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POTENTIOMETRIC SURFACE AND WATER-LEVEL DIFFERENCE MAPS OF SELECTED CONFINED AQUIFERS IN SOUTHERN MARYLAND AND MARYLAND'S EASTERN SHORE, 1975-2015

by

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Prepared in cooperation with the
Maryland Power Plant Research Program of the Maryland Department of Natural Resources
and the U.S. Geological Survey

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KEY RESULTS

This report presents potentiometric-surface maps of the Aquia and Magothy aquifers and the Upper Patapsco, Lower Patapsco, and Patuxent aquifer systems using water levels measured during September 2015. Water-level difference maps are also presented for these aquifers. The water-level differences in the Aquia aquifer are shown using groundwater-level data from 1982 and 2015, while the water-level differences are shown for the Magothy aquifer using data from 1975 and 2015. Water-level difference maps for both the Upper Patapsco and Lower Patapsco aquifer systems are shown using data from 1990 and 2015. The water-level differences in the Patuxent aquifer system are shown using groundwater-level data from 2007 and 2015.

The potentiometric surface maps show water levels ranging from 53 feet above sea level to 164 feet below sea level in the Aquia aquifer, from 86 feet above sea level to 106 feet below sea level in the Magothy aquifer, from 115 feet above sea level to 115 feet below sea level in the Upper Patapsco aquifer system, from 106 feet above sea level to 194 feet below sea level in the Lower Patapsco aquifer system, and from 165 feet above sea level to 171 feet below sea level in the Patuxent aquifer system. Water levels have declined by as much as 116 feet in the Aquia aquifer since 1982, 99 feet in the Magothy aquifer since 1975, 66 and 83 feet in the Upper Patapsco and Lower Patapsco aquifer systems, respectively, since 1990, and 80 feet in the Patuxent aquifer system since 2007.

INTRODUCTION

The Maryland Geological Survey (MGS) and U.S. Geological Survey (USGS) have maintained a groundwater-level monitoring network since the 1940s to observe changes in groundwater levels through time. Groundwater-level monitoring has been especially critical for Southern Maryland and Maryland's Eastern Shore where groundwater is the primary source of water supply. Many observation wells were added to the network in the early 1970s following the establishment of the Power Plant Research Program (PPRP) of the Maryland Department of Natural Resources in order to monitor groundwater levels at Maryland's power plants. Currently, groundwater is the source of freshwater supply used in the operation of the Calvert Cliffs, Chalk Point, Morgantown, and Panda Brandywine power plants. Water-level data collected from the monitoring network and water-withdrawal data from the confined aquifer systems that supply water for the operation of Maryland's power plants are used by the PPRP to evaluate potential impacts of Maryland's power plants on groundwater resources.

PURPOSE AND SCOPE

The purpose of this report is to assess the regional effects of groundwater withdrawals on water levels in Southern Maryland and Maryland's Eastern Shore. This report presents potentiometric surface maps for the Aquia and Magothy aquifers and the Upper Patapsco, Lower Patapsco, and Patuxent aquifer systems for September 2015. The potentiometric surface maps in this report are meant to represent groundwater levels and withdrawal amounts at an instant in time. The water-level measurements were actually made over a period of approximately one month and may reflect short-term variations in water levels throughout the study area, related primarily to short-term changes in groundwater withdrawal rates. Withdrawal amounts are an annual average daily rate calculated from reported monthly pumpage of permitted withdrawals greater than 10,000 gallons per day. This report also presents water-level difference maps for the Aquia aquifer (1982-2015), the Magothy aquifer (1975-2015), the Upper and Lower Patapsco aquifer systems (1990-2015), and the Patuxent aquifer system (2007-2015). The water-level difference maps represent the change in potentiometric surfaces over time.

DESCRIPTION OF STUDY AREA

The study area includes Anne Arundel, Prince George's, Calvert, Charles and St. Mary's Counties, and portions of Baltimore City, Washington D.C., and Howard, Baltimore, and Harford Counties, all of which are located west of Chesapeake Bay. On Maryland's Eastern Shore, the study area includes Talbot County, and portions of Cecil, Kent, Queen Anne's, Caroline, and Dorchester Counties (fig. 1). Two wells used for these maps are located in Northern Virginia, just across the Potomac River to the south of Charles County.

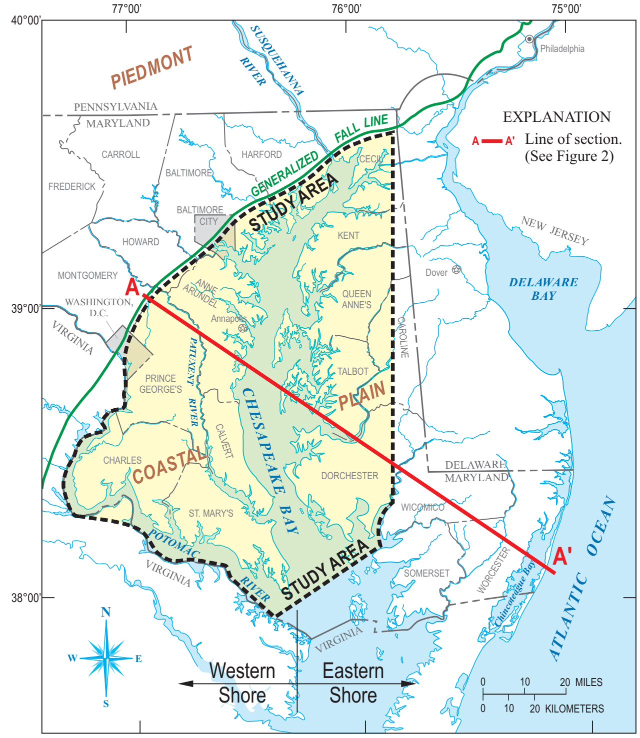

Figure 1. Location of study area in the Atlantic Coastal Plain of Maryland and part of northern Virginia.

The Aquia aquifer, Magothy aquifer, and Upper Patapsco, Lower Patapsco, and Patuxent aquifer systems are part of the Atlantic Coastal Plain sediments, which become deeper and thicker towards the southeast (fig. 2; tab. 1). The Paleocene-age Aquia Formation, which comprises the Aquia aquifer, is composed of fine to coarse-grained, greenish-brown sand that contains layers of silty clay. Cemented layers of shell debris are found throughout the formation. The Aquia's characteristic

