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HYDROGEOLOGIC DATA FOR THE COASTAL PLAIN SEDIMENTS NORTHWEST OF FT. MEADE, MARYLAND

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HYDROGEOLOGIC DATA FOR THE COASTAL PLAIN SEDIMENTS NORTHWEST OF FT. MEADE, MARYLAND

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KEY RESULTS

- Eight test wells were constructed at four sites northwest of Fort George G. Meade, Anne Arundel County, Maryland, to (1) provide basic geological and hydrogeological data necessary to help characterize the Patuxent aquifer in its unconfined/semi-confined outcrop zone, and (2) begin to provide long-term water-level data to help determine the effects of future groundwater withdrawals in the Ft. Meade region. One test hole at each of the sites penetrated the full thickness of the unconsolidated Coastal Plain sediments to reach crystalline basement rock. All of the test wells were screened in sands of the Patuxent aquifer, which is the main aquifer used for water supply in the Fort Meade area.

- Sands of the Patuxent aquifer generally appear to correlate from Ft. Meade northwest to the outcrop area of the Patuxent based on geophysical logs. Because of the highly complex nature of the sand-clay deposits, however, hydraulic continuity of individual sands within the Patuxent aquifer across this area is uncertain.

- The surface of the pre-Cretaceous basement rock is irregular, with local relief on the scale of tens of feet.

- The Arundel Clay confining unit becomes thinner, more variable in lithology, and discontinuous west of Ft. Meade.

- Transmissivity values calculated from aquifer tests for the test wells range widely as a result of the highly variable lithology and internal structure of the Patuxent aquifer. Transmissivities calculated from the recovery phase of the aquifer tests ranged from 18 to 14,400 feet squared per day. Transmissivities calculated from the recovery portion of the tests are considered more reliable than those calculated from the drawdown portion, due to occasional variations in the pumping rates. Only one test well (AA Bb 90 at the National Security Agency National Cryptologic Museum site) showed a drawdown and recovery response characteristic of a confined aquifer.

- Hydrographs for test wells at three of the sites correlate with barometric pressure and earth tides. Hydrographs for test wells from one site (AA Bb 88 and AA Bb 92 at the Maryland Correctional Institution for Women) correlate with precipitation and stream discharge. Water-level fluctuations indicate that most test wells are screened in semi-confined or unconfined aquifers.

- Water samples from the Patuxent aquifer were acidic (pH 4.4-5.3) and had relatively low dissolved-solids contents (28 to 307 milligrams per liter). Four samples exceeded the 15-picocurie Maximum Contaminant Level for gross alpha-particle activity, and Secondary Maximum Contaminant Levels were exceeded for pH, iron, manganese, and aluminum in several samples.

- Stream-discharge data obtained from a stream gage installed on Dorsey Run for this study indicate that the stream responds rapidly to rainfall events characteristic of an urbanized basin. Mean daily discharge recorded from November 2008 to August 2009 ranges between 3 and 480 cubic feet per second but was generally less than 10 cubic feet per second.

INTRODUCTION

Groundwater withdrawals from the Patuxent aquifer at Fort George G. Meade (Ft. Meade), Anne Arundel County, Maryland, and surrounding areas are expected to increase to meet new demands resulting from growth associated with U.S. Department of Defense Base Realignment and Closure Commission (BRAC) activity. To obtain basic hydrogeologic data to help assess the potential effects of increased groundwater withdrawals, eight test wells were constructed at four sites northwest of Ft. Meade. One test hole at each of the sites penetrated the entire section of Coastal Plain sediments to reach basement rock. All of the test wells were screened in the Patuxent aquifer, which is the predominant aquifer used for water supply in the Ft. Meade area. Water at Ft. Meade itself is supplied by six production wells tapping the Patuxent aquifer. The test-well sites were located to the northwest of the base in order to provide information on the continuity of aquifer layers as they transition from deeper (confined) to shallower (unconfined) settings. An increased understanding of the hydrologic system in this transition zone will provide basic information that will help guide groundwater appropriation policies. The test wells will provide long-term water-level data to help determine the effects of future groundwater withdrawals in the Ft. Meade region and will aid in understanding how withdrawals from the confined part of the Patuxent aquifer affect water levels in the outcrop area.

PURPOSE AND SCOPE

This report describes the geologic and hydrogeologic data collected during construction and testing of the wells drilled for this project. Information collected for this project includes lithologic descriptions from drill cuttings and cores, borehole geophysical data, aquifer-test data, water-quality analyses, and water-level data. In addition, this report presents stream discharge and precipitation data obtained from gages installed for this study by the U.S. Geological Survey (USGS) near the outlet of the Dorsey Run basin, which is located in the recharge area of the Patuxent aquifer northwest of Ft. Meade.

LOCATION OF THE STUDY AREA AND TEST WELLS

The study area is located on the west side of Ft. Meade and the National Security Agency (NSA), in the eastern part of Howard County and northwestern part of Anne Arundel County, Maryland (fig. 1). Most of the study area is located in the Coastal Plain physiographic province, with a relatively small portion in the Piedmont physiographic province in Howard County. One test-well site is located in Howard County and three sites are in Anne Arundel County. The wells constructed for this study form an updip extension of a transect of wells that run through Ft. Meade (fig. 1). All four test-well sites are located on Coastal Plain deposits within the Dorsey Run basin, an 11.6–square-mile basin which straddles the Fall Line (the boundary between the Coastal Plain and Piedmont physiographic provinces). Dorsey Run is a tributary of the Little Patuxent River; the confluence is located south of Route 32 and west of Route 295.

HYDROGEOLOGIC DATA

DRILLING AND CONSTRUCTION OF THE TEST WELLS

Test-well construction took place between March 6 and June 19, 2009. All wells were drilled by A.C. Schultes of Maryland, Inc. using the direct rotary method. Geophysical logging of the boreholes was performed by USGS and Earth Data, Inc. A summary of well-construction information is given in table 1 and diagrams of well-construction features are shown in figure 2. Diagrams showing the borehole geophysics, lithology, geologic formations, and hydrostratigraphic units at each test site are shown in figure 3.

One well at each site was drilled to basement rock and screened in the lower portion of the Patuxent aquifer. A second well was drilled to a clay layer (if present) separating the deeper sand from shallower sands. The second well was screened in a shallower sand and constructed in the same manner as the deeper well. Drill cuttings were collected at 10-foot (ft) intervals and also during any noticeable change in sediment type (see app. A for lithologic descriptions). Geophysical logs were run to total depth in the uncased holes (the logs included gamma radiation, multiple-point resistivity, single-point resistance, 6-ft lateral, and self-potential). During drilling of the second well at each site, down-hole, 2-inch-diameter, split-spoon cores were collected at selected intervals based on interpretations from the geophysical logs and drill cuttings of the first well (see app. B for descriptions of cores).

After construction, the wells were developed by air-lift, pump-and-surge, and in one instance, chemical treatment to remove fine-grained material from the well casing and screen openings. Development continued until the water was free of sediment and discoloration, and a well yield acceptable for aquifer testing was obtained. Final work at the sites included installation of 6-inch diameter steel protective casings and site restoration. Once both wells were completed and developed at each site, 8-hour aquifer tests were conducted, during which water samples were collected for chemical analysis. Land-surface altitude at each site was determined using differential global positioning system (GPS) technology by the USGS.

Test well HO Df 59 (Maryland State Prison Training Facility site) did not yield a sufficient quantity of water to conduct a pump test or obtain a representative water sample. The well is screened in a sand of the Patuxent Formation immediately overlying the weathered basement rock (saprolite). Clay and mica present in the intergranular spaces in this section likely clogged the well screen, making well development difficult and resulting in a non-producing well.

AQUIFER TESTING

Aquifer tests were performed on seven of the eight test wells drilled during this study. Each test consisted of an 8-hour pumping phase followed by an 8-hour recovery phase. Discharge was measured periodically using a 55-gallon drum and stopwatch. At each site, water levels were measured in the pumping and observation wells using both a hand-held electric tape and a pressure transducer with digital recorder. While every effort was made to pump the wells at constant rates during the pumping phase, some fluctuation in discharge occurred in the latter portion of the tests during collection of water samples from an off-line valve. For this reason, recovery data is considered a more reliable and accurate reflection of the actual aquifer properties than drawdown data.

Transmissivity (T) was calculated for each pumped well using the Cooper-Jacob straight-line method, in which drawdown or residual drawdown data is plotted against elapsed time on semi-logarithmic axes (fig. 4) (Cooper and Jacob, 1946). This method assumes that the following conditions are met: (1) the aquifer has infinite extent, and is homogeneous and isotropic; (2) well discharge is at a constant rate; (3) the well screen fully penetrates the confined aquifer, resulting in horizontal flow to the well, and the flow is laminar; (4) the aquifer has uniform thickness and is horizontal; (5) the potentiometric surface is initially horizontal; and, (6) the aquifer is fully confined and discharge is derived exclusively from storage in the aquifer.

The results of the analyzed aquifer tests can be found in table 1. Analyzed transmissivities for the test wells (pumping and recovery phase) range widely from 18 feet squared per day (ft^2/d) to 52,500 ft^2/d. Transmissivities calculated from the recovery phase of the aquifer tests ranged from 18 to 14,400 ft^2/d. It should be emphasized that the complex and variable geometry of the Patuxent aquifer system makes aquifer hydraulic property estimates complicated and limited in geographic relevance. Additionally, many of the assumptions of the Cooper-Jacob method are not fully met in the test wells.

In only one of the wells tested (AA Bb 90) does drawdown and recovery data follow a straight line characteristic of a confined aquifer (fig. 4). Semi-logarithmic plots of aquifer-test results for the other six wells tested (HO Df 60, AA Bb 86, AA Bb 87, AA Bb 88, AA Bb 92, and AA Bb 91) show two distinct slopes. The first slope, s1, is relatively steep and occurs within the first 10 to 20 minutes of pumping and recovery. The second slope, s2, is relatively flat and occurs for the remainder of the pumping or recovery phase (fig. 4). The resulting calculated transmissivities, T1 and T2, for a given well may differ by more than an order of magnitude (tab. 1).

It is likely that the two distinct slopes of the semi-logarithmic plots of the aquifer tests follow a pattern characteristic of unconfined or semi-confined aquifers. Time-drawdown curves for unconfined and semi-confined aquifers plotted on semi-logarithmic axes tend to consist of three segments with differing slopes (Boulton, 1954).

The first segment is the relatively steep early period of drawdown, lasting a few minutes, where discharge is derived from elastic storage within the aquifer similar to a confined aquifer as described by the Theis equation (Theis, 1935). The second segment is a relatively flat curve, lasting minutes to days, where the delayed yield of gravity drainage that accompanies the falling water table slows average drawdown and the curve no longer conforms to the Theis curve. This second slope may overestimate transmissivity (T2) due to the addition of water derived from vertical gravity drainage. The third segment, a relatively steep curve, occurs when the flow in the aquifer becomes predominantly horizontal again after gravity drainage ceases, at which point the curve again conforms to the Theis curve. A period of two to three days of continual pumping may be required before this third segment is reached (Weight and Sonderegger, 2001). The two distinct slopes observed on semi-logarithmic plots from these test wells may represent the first two of the three segments (fig. 4), with the possibility that the third, steeper segment would have developed had the tests been extended a sufficient amount of time beyond the 8-hour tests.

It is also likely for two wells (AA Bb 88 and AA Bb 91) that the early, steeper slope (s1) visible on the semi-logarithmic plot of the aquifer-test data is the result, to varying degrees, of casing storage effects. The tightness of aquifer sediments, the degree of well development and the relationship of casing diameter, pump column diameter, and discharge rate all contribute to this phenomenon. In this scenario, rapid drawdown during the initial stages of pumping will occur when discharge is derived mainly from water stored in the well casing and prior to a stage when a head gradient has been established which allows the aquifer to become the sole source of the discharge (Driscoll, 1986). Based on calculations to estimate the time after which casing storage becomes negligible (Schafer, 1978), test results for both AA Bb 88 and AA Bb 91 show that the effects of casing storage must be considered in the analysis. In these cases, T1 is not considered an accurate reflection of the aquifer properties.

Hydrographs showing water levels plotted against elapsed time in both pumped and observation wells during pumping and recovery phases of tests at three of the sites are shown in figure 5. Non-production in HO Df 59 at the Maryland State Prison Training Facility site makes interpretation of water levels in that well uncertain. The wells at the Jessup Water Tower site (AA Bb 86 and AA Bb 87) are separated laterally by 172 ft but are screened in different portions of the same sand body (fig. 3). The observation wells in these tests show a nearly instantaneous response to pumpage and recovery. The wells at the Maryland Correctional Facility for Women site (AA Bb 88 and AA Bb 92) are screened with 32 ft of vertical separation through predominantly sandy sediments between the bottom of the shallow well screen and the top of the deep well screen. Hydrographs from these tests show a delayed response in the observation wells with the magnitude being dependent on the discharge of the pumped well. The wells at the NSA National Cryptologic Museum site are screened in two different sand bodies vertically separated by 90 ft of predominantly clayey sediment. The hydrograph from the AA Bb 90 aquifer test shows a delayed response to pumpage and recovery in the observation well, indicating that the clays separating the wells were leaking water at a very slow rate. The discharge during the AA Bb 91 test was not high enough to have an influence on water levels in the observation well.

WATER LEVELS

Hydrographs showing continuous water-level data for seven of the eight test wells drilled during this study are shown in figure 6. Reliable water-level data could not be obtained from the deep well at the Maryland State Prison Training Facility site (HO Df 59). Water levels were recorded at 15-minute intervals using pressure transducers and digital data-recording devices. Water-level measurements began June 12, 2009 for all wells with the exception of the wells at the NSA National Cryptologic Museum site, which began August 3, 2009.

Water levels in the test wells range from approximately 165 ft above sea level in the shallow portion of the Patuxent aquifer at the Maryland State Prison Training Facility site (HO Df 60) to approximately 105 ft above sea level in the deeper portion of the Patuxent aquifer at the NSA National Cryptologic Museum site (AA Bb 90). Water levels are generally higher in topographically higher areas. The deeper water level in AA Bb 90 may be partly attributed to withdrawals from the Patuxent aquifer at Ft. Meade. The production wells at Ft. Meade are screened mostly in the deeper portion of the Patuxent aquifer.

Water levels in the deep and shallow wells at the Jessup Water Tower and NSA National Cryptologic Museum sites show a downward (recharge) gradient in which the shallower well has a higher water level (fig. 6).

These sites occur in topographically higher areas. Water levels at the Maryland Correctional Institution for Women site, however, indicate an upward (discharge) gradient with the deeper well having a higher water level. This site is located adjacent to Dorsey Run in a topographically lower area (fig. 1).

Hydrographs for HO Df 60, AA Bb 86, AA Bb 87, AA Bb 90, and AA Bb 91 show a pattern in which water levels fluctuate on the order of 0.2 to 0.8 ft over a period of 2 to 7 days. This pattern seems to closely track the barometric pressure recorded at Tipton Airport, Ft. Meade over the period of record. A smaller-scale semidiurnal pattern, with fluctuations of 0.1 ft, is superimposed on the first pattern and appears to correlate with the moon's gravitational influence on the earth (earth tides). In addition, AA Bb 90 shows a third pattern of fluctuations of 0.2 to 0.5 ft, lasting a period of several hours which is likely caused by pumpage in the area. The patterns in these hydrographs do not appear to be related to precipitation events. The responsiveness to barometric pressure and tidal influence in these hydrographs suggests that these wells are screened in confined or semi-confined aquifers.

Hydrographs for wells AA Bb 88 and AA Bb 92 at the Maryland Correctional Institution for Women site show a pattern of relatively flat water levels punctuated by sharp increases of up to 1.5 ft which last 1 to 3 days. This pattern seems to closely track precipitation and discharge data collected at the Dorsey Run stream gage over the period of record. A very faint semidiurnal pattern, with fluctuations of less than 0.1 ft, is superimposed on the first pattern and is probably the result of earth tides. Water levels at this site are not affected by withdrawals or changes in barometric pressure. The responsiveness to precipitation events in these hydrographs suggest that these wells are screened in aquifer sands that are poorly confined. In addition, the proximity of the well site to Dorsey Run suggests that the stream may act as a source of recharge during periods of high stage.

WATER QUALITY

Water samples were collected from seven of the eight wells toward the end of the drawdown phase of the pump test on each well. Well HO Df 59 was not sampled because of its low yield. Samples were analyzed for major ions, nutrients¸ trace metals, radionuclides (radon, gross alpha-particle activity, and gross beta-particle activity), and selected volatile organic compounds. Samples were collected in a consistent manner to optimize data comparability. For all wells, each sample was collected after specific conductance, pH, and water-temperature measurements were stable and the water was clear. Samples were shipped via priority overnight courier to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Samples being analyzed for gross alpha-particle activity (GAPA) and gross beta-particle activity (GBPA) were shipped via priority overnight courier to Eberline Services Laboratory (the USGS subcontract laboratory for these constituents) in Richmond, California. Water-quality data are given in appendix C and are presented graphically in figures 7 and 8.

Overall, water samples were acidic (pH 4.4-5.3) and had low dissolved-solids contents (28 to 307 milligrams per liter [mg/L]). pH tended to be lower and conductivity tended to be higher in the shallow wells at each site. Higher pH at depth likely reflects longer residence time and, therefore, longer contact and reaction time with aquifer minerals in the deeper wells. Sodium and chloride account for much of the higher dissolved solids in the shallow wells. Chloride and nitrate concentrations in most of the shallow wells suggest anthropogenic sources for these constituents. Because of the low pH, samples had low alkalinity levels and correspondingly higher milliequivalent percentages of nitrate, sulfate, and chloride (although absolute concentrations were low) (fig. 7). Cation composition was mixed.

Primary Maximum Contaminant Level (MCL) drinking-water standards based on health considerations have been established for public water supplies by the U.S. Environmental Protection Agency (USEPA) (2009a). Four samples exceeded the 15-picocurie MCL for gross alpha-particle activity (GAPA). Samples in the Patuxent Formation in Anne Arundel County often have elevated levels of GAPA, which is associated with radium-226, radium-228, and radium-224 (Bolton, 2000). GAPA and gross beta-particle activity (GBPA) were measured twice for each sample: once within three days of sampling ("short-term") and again 30 days after sampling ("long-term"). The decrease between the short-term and long-term GAPA values seen in most of the wells likely reflects the presence of radium-224, which has a half-life of 3.6 days.

Secondary Maximum Contaminant Levels (SMCLs; drinking-water standards based on taste, odor, and other aesthetic characteristics [USEPA, 2009b]) were exceeded for pH, iron, manganese, and aluminum in several samples. Low pH is not uncommon in shallow wells in the Patuxent aquifer, owing to the relatively short flow paths and relative lack of reactive minerals in the aquifer. High iron and manganese concentrations are likewise not uncommon in the Patuxent aquifer, and may be due to dissolution of iron oxides and oxyhydroxides that often coat the mineral grains in the aquifer. Aluminum solubility increases with decreasing pH; the sample that exceeded the SMCL also had the lowest pH.

Samples were analyzed for the organic compounds benzene, ethylbenzene, toluene, xylene, and methyl *tert*-butyl ether (MTBE). MTBE, a gasoline additive, was detected in well AA Bb 86 (shallow well at the Jessup Water Tower site) at a concentration of 0.6 micrograms per liter (µgL), well below the 20- to 40- µg/L Drinking Water Advisory Level that the USEPA has established based on taste and odor considerations. No MCL or SMCL has been established for MTBE. Low-level detections (0.3-1.6 µg/L) of toluene were found at one or both wells at each of the four sites. The concentrations were well below the 1,000 µg/L MCL. The samples do not appear to have been contaminated during transport to the laboratory, since none of the trip blanks that were submitted with each sample had any detections of any of the compounds. The source of toluene was not determined.

DORSEY RUN STREAM FLOW

An understanding of the interaction between surface water and groundwater in aquifer recharge areas is an important component for assessing long-term groundwater sustainability. Groundwater withdrawals from the confined portion of the Coastal Plain aquifers may affect the water balance in the recharge areas in the form of reduced baseflow. To help evaluate this potential effect, a stream gage was installed by the USGS near the outlet of the Dorsey Run basin in October 2008. This basin was selected for monitoring because it lies within the recharge area of the Patuxent aquifer and is directly up-gradient from the Ft. Meade well field. The stream gage is located north of Route 32 and south of Guilford Road (figs. 1 and 9). The USGS had previously operated a stream gage at Dorsey Run on the downstream (south) side of the Route 32 bridge from 1948-58, but the original site had been buried during bridge reconstruction and road widening in 1984. A precipitation gage was also installed at the Dorsey Run stream-gage site in early November 2008 (fig. 10). The stream-gage site is identified as USGS 01594400 Dorsey Run near Jessup, Maryland.

Mean daily discharge recorded from November 2008 to August 2009 ranged between 3 and 480 cubic feet per second (cfs) (fig. 11). Between late fall 2008 to early spring 2009 stream discharge was generally less then 10 cfs with the exception of multiple rainfall events that increased discharge to as much as 240 cfs. During the spring and early summer 2009 stream discharge was generally higher (greater than 10 cfs), with increased rainfall events. In late summer discharge declined (generally about 4 cfs). Stream discharge in Dorsey Run increases rapidly after rainfall events which is characteristic of an urbanized basin. The Dorsey Run basin is highly developed with a high percentage of impervious surfaces that increase runoff. A portion of stream discharge is attributed to outflow from the Dorsey Run Advanced Waste Water Treatment Plant. Mean daily discharge to Dorsey Run from the waste-water plant is approximately 2.3 cfs (Maryland Department of the Environment, 2005).

LITHOSTRATIGRAPHIC AND HYDROSTRATIGRAPHIC FRAMEWORK

LITHOSTRATIGRAPHY

The study area is underlain principally by clastic sediments belonging to the Potomac Group of Lower Cretaceous age, overlain unconformably at some locations by a thin veneer of Quaternary-age alluvial deposits (tab. 2). Potomac Group sediments rest unconformably on the pre-Cretaceous crystalline basement rocks of mainly Precambrian to lower Paleozoic age throughout much of Maryland's Coastal Plain region, including the study area. The Potomac Group stratigraphic interval increases in overall thickness southeastward, parallel to the regional stratigraphic dip along the axis of the Chesapeake-Delaware Basin/Salisbury Embayment, from near zero at updip locations along the Fall Line to over 4,000 ft on the coast near Ocean City, Maryland (Glaser, 1968).

In the outcrop area between Washington, D.C. and Baltimore City, the Potomac Group has been formally divided into, from oldest to youngest, the Patuxent, Arundel, and Patapsco Formations (tab. 2). Lithologically, all three contain clay, silt, sand, and gravel, but the Patuxent and Patapsco Formations generally show a higher proportion of sand with varying amounts of gravel and less clay, whereas the intervening Arundel Formation tends to be characterized by more clay and silt and less sand and gravel (Glaser, 1967, 1968, and 1969). The Arundel Formation is sometimes also distinguishable by a higher content of black, lignitic clay, but those clays and clays of other colors (particularly reddish, green-variegated, and light gray to white), along with silts, sands, and gravels are present in all three formations (Glaser, 1967, 1968).

An extensive analysis of Potomac Group pollen was carried out by Brenner (1963). It shows the Patuxent and Arundel Formations in Maryland to be Neocomian to Aptian in age (regional Pollen Zone I), and the Patapsco to be Albian (uppermost Lower Cretaceous) (Pollen Zones IIA, B).

Basement Rocks

The crystalline basement rocks in the study area belong to the Baltimore Complex, a mainly very dark-colored plagioclase-hornblende amphibolite (Crowley, 1976; Edwards, 1993). The name "Baltimore Gabbro Complex" appears on the Geologic Map of Maryland (Cleaves, Edwards, and Glaser, 1968). In quarry exposures near the northern boundary of the study area, the bedrock consists of black to very dark green, fine to coarse-textured, highly indurated amphibole-rich schist to gneiss containing scattered horizons of abundant, centimeter-scale lenses and laths of white plagioclase. The overall fracture pattern in these exposures appears relatively widely-spaced, with several sets present and oriented at various spatial attitudes; individual fractures appeared straight-sided and mainly millimeter- to decimeter- scale in width. Also in these exposures, the basement surface showed rapid vertical topographic undulations typical of an ancient dissected erosional surface. Of note is the clay-rich saprolite cap formed on the basement top, which, in the quarry exposures, showed rapid lateral variations in thickness from near zero to an estimated 35 ft. The deep wells at each of the four study sites were drilled into the saprolite, which was identified mainly by the conspicuous presence of black to very dark green, angular, shiny lithic fragments in the drill cuttings, often mixed in a clayey to sandy matrix. Identification was sometimes aided by corresponding changes in the geophysical log pattern from the overlying Patuxent sediments. None of these holes penetrated the unweathered basement rock beneath the saprolite. Overall, the basement surface dips southeastward but appears to undulate with unpredictable topographic variations (figs. 12 and 13).

Patuxent Formation

The Patuxent Formation is the dominant stratigraphic unit underlying the study area (figs. 3, 13, and 14; tab. 2). It is differentiated from the overlying Arundel Formation mainly by its greater proportion of sand and gravel to clay and silt. The majority of the drill cuttings collected in this investigation assigned to the Patuxent Formation (app. A) consist of quartzose sand that is fine to coarse-grained, poorly to moderately-sorted, subangular to subrounded, with varying amounts of clay and/or silt. Quartzose compositions most often observed include quartzite and vein quartz; other volumetrically important sand grain compositions may include clay, sand-size aggregates bound by iron cements, or lignite. Grains sometimes show iron staining or even irony coats. Patuxent cutting samples that were dominated by fines (clay and/or silt) were usually reddish or green-variegated in color and sometimes contained pyrite/marcasite and/or siderite (usually as small masses); some light gray clays and dark lignitic clays were also noted. Purer clays were usually tough in texture and capable of interfering with drilling progress. Rounded quartzose gravel was collected in two cores from this investigation (app. B).

In quarry exposures of Patuxent strata within and just outside the study area, we observed that the bedded lithofacies listed above tended to be arranged in upward-fining, smaller-scale vertical successions. These stratigraphic packages appeared to average several tens of feet in thickness and to repeat cyclically upward. They were described and analyzed by Glaser (1969), who interpreted them to be individual braided-stream depositional units; additional descriptions of facies and environments are given in Glaser (1967; 1968). Such upward-fining fluvial units are known to occur during successive floods and stack upward under rising base-level conditions. A complete, ideal version of one of these packages consists of a basal gravel and/or coarse-sand dominated subunit often having a channel-form cross-section and erosive base (channel-bottom gravels, frequently bright-red to yellow in color and tightly cemented by iron cements), followed upward by a middle, sand-dominated subunit of cross-bedded horizontal bed sets (channel-bar deposits), and a capping subunit of bedded clays or clay-silts, often red, green, and light gray in color (levee-overbank and floodplain deposits). The spatial distribution of the cross-bedded sandy subunits, which are of interest to predictive groundwater-flow modeling, is poorly understood. They are assumed by their fluvial-channel origin to have lensatic geometries and to be spatially arrayed in multistory, complex patterns, and their lateral extent and interconnectivity are not known (fig. 15).

