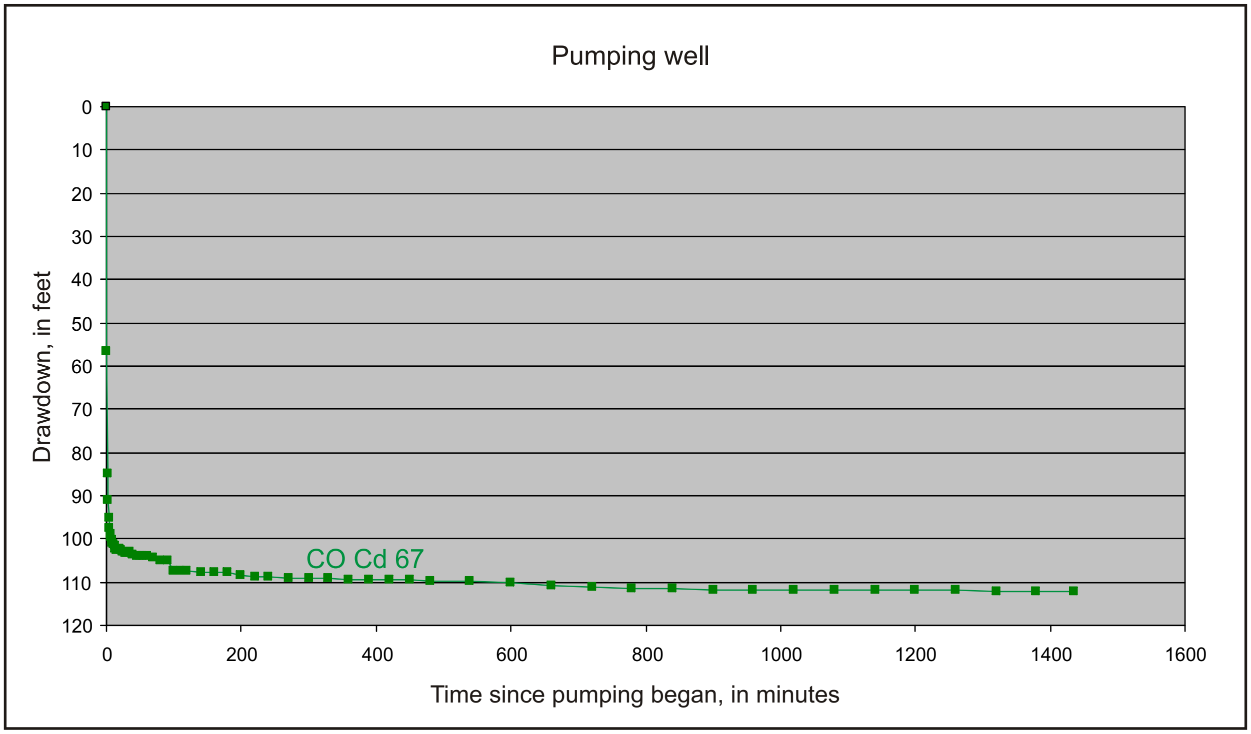




**Figure 22b. Aquifer test data for test well CO Cd 66 at Greensboro -- recovery phase.**



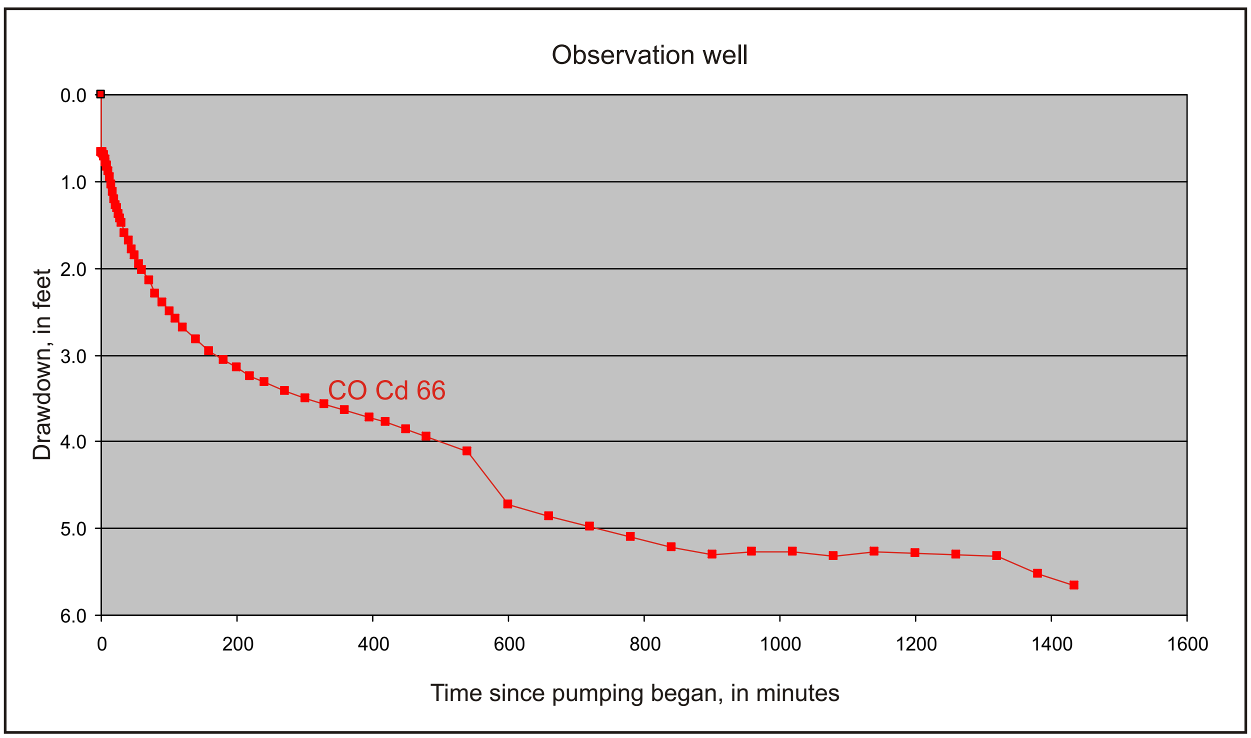
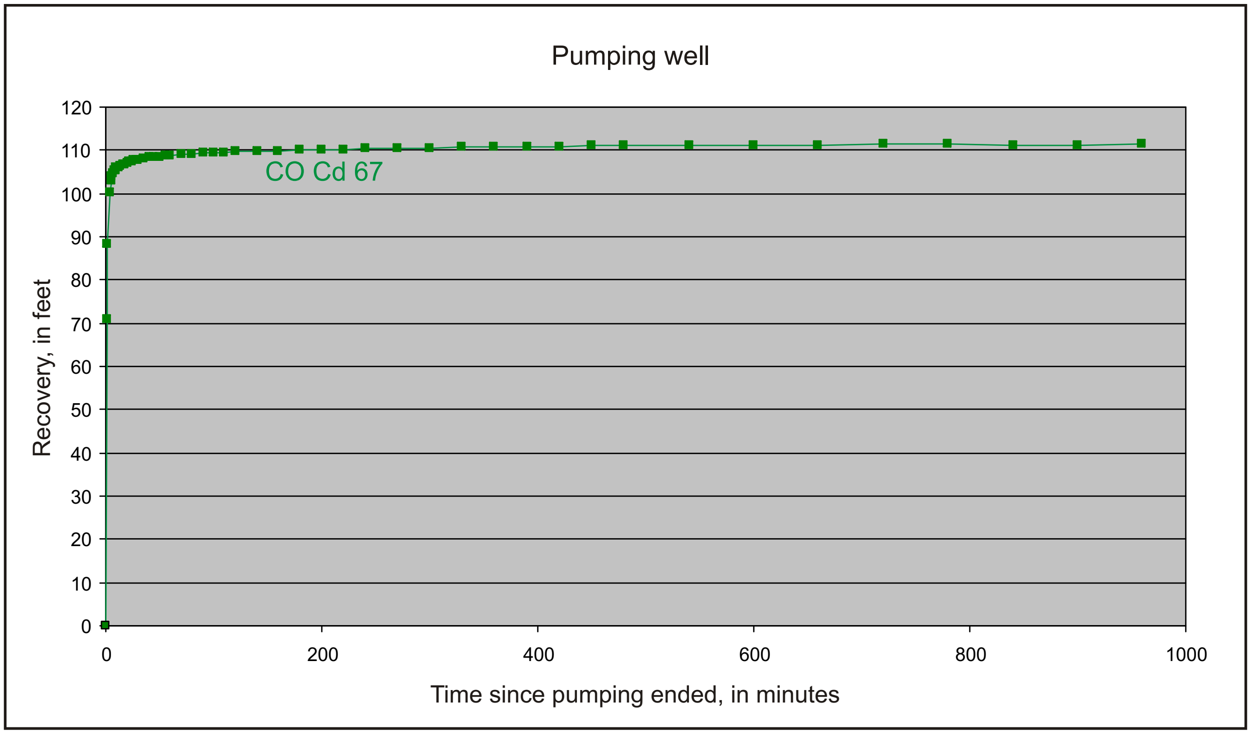




**Figure 23a. Aquifer test data for test well CO Cd 67 at Greensboro -- drawdown phase.**



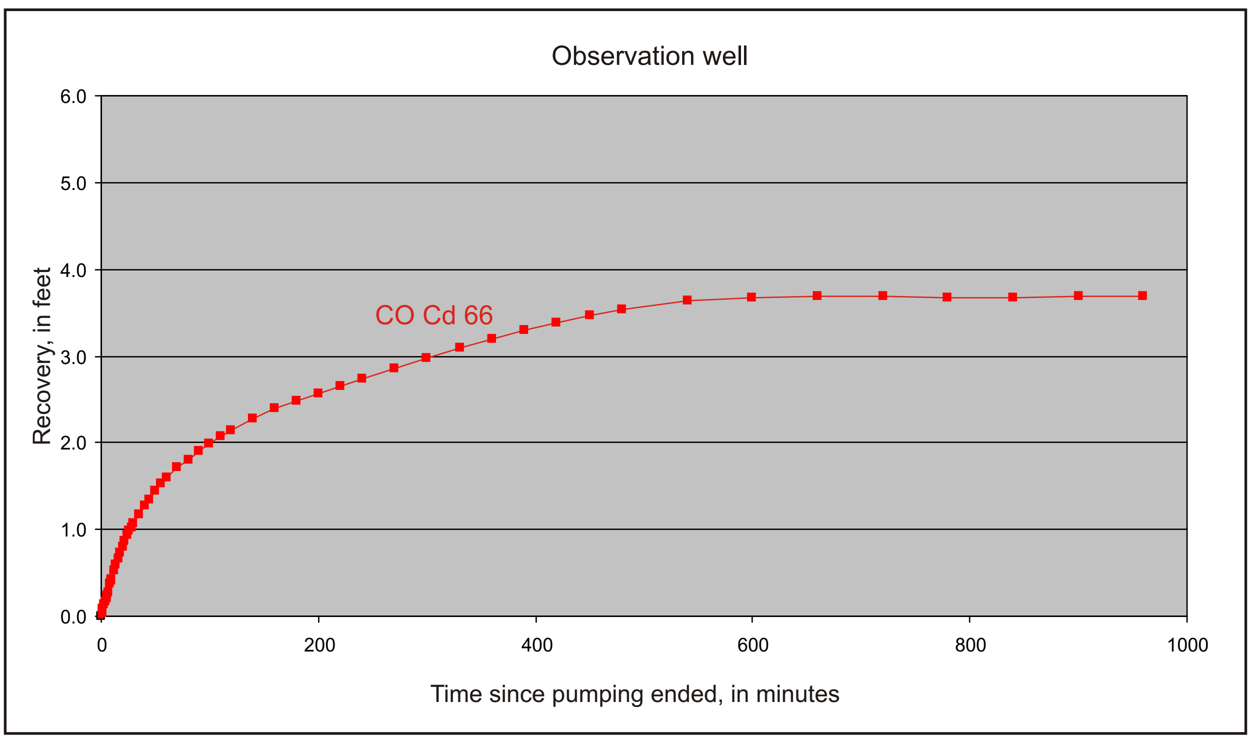
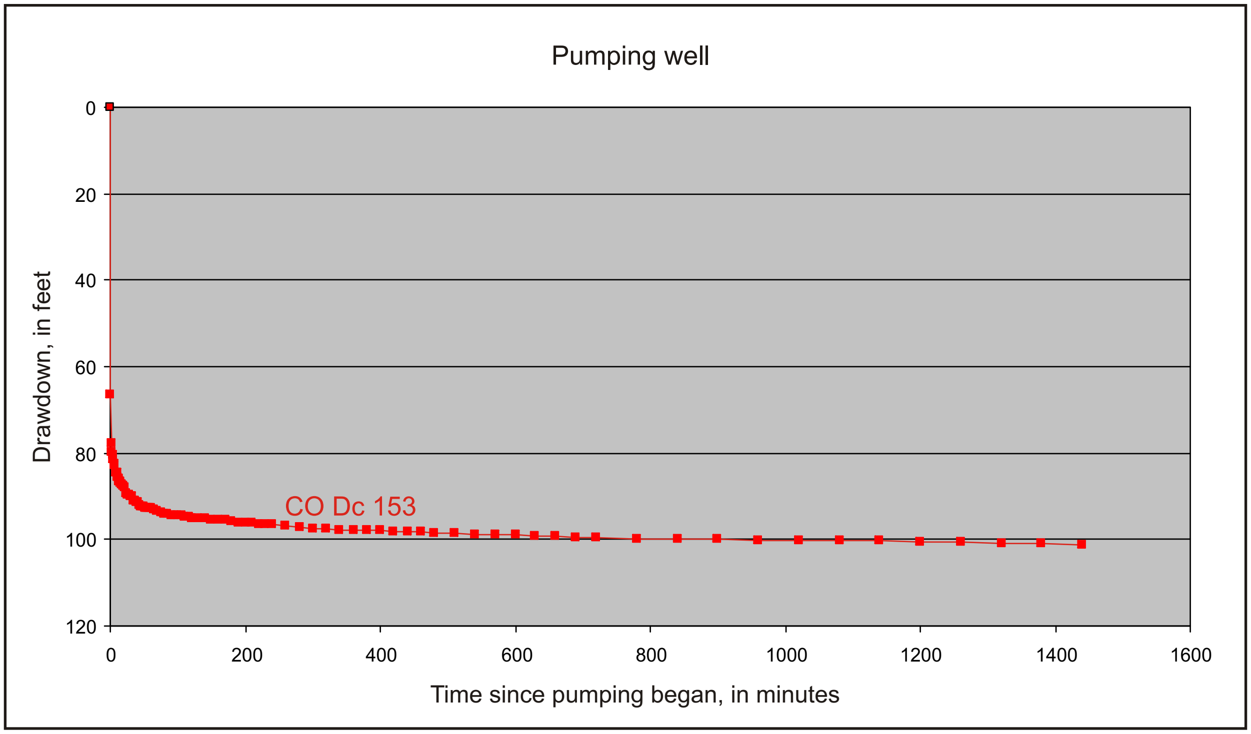




**Figure 23b. Aquifer test data for test well CO Cd 67 at Greensboro -- recovery phase.**



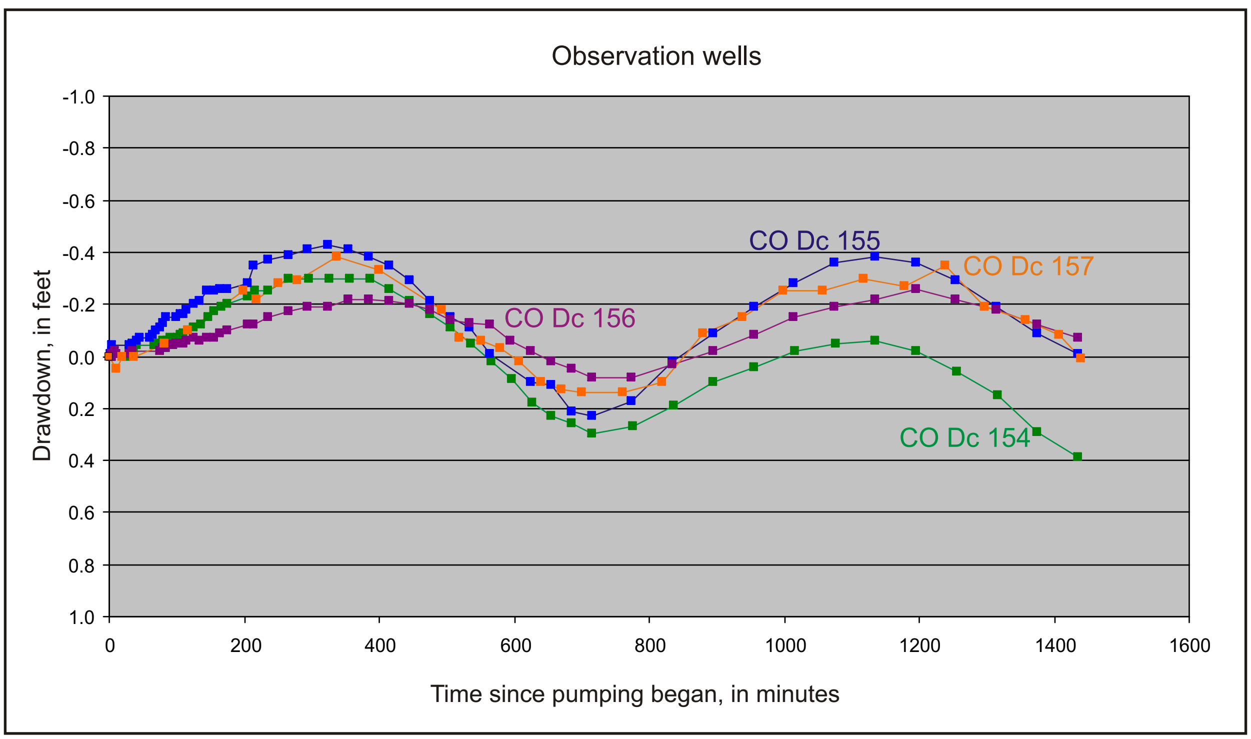
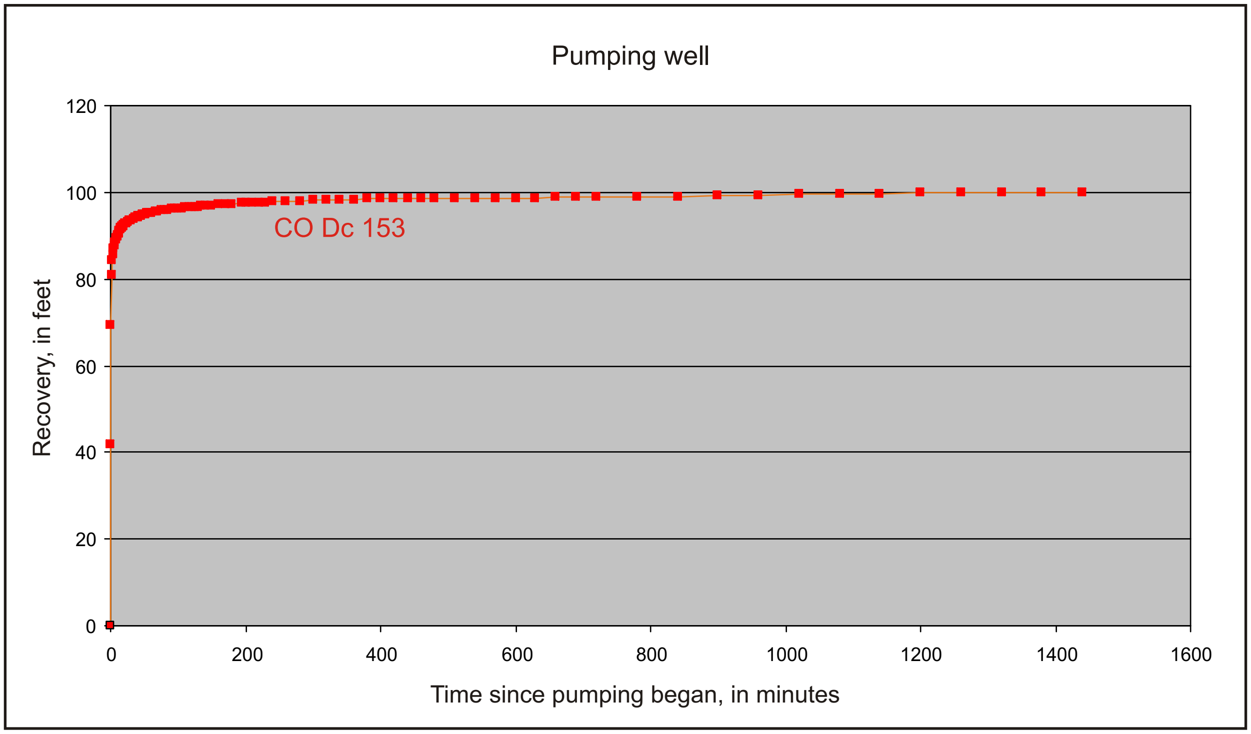




**Figure 24a. Aquifer test data for test well CO Dc 153 at Martinak -- drawdown phase.**



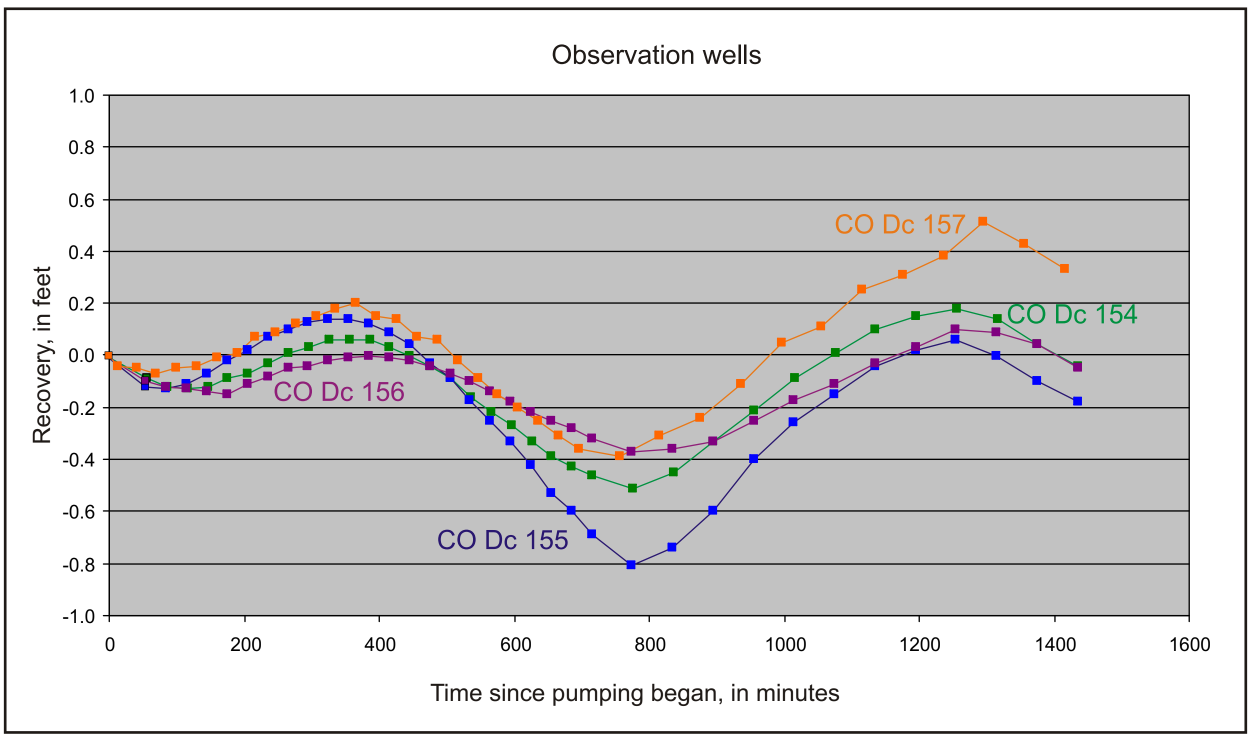
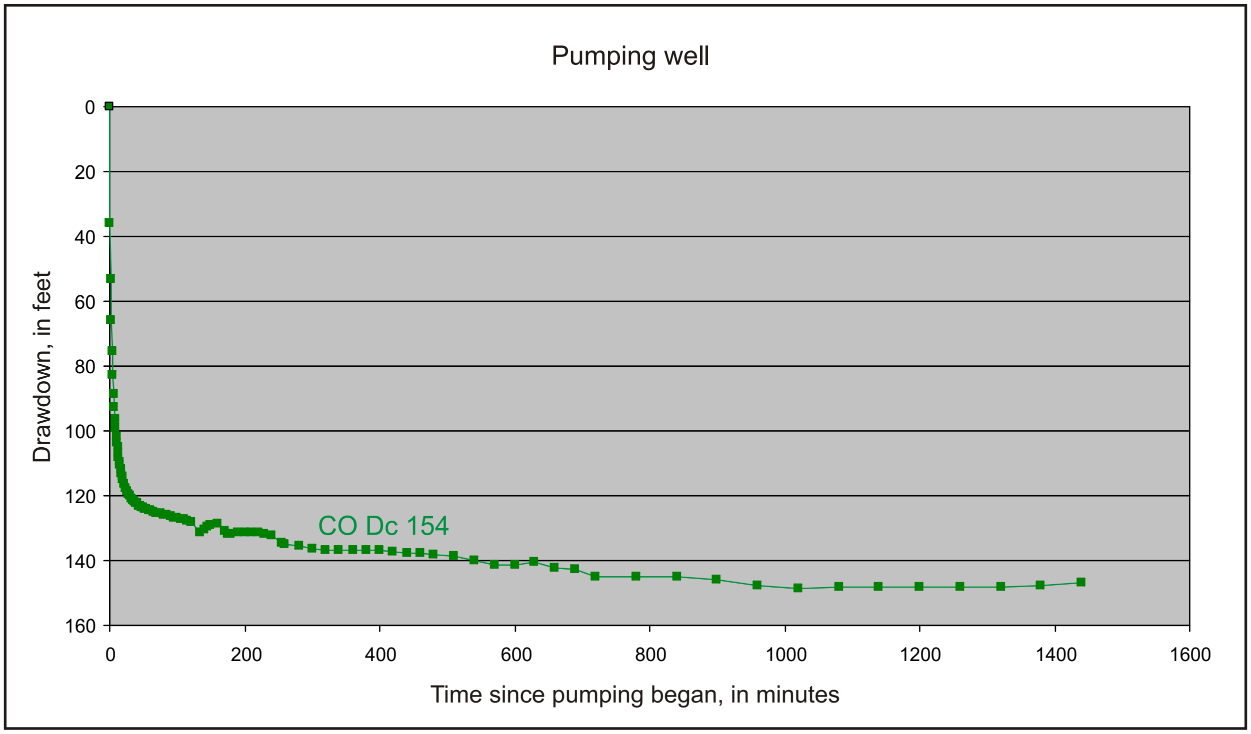




**Figure 24b. Aquifer test data for test well CO Dc 153 at Martinak -- recovery phase.**



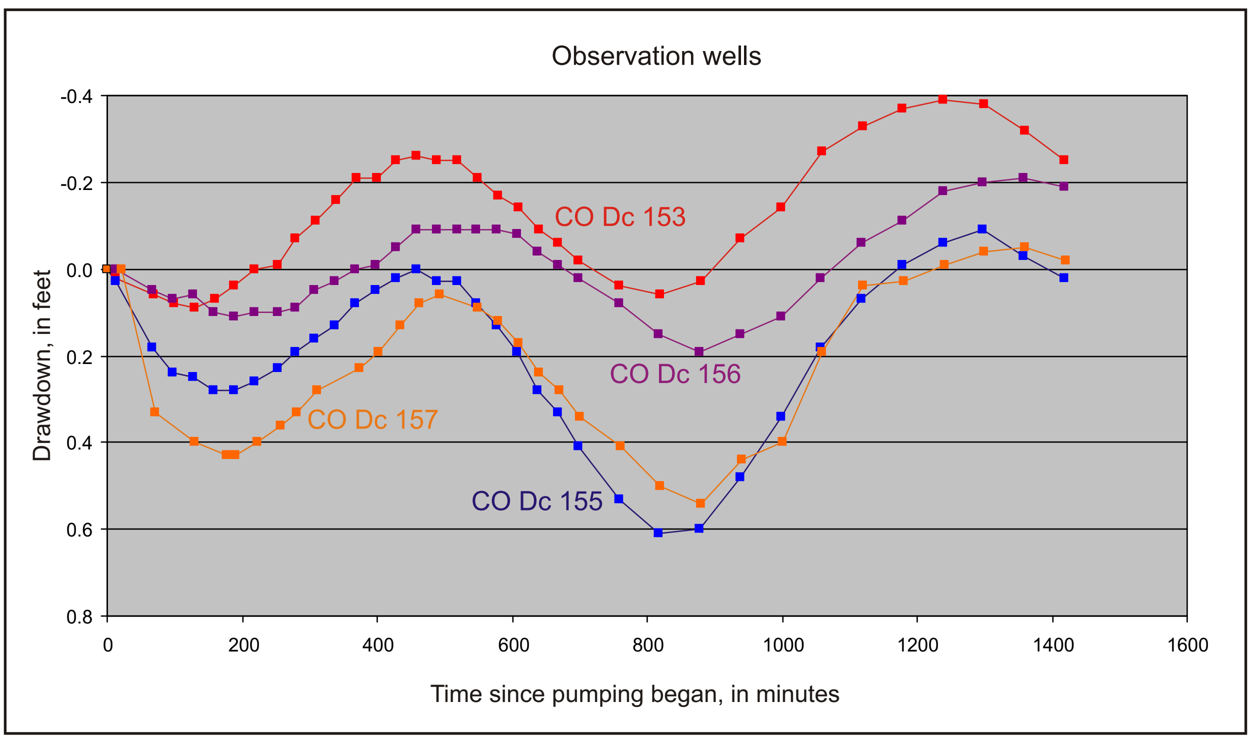
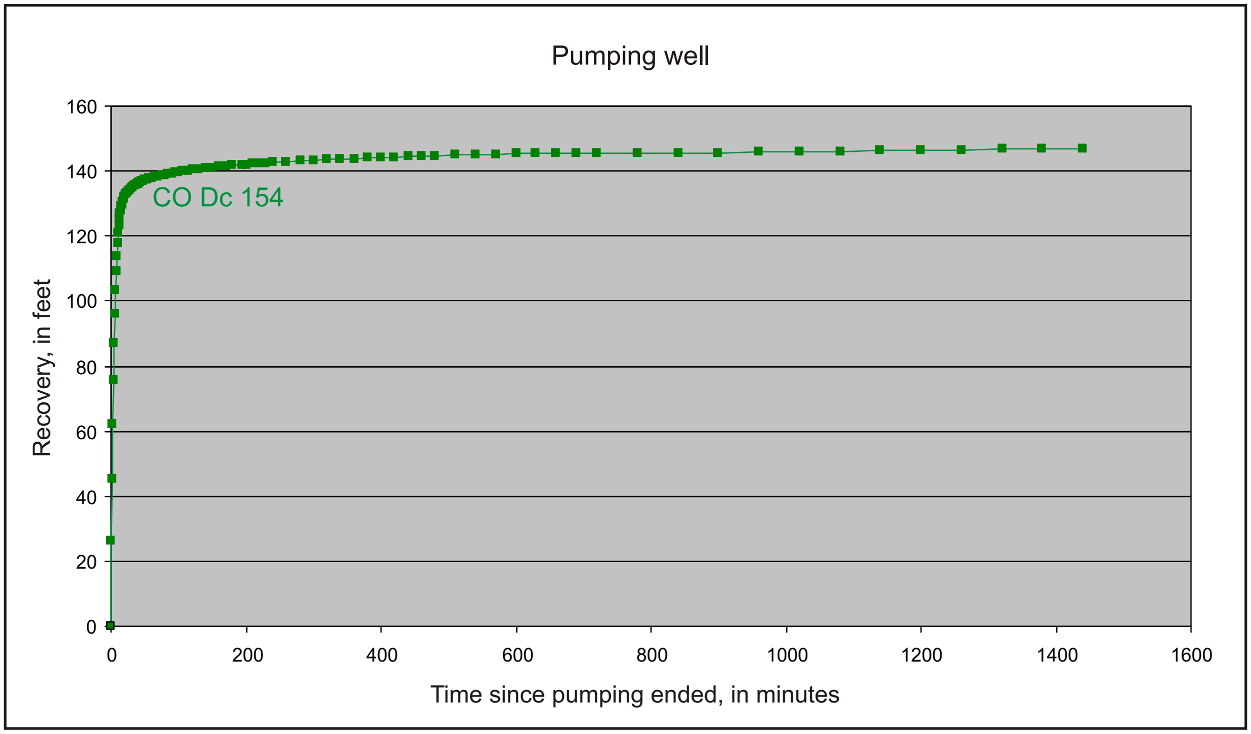