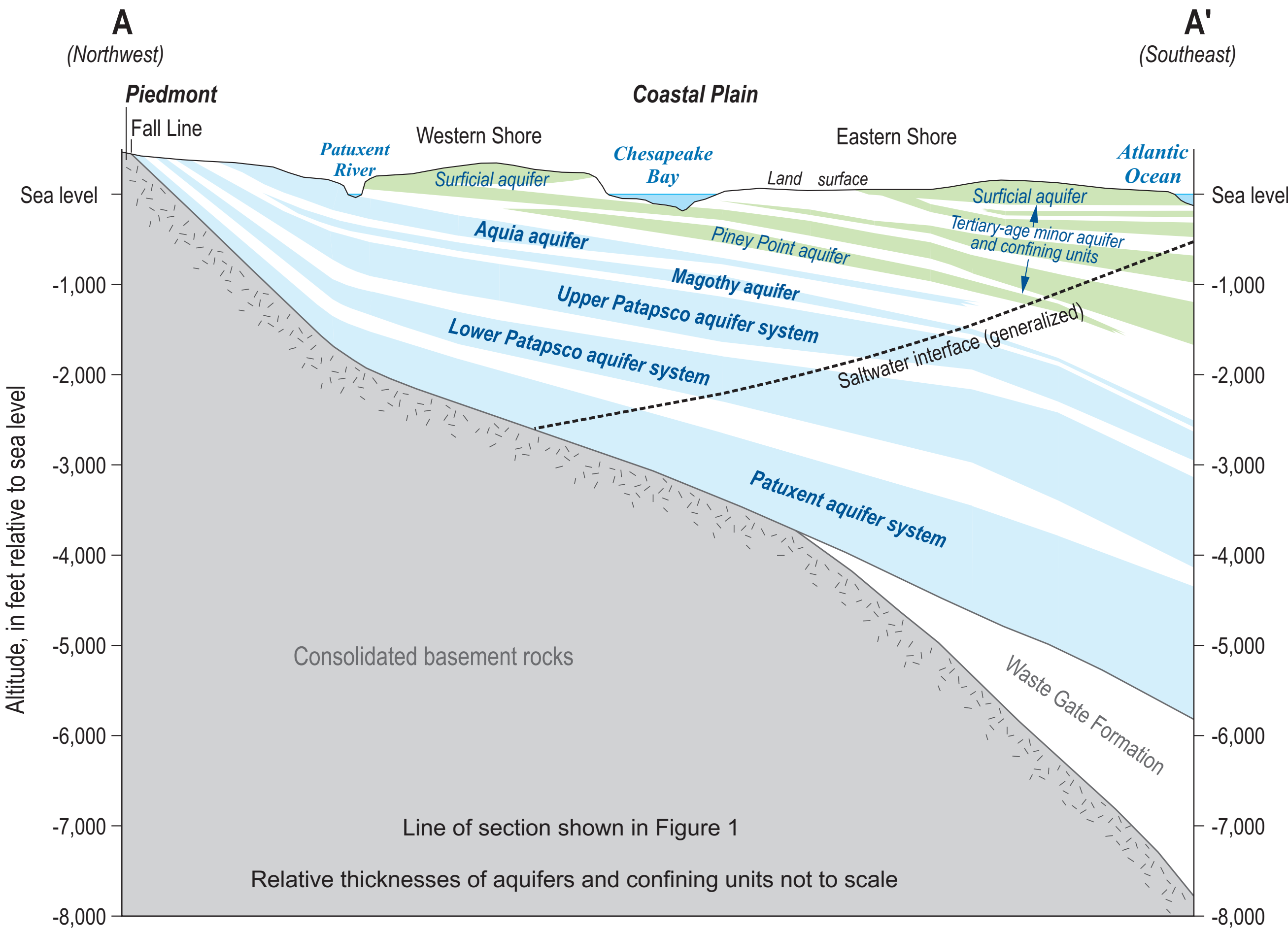

Figure 2. Generalized cross-section of the Atlantic Coastal Plain aquifer system in Maryland. Aquifers shaded in blue are discussed in this report.

green color is caused by the presence of glauconitic sand. The Aquia aquifer is the source of water for many self-supplied private residences and some public suppliers in St. Mary's, Calvert, and Talbot Counties, and for extensive irrigation in Queen Anne's and Kent Counties. The late Cretaceous Magothy Formation, which comprises the Magothy aquifer, consists of light gray to white sand and fine gravel interbedded with thin layers of clay. The aquifer's excellent water-bearing characteristics make it a valuable source of water for most users, including public suppliers in Charles, Anne Arundel, Talbot, and Dorchester Counties. The early Cretaceous Patapsco Formation, which is included in the Potomac Group, comprises the Upper and Lower Patapsco aquifer systems and is a complexly layered unit having lenses of tan and gray sand and gravel, interbedded with variegated red, brown, and gray silt and clay. The Upper and Lower Patapsco aquifer systems are generally very productive and widely used, particularly by public suppliers and industries in Anne Arundel, Charles, and St. Mary's Counties. The early Cretaceous Patuxent Formation, which includes the Patuxent aquifer system, is the basal unit of the Potomac Group in the study area and is lithologically similar to the Patapsco Formation. The Patuxent aquifer system is also generally very productive and widely used in southern Baltimore County, the central and northern part of Anne Arundel County, northern and extreme southern parts of Prince George's County, and northwestern Charles County, but is not widely used in the rest of Southern Maryland and the Eastern Shore.

Table 1. Generalized stratigraphy and hydrogeology of Southern Maryland and Maryland's Eastern Shore. Aquifers shaded in blue are discussed in this report.

System		Series	Group	Formation	Hydrogeology
Quaternary		Holocene		undifferentiated	*surficial aquifers*
Quaternary		Pleistocene		undifferentiated	*surficial aquifers*
Tertiary	Neogene	Pliocene			*surficial aquifers*
Tertiary	Neogene	Miocene	Chesapeake	St. Mary's	confining units and minor aquifers
Tertiary	Neogene	Miocene	Chesapeake	Choptank	confining units and minor aquifers
Tertiary	Neogene	Miocene	Chesapeake	Calvert	confining units and minor aquifers
Tertiary	Paleogene	Oligocene		unnamed	*Piney Point aquifer*
Tertiary	Paleogene	Eocene	Pamunkey	Piney Point	*Piney Point aquifer*
Tertiary	Paleogene	Eocene	Pamunkey	Nanjemoy	confining unit
Tertiary	Paleogene	Eocene	Pamunkey	Marlboro	confining unit
Tertiary	Paleogene	Paleocene	Pamunkey	Aquia	*Aquia aquifer*
Tertiary	Paleogene	Paleocene	Pamunkey	Brightseat/ Hornerstown	*Aquia aquifer*
Cretaceous		Upper Cretaceous		Severn or Monmouth	confining units and minor aquifers
Cretaceous		Upper Cretaceous		Matawan	confining units and minor aquifers
Cretaceous		Upper Cretaceous		Magothy	*Magothy aquifer*
Cretaceous		Lower Cretaceous	Potomac	Patapsco	confining unit
					Upper Patapsco aquifer system
					confining unit
					Lower Patapsco aquifer system
Cretaceous		Lower Cretaceous	Potomac	Arundel Clay	confining unit
Cretaceous		Lower Cretaceous	Potomac	Patuxent	*Patuxent aquifer system*
Cretaceous		Lower Cretaceous	Potomac	Waste Gate	*"Waste Gate" brine aquifer*[1]
Jurassic, Triassic, Paleozoic to Precambrian					**consolidated basement rocks**

[Modified from Soeder and others, 2007 and Andreasen and others, 2013]

[1]Unit is only present beneath the lower Eastern Shore.

BACKGROUND

In the early 1940s MGS, in cooperation with the USGS, began systematic monitoring of groundwater levels to evaluate the effects of groundwater withdrawals. The monitoring effort was expanded in the early 1970s to evaluate groundwater withdrawals from the Chalk Point coal-fired power plant in southern Prince George's County. In subsequent years, monitoring was further expanded to evaluate groundwater withdrawals from the Calvert Cliffs nuclear power plant in southern Calvert County and the Morgantown coal-fired power plant in southern Charles County, as well as from an increased number of municipal, commercial, domestic, and irrigation wells. The PPRP of the Maryland Department of Natural Resources was established as a result of the Power Plant Siting and Research Act of 1971. This act required the evaluation of the environmental impacts associated with power generation plants in Maryland. Potentiometric surface and water-level difference maps were prepared and published as part of a funding agreement between USGS, MGS, and PPRP in order to supply groundwater data for inclusion in PPRP's periodic Cumulative Environmental Impact Reports. The first potentiometric surface map published as part of this effort was for the Magothy aquifer using groundwater levels from September 1975, followed by a map of the Aquia aquifer using groundwater levels from September 1982. These maps helped evaluate the effects of withdrawals at the Chalk Point plant in southern Prince George's County and the Calvert Cliffs nuclear power plant in southern Calvert County, respectively. To evaluate the effects of withdrawals at the Morgantown power plant in southern Charles County and from additional withdrawal wells at the Chalk Point power plant, potentiometric surface maps were published for the Upper and Lower Patapsco aquifer systems using groundwater levels from September 1990. In 2009, a potentiometric surface map was published using groundwater levels from September 2007 to evaluate the effects of groundwater withdrawals from the Patuxent aquifer system at the Chalk Point power plant. The most recent set of maps displayed water-level data for 2013 (Staley and others, 2014).

In addition to the maps published for the PPRP reports, Achmad and Hansen (2001) assembled a comprehensive set of potentiometric surface and water-level difference maps for the Piney Point, Aquia, Magothy, Upper Patapsco, Lower Patapsco, and Patuxent aquifers using groundwater level data from 1970 through 1996. This report also includes a compilation of groundwater withdrawals and select hydrographs. Soeder and others (2007) published a similar report for the same set of aquifer systems for the period 1980-2005, which included a model evaluation of the relationship between withdrawals and water levels.