Arundel Formation

The Arundel Formation was identified at two of the test-well site locations: the Jessup Water Tower site, where it was found in the upper 90 ft of the hole, and at the NSA National Cryptologic Museum site, where it occurred from 40-90 ft (figs. 3 and 13; app. A). Identification was based mainly on the frequent presence of black clay in some of the cuttings, higher overall frequency of lignite occurrence in this interval compared to underlying Patuxent sediments, and overall higher proportion of clay and silt to sand (app. A). The individual lithofacies were indistinguishable from those in the Patuxent Formation. Placement of the contact with the underlying Patuxent Formation was based on a combination of the lithologic observations (drill cuttings, bit samples, etc.) and the geophysical-log criteria. Lithologically, it was picked at the bottom of the clay-silt-dominated, lignite-rich interval containing some black clays above the continuously sand-dominated interval below identified as the Patuxent Formation. Just below the bottom of this interval, a significant down-hole change in the geophysical-log signatures to a continually "blocky" pattern was observed (fig. 3); such patterns are traditionally interpreted as well-bedded, cleaner sands with intervening clay layers, characteristic of the Patuxent Formation. The Patuxent-Arundel contact shown on the cross section (fig. 13) through the existing wells in the southern part of the study area is based on existing data (mainly geophysical logs). One short-barrel core consisting of black clay was collected from the Arundel Formation for pollen analysis and dating in test well AA Bb 87 (app. B); results are pending as of September, 2009.

Patapsco Formation

The Patapsco Formation was identified at the Jessup Water Tower site and NSA National Cryptologic Museum site, where it constituted the upper part of the section (fig 3; app. A). As mentioned previously, both the Patapsco Formation and the Patuxent Formation are differentiated from the intervening Arundel Formation mainly by a greater proportion of sand and gravel to silt and clay, and also by a much lower amount of the very dark, lignitic clay characteristic of the Arundel Formation. Based on the drill cuttings and geophysical-log data (app. A; fig. 3) collected at the drill sites, the lower contact of the Patapsco Formation was placed at the top of the clay-silt-dominated interval containing black, lignitic clays that was identified as the Arundel Formation. However, individual lithologies collected from the Patapsco during this investigation were not distinguishable from the same lithologies in the underlying Arundel and Patuxent Formations. The Patuxent, Arundel, and Patapsco Formations and their contacts at the NSA National Cryptologic Museum site were correlated with the existing drill sites in the southern part of the transect as shown on the cross section (fig. 13) by use of the geophysical-log data.

HYDROSTRATIGRAPHY

The test wells drilled for this study penetrate (from top to bottom) the Lower Patapsco aquifer, the Arundel Clay confining unit, the Patuxent aquifer, and the weathered saprolite of the pre-Cretaceous basement rock (tab. 2). The Lower Patapsco aquifer, the Arundel Clay confining unit, and the Patuxent aquifer are all composed of sediments from the Potomac Group of Lower Cretaceous age and roughly correspond to their formational equivalents, though there are instances where the hydrostratigraphic and lithostratigraphic units do not coincide.

Figure 13 shows a cross section through the Ft. Meade area extending from the Fall Line to Kings Heights, Anne Arundel County. The section includes three of the four test-well sites in addition to logs at both the NSA and Ft. Meade production-well sites. Basement rock, ranging from about 300 ft above sea level at the Fall Line to about 750 ft below sea level at Kings Heights, dips at about 90 ft per mile (mi). The overlying Patuxent aquifer consists of multiple sand bodies that individually range in thickness from about 10 to 100 ft. The degree of hydraulic connection between individual sand bodies is uncertain. The Patuxent aquifer outcrops west of the NSA. Isolated sections of the Patuxent sands occur west of the Fall Line on some hilltops. The Patuxent aquifer is overlain by a predominantly clayey section composed mostly of sediments of the Arundel Formation. Thickness of this unit ranges from a few tens of feet at the NSA National Cryptologic Museum site to about 200 ft at Ft. Meade production well 1R (AA Bb 83). The Arundel Clay confining unit contains locally developed sandy zones. The Lower Patapsco aquifer, overlying the Arundel Clay confining unit, is the outcropping unit over most of the Ft. Meade area. It consists of multiple sand bodies similar to the Patuxent aquifer. Overall, the cross section illustrates the high degree of complexity and heterogeneity of the aquifer system through the Ft. Meade area. Correlation of individual sand or clay units is problematic. The Patuxent and Lower Patapsco aquifers and the Arundel Clay confining unit, generally correspond to sandy and clayey zones, respectively.

Basement Rocks

The pre-Cretaceous basement rock (Baltimore Complex) forms an impermeable lower boundary of the unconsolidated sedimentary aquifer system of the Maryland Coastal Plain. Four test holes drilled for this project reached basement rock, the elevations of which indicate that its surface contains unpredictable topographic relief (figs. 12 and 13). The basement rocks are not considered to be an aquifer because there is no evidence that they can yield significant quantities of water. The saprolitic portion of the Baltimore Complex, consisting of a decomposed clayey residuum capping the upper several feet of the crystalline rock, contains 40- to 60-percent porosity (Nutter and Otton, 1969). Permeability of the saprolite, however, is so low (0.2 to 7.6 gallons per day per square foot [gpd/ft^2]) (Nutter and Otton, 1969) compared to Patuxent aquifer sands (20 to 1,000 gpd/ft^2) (Mack, 1962) that the saprolite is considered a relatively insignificant element of the overall aquifer system.

Patuxent Aquifer

The Patuxent aquifer consists of a complex system of interbedded sands, clays, and silts roughly coincident with the Patuxent Formation. This aquifer is unconfined in areas where the Patuxent sediments are outcropping, which occurs between the Fall Line and the first occurrence of the Arundel Clay confining unit just west of Ft. Meade (figs. 13 and 14). The outcrop of the Patuxent aquifer forms an irregular band from 1.5 to 3 mi in width, with its eastern extent occurring approximately 0.5 mi west of NSA and Ft. Meade. In the study area, the Patuxent aquifer is considered to be confined beneath Ft. Meade, and unconfined to the west of Ft. Meade. The top of the Patuxent aquifer is delineated as the first sand to occur below the Arundel Clay confining unit but, because of the difficulty in differentiating formational boundaries, the Patuxent aquifer may include sandy zones of the Arundel Formation (fig. 13; tab. 2). Due to the nature of the depositional environments (fluvial, lacustrine, and deltaic) in which these sediments formed, individual sand bodies show considerable lateral and vertical variation and may be difficult to correlate over very short distances, let alone between well sites. Mack and Achmad (1986) have reported sand lenses 25 ft thick at specific points to be much thicker, thinner, or absent 25 to 100 ft away.

Figure 15 is a schematic cross section showing individual sand bodies within the Potomac Group sediments. This figure illustrates the complexity of the aquifer systems within the Potomac Group. In general, where the sand percentage is relatively high, the individual sand bodies are likely hydraulically connected and form an aquifer system. In contrast, where sand percentage is relatively low, the sand bodies are likely hydraulically disconnected and form a confining unit.

All eight test wells drilled for this project were screened in sand layers within the Patuxent aquifer. The sand layers, ranging in thickness from 5 to 40 ft, are separated by interbedded clays with thicknesses of up to 60 ft. The extent, thickness, and lithologic characteristics of the interbedded clays control the degree of connectivity among sand bodies within the Patuxent aquifer. Indeed, the interbedded clay layers within the Patuxent aquifer may act as effective confining layers. The two test wells drilled at the NSA National Cryptologic Museum site (AA Bb 90 and AA Bb 91) are both screened in Patuxent sands, but water-level and water-quality data indicate that the deeper well (AA Bb 90) is hydraulically separated from the shallow well (AA Bb 91) to a significant extent (figs. 5 and 6).

Arundel Clay Confining Unit

The Arundel Clay confining unit consists of low-permeability clay and silt which impede the vertical flow of groundwater between the overlying Patapsco sands and the underlying Patuxent sands. The outcrop area of the Arundel Clay confining unit in the study area forms an irregular band ranging from about 0.25 mi to 1 mi in width (fig. 16). Throughout most of the Ft. Meade area the Arundel Clay confining unit is relatively thick and predominantly clayey (fig. 13). Water-level data from a Lower Patapsco well (AA Cc 40) in the southeastern portion of Ft. Meade shows consistently higher heads than nearby Patuxent wells (AA Cc 119 and AA Cc 124), and is not influenced by pumpage from the Patuxent wells (Curtin and Dine, 1995). This suggests that the Arundel Clay confining unit in this area forms an effective hydraulic barrier between the Lower Patapsco sands and the Patuxent sands. The Arundel Clay confining unit becomes discontinuous and more difficult to identify to the west of well AA Bb 83, in the western portions of Ft. Meade and beneath NSA (fig. 13). In this region it is generally thinner (50 to 70 ft) and contains more sand bodies, which likely makes it a less effective hydraulic barrier above the Patuxent aquifer.

Lower Patapsco Aquifer

A relatively thin section of the Lower Patapsco aquifer was penetrated near land surface in the test wells at both the Jessup Water Tower site (AA Bb 86 and AA Bb 87) and at the NSA National Cryptologic Museum site (AA Bb 90 and AA Bb 91) (figs. 3 and 13). These sites are on the western margin of the outcrop area of the Patapsco sediments, which includes Ft. Meade. Lower Patapsco sands and clays are similar in composition and structure to those of the Patuxent aquifer. Sands of the Lower Patapsco aquifer in this area likely occur mostly above the water table.

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Appendix A. Lithologic logs from test wells.

Test Well HO Df 59 (Maryland State Prison Training Facility)

Surface altitude = 211 feet (ft).

Patuxent Formation:

0 – 10 ft:	Sand and clay in subordinate proportions, silty, light greenish-brown. Sand is very fine to coarse, moderately sorted, subangular to subrounded, mainly quartz with lesser clay- and mica grains, and minor accessory minerals.
10 – 20 ft:	Sand, clayey, silty, orange-tan. Sand is very fine to medium, poorly-sorted, subangular, mainly quartz and clay grains, with minor mica and accessory minerals.
20 – 30 ft:	Sand, slightly clayey, reddish-tan. Sand is fine to coarse, medium-sorted, subangular to subrounded, mainly quartz with lesser clay grains, minor dark lithic grains and accessory minerals.
30 – 40 ft:	Sand, slightly clayey with scattered granules, tan to buff. Sand is fine to coarse, moderately-sorted, subangular to subrounded, with grain composition same as 20 – 30 ft interval. Some grains iron-stained. Scattered granule-size clasts, mainly quartz.
40 – 50 ft:	Sand, silty, clayey, orange-tan, with scattered granule-size clasts. Sand is very fine to very coarse, poorly-sorted, and subangular to subrounded, with same grain composition as 20 - 30 ft interval.
50 – 60 ft:	Sand and gravel in subequal proportions, silty, clayey, buff to tan. Sand is fine to coarse, poorly-sorted, subangular to subrounded, with same grain composition as 20 – 30 ft interval. Gravel is granule size, subrounded, mainly quartz, some clay clasts. Some grains and clasts iron-stained.
60 – 70 ft:	Sand, tan to buff, with scattered granule-size clasts. Sand is fine to coarse, subrounded, poorly-sorted, mostly quartz and clay grains with minor mica. Granules are subrounded, mainly quartz with scattered clay clasts.
70 – 80 ft:	Sand with scattered granules, same as 60 – 70 ft interval. Granules are mainly quartz.
80 – 90 ft:	Sand, slightly silty, light pinkish-tan. Sand is fine to medium, moderately-sorted, subangular to subrounded, mostly quartz with minor mica and dark accessory minerals.
91 – 95 ft:	Clay and sand, in subequal proportions, silty and gravelly, reddish tan. Sand is fine to coarse, poorly-sorted, subangular to subrounded, mainly quartz and clay grains in subequal proportions; many grains iron-stained. Clay is reddish, tough. Gravel is granule-size, angular to subrounded, mainly quartz and iron-cemented aggregates of quartz sand and silt.
95 – 100 ft:	Clay, gravelly, sandy, tough, red to maroon or variegated. Sand and gravel same as 91 – 95 ft interval.
100 – 110 ft:	Clay, gravelly, tough, dark maroon. Gravel is granule-size; granules are same as 91 – 95 ft interval.
110 – 120 ft:	Clay, sandy, gravelly, maroon, same as 91 – 95 ft interval.
120 – 125 ft:	Sand, micaceous, maroon, fine-medium, angular to subrounded, moderately-sorted, mainly quartz, iron-stained, with some clay- and black lithic grains.

Pre-Cretaceous basement rock or basement-top saprolite:

125 – 130 ft:	Gravel, very clayey, abundant weathered lithic fragments, some sand; dark reddish-gray to dark green. Gravel clasts are granule-size, angular to subrounded, clay-coated and/or iron-stained quartz or black, fine-textured lithic grains, in subequal proportions.
130 – 140 ft:	Mainly sand- and granule-size particles, clayey, dark brown with black- and dark green spotting. Particles are angular to subrounded, quartz, clay, or black, fine-textured lithic fragments, frequently clay-coated and/or iron-stained. Scattered mica flakes.

Appendix A. Continued

Test Well AA Bb 87 (Jessup Water Tower)

Surface altitude = 269 ft

Patapsco Formation (?):

0 – 10 ft:	Sand, pink-tan, fine to coarse, moderately-sorted, subangular to subrounded, mainly quartz with conspicuous lignite grains.
10 – 20 ft:	Sand and clay in subequal proportions, reddish brown. Sand is same as 0 -10 ft interval with scattered lignite grains.

Arundel Formation:

20 – 30 ft:	Clay, sandy, silty, reddish-tan. Sand is same as 0 – 10 ft interval with scattered tiny mica- and lignite grains.
30 – 40 ft:	Sand and silt in subequal proportions, clayey, brown. Sand is fine to medium, moderately-sorted, angular to subrounded, mostly quartz with scattered tiny mica- and clay grains. Iron stain on some grains.
40 – 50 ft:	Sand and gravel in subequal proportions, brown. Sand is fine to coarse, poorly-sorted, subangular, mostly quartz with scattered clay- and lignite grains. Gravel is granule-size, subangular to subrounded, mostly quartz with scattered clay clasts.
50 – 60 ft:	Clay and silt in subequal proportions, slightly sandy, brown. Sand is fine to medium, subangular to subrounded, mainly quartz with scattered fine mica and minor lignite grains.
60 ft:	(bit sample): Clay, gravelly. Clay is very tough, very dark red-brown or gray-brown to black. Gravel is granule- to pebble-size, rounded, mainly quartz.
60 – 70 ft:	Silt, clayey, sandy, red-brown to gray-brown, with scattered quartz granules and minor lignite grains.
70 – 80 ft:	Clay, silt, and fine sand in subequal proportions, reddish-tan. Sand is mostly quartz with conspicuous mica; scattered quartz granules present.
80 – 90 ft:	Fine sand and silt in subequal proportions, brownish-tan, with scattered medium sand, mostly quartz with scattered clay grains and mica.

Patuxent Formation:

90 – 100 ft:	Sand, silty and clayey, light gray-brown. Sand is mostly fine to medium, subangular, moderately-sorted, quartz with scattered mica and clay grains.
100 – 110 ft:	Sand, silty, gray-brown. Sand is same as 90 – 100 ft interval.
110 – 120 ft:	Sand, same as 90 – 100 ft interval.
120 – 130 ft:	Sand, micaceous, maroon, fine to medium, angular to subrounded, moderately-sorted, mainly quartz, iron-stained, with some clay- and black (lignite?) grains.
130 – 140 ft:	Gravel, very clayey, some sand; dark reddish-gray. Gravel clasts are granule-size, angular to subrounded, clay-coated, iron-stained quartz- and/or lesser black (lignite?) fragments.
140 – 150 ft:	Mainly sand- and granule-size particles, clayey, dark brown. Particles are angular to subrounded, quartz, clay, or black (lignite?) fragments, frequently clay-coated and/or iron-stained. Scattered mica flakes.
150 – 160 ft:	Silt and clay in subequal proportions, with lesser sand; brown-tan, micaceous. Sand is mainly very fine to fine, subangular to subrounded, mostly quartz.
160 – 170 ft:	Sand, reddish brown-gray, subangular to subrounded, mainly medium-grained, moderately-sorted, quartz with scattered clay grains and rare black (lignite?) grains.
170 – 180 ft:	Sand, medium gray-tan, very fine to medium, poorly-sorted, subangular to subrounded, mostly quartz with scattered clay grains and minor mica.
180 – 190 ft:	Sand, same as 170-180 ft interval. except slightly silty.
190 – 200 ft:	Sand, silty, tan-gray, very fine to medium, poorly-sorted, subangular, mostly quartz with lesser clay grains and scattered lignite grains.
200 – 210 ft:	Sand and silt, clayey, medium brown-gray. Sand is very fine to medium, poorly-sorted, angular to subrounded, subequal quartz and clay grains, and minor lignite grains. Scattered, very thin, flat, granule-size pieces of broken hematitic crust are present.

Appendix A. Continued

Test Well AA Bb 87 (Jessup Water Tower) (Continued)

Patuxent Formation (continued):

210 – 220 ft: Gravel, sandy, medium brown-gray. Gravel clasts up to small pebble size, rounded to subangular, mostly quartz. Sand is fine to very coarse, poorly-sorted, mostly quartz with scattered clay grains.

220 – 230 ft: Sand, very gravelly, pink tan-gray. Sand is fine to coarse, moderately-sorted, mostly quartz with scattered clay grains and minor lignite grains. Gravel is up to small pebble-size, subangular to rounded, mostly quartz, sometimes clay-coated.

230 – 240 ft: Sand, gravelly, medium gray-red. Sand is fine to coarse, poorly-sorted, angular to subrounded, mostly quartz with scattered clay grains and black, angular, shiny lithic grains. Gravel is granule-size, angular to rounded, mostly quartz.

240 – 250 ft: Sand, gravelly, dark gray-red. Sand is same as 230-240 ft interval except with minor black lithic grains. Gravel is up to small pebble-size, otherwise same as 230-240 ft interval.

Pre-Cretaceous basement rock or basement-top saprolite (?):

260 ft: Sand, clayey, dark green-black, mostly medium-grained, angular to subangular, quartz with lesser proportions of black, shiny lithic grains and scattered clay grains.

Test Well AA Bb 88 (Maryland Correctional Institution for Women)

Surface altitude = 174 ft

Artificial fill, with or without Patuxent Formation admixed in varying proportions:

0 – 50 ft: Mix of silt, sand, gravel, and clay, pink-tan to reddish gray. Sand is fine to coarse, poorly-sorted, mostly quartz with some feldspar and clay grains. Gravel is pebble-size, subangular to rounded; clast compositions include quartz, quartzite, feldspar, fine-grained quartz-feldspar-mica-garnet gneiss, and white, rounded aggregates cemented with calcite.

Patuxent Formation:

50 - 60 ft: Sand, very gravelly, light pink-tan. Sand is fine to coarse, poorly-sorted, angular to subrounded, quartz with lesser clay grains and scattered feldspar grains. Gravel is up to pebble-size, subangular to rounded, with similar range of compositions as 0 - 50 ft interval.

60 - 70 ft: Gravel, slightly sandy. Clasts are up to pebble-size, subangular to rounded, often clay-coated, mostly quartz with lesser clay- and quartzose lithic clasts, including quartz-feldspar-garnet gneiss and quartzite or meta-arkose. Sand is mainly quartz with lesser feldspar-, clay- and quartzose lithic grains.

70 - 80 ft: Clay, gravelly, slightly sandy, tough, dark red, red-orange, or maroon. Gravel clasts are mainly pebble-size, rounded quartz.

80 - 90 ft: Clay, same as 70 - 80 ft interval.

90 - 100 ft: Sand, gravelly, clayey, same reddish colors as 70 - 80 ft interval. Sand is mainly coarse to very coarse, moderately-sorted, angular to subrounded, mainly quartz with scattered lignite grains. Gravel clasts are mainly granule-size, subangular to subrounded quartz and lignite fragments; siderite coatings were observed on some clasts.

95 ft: (bit sample): Clay, slightly sandy, plastic, very sticky, medium to dark gray or greenish gray. Sand grains are mainly quartz and lignite.

100 - 110 ft: Gravel and sand, clayey, dark red to maroon. Gravel is up to pebble-size, rounded to subangular, mainly quartz with lesser clay fragments that are soft and appear same as clay at 95 ft. Sand is medium to very coarse, poorly-sorted, subangular to subrounded, composed of same fragment types as the gravel.

110 - 120 ft: Sand, clayey, dark brown-red, fine to medium, moderately-sorted, subangular to subrounded, mainly quartz with scattered feldspar- and clay grains, and minor black, soft grains, probably lignite.

120 - 130 ft: Sand, dark red-brown, subangular, fine to medium, moderately-sorted, mainly quartz with rare to scattered black, well-indurated grains of undetermined composition but appear to be aggregates of smaller crystals or detrital particles. Some grains are coated with sticky, gray clay similar to that at 95 ft.

130 - 140 ft: Fine sand and silt, medium red-gray to red-brown. Sand is very fine to fine with lesser medium grains, moderately sorted, mainly angular quartz with scattered clay grains and mica.

140 - 150 ft: Sand, dark brown-red, fine to coarse, poorly-sorted, angular to subrounded, mainly quartz with lesser feldspar and clay grains, and scattered, dark sulfate grains or sulfate-coated quartz grains.

150 - 160 ft: Sand, silty, clayey, medium red-gray. Sand is very fine to medium, moderately sorted, subangular to subrounded; grain compositions include quartz, feldspar, clay, lignite, and dark, soft to crumbly, rounded, iron sulfate or -oxide grains containing tiny relict sulfide crystals.

160 - 170 ft: Sand, same as 150 - 160 ft interval, except with an increased percent of iron-sulfate and/or -oxide grains.

170 - 180 ft: Sand, same as 150 - 160 ft interval.

180 - 190 ft: Sand, same as 150 - 160 ft interval, except with an even larger percent of iron-sulfate and/or -oxide grains.

190 - 200 ft: Sand, same as 180 - 190 ft interval.

Appendix A. Continued

Test Well AA Bb 88 (Maryland Correctional Institution for Women) (Continued)

Pre-Cretaceous basement rock or basement-top saprolite:

200 - 210 ft: Sand, very dark-reddish brown to black, medium to coarse, moderately sorted, subangular quartz grains and rounded, dark, greenish, soft clay grains.

210 - 220 ft: Clay, greenish, soft, with same composition and appearance as clay grains in 200 - 210 ft interval, except with scattered black, crumbly weathered, iron-stained lithic grains.

220 - 227 ft: Clay, same as 210 - 220 ft interval, except peppered with a conspicuous quantity of black, unweathered to partly-weathered, angular black, shiny lithic grains.

Appendix A. Continued

Test Well AA Bb 90 (NSA National Cryptologic Museum)

Surface altitude = 163 ft

Patapsco Formation:

0 - 10 ft:	Sand, tan-gray, fine to medium, moderately-sorted, subangular to rounded, mainly quartz with fine, scattered black grains.
10 - 20 ft:	Sand, medium to coarse, with pebble-size gravel, both predominantly quartzose. Light tan color.
20 - 30 ft:	Sand, same as 10 - 20 ft interval, with pebble size increasing.
30 - 40 ft:	Sand, same as 20 - 30 ft interval.

Arundel Formation:

40 - 50 ft:	Sand, very clayey, white to buff. Sand is medium to very coarse, poorly-sorted, subangular to rounded, mostly quartz.
50 - 60 ft:	Sand, clayey (up to about 25 percent) and pebbly. Sand is medium to coarse, subangular to round; sand and gravel are mainly clear quartz with lesser feldspar and iron-coated grains. Clay is white to buff.
60 - 70 ft:	Sand, same as 50 - 60 ft interval.
70 - 80 ft:	Sand, same as 50 - 60 ft interval, with more white- and some pink clay.
80 - 90 ft:	Sand, pebbly. Sand is fine to coarse, angular to rounded, poorly-sorted, mainly quartz and feldspar and iron-coated grains. Abundant clay grains and clasts, tan, reddish, green or white in color, some sideritic.

Patuxent Formation:

90 - 100 ft:	Sand, same as 80 - 90 ft interval, with more sideritic grains.
100 - 110 ft:	Clay, slightly sandy to gravelly, gray or tan to white. Sand is fine to coarse; gravel is granule-size. Both sand and gravel are mainly quartz, some coated with siderite.
110 - 120 ft:	Clay with minor fine to coarse sand; gray to white, with minor fine black particles, probably lignite.
120 - 130 ft:	Clay, same as 110 - 120 ft interval; slightly larger black (lignite) particles.
130 - 140 ft:	Clay, same as 110 - 120 ft. and 120 - 130 ft intervals.
140 - 150 ft:	Clay, as in 110 - 140 ft intervals, gray.
150 - 160 ft:	Clay, sandy; sooty gray, with significant lignite. Sand is medium-grained, subangular, quartz and feldspar, with some pyrite.
160 - 170 ft:	Sand, clayey, with significant lignite, abundant pyrite; overall sooty gray color. Some clay is yellow. Sand is mainly quartzose, medium to coarse.
170 - 180 ft:	Sand, same as 160 - 170 ft interval.
180 - 190 ft:	Sand, clayey, with abundant lignite; sooty gray overall color. Sand is quartzose, micaceous, fine to medium, subrounded.
190 - 200 ft:	Sand, same as 180 - 190 ft interval; sand is very fine to medium.
200 - 210 ft:	Sand, with less lignite than 190-200 ft interval, medium gray. Sand is quartzose, micaceous, medium to coarse, subrounded.
210 - 220 ft:	Sand, same as 200 - 210 ft interval.
220 - 230 ft:	Sand, same as 200 - 220 ft intervals, except sand is fine to medium.
230 - 240 ft:	Gravel, with some pyrite and minor lignite; clasts are quartzose and feldspar, granule to pebble-size, rounded to subrounded.

Pre-Cretaceous basement rock or basement-top saprolite:

240 - 250 ft:	Mainly lithic fragments, light to dark green, crumbly, with admixed quartz fragments, highly angular, and some lignite.
250 – 252 ft:	Lithic fragments, as in 240 – 250 ft interval, but more indurated and resistant to drilling.

Appendix B. Lithologic descriptions of split-spoon cores.

Test Well HO Df 60 (Maryland State Prison Training Facility)

Patuxent Formation:

Depth: 15.0 - 15.3 ft	(Core disaggregated): Gravel with a lesser proportion of sand; silty and clayey. Gravel clasts are granule- to small-pebble-size, angular to subrounded, quartz, metasiltstone, quartzite, schist, clay, red iron-cemented sand aggregates, and feldspar. Sand is very fine to coarse, moderately sorted, subangular to subrounded, mainly quartz.
Depth: 58.0 - 59.0 ft:	
58.0 - 58.4 ft:	Clay, gravelly, tough, cream-colored to very light-gray. Gravel clasts are up to pebble-size, subangular to subrounded, mainly quartz and quartzite.
58.4 - 58.8 ft:	Clay, homogeneous, tough, same color as 58.0 - 58.4 ft interval; maroon stains on some surfaces.
58.8 - 59.0 ft:	Clay, as in 58.4-58.8 ft interval, with scattered sand; overall light yellow color with iron stains on some surfaces.
Depth: 93.0 - 94.0 ft	(Core in two, disaggregated parts):
93.0 - 93.8 ft:	Gravel, slightly silty, clayey; clasts are up to pebble-size, subangular to subrounded, mainly quartz and dark metasiltstone/fine-grained quartzite.
93.8 - 94.0 ft:	Clay, slightly silty, crumbly, dark yellow-gray; yellow-brown (iron?) stains on some surfaces.

Test Well AA Bb 87 (Jessup Water Tower)

Arundel Formation:

Depth: 20.0 - 21.1 ft:	
20.0 - 20.4 ft:	Sand and gravel, densely-packed in clay matrix, brown-red to maroon on exterior surface. Clay is tough, medium to dark green-gray in core interior. Sand is fine-coarse, poorly-sorted, subangular to subrounded, mostly quartz with lesser clay- and feldspar grains; scatted tiny lignite grains. Gravel clasts are up to pebble-size, rounded to subangular, mostly quartz with lesser clay clasts and scattered dark fragments of coarse-grained schist. Many particles coated with iron-stain, reddish.
20.4 - 21.1 ft:	Clay, tough, green-gray with red-brown mottling in core interior; exterior is uniform red-brown or red-gray.
Depth: 60.0 - 61.1 ft:	
60.0 - 60.4 ft:	Clay, very gravelly, tough, dark brown; gravel clasts are mainly pebble-size, well- to partly-rounded quartz.
60.4 - 60.7 ft:	Clay, silty, tough, dark brown; scattered tiny lignite grains.
60.7 - 61.1 ft:	Silt with lesser proportion of very fine- and fine sand; clayey, dark gray-brown.