**Figure 25a. Aquifer test data for test well CO Dc 154 at Martinak -- drawdown phase.**



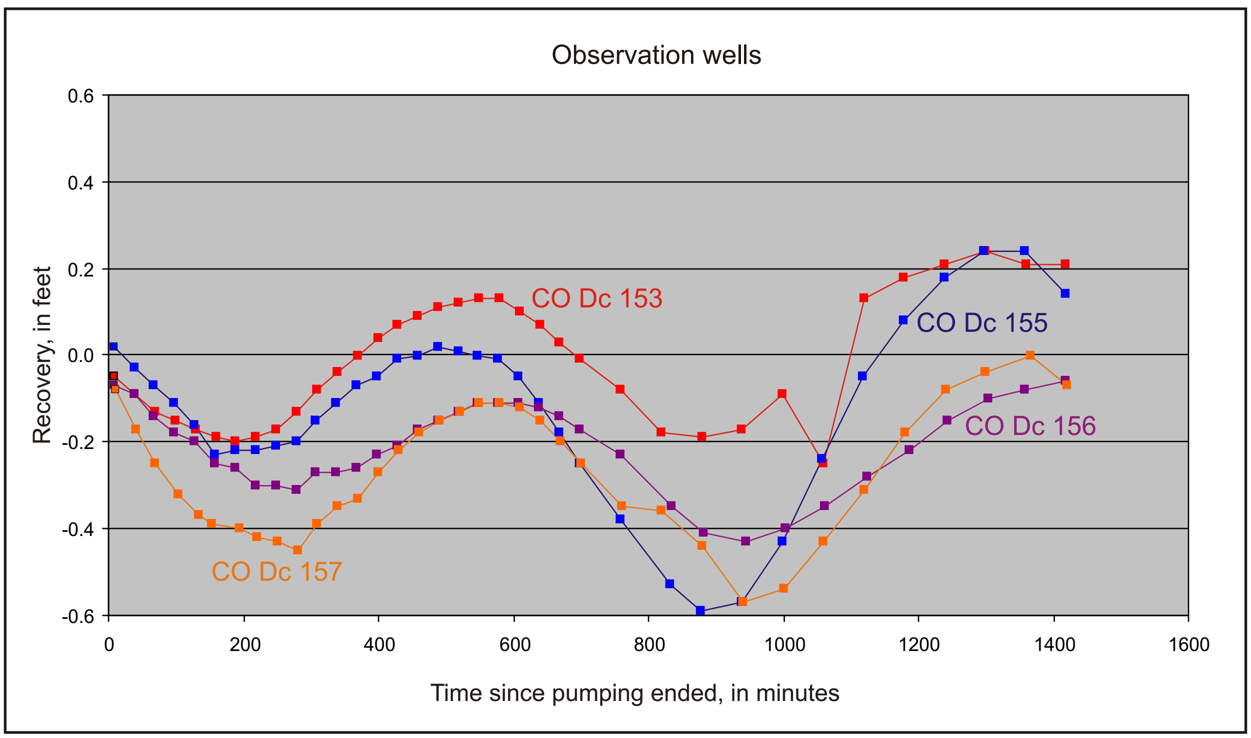
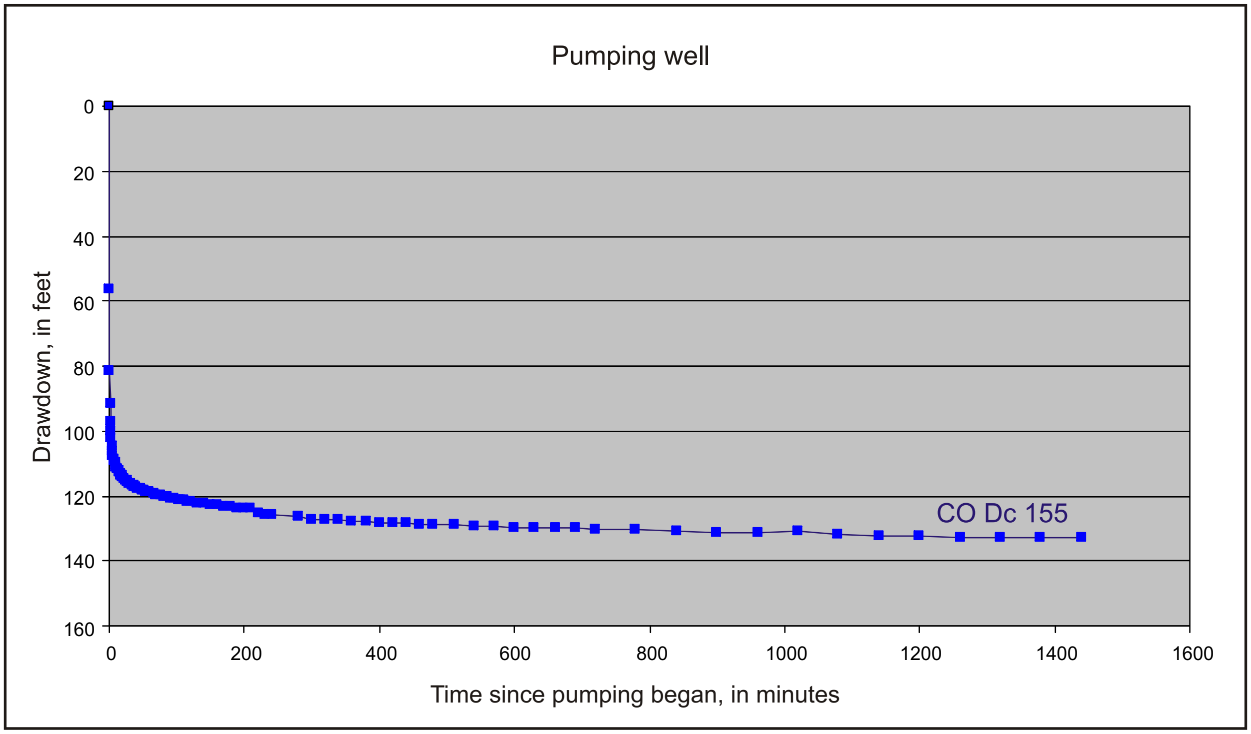




**Figure 25b. Aquifer test data for test well CO Dc 154 at Martinak -- recovery phase.**



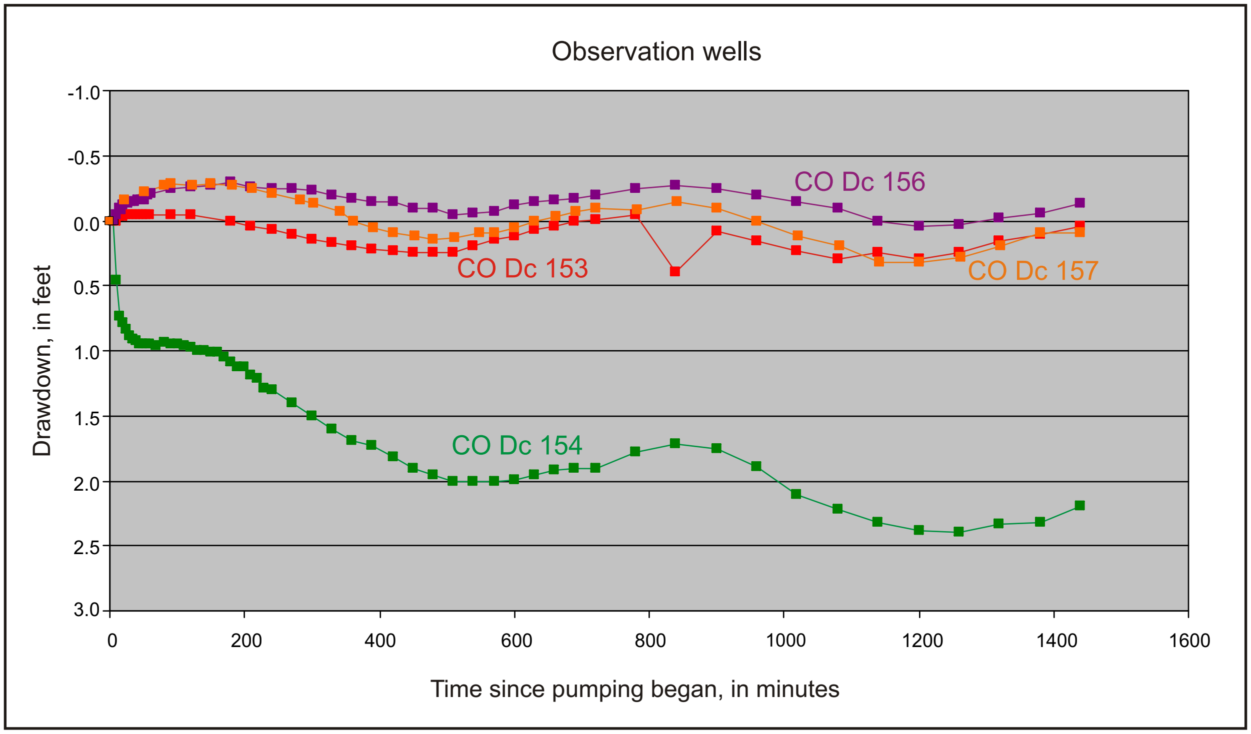
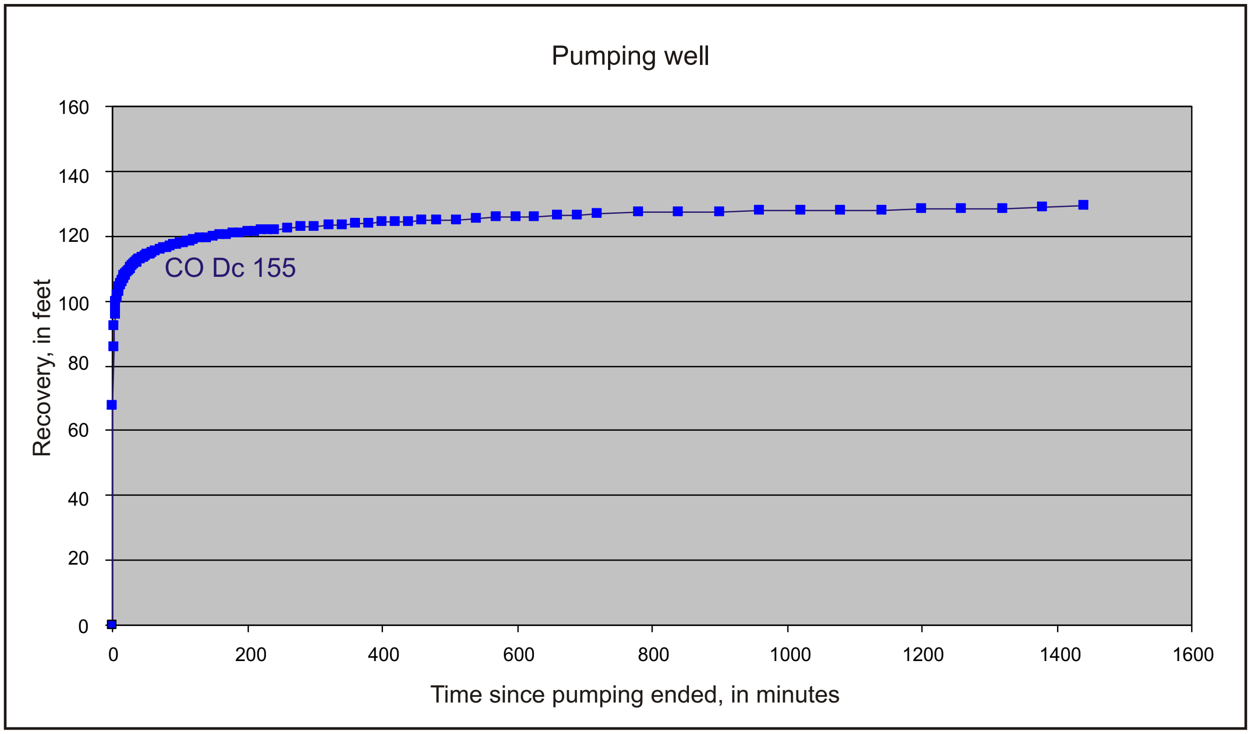




**Figure 26a. Aquifer test data for test well CO Dc 155 at Martinak -- drawdown phase.**



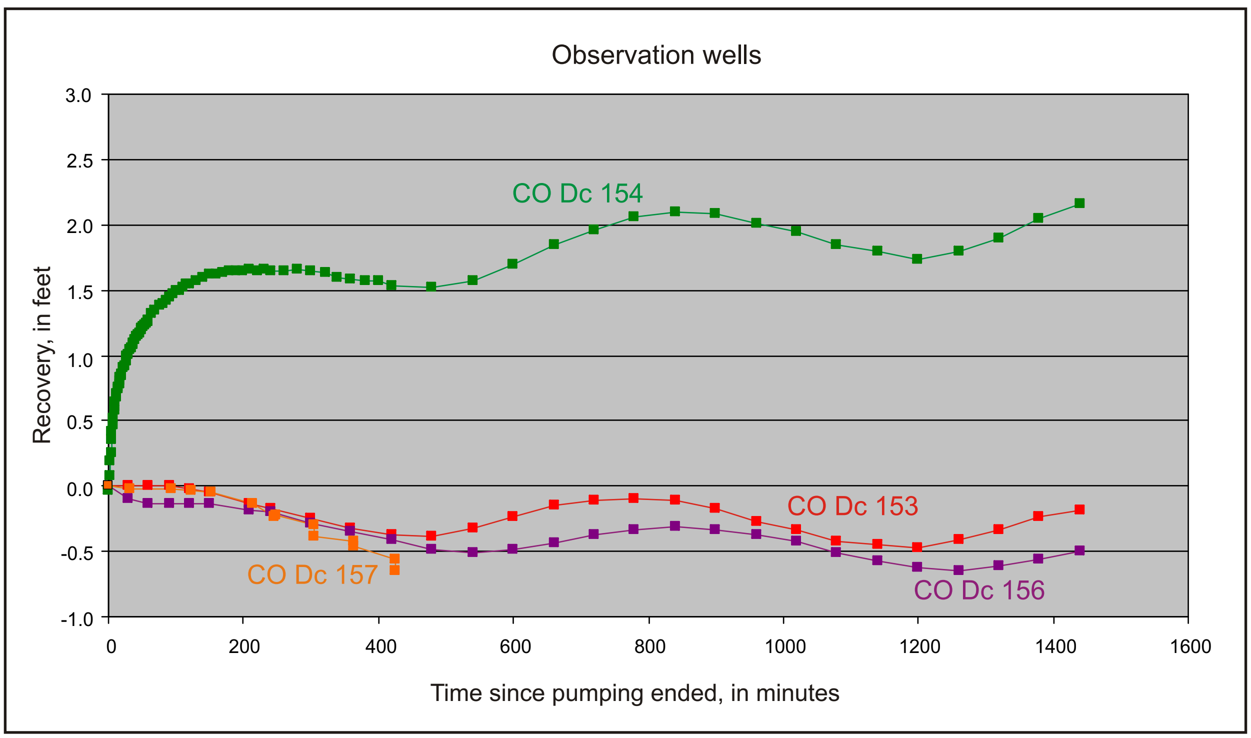
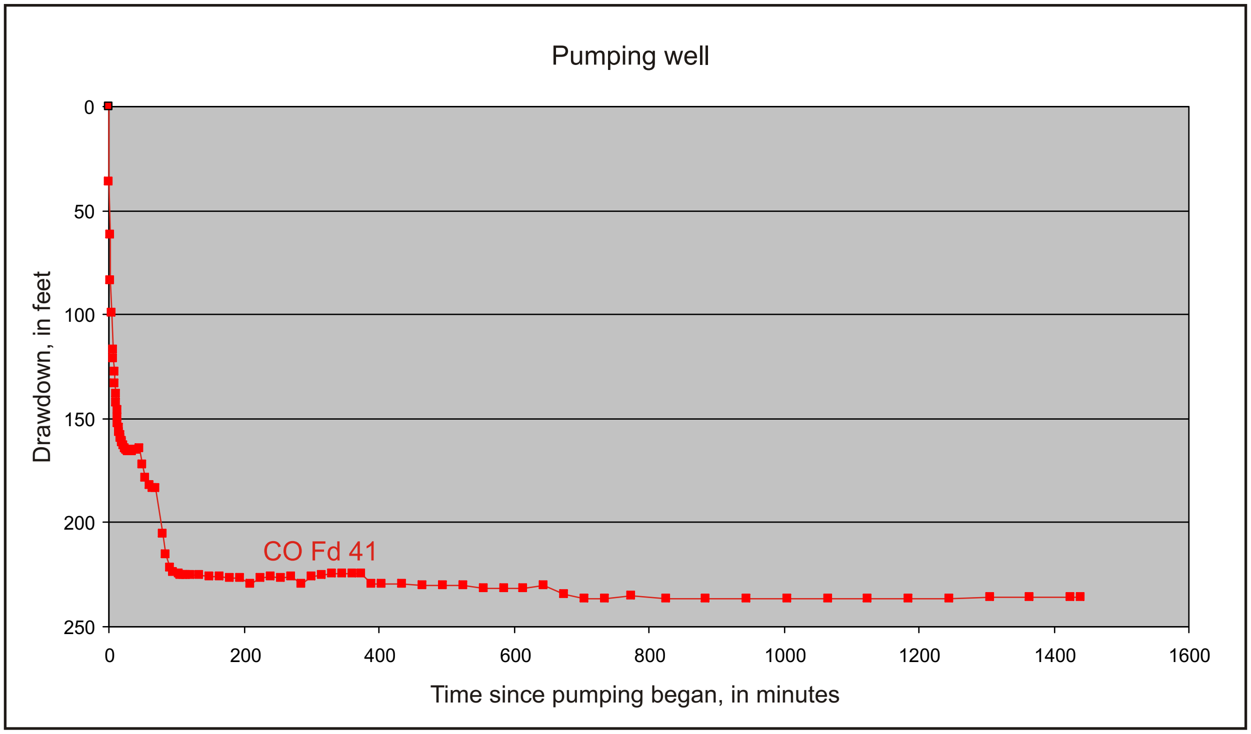




**Figure 26b. Aquifer test data for test well CO Dc 155 at Martinak -- recovery phase.**



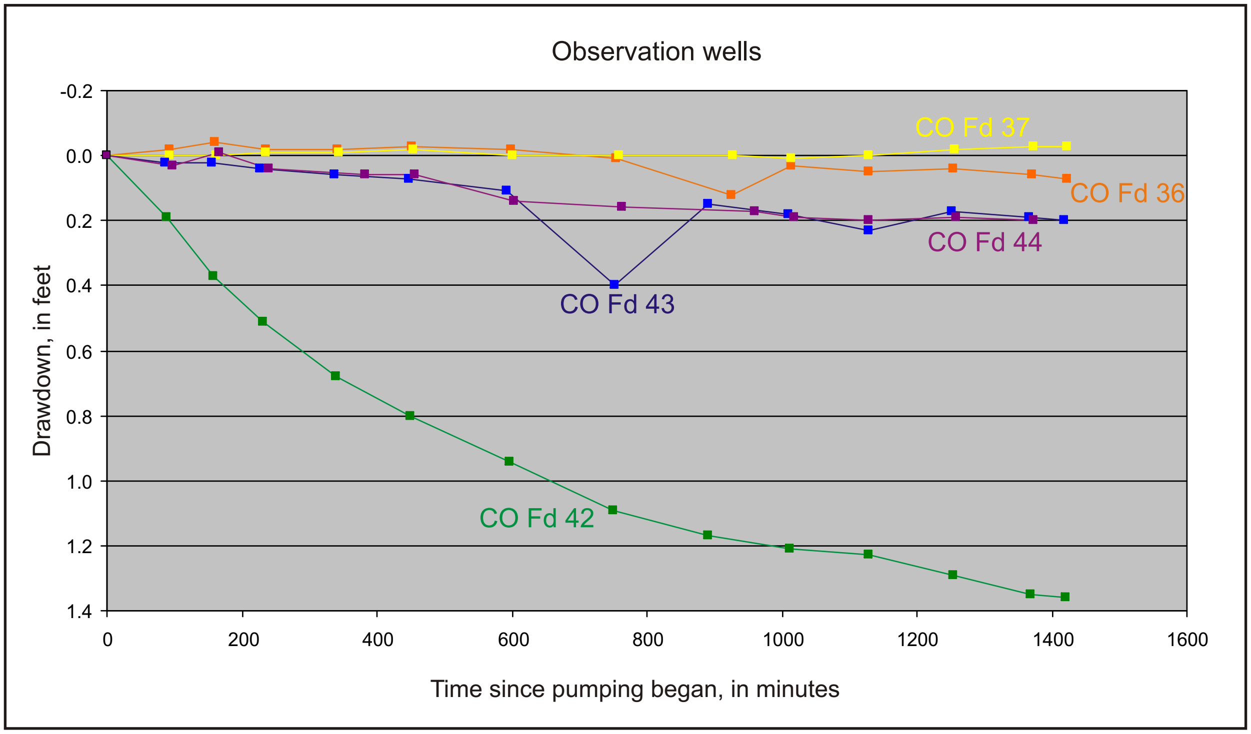
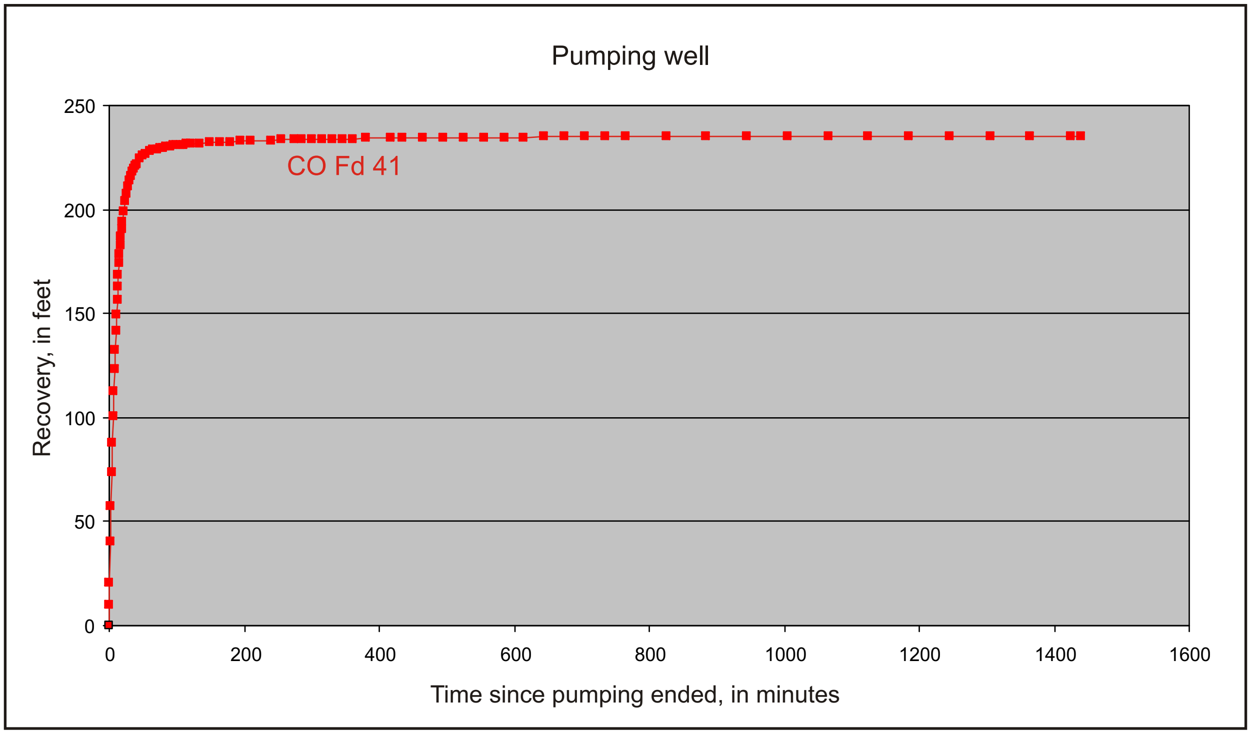




**Figure 27a. Aquifer test data for test well CO Fd 41 at Idylwild -- drawdown phase.**



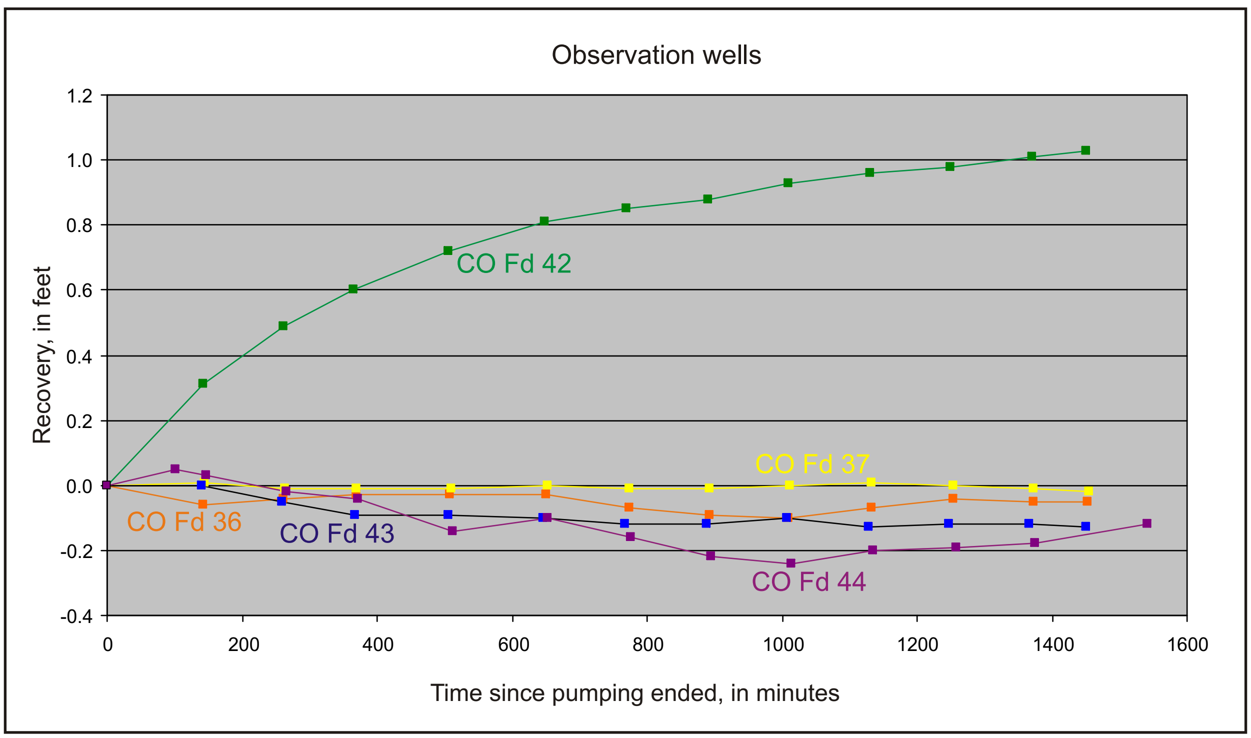
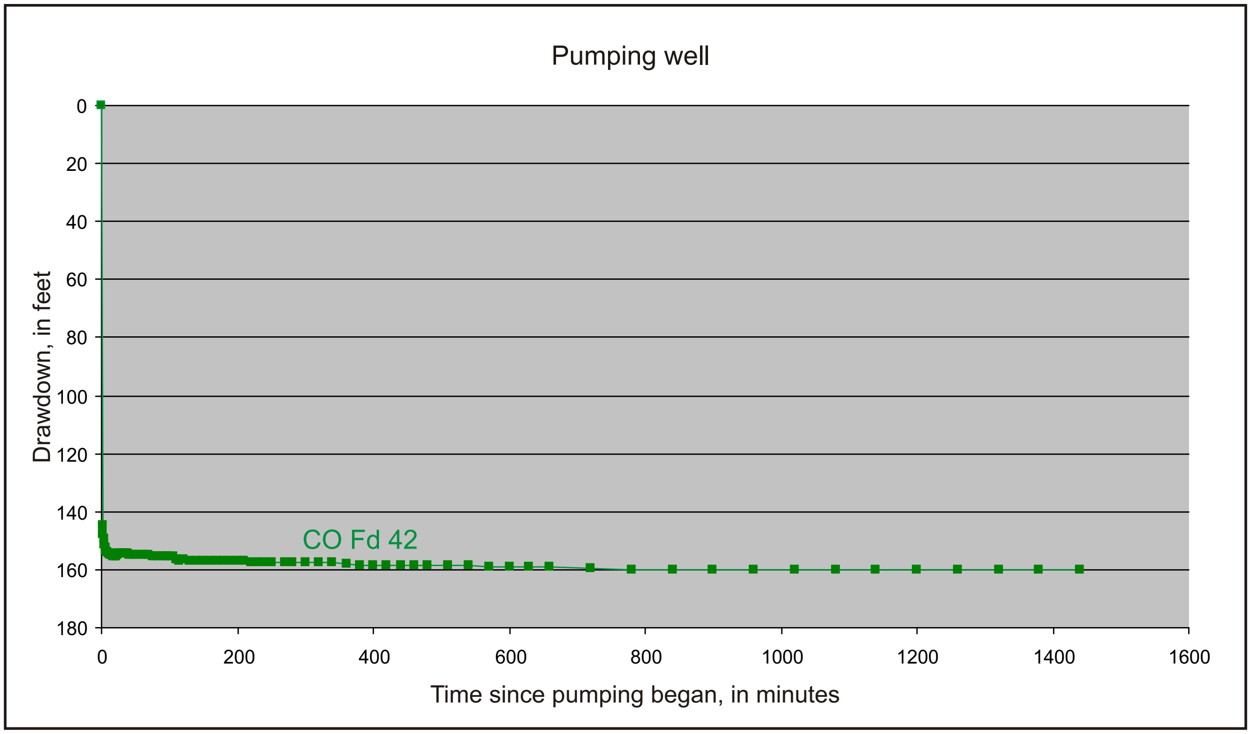




**Figure 27b. Aquifer test data for test well CO Fd 41 at Idylwild -- recovery phase.**



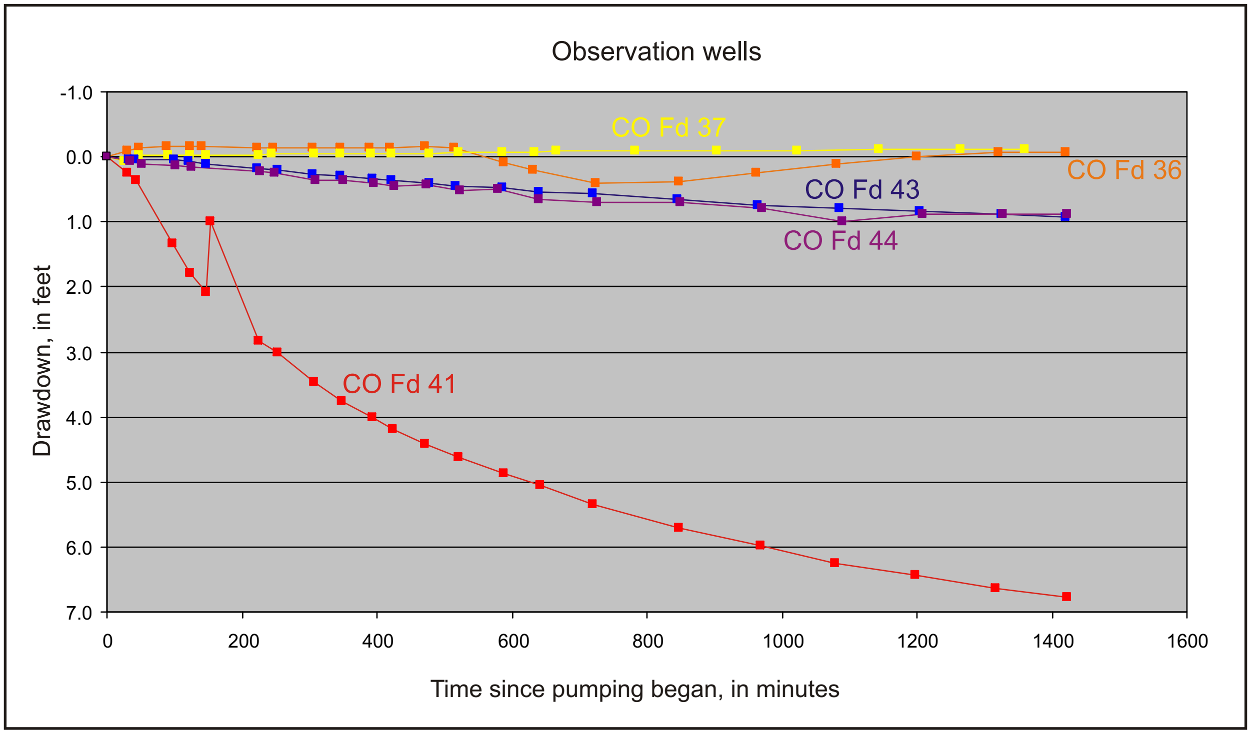
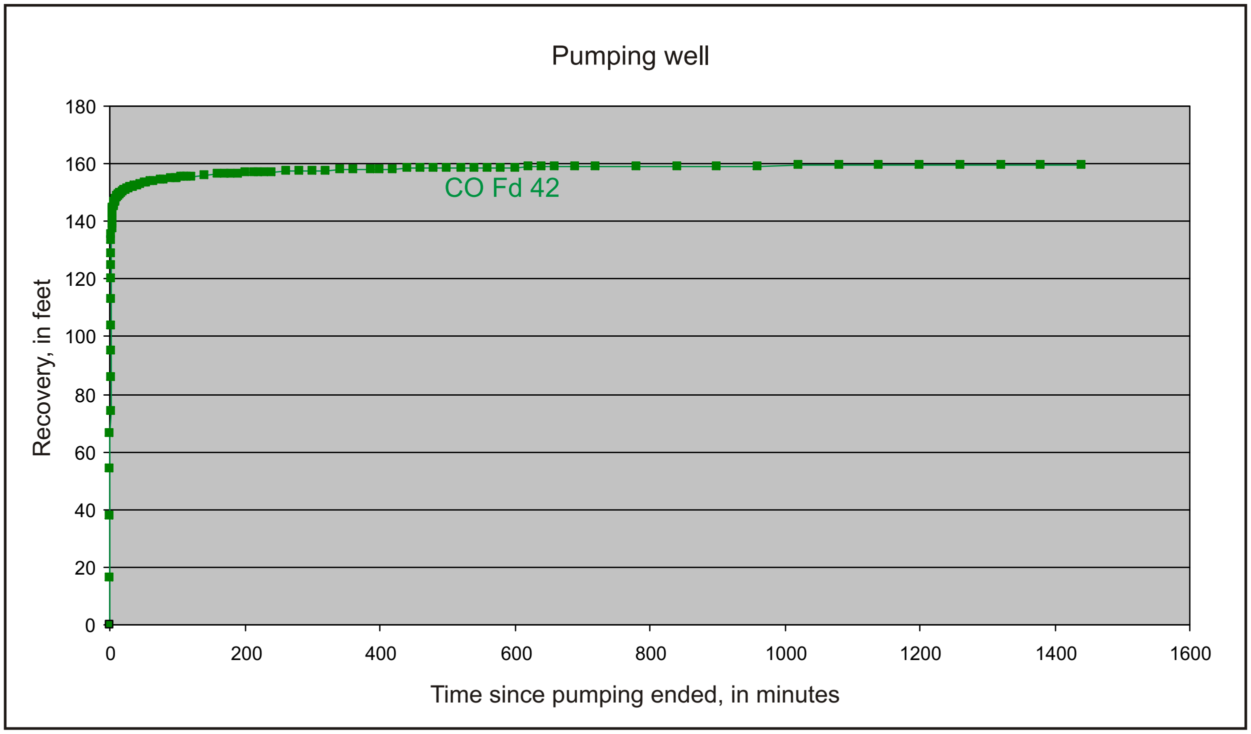