METHOD OF ANALYSIS

MGS and USGS personnel measured groundwater levels predominantly during the month of September for those years that were used to construct the potentiometric surface and water-level difference maps. The water-level data were reviewed and approved by the MGS and USGS and stored in the Groundwater Site Inventory (GWSI) database, which is part of the National Water Information System (NWIS) maintained by USGS. This database is available to the public through the NWIS website (http://waterdata.usgs.gov/nwis/). Selected water-level data (apps. 1a-1e) were retrieved from GWSI and used in the preparation of the maps in this report (figs. 3-7). Water-withdrawal data included on the maps and described in text were derived from the Maryland Department of the Environment (MDE) water-withdrawal database (John Smith, Maryland Department of the Environment, written commun., 2016). Water-use data are presented on the maps using a series of symbols representing the location and rates of groundwater withdrawals for users that have water appropriation and use permits for average annual rates greater than 10,000 gallons per day. Domestic wells and other small users are not shown on the maps. The 2015 potentiometric surface maps show water-withdrawal data for 2014 (the most recent data available). Permitted users of water greater than 10,000 gallons per day (gal/d) are required to record monthly withdrawal amounts, which are subsequently submitted to MDE (annually for agricultural users and semi-annually for non-agricultural users) and ultimately entered into MDE's database.

In preparing the potentiometric surface maps, groundwater levels were adjusted to feet (ft) related to sea level using North American Vertical Datum of 1988 (NAVD88) land-surface elevations. The data were plotted and manually contoured by visually interpolating between data points. The contours are dashed in areas of sparse data. The maps also include the outcrop and subcrop areas (undifferentiated) of the aquifers or aquifer systems, and the aquifer boundary if its location is within the project area. Subcrop areas are defined as areas where an aquifer is exposed beneath a blanket of surficial sediments. Because water levels in outcrop and subcrop areas are likely under water-table conditions with locally variable heads dependent on topographic elevation, they were not contoured as part of the confined portion of the aquifers in this report.

POTENTIOMETRIC SURFACE AND WATER-LEVEL DIFFERENCE MAPS

Maps are presented for the Aquia and Magothy aquifers, and Upper Patapsco, Lower Patapsco, and Patuxent aquifer systems for Southern Maryland and a portion of Maryland’s Eastern Shore using water levels measured in September 2015. The location and quantity of major groundwater-withdrawal sites in 2014 are presented on the maps to show the relation between pumping centers and water levels. Maps showing the decline in water levels from 1975, 1982, 1990, or 2007 to 2015 are also presented.

AQUIA AQUIFER

The potentiometric surface of the Aquia aquifer during September 2015 (fig. 3a) is based on water-level measurements in 86 wells. The highest measured water level on the Western Shore was 53 ft above sea level in the outcrop area of the aquifer in the eastern part of Anne Arundel County. The hydraulic gradient increased southward toward a cone of depression around well fields at Lexington Park and Solomons Island. The Calvert Cliffs nuclear power plant is located along the northern edge of this cone of depression, where the water level was measured at 110 ft below sea level. The lowest measured water level of 164 ft below sea level occurred at the center of a cone of depression at Lexington Park. On the Eastern Shore, water levels in the subcrop area of Kent County were as high as 26 ft above sea level. South of those areas, water levels are lower and mostly below sea level. The lowest measured water level on the Eastern Shore occurred near St. Michael’s at 58 ft below sea level. While the greatest concentration of production wells (primarily for irrigation use) occur in northern and central Queen Anne’s County, no regional cones of depression have formed in that area.

The water-level differences in the Aquia aquifer in Southern Maryland and portions of Maryland’s Eastern Shore between September 1982 and September 2015 are shown on figure 3b. The map, based on water-level differences obtained from 50 wells, shows that the water levels increased 4 ft in the outcrop area of the aquifer in eastern Anne Arundel County, and declined 116 ft at Lexington Park. Lexington Park, located in the southeastern-most part of the study area, is near the downdip boundary of the aquifer. At the Calvert Cliffs nuclear power plant, water levels declined 80 ft. Withdrawals from the Aquia aquifer in the study area have increased from approximately 5 million gallons per day (Mgal/d) in 1982 (Wheeler and Wilde, 1989) to approximately 13 Mgal/d in 2014.

MAGOTHY AQUIFER

The potentiometric surface of the Magothy aquifer during September 2015 (fig. 4a) is based on water-level measurements in 63 wells. The highest measured water level was 86 ft above sea level in the outcrop area of the aquifer in the central part of Anne Arundel County. Water levels are lower towards the south. A shallow cone of depression has formed around the Arnold well field caused by downward leakage to the underlying Upper Patapsco aquifer system due to a hydraulic connection between the two aquifers on the Broadneck Peninsula (Mack and Andreasen, 1991). A relatively large cone of depression has developed in the Waldorf area, where groundwater levels are as low as 94 ft below sea level. Groundwater withdrawals from the Chalk Point power plant resulted in a water level of 53 ft below sea level in an observation well at that site. A relatively large cone of depression has developed at Easton on the Eastern Shore, which resulted in a water level of 106 ft below sea level. The groundwater level at Easton is likely highly affected by localized, short-term pumping from the Easton well field. Relatively high groundwater levels in the northwestern portion