Test Well AA Bb 92 (Maryland Correctional Institution for Women)

Patuxent Formation:

Depth: 95 - 95.1 ft (Core disaggregated):
Gravel, sandy, silty, clayey, brownish-red; gravel clasts are mainly pebble-size, rounded to subrounded quartz and quartzite; some quartz pebbles contain tiny, hematite-coated sulfide crystals. Sand is fine-coarse, poorly-sorted, subangular to subrounded quartz and quartzite. Clay is brown-red.

Test Well AA Bb 91 (NSA National Cryptologic Museum)

Patuxent Formation:

Depth: 121.5 – 121.8 ft: Clay, silty, sandy and gravelly, dark gray. Sand is scattered, fine to coarse. Gravel clasts are scattered, up to pebble-size, rounded, and are either white- to light-gray quartz or dark red, iron-cemented clay.

Appendix C. Water-quality data from test wells.

[ft, feet; bls, below land surface; asl, above sea level; gal/min, gallons per minute; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; deg. C, degrees Celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; mrem/yr, millirems per year; <, less than; E, estimated; MCL, Maximum Contaminant Level; SMCL, Secondary Maximum Contaminant Level]

,

Well number	Location	Sample date	Top of screen (ft bls)	Bottom of screen (ft bls)	Elevation (ft asl)	Flow rate, instant. (gal/min)	Color (platinum-cobalt units)	Dissolved oxygen (mg/L)
AA Bb 86	Jessup Water Tower	5/19/2009	155	185	270	100	2	6.2
AA Bb 87		5/14/2009	190	215	270	50	10	4.5
AA Bb 91	NSA National Cryptologic Museum	6/30/2009	100	120	170	10	5	4.4
AA Bb 90		6/29/2009	215	235	170	90	5	<2
AA Bb 92	Maryland Correctional Institution for Women	5/21/2009	56.5	81.5	175	120	2	4.8
AA Bb 88		5/28/2009	115	140	175	25	5	3
HO Df 60[1]	Maryland State Prison Training Facility	3/30/2009	55	60	200	50	5	6.4
MCL							--	--
SMCL							15	--

[1] HO Df 59 not sampled

Well number	Sample date	pH (field)	Specific conductance (µS/cm at 25 deg. C)	Temperature (deg. C)	Calcium, filtered, (mg/L)	Magnesium, filtered, (mg/L)	Potassium, filtered, (mg/L)
AA Bb 86	5/19/2009	4.8	156	13.8	4.09	3.35	1.71
AA Bb 87	5/14/2009	5.1	118	14.1	4.77	1.01	1.4
AA Bb 91	6/30/2009	4.4	530	16.5	11.5	4.92	1.98
AA Bb 90	6/29/2009	5.0	35	14.7	1.01	0.537	0.518
AA Bb 92	5/21/2009	4.7	234	14.1	7.03	5.23	1.91
AA Bb 88	5/28/2009	4.7	70	14.4	2.42	1.33	1.07
HO Df 60	3/30/2009	5.3	75	13.9	3.1	2.08	0.967
MCL		--	--	--	--	--	--
SMCL		6.5-8.5	--	--	--	--	--

Appendix C. Continued

Well number	Sample date	Sodium, filtered, (mg/L)	Alkalinity, filtered, $CaCO_3$ (field) (mg/L)	Bicarbonate, filtered, (mg/L)	Chloride, filtered, (mg/L)	Fluoride, filtered, (mg/L)	Silica, filtered, (mg/L)	Sulfate, filtered, (mg/L)
AA Bb 86	5/19/2009	14.2	3	4	29.4	<0.08	8.21	2.44
AA Bb 87	5/14/2009	13	4	5	--[2]	E.01	<0.20	--[2]
AA Bb 91	6/30/2009	69.7	<8	4	149	E0.06	8.7	2.94
AA Bb 90	6/29/2009	1.32	3	4	1.62	<0.08	8.9	7.31
AA Bb 92	5/21/2009	23.6	3	4	40.3	<0.08	8.43	19.7
AA Bb 88	5/28/2009	4.24	0.5	0.6	8.26	<0.08	9.28	4.57
HO Df 60	3/30/2009	5.17	6	7	11.6	<0.08	9.43	5.93
MCL		--	--	--	--	4.0	--	--
SMCL		--	--	--	250	2.0	--	250

[2] Sample destroyed at laboratory

Well number	Sample date	Dissolved solids (residue on evaporation at 180 deg. C), filtered, (mg/L)	Ammonia, filtered, (mg/L as N)	Nitrate plus nitrite, filtered, (mg/L as N)	Nitrite, filtered, (mg/L as N)	Orthophosphate, filtered, (mg/L as P)
AA Bb 86	5/19/2009	90	<0.02	3.9	E.001	E.006
AA Bb 87	5/14/2009	83	0.061	1.25	0.006	E.006
AA Bb 91	6/30/2009	307	<0.02	1.35	E.001	E.007
AA Bb 90	6/29/2009	28	<0.02	<0.04	<0.002	0.014
AA Bb 92	5/21/2009	133	<0.02	4.01	E.001	E.006
AA Bb 88	5/28/2009	49	<0.02	2.12	0.004	E.006
HO Df 60	3/30/2009	46	<0.02	0.529	<0.002	E.006
MCL		--	--	--	--	--
SMCL		500	--	10[3]	1	--

[3] Nitrate only

Appendix C. Continued

Well number	Sample date	Phosphorus, filtered, (mg/L)	Organic carbon (total), (mg/L)	Aluminum, filtered, (µg/L)	Antimony, filtered, (µg/L)	Arsenic, filtered, (µg/L)	Barium, filtered, (µg/L)	Beryllium, filtered, (µg/L)
AA Bb 86	5/19/2009	<0.04	0.72	55.1	<0.04	0.104	33.9	0.441
AA Bb 87	5/14/2009	<0.04	E.48	79.6	<0.04	0.168	13.3	0.122
AA Bb 91	6/30/2009	<0.04	--	594	E0.02	1.6	93	0.75
AA Bb 90	6/29/2009	<0.04	<0.6	16	<0.04	0.125	16.2	0.181
AA Bb 92	5/21/2009	<0.04	E.51	101	<0.04	0.143	60.3	0.524
AA Bb 88	5/28/2009	<0.04	0.83	75.1	E.033	0.737	25	0.894
HO Df 60	3/30/2009	<0.04	E.45	4.4	<0.04	E.048	23.9	E.018
MCL		--	--	--	6	10	2,000	4
SMCL		--	--	50-200	--	--	--	--

Well number	Sample date	Boron, filtered, (µg/L)	Cadmium, filtered, (µg/L)	Chromium, filtered, (µg/L)	Cobalt, filtered, (µg/L)	Copper, filtered, (µg/L)	Iron, filtered, (µg/L)	Iron, unfiltered, (µg/L)
AA Bb 86	5/19/2009	E3.9	0.161	E.077	19.4	8.17	7.8	21.5
AA Bb 87	5/14/2009	4.6	0.068	0.183	10.3	5.87	164	--
AA Bb 91	6/30/2009	E3	0.56	0.14	40.3	19.8	23	43
AA Bb 90	6/29/2009	4.1	0.035	<0.12	3.75	E.63	1500	1470
AA Bb 92	5/21/2009	7.5	0.184	0.25	16	11.1	7.7	E9.6
AA Bb 88	5/28/2009	4.2	1.42	0.142	17.9	8.64	244	292
HO Df 60	3/30/2009	5.7	0.035	<0.12	0.639	2.74	29.5	31.4
MCL		--	5	100	--	1,300[4]	--	--
SMCL		--	--	--	--	1,000[4]	300	300

[4] Total Treatment Action Level

Appendix C. Continued

Well number	Sample date	Lead, filtered, (µg/L)	Lithium, filtered, (µg/L)	Manganese, filtered, (µg/L)	Manganese, unfiltered, (µg/L)	Molybdenum, filtered, (µg/L)	Nickel, filtered, (µg/L)	Selenium, filtered, (µg/L)
AA Bb 86	5/19/2009	3.17	4.94	165	169	E.010	32	0.069
AA Bb 87	5/14/2009	12.4	4.39	39.9	--	0.114	13.3	0.612
AA Bb 91	6/30/2009	7.12	4.4	263	266	0.1	54.9	0.21
AA Bb 90	6/29/2009	1.48	5.78	46.7	45.3	E.011	8.25	<0.06
AA Bb 92	5/21/2009	3.84	2.64	118	119	<0.02	29.9	0.75
AA Bb 88	5/28/2009	2.17	5.75	56.2	56.2	<0.02	24.5	1.34
HO Df 60	3/30/2009	0.966	<1	7.74	7.72	<0.02	1.61	0.817
MCL		15[4]	--	--	--	--	--	50
SMCL		--	--	50	50	--	--	--

[4] Total Treatment Action Level

Well number	Sample date	Silver, filtered, (µg/L)	Strontium, filtered, (µg/L)	Thallium, filtered, (µg/L)	Vanadium, filtered, (µg/L)	Zinc, filtered, (µg/L)	Xylene, (µg/L)	Benzene, (µg/L)
AA Bb 86	5/19/2009	<0.008	35.1	0.12	E.123	339	<0.2	<0.1
AA Bb 87	5/14/2009	<0.008	27.4	0.211	E.125	210	<0.2	<0.1
AA Bb 91	6/30/2009	<0.008	57.3	0.15	0.77	1,010	<0.2	<0.1
AA Bb 90	6/29/2009	<0.008	6.43	<0.04	0.384	197	<0.2	<0.1
AA Bb 92	5/21/2009	<0.008	47.5	<0.04	<0.16	146	<0.2	<0.1
AA Bb 88	5/28/2009	<0.008	13.6	0.102	0.346	399	<0.2	<0.1
HO Df 60	3/30/2009	<0.008	24.1	<0.04	E.141	108	<0.2	<0.1
MCL		--	--	2	--	--	10,000[5]	5
SMCL		100	--	--	--	5,000	--	--

[5] Total xylenes

Appendix C. Continued

Well number	Sample date	Ethylbenzene, (µg/L)	m- + p-Xylene, (µg/L)	o-Xylene, (µg/L)	Methyl *tert*-butyl ether, (µg/L)	Toluene, (µg/L)	Uranium, filtered, (µg/L)
AA Bb 86	5/19/2009	<0.1	<0.2	<0.1	0.6	1.6	0.072
AA Bb 87	5/14/2009	<0.1	<0.2	<0.1	<0.2	0.3	0.229
AA Bb 91	6/30/2009	<0.1	<0.2	<0.1	<0.2	<0.1	0.18
AA Bb 90	6/29/2009	<0.1	<0.2	<0.1	<0.2	1.0	0.014
AA Bb 92	5/21/2009	<0.1	<0.2	<0.1	<0.2	1.0	0.291
AA Bb 88	5/28/2009	<0.1	<0.2	<0.1	<0.2	<0.1	0.076
HO Df 60	3/30/2009	<0.1	<0.2	<0.1	<0.2	1.0	0.023
MCL		700	10,000[5]	10,000[5]	--[6]	1,000	30
SMCL		--	--	--	--	--	--

[5] Total xylenes
[6] Drinking-Water Advisory Level (for taste and odor) is 20 to 40 µg/L

Well number	Sample date	Gross alpha-particle activity (Th-230), measured within 3 days of sample collection (pCi/L)	Gross alpha-particle activity (Th-230), measured 30 days after sample collection (pCi/L)	Gross beta-particle activity (Cs-137), measured within 3 days of sample collection (pCi/L)	Gross beta-particle activity (Cs-137), measured 30 days after sample collection (pCi/L)	Radon-222, (pCi/L)
AA Bb 86	5/19/2009	20.5	11.3	8.3	2.36	170
AA Bb 87	5/14/2009	37.5	26	8.9	11.3	420
AA Bb 91	6/30/2009	107	24	23.2	17.2	190
AA Bb 90	6/29/2009	3.5	4.1	1.8	2.0	180
AA Bb 92	5/21/2009	22	20.2	5.34	7.74	520
AA Bb 88	5/28/2009	14.8	10.4	5.53	5.78	220
HO Df 60	3/30/2009	12.3	6.22	4.98	4.44	150
MCL		15	15	4 mrem/yr	4 mrem/yr	--
SMCL		--	--	--	--	--

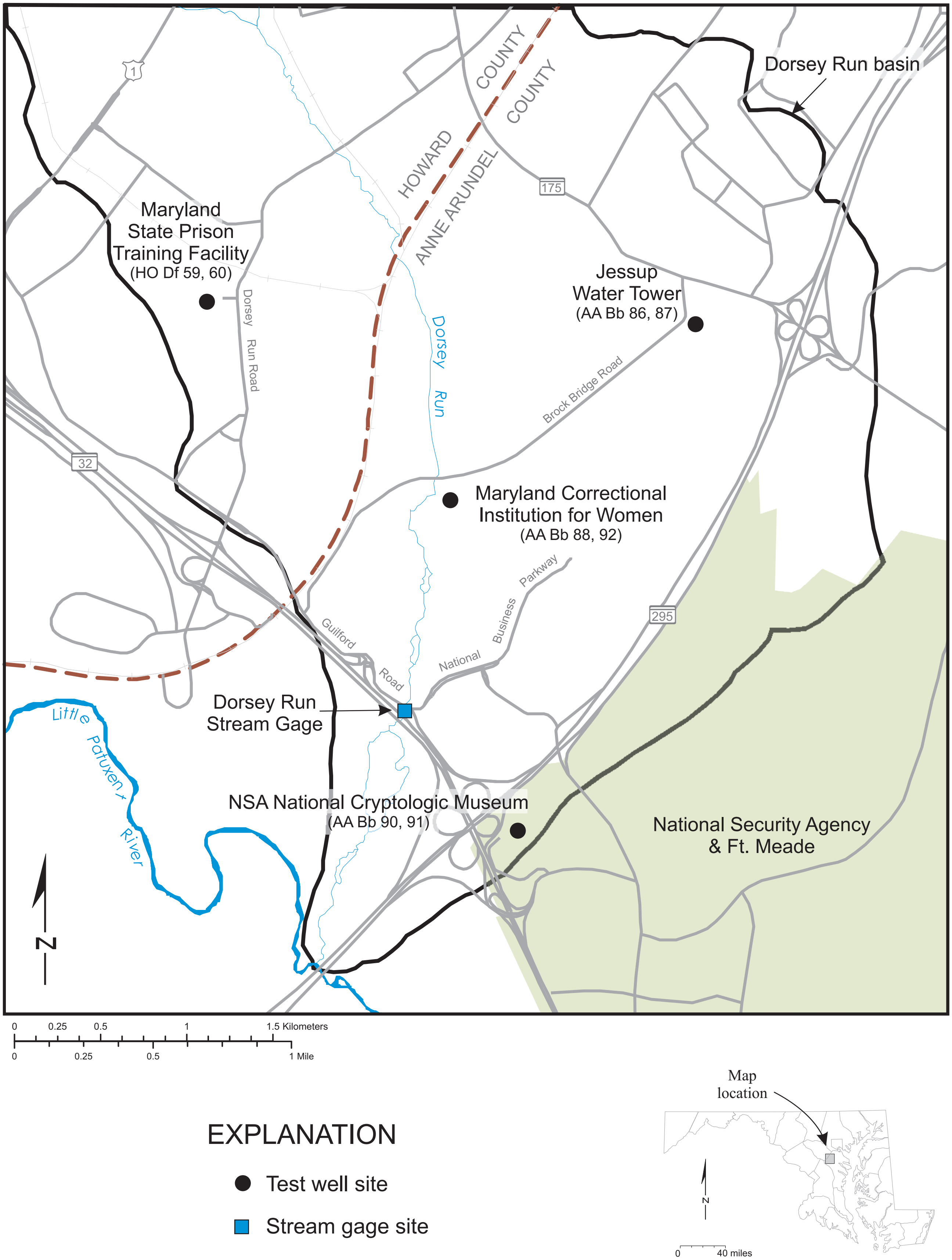
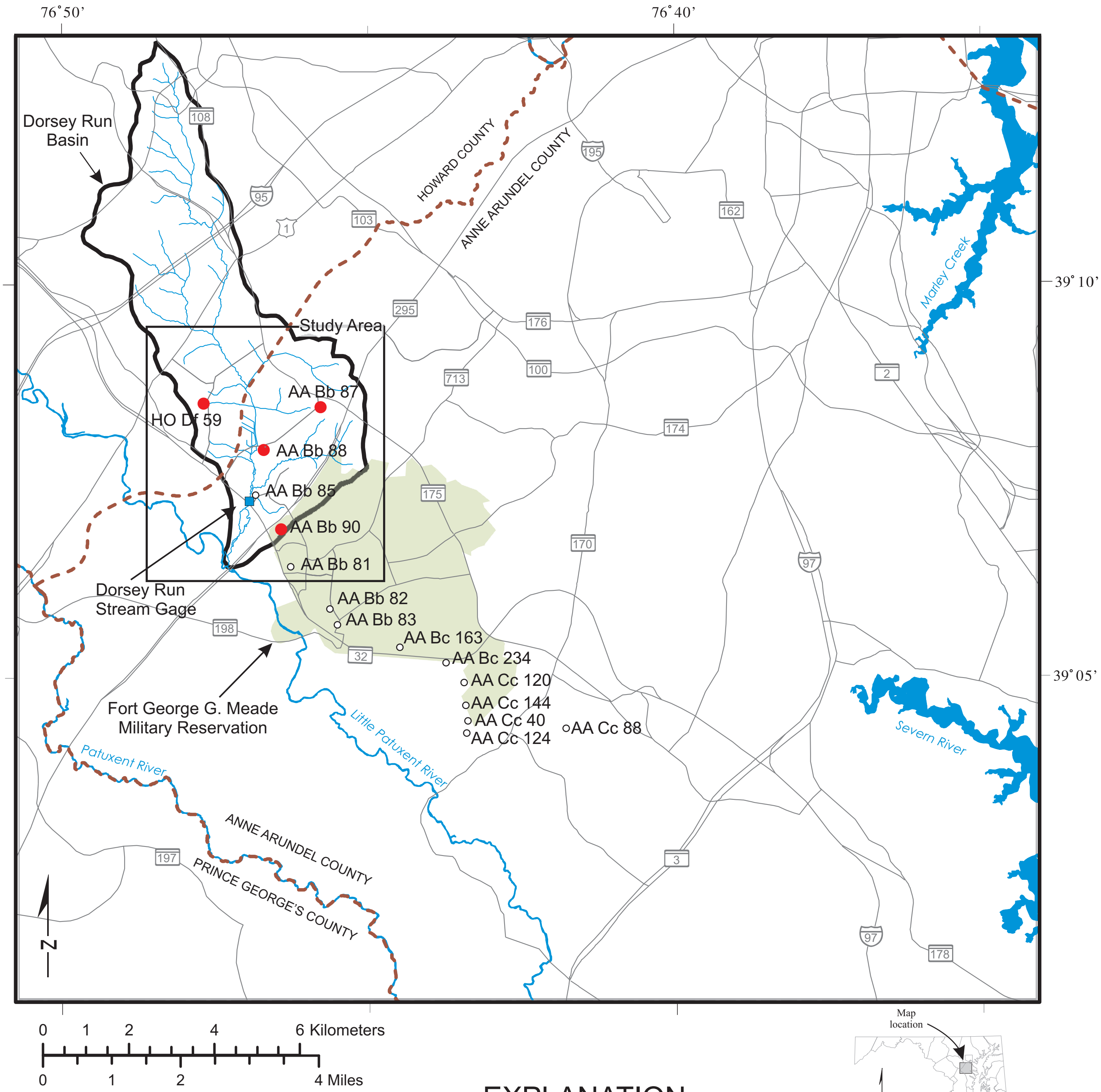


Figure 1. Location of the study area.



EXPLANATION

● Test well
○ Observation or production well

Figure 1, Continued.

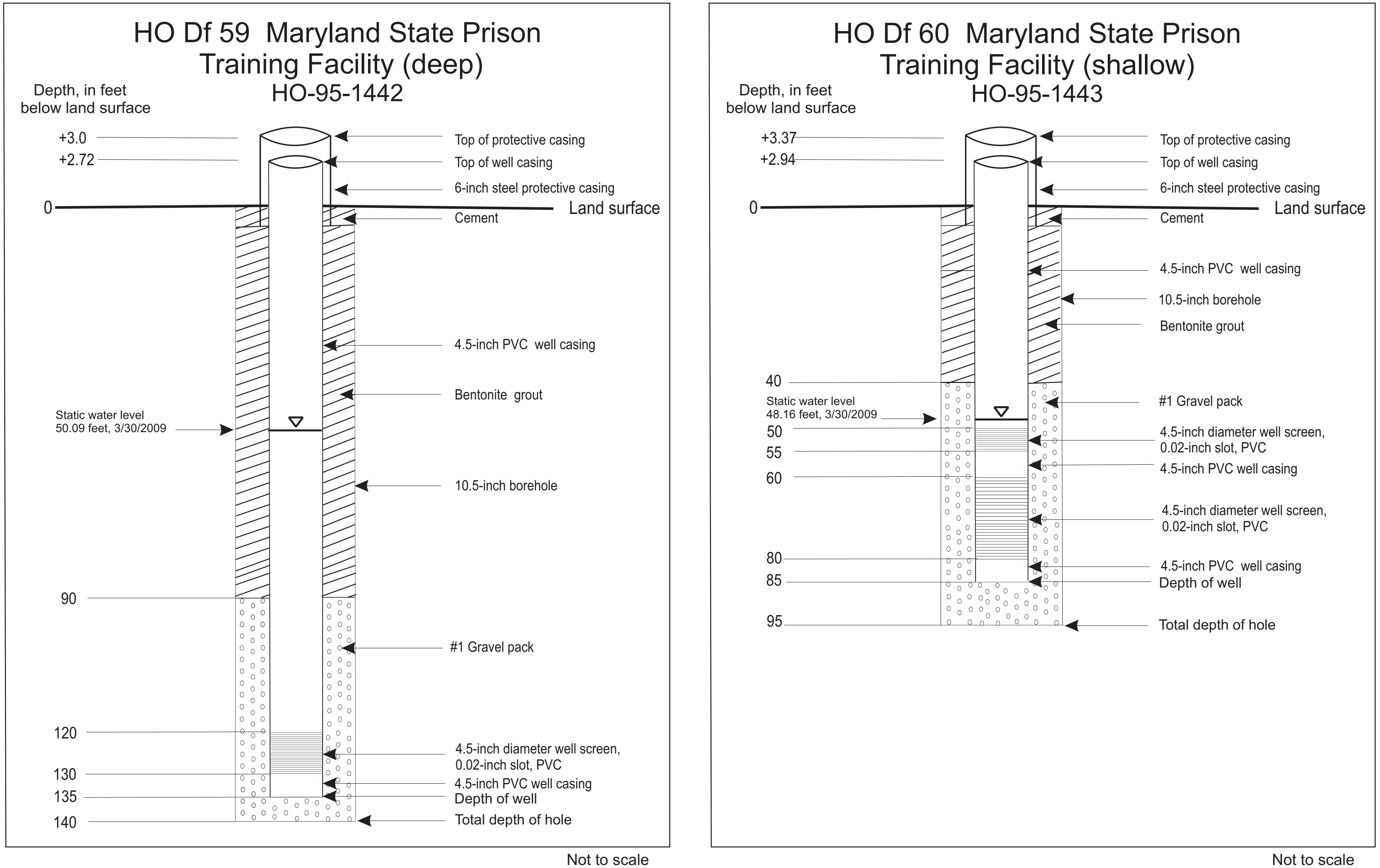
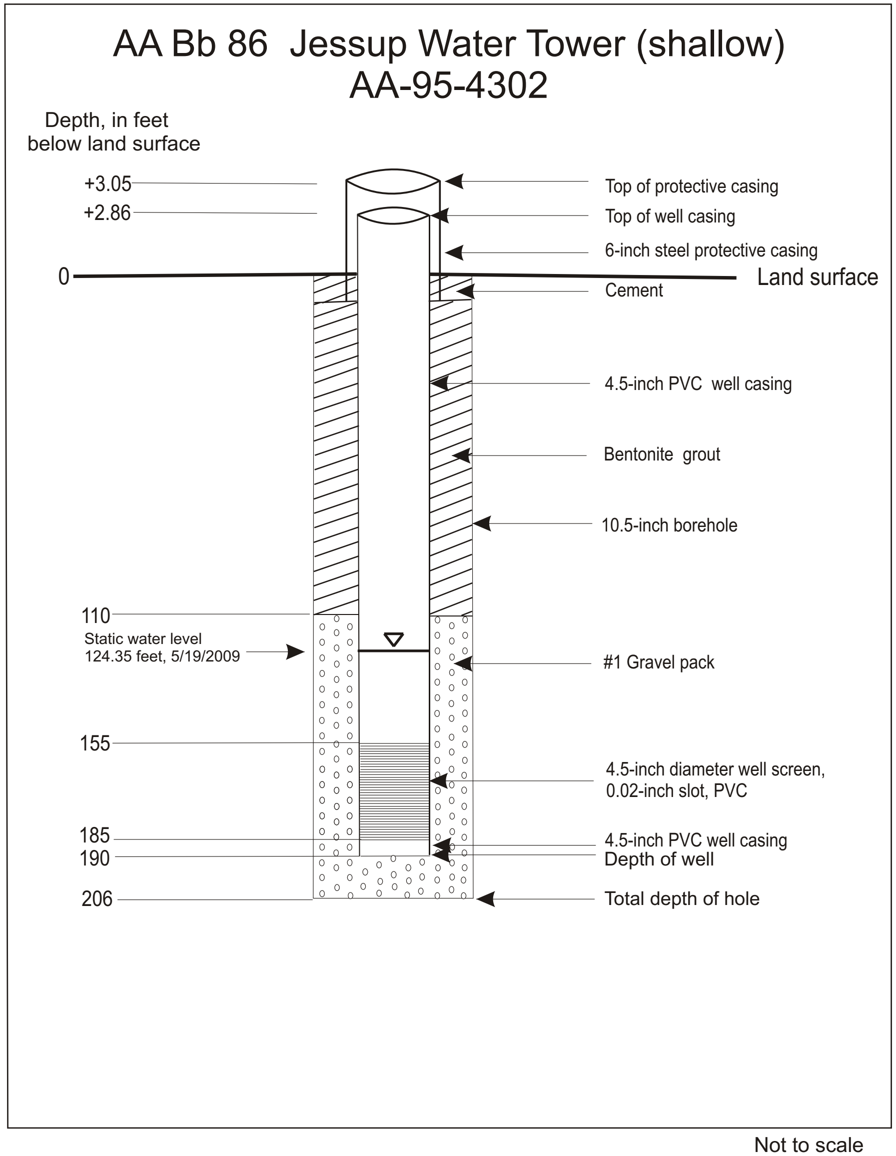


Figure 2. Test-well construction schematics.