**Figure 28a. Aquifer test data for test well CO Fd 42 at Idylwild -- drawdown phase.**



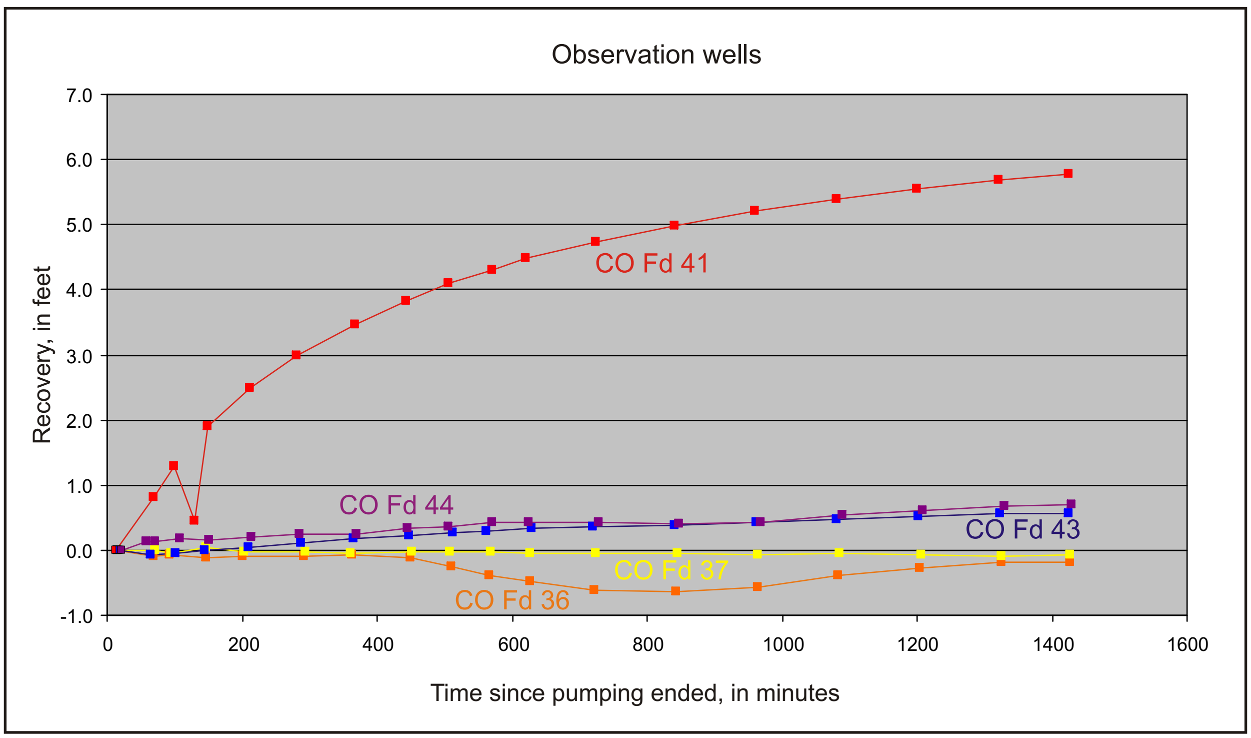
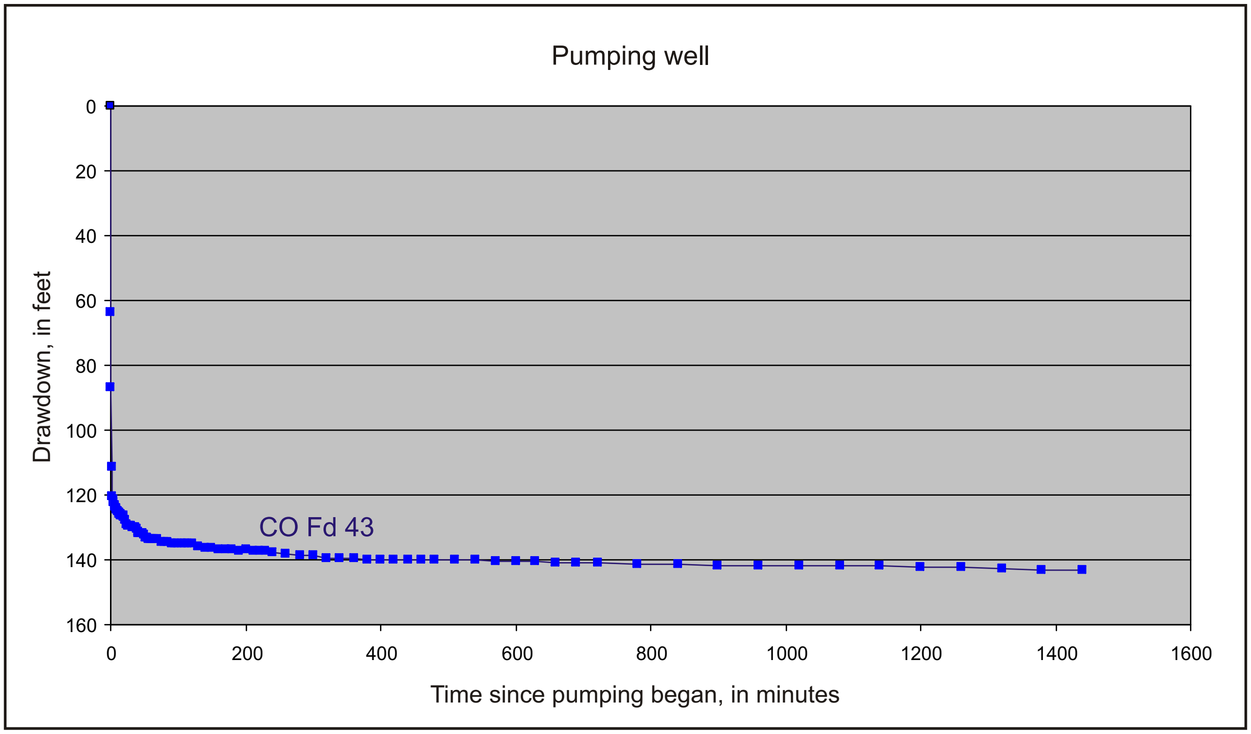




**Figure 28b. Aquifer test data for test well CO Fd 42 at Idylwild -- recovery phase.**



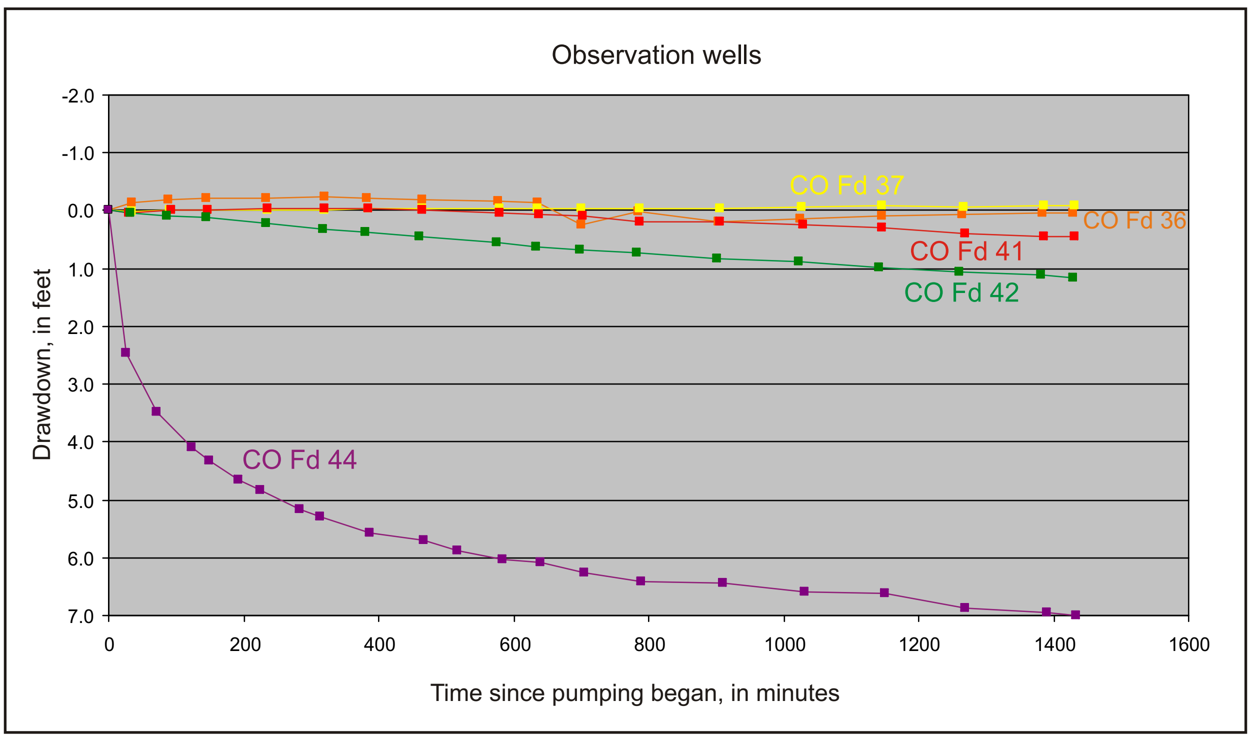
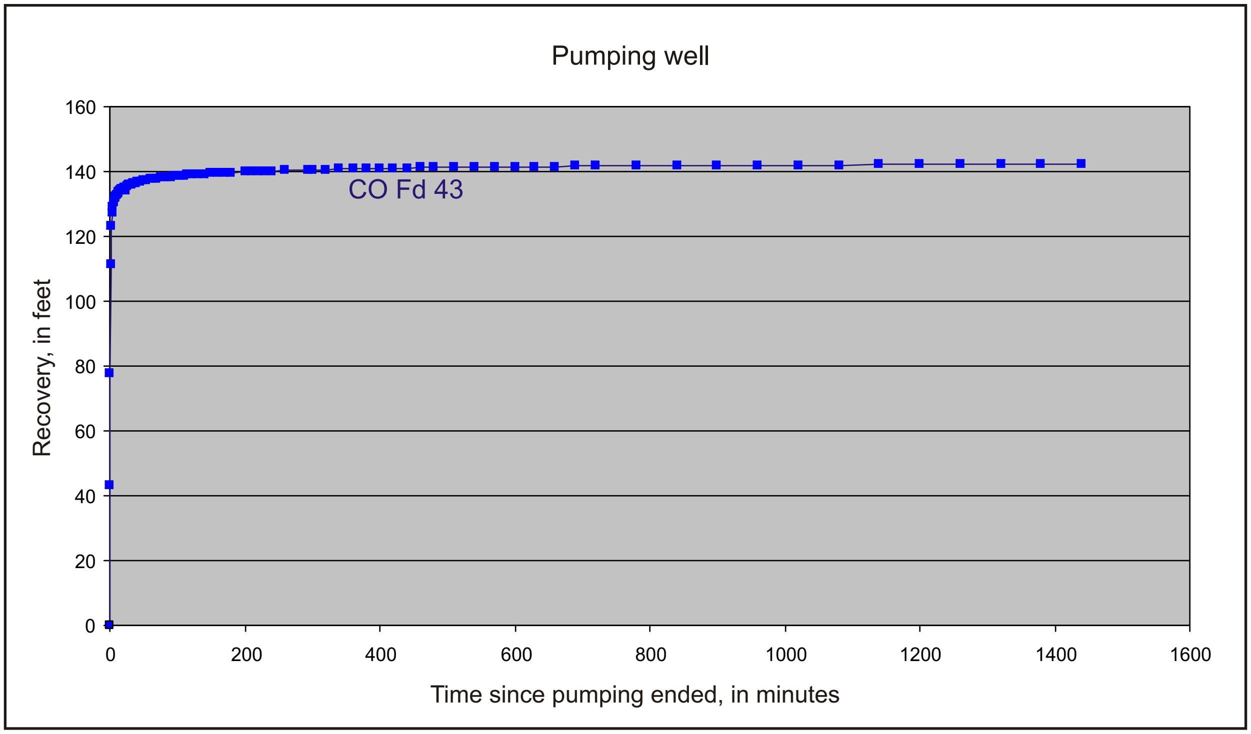




**Figure 29a. Aquifer test data for test well CO Fd 43 at Idylwild -- drawdown phase.**



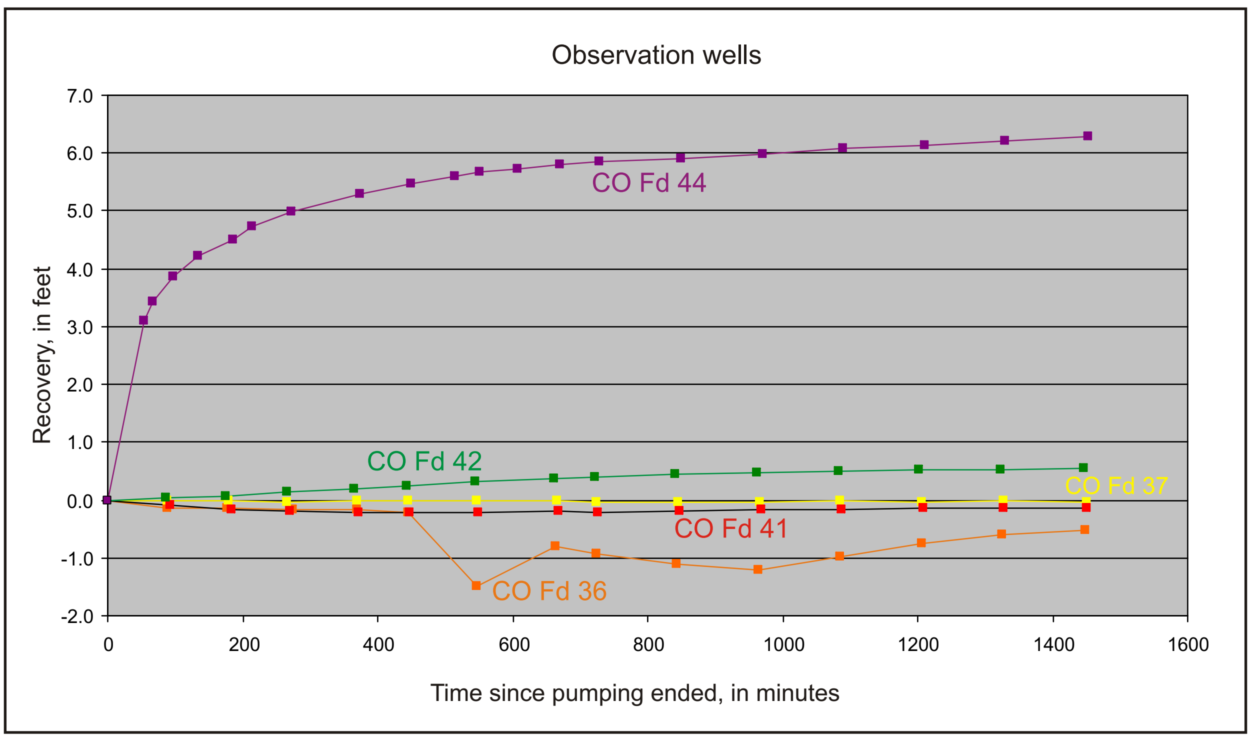
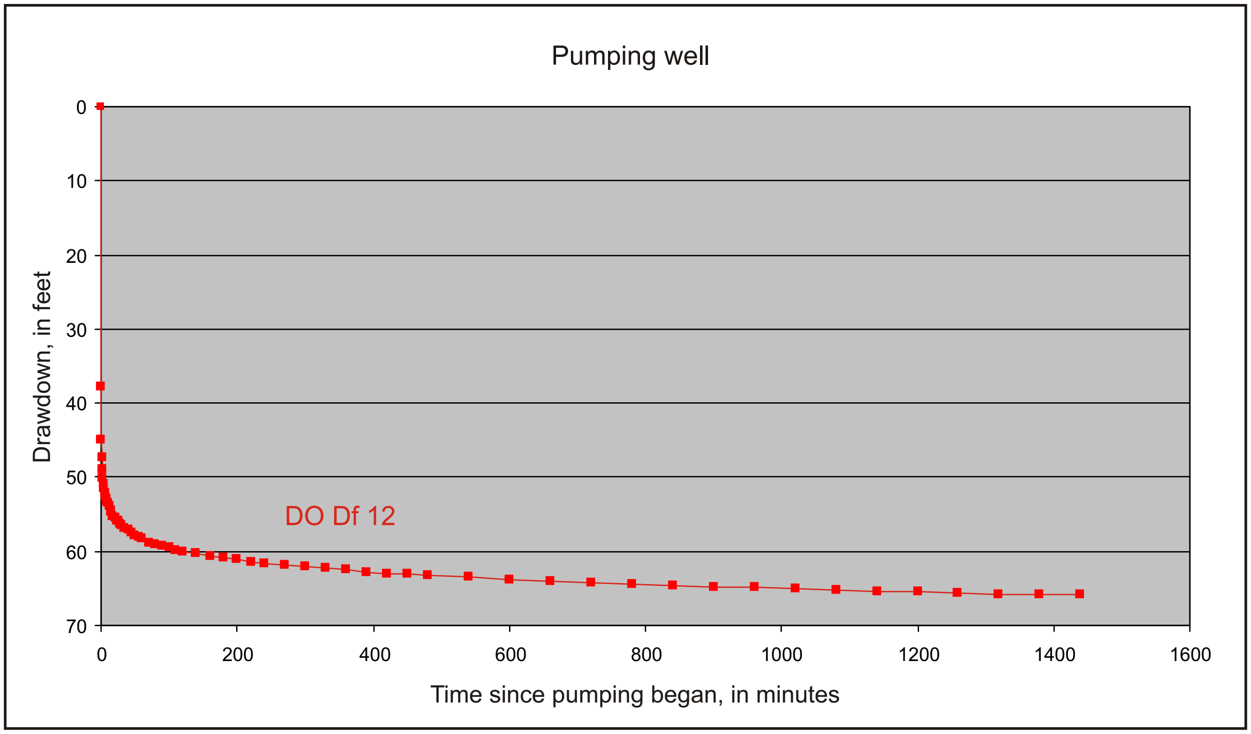




**Figure 29b. Aquifer test data for test well CO Fd 43 at Idylwild -- recovery phase.**



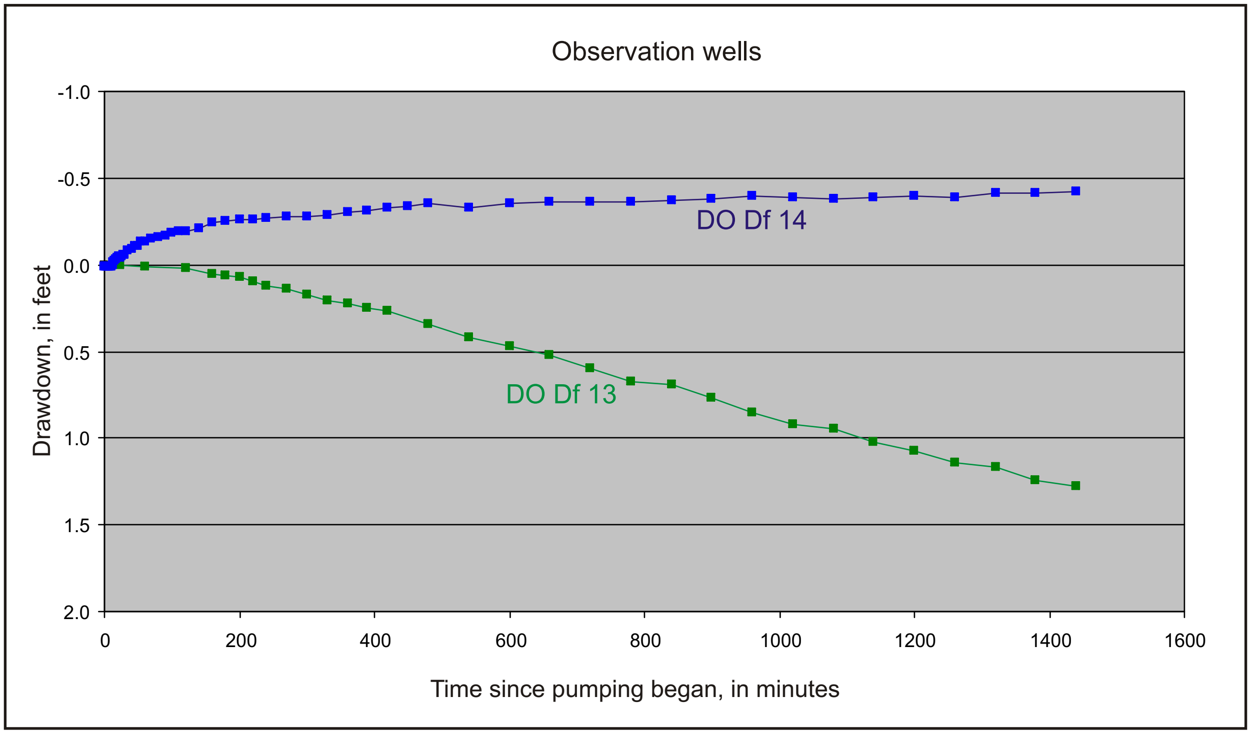
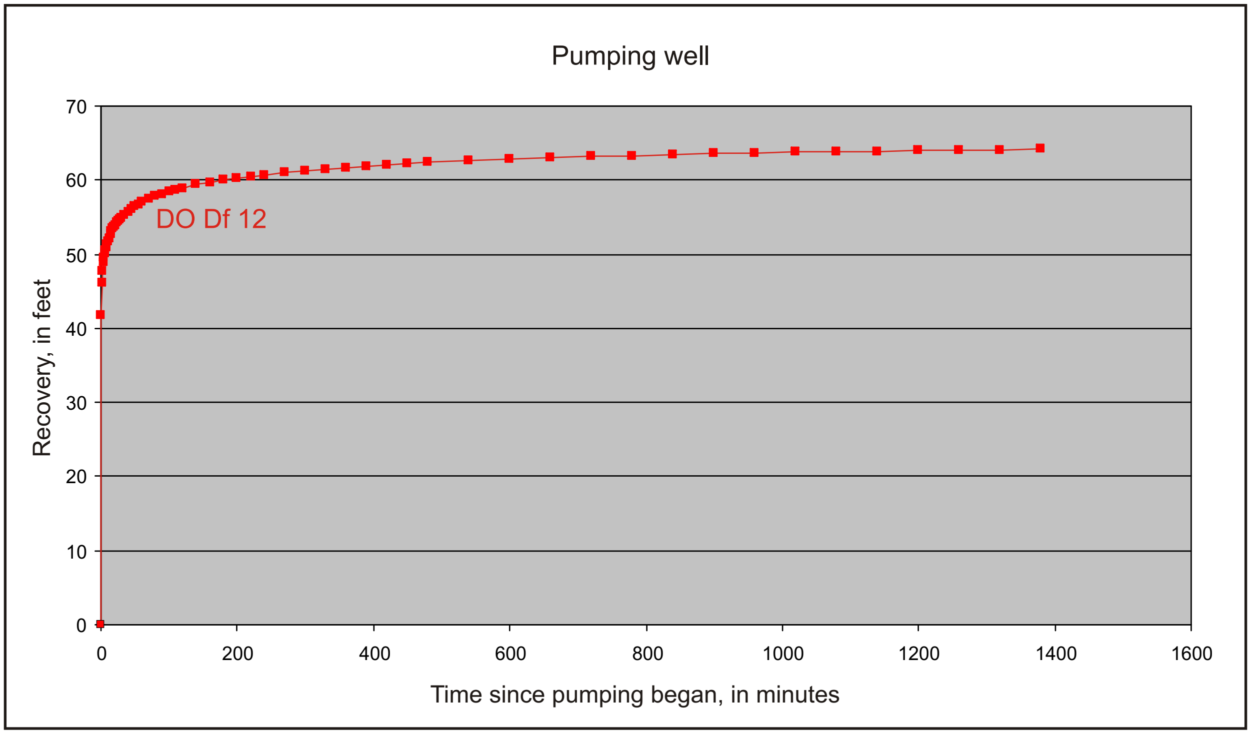




**Figure 30a. Aquifer test data for test well DO Df 12 at Warner -- drawdown phase.**



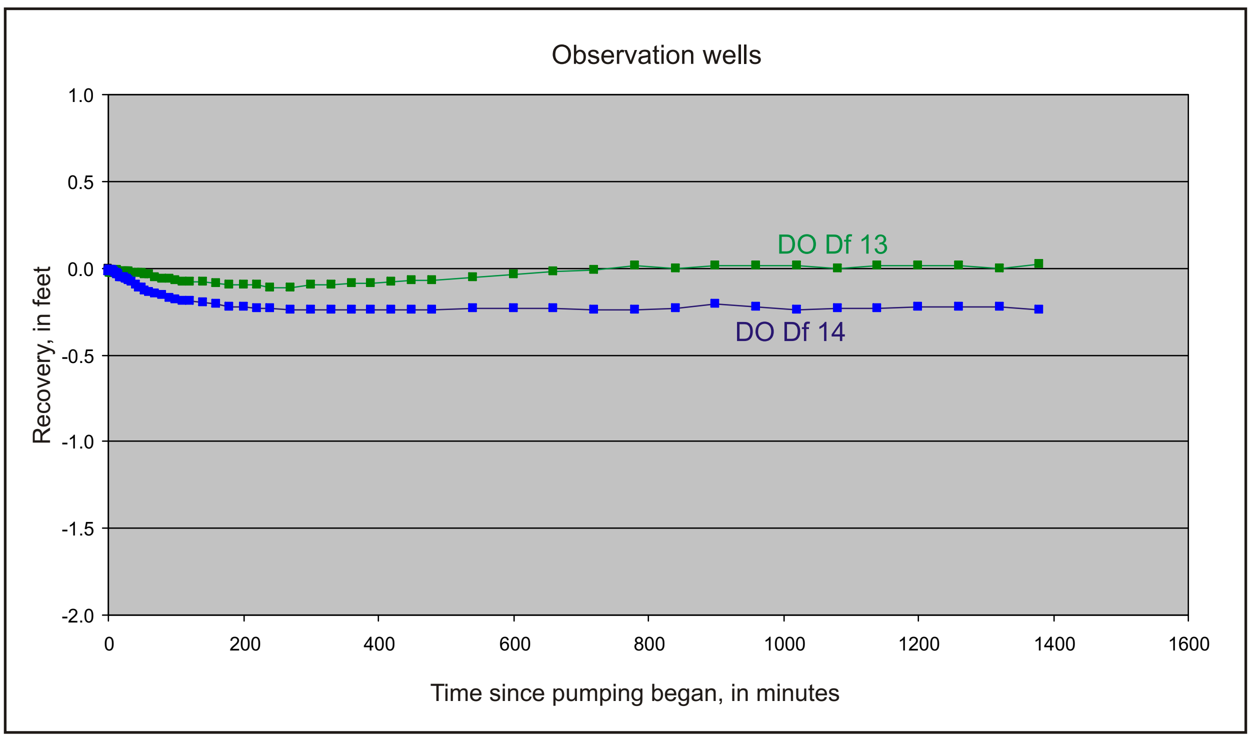
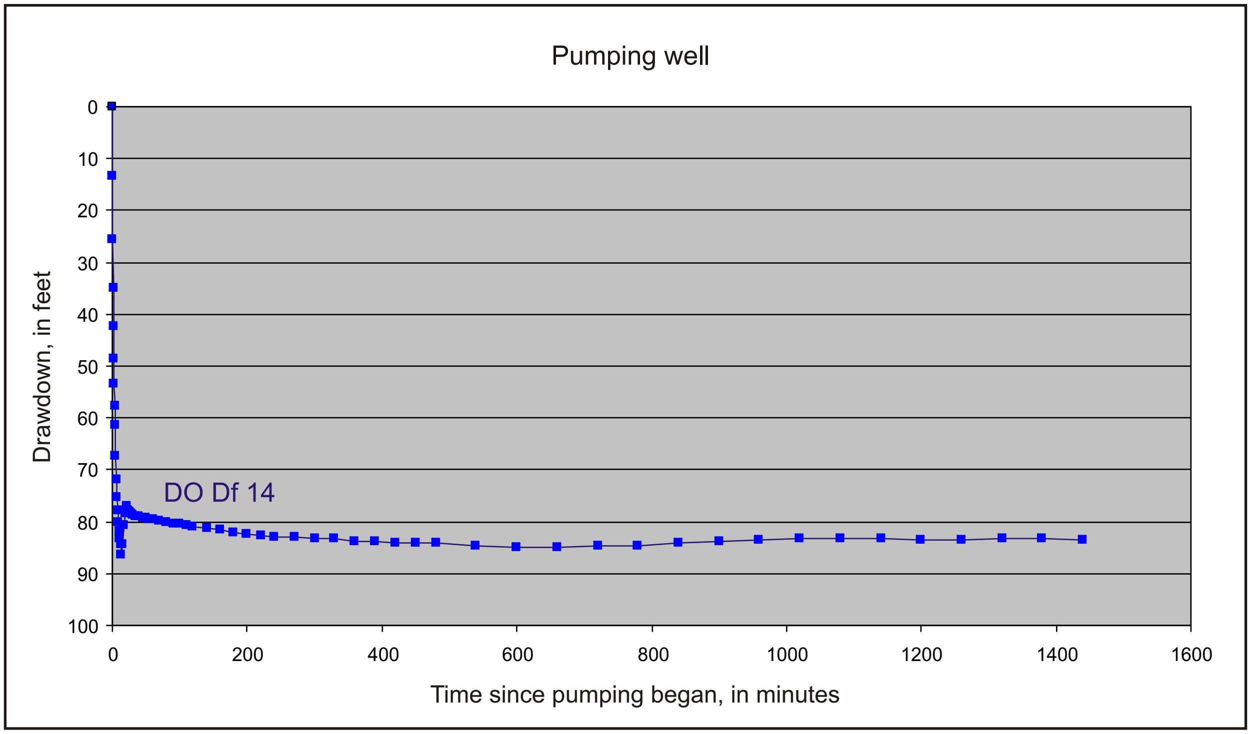