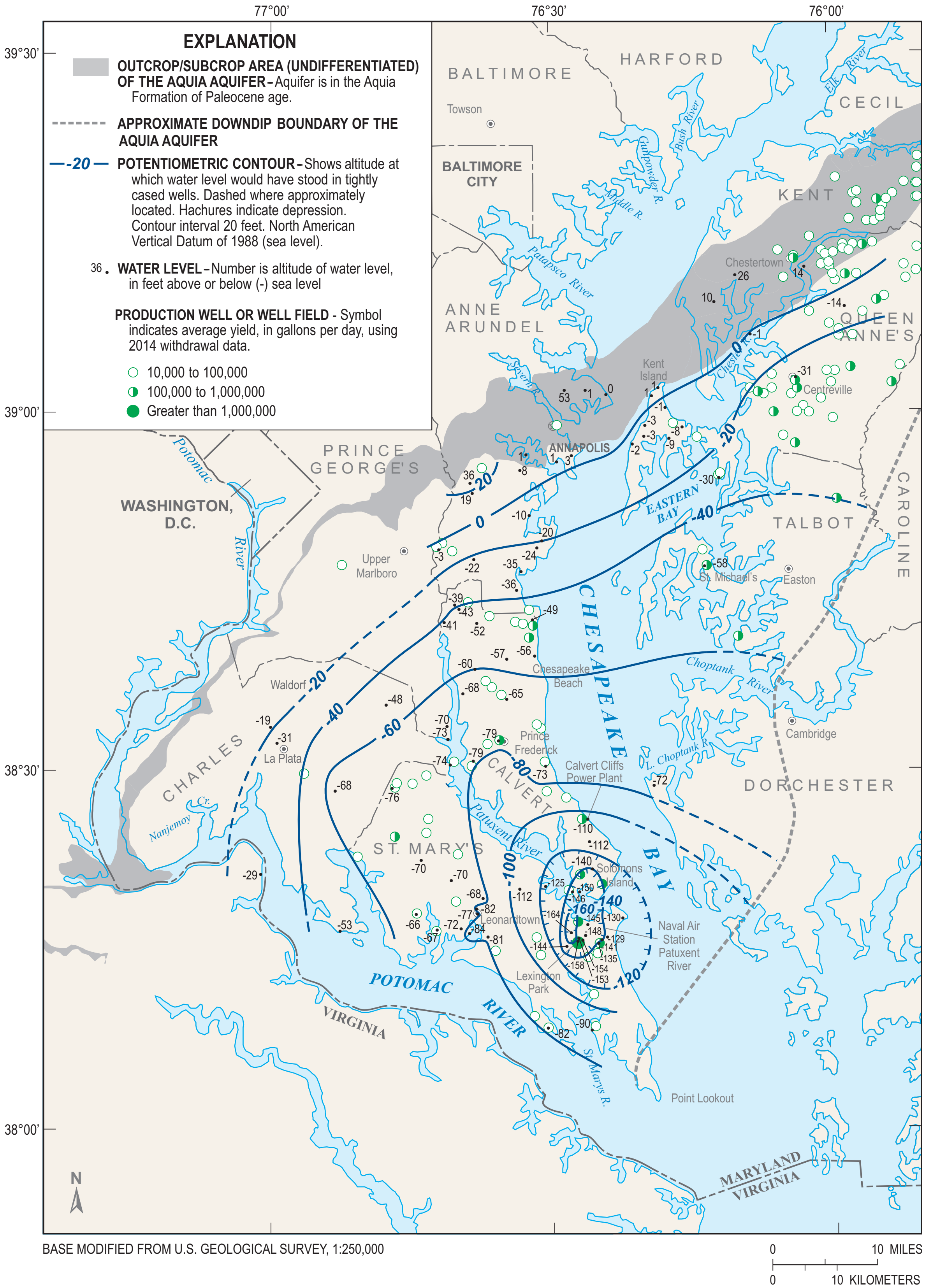

Figure 3a. Potentiometric surface of the Aquia aquifer in Southern Maryland and Maryland's Eastern Shore, September 2015.

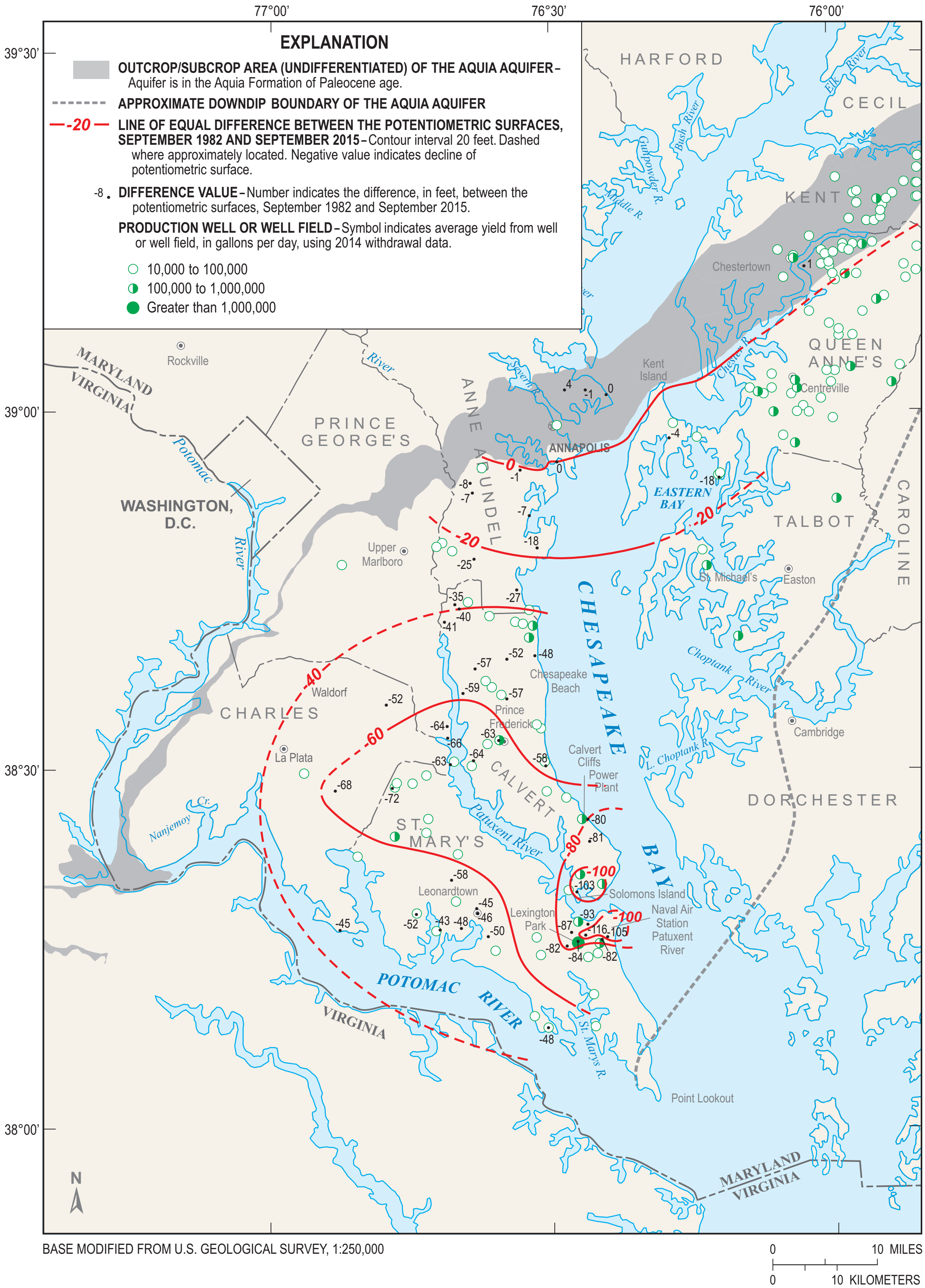

Figure 3b. The difference between the potentiometric surfaces of the Aquia aquifer in Southern Maryland and Maryland's Eastern Shore, September 1982 and September 2015.