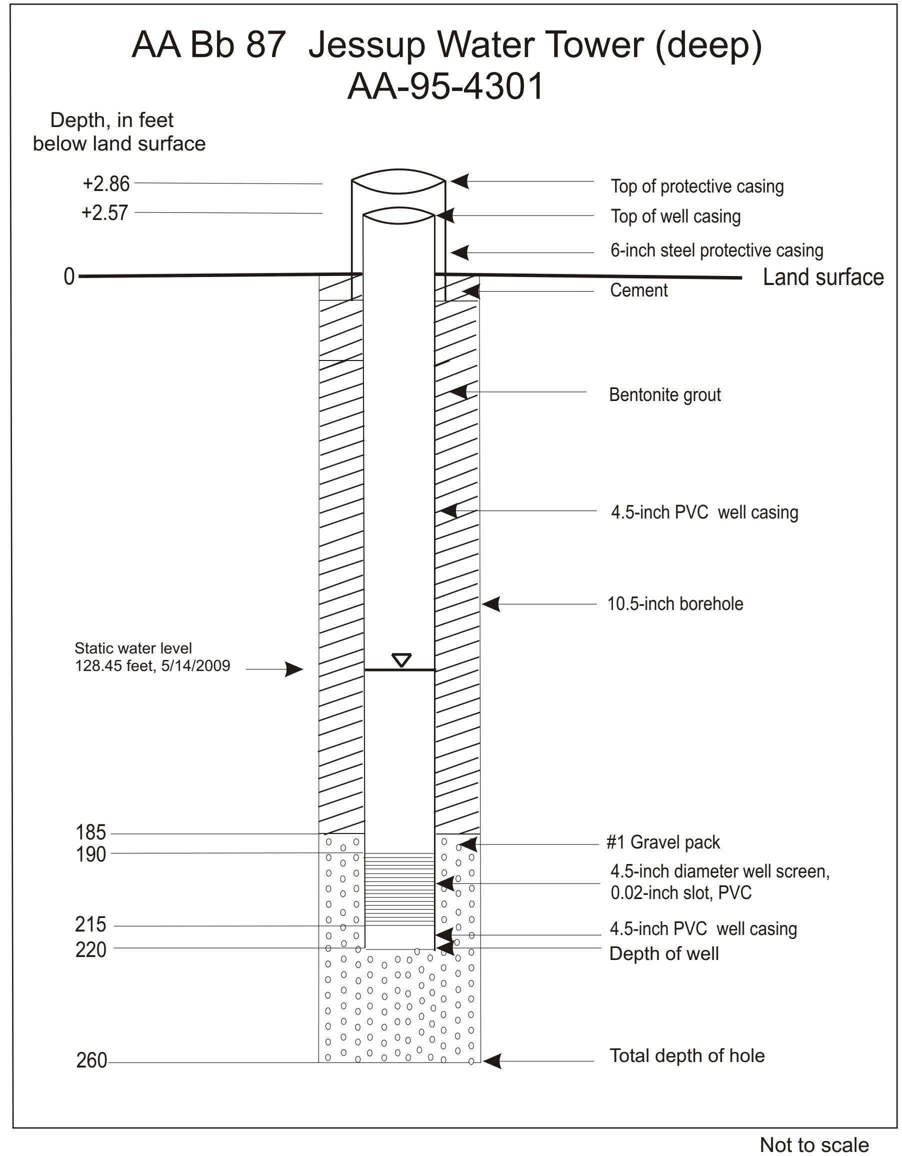
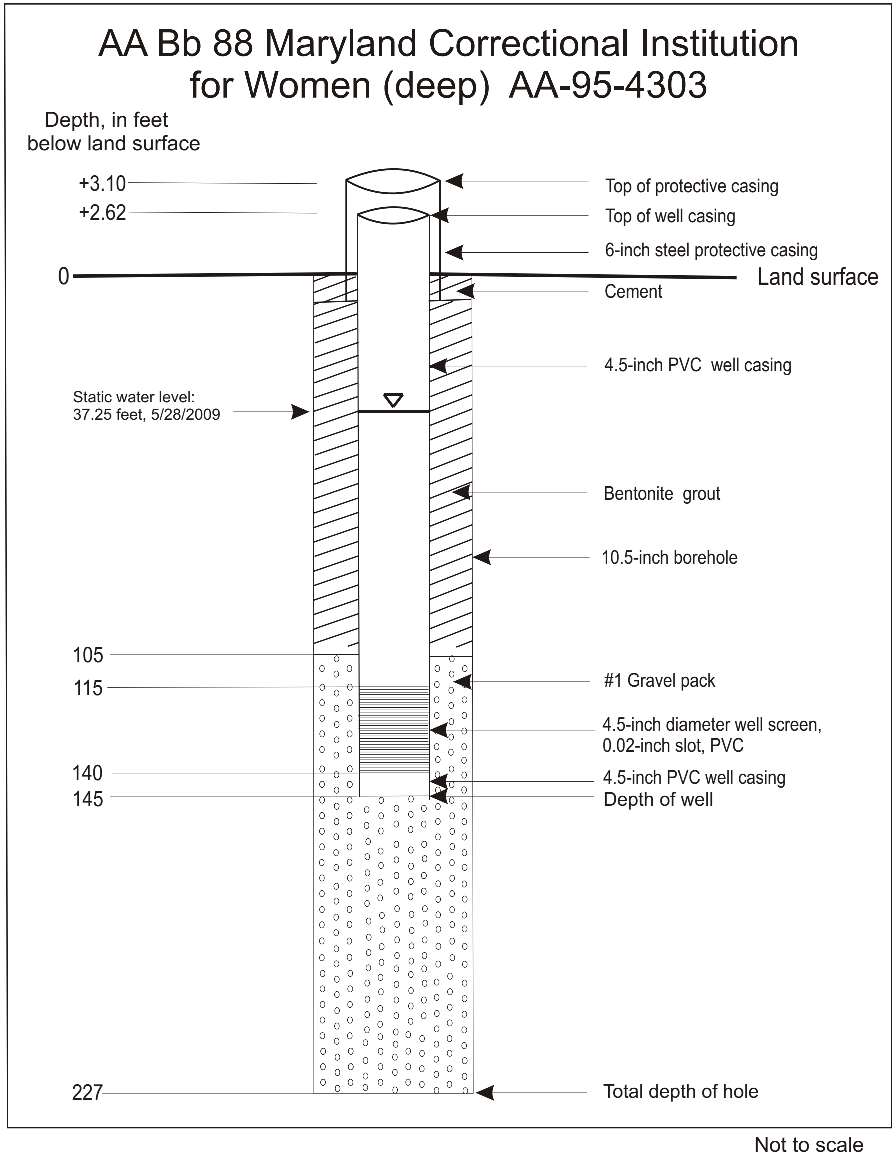


Figure 2, Continued.



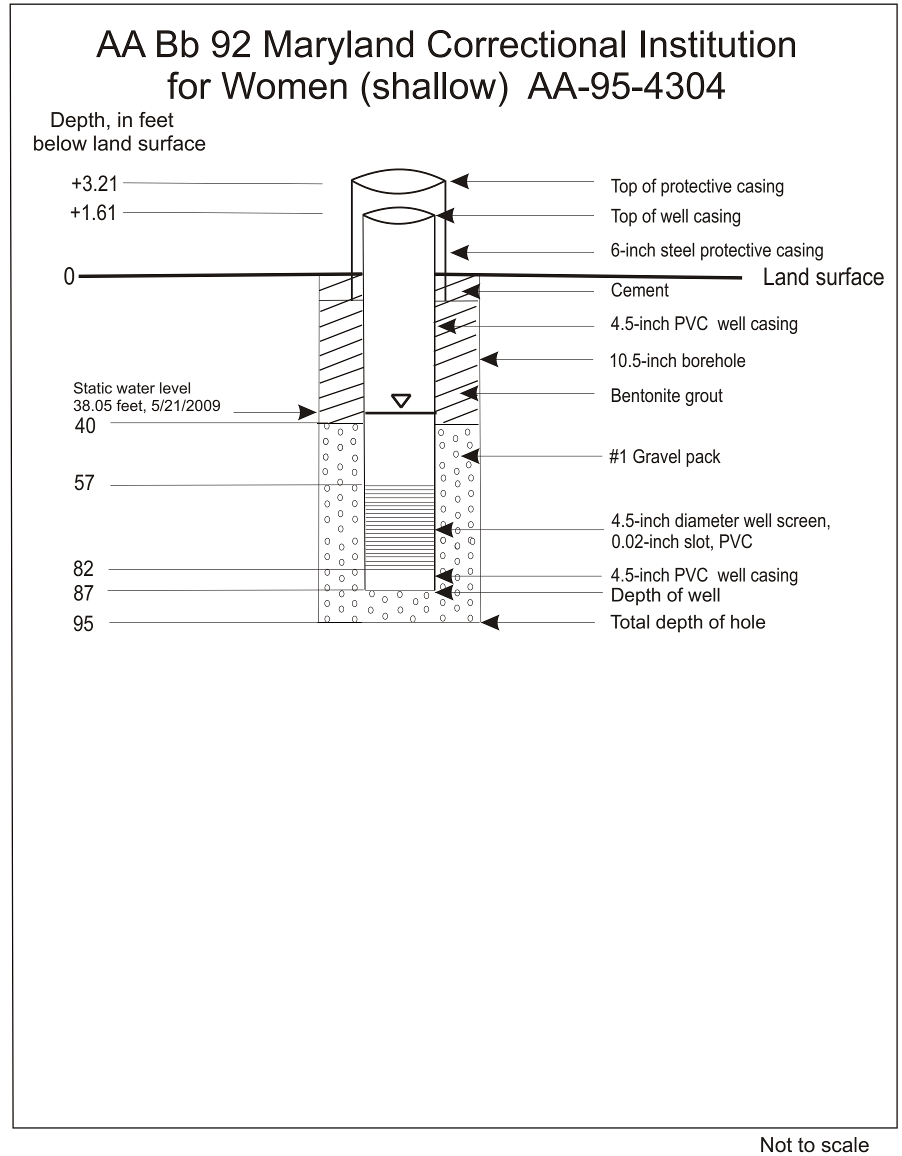
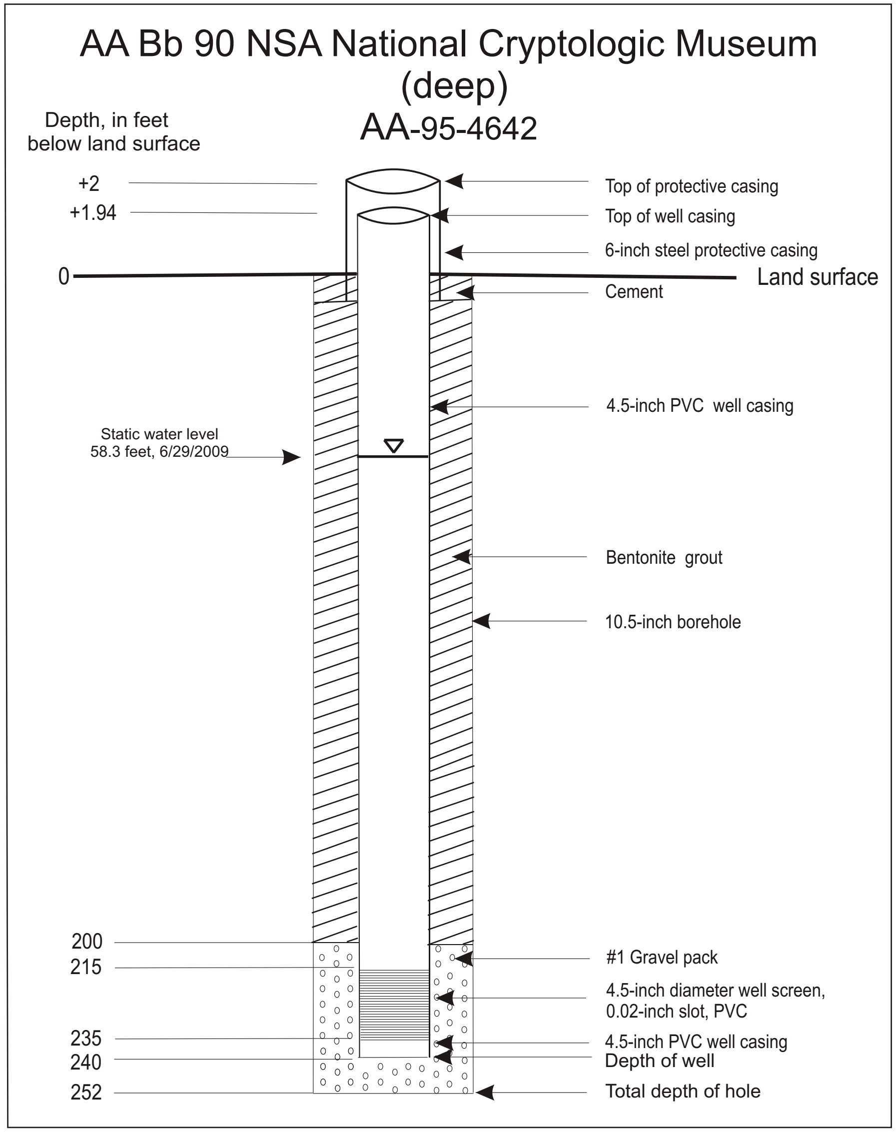


Figure 2, Continued.



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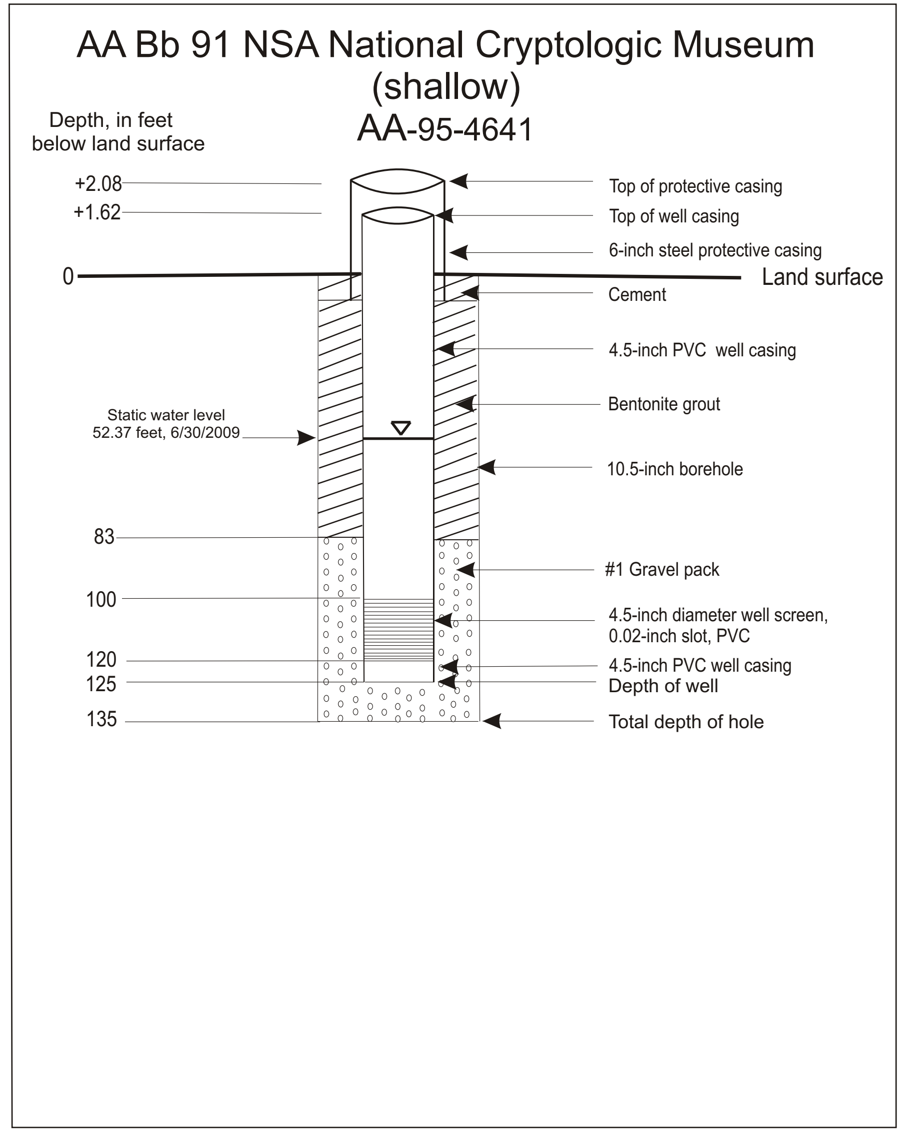

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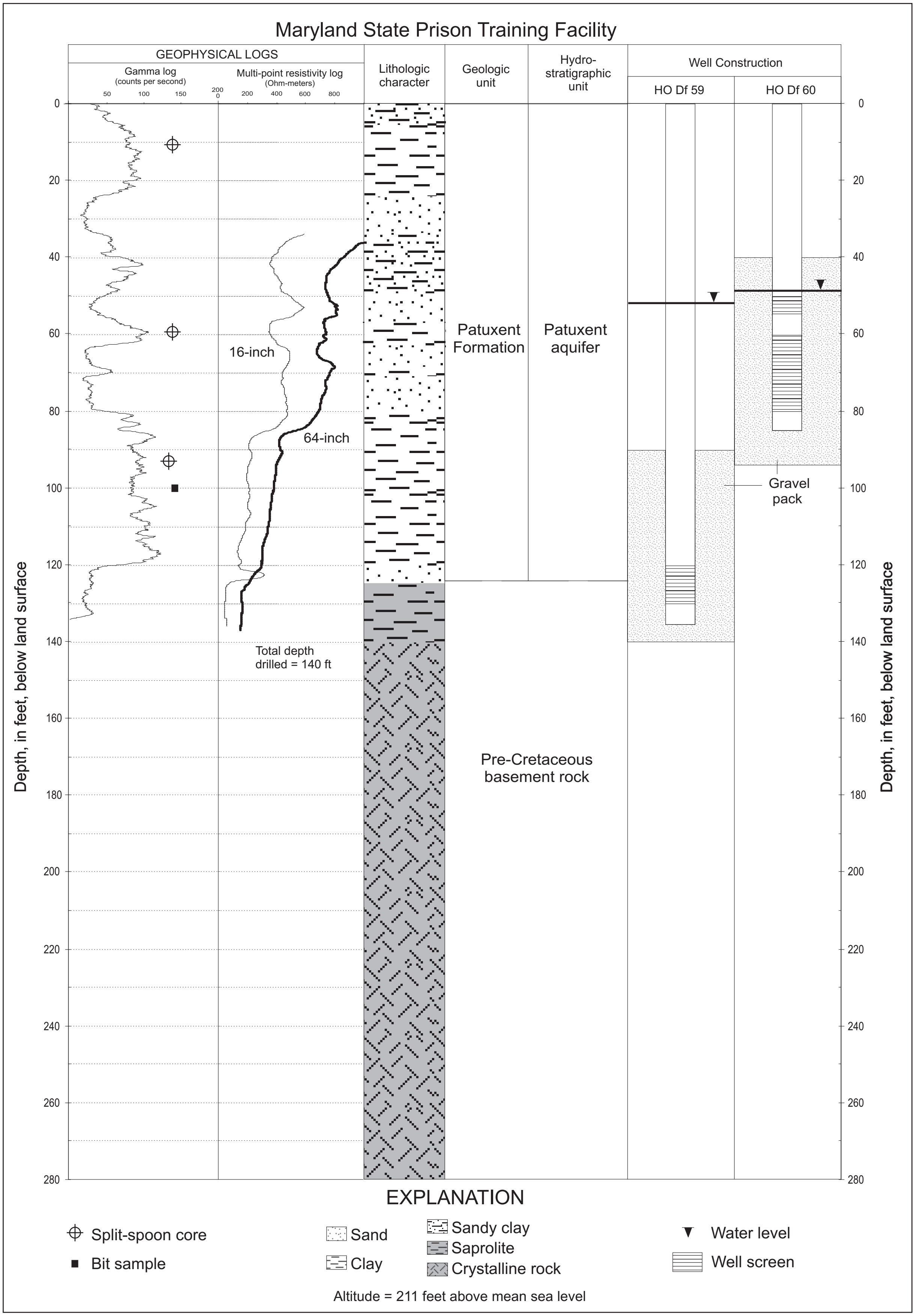
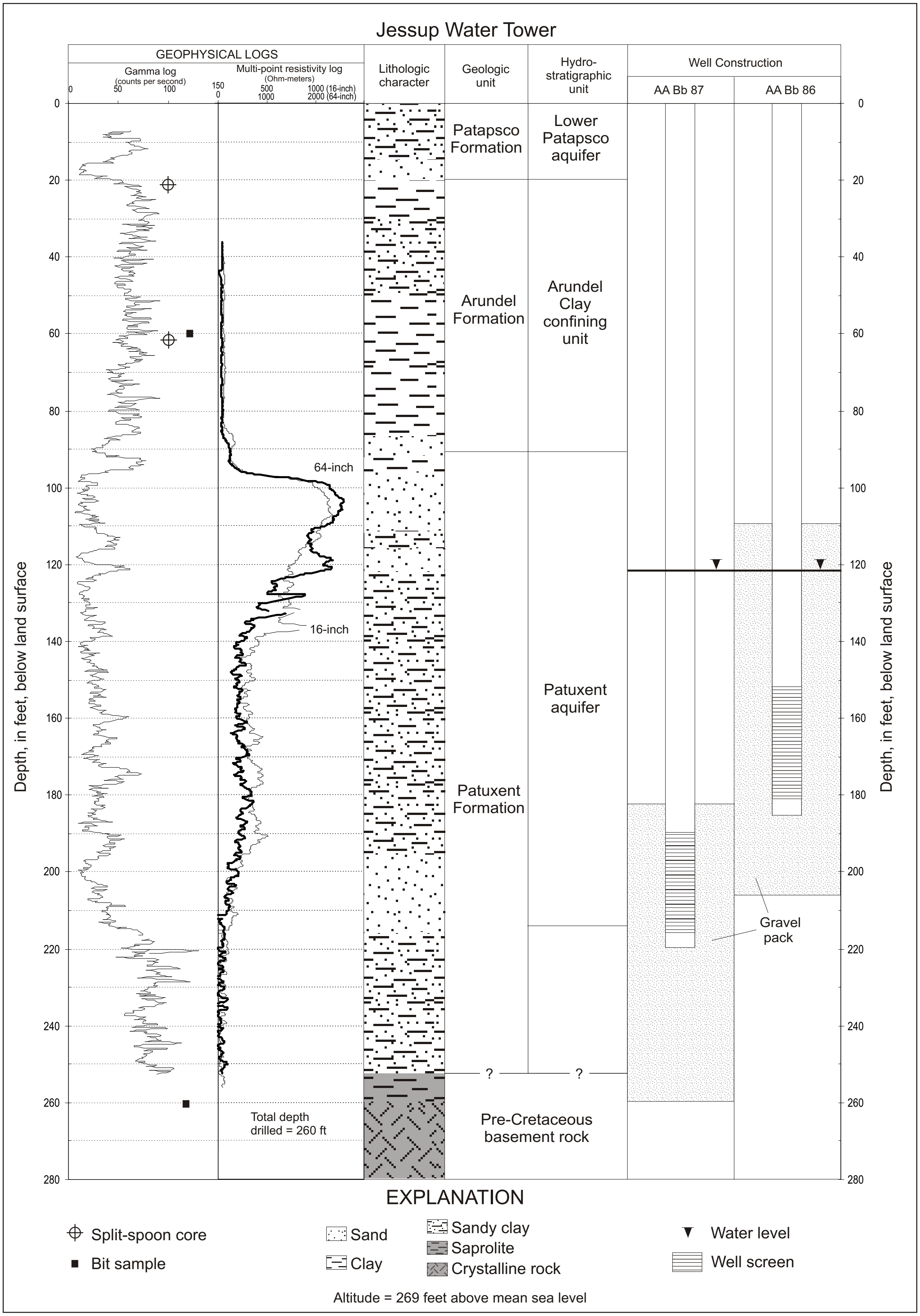


Figure 3. Geophysical, geologic, and hydrogeologic data from test wells.



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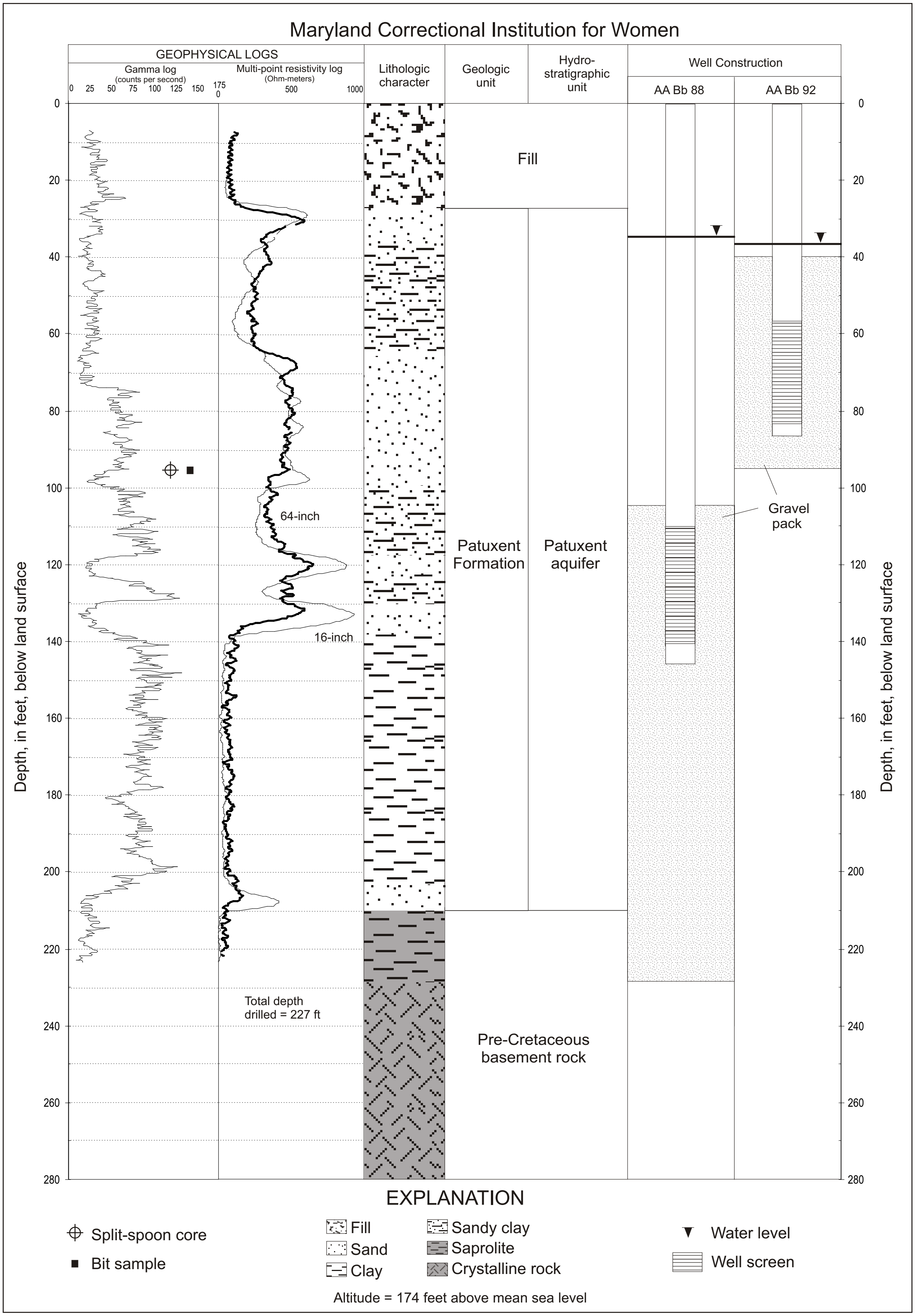