**Figure 30b. Aquifer test data for test well DO Df 12 at Warner -- recovery phase.**



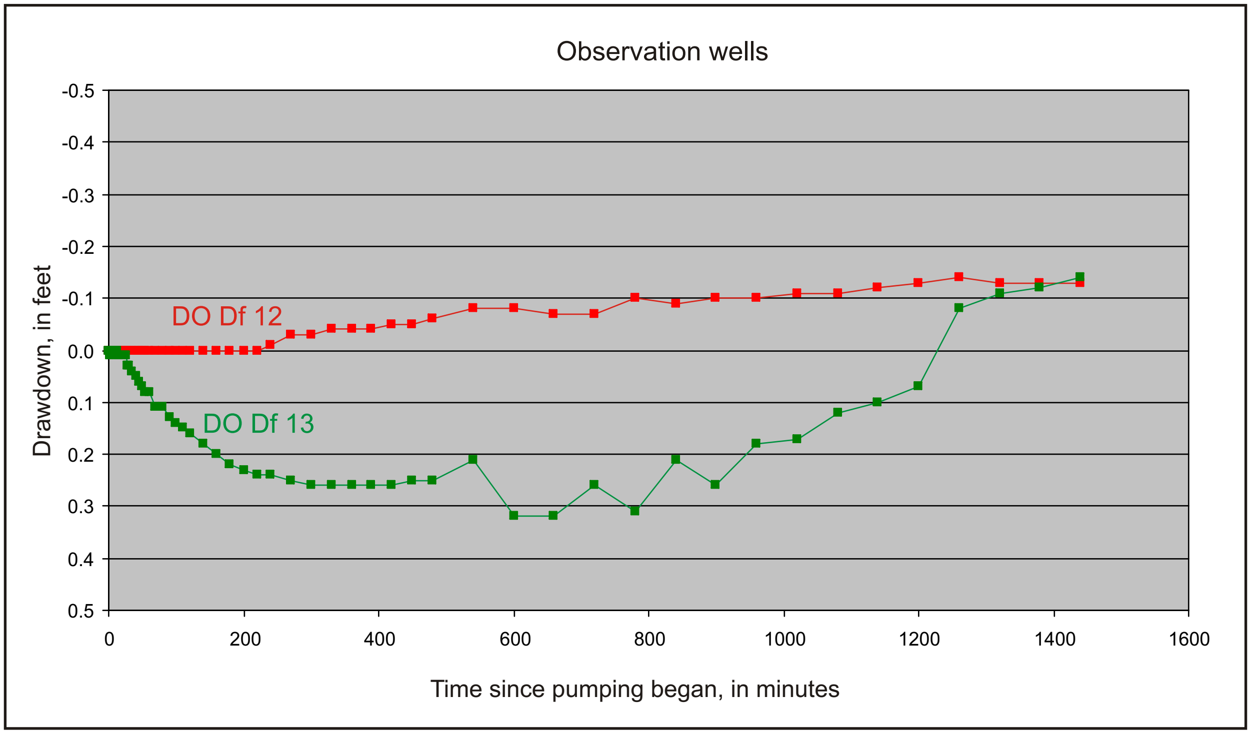
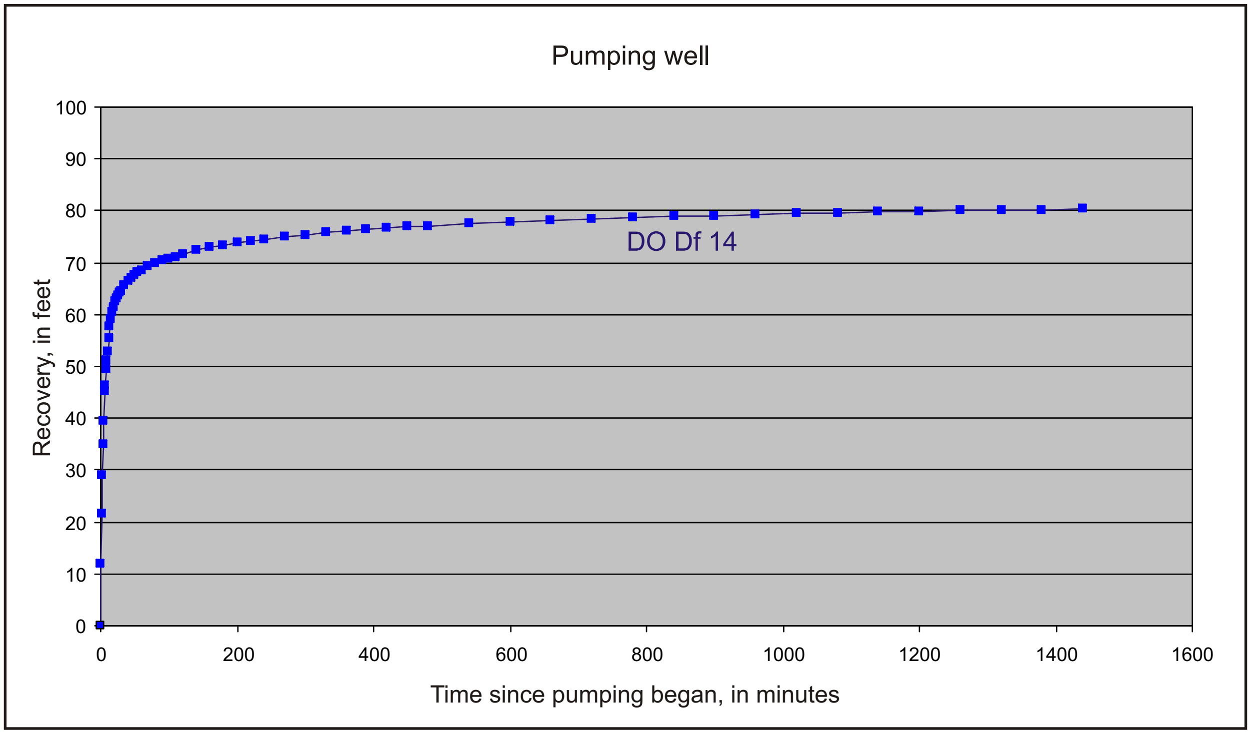




**Figure 31a. Aquifer test data for test well DO Df 14 at Warner -- drawdown phase.**



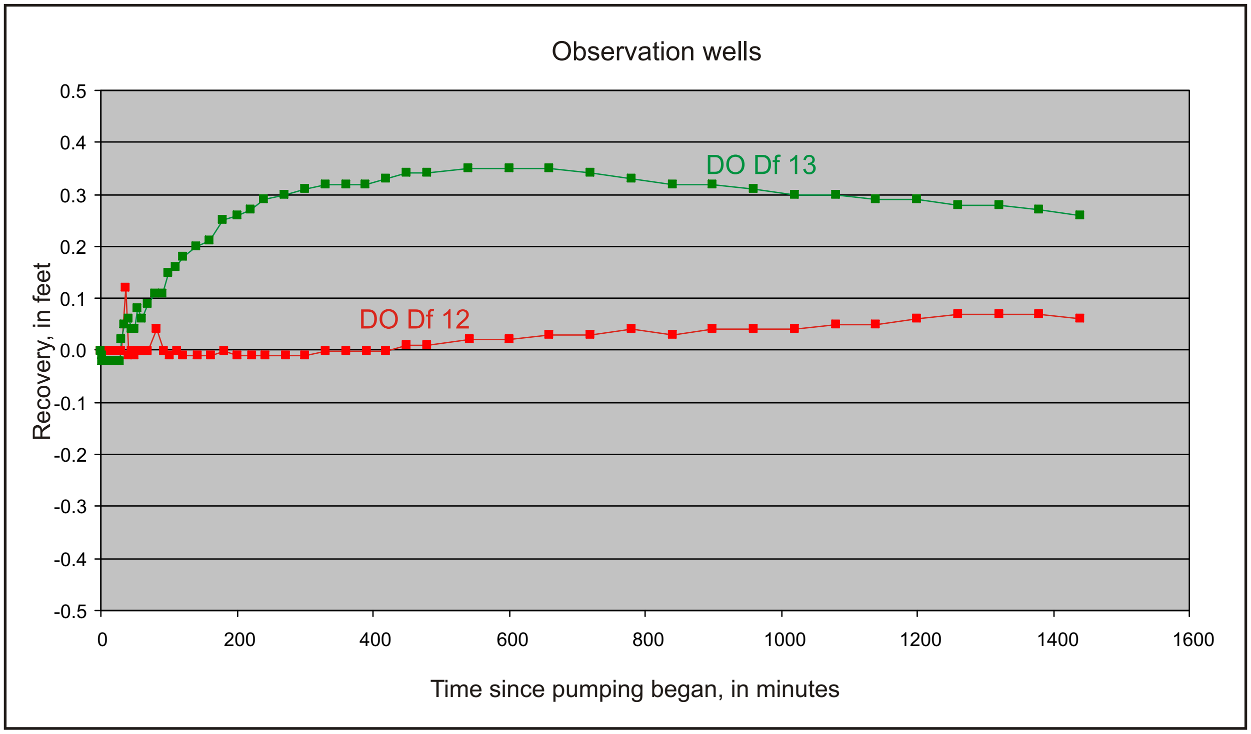
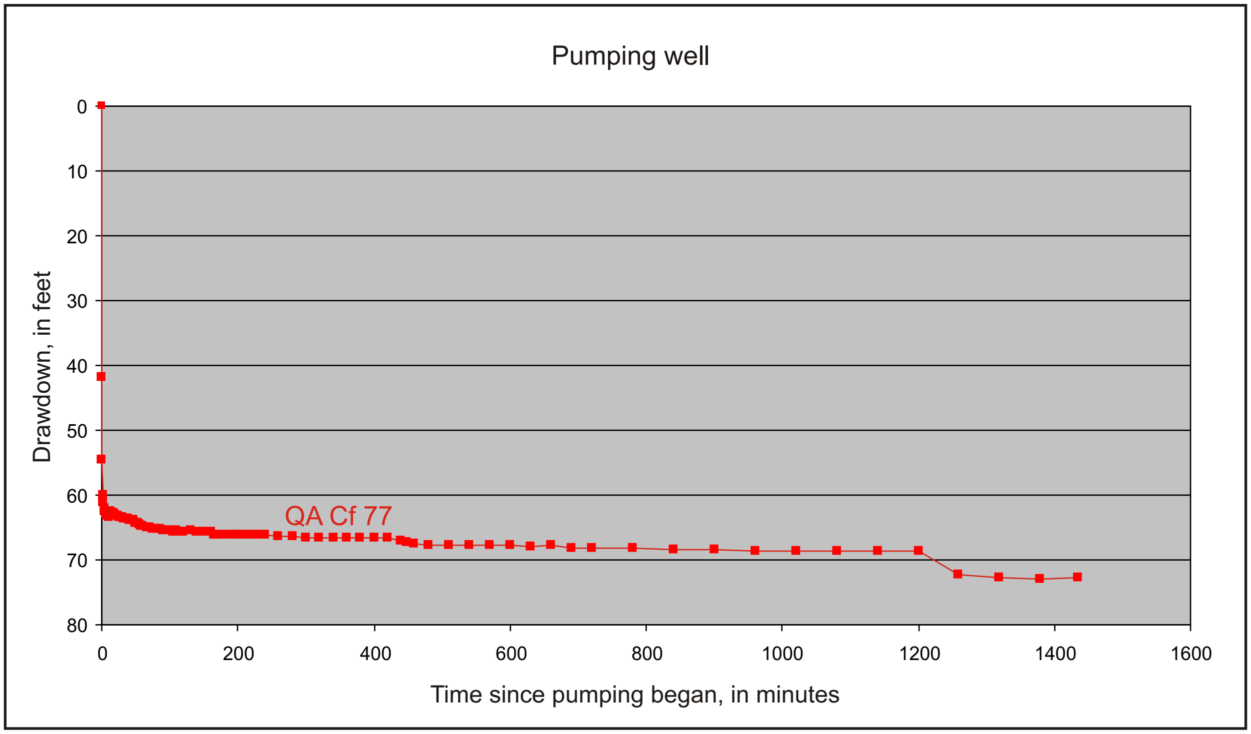




**Figure 31b. Aquifer test data for test well DO Df 14 at Warner -- recovery phase.**



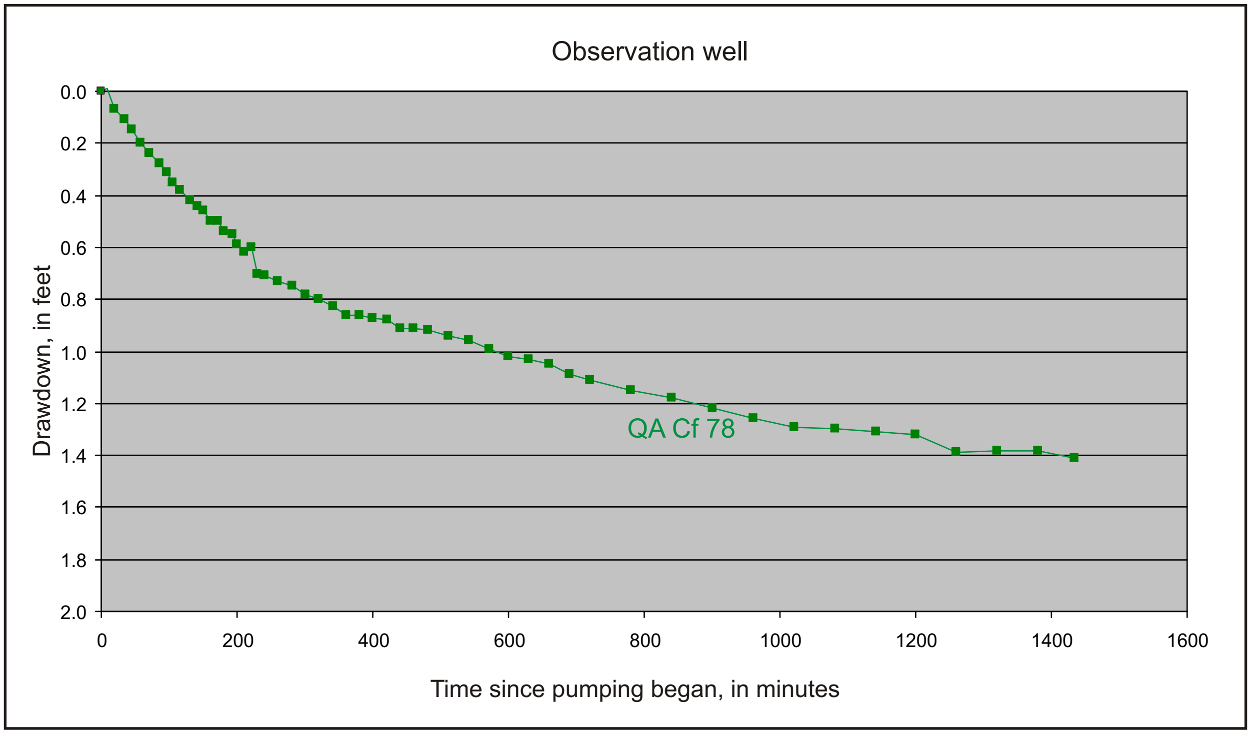
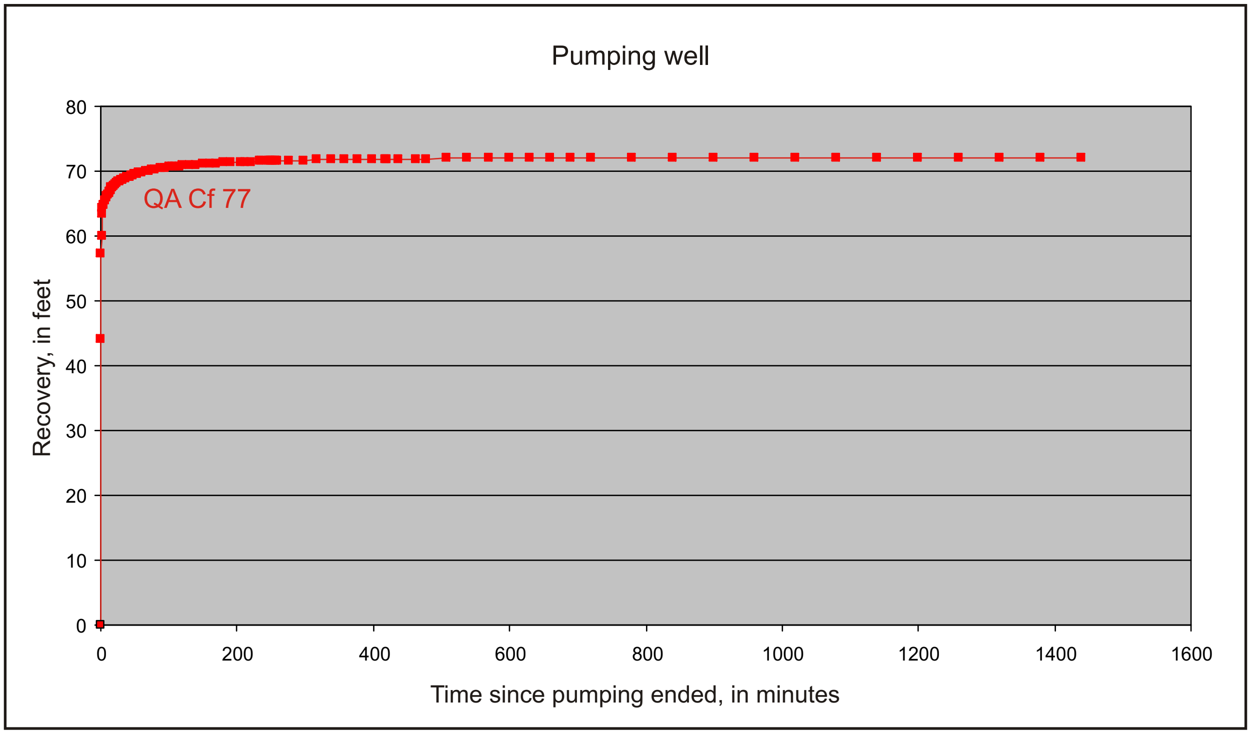




**Figure 32a. Aquifer test data for test well QA Cf 77 at Church Hill -- drawdown phase.**



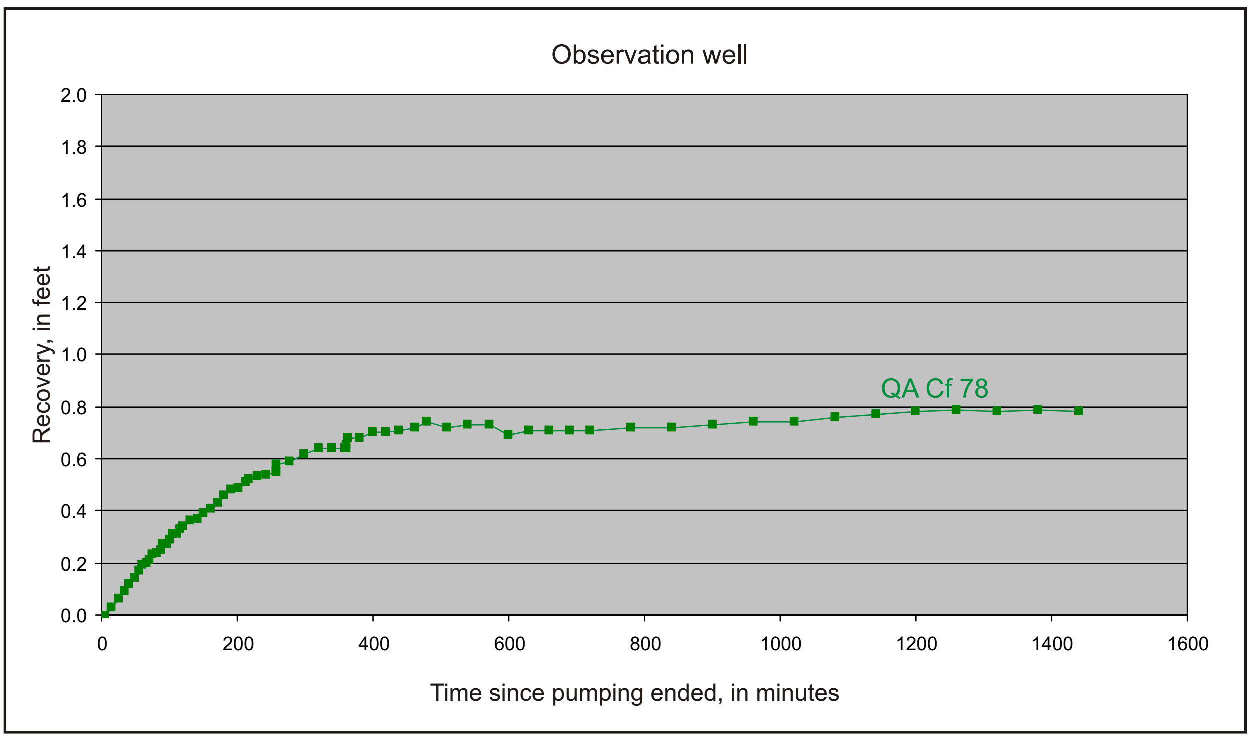
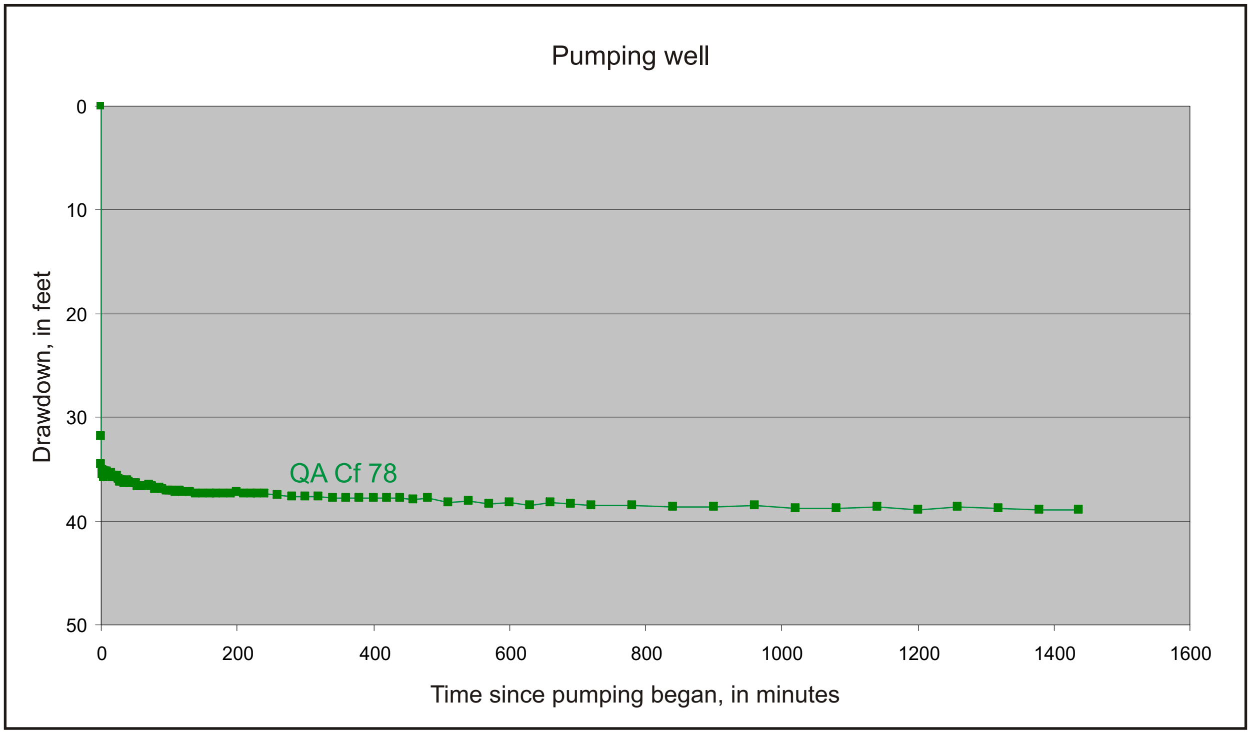




**Figure 32b. Aquifer test data for test well QA Cf 77 at Church Hill -- recovery phase.**



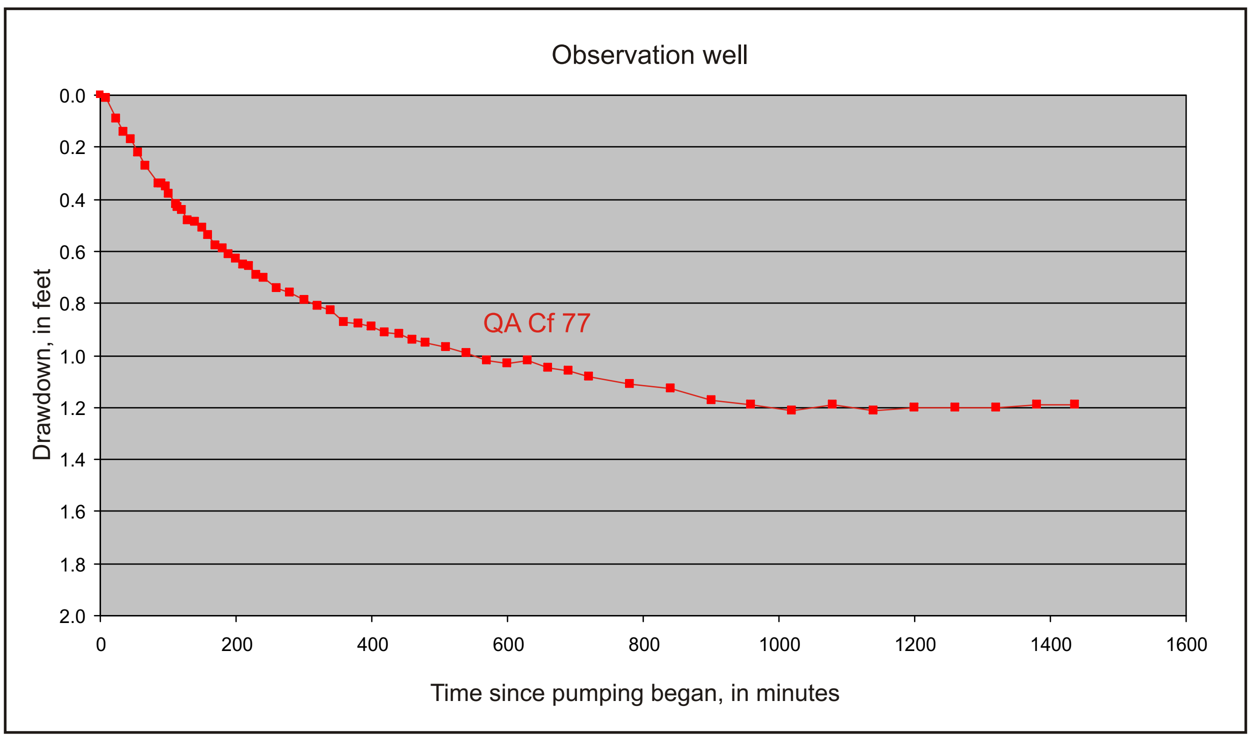
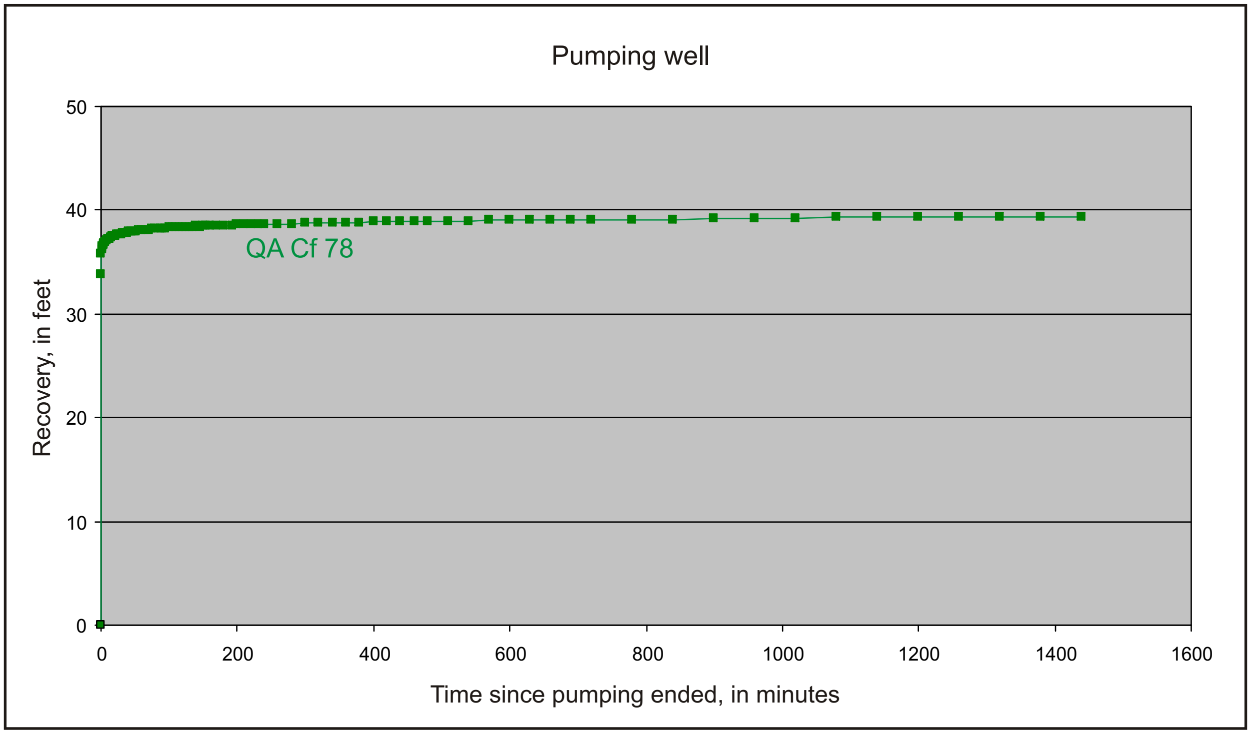




**Figure 33a. Aquifer test data for test well QA Cf 78 at Church Hill -- drawdown phase.**



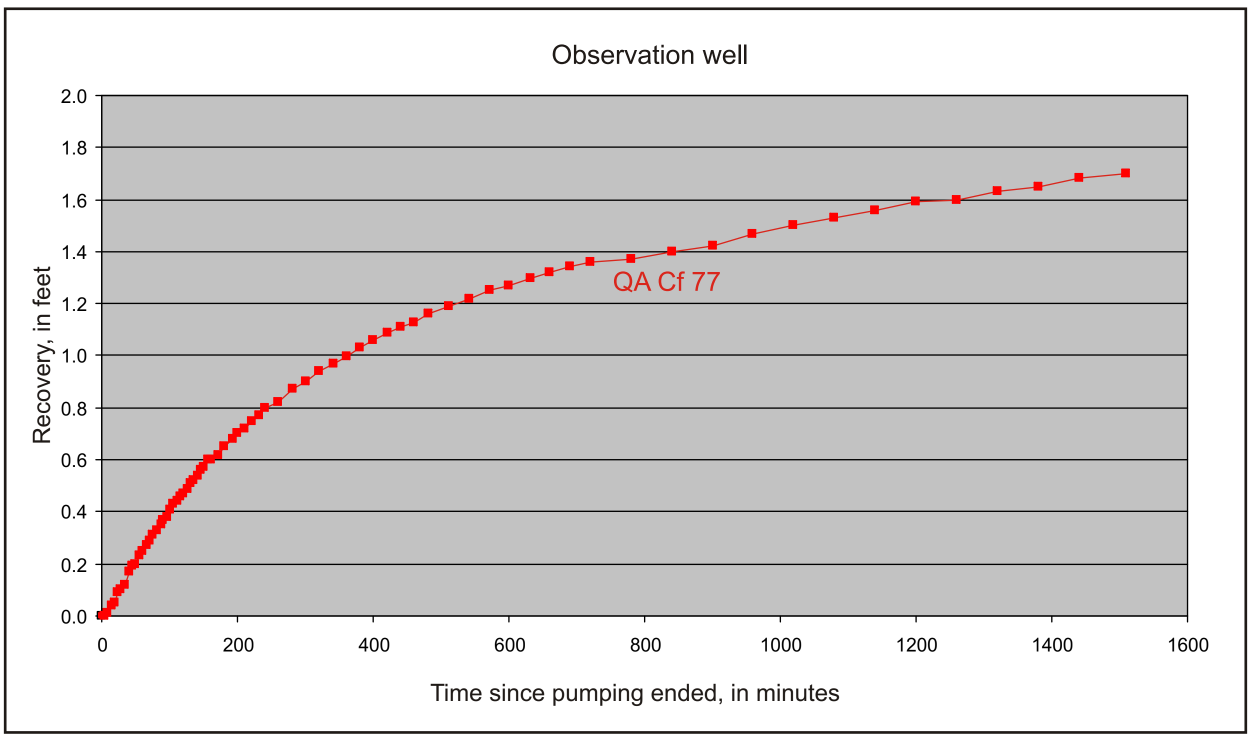
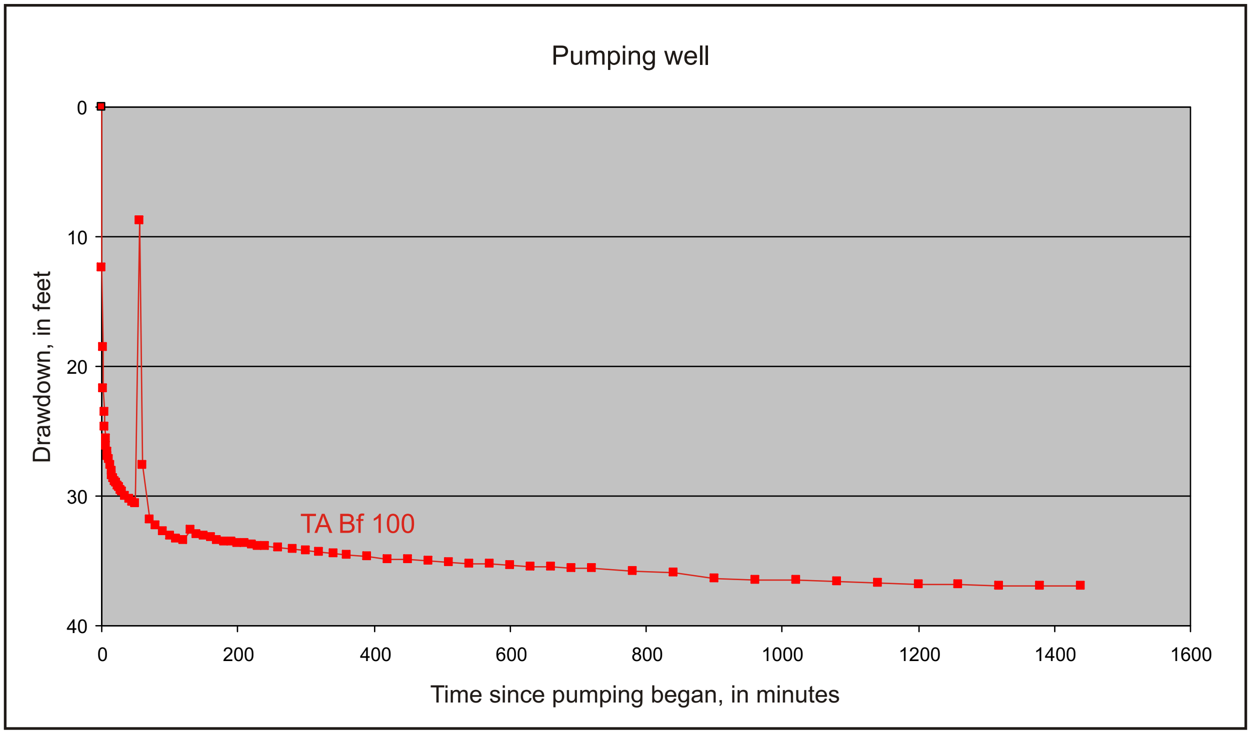