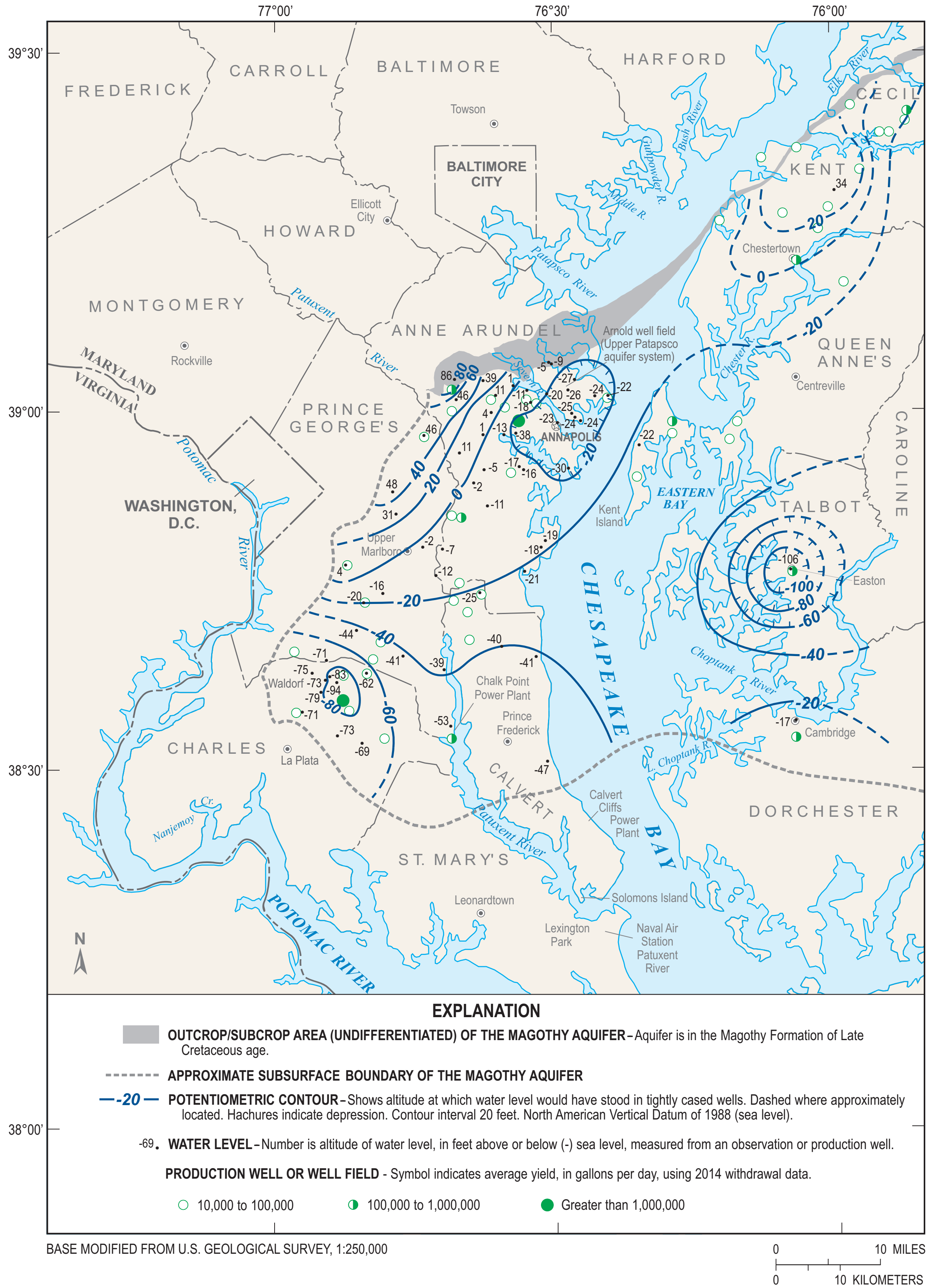

Figure 4a. Potentiometric surface of the Magothy aquifer in Southern Maryland and Maryland's Eastern Shore, September 2015.

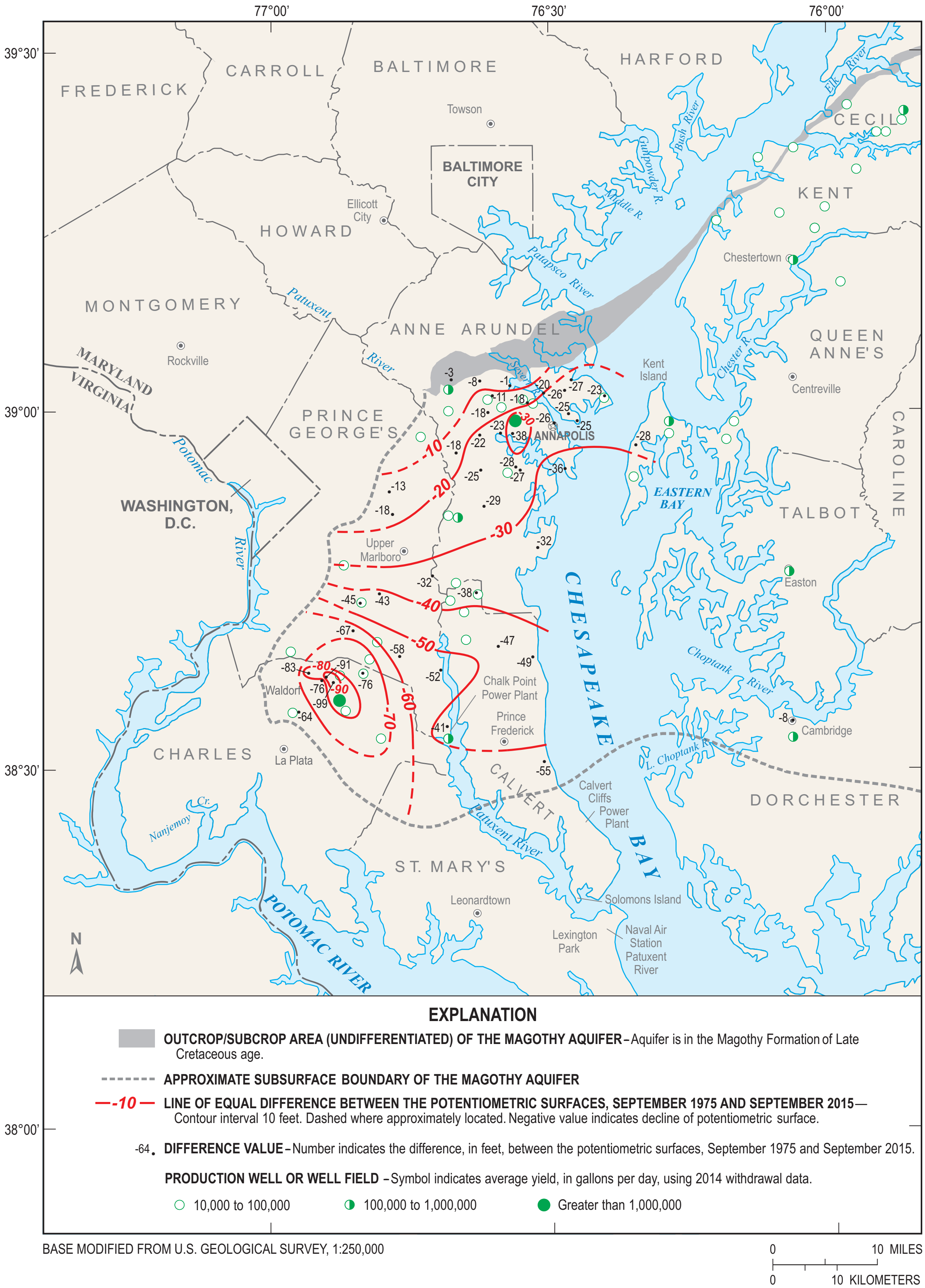

Figure 4b. The difference between the potentiometric surfaces of the Magothy aquifer in Southern Maryland and Maryland's Eastern Shore, September 1975 and September 2015.

of Kent County indicate that this is an area of groundwater recharge.

The water-level differences in the Magothy aquifer in Southern Maryland and portions of Maryland's Eastern Shore between September 1975 and September 2015 are shown in figure 4b. The map, based on water‑level differences obtained from 44 wells, shows that over the 40-yr period, the potentiometric surface had changed relatively little near the outcrop area (in the northern part of the study area), but has declined as much as 99 ft at Waldorf. Waldorf is located near the southern extent and downdip boundary of the aquifer. Withdrawals from the Magothy aquifer in the study area increased from approximately 7 Mgal/d in 1975 (Wheeler and Wilde, 1989) to approximately 8 Mgal/d in 2014.

UPPER PATAPSCO AQUIFER SYSTEM

The potentiometric surface of the Upper Patapsco aquifer system during September 2015 (fig. 5a) is based on water-level measurements in 65 wells. The highest measured water level was 115 ft above sea level near the outcrop area of the aquifer system in northern Anne Arundel County. From this area, water levels are lower to the southeast toward well fields in the Annapolis-Arnold area, where water levels were 73 ft below sea level at the Arnold well field. Two relatively large cones of depression were located in the Waldorf area in central Charles County and the Lexington Park-Leonardtown area in southern St. Mary's County. Groundwater levels were 111 ft below sea level south in the center of the Waldorf cone of depression, and 88 ft below sea level at Leonardtown. A less extensive cone of depression formed around the Chalk Point power plant where the water level was as low as 75 ft below sea level. The lowest measured water level of 115 ft below sea level is located in a cone of depression formed around Easton, on the Eastern Shore. A cone of depression centered on Cambridge (73 ft below sea level) was recorded in 2013 (Staley and others, 2014). Data were not collected in this area during September 2015, but the cone is assumed to still exist based on water use data (1.25 Mgal/d in 2012 and 2 Mgal/d in 2014), and therefore is shown on figure 5a.

The water-level differences in the Upper Patapsco aquifer system in Southern Maryland and portions of Maryland's Eastern Shore between September 1990 and September 2015 are shown in figure 5b. The map, based on water‑level differences obtained from 38 wells, shows that over the 25-yr period, the potentiometric surface had little overall change at the edge of the outcrop area in northern Anne Arundel County. Water-level declines of 16 ft at Broad Creek, 66 ft near Arnold, 38 ft at Waldorf, 51 ft at the Chalk Point power plant, and 52 ft at Lexington Park were observed over the same 25-yr period. Total withdrawals from the Upper and Lower Patapsco aquifer systems increased from approximately 29 Mgal/d in 1990 to approximately 37 Mgal/d in 2014. Withdrawals in 2014 from the Upper Patapsco aquifer system totaled approximately 13 Mgal/d. Withdrawals reported in 1990 were not differentiated between the Upper and Lower Patapsco aquifer systems.