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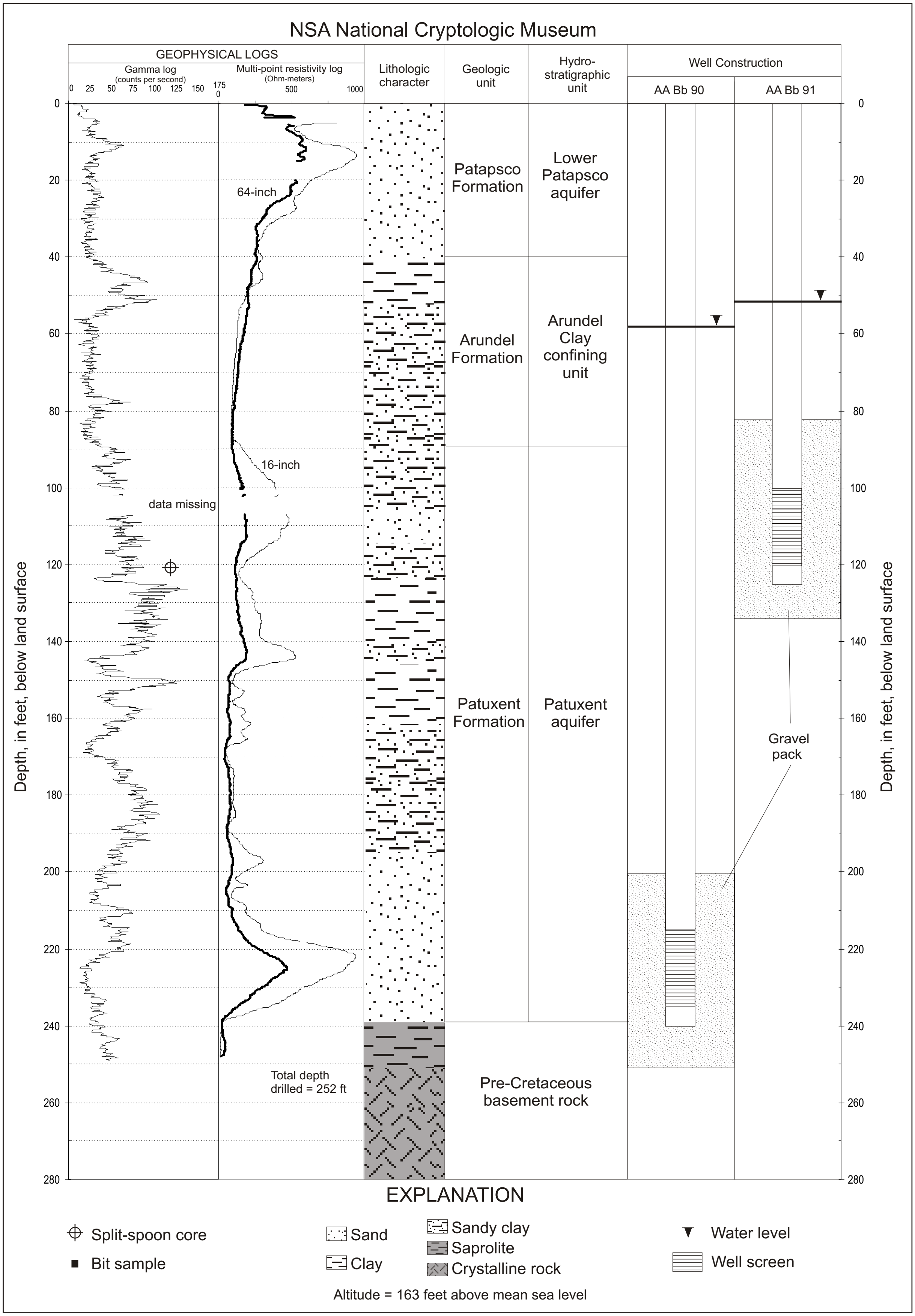

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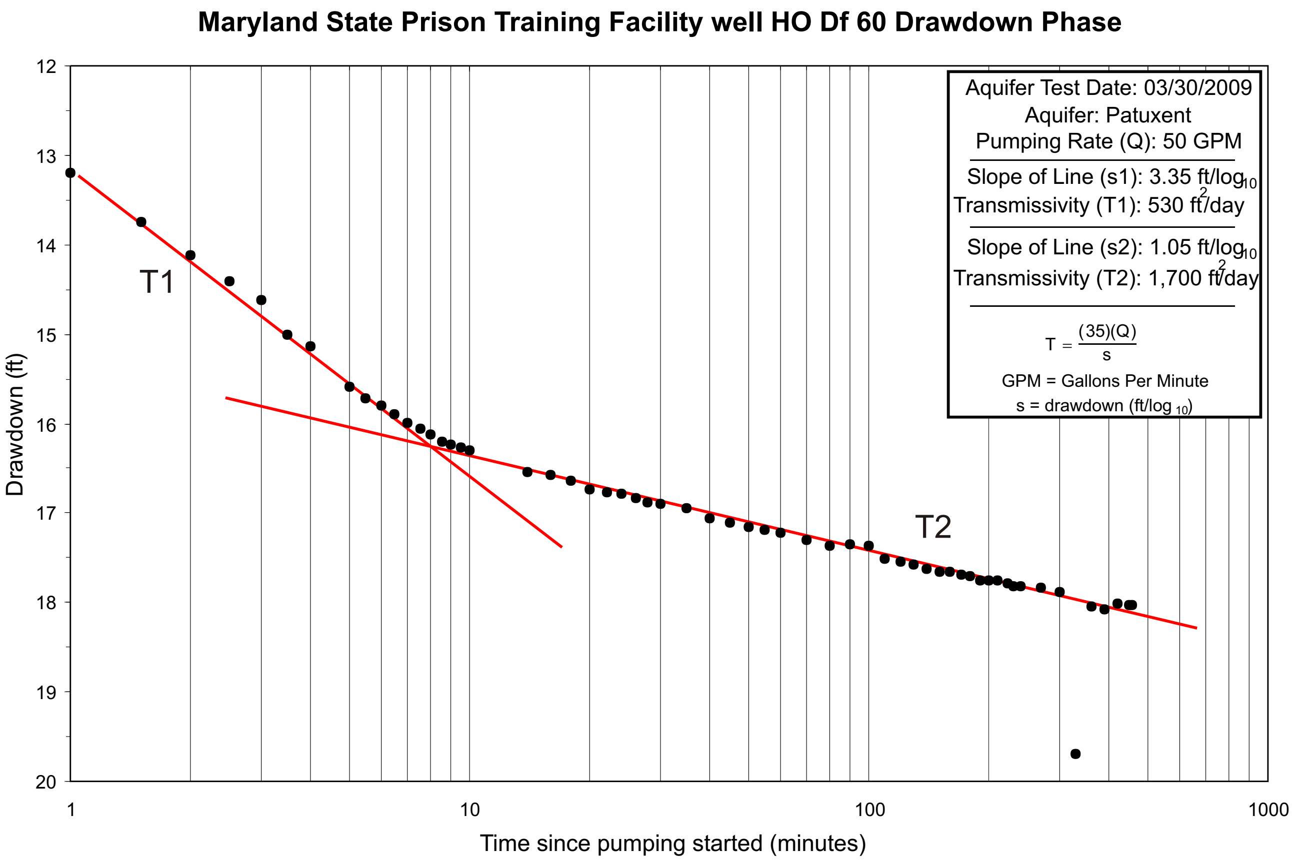


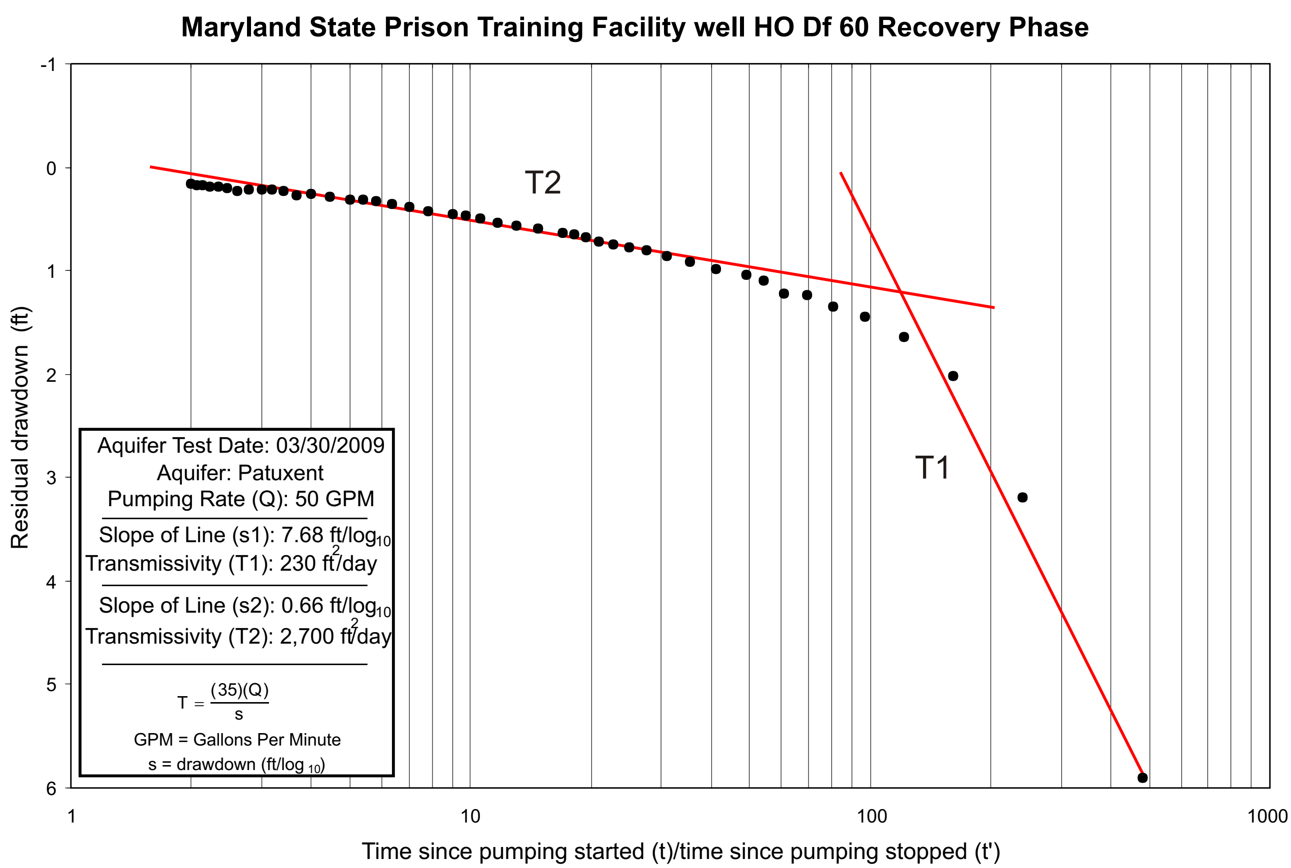
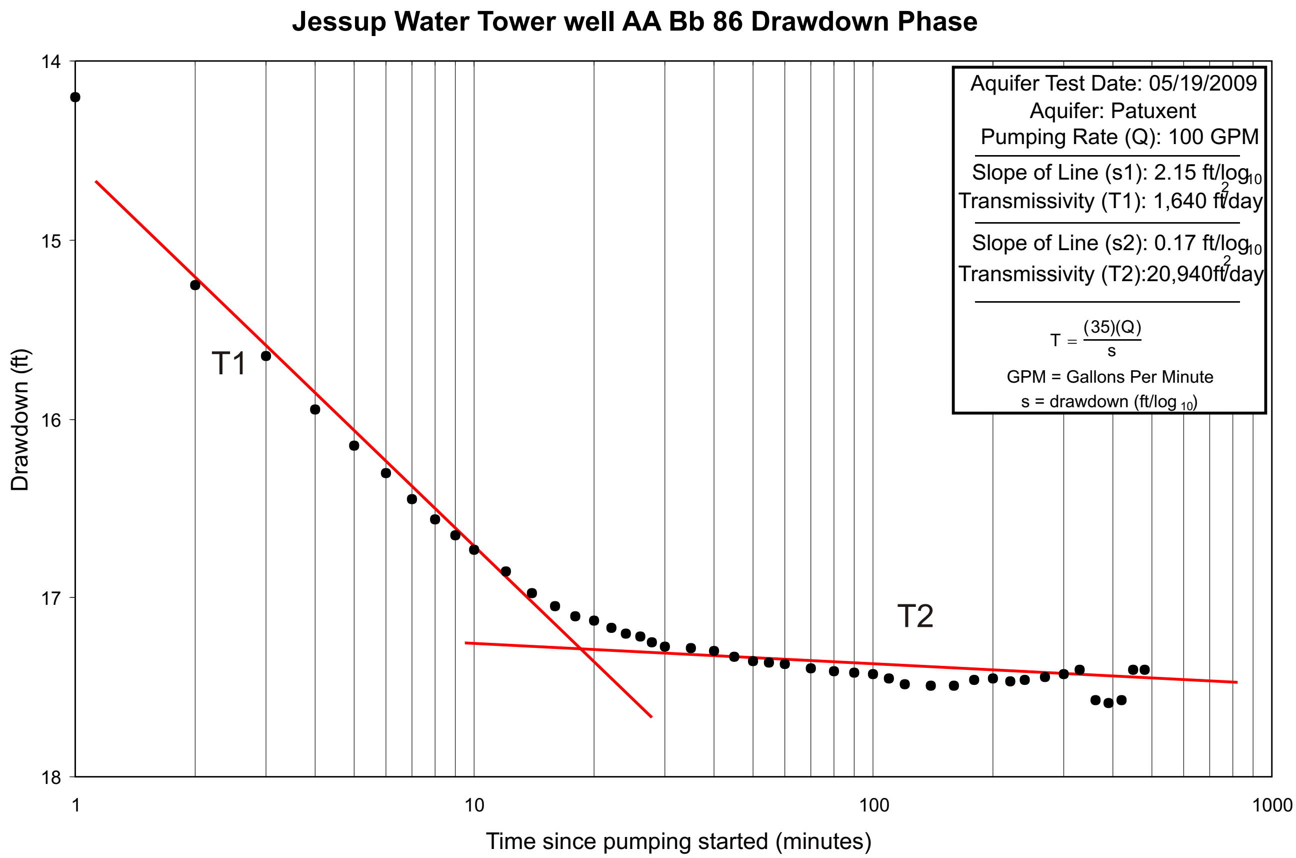
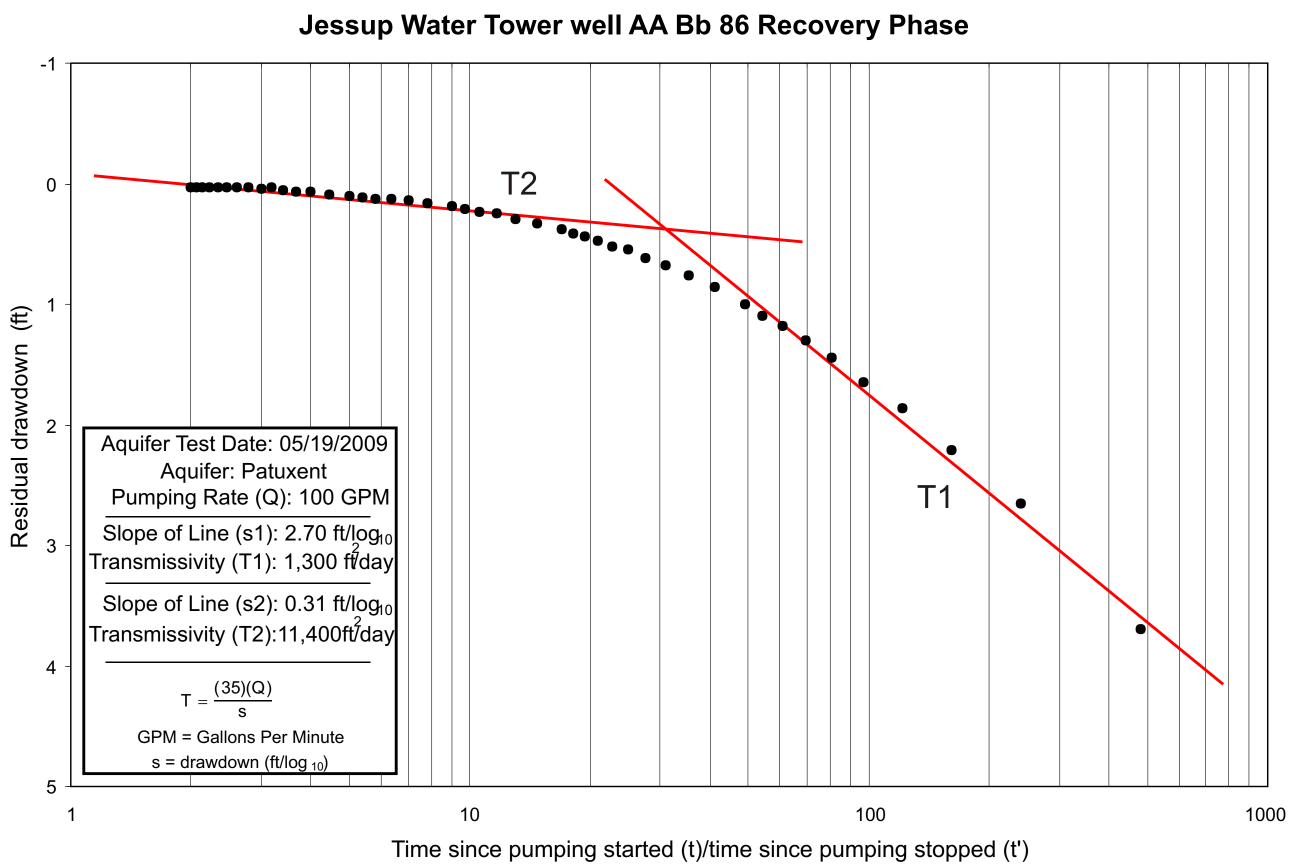


Figure 4. Drawdown and recovery data and transmissivity calculations for test wells.





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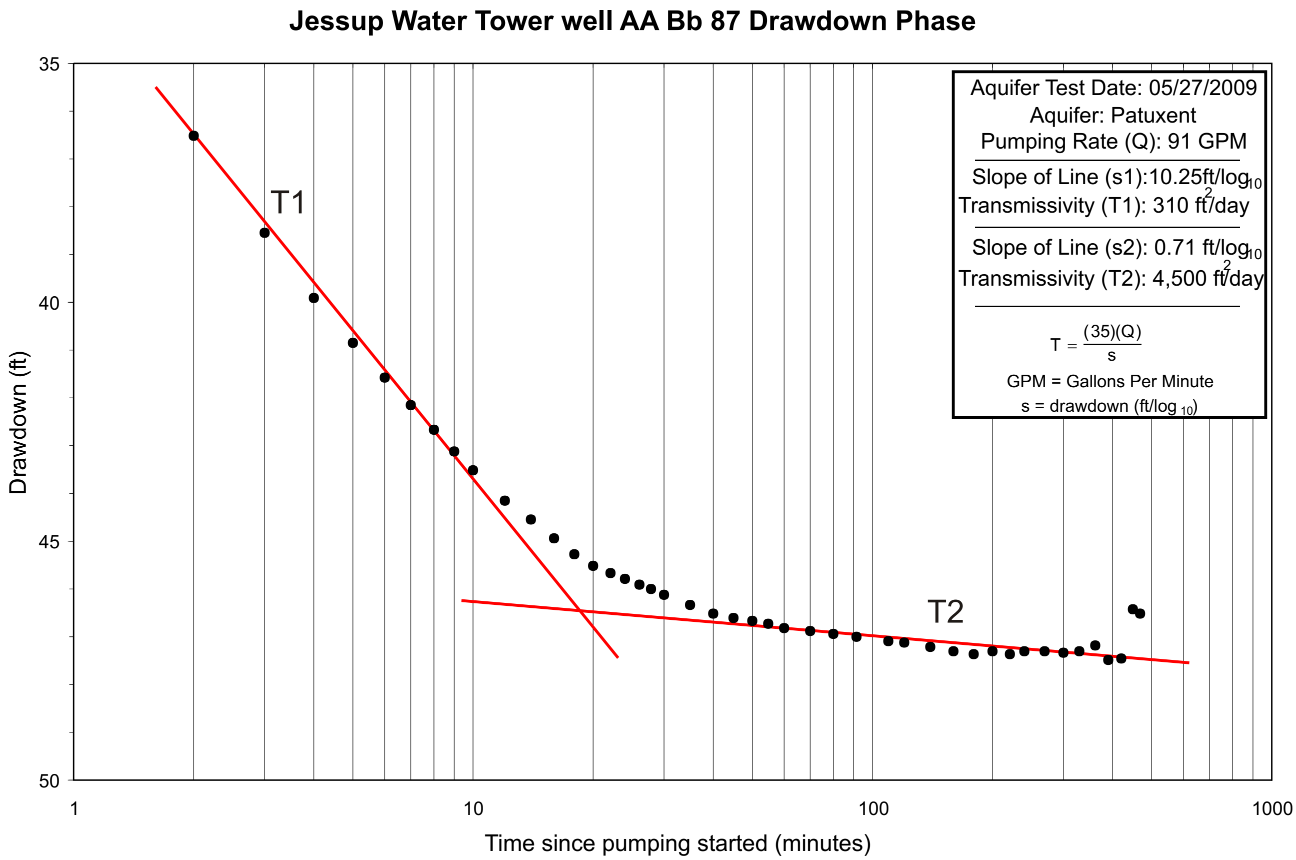

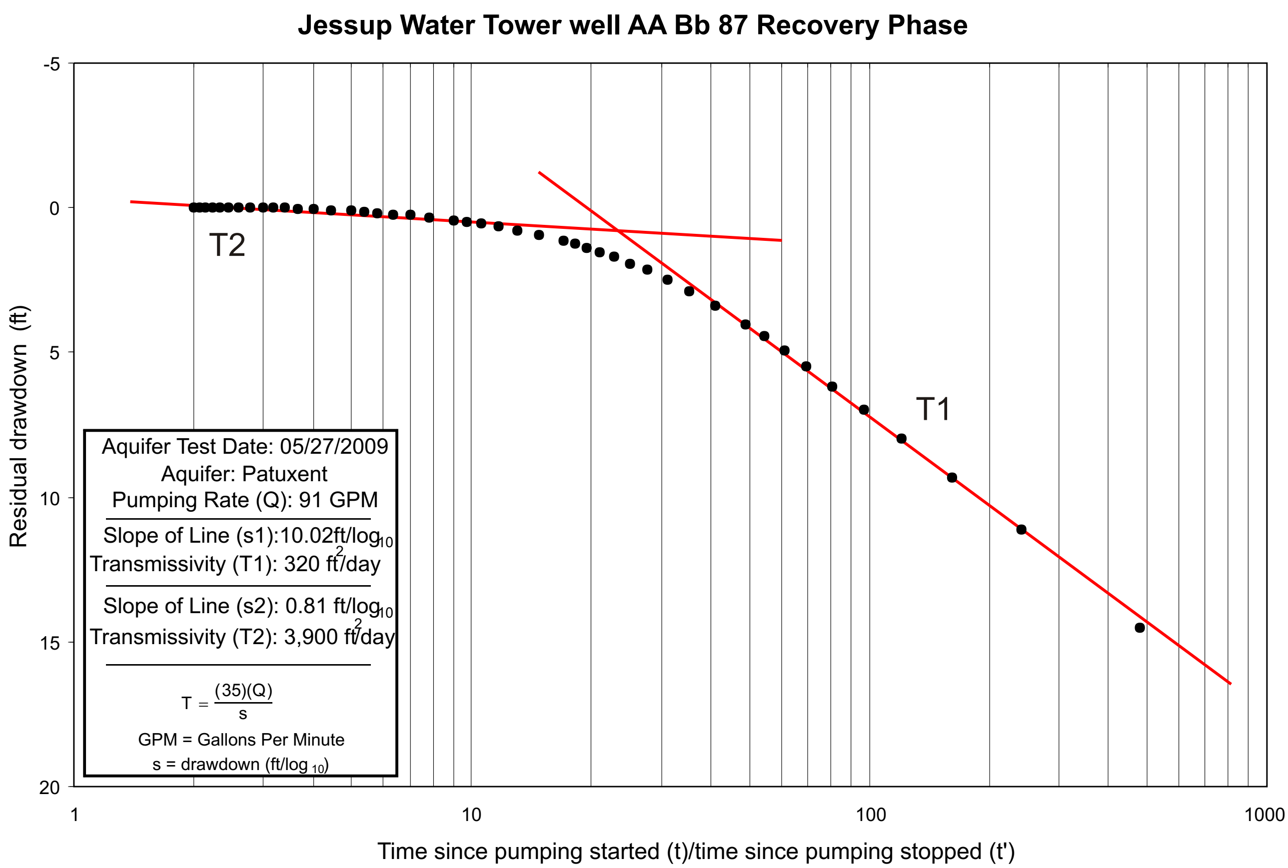

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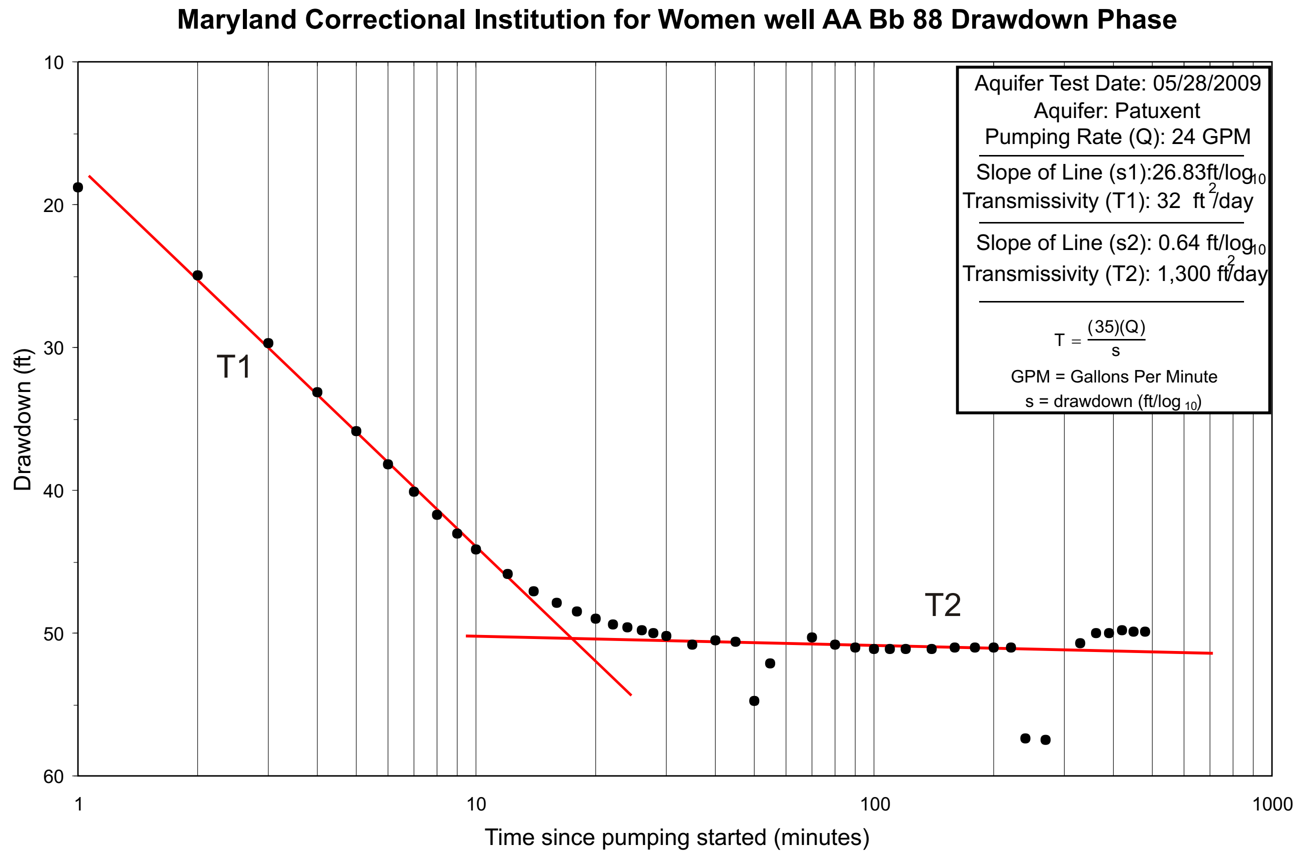