**Figure 33b. Aquifer test data for test well QA Cf 78 at Church Hill -- recovery phase.**



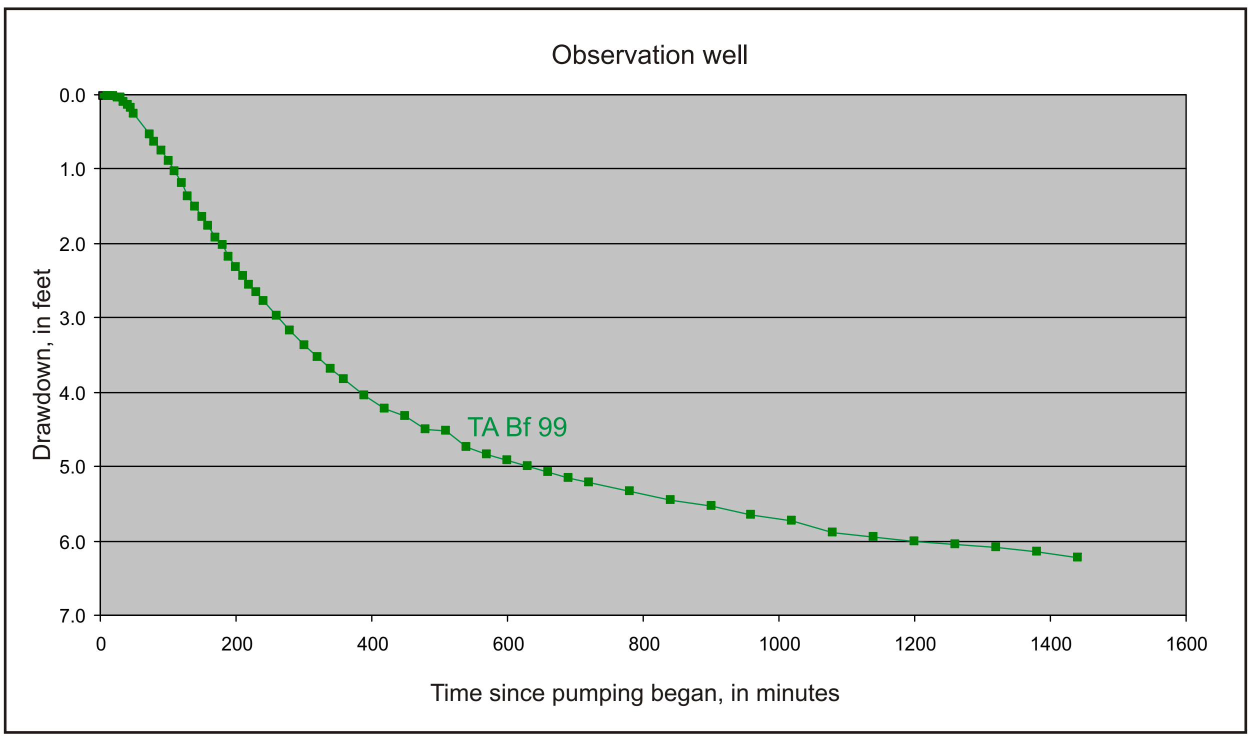
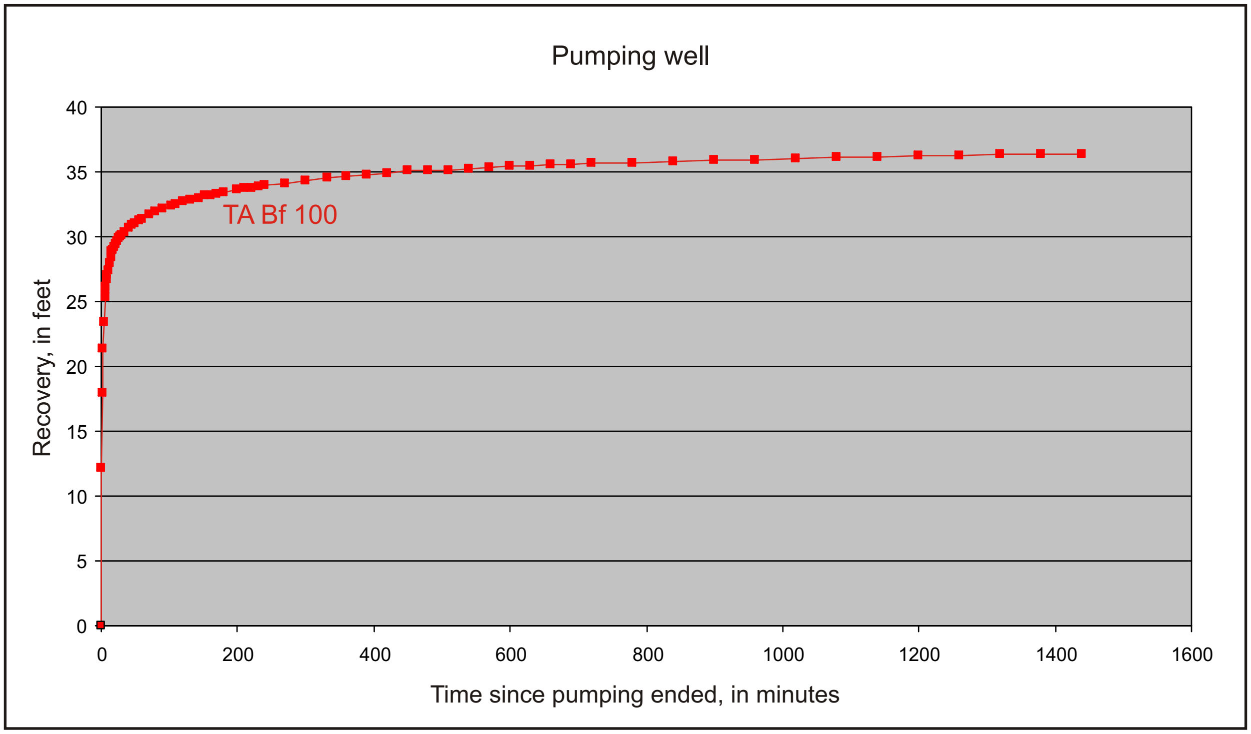




**Figure 34a. Aquifer test data for test well TA Bf 100 at Cordova -- drawdown phase.**



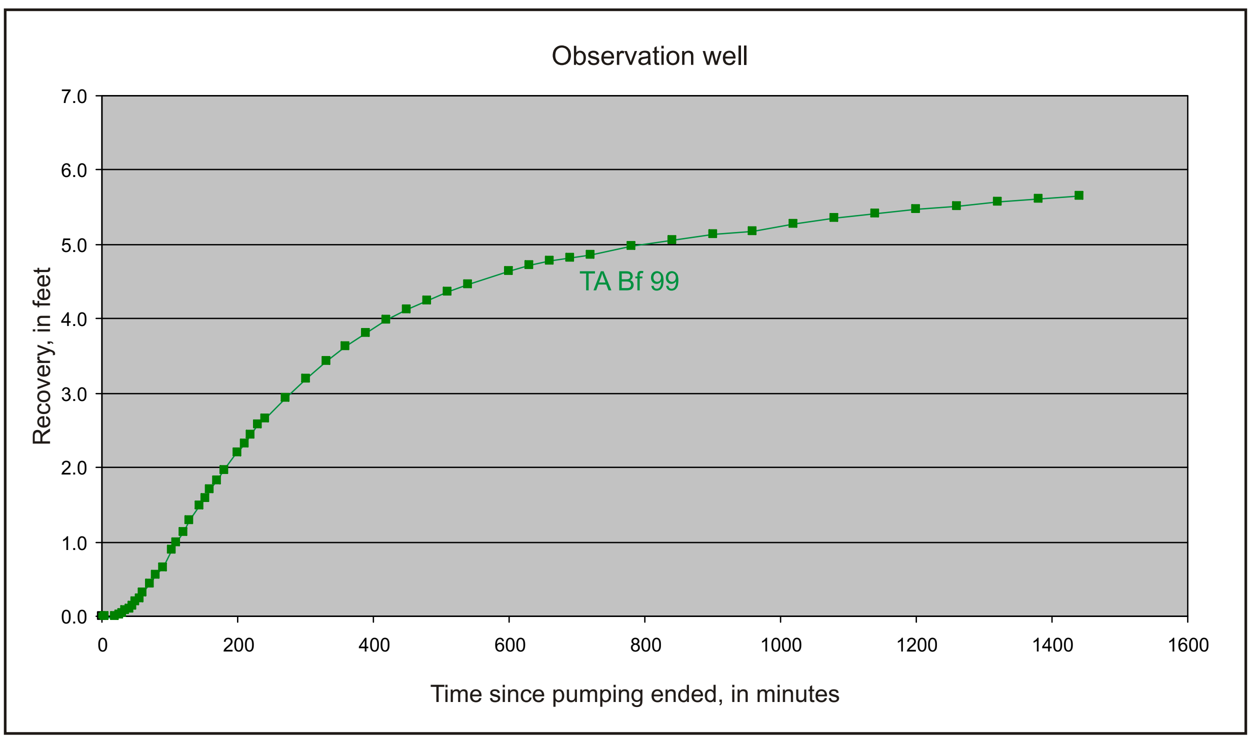
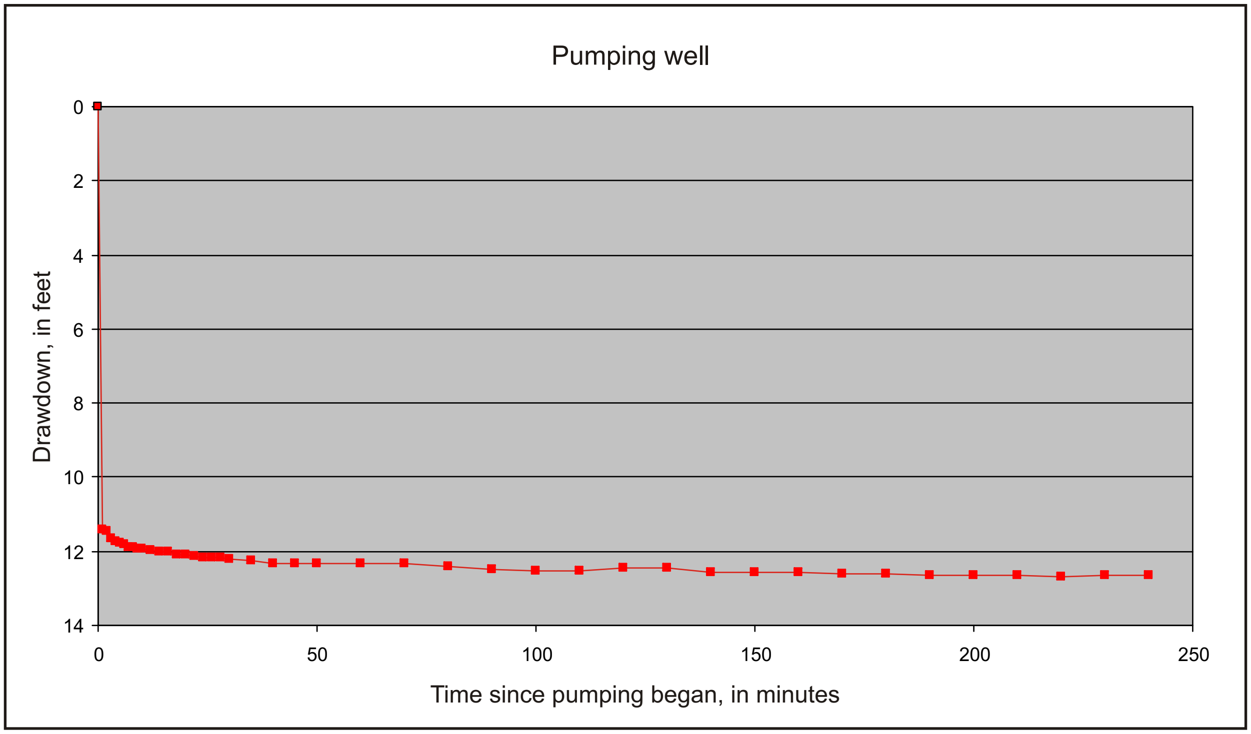