LOWER PATAPSCO AQUIFER SYSTEM

The potentiometric surface of the Lower Patapsco aquifer system during September 2015 (fig. 6a) is based on water-level measurements in 78 wells. The highest measured water level was 106 ft above sea level near the outcrop area of the aquifer system in northern Prince George's County. Water levels were lower towards well fields at Severndale, Broad Creek, Arnold, and Crofton Meadows. Measured groundwater levels were 91 ft below sea level at Severndale, 63 ft below sea level at Broad Creek, 80 ft below sea level at Arnold, and 43 ft below sea level at Crofton Meadows. There is also a large cone of depression in Charles County that includes Waldorf, La Plata, Indian Head, and the Morgantown power plant. The groundwater levels measured were as low as 194 ft below sea level at Waldorf, 150 ft below sea level near La Plata, 114 ft below sea level at Indian Head, and 92 ft below sea level at the Morgantown power plant.

The water-level differences in the Lower Patapsco aquifer system in Southern Maryland and portions of Maryland's Eastern Shore between September 1990 and September 2015 are shown in figure 6b. The map, based on water‑level differences obtained from 47 wells, shows that overall change of the potentiometric surface over the 25-yr period ranged from increases of 30 ft at Indian Head and 43 ft near the outcrop area in Glen Burnie, to declines of 79 ft at Arnold, 48 ft at Severndale, 52 ft at Crofton Meadows, 51 ft at Waldorf, 83 ft near La Plata, 30 ft at the Morgantown power plant, 41 ft at the Chalk Point

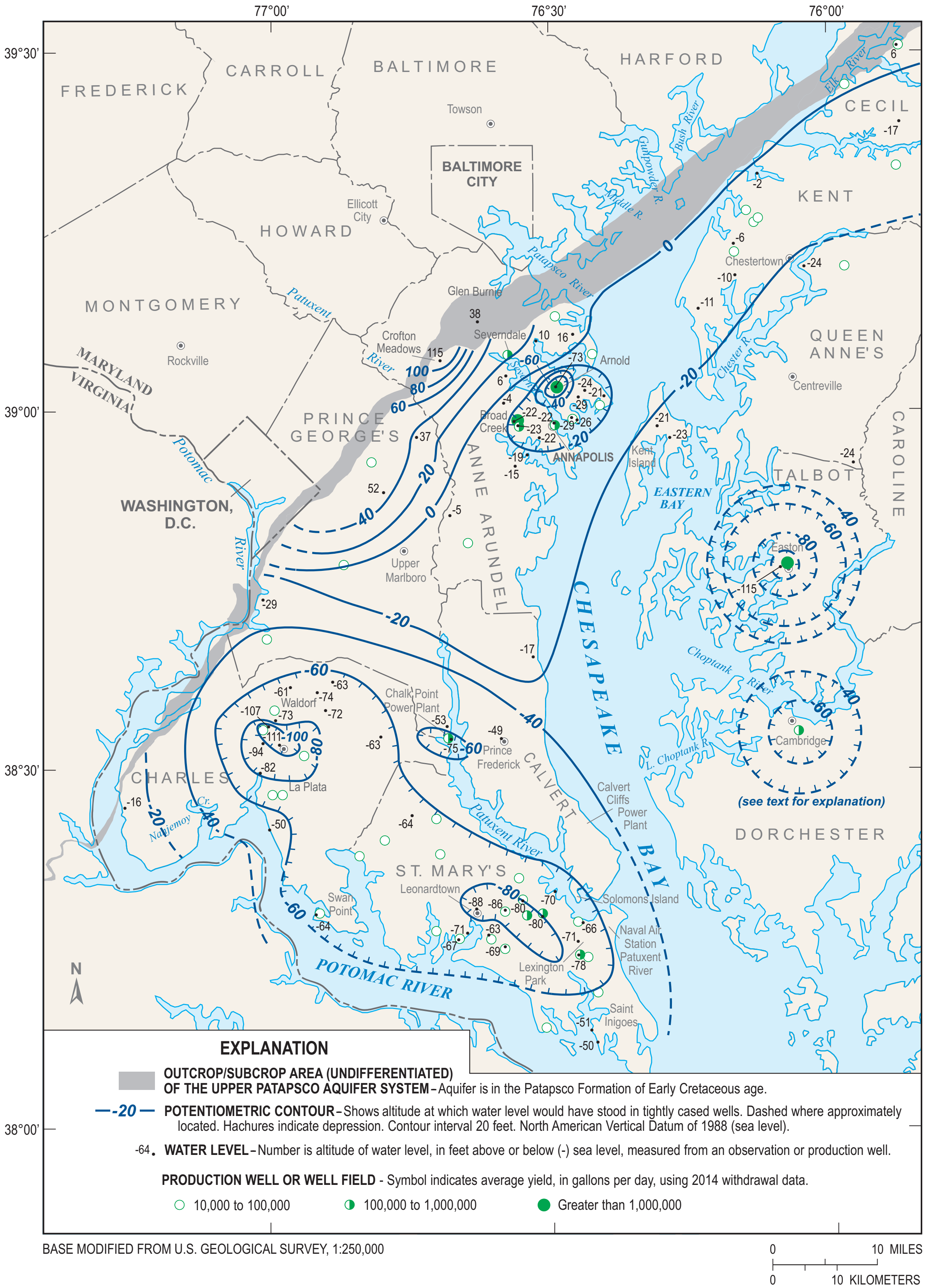

Figure 5a. Potentiometric surface of the Upper Patapsco aquifer system in Southern Maryland and Maryland's Eastern Shore, September 2015.