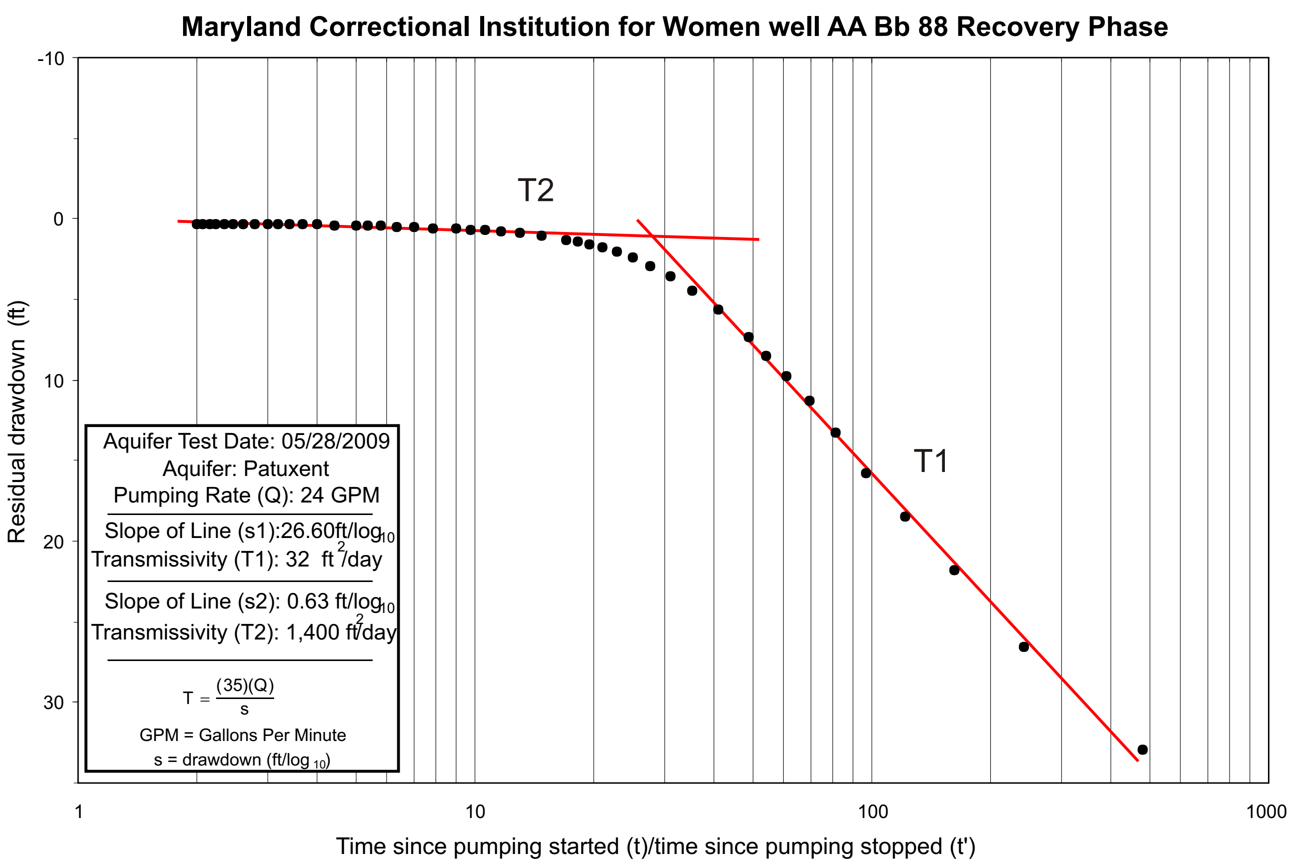
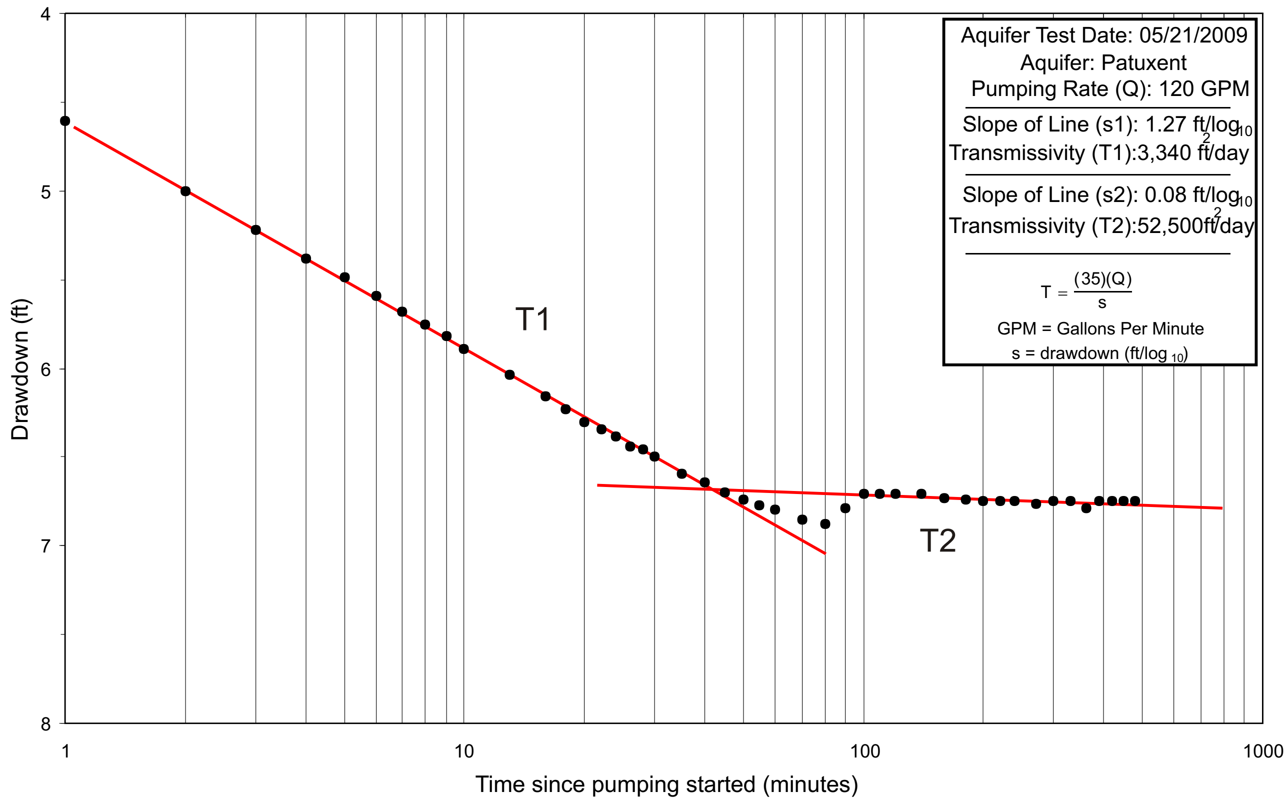


Figure 4, Continued.

Maryland Correctional Institution for Women well AA Bb 92 Drawdown Phase



Maryland Correctional Institution for Women well AA Bb 92 Recovery Phase

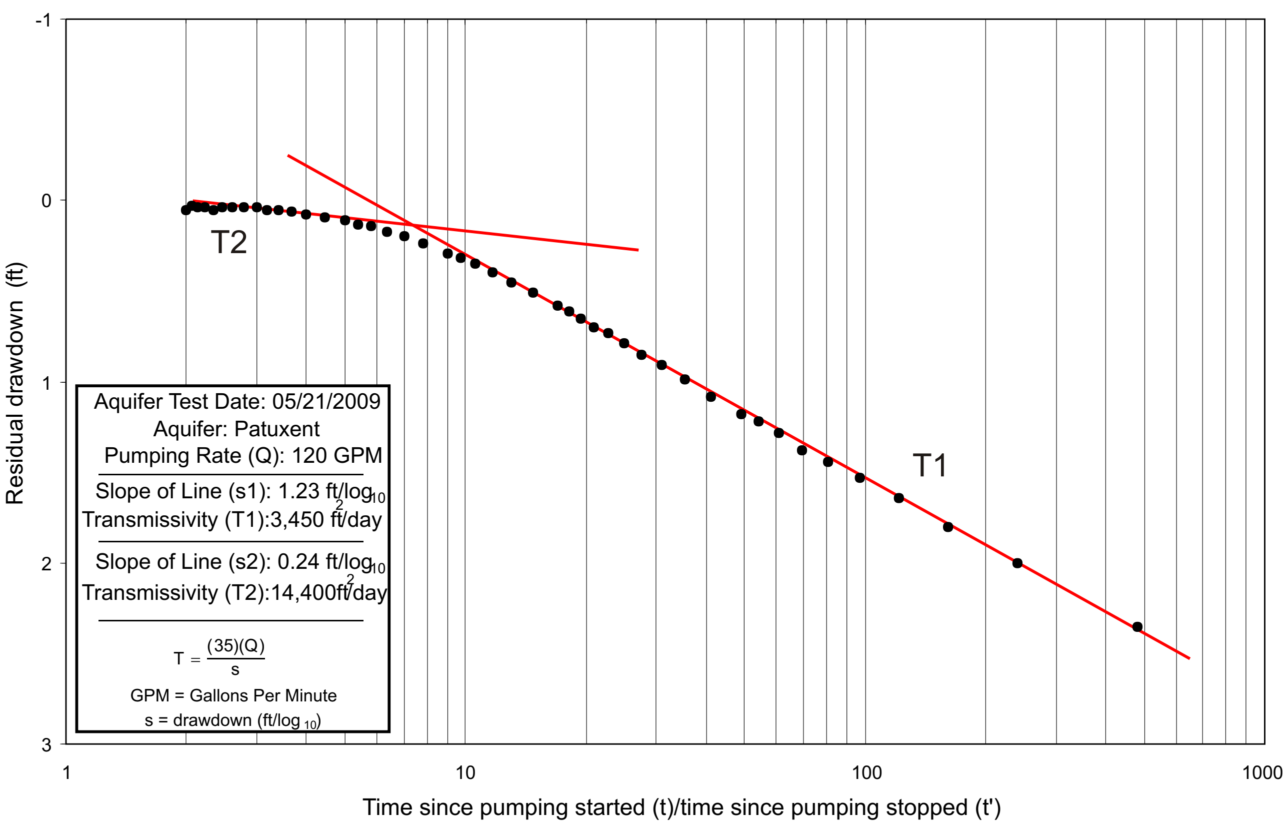
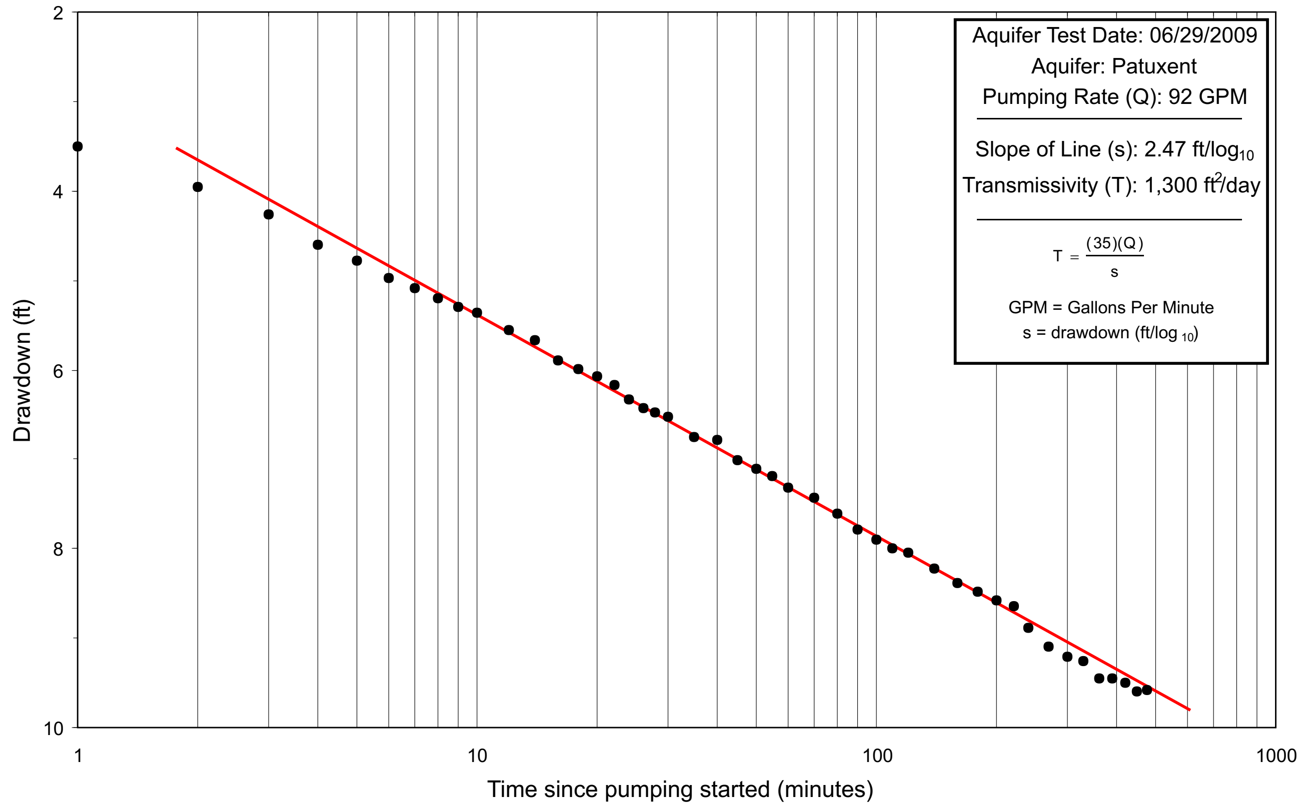
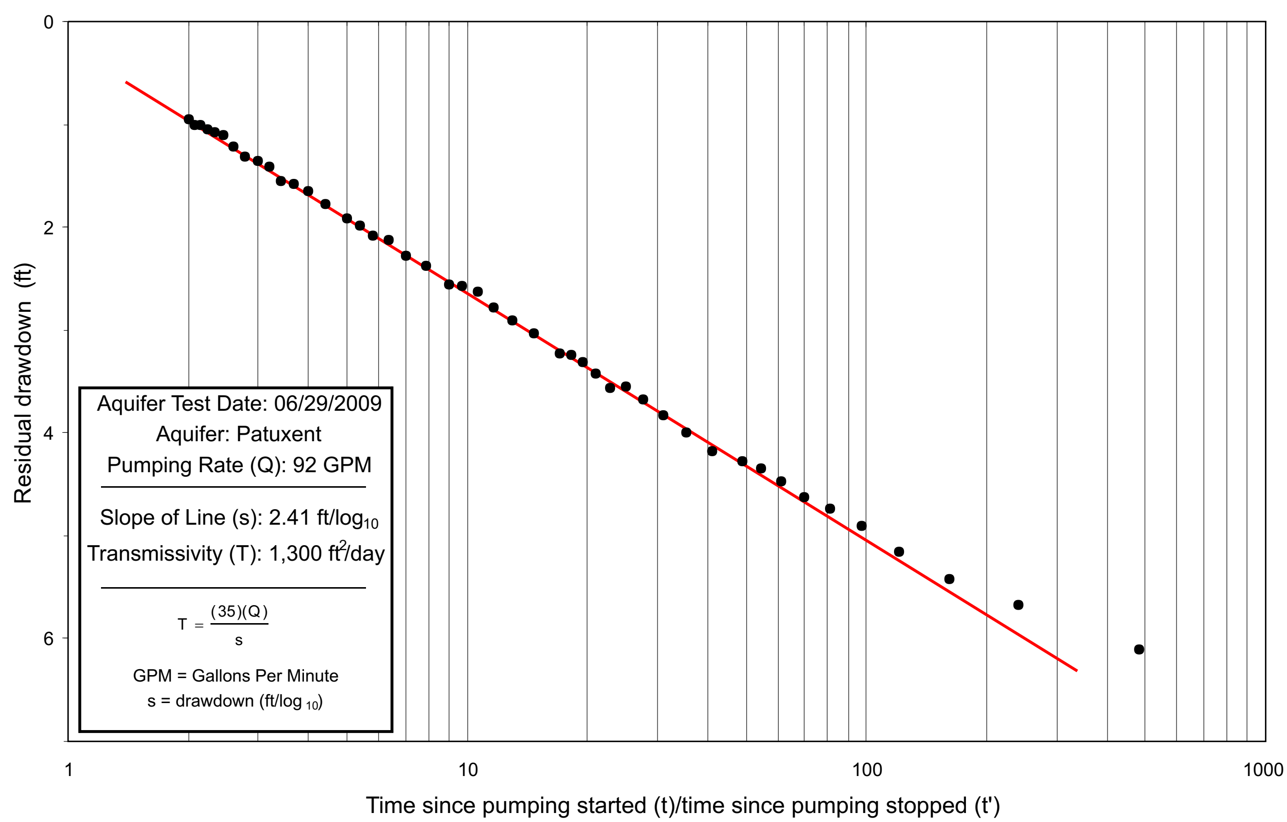


Figure 4, Continued

NSA National Cryptologic Museum well AA Bb 90 Drawdown Phase



NSA National Cryptologic Museum well AA Bb 90 Recovery Phase



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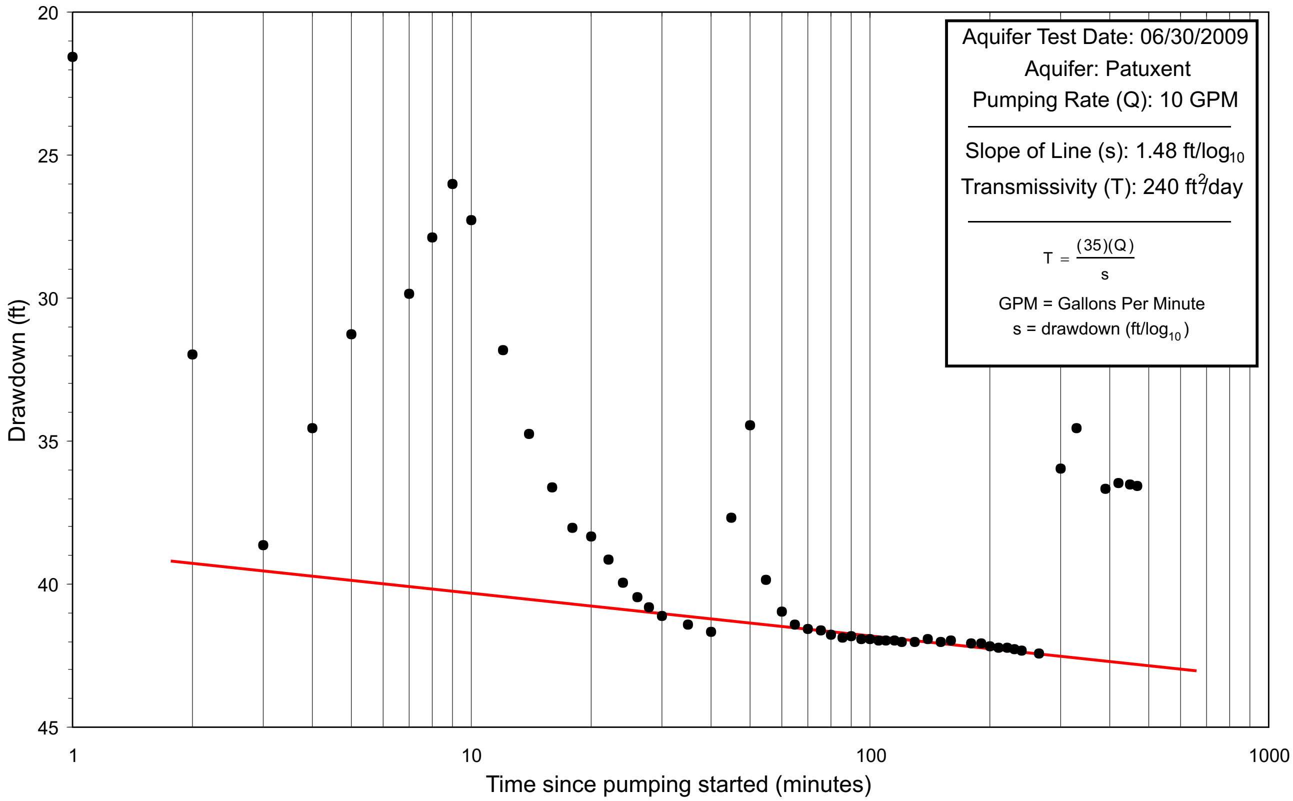
NSA National Cryptologic Museum well AA Bb 91 Drawdown Phase



NSA National Cryptologic Museum well AA Bb 91 Recovery Phase

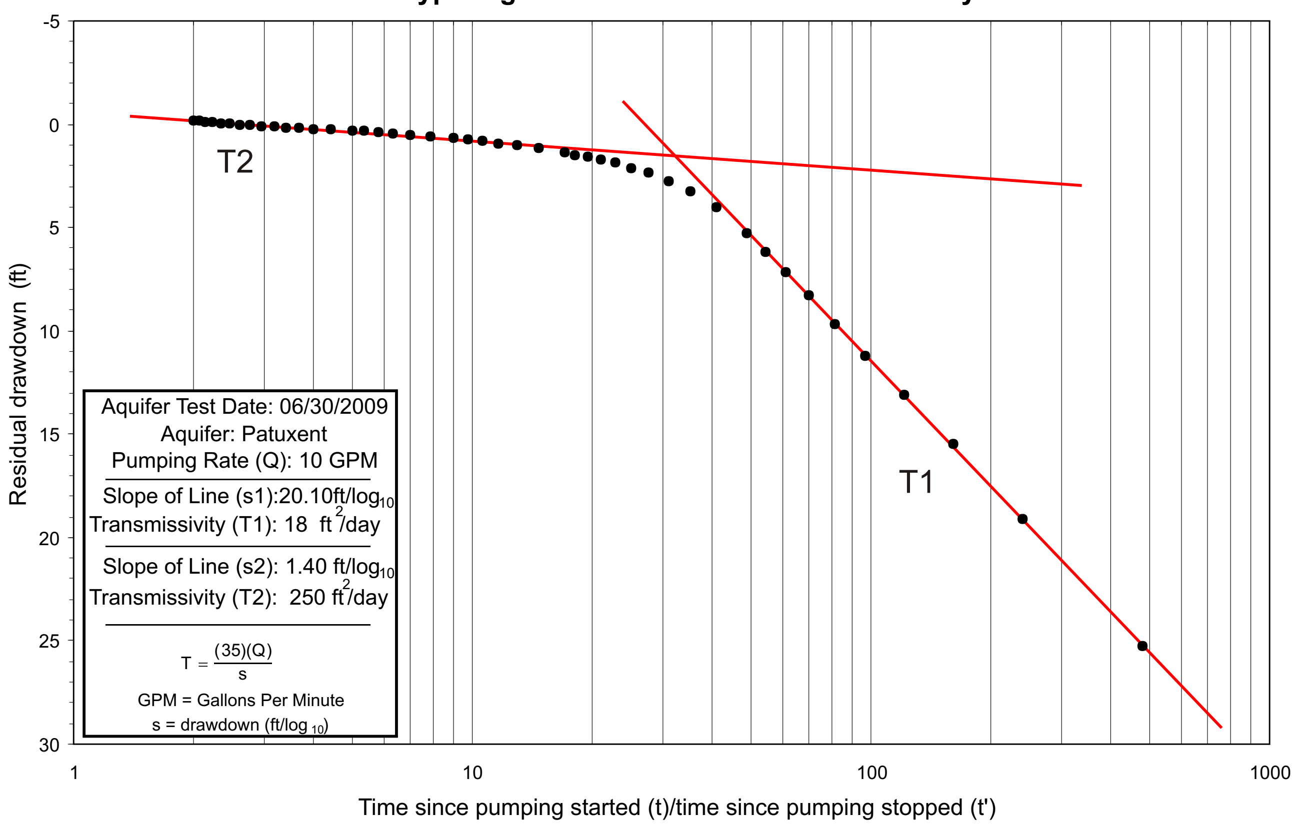
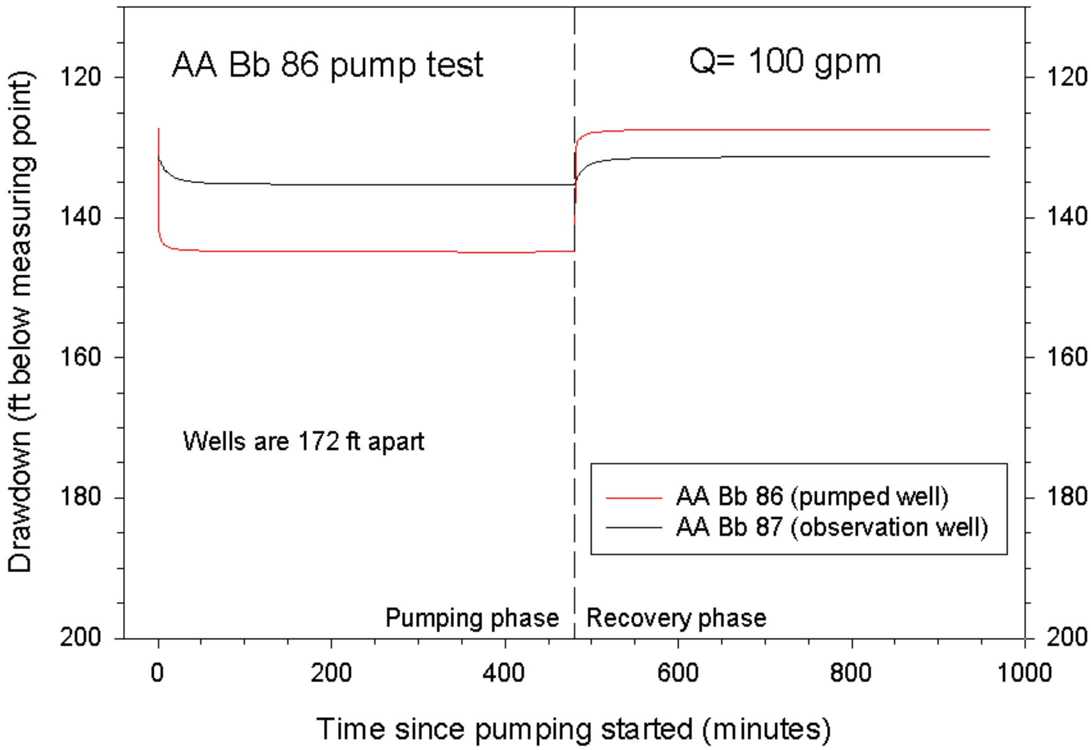


Figure 4, Continued.