**Figure 34b. Aquifer test data for test well TA Bf 100 at Cordova -- recovery phase.**



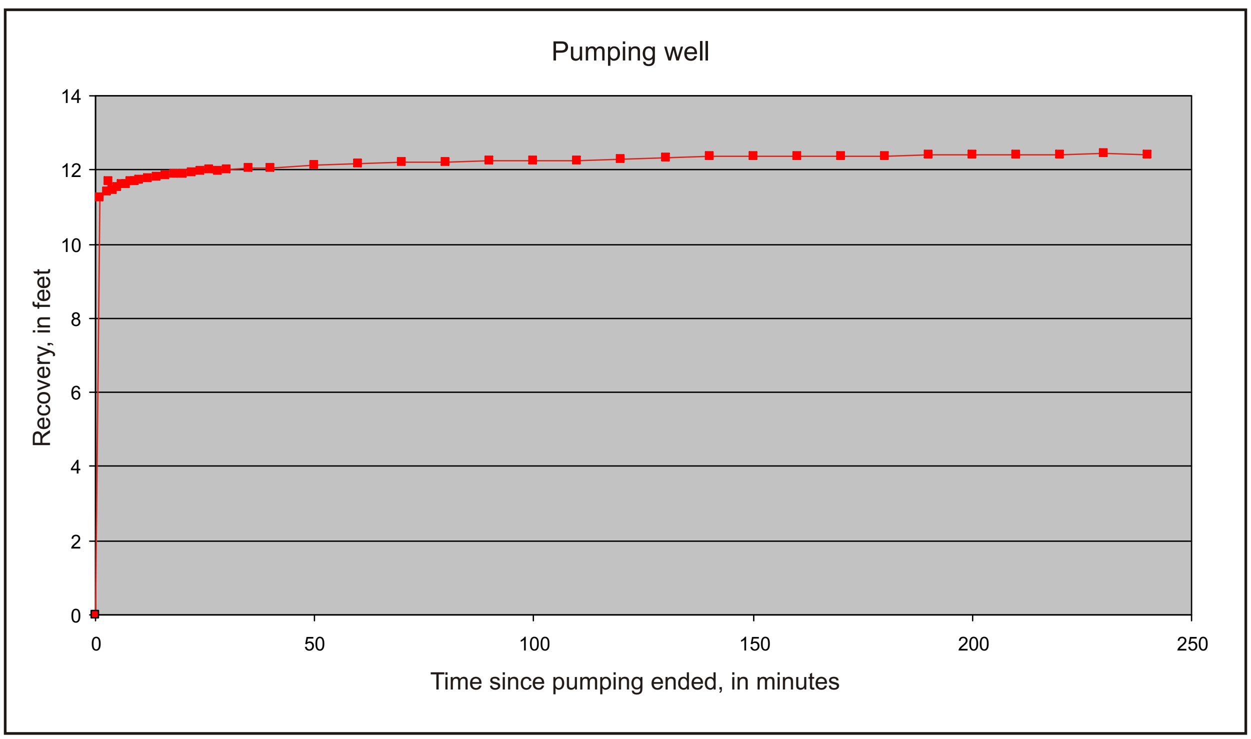




**Figure 35. Aquifer test data for test well WI Ce 327 at LESREC -- drawdown and recovery phases.**

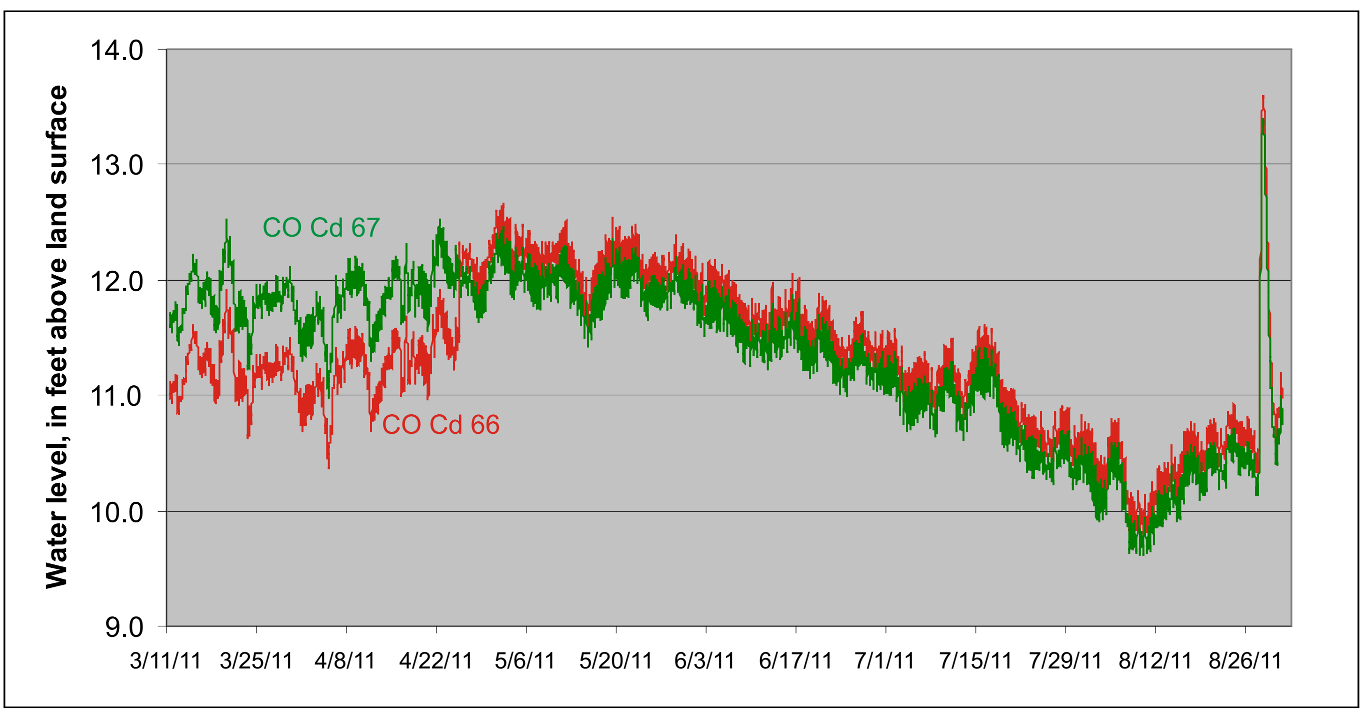



**Figure 36. Hydrographs for test wells CO Cd 66 and 67, at Greensboro.**

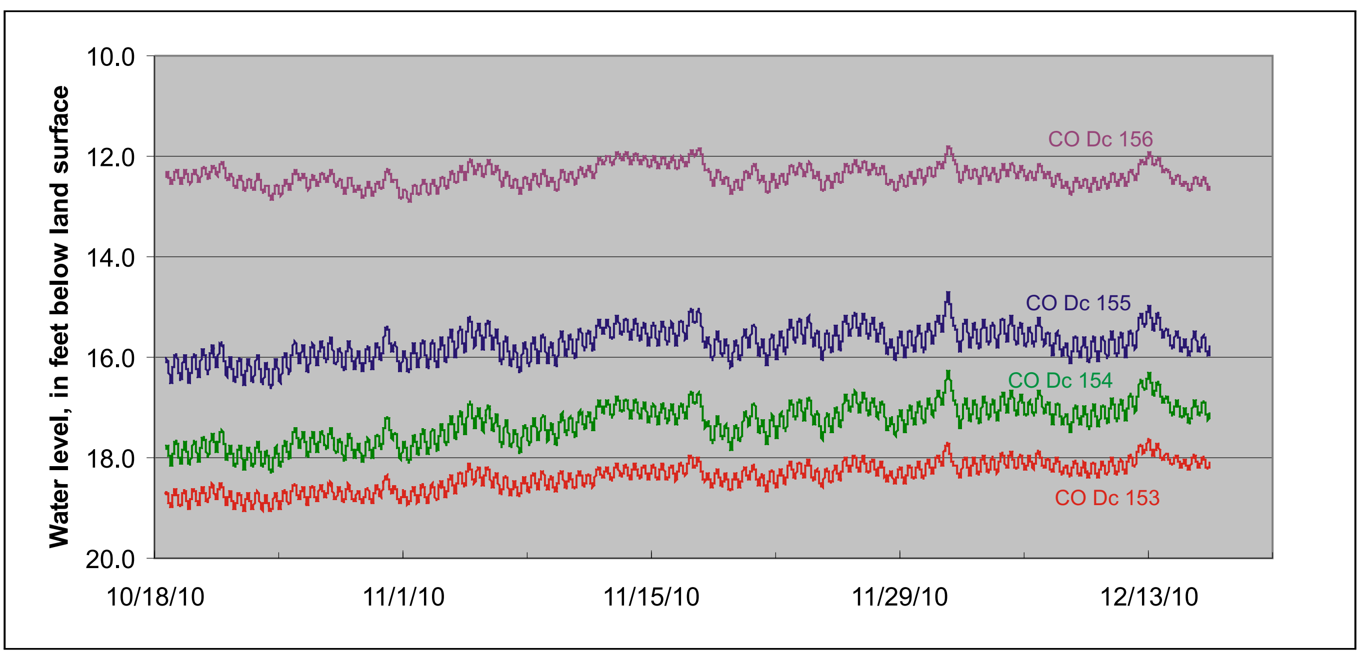



**Figure 37. Hydrographs for test wells CO Dc 153, 154, 155, and 156, at Martinak.**

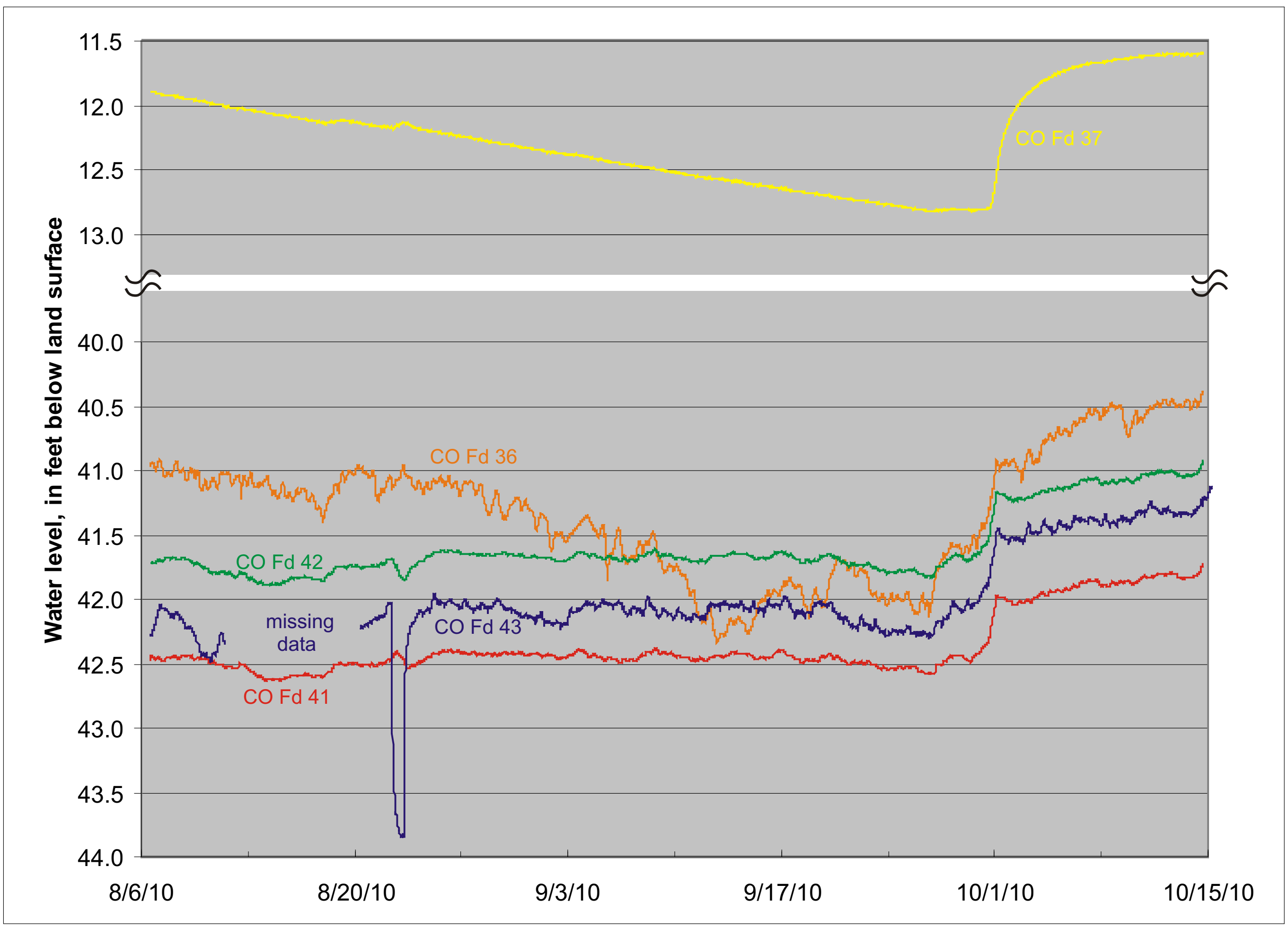



**Figure 38. Hydrographs for test wells CO Fc 36, 37, 41, 42, and 43 at Idylwild.**

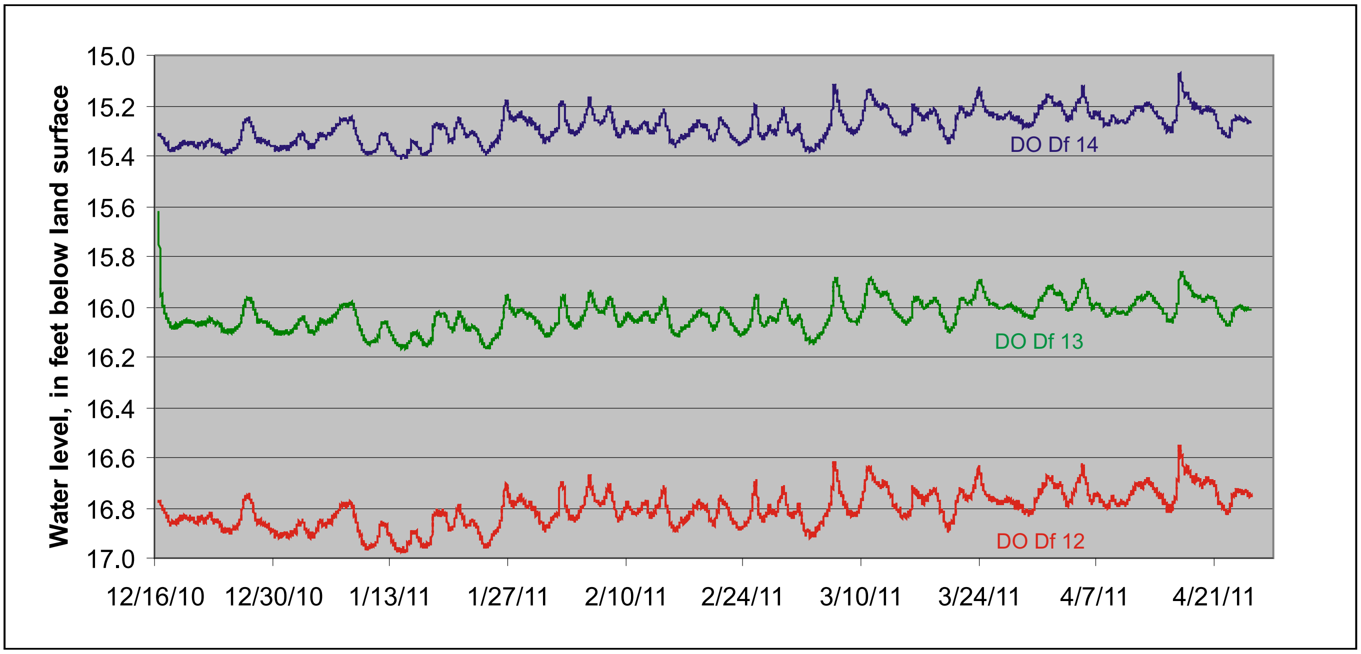



**Figure 39. Hydrographs for test wells DO Df 12, 13, and 14, at Warner.**

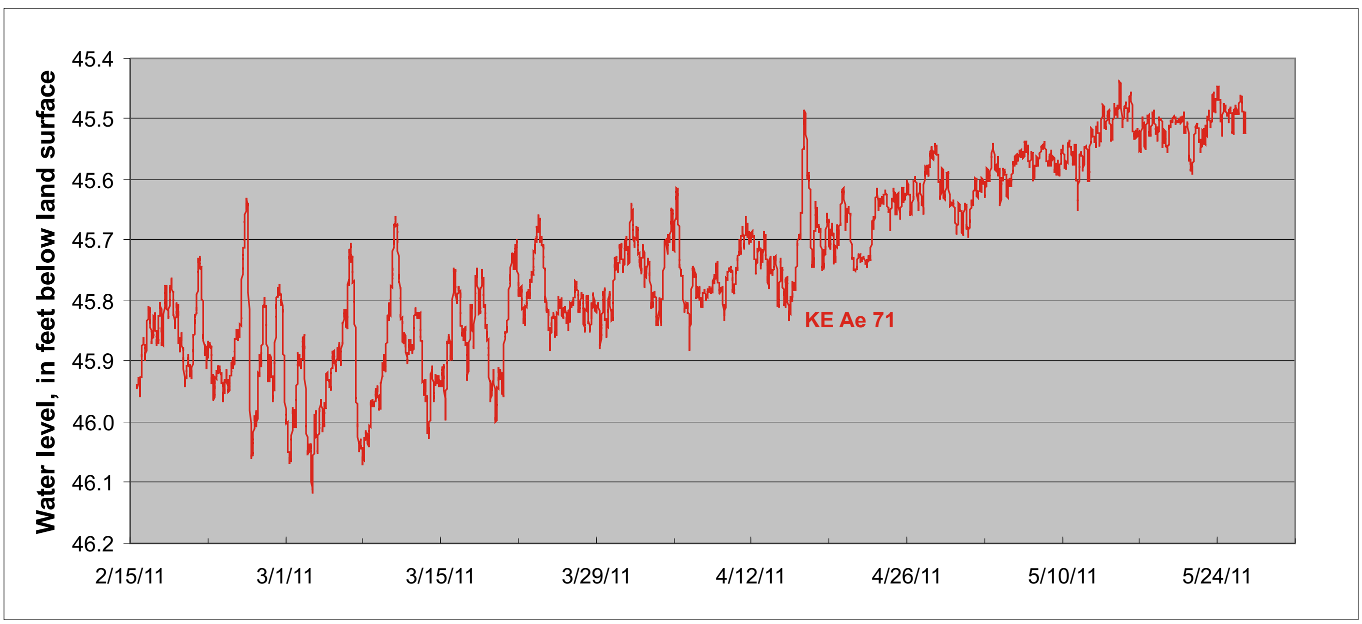



**Figure 40. Hydrograph for test well KE Ae 71, at Sassafras.**

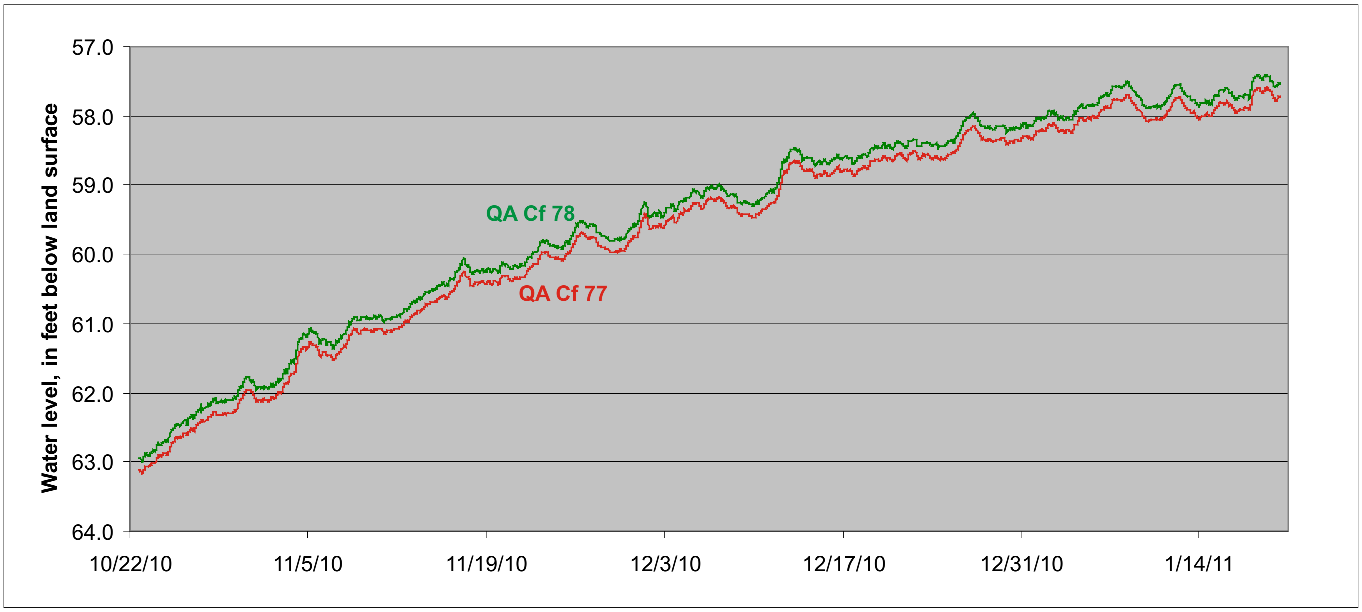



**Figure 41. Hydrographs for test wells QA Cf 77 and 78, at Church Hill.**

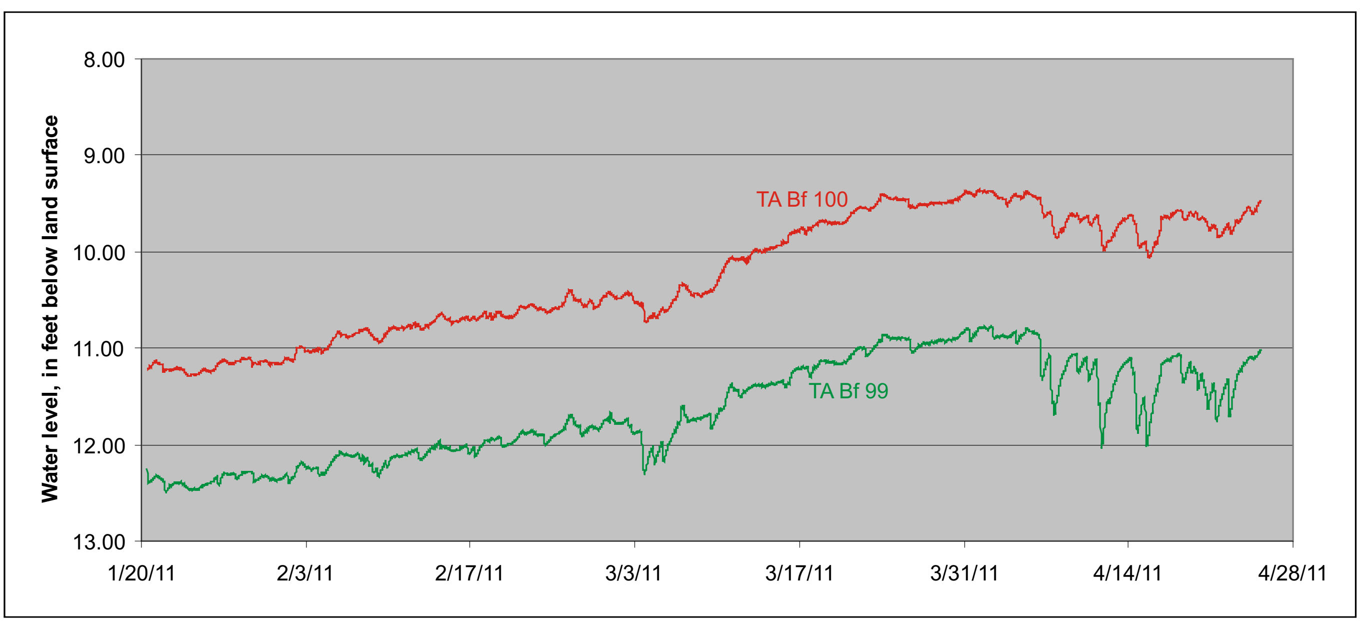



**Figure 42. Hydrographs for test wells TA Bf 99 and 100, at Cordova.**

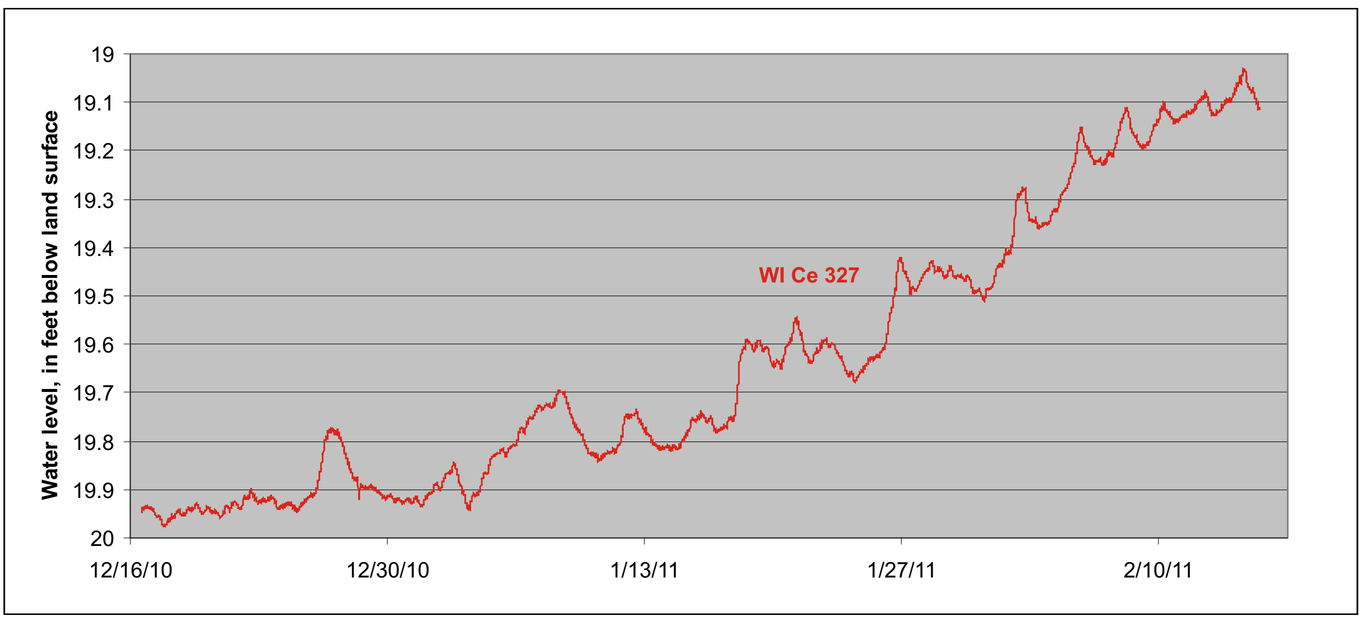



**Figure 43. Hydrograph for test well WI Ce 327, at LESREC.**

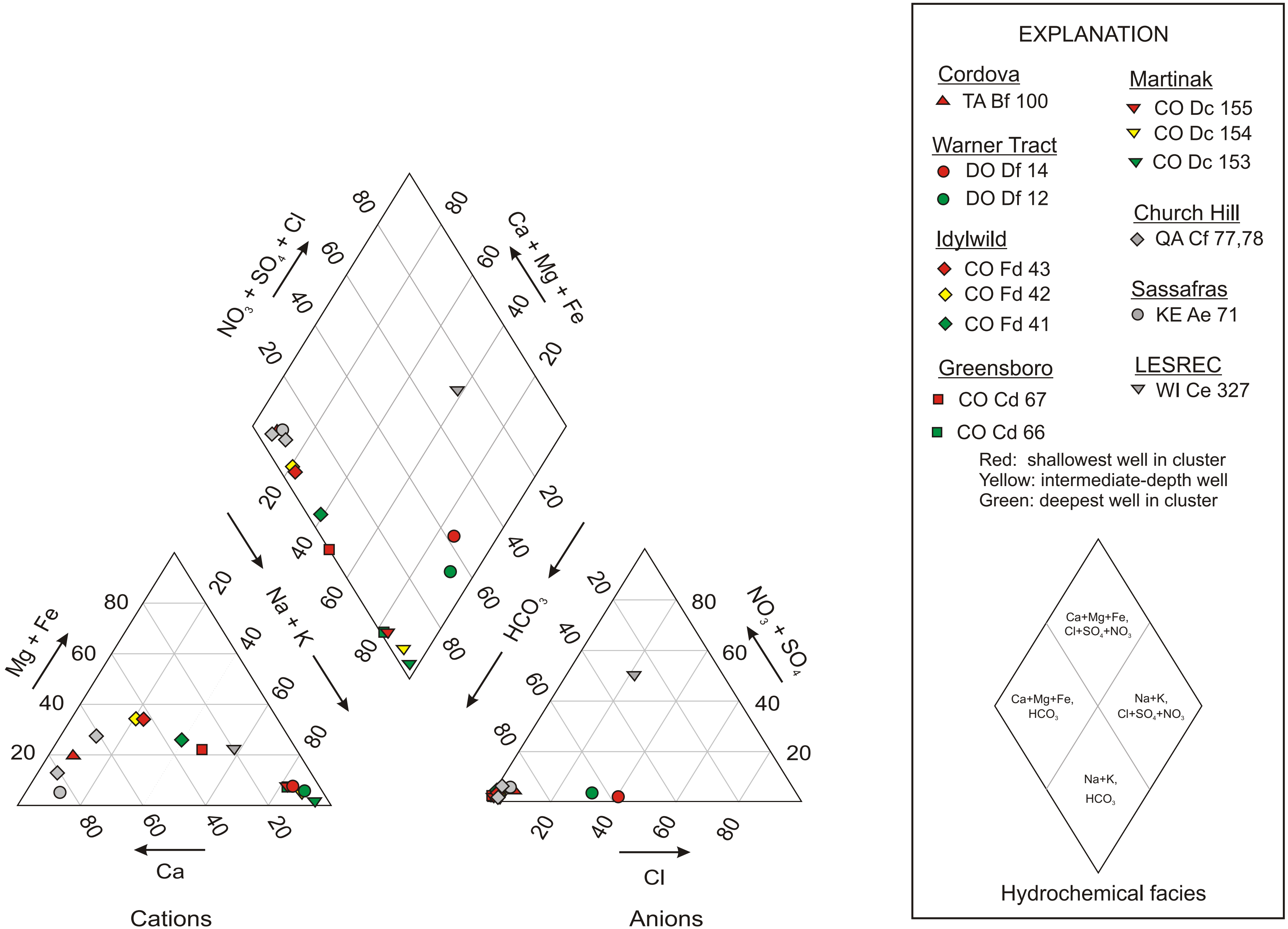



**Figure 44. Piper diagram showing milliequivalent percentages of major ions from wells sampled in 2010.**

## Table 1. Generalized stratigraphy and hydrogeology of the Eastern Shore of Maryland

[Modified from Werkheiser, 1990 and Drummond, 2001]

| System | Series | Strati-graphic unit | Hydro-geologic unit | Approximate maximum thickness (feet) | Lithology | Water-bearing properties |
|---|---|---|---|---|---|---|
| Quaternary | Pleistocene | Kent Island Formation | Columbia aquifer | 70 | Loose, light-colored medium to coarse sand and dark-colored, massive silt clay. | Functions as an unconfined or semi-confined aquifer. Yields moderate amounts of water to shallow wells. Vulnerable to contamination from surface sources. |
| Tertiary | Pliocene (?) and/or Upper Miocene (?) | Pensauken Formation | | | Orange to reddish brown, fine to coarse sand and gravelly sand. | |
| | ? Miocene | Yorktown Formation (?) | Pocomoke and Ocean City aquifers with confining units | 240 | Gray fine to medium sand with stringers of coarse sand and interbeds of clay and silt. | Aquifers used on the lower Eastern Shore; not addressed in this study. |
| | | ? Eastover Formation (?) | | | Grayish tan fine to coarse sandwith some shell and glauconite. | |
| | | ? | Manokin aquifer | 180 | Gray fine to medium sand with some shell material. | A productive aquifer on the lower Eastern Shore. |
| | | St. Mary's Formation | St. Mary's confining unit | 190 | Greenish-gray sandy clay and clayey fine-grained sand. | Functions as confining unit. |
| | | Choptank Formation | Choptank aquifer | 270 | Gray fine to coarse sand with shell beds and lenses of gray clay. | A minor aquifer on the middle and lower Eastern Shore. |
| | | Calvert Formation | Calvert aquifer system and confining units | 580 | Gray quartz sand and dark gray silt and clay with abundant shell material. | Contains multiple sandy units in the southeastern part of the study area. Elsewhere functions as a leaky confining unit. |
| | Eocene | Piney Point Formation | Piney Point aquifer | 260 | Green to gray, fine to coarse glauconitic quartz sand with abundant shell material. | An important confined aquifer in the middle Eastern Shore. |
| | | Nanjemoy Formation | Nanjemoy confining unit | 380 | Green to gray glauconitic sandy silt and clay. | Functions as a leaky confining unit on the middle and lower Eastern Shore. |
| | | Lower Eocene sand | Aquia aquifer | 260 | Green to gray, fine to medium, glauconitic quartz sand with abundant shell material and layers of calcite-cemented sand. | An important confined aquifer on the upper and middle Eastern Shore. |
| | Paleocene | Aquia Formation | | | | |
| | | Hornerstown Formation | | | | |
| Cretaceous | Upper Cretaceous | Monmouth Formation | Monmouth aquifer/ Severn confining unit | 140 | Dark gray to dark green glauconitic sandy, silty clay. | Functions as an aquifer on the upper Eastern Shore; elsewhere as a confining unit. |
| | | Matawan Group (undivided) | Matawan aquifer/ confining unit | 550 (?) | Dark gray to dark green glauconitic sandy, silty clay with lenses of light gray, fine to medium quartz sand. . | Functions as a poor aquifer in the northern part of the study area; elsewhere as a confining unit. |
| | | Magothy Formation | Magothy aquifer/ confining unit | 160 | Light gray, fine to coarse quartz sand and gray to black lignitic clay. | Functions as a confined aquifer on parts of the upper and middle Eastern Shore; elsewhere as a confining unit. |
| | ? Lower Cretaceous | Potomac Group | Aquifers and confining units | 4,700 (?) | Light gray to white fine to very coarse quartz sand, interbedded with dark gray and variegated clay. | Very productive confined aquifers interbedded with thick confining units; not penetrated by wells in this study. |
| Paleozoic | --- | Basement Complex | --- | --- | Variable types of crystalline rock. | Not used for water supply in the study area. |

## Table 2. Construction and yield characteristics of test wells drilled in 2010

[ft, feet; in., inches; gal/min, gallons per minute; [(gal/min)/ft], gallons per minute per foot; deg, degrees; min, minutes; sec, seconds; --, not applicable. All wells were constructed with 4.5-inch diameter plastic casing and screen; screen slot-size is 0.02 inches.]

| Well number | State permit number | Location | Latitude deg min sec | Longitude deg min sec | Date completed | Altitude of land surface (ft above sea level) | Depth drilled (ft below land surface) |
|---|---|---|---|---|---|---|---|
| CO Cd 66 | CO-95-0869 | Greensboro | 38 58 19 | 75 48 07 | 6/11/2010 | 5 | 240 |
| CO Cd 67 | CO-95-0870 | Greensboro | 38 58 19 | 75 48 07 | 6/15/2010 | 5 | 168 |
| CO Dc 153 | CO-95-0860 | Martinak State Park, Denton | 38 51 59 | 75 50 22 | 8/4/2010 | 18 | 310 |
| CO Dc 154 | CO-95-0861 | Martinak State Park, Denton | 38 51 59 | 75 50 22 | 8/7/2010 | 18 | 249 |
| CO Dc 155 | CO-95-0862 | Martinak State Park, Denton | 38 51 59 | 75 50 22 | 8/9/2010 | 18 | 214 |
| CO Dc 156 | CO-95-0942 | Martinak State Park, Denton | 38 51 59 | 75 50 22 | 8/9/2010 | 18 | 81 |
| CO Fd 41 | CO-95-0864 | Idylwild Wildlife Management Area, Federalsburg | 38 41 57 | 75 45 41 | 6/25/2010 | 32 | 400 |
| CO Fd 42 | CO-95-0865 | Idylwild Wildlife Management Area, Federalsburg | 38 41 57 | 75 45 41 | 6/30/2010 | 32 | 341 |
| CO Fd 43 | CO-95-0866 | Idylwild Wildlife Management Area, Federalsburg | 38 41 57 | 75 45 41 | 7/2/2010 | 32 | 279 |
| DO Df 12 | DO-95-1027 | Warner Tract | 38 29 45 | 75 57 02 | 7/21/2010 | 9 | 400 |
| DO Df 13 | DO-95-1028 | Warner Tract | 38 29 45 | 75 57 02 | 7/27/2010 | 9 | 280 |
| DO Df 14 | DO-95-1029 | Warner Tract | 38 29 45 | 75 57 02 | 7/29/2010 | 9 | 180 |
| KE Ae 71 | KE-95-0814 | Sassafras Natural Resource Management Area | 39 20 53 | 75 59 29 | 10/4/2010 | 85 | 290 |
| QA Cf 77 | QA-95-2124 | Church Hill Park, Church Hill | 39 08 45 | 75 58 23 | 8/27/2010 | 59 | 400 |
| QA Cf 78 | QA-95-2125 | Church Hill Park, Church Hill | 39 08 45 | 75 58 23 | 8/30/2010 | 59 | 225 |
| TA Bf 99 | TA-95-1559 | Cordova | 38 52 23 | 75 59 50 | 8/17/2010 | 53 | 240 |
| TA Bf 100 | TA-95-1560 | Cordova | 38 52 23 | 75 59 50 | 8/19/2010 | 53 | 140 |
| WI Ce 327 | WI-95-3050 | University of Maryland Lower Eastern Shore Research and Education Center (LESREC) | 38 22 20 | 75 39 23 | 5/20/2010 | 38 | 240 |

**Table 2. Construction and yield characteristics of test wells drilled in 2010—Continued**

| Screen interval (ft below land surface) | Aquifer | Water Levels, (ft below land surface) (negative levels are above land surface) | | Drawdown (ft) | Date measured | Pumping rate (gal/min) | Hours pumped | Specific capacity [(gal/min)/ft] | Well number |
|---|---|---|---|---|---|---|---|---|---|
| | | Static | Pumped | | | | | | |
| 175-190 | Calvert | -11.99 | 64.14 | 76.13 | 6/29/2010 | 65.8 | 24 | 0.86 | CO Cd 66 |
| 145-160 | Calvert | -10.72 | 101.52 | 112.24 | 7/6/2010 | 45.3 | 24 | 0.40 | CO Cd 67 |
| 286-302 | Calvert | 18.51 | 119.62 | 101.11 | 8/16/2010 | 86 | 24 | 0.85 | CO Dc 153 |
| 232-244 | Calvert | 18.23 | 165.18 | 146.95 | 8/19/2010 | 18 | 24 | 0.12 | CO Dc 154 |
| 184-209 | Calvert | 16.61 | 149.36 | 132.75 | 8/25/2010 | 76 | 24 | 0.57 | CO Dc 155 |
| 66-76 | Choptank | 12.64 | -- | -- | 8/13/2010 | -- | -- | -- | CO Dc 156 |
| 364-374 | Calvert | 41.34 | 277.21 | 235.87 | 7/13/2010 | 13 | 24 | 0.05 | CO Fd 41 |
| 326-336 | Calvert | 40.95 | 201.21 | 160.26 | 7/22/2010 | 61 | 24 | 0.38 | CO Fd 42 |
| 234-244<br>248-258<br>264-274 | Calvert | 42.30 | 185.31 | 143.01 | 7/19/2010 | 65 | 24 | 0.45 | CO Fd 43 |
| 290-330 | Calvert | 17.57 | 83.45 | 65.88 | 8/4/2010 | 101 | 24 | 1.53 | DO Df 12 |
| 242-272 | Calvert | 17.01 | -- | -- | 8/4/2010 | -- | -- | -- | DO Df 13 |
| 134-174 | Choptank | 16.13 | 99.55 | 83.42 | 8/9/2010 | 8.6 | 24 | 0.10 | DO Df 14 |
| 110-120 | Monmouth | 45.25 | 89.20 | 43.95 | 11/3/2010 | 9 | 3.3 | 0.20 | KE Ae 71 |
| 315-355 | Aquia (Hornerstown Fm.) | 70.46 | 143.13 | 72.67 | 9/8/2010 | 80 | 24 | 1.10 | QA Cf 77 |
| 190-220 | Aquia (Aquia Fm.) | 70.25 | 109.16 | 38.91 | 9/13/2010 | 89.3 | 24 | 2.30 | QA Cf 78 |
| 178-188 | Calvert | 16.82 | -- | -- | 9/1/2010 | -- | -- | -- | TA Bf 99 |
| 110-130 | Calvert | 16.02 | 52.97 | 36.95 | 9/1/2010 | 12 | 24 | 0.32 | TA Bf 100 |
| 140-160 | Manokin | 20.27 | 32.90 | 12.63 | 5/26/2010 | 118 | 4 | 9.34 | WI Ce 327 |

**Table 3. Lithologic description of drill cuttings and cores for test well CO Cd 66, at Greensboro**

Greensboro Carnival Ground, Caroline County

CO Cd 66
Alt. = 5 ft

| Depth (feet) | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, coarse to medium, orange, predominantly subrounded quartz, some black and iron-stained grains |
| 10 – 20 | Clay, silty, brownish gray, abundant heavily pitted and abraded shell fragments, minor quartz clasts with iron staining |
| **Calvert aquifer system** | |
| 20 – 30 | Clay, silty, brownish gray, minor shell fragments |
| 30 – 40 | Silt, stiff, brownish gray, minor small shell fragments |
| 40 – 50 | Silt, as above |
| 50 – 60 | Silt, as above |
| 60 – 70 | Clay, silty, brown to gray, soft, minor fine sand and fine shell fragments |
| 70 – 80 | Clay, as above |
| 80 – 90 | Clay, as above |
| **90 - 91.8** | **Split-spoon core** Clay, silty, dark brown, stiff, massively bedded |
| 90 – 100 | Clay, silty, gray to light tan, soft, minor fine sand and fine shell fragments |
| 100 – 110 | Silt, clayey, stiff, dark brownish gray, significant shell fragments |
| 110 – 120 | Clay, greenish gray, significant shell fragments |
| 120 – 130 | Clay, as above, with minor brown clay |
| 130 – 140 | Clay, silty, greenish gray, some fine sand, abundant shell fragments, large clasts of indurated green sand |
| 140 – 150 | Sand, medium, greenish gray, subangular to subrounded, predominantly quartz, abundant shell fragments |

**Table 3. Lithologic description of drill cuttings and cores for test well CO Cd 66, at Greensboro–Continued**

CO Cd 66 — Continued

| Depth (feet) | Description |
|---|---|
| **Calvert aquifer system — continued** | |
| 150 – 160 | Sand, as above; minor clay, sand content less than previous interval |
| 160 – 170 | Sand, fine to medium, subrounded, greenish gray, predominantly quartz, clay present in matrix, abundant shell fragments |
| **168 - 170** | **Split-spoon core** Sand, clayey, greenish gray, partially indurated layering, abundant shell fragments |
| 170 – 180 | Shell and Sand, medium, subrounded, chiefly composed of unbroken and/or fragments of marine mollusk shells |
| 180 – 190 | Shell hash and Sand, fine, greenish gray, subrounded quartz |
| 190 – 200 | Shell hash and Sand, as above, with greater fraction of shells |
| **Calvert confining unit** | |
| 200 – 210 | Clay, silty, brownish to greenish gray, abundant shell fragments |
| 210 – 220 | Clay, as above, with fewer shells |
| 220 – 230 | Clay, as above |
| 230 – 240 | Clay, as above |
| **240 – 241.5** | **Split-spoon core** Clay, dark brown, dense, plastic, minor shell fragments |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak**