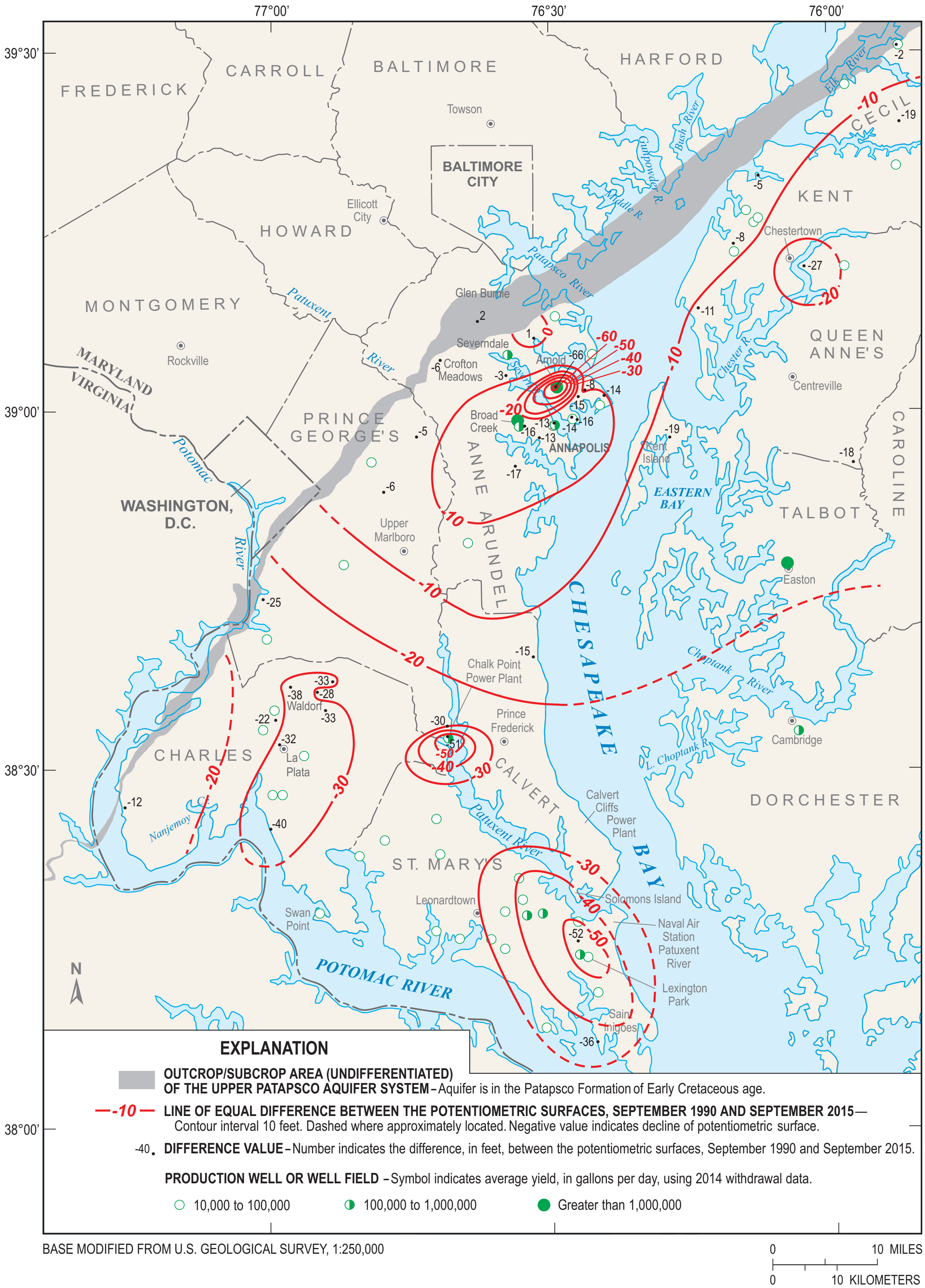

Figure 5b. The difference between the potentiometric surfaces of the Upper Patapsco aquifer system in Southern Maryland and Maryland's Eastern Shore, September 1990 and September 2015.

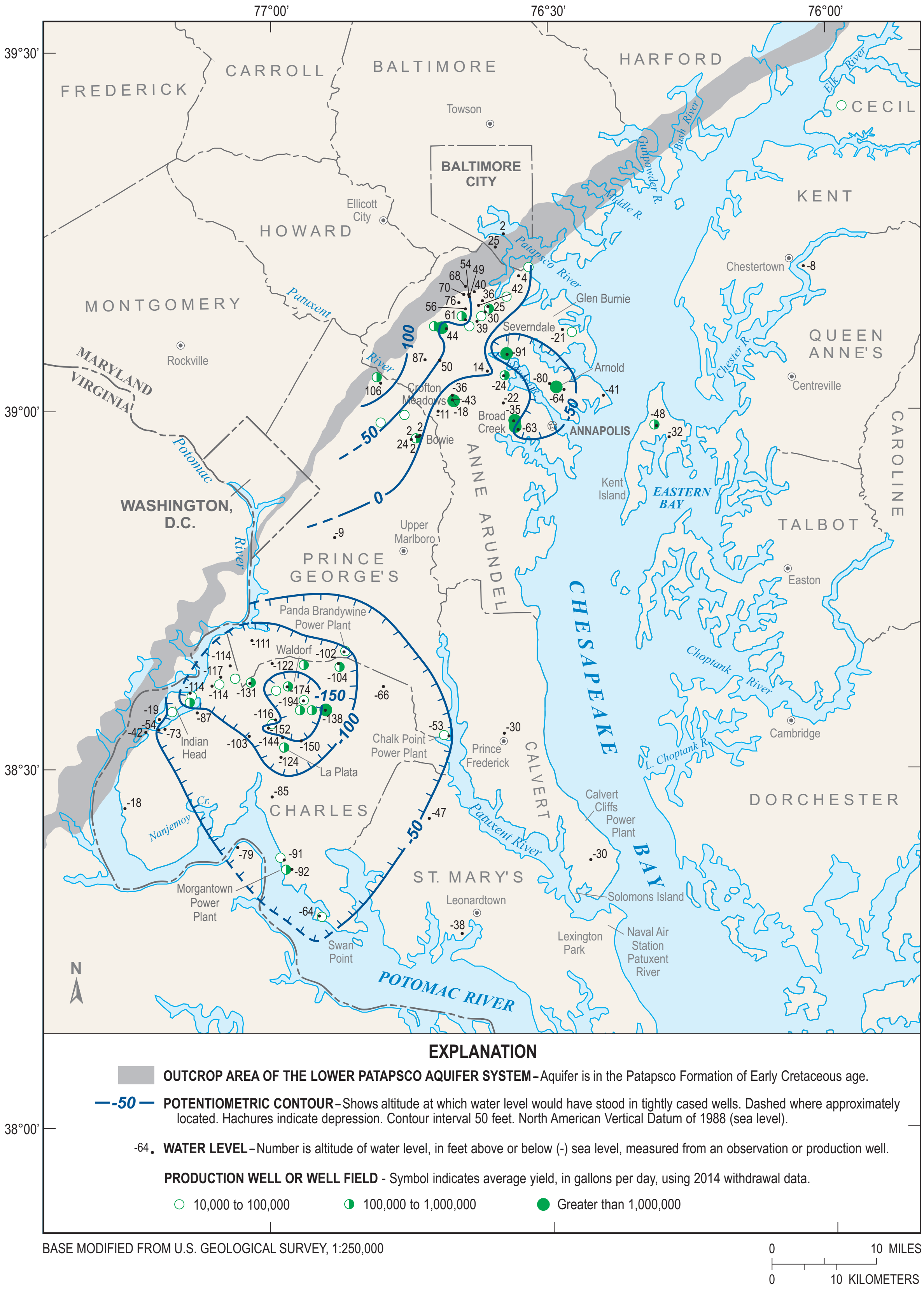

Figure 6a. Potentiometric surface of the Lower Patapsco aquifer system in Southern Maryland and Maryland's Eastern Shore, September 2015.