JESSUP WATER TOWER



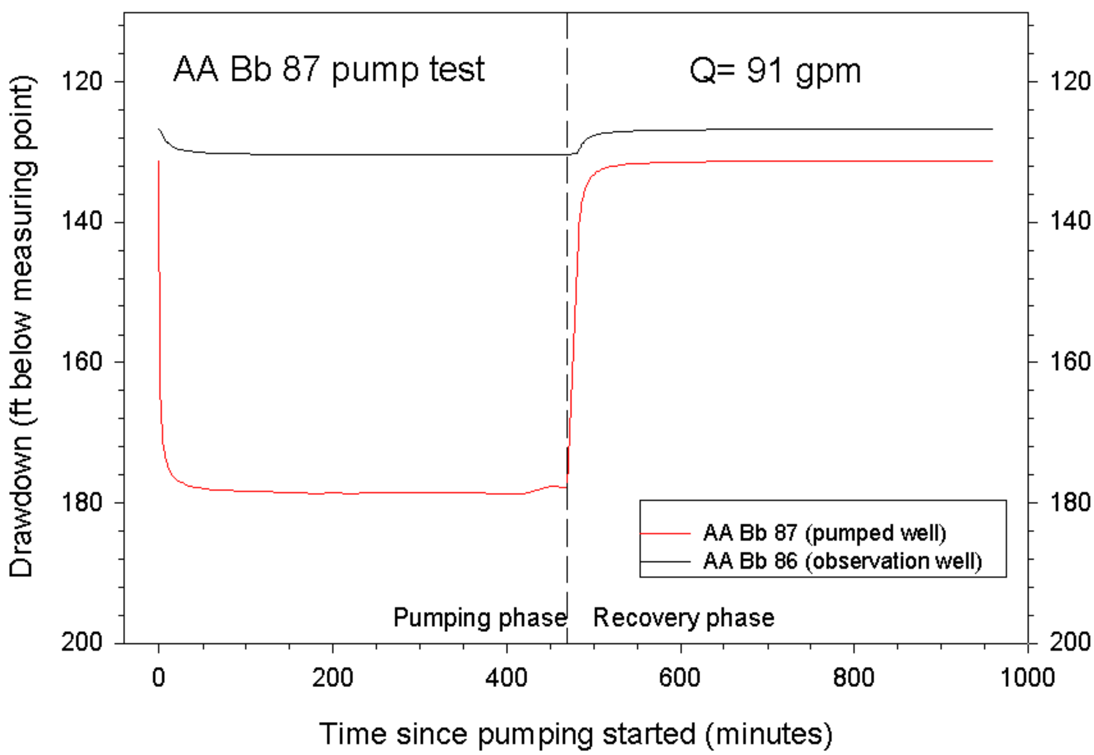
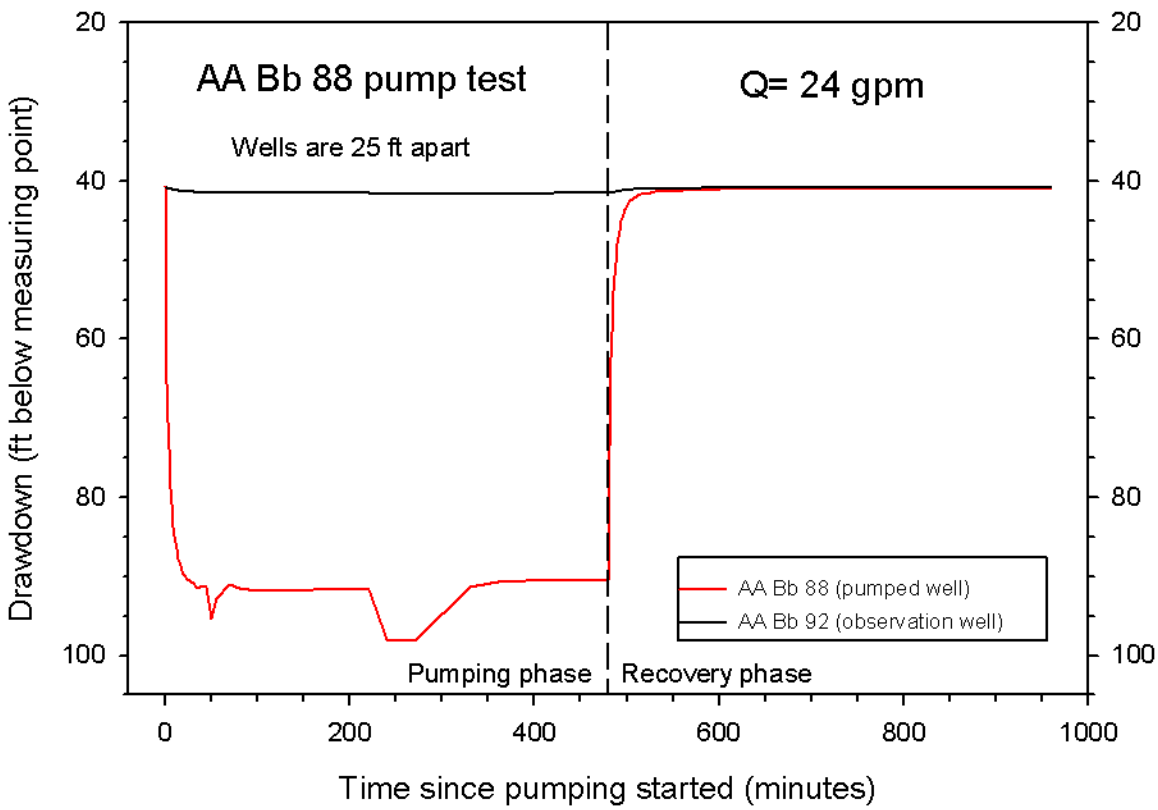


Figure 5. Drawdown and recovery data from pump tests in paired wells.

MARYLAND CORRECTIONAL INSTITUTION FOR WOMEN



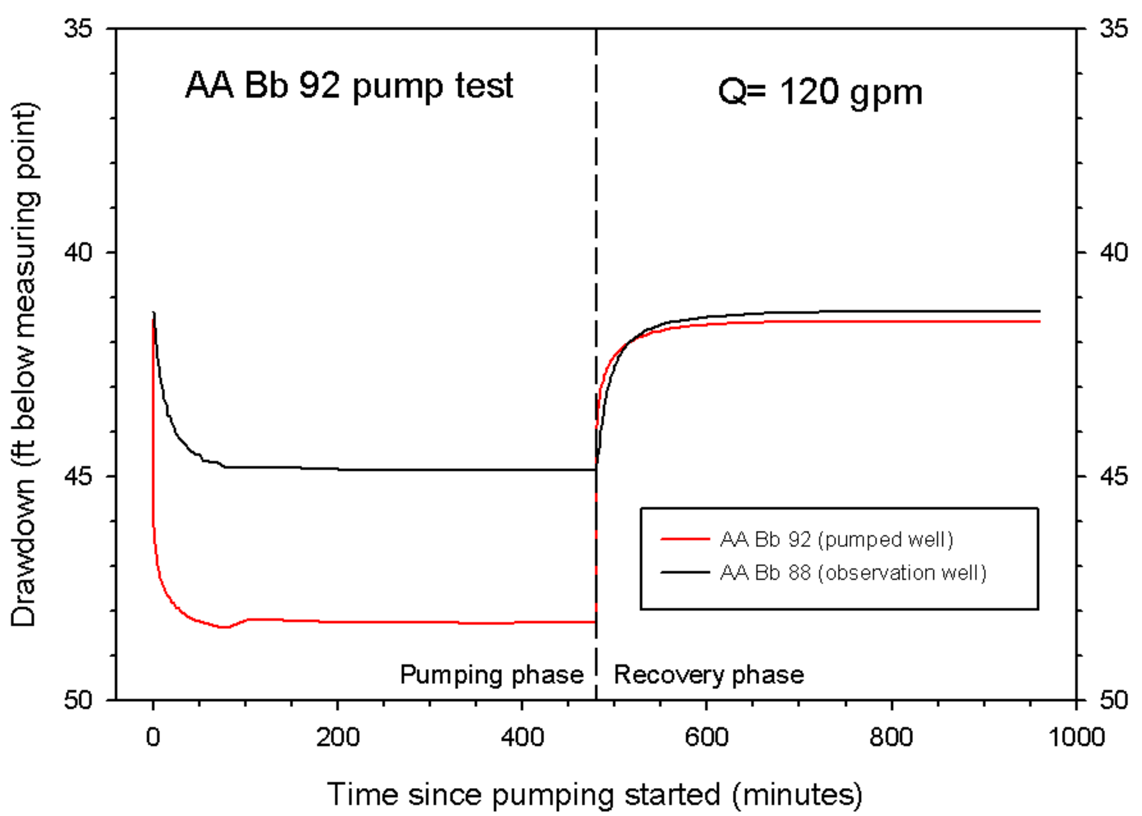
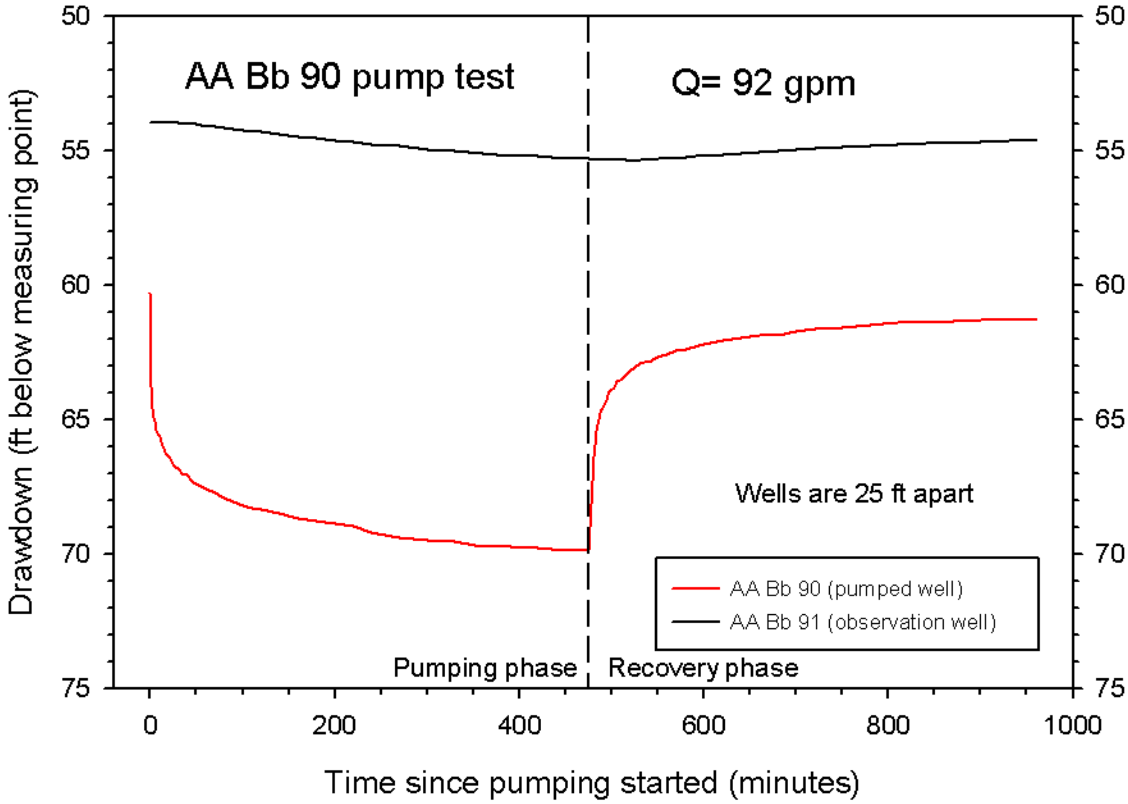


Figure 5, Continued.

NSA NATIONAL CRYPTOLOGIC MUSEUM



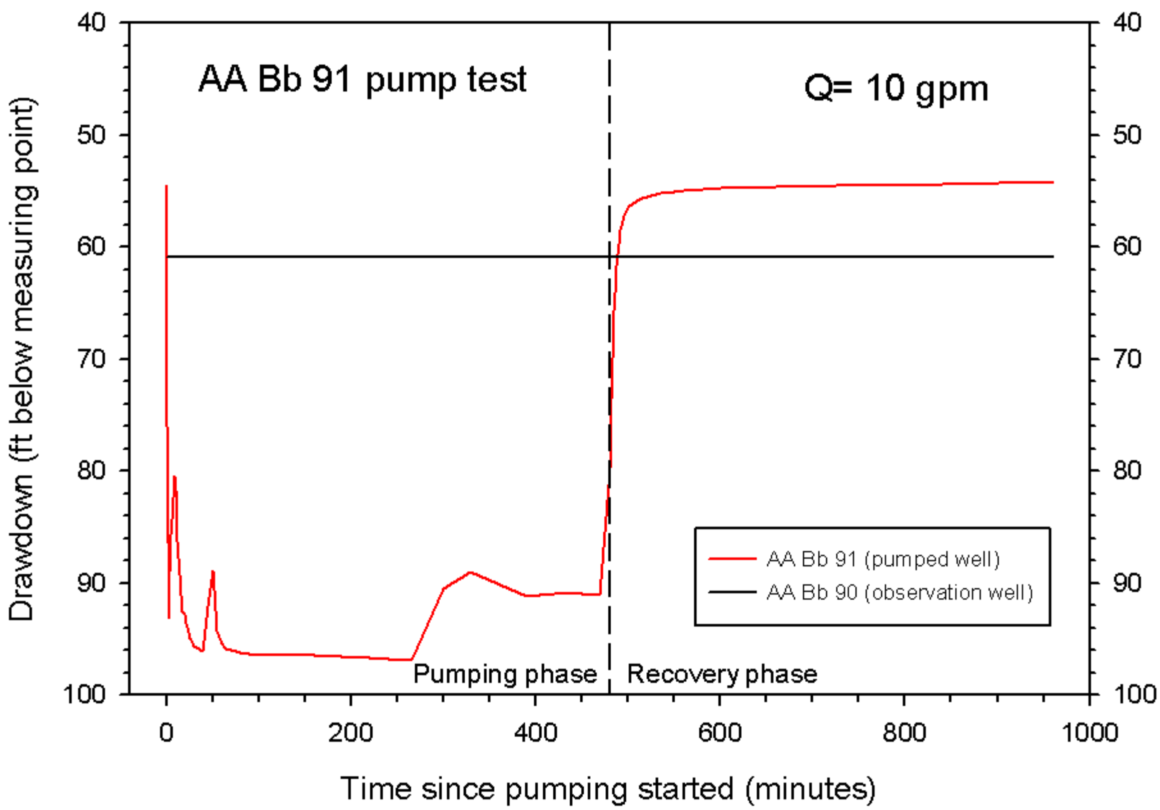


Figure 5, Continued.

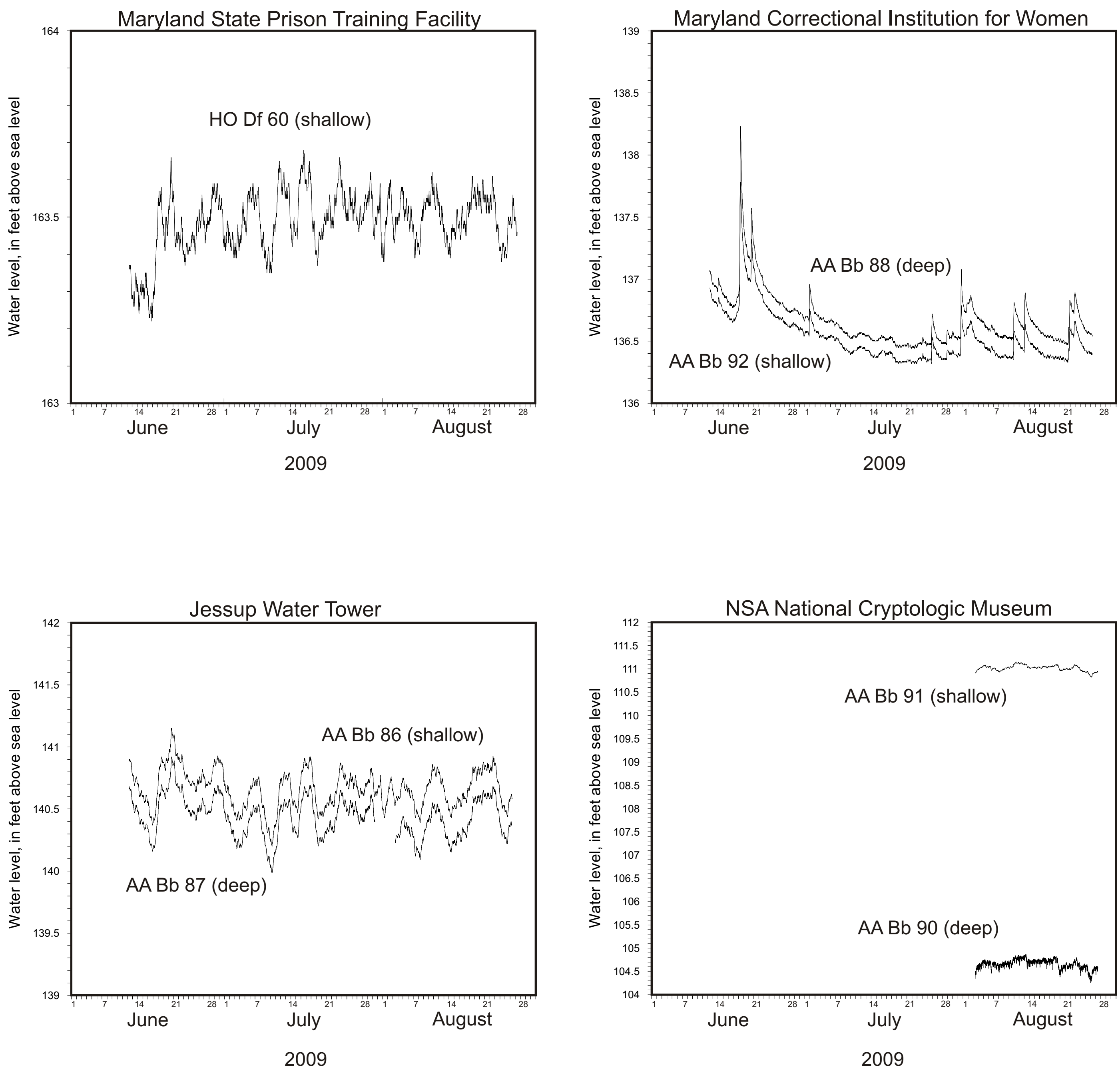


Figure 6. Hydrographs from test wells.

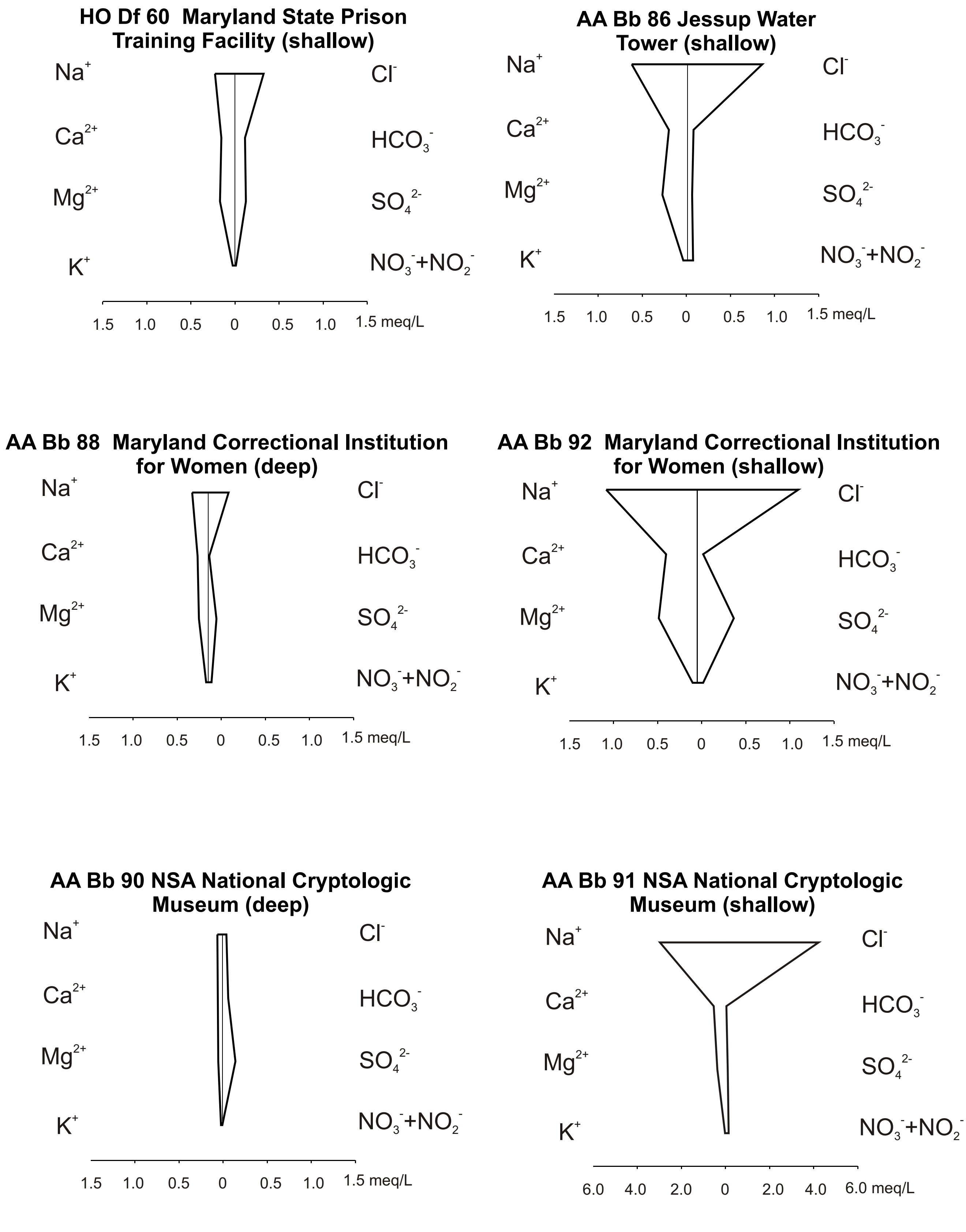


Figure 7. Stiff diagrams showing milliequivalents of major ions in water samples taken from BRAC test wells in 2009. Data from AA Bb 87 incomplete as of September, 2009.

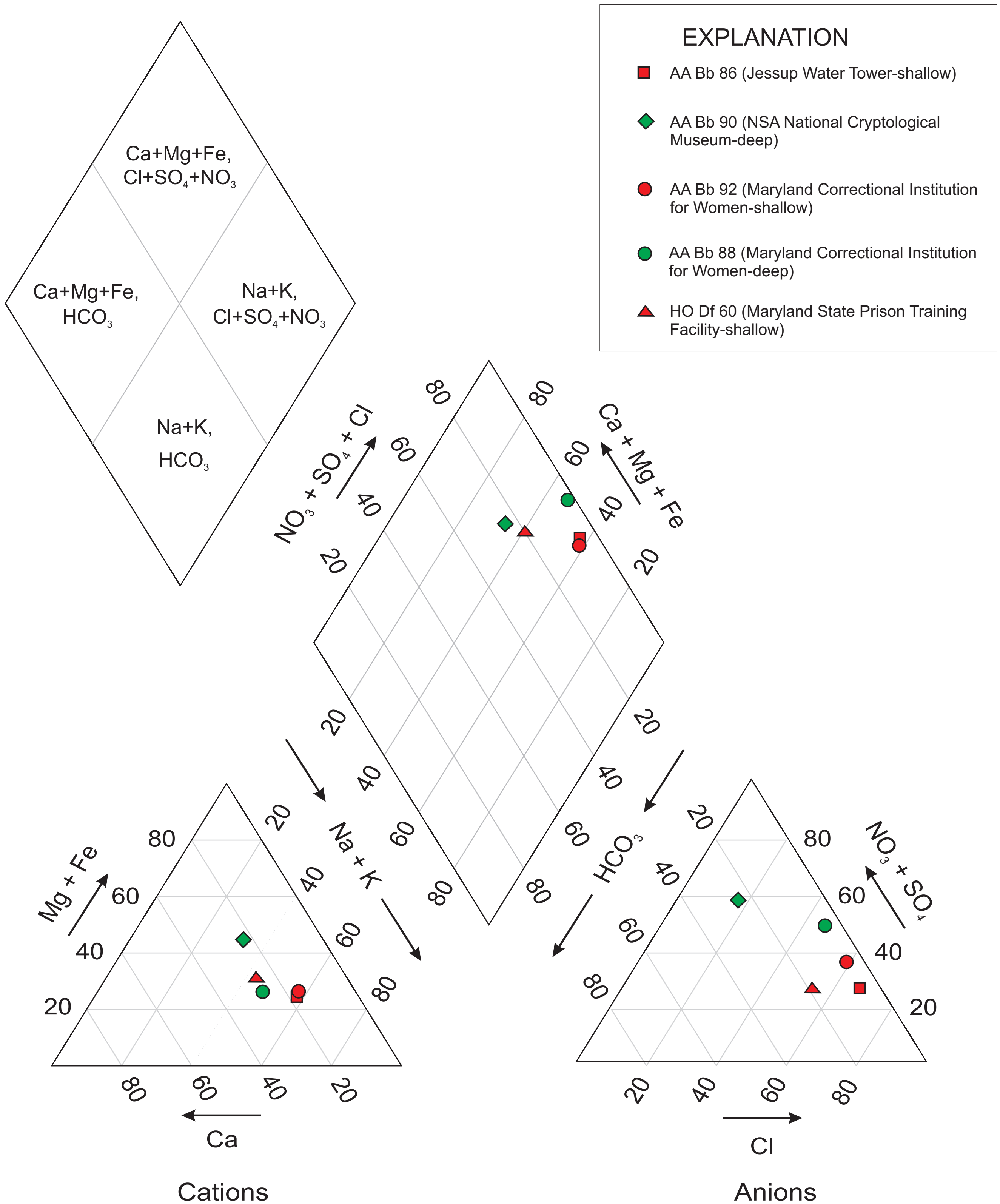


Figure 8. Piper diagram showing milliequivalent percentages of major ions from BRAC test wells (2009).

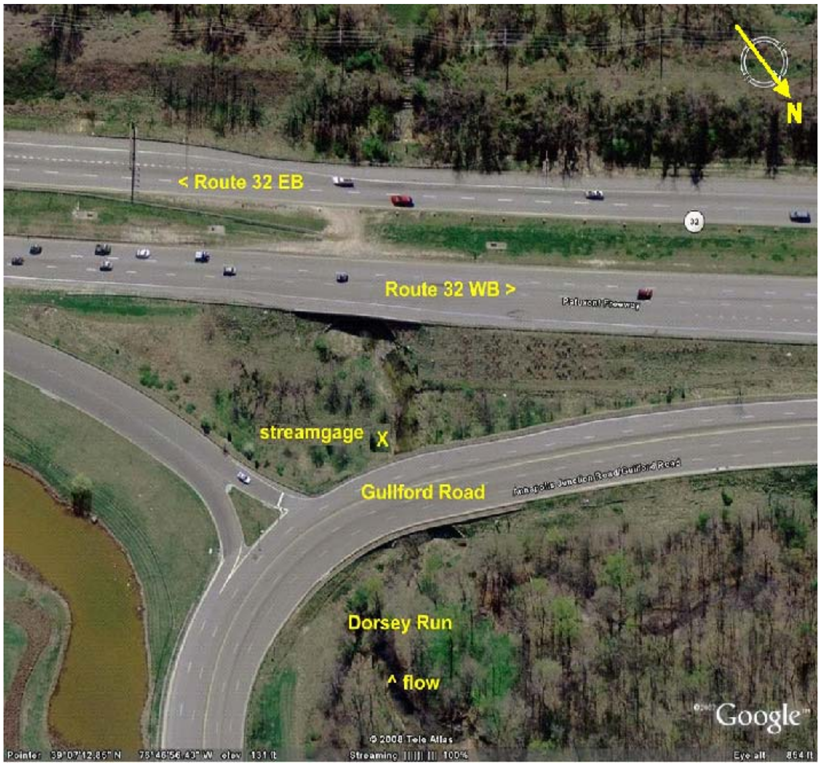


Figure 9. Stream gage (USGS 01594400) on Dorsey Run near Ft. Meade between Guilford Road and Rt. 32 bridges. [View is to the southwest]

Figure 10. Stream gage and rain gage at Dorsey Run.