Martinak State Park, Caroline County

CO Dc 152
Alt. 18 feet

| Depth (feet) | Description |
|---|---|
| **Pensauken Formation – Surficial Aquifer** | |
| 0 – 7 | Sand, fine to coarse; coarsening downward to gravel at 7.0 ft; poorly sorted; (10YR 5/4) yellowish brown; mostly quartz, some clear, frosted, iron stained; rare black grains. Description from drill cuttings; no core 0 – 7 ft. |
| 7.0 – 8.1 | Sand, gravel, fine to coarse gravel, up to 2 cm; poorly sorted; mottled, (7.5 YR 5/8 and 10YR 5/6), yellowish brown; some clay. |
| 8.1 – 10.0 | No recovery |
| 10.0 – 11.0 | Sand, medium; moderately sorted, subangular, (10YR 6/4) light yellowish brown; rare black grains; mostly clear quartz; massive at top, faint reddish mottling 10.8-11.0 ft. |
| 11.0 – 12.0 | No recovery |
| 13.0 – 15.1 | Sand, medium; moderately sorted, subangular to subrounded, as above, faint mottling to 14.0; stronger mottling 14.0-15.1 with olive brown (10YR 4/6). |
| 15.1 – 16.0 | No recovery |
| 16.0 – 18.2 | Sand, as above, strong mottling. |
| 18.2 – 20.0 | No recovery |
| 20.0 – 20.6 | Sand, as above. |
| 20.6 – 21.2 | Sand, as above, slightly darker with layers (~5mm); black fine grains; (7.5YR 5/6). |
| 21.1 – 22.8 | Sand, as above, faintly mottled, (5YR 5/8) yellowish red. |
| **Choptank Formation – Choptank Aquifer** | |
| 22.8 – 23.2 | Sand, medium to coarse, clayey, moderately sorted, rounded; very dark greenish gray (Gley 1 3/5G); quartz, clear, colorless, sparse glauconite (?) grains; contact with above sand appears burrowed (?). |
| 23.2 – 25.0 | No recovery |
| 25.0 – 29.5 | Sand, as above, grading downward to fine sand and silt at 26.3 ft, then to clay at 26.9ft; greenish gray (Gley 1 5/10Y), massive; sparse lignite |
| 29.5 – 30.0 | No recovery |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Choptank Formation - Choptank Aquifer – continued** | |
| 30.0 – 38.4 | Clay, as above. Layers of slightly darker clay, silty, 0.5-1 cm thick. |
| 38.4 – 41.6 | Clay, silty, greenish-gray (Gley 1 5/5GY); sparse shell fragments (acid fizz); contact above gradational; irregular patches of lighter and darker clay. |
| 41.6 – 47.3 | Clay, reddish gray (2.5YR 5/1), slightly silty; fine (0.0-2.0 cm) layering; interlayered with greenish-gray clay (Gley 1 5/5 GY), 2-3 cm thick; irregular patches of light gray clay (5Y 7/2), up to 2.5 cm thick at 44.4 and 46.1 ft. |
| 47.3 – 52.0 | Clay, slightly silty, greenish gray (Gley 1 5/5GY), with patches and layers of darker (lignitic ?) clay, 5-10 mm thick; sparse pinkish shell fragments. |
| 52.0 – 56.0 | Clay, dark greenish gray (Gley 1 4/5GY); with abundant shell fragments; grading downward to silty sand, fine to medium, dark greenish gray (Gley 1 4/10Y), with sparse shell fragments. Grades downward. |
| 56.0 – 60.1 | Sand, fine to medium, silty (above), with faint bedding (Gley 1 4/10Y) |
| 60.1 – 65.4 | Clay, dark greenish gray (Gley 1 4/10Y), silty, very fine sand, fine bedding 0.1 mm; sparse shell fragments. |
| 65.4 – 66.5 | Sand, fine to medium, clayey, dark greenish gray (Gley 1 4/10Y) with sparse shell fragments (a turritella) (whole clam shell, 3 mm). |
| 66.5 – 67.5 | No recovery |
| 67.5 – 69.9 | Sand, as above, with abundant shell material 68.9 to 69.9 ft. |
| 69.9 – 70.0 | No recovery |
| 70.0 – 70.4 | Sand, clayey, as above. |
| 70.4 – 76.4 | Sand, fine, well sorted, subrounded, slightly clayey, very dark greenish gray (Gley 1 3/10Y); sparse shell material but abundant 70.9-71.3; sparse glauconite (?), very fine; massive with very faint bedding: clayey intervals 74.7 – 75.5 ft. |
| **Calvert Formation – Calvert Aquifer System** | |
| 76.4 – 77.1 | Clay, silty, dark greenish gray (Gley 1 4/10Y). |
| 77.1 – 77.4 | Sand, fine well sorted (Gley 1 3/10Y). |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert Formation – Calvert Aquifer System – continued** | |
| 77.4 – 79.7 | Clay, dark grayish brown (2.5Y 3/2); with layers of sand, medium to coarse, dark greenish gray (Gley 1 4/10Y) well sorted, subrounded, quartz stained greenish gray, rare glauconite (?); sand layers irregular, 2-20 mm thick. Contact above irregular, burrowed. |
| 79.7-80.0 | No recovery |
| 80.0 – 82.5 | Clay, as above, with sand stringers. |
| 82.5 – 83.4 | Clay, as above, with layers of find sand, light gray. |
| 83.4 – 84.0 | No recovery |
| 84.0 – 90.0 | Clay, as above, finely bedded, with occasional layers and pods of fine, medium sand, as above. |
| 90.0 – 93.5 | Clay, as above, with layers and pods of sand (some with shell material). |
| 93.5 – 94.7 | Clay, sandy, silty, dark greenish gray (Gley 1 4/10Y), with very abundant shell materials, gravel. |
| 94.7 – 95.0 | No recovery |
| 95.0 – 96.4 | Clay, sandy, as above. |
| 96.4 – 100.0 | Clay, dark grayish brown (2.5Y 3/2), silty, with layers of dark greenish gray clay, sand; shells 10-30 mm thick, irregular; contact above alternating 40mm-50mm. |
| 100.0- 102.0 | Clay, as above with sandy layers. |
| 102.0 – 110 | Clay, as above, no sandy layers. |
| 110.0 – 111.1 | Clay, as above, with sparse shell fragments. |
| 111.1 – 113.2 | Clay, silty, sandy, with very abundant shells, shell fragments; dark greenish gray (Gley 1 4/10Y); contact above transitional over 10 cm. |
| 113.2 – 115.7 | Clay, very dark grayish brown (2.5Y 3/2), with layers of sandy clay, abundant shells 3cm – 8 cm thick. |
| 115.7 – 121.9 | Clay, as above, interbedded with layers of find silty sand, clayey, very dark greenish gray (Gley 1 3/10Y), 1-10mm interlayers; some shelly intervals. |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert Formation – Calvert Aquifer System – continued** | |
| 121.9 – 128.0 | Sand, very fine to fine, clayey, sparse shell material, dark greenish gray (Gley 1 3/10Y), sparse glauconite(?); layer of coarse sand 126.3-126.6 ft, shelly. |
| 128.0 – 128.5 | Clay, silty, very dark grayish brown (2.5Y 3/2), with layers of fine to medium silty sand, very dark greenish gray (Gley 1 3/10Y), shelly, 2-30mm thick; contact above gradational. |
| 128.5 – 130.0 | No recovery |
| 130.0 – 133.7 | Clay, as above, with shelly sand stringers; sand percentage increases downward to transitional contact. |
| 133.7 – 137.9 | Sand, fine to medium, well sorted, subrounded to subangular, very dark greenish gray (Gley 1 3/10Y); mostly quartz, clear colorless and green stained; common glauconite, very fine, black-green; sparse shell fragments; layers of dark grayish brown clay 10-40 mm thick; contact above transitional. |
| 137.9 – 140.0 | Clay, very dark grayish brown (2.5Y 3/2), alternating with layers of find sand, very dark greenish gray (Gley 1 3/10Y) with very fine glauconite; well sorted, subangular; sand contains fine fragments of shell material; sandy layers 2-30mm; sparse lignite(?) in clay. |
| 140.0 – 147.0 | Clay, as above, with sandy stringers; very fine bedding with very fine sand beds, 0.5mm and thicker. |
| 147.0 – 148.3 | Clay, as above, with thicker interbeds of medium sand and shell fragments. |
| 148.3 – 149.7 | Sand, medium, well sorted, subround to subangular, quartz clear, colorless, green-stained, fine glauconite (sparse), very abundant shell. |
| 149.7 – 150.0 | No recovery |
| 150.0 – 153.0 | Sand, shells, as above. |
| 153.0 – 154.3 | Sand, shells, as above, but darker, with some interstitial dark gray clay. |
| 154.3 – 154.5 | No recovery |
| 154.5 – 156.0 | Clay, dark greenish gray (Gley 1 4/10Y), silty; indurated, very hard 154.5 to 154.7; abundant small shell fragments 154.5 to 155.4 ft; layer of sand, medium, very dark greenish gray (Gley 1 3/10Y), 1 cm thick at 155.5. |
| 156.0 – 156.8 | Clay, as above, but no silt. |
| 156.8 – 160.0 | No recovery |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert Formation – Calvert Aquifer System – continued** | |
| 160.0 – 169.8 | Clay, silty, dark greenish gray (Gley 1 4/10Y), weakly cemented, calcareous (acid fizz); irregular banding with lighter-darker, slightly sandy patches; sparsely glauconitic (very fine). |
| 169.8 – 170.0 | No recovery |
| 170.0 – 180.0 | Clay, silty, as above. Large shells 30-40mm at 170.0, 171.4, 173.7, 174.6, 175.3, 176.3, 176.5, 176.9, 177.2; several between 177.5 to 179.0 ft. |
| 180.0 – 182.7 | Clay, silty, as above, with occasional large thin shells. |
| 182.7 – 185.2 | Clay, silty, as above, with very abundant shells; shells mostly white to light pink, also some black, light green glauconitic shell fragments; indurated, hard 183.0-183.2, 184.2-185.0 ft. |
| 185.2 – 187.7 | Sand, medium, well sorted, subrounded to subangular, dark greenish gray (Gley 1 4/10Y); sand quartz, clear, stained green; glauconite 5-10 percent, black, fine to medium; layers, irregular thin patches 2-5mm of lighter, clayey sand (burrows?). |
| 187.7 – 190.0 | No recovery |
| 190.0 – 190.4 | Clay, dark greenish gray (Gley 1 4/10Y), mixed with sand, as below, possible sluff. |
| 190.4 – 191.6 | Sand, medium, well sorted, subrounded to subangular, very dark greenish gray (Gley 1 3/10Y); sand quartz, clear and green-stained; glauconite fine grained, black, 5-10 percent. |
| 191.6 – 200.0 | No recovery |
| 200.0 – 201.6 | Sand, as above; becoming clayey toward bottom; slightly lighter gray in faint irregular structures. |
| 201.6 – 204.0 | No recovery |
| 204.0 – 207.9 | Sand, as above, not much clay. |
| 207.9 – 209.0 | Clay, silty with very fine sand, dark greenish gray (Gley 1 4/10Y); sparse shell fragments 2-3mm; faint structures with slightly different colors, different amounts of silt. |
| 209.0 - 210.0 | No recovery |
| 210.0 – 211.5 | Sand, fine (Gley 1 3/10Y). |
| 211.5 – 212.5 | Clay, silty with very fine sand (Gley 1 4/10Y), sparse shell material. |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert Formation – Calvert Aquifer System – continued** | |
| 212.5 – 212.9 | Sand, clayey, medium, well sorted, subrounded to subangular, quartz, clear colorless and green-stained (Gley 1 3/10Y); with abundant shell material, hash; sparse, very fine glauconite, black; sparse lignite. |
| 212.9 – 220.0 | No recovery |
| 220.0 – 220.7 | Sand, clayey, as above, with abundant shell material. |
| 220.7 – 222.3 | Sand, clayey, as above, but shell material less abundant. |
| 222.3 – 226.4 | Sand, as above, but sparse shell material. |
| 226.4 – 229.7 | Clay, very dark grayish brown (10YR 3/2), silty , with layers of gray silt, very find sand, 0.5 to 4 mm thick, and irregular layers of black clay 1-3mm thick; contact above irregular, transitional. |
| 229.7 – 230.0 | No recovery |
| 230.0 – 231.2 | Clay, as above, with very fine sand stringers. |
| 231.2 – 240.0 | No recovery |
| 240.0 – 244.4 | Sand, very fine to fine, clayey, silty; poorly sorted; abundant shell material 240.0 to 242.2 ft. Fining upward from 245.8 to 240.0 ft. |
| 244.4 – 245.8 | Sand, medium to coarse, clayey, poorly sorted, subangular to subrounded, very dark greenish gray (Gley 1 3/5GY); abundant sand-sized shell fragments; common glauconite (black, fine); contact above gradual. Fining upward. |
| 245.8 – 246.3 | Clay, dark greenish gray (Gley 1 4/10Y). |
| 246.3 – 246.8 | Sand, fine to medium, clayey, with abundant shell material. |
| 246.8 – 247.0 | No recovery |
| 247.0 – 249.2 | Sand, fine, very clayey, poorly sorted, angular to subangular, greenish gray to dark greenish gray (Gley 1 5/10Y, 4/10Y); abundant shell material, highly altered (soft), abundant fine shell fragments (sand size); common glauconite, very fine, black. |
| 249.2 – 250.0 | No recovery |
| 250.0 – 254.2 | Sand, fine, clayey, as above; shell material, glauconite increase downward. |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert Formation – Calvert Aquifer System – continued** | |
| 254.2 – 254.5 | No recovery |
| 254.5 -254.7 | Sand, clayey, as above. |
| 254.7 – 260.0 | Sand, fine to medium, some coarse, very coarse sand grains, very clayey, very poorly sorted dark greenish gray (Gley 1 4/10Y); slightly indurated with calcareous cement hash; very abundant shell fragments; common glauconite, very fine to coarse grains, black; fragments hard black material (shell?); abundant black fragments at 257.0 ft; shell less abundant, 257.3-260.0 ft. |
| 260.0 – 263.4 | Sand, fine to medium, well sorted, subrounded to subangular; dark greenish gray (Gley 1 4/10Y); abundant shell fragments, sand-sized; sparse glauconite, fine sand-sized; quartz clear, colorless, gray stained; alternating with layers of clay 3 to 15 mm thick, dark greenish gray (Gley 1 4/5GY). |
| 263.4 – 263.5 | No recovery |
| 263.5 – 270.0 | Sand, as above. |
| 270.0 – 273.8 | Sand, clay layers alternating as above. |
| 273.8 – 280.0 | No recovery |
| 280.0 – 280.4 | Sand, as above |
| 280.4 – 282.0 | Clay, silty, dark greenish gray (Gley 1 4/10Y), with layers of sand (as above) 10-20cm. |
| 282.0 – 290.0 | No recovery. Note: Sample taken from shoe of this run, of questionable integrity: Sand, fine to medium, poorly sorted, subangular to subrounded, common fine glauconite, fine shell fragments; quartz clear colorless and gray-green stained. |
| 290.0 – 293.1 | Sand, medium to coarse, moderately sorted, subrounded; dark grayish green (Gley 1 4/10Y); common shell fragments, sand-sized, white and black; glauconite common, fine sand-sized, black; no bedding or other structure.<br>Note: This entire interval is questionable (fairly soft, no bedding); driller reports hole is collapsing. Sand may have sluffed into bottom of hole from above. |
| 293.1 – 294.5 | Sand, clayey, fine to medium, poorly sorted; dark greenish gray (Gley 1 4/5GY); fine sand-sized shell fragments, hash; common glauconite; very hard, calcite-cemented section 294.2 to 294.5 ft. |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert Formation – Calvert Aquifer System – continued** | |
| 294.5 – 297.7 | Sand, clayey, fine to medium, poorly sorted, subrounded, greenish- gray (Gley 1 5/10Y); glauconite abundant sand-size shell fragments, ranging white, green, gray, black; common; irregular layers and lenses of clay, very dark greenish gray (Gley 3/10Y), 10-30 cm thick; all clay 296.1 to 297.4 ft; mostly sand 297.4 to 297.7 ft. |
| 297.7 – 300.0 | No recovery |
| 300.0 – 302.0 | Sand, medium to coarse, poorly sorted, subangular to subrounded; very dark gray (Gley 1 3/10Y); abundant shell fragments, medium to coarse sand-sized, mostly black, some white, green; common glauconite; clay intervals 300.35 to 300.45 ft, 300.8-300.9 (as below). |
| 302.0 – 310.0 | Clay, dark olive-gray (5Y 3/2); slightly silty; sparse shell fragments, white, beige; contact above transitional over 0.2 ft. |
| 310.0 – 310.4 | Clay, silty, dark olive gray (5Y 3/2); faint bedding with siltier laminae; rare pyrite grains, very fine; sparse shell fragments 2-3mm. |
| 310.4 - 319.7 | No recovery |
| 319.7 – 320.0 | Clay, as above. |
| 320.0 – 326.4 | Clay, silty, dark olive gray (5Y 3/2), as above; glauconite rare at top (320.0 ft), increasing to abundant at 320.7 ft, glauconite very fine to fine, black; muscovite rare, very fine; shell material increasing with glauconite percentage; glauconite-rich sand in irregular layers and pods; glauconite reduces to rare at 322.4 ft. |
| 326.4 - 329.1 | Sand, fine to medium, very clayey, black (5Y 2.5/1), poorly sorted, subangular; abundant glauconite, black, very fine to medium; common shell material (fragments and whole) more abundant 328.5 to 329.1 ft; contact above indistinct. |
| 329.1 – 330.0 | No recovery |
| 330.0 – 330.1 | Sand, as above. |
| 330.1 – 333.4 | Sandstone, with very abundant shells, fragments, cemented with calcite, very hard; color varies: very dark greenish gray (Gley 1 3/10Y); contact above distinct. |
| **Piney Point Formation – Piney Point Aquifer** | |
| 333.4 – 333.5 | Sand, clayey, fine to coarse, mostly medium, poorly sorted; subangular, some subrounded; very dark greenish gray (Gley 1 3/10Y), color caries; abundant glauconite (20%?) mostly black, botryoidal, fine sand-sized, some lighter green, very fine; common (blue) quartz grains, coarse sand to 5 mm; common shell fragments; clayey matrix calcitic (acid fizz). |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Piney Point Formation – Piney Point Aquifer -- continued** | |
| 333.5 – 335.0 | No recovery |
| 335.0 – 336.2 | Sand, clayey, as above. |
| 336.2 – 339.15 | Sand (not clayey), medium to coarse, moderate-sorting; subangular; greenish black (Gley 1 2.5/5GY); glauconite very abundant, 20-30 percent; mostly black, botryoidal, medium grained, some light green; sparse pyrite, very fine grained; rare shell fragments. |
| 339.15 – 340.0 | No recovery |
| 340.0 – 342.2 | Sand, medium to coarse, as above. Shells, fragments more abundant 341.6-342.2 ft. |
| 342.2 – 350.0 | Sand, medium to coarse, as above; with calcareous matrix; abundant shell fragments; (Gley 1 4/5GY), dark greenish gray; orange shell fragments 348.4, 347.5 ft; sparse phosphate pellets; sparse quartz grains very coarse, up to 6 mm. |
| 350.0 – 353.7 | Sand, as above; calcite cemented bed at 351.3 to 351.4, very hard. |
| 353.7 – 354.1 | Sand, clayey, cement (calcareous), dark greenish gray (Gley 1 4/10Y). |
| 354.1 – 360.0 | No recovery |
| 360.0 – 369.7 | Sand, medium to coarse, medium sorting, subangular; greenish black (Gley 2.5/5GY); weakly indurated with calcite matrix in irregular patches; glauconite abundant, up to 50 percent, black, botryoidal, medium grained; abundant shell fragments, mostly sand-sized, a few larger; quartz mostly clear colorless, and green-gray strained, common reddish-brown opaque, some very coarse sand-sized. |
| 369.7 – 370.0 | No recovery |
| 370.0 – 371.75 | Sand, as above, with patches of light green clay (drilling mud?).<br>Note: There was 0.5 ft of sluff in the middle of good (?) material that was discarded; amount of loss is unknown. |
| 371.75 – 380.0 | No recovery |
| 380.0 – 389.6 | Sand, medium to coarse, as above, moderate sorting, subangular; very dark greenish gray (Gley 1 3/10Y); weakly indurated with calcitic matrix 380.2 to 380.6 ft; very abundant glauconite, 50 percent in places, black, botryoidal, some light greenish gray, some brown; abundant very coarse sand grains, some medium yellow-brown; common shell fragments. Layer of sandy clay, 384.2 to 384.6 ft, dark greenish gray (Gley 1 4/10Y); matrix calcareous; sand medium to coarse, glauconitic. |

**Table 4. Lithologic description of drill cuttings and cores for test well CO Dc 152, at Martinak—Continued**

CO Dc 152 - Continued

| Depth (feet) | Description |
|---|---|
| **Piney Point Formation – Piney Point Aquifer – continued** | |
| 389.6 - 390.0 | No recovery |
| 390.0 – 396.6 | Sand, as above, with some clay matrix, clay increasing downward; a few large (>50 mm) shells (oyster?). |
| 396.6 – 400.0 | No recovery<br>End of hole |

**Table 5. Lithologic description of drill cuttings and cores for test well CO Fd 41, at Idylwild**

Idylwild Wildlife Management Area, Caroline County

CO Fd 41
Alt. 32 feet

| Depth (feet) | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, coarse, well sorted, subrounded; 0-5 ft dark yellowish brown (10YR 4/4); 5 -10 ft light olive brown (10 YR 5/3); clear, colorless, some iron-stained quartz. |
| 10 -20 | Sand, coarse, with abundant very coarse grains, light olive brown (10YR 5/3), subrounded, poorly sorted; mostly clear colorless quartz with some iron stained, white opaque, and black grains. |
| 20 -30 | Sand, very coarse, poorly sorted, subrounded-subangular, dark yellowish brown (10YR 4/4); mixed clear, iron stained yellow, red, brown, sparse black grains. |
| 30 – 40 | Sand, as above, coarse to very coarse mostly iron stained; dark yellowish brown (10YR 4/6). |
| 40 – 50 | Gravel up to 13 mm, subrounded-subangular; mixed clear colorless, iron stained red, orange, brown, white; some grains have rinds of iron oxide; dark yellowish brown (10YR 4/4); few clasts of clay, dark greenish gray (Gley 1 4/10Y), not silty; driller reports clay 45-50 ft; chert grains; fragments of iron-cemented sandstone, glauconitic. |
| **Calvert aquifer system** | |
| 50 – 60 | Clay, gray (5 YR 5/1) and reddish gray (5YR 5/2); slightly silty, very fine muscovite; black grains (lignite ?); sample contains mostly gravel from above. |
| 60 – 70 | Clay, slightly silty, gray as above. |
| 70 – 80 | Clay, as above, not silty; driller reports pinkish clay at top of interval, greenish below, greenish gray (Gley 5/10Y). |
| 80 – 90 | Clay, greenish gray (Gley 5/10Y); slightly more black grains; slightly silty. |
| 90 – 100 | Clay, dark greenish gray (Gley 4/10Y); more black grains; slightly silty. |
| 100 – 110 | Clay, very dark greenish gray (Gley 3/10Y); some shell fragments 105-108 ft. |
| 110.0 – 110.7 | Core: Clay, mottled light to dark gray, some pinkish (Gley 1 4/10Y to 2/10Y, 5YR 5/1), with a few large gravels up to 12 mm (this interval is highly questionable). |
| 110.7-111.2 | Core: Sand, very fine to fine, silty; poorly sorted, angular to subangular; very dark greenish gray (Gley 1 3/10Y); mostly quartz clear colorless; some green-stained; common black very fine grains. |

**Table 5. Lithologic descrtiption of drill cuttings and cores for test well CO Fd 41, at Idylwild—Continued**

CO Fd 41 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert aquifer system – continued** | |
| 110 – 120 | Clay, dark greenish gray (Gley 4/10Y); very abundant shell fragments 115-120 ft, mostly pale brown, some black, clams, pectinids? |
| 120- 130 | Clay, very dark greenish gray (Gley 3/10Y) with very abundant shells, fragments, some whole clams up to 12 mm, also snails, pectinids, oysters; some sand, medium, subangular to subrounded, quartz; sparse black glauconite. |
| 130 -140 | Clay, sandy, very dark greenish gray (Gley 3/10Y), with very abundant shell fragments (as above); sand fine, clear colorless quartz, with sparse black glauconite very fine. |
| 140 – 150 | Clay, sandy as above, with some lighter greenish gray (Gley 6/5G), with calcareous matrix (acid fizz). |
| 150 – 160 | Clay, silty, sandy as above, greenish gray (Gley 1 5/5G), calcareous matrix, fine shell fragments. |
| 160 – 170 | Clay, as above. |
| 170 – 180 | Clay, silty, as above, dark greenish gray (Gley 1 4/10Y), abundant shell material 178-180 ft. |
| 180.0 – 180.5 | Core: Clay, silty, dark greenish gray (Gley 1 4/10Y); abundant shell material at 180.25, 180.4 weathered fairly soft, light gray (10YR 7/2). |
| 180 – 190 | Clay, very sandy, silty; dark greenish gray (Gley 1 4/10Y), very abundant shell material, as above; sand fine to medium, poorly sorted (?), subangular to subrounded, clear colorless, green-stained quartz, sparse black grains. |
| 190 – 200 | Clay, very sandy as above, abundant sand, medium to coarse, subangular, clear green stained quartz, with abundant black glauconite, medium; sparse fragments of clay, very dark grayish brown (2.5Y 3/2), with abundant fine glauconitic sand. |
| 200 – 210 | Clay, silty, sandy, as above; mostly dark greenish gray (Gley 1 4/10Y), some very dark grayish brown (2.5Y 3/2), very glauconitic; sparse shell material; some sand, as above; sparse coarse, black grains (glauconite ?); sparse lignite/peat. |
| 210 – 220 | Clay, silty, as above, mostly very dark grayish brown (2.5Y 3/2), sparse shell material (2 turritellid fragments); less sand than above. |
| 220 – 230 | Clay, slightly silty; dark olive gray (5Y 3/2); sparse shell fragments; sand in sample, as above, not in clay. |

**Table 5. Lithologic descrtiption of drill cuttings and cores for test well CO Fd 41, at Idylwild—Continued**

CO Fd 41 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert aquifer system – continued** | |
| 230 – 240 | Clay, silty, as above; abundant shell fragments; sand in sample, as above. |
| 240 – 250 | Sand, fine to medium, subangular; very dark greenish gray (Gley 1 4/10Y); mostly clear colorless quartz, some green-stained; sparse black grains irregularly shaped (glauconite?); common shell fragments. |
| 250 – 260 | Clay, sand (as above), abundant shell fragments; clay mixed very dark grayish brown (2.5Y 3/2) and dark greenish gray (Gley 1 4/10Y), silty; shell mixed beige, black, white. |
| 260 – 270 | Sand, medium to coarse, subangular, clear colorless green-stained quartz, some yellow-gray (shell fragments ?); abundant shell fragments, mixed as above; some clay, dark greenish gray, silty; sparse black fragments. |
| 270.0-271.0 | Core: Sand, fine to medium, clayey, silty with abundant shell material; poorly sorted, dark greenish gray (Gley 1 4/10Y) to olive gray (5Y 5/2). |
| 270 – 280 | Sand, medium to very coarse, with abundant shell fragments, as above; subangular; mostly clear colorless some gray, green, lavender stained; some clear grains have dark gray to black inclusions; very dark greenish gray (Gley 1 3/10Y); sparse clay clasts dark greenish gray (Gley 1 4/10Y). |
| 275 – 280 | Clay, very dark grayish brown (2.5Y 3/2), slightly silty. |
| 280 – 290 | Clay, very dark grayish brown (2.5Y 3/2) slightly silty (as above); no shell, sparse sand in sample fine to medium, poorly sorted subangular-subrounded clear colorless quartz, some green stained. |
| 290 – 300 | Clay, as above. |
| 300 – 310 | Clay, as above. |
| 310 – 320 | Clay, as above. |
| 320 – 330 | Sand, medium, subangular; mostly clear colorless quartz, some green gray stained (sparse lavender); common shell fragments 1-3 mm mostly beige; common black grains (glauconite?) irregular, sand-size. |
| 330 – 340 | Sand, fine to medium, as above; sparse shell fragments; some clay fragments – olive gray (5Y 4/2) (but slightly greener); silty. |
| 340 – 350 | Sand, very fine to medium, subangular, clear colorless quartz, some black green inclusions; greenish gray (Gley 1 5/10Y); sparse shell fragments, sparse black irregular grains. |

**Table 5. Lithologic descrtiption of drill cuttings and cores for test well CO Fd 41, at Idylwild—Continued**

CO Fd 41 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert aquifer system – continued** | |
| 350 – 360 | Sand, as above, black grains more common. |
| 360 -370 | Sand as above more medium sand; black grains even more common, coarse sand sized; some clay pieces, greenish gray (Gley 1 6/5GY) (but slightly greener); silty. |
| 370 -380 | Sand, clay as above; sand mostly fine, common black grains, clay dark greenish gray (Gley 1 4/10Y), silty. |
| 380 – 390 | Clay, silty, dark greenish gray (Gley 1 4/10Y). |
| 390 – 400 | Clay, silty, as above; some sand in sample (not in clay chips) very fine to fine, subangular; clear colorless quartz, some green-stained; common fine black grains irregular shaped (glauconite?). |
| **400.0 – 400.5** | **Core description --** Clay, silty, dark greenish gray (Gley 1 4/10Y), homogeneous; 2 shell fragments 400.17 ft to 400.28 ft; sandy interval 400.40 ft to 400.50 ft, fine, moderate sorting; subangular, clear colorless quartz; common very fine to fine black grains, dark greenish gray (Gley 1 4/10Y); clay matrix has moderate acid fizz. |

**Table 6. Lithologic description of drill cuttings and cores for test well DO Df 12, at Warner**

Warner Tract, Dorchester County

DO Df 12
Alt. = 9 ft

| Depth (feet) | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, coarse, light tan |
| 10 – 20 | Sand, coarse to very coarse, light tan to gray, clear and opaque quartz grains, with some small white gravel |
| 20 – 30 | Sand, very coarse, and gray small gravel, white, clear, and gray grains, with occasional pink and black grains |
| 30 – 40 | Sand as above, but finer-grained, well sorted |
| **St. Mary's confining unit** | |
| 40 – 50 | Sand, fine, darker gray than previous intervals |
| 50 – 60 | Sand, very fine, dark gray, with slightly micaceous gray clay |
| 60 – 70 | Silt and clay, dark gray |
| 70 – 80 | Clay, dark gray, silty, soft |
| 80 – 90 | Clay, as above |
| 90 – 100 | Clay, as above, but medium gray to light tan |
| 100 – 110 | Clay, as above |
| 110 – 120 | Clay, dark grayish-green, sticky, more pure clay (less silt than previous 50 feet) |
| **Choptank aquifer** | |
| 120 – 130 | Clay, as above, with small weathered shell fragments common |
| 130 – 140 | Silt, clay, with some fine-grained sand lenses, dark greenish-gray, very shelly; drill rig chattering at about 135 feet |
| 140 – 150 | Sand, fine-grained, with silt, clay, and shell fragments |
| 150 – 160 | Sand, above; sand content less than previous interval |
| 160 – 170 | Sand, as above; driller reports more clay and drill rig chattering at 165 feet |

**Table 6. Lithologic description of drill cuttings and cores for test well DO Df 12, at Warner—Continued**

DO Df 12 - Continued

| Depth (feet) | Description |
|---|---|
| **Choptank aquifer - continued** | |
| 170 – 180 | Clay, dark greenish-gray, with some shell |
| 180 – 190 | Clay, greenish-gray, no shell; drill rig chattering at 195 feet |
| **Lower Chesapeake confining unit** | |
| 190 – 200 | Clay, greenish-gray, with silt-size black particles |
| **Calvert aquifer system** | |
| 200 – 210 | Clay, as above |
| 210 – 220 | Clay, as above |
| 220 – 230 | Clay, as above |
| 230 – 240 | Clay, as above, with silt and very fine sand |
| 240 – 250 | Silt, with clay |
| 250 – 260 | Clay, olive-green, with minor amounts of shell; driller reported some hard clay |
| 260 – 270 | Clay, olive greenish-gray, with minor amounts of shell |
| 270 – 280 | Clay, olive-green |
| 280 – 290 | Clay, as above |
| 290 – 300 | Clay, as above, with some shell and minor amounts of silty sand |
| 300 – 310 | Sand, very fine to silty, with some clay and minor amounts of shell |
| 310 – 320 | Sand, as above |
| 320 – 330 | Clay, dark olive-green |
| 330 – 340 | Clay, as above, with possible silty lenses |
| 340 – 350 | Clay, as above, with silt and very fine sand |
| **Calvert confining unit** | |
| 350 – 360 | Clay, as above, with less silt and sand |

**Table 6. Lithologic description of drill cuttings and cores for test well DO Df 12, at Warner**

DO Df 12 - Continued

| Depth (feet) | Description |
|---|---|
| **Calvert confining unit — continued** | |
| 360 – 370 | Clay, as above |
| 370 – 380 | Clay, olive-green |
| 380 – 390 | Clay, as above |
| 390 – 400 | Clay, as above |

**Table 7. Lithologic description of drill cuttings and cores for test well KE Ae 71, at Sassafras**

Sassafras Natural Resources Management Area, Kent County

KE Ae 71
Alt. = 85 ft

| Depth (feet) | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, medium to coarse, orange, with small pebbles |
| 10 – 20 | Sand, as above, coarser-grained, with white, “crusty” particles and black limonite? Grains |
| 20 – 30 | Sand, medium to coarse, dark orange to rust, mostly iron-stained, with some coarse quartz grains; rig chattering between 22 to 25 feet. |
| 30 – 40 | Sand, as above |
| 40 – 50 | Sand, very fine, orange, with very fine dark silt |
| 50 – 60 | Gravel, white to orange, with some tan, silty clay |
| 60 – 70 | Sand, fine, black, glauconitic? |
| **Severn confining unit** | |
| 70 – 80 | Clay, silty, black, glauconitic; gravel from up-hole |
| 80 – 90 | Clay, greenish-gray, with fine sand and weathered shell |
| 90 – 100 | Clay, silty, black |
| **Monmouth aquifer** | |
| 100 – 110 | Sand, medium, iron-stained quartz, glauconitic; driller reports some clay in interval |
| 110 – 120 | Sand, fine, black glauconite with clear quartz |
| 120 – 130 | Sand, very fine to fine, gray, quartzose |
| 130 – 140 | Sand, as above with gray, silty clay, and some silty green clay |
| **Matawan confining unit** | |
| 140 – 150 | Clay, silty, black, with very fine sand, and some pods of white, silty clay |
| 150 – 160 | Clay, silty, black |

**Table 7. Lithologic description of drill cuttings and cores for test well KE Ae 71, at Sassafras—Continued**

KE Ae 71 - Continued

| Depth (feet) | Description |
|---|---|
| **Matawan confining unit – continued** | |
| 160 – 170 | Sand, fine, lightly micaceous, with black, silty clay |
| 170 – 180 | Clay, black, lightly micaceous, with very fine black sand and silt, greasy appearance |
| 180 – 190 | Clay, dark gray, lightly micaceous |
| 190 – 200 | Clay, as above |
| 200 – 210 | Clay, as above |
| 210 – 220 | Clay, as above, with trace lignite |
| **Magothy aquifer** | |
| 220 – 230 | Sand, fine, gray |
| 230 – 240 | Sand, medium to coarse, gray |
| 240 – 250 | Sand, coarse, gray, lignite |
| 250 – 260 | Sand, very coarse, clear, pink, and purple grains |
| 260 – 270 | Sand, medium, light gray, well sorted, “clean” |
| 270 – 280 | Sand, coarse, gray, well sorted |
| **Magothy-Patapsco confining unit** | |
| 280 – 290 | Sand, medium with dark gray clay |

**Bit sample at 290 feet**: Clay, dark gray, tough, plastic, pale purple to pale red

**Table 8. Lithologic description of drill cuttings and cores for test well QA Cf 77, at Church Hill**

Church Hill County Park, Queen Anne's County

QA Cf 77
Alt. = 59 feet

| Depth (feet) | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, very clayey, fine to coarse, poorly sorted, light yellowish brown (2.5Y 6/5). |
| 10 – 20 | Sand, gravel medium to very coarse, poorly sorted; dark yellowish brown (10YR 4/6); subangular to subrounded; mostly quartz, heavily iron-stained, some frosted; common fine black grains. |
| **Calvert confining unit** | |
| 20 – 30 | Clay, silty, dark greenish gray (Gley 1 4/10Y). |
| 30 – 40 | Clay, silty, as above, no acid fizz. |
| 40 – 50 | Clay, silty, as above, slightly darker, very dark greenish gray (Gley 3/10Y); weak acid fizz. |
| 50 – 60 | Clay, silty, as above; with sparse shell fragments; matrix has moderate acid fizz. |
| 60 – 70 | Clay, silty, as above, sparse shell fragments; weak acid fizz. |
| 70 – 80 | Clay, silty, as above. |
| 80 – 90 | Clay, silty, as above; with some lighter clay fragments, greenish gray (Gley 1 6/10Y). |
| 90 – 100 | Clay, sandy, silty, very dark greenish gray (Gley 1 3/10Y); sand medium to coarse, mostly clear quartz; abundant fine black grains (lignite?); common shell fragments; some fragments of dark olive gray clay (5Y 3/2). |
| 100 – 110 | Clay, very sandy, glauconitic; clay very dark greenish gray (Gley 1 3/10Y) and dark olive gray (5Y 3/2); sand fine to medium, quartz clear colorless, some green-stained; with abundant glauconite, medium black botryoidal, 50% of sand fraction; common shell fragments. |
| 110 – 120 | Clay, sand, as above. |
| 120 – 130 | Sand, as above, with some clay, as above. |
| 130 – 140 | Clay, as above, sandy as above, with common very coarse grains of yellow-brown iron-stained quartz; sparse fragments of calcite-cemented shell and sand; clay dark greenish gray (Gley 1 4/10Y). |
| 140 – 150 | Sand, fine to medium, clayey; glauconite very abundant 50-70% sand fraction, black, botryoidal; quartz clear, colorless and green; clay as above; common fragments of calcite-cement; shell fragments. |

**Table 8. Lithologic description of drill cuttings and cores for test well QA Cf 77, at Church Hill—Continued**

QA Cf 77 - Continued

| Depth (feet) | Description |
|---|---|
| **Aquia aquifer (Aquia formation)** | |
| 150 – 160 | Sand, medium to coarse, some very coarse; poorly sorted, subrounded; mostly quartz, abundant black glauconite 30-40%; abundant fragments of calcite-cemented fine sand; sparse shell fragments. |
| 160 – 170 | Sand as above, but less glauconite (10-20%); less calcite cement. |
| 170 – 180 | Sand, medium to coarse, as above; glauconite 10-20%; calcite cement 10-20%. |
| 180 – 190 | Sand, medium to coarse, as above; echinoid spines. |
| 190.0 – 191.1 | Core: Sand, very dark greenish gray (Gley 1 3/5G); medium, some fine, moderately sorted; mostly quartz, clear colorless, some green-stained; abundant glauconite (40-50%), black botryoidal, rounded irregular grains, fine to medium; common forams; clay at 190.65-190.8, mixed grayish green (Gley 1 4/5G2) and very dark grayish brown (2.5Y 3/2). Nose material 190.8-191.1 has very fine light gray silt/calcite cement –strong acid fizz. |
| 190 – 200 | Sand, medium to coarse, as above. |
| 200 – 210 | Sand, medium to coarse, as above. |
| 210 – 220 | Sand, medium to coarse, as above with very abundant shell fragments. |
| 220.0 – 220.3 | Core: Sand, greenish black (Gley 1 2.5/10Y), fine to medium, with interstitial clay; sand mostly quartz (80%), yellow-brown stained, subrounded to subangular; glauconite common (20%), fine, black, botryoidal and rounded; common shell material and cemented fragments. |
| 220 – 230 | Sand, medium to very coarse, with very abundant shell fragments; poorly sorted, quartz clear, frosted, stained green, yellow, common glauconite; common phosphate pellets, sparse cemented fragments. |
| 230 – 240 | Sand, as above, medium to very coarse. |
| 240 – 250 | Sand, as above, medium to very coarse. |
| (2nd hole) | |
| 250 – 260 | Sand, as above, medium to coarse, some very coarse; abundant glauconite – 20-30%. |
| 260 – 270 | Sand, as above, medium to coarse; abundant glauconite 20-30%. |
| 270 – 280 | Sand, as above, medium to coarse; glauconite 20%; a few chips of clay, medium gray. |

**Table 8. Lithologic description of drill cuttings and cores for test well QA Cf 77, at Church Hill**

QA Cf 77 - Continued

| Depth (feet) | Description |
|---|---|
| **Aquia aquifer (Aquia formation) – continued** | |
| 280 – 290 | Sand as above, medium to coarse few chips of greenish gray clay (Gley 1 5/10Y). |
| 284.0 – 285.5 | Core: Sand, medium to very coarse, with abundant shell fragments; poorly sorted; medium grains subangular, coarser grains well rounded; dark greenish gray (Gley 1 4/10Y); shell fragments mostly 2-5 mm, light gray to tan; abundant glauconite (20-30% of sand); clayey matrix; fragments of calcite-cemented sand, with strong acid fizz; faint layering of shell fragments, otherwise no structure. |
| 290 – 300 | Sand, fine to medium with abundant shell material and greenish gray clay, as above; common nodosariid forams, and other smaller forams (?); glauconite abundant 10-20%, mostly black, fine; sparse chips of punctuate brachiopods, (Oleneothyris harlani ?). |
| 300 – 310 | Sand, medium to coarse, as above; quartz grains mostly clear, colorless, with green-gray, yellow, brown stained grains. |
| **Aquia aquifer (Hornerstown Formation)** | |
| 310 – 320 | Sand, coarse, as above, but a higher percentage of yellow-brown grains, giving a brown tint to sand. |
| 320.0 – 321.4 | Core: Sand, medium to coarse, abundant shell fragments; similar to above core; hole material in nose appears darker, fresher (no drill mud?). |
| 320 – 330 | Sand, medium to coarse, mostly clear quartz, common yellow, brown stained; medium grains tend to be clear, subangular; coarser grains brown-stained, rounded; glauconite common 20%, mostly black, rounded to botryoidal; shell fragments common; sparse chips of light gray clay; rare nodosariid; rare cemented clasts. |
| 330 – 340 | Sand, medium to coarse, as above; higher percentage of gray clay. |
| 340 – 350 | Sand, medium to coarse, as above. |
| 350 – 360 | Sand, medium to coarse, as above; more clay than above; sparse nodasariid; sparse clasts of very dark greenish gray (Gley 1 3/5GY) clay with abundant interstitial glauconitic sand; common shell fragments. |
| 360 – 370 | Sand, medium, abundant glauconite; sand mostly quartz, clear colorless, some yellow- brown stained; clear grains subangular; brown grains rounded; abundant glauconite, 30-40%, black botryoidal, fine to medium; a few greenish-brown grains, more rounded, oblong (goethite?), sparse nodosariid. |

**Table 8. Lithologic description of drill cuttings and cores for test well QA Cf 77, at Church Hill—Continued**

QA Cf 77 - Continued

| Depth (feet) | Description |
|---|---|
| **Severn confining unit (?)** | |
| 370 – 380 | Sand, medium to coarse, very abundant glauconite; mostly glauconite, 70-80%, black botryoidal, few brownish grains, oblong; quartz mostly yellow-brown stained, some clear colorless, green; rare medium gray clay clasts; no shell or cement. |
| 380 – 390 | Sand, medium to coarse, as above, very abundant glauconite 80-90%, as above; sparse shell material. |
| 390 – 400 | Sand, medium, nearly all glauconite (90-100%), mostly black botryoidal, medium grained, some with greenish alteration, some brown oblong (goethite/phosphate ?); sparse shell fragments, medium gray clay fragments, and cemented sand fragments. |
| 400.0 – 400.2 | Core: Sand, glauconitic (80-90%), fine to medium, some interstitial clay; glauconite is black, botryoidal; quartz grains mostly clear colorless, subangular, a few yellow-stained grains; black (Gley 1 2.5/N); sparse fragments of cemented sand, greenish black (Gley 1 2.5/10Y), weak acid fizz. |

**Table 9. Lithologic description of drill cuttings and cores for test well TA Bf 99, at Cordova**

Cordova Volunteer Fire Department, Talbot County

TA Bf 99
Alt. = 53 ft

| Depth feet | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, very coarse, light gray, with some light gray to white clay |
| 10 – 18 | Sand, very coarse with small gravel, orange, iron-stained grains |
| **Calvert aquifer system** | |
| 18 – 20 | Clay, gray, dense, sticky |
| 20 – 30 | Clay, gray, dense, sticky, with abundant weathered shell fragments; rig chattering |
| 30 – 40 | Clay, as above, with greater amount of weathered shell |
| 40 – 50 | Clay, dark greenish-brown, with some weathered shell fragments |
| **Split-spoon core (16 inches) at 50 feet**: Clay, dark brown, dense, with very thin gray, silty laminae | |
| 50 – 60 | Clay, dark brown |
| 60 – 70 | Clay, dark green, with some weathered shell fragments and silty sand lenses |
| 70 – 80 | Clay, as above with greater amounts of fine sand |
| 80 – 90 | Clay, greenish-gray, with fine sand and weathered shell |
| 90 – 100 | Sand, fine, with some greenish-gray clay |
| 100 – 110 | Sand, as above, with some weathered shell fragments; Brown clay in lower part of interval |
| **Split-spoon core (15 inches) at 103 feet**: Clay, brown, dense, with occasional lenses of gray silt | |
| 110 – 120 | Shell fragments (weathered) with minor amount of fine sand |
| 120 – 130 | Silt, and very fine sand, greenish-gray |
| 130 – 140 | Silt, as above, with some weathered shell fragments |
| **Split-spoon core (9 inches) at 140 feet**: Clay, silty, muddy, green; top two inches of core contains weathered shell fragments in green silty-clay matrix (possible contamination) | |

**Table 9. Lithologic description of drill cuttings and cores for test well TA Bf 99, at Cordova—Continued**

TA Bf 99 - Continued

| Depth feet | Description |
|---|---|
| **Calvert aquifer system - continued** | |
| 140 – 150 | Silt, as above, muddy |
| 150 – 160 | Sand, very fine, muddy, greenish-gray |
| 160 – 170 | Clay, greenish-gray, silty, muddy |
| 170 – 180 | Clay, as above, with some shell fragments; rig chattering at about 180 feet |
| 180 – 190 | Sand, fine to medium, grayish-green, with some minor weathered shell fragments and silt-size black particles |
| **Calvert confining unit** | |
| 190 – 200 | Clay, olive-green |
| 200 – 210 | Clay, as above with some minor weathered shell fragments |
| 210 – 220 | Clay, as above, no shell |
| 220 – 230 | Clay, as above |
| 230 – 240 | Clay, as above, with silt and very fine sand |

**Split-spoon core (10.5 inches) at 240 feet**: Clay, silty, olive-green

**Table 10. Lithologic description of drill cuttings and cores for test well WI Ce 327, at LESREC**

University of Maryland Lower Eastern Shore Research and Education Center, Wicomico County

WI Ce 327
Alt. = 38 ft

| Depth feet | Description |
|---|---|
| **Surficial aquifer** | |
| 0 – 10 | Sand, coarse, some small gravel, brownish-orange, "irony", subangular quartz grains, mostly clear with occasional white and orange grains |
| 10 – 20 | Sand, fine to very coarse, orange-tan, less "irony" than previous interval, subangular quartz grains, mostly clear with occasional white and orange grains |
| 20 – 30 | Sand, fine to very coarse, light brown, subangular quartz grains, mostly clear with occasional white grains; black silt size particles coating quartz grains (rare) |
| 30 – 40 | Sand, medium to very coarse, brown, less oxidized then previous intervals, mostly clear angular quartz grains with occasional white grains; black silt size particles coating quartz grains (rare) |
| 40 – 50 | Sand, fine to very coarse, light brown, clear quartz with some black silt size particles coating quartz grains; much less iron-staining then previous intervals |
| 50 – 60 | Sand, very fine to very coarse, poorly sorted, with small gravel, light tan, clear, white, and orange subangular quartz grains, occasional black silt coating grains |
| 60 – 70 | Sand, very fine to coarse, dark tan, clear quartz, lightly iron-stained with occasional white and orange grains; small amount of soft, sticky, gray clay; driller reported clay 67 feet |
| 70 – 80 | Sand, fine to medium, tan, well sorted, mostly angular to subangular clear quartz, minor iron staining on grains |
| 80 – 88 | Sand, very fine to fine, light tan, very little iron staining on grains |
| **Upper Chesapeake confining unit** | |
| 88 – 100 | Clay, greenish-gray, sticky; sand, fine to coarse, poorly sorted, white particles; geophysical log indicates clay (sand may be from up-hole) |
| 100 – 110 | Clay, greenish-gray, soft, with very fine to silty sand |
| 110 – 120 | Clay, silty, greenish-gray |
| 120 – 134 | Silt, gray (clear quartz), with greenish-gray clay |

**Table 10. Lithologic description of drill cuttings and cores for test well WI Ce 327, at LESREC—Continued**

WI Ce 327 — Continued

| Depth feet | Description |
|---|---|
| **Manokin aquifer** | |
| 134 – 140 | Sand, very fine, gray |
| 140 – 150 | Sand, as above; driller reported sand beginning at 145 feet |
| 150 – 160 | Sand, fine, gray, well sorted, clear quartz with occasional pinkish-purple grains |
| 160 – 170 | Sand, medium, gray, subangular clear quartz with occasional pinkish-purple grains |
| 170 – 180 | Sand, medium to coarse, gray, clear and purple quartz grains, rare lignite |
| 180 – 190 | Sand, fine, pale gray, clear quartz |
| 190 – 200 | Sand, medium, gray, clear quartz |
| **St. Mary's confining unit** | |
| 200 – 210 | Sand, very fine to fine, grayish-green |
| 210 – 220 | Silt, sandy, slightly clayey, greenish-gray |
| 220 – 230 | Sand, silty, clayey (poor return); geophysical log indicates clay or silty clay |
| 230 – 240 | Silt, clayey, light olive green |

**Table 11. Water-quality data from wells sampled during this project.**

**[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; deg. C., degrees Celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; --, no data]**

| Well number | Sample date | Aquifer | Color (platinum-cobalt units) | Dissolved oxygen, mg/L | pH, field | Specific Conductance, field (µS/cm @ 25 deg. C.) | Temperature, deg C. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| CO Cd 66 | 6/29/2010 | Calvert | 5 | – | 8.3 | 360 | 17.6 |
| CO Cd 67 | 7/6/2010 | Calvert | 2 | <1 | 8.1 | 332 | 17.1 |
| CO Dc 153 | 8/16/2010 | Calvert | 35 | <1 | 8.6 | 517 | 17.4 |
| CO Dc 154 | 8/19/2010 | Calvert | 8 | – | 8.4 | 475 | 19.0 |
| CO Dc 155 | 8/25/2010 | Calvert | 2 | – | 8.2 | 494 | 16.5 |
| CO Fd 41 | 7/14/2010 | Calvert | <1 | <1 | 7.6 | 308 | 19.6 |
| CO Fd 42 | 7/22/2010 | Calvert | <1 | <1 | 7.9 | 295 | 17.3 |
| CO Fd 43 | 7/20/2010 | Calvert | <1 | <1 | 7.9 | 301 | 17.8 |
| DO Df 12 | 8/4/2010 | Calvert | 5 | <1 | 8.0 | 1,150 | 17.5 |
| DO Df 14 | 8/9/2010 | Calvert | 12 | <1 | 7.8 | 1,300 | 18.2 |
| KE Ae 71 | 11/3/2010 | Monmouth | <1 | – | 7.4 | 268 | 13.7 |
| QA Cf 77 | 9/9/2010 | Aquia | 8 | <1 | 7.9 | 278 | 15.6 |
| QA Cf 78 | 9/13/2010 | Aquia | <1 | <1 | 7.8 | 311 | 15.5 |
| QA Cf 79 | 9/8/2010 | Aquia | 8 | – | 7.8 | 311 | 16.8 |
| TA Bf 100 | 9/1/2010 | Calvert | <1 | <1 | 7.6 | 323 | 15.6 |
| WI Ce 327 | 5/26/2010 | Manokin | <1 | <1 | 5.5 | 57 | 17.5 |

| Well number | Sample date | Total dissolved solids (residue on evaporation at 180 deg. C) | Calcium, 0.45µ–filtered, mg/L | Magnesium, 0.45µ–filtered, mg/L | Potassium, 0.45µ–filtered, mg/L | Sodium, 0.45µ–filtered, mg/L |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | 253 | 8.32 | 3.73 | 5.4 | 71.2 |
| CO Cd 67 | 7/6/2010 | 245 | 21.6 | 9.86 | 6.57 | 37.1 |
| CO Dc 153 | 8/16/2010 | 364 | 4.29 | 1.63 | 5.26 | 119 |
| CO Dc 154 | 8/19/2010 | 321 | 6.36 | 3.01 | 5.59 | 97.5 |
| CO Dc 155 | 8/25/2010 | 339 | 9.36 | 5.12 | 6.3 | 96.4 |
| CO Fd 41 | 7/14/2010 | 225 | 22.7 | 11.5 | 10.1 | 23.7 |
| CO Fd 42 | 7/22/2010 | 217 | 29.4 | 13.1 | 8.08 | 10.2 |
| CO Fd 43 | 7/20/2010 | 239 | 28.4 | 13.6 | 8.61 | 12.3 |
| DO Df 12 | 8/4/2010 | 735 | 11.3 | 6.94 | 11.7 | 252 |
| DO Df 14 | 8/9/2010 | 763 | 19.9 | 10.2 | 10.4 | 242 |
| KE Ae 71 | 11/3/2010 | 167 | 50 | 1.45 | 2.15 | 5.21 |
| QA Cf 77 | 9/9/2010 | 151 | 35.7 | 8.81 | 9.47 | 2.60 |
| QA Cf 78 | 9/13/2010 | 191 | 53.7 | 4.95 | 4.12 | 3.93 |
| QA Cf 79 | 9/8/2010 | 201 | 54.2 | 3.85 | 4.51 | 3.11 |
| TA Bf 100 | 9/1/2010 | 248 | 52.2 | 8.68 | 2.54 | 5.98 |
| WI Ce 327 | 5/26/2010 | 47 | 1.43 | 0.517 | 1.47 | 4.72 |

**Table 11. Water-quality data from wells sampled during this project—Continued.**

| Well number | Sample date | Alkalinity, 0.45μ–filtered, mg/L as CaCO3 | Bromide, 0.45μ–filtered, mg/L | Chloride, 0.45μ–filtered, mg/L | Fluoride, 0.45μ–filtered, mg/L | Silica, 0.45μ–filtered, mg/L |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | 190 | <0.02 | 0.83 | 0.36 | 54.6 |
| CO Cd 67 | 7/6/2010 | 181 | <0.02 | 0.94 | 0.35 | 61.3 |
| CO Dc 153 | 8/16/2010 | 260 | <0.02 | 1.34 | 0.57 | 56.8 |
| CO Dc 154 | 8/19/2010 | 235 | <0.02 | 1.17 | 0.79 | 56.2 |
| CO Dc 155 | 8/25/2010 | 252 | <0.02 | 1.45 | 0.73 | 58.6 |
| CO Fd 41 | 7/14/2010 | 153 | <0.02 | 1.21 | 0.31 | 62.3 |
| CO Fd 42 | 7/22/2010 | 143 | <0.02 | 1.55 | 0.28 | 54.2 |
| CO Fd 43 | 7/20/2010 | 151 | <0.02 | 1.42 | 0.33 | 61.5 |
| DO Df 12 | 8/4/2010 | 378 | 0.46 | 125 | 0.69 | 60.5 |
| DO Df 14 | 8/9/2010 | 379 | 0.63 | 183 | 0.68 | 46.0 |
| KE Ae 71 | 11/3/2010 | 125 | 0.02 | 3.96 | 0.71 | 22.4 |
| QA Cf 77 | 9/9/2010 | 124 | <0.02 | 1.80 | 0.28 | 11.5 |
| QA Cf 78 | 9/13/2010 | 149 | <0.02 | 2.51 | 0.20 | 25.1 |
| QA Cf 79 | 9/8/2010 | 147 | <0.02 | 2.48 | 0.14 | 21.9 |
| TA Bf 100 | 9/1/2010 | 153 | 0.02 | 3.57 | 0.15 | 54.6 |
| WI Ce 327 | 5/26/2010 | 6 | <0.02 | 3.38 | <0.08 | 21.6 |

| Well number | Sample date | Sulfate, 0.45μ–filtered, mg/L | Ammonia, 0.45μ–filtered, mg/L as N | Nitrate+Nitrite, 0.45μ–filtered, mg/L as N | Nitrite, 0.45μ–filtered, mg/L as N | Orthophosphate, 0.45μ–filtered, mg/L as P |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | <0.18 | 0.359 | <0.04 | <0.002 | 0.042 |
| CO Cd 67 | 7/6/2010 | <0.18 | 0.445 | <0.04 | <0.002 | 0.045 |
| CO Dc 153 | 8/16/2010 | 4.79 | 0.225 | <0.04 | <0.002 | 0.048 |
| CO Dc 154 | 8/19/2010 | 5.86 | 0.236 | <0.04 | <0.002 | 0.052 |
| CO Dc 155 | 8/25/2010 | 2.27 | 0.272 | <0.04 | <0.002 | 0.034 |
| CO Fd 41 | 7/14/2010 | 5.7 | 0.294 | <0.04 | <0.002 | 0.090 |
| CO Fd 42 | 7/22/2010 | 4.56 | 0.219 | <0.04 | <0.002 | 0.046 |
| CO Fd 43 | 7/20/2010 | 4.6 | 0.266 | <0.04 | <0.002 | 0.040 |
| DO Df 12 | 8/4/2010 | 20.4 | 0.369 | <0.04 | <0.002 | 0.039 |
| DO Df 14 | 8/9/2010 | 12.9 | 0.374 | <0.04 | <0.002 | 0.058 |
| KE Ae 71 | 11/3/2010 | 5.79 | 0.041 | <0.02 | <0.001 | 0.107 |
| QA Cf 77 | 9/9/2010 | 7.37 | 0.400 | <0.02 | <0.002 | 0.012 |
| QA Cf 78 | 9/13/2010 | 3.01 | 0.121 | <0.04 | <0.002 | 0.039 |
| QA Cf 79 | 9/8/2010 | 7.05 | 0.149 | <0.04 | <0.002 | 0.048 |
| TA Bf 100 | 9/1/2010 | 7.43 | 0.040 | <0.04 | <0.002 | 0.046 |
| WI Ce 327 | 5/26/2010 | 10.6 | <0.020 | <0.04 | <0.002 | 0.010 |

**Table 11. Water-quality data from wells sampled during this project—Continued.**

| Well number | Sample date | Phosphate, 0.45μ–filtered, mg/L as P | Aluminum. 0.45μ–filtered, μg/L | Barium, 0.45μ–filtered, μg/L | Beryllium, 0.45μ–filtered, μg/L | Cadmium, 0.45μ–filtered, μg/L |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | 0.07 | 6.7 | 0.49 | <0.01 | <0.02 |
| CO Cd 67 | 7/6/2010 | 0.06 | <3.4 | 1.8 | <0.01 | <0.02 |
| CO Dc 153 | 8/16/2010 | <0.04 | <3.4 | 0.354 | 0.01 | <0.02 |
| CO Dc 154 | 8/19/2010 | 0.24 | <3.4 | 0.71 | 0.02 | <0.02 |
| CO Dc 155 | 8/25/2010 | <0.04 | <3.4 | 0.67 | 0.02 | <0.02 |
| CO Fd 41 | 7/14/2010 | 0.14 | 3.7 | 3.5 | <0.01 | <0.02 |
| CO Fd 42 | 7/22/2010 | 0.05 | 4.6 | 1.1 | <0.01 | <0.02 |
| CO Fd 43 | 7/20/2010 | <0.04 | <3.4 | 1.5 | <0.01 | <0.02 |
| DO Df 12 | 8/4/2010 | <0.04 | 4.4 | 1.4 | 0.03 | <0.02 |
| DO Df 14 | 8/9/2010 | 0.11 | 6.6 | 12 | 0.03 | <0.02 |
| KE Ae 71 | 11/3/2010 | 0.12 | 4.0 | 281 | <0.01 | <0.02 |
| QA Cf 77 | 9/9/2010 | <0.04 | <3.4 | 346 | <0.01 | <0.02 |
| QA Cf 78 | 9/13/2010 | <0.04 | <3.4 | 166 | <0.01 | <0.02 |
| QA Cf 79 | 9/8/2010 | <0.04 | <3.4 | 198 | <0.01 | <0.02 |
| TA Bf 100 | 9/1/2010 | 0.07 | <3.4 | 1.4 | <0.01 | <0.02 |
| WI Ce 327 | 5/26/2010 | <0.04 | <3.4 | 13 | 0.12 | <0.02 |

| Well number | Sample date | Chromium, 0.45μ–filtered, μg/L | Cobalt, 0.45μ–filtered, μg/L | Copper, 0.45μ–filtered, μg/L | Iron, 0.45μ–filtered, μg/L | Iron, unfiltered, μg/L |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | <0.12 | 0.02 | <1.0 | <6 | 9 |
| CO Cd 67 | 7/6/2010 | <0.12 | 0.04 | <1.0 | <6 | <9 |
| CO Dc 153 | 8/16/2010 | <0.12 | <0.01 | <1.0 | <6 | <9 |
| CO Dc 154 | 8/19/2010 | <0.12 | <0.01 | <1.0 | 7 | 35 |
| CO Dc 155 | 8/25/2010 | <0.12 | 0.01 | <1.0 | <6 | <9 |
| CO Fd 41 | 7/14/2010 | <0.12 | 0.09 | <1.0 | 38 | 99 |
| CO Fd 42 | 7/22/2010 | <0.12 | 0.01 | <1.0 | 13 | 22 |
| CO Fd 43 | 7/20/2010 | <0.12 | 0.02 | <1.0 | 11 | 44 |
| DO Df 12 | 8/4/2010 | <0.12 | 0.02 | <1.0 | 14 | 44 |
| DO Df 14 | 8/9/2010 | <0.12 | 0.03 | <1.0 | 96 | 236 |
| KE Ae 71 | 11/3/2010 | <0.06 | 0.04 | <0.50 | 272 | 316 |
| QA Cf 77 | 9/9/2010 | <0.12 | 0.02 | <1.0 | 70 | 416 |
| QA Cf 78 | 9/13/2010 | <0.12 | <0.01 | <1.0 | 107 | 316 |
| QA Cf 79 | 9/8/2010 | <0.12 | 0.02 | <1.0 | 45 | 562 |
| TA Bf 100 | 9/1/2010 | <0.12 | 0.02 | <1.0 | 9 | 12 |
| WI Ce 327 | 5/26/2010 | <0.12 | 0.13 | <1.0 | 1,570 | 1,580 |

**Table 11. Water-quality data from wells sampled during this project—Continued.**

| Well number | Sample date | Lead, 0.45μ–filtered, μg/L | Lithium, 0.45μ–filtered, μg/L | Manganese, 0.45μ-filtered μg/L | Manganese, unfiltered μg/L | Molybdenum, 0.45μ–filtered, μg/L |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | 0.10 | 15.6 | 0.7 | 0.7 | 0.1 |
| CO Cd 67 | 7/6/2010 | <0.03 | 18.3 | 0.9 | 0.9 | 0.1 |
| CO Dc 153 | 8/16/2010 | <0.03 | 9.68 | 0.02 | <0.5 | 0.9 |
| CO Dc 154 | 8/19/2010 | <0.03 | 10.1 | 1.5 | 1.8 | 1.5 |
| CO Dc 155 | 8/25/2010 | <0.03 | 16.9 | 0.5 | <0.3 | 0.9 |
| CO Fd 41 | 7/14/2010 | 0.11 | 14.2 | 2.7 | 3.3 | 0.4 |
| CO Fd 42 | 7/22/2010 | <0.03 | 10.2 | 1.1 | 1.0 | 0.2 |
| CO Fd 43 | 7/20/2010 | <0.03 | 12.9 | 1.1 | 1.3 | 0.1 |
| DO Df 12 | 8/4/2010 | <0.03 | 30.3 | 0.6 | 0.9 | 0.9 |
| DO Df 14 | 8/9/2010 | <0.03 | 30.6 | 5.5 | 5.5 | 0.6 |
| KE Ae 71 | 11/3/2010 | <0.01 | 10.7 | 19.5 | 17.9 | 0.4 |
| QA Cf 77 | 9/9/2010 | <0.03 | 3.3 | 2.0 | 2.1 | 0.3 |
| QA Cf 78 | 9/13/2010 | <0.03 | 9.8 | 2.7 | 3.2 | 0.1 |
| QA Cf 79 | 9/8/2010 | <0.03 | 8.0 | 5.5 | 5.8 | <0.028 |
| TA Bf 100 | 9/1/2010 | 0.03 | 11.6 | 4.0 | 3.8 | 0.2 |
| WI Ce 327 | 5/26/2010 | 0.06 | 3.2 | 79.3 | 76.2 | <0.028 |

| Well number | Sample date | Nickel, 0.45μ–filtered, μg/L | Silver, 0.45μ–filtered, μg/L | Strontium, 0.45μ–filtered, μg/L | Thallium, 0.45μ–filtered, μg/L | Vanadium, 0.45μ–filtered, μg/L |
|---|---|---|---|---|---|---|
| | | | | | | |
| CO Cd 66 | 6/29/2010 | 0.15 | <0.01 | 114 | <0.02 | <0.16 |
| CO Cd 67 | 7/6/2010 | 0.28 | <0.01 | 269 | <0.02 | <0.16 |
| CO Dc 153 | 8/16/2010 | <0.12 | <0.01 | 61.5 | <0.02 | <0.16 |
| CO Dc 154 | 8/19/2010 | <0.12 | <0.01 | 93.2 | <0.02 | <0.16 |
| CO Dc 155 | 8/25/2010 | 0.28 | <0.01 | 148 | <0.02 | <0.16 |
| CO Fd 41 | 7/14/2010 | 0.31 | <0.01 | 314 | <0.02 | 0.20 |
| CO Fd 42 | 7/22/2010 | <0.12 | <0.01 | 331 | <0.02 | <0.16 |
| CO Fd 43 | 7/20/2010 | <0.12 | <0.01 | 369 | <0.02 | <0.16 |
| DO Df 12 | 8/4/2010 | 0.14 | <0.01 | 169 | <0.02 | 0.23 |
| DO Df 14 | 8/9/2010 | 0.18 | <0.01 | 259 | <0.02 | 0.44 |
| KE Ae 71 | 11/3/2010 | 0.20 | <0.01 | 132 | <0.01 | 0.13 |
| QA Cf 77 | 9/9/2010 | <0.12 | <0.01 | 1,720 | <0.02 | <0.16 |
| QA Cf 78 | 9/13/2010 | <0.12 | <0.01 | 737 | <0.02 | <0.16 |
| QA Cf 79 | 9/8/2010 | <0.12 | <0.01 | 554 | <0.02 | <0.16 |
| TA Bf 100 | 9/1/2010 | 0.22 | <0.01 | 383 | <0.02 | <0.16 |
| WI Ce 327 | 5/26/2010 | 0.42 | <0.01 | 18.1 | <0.02 | <0.16 |

**Table 11. Water-quality data from wells sampled during this project—Continued.**

| Well number | Sample date | Zinc, 0.45μ–filtered, μg/L | Antimony, 0.45μ–filtered, μg/L | Arsenic, 0.45μ–filtered, μg/L | Boron, 0.45μ–filtered, μg/L | Selenium, 0.45μ–filtered, μg/L | Benzene, unfiltered, μg/L |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| CO Cd 66 | 6/29/2010 | 6.1 | <0.05 | <0.04 | 403 | 0.06 | <0.1 |
| CO Cd 67 | 7/6/2010 | <2.8 | <0.05 | <0.04 | 322 | <0.04 | <0.1 |
| CO Dc 153 | 8/16/2010 | <2.8 | <0.05 | <0.04 | 571 | <0.04 | – |
| CO Dc 154 | 8/19/2010 | <2.8 | <0.05 | 0.06 | 543 | <0.04 | <0.1 |
| CO Dc 155 | 8/25/2010 | 2.9 | <0.05 | 0.06 | 628 | <0.04 | <0.1 |
| CO Fd 41 | 7/14/2010 | 66.9 | 0.07 | 0.10 | 208 | 0.04 | <0.1 |
| CO Fd 42 | 7/22/2010 | 17.6 | <0.05 | <0.04 | 122 | <0.04 | <0.1 |
| CO Fd 43 | 7/20/2010 | 3.9 | <0.05 | <0.04 | 216 | <0.04 | <0.1 |
| DO Df 12 | 8/4/2010 | <2.8 | <0.05 | 0.05 | 1210 | <0.04 | <0.1 |
| DO Df 14 | 8/9/2010 | 59.9 | <0.05 | 0.15 | 855 | <0.04 | <0.1 |
| KE Ae 71 | 11/3/2010 | 1.9 | <0.03 | 16 | 10 | 0.04 | |
| QA Cf 77 | 9/9/2010 | 4.7 | <0.05 | 2.5 | 37 | <0.04 | <0.1 |
| QA Cf 78 | 9/13/2010 | 6.6 | <0.05 | 0.61 | 32 | <0.04 | <0.1 |
| QA Cf 79 | 9/8/2010 | 7.1 | <0.05 | 0.26 | 18 | <0.04 | <0.1 |
| TA Bf 100 | 9/1/2010 | 4.7 | <0.05 | <0.04 | 17 | <0.04 | – |
| WI Ce 327 | 5/26/2010 | 57.4 | <0.05 | 0.32 | 5 | <0.04 | <0.1 |

| Well number | Sample date | Ethylbenzene, unfiltered, μg/L | Methyl tert-butyl ether (MTBE), unfiltered, μg/L | Organic carbon, unfiltered, mg/L | Toluene, unfiltered, μg/L | m+p-Xylene unfiltered, μg/L | o-Xylene, unfiltered, μg/L | Xylene, unfiltered, μg/L |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| CO Cd 66 | 6/29/2010 | <0.1 | <0.2 | <0.6 | <0.1 | <0.2 | <0.1 | <0.2 |
| CO Cd 67 | 7/6/2010 | <0.1 | <0.2 | <0.6 | <0.1 | <0.2 | <0.1 | <0.2 |
| CO Dc 153 | 8/16/2010 | – | – | 1.4 | – | – | – | – |
| CO Dc 154 | 8/19/2010 | <0.1 | <0.2 | 1 | 1 | <0.2 | <0.1 | <0.2 |
| CO Dc 155 | 8/25/2010 | <0.1 | <0.2 | 1 | <0.1 | <0.2 | <0.1 | <0.2 |
| CO Fd 41 | 7/14/2010 | <0.1 | <0.2 | <0.6 | 1.9 | <0.2 | <0.1 | <0.2 |
| CO Fd 42 | 7/22/2010 | <0.1 | <0.2 | <0.6 | 0.2 | <0.2 | <0.1 | <0.2 |
| CO Fd 43 | 7/20/2010 | <0.1 | <0.2 | <0.6 | 0.1 | <0.2 | <0.1 | <0.2 |
| DO Df 12 | 8/4/2010 | <0.1 | <0.2 | 1.2 | <0.1 | <0.2 | <0.1 | <0.2 |
| DO Df 14 | 8/9/2010 | <0.1 | <0.2 | 2 | 1.7 | <0.2 | <0.1 | <0.2 |
| KE Ae 71 | 11/3/2010 | – | – | 0.6 | – | – | – | – |
| QA Cf 77 | 9/9/2010 | <0.1 | <0.2 | <0.6 | 0.1 | <0.2 | <0.1 | <0.2 |
| QA Cf 78 | 9/13/2010 | <0.1 | <0.2 | 0.7 | 0.1 | <0.2 | <0.1 | <0.2 |
| QA Cf 79 | 9/8/2010 | <0.1 | <0.1 | 0.6 | <0.1 | <0.1 | <0.1 | <0.2 |
| TA Bf 100 | 9/1/2010 | – | – | <0.6 | – | – | – | – |
| WI Ce 327 | 5/26/2010 | <0.1 | <0.2 | <0.6 | <0.1 | <0.2 | <0.1 | <0.2 |

**Table 11. Water-quality data from wells sampled during this project—Continued.**

| Well number | Sample date | Gross alpha particle activity, Th-230, short-term[1], 0.45μ–filtered, pCi/L | Gross alpha particle activity, Th-230, long-term[2], 0.45μ–filtered, pCi/L | Gross beta particle activity, Cs-137, short-term[1], 0.45μ–filtered, pCi/L | Gross beta particle activity, Cs-137, long-term[2], 0.45μ–filtered, pCi/L |
|---|---|---|---|---|---|
| | | | | | |
| CO Cd 66 | 6/29/2010 | 0.9 | 1.1 | 4 | 3.9 |
| CO Cd 67 | 7/6/2010 | <0.4 | <0.4 | 5.1 | 6.2 |
| CO Dc 153 | 8/16/2010 | <0.4 | <0.4 | 5 | 3.9 |
| CO Dc 154 | 8/19/2010 | <0.4 | <0.4 | 4.7 | 4.3 |
| CO Dc 155 | 8/25/2010 | <0.4 | <0.4 | 6 | 5 |
| CO Fd 41 | 7/14/2010 | 1.1 | <0.4 | 8.3 | 8.6 |
| CO Fd 42 | 7/22/2010 | <0.4 | <0.4 | 6.6 | 6.8 |
| CO Fd 43 | 7/20/2010 | <0.4 | <0.4 | 6.7 | 8.2 |
| DO Df 12 | 8/4/2010 | <0.4 | <0.4 | 9.1 | 10.4 |
| DO Df 14 | 8/9/2010 | <0.4 | 1.8 | 8.9 | 9.1 |
| KE Ae 71 | 11/3/2010 | 1.1 | <0.4 | 1.8 | 1.9 |
| QA Cf 77 | 9/9/2010 | <0.5 | <0.4 | 7.9 | 8.2 |
| QA Cf 78 | 9/13/2010 | 1.4 | <0.4 | 3.2 | 3.5 |
| QA Cf 79 | 9/8/2010 | 0.6 | <0.4 | 3.6 | 3.6 |
| TA Bf 100 | 9/1/2010 | <0.4 | <0.4 | 2.1 | 2 |
| WI Ce 327 | 5/26/2010 | 0.42 | 0.6 | 1 | 0.8 |

[1] Measured approximately 72 hours after sample collection
[2] Measured approximately 30 days after sample collection

| Well number | Sample date | Radon-222, pCi/L | Uranium, 0.45μ–filtered, μg/L |
|---|---|---|---|
| | | | |
| CO Cd 66 | 6/29/2010 | 268 | 0.02 |
| CO Cd 67 | 7/6/2010 | 470 | <0.01 |
| CO Dc 153 | 8/16/2010 | 170 | <0.01 |
| CO Dc 154 | 8/19/2010 | – | 0.01 |
| CO Dc 155 | 8/25/2010 | 510 | <0.01 |
| CO Fd 41 | 7/14/2010 | 440 | 0.01 |
| CO Fd 42 | 7/22/2010 | 223 | <0.01 |
| CO Fd 43 | 7/20/2010 | 270 | <0.01 |
| DO Df 12 | 8/4/2010 | 430 | <0.01 |
| DO Df 14 | 8/9/2010 | 700 | 0.04 |
| KE Ae 71 | 11/3/2010 | 545 | 0.08 |
| QA Cf 77 | 9/9/2010 | 280 | <0.01 |
| QA Cf 78 | 9/13/2010 | 270 | <0.01 |
| QA Cf 79 | 9/8/2010 | 170 | <0.01 |
| TA Bf 100 | 9/1/2010 | 500 | 0.01 |
| WI Ce 327 | 5/26/2010 | 62 | <0.01 |

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A message to Maryland's citizens

The Maryland Department of Natural Resources (DNR) seeks to balance the preservation and enhancement of the living and physical resources of the state with prudent extraction and utilization policies that benefit the citizens of Maryland. This publication provides information that will increase your understanding of how DNR strives to reach that goal through the earth science assessments conducted by the Maryland Geological Survey.

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