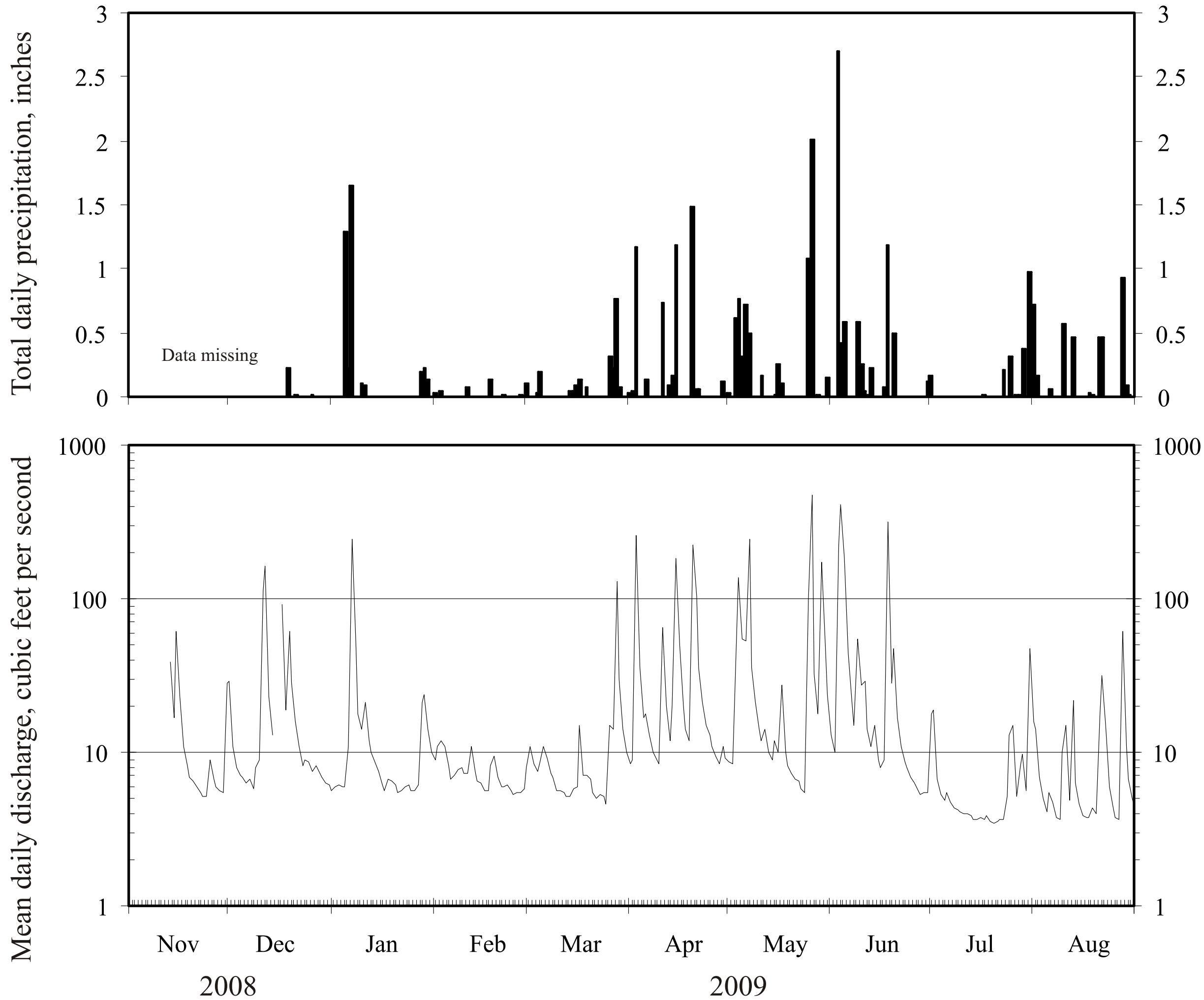
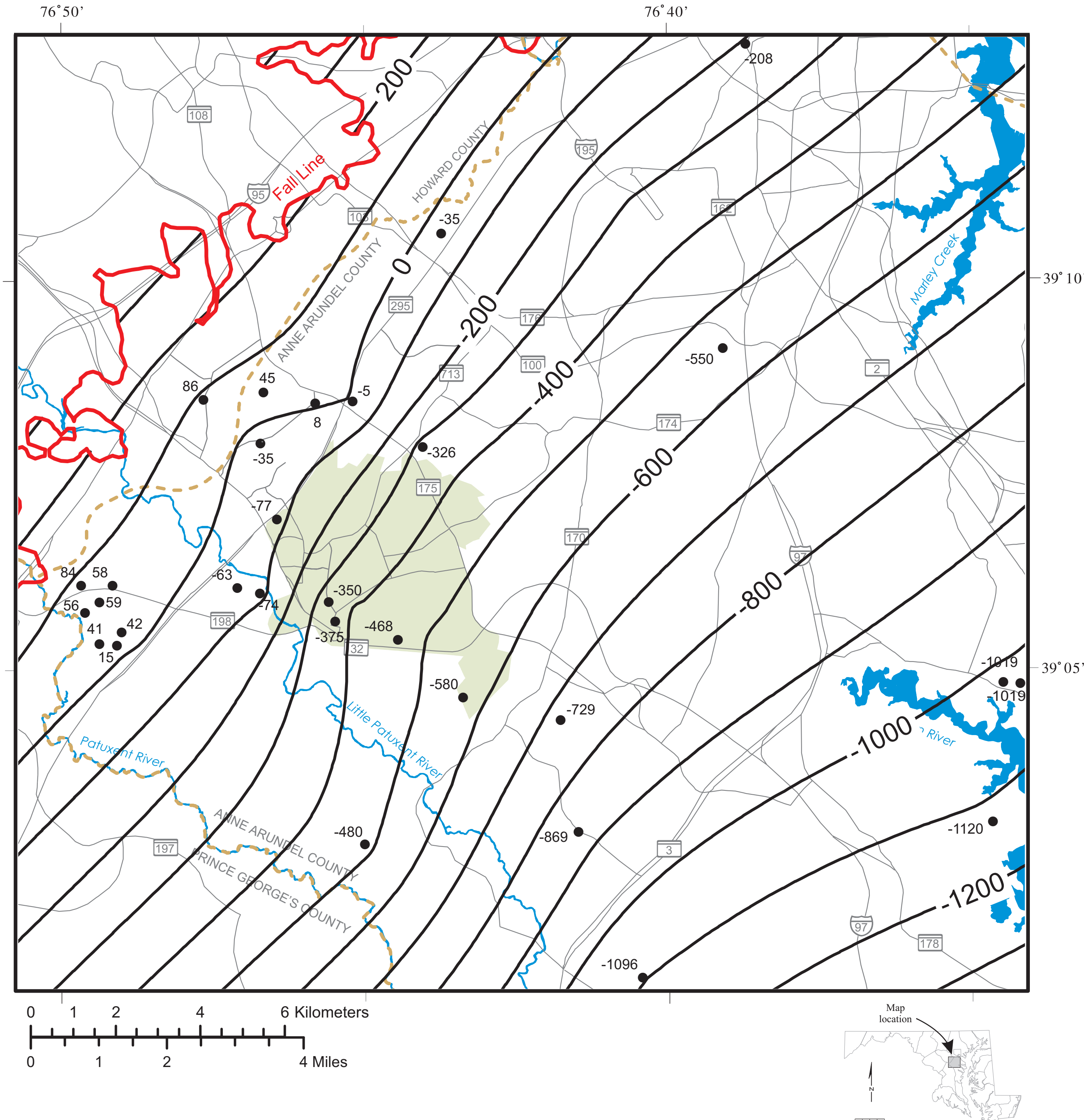


Figure 11. Stream discharge and precipitation at Dorsey Run.



EXPLANATION

—— -200 —— Contour showing the altitude of the top of basement rock, in feet relative to sea level. Contour interval is 100 feet.

● -480 Data point. Number is altitude of the top of basement rock, in feet relative to sea level.

Fall Line

Figure 12. Top of the basement rock in the Ft. Meade area.

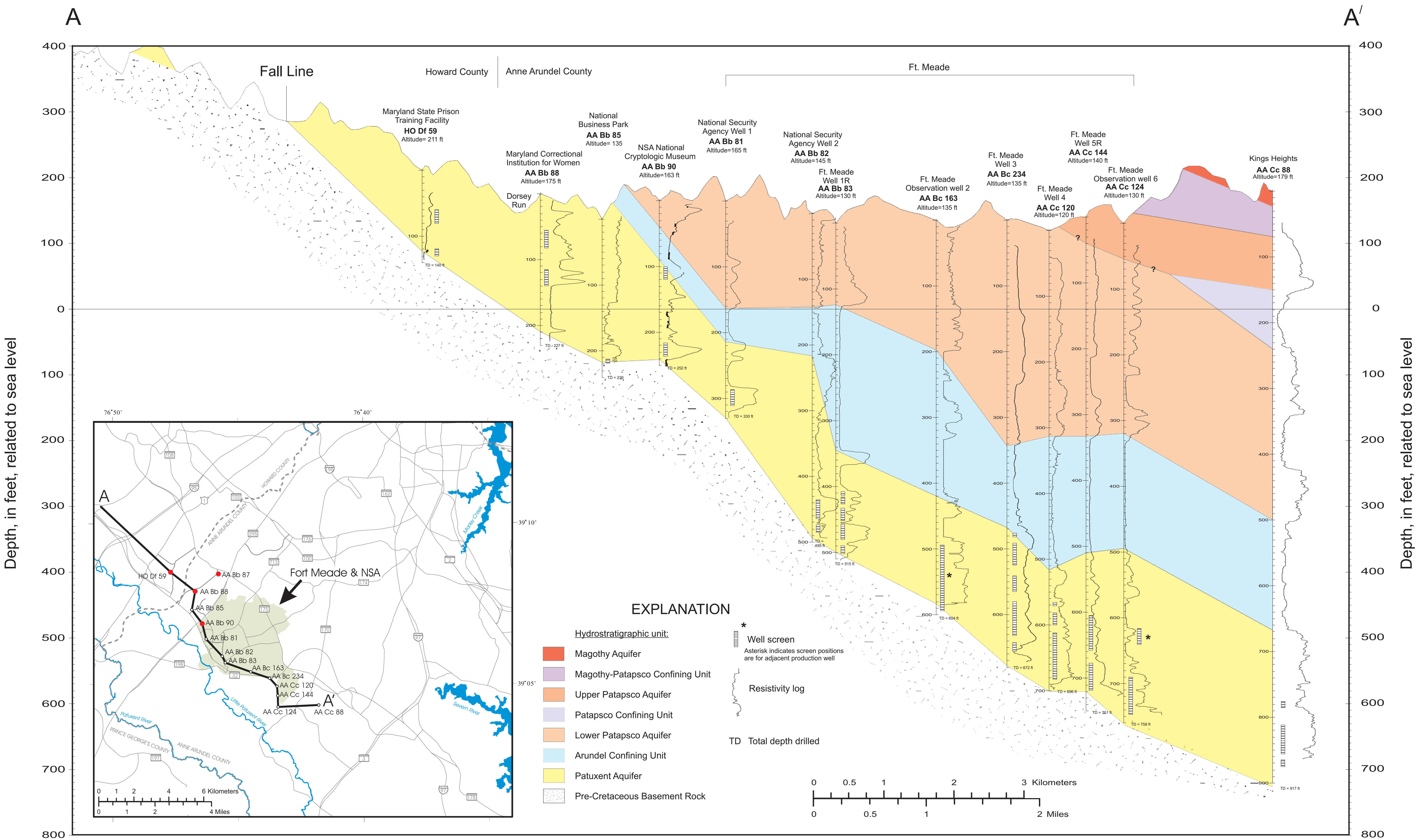
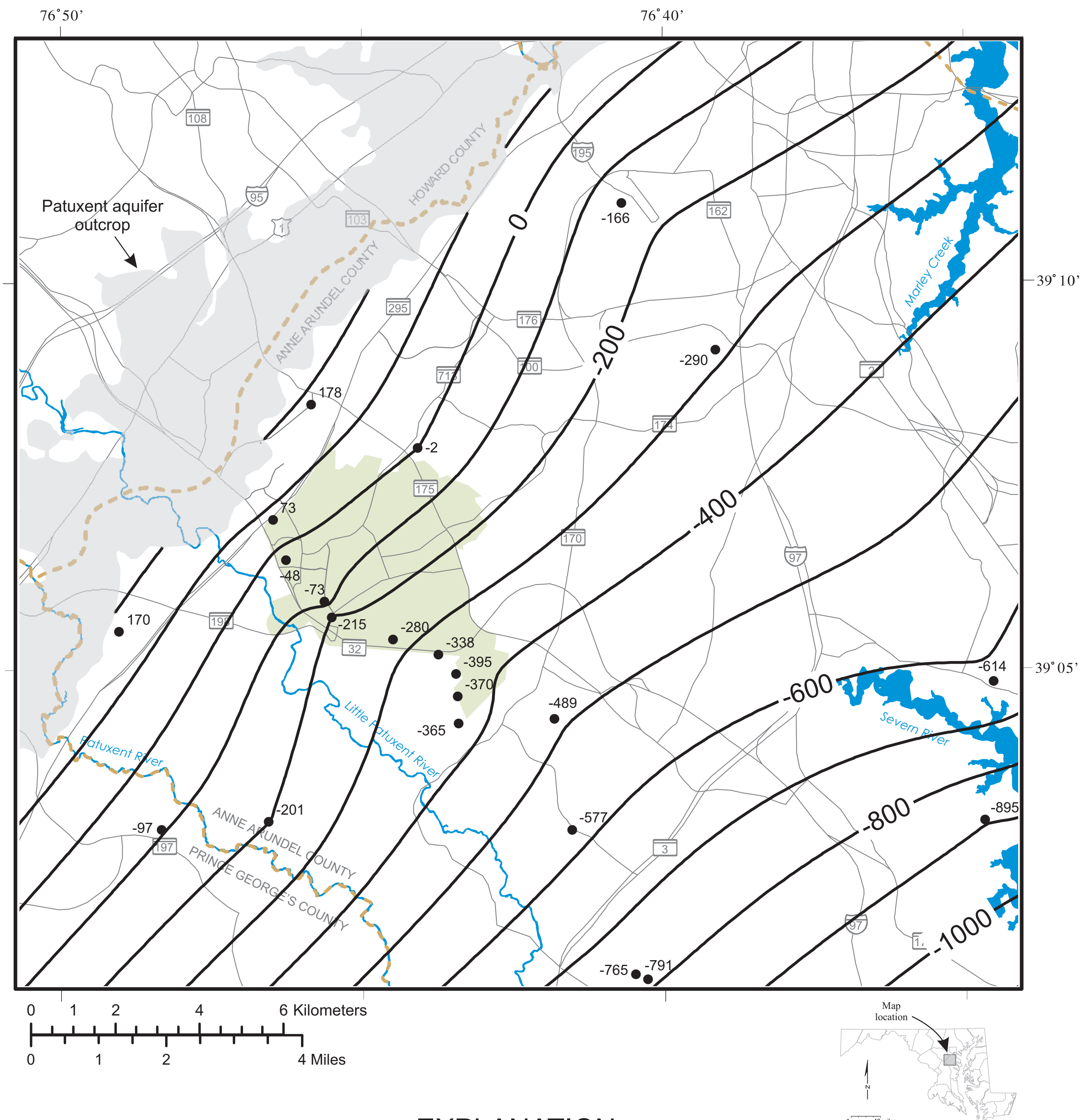


Figure 13. Hydrostratigraphic cross section A-A/ from the Fall Line to Kings Heights.



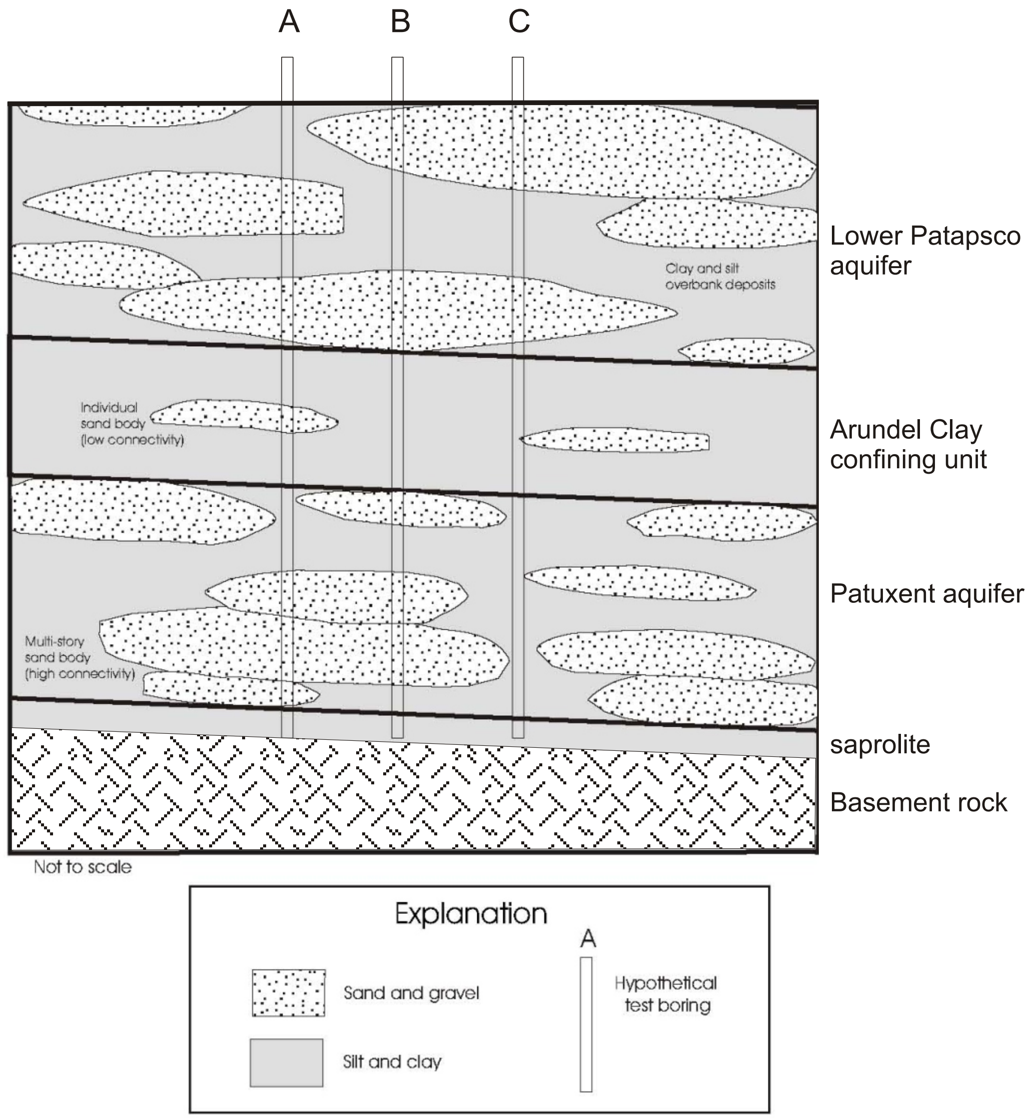
EXPLANATION

-200 — Contour showing the altitude of the top of the Patuxent aquifer, in feet relative to sea level. Contour interval is 100 feet.

● -577 Data point. Number is altitude of the top of the Patuxent aquifer, in feet relative to sea level.

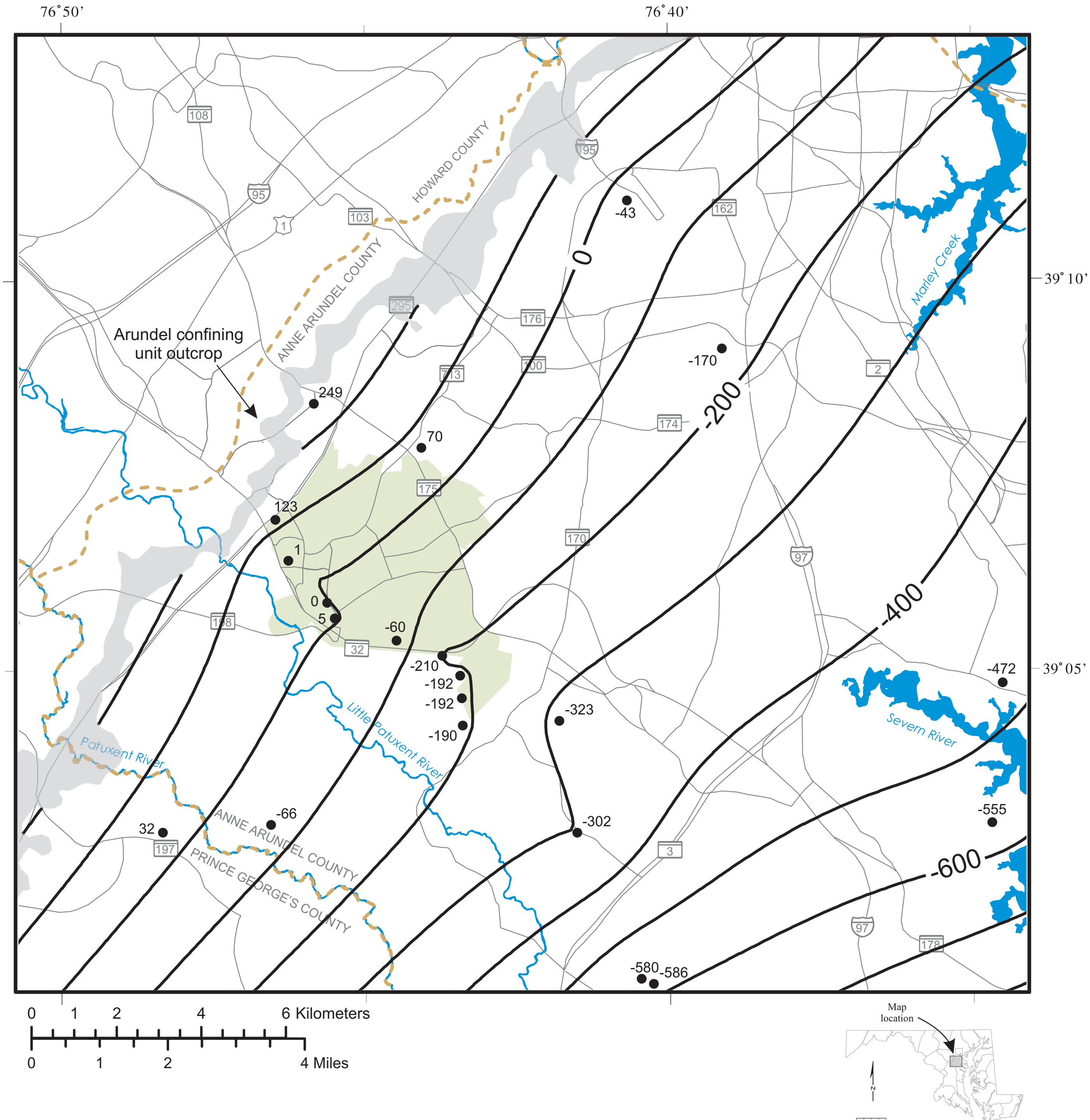
Generalized outcrop area of the Patuxent aquifer.

Figure 14. Top of the Patuxent aquifer in the Ft. Meade area.



(modified from Drummond, 2007)

Figure 15. Conceptual cross section showing individual sand bodies in the Potomac Group.



EXPLANATION

— -200 —	Contour showing the altitude of the top of the Arundel Clay confining unit, in feet relative to sea level. Contour interval is 100 feet.
● -425	Data point. Number is altitude of the top of the Arundel Clay confining unit, in feet relative to sea level.
(gray area)	Generalized outcrop area of the Arundel Clay confining unit.

Figure 16. Top of the Arundel Clay confining unit in the Ft. Meade area.

Table 1. Construction data and hydraulic properties for the test wells.

Well number	State permit number	Location	Latitude (deg min sec)	Longitude (deg min sec)	Northing (MD state plane ft)	Easting (MD state plane ft)	Well Driller	Date completed
HO Df 59	HO-95-1442	MD State Prison Training Facility	39 08 29	76 47 38	537145	1370792	AC Schultes of MD	3/11/2009
HO Df 60	HO-95-1443	MD State Prison Training Facility	39 08 29	76 47 38	537145	1370792	AC Schultes of MD	3/18/2009
AA Bb 86	AA-95-4302	Jessup Water Tower	39 08 26	76 45 48	536863	1379460	AC Schultes of MD	4/3/2009
AA Bb 87	AA-95-4301	Jessup Water Tower	39 08 26	76 45 48	536863	1379460	AC Schultes of MD	5/6/2009
AA Bb 88	AA-95-4303	MD Correctional Institution for Women	39 07 56	76 46 42	533817	1375212	AC Schultes of MD	4/28/2009
AA Bb 92	AA-95-4304	MD Correctional Institution for Women	39 07 56	76 46 42	533817	1375212	AC Schultes of MD	4/30/2009
AA Bb 90	AA-95-4642	NSA National Cryptologic Museum	39 06 57	76 46 26	527851	1376488	AC Schultes of MD	6/17/2009
AA Bb 91	AA-95-4641	NSA National Cryptologic Museum	39 06 57	76 46 26	527851	1376488	AC Schultes of MD	6/19/2009

Well number	Altitude of land surface (ft above sea level)	Depth of well (ft below land surface)	Diameter of Well (in)	Depth to top of screen (ft below land surface)	Total length of screen (ft)	Water levels below land surface (ft)		Drawdown (ft)
						Static	Pumped	
HO Df 59	211	135	4.5	120	10	50.09	NA	NA
HO Df 60	211	85	4.5	50	25	48.16	66.19	18.03
AA Bb 86	265	190	4.5	155	30	124.35	141.72	17.37
AA Bb 87	269	220	4.5	190	25	128.45	174.97	46.52
AA Bb 88	174	145	4.5	115	25	37.25	87.17	49.92
AA Bb 92	174	87	4.5	57	25	38.05	44.8	6.75
AA Bb 90	163	240	4.5	215	20	58.3	67.88	9.58
AA Bb 91	163	125	4.5	100	20	52.37	88.92	36.55

Well number	Date Measured	Pumping Rate (gal/min)	Hours pumped	Specific capacity [(gal/min)/ft]	Transmissivity - drawdown (ft^2/day)		Transmissivity - recovery (ft^2/day)	
					T1	T2	T1	T2
HO Df 59	NA	NA	NA	NA	NA	NA	NA	NA
HO Df 60	3/30/2009	50	8	2.8	530	1,700	230	2,700
AA Bb 86	5/19/2009	100	8	5.8	1,640	20,940	1,300	11,400
AA Bb 87	5/27/2009	91	8	2	310	4,500	320	3,900
AA Bb 88	5/28/2009	24	8	0.5	32	1,300	32	1,400
AA Bb 92	5/21/2009	120	8	17.8	3,340	52,500	3,450	14,400
AA Bb 90	6/29/2009	92	8	9.6	1,300	NA	1,300	NA
AA Bb 91	6/30/2009	10	8	0.3	NA	240	18	250

AGE	LITHO-STRATIGRAPHY		LITHO-FACIES[1]	HYDRO-STRATIGRAPHY
Quaternary	Patuxent River and un-named terrace deposits		sand-gravel	where present forms part of surficial aquifer
Cretaceous (Lower)	Potomac Group	Patapsco Formation	sand-gravel	Lower Patapsco aquifer
			silt-clay	
			sand-gravel	
		Arundel Formation	silt-clay	Arundel Clay confining unit
			sand-gravel	
			silt-clay	
		Patuxent Formation	sand-gravel	Patuxent aquifer
			silt-clay	
			sand-gravel	
Cambrian/ Precambrian (?)	Baltimore Complex		saprolite	Basement rock
			Crystalline rock	

[1] Lithofacies are shown for illustrative purposes

Table 2. Lithostratigraphy and hydrostratigraphy northwest of Ft. Meade.