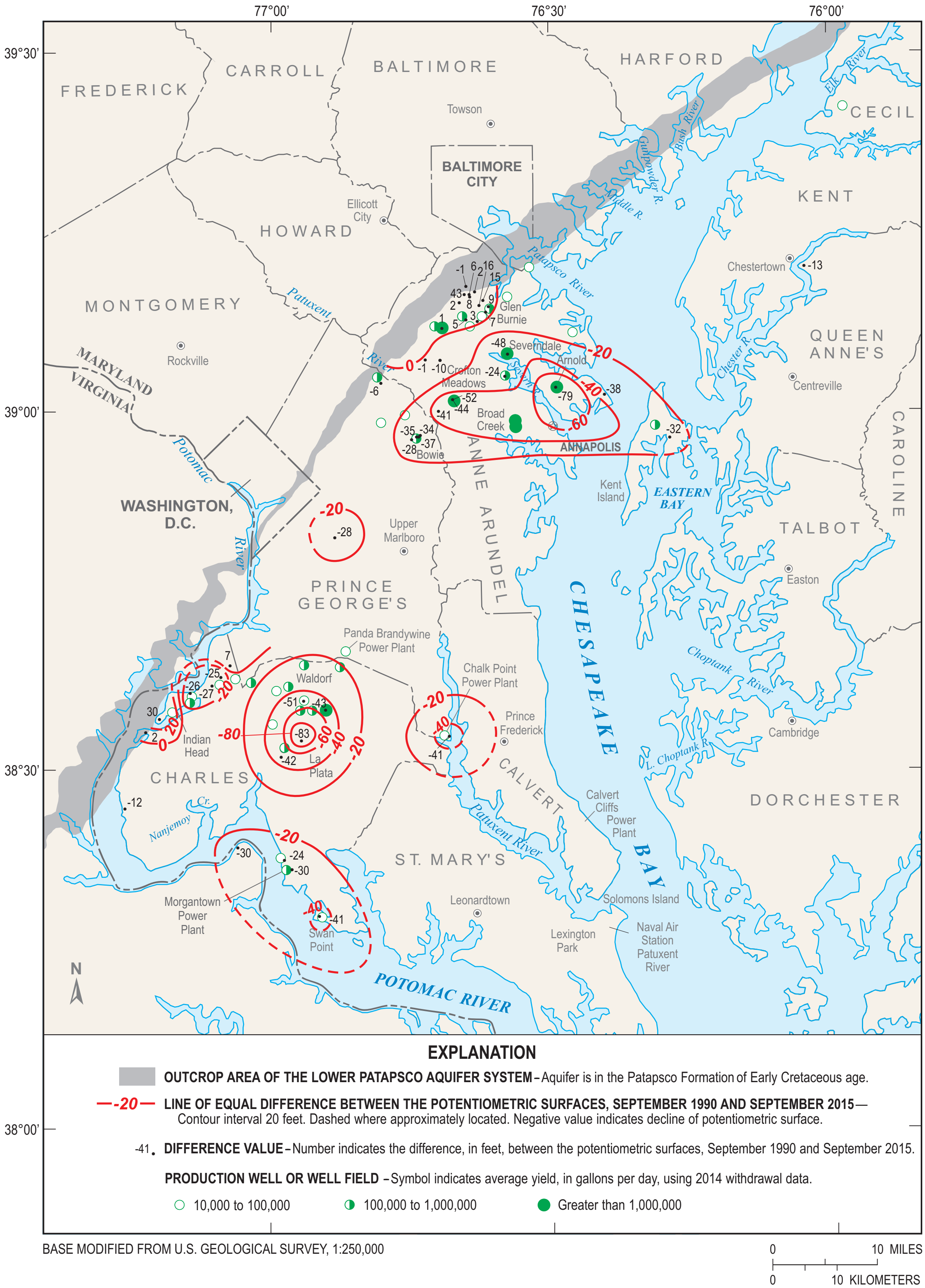

Figure 6b. The difference between the potentiometric surfaces of the Lower Patapsco aquifer system in Southern Maryland and Maryland's Eastern Shore, September 1990 and September 2015.

power plant, and 41 ft at Swan Point. Total withdrawals from the Upper and Lower Patapsco aquifer systems increased from approximately 29 Mgal/d in 1990 to approximately 37 Mgal/d in 2014. Withdrawals in 2014 from the Lower Patapsco aquifer system totaled approximately 24 Mgal/d. Withdrawals reported in 1990 were not differentiated between the Upper and Lower Patapsco aquifer systems.

PATUXENT AQUIFER SYSTEM

The potentiometric surface of the Patuxent aquifer system during September 2015 (fig. 7a) is based on water-level measurements in 60 wells. The highest measured water level was 165 ft above sea level in the outcrop area of the aquifer system in southeastern Howard County. Water levels are lower south and east towards well fields at Dorsey Road, Bryans Road, the Morgantown power plant, and the Chalk Point power plant. The measured groundwater levels were 171 ft below sea level at Dorsey Road, 113 ft below sea level near Bryans Road, 35 ft below sea level at the Morgantown power plant, and 98 ft below sea level at the Chalk Point power plant. Relatively deep cones of depression have formed around the Dorsey Road, Arnold, and Bryans Road-Indian Head well fields, and the Chalk Point power plant. A shallow cone of depression has formed around Crofton Meadows. An additional, less extensive cone of depression has formed around the well field at Fort George G. Meade (fig. 7a, inset map). The water-use symbol for that well field represents multiple wells and is not centered in the cone of depression.

The water-level differences in the Patuxent aquifer system in Southern Maryland and portions of Maryland’s Eastern Shore between September 2007 and September 2015 are shown in figure 7b. The map, based on water-level differences obtained from 44 wells, shows that during the 8-yr period, overall changes in the potentiometric surface ranged from increases of 22 ft near Baltimore City, to declines of 80 ft at Bryans Road, 75 ft at Chalk Point power plant, 58 ft at Dorsey Road, 42 ft at Crofton Meadows, and 41 ft near Arnold. Water levels at Bryans Road and Chalk Point power plant have declined approximately 10 ft per year since 2007 (Staley, 2015), one of the highest rates of water decline in the Coastal Plain of Maryland over that period. The withdrawal rates in the Patuxent aquifer system in the study area in 2007 and 2014 were approximately 18 and 24 Mgal/d, respectively; however, the locations of withdrawals have shifted in recent decades. The most significant changes in Patuxent withdrawals have been the start of pumpage in Charles County in 2007 and at the Chalk Point power plant in 2009, and the reduction of pumpage in northern Anne Arundel County, the City of Bowie, and the industrial areas east of Baltimore City over the last three decades.

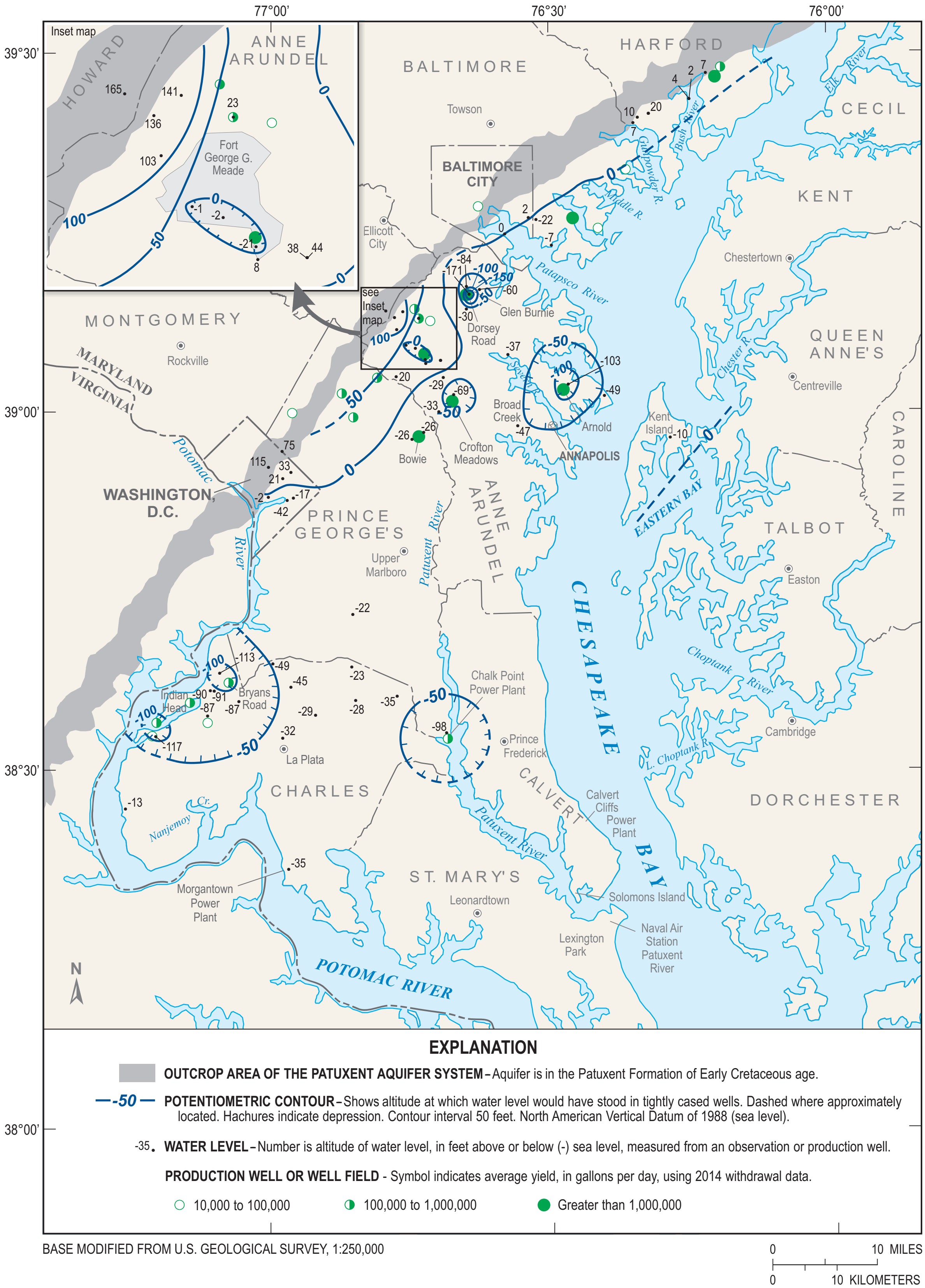

Figure 7a. Potentiometric surface of the Patuxent aquifer system in Southern Maryland and Maryland's Eastern Shore, September 2015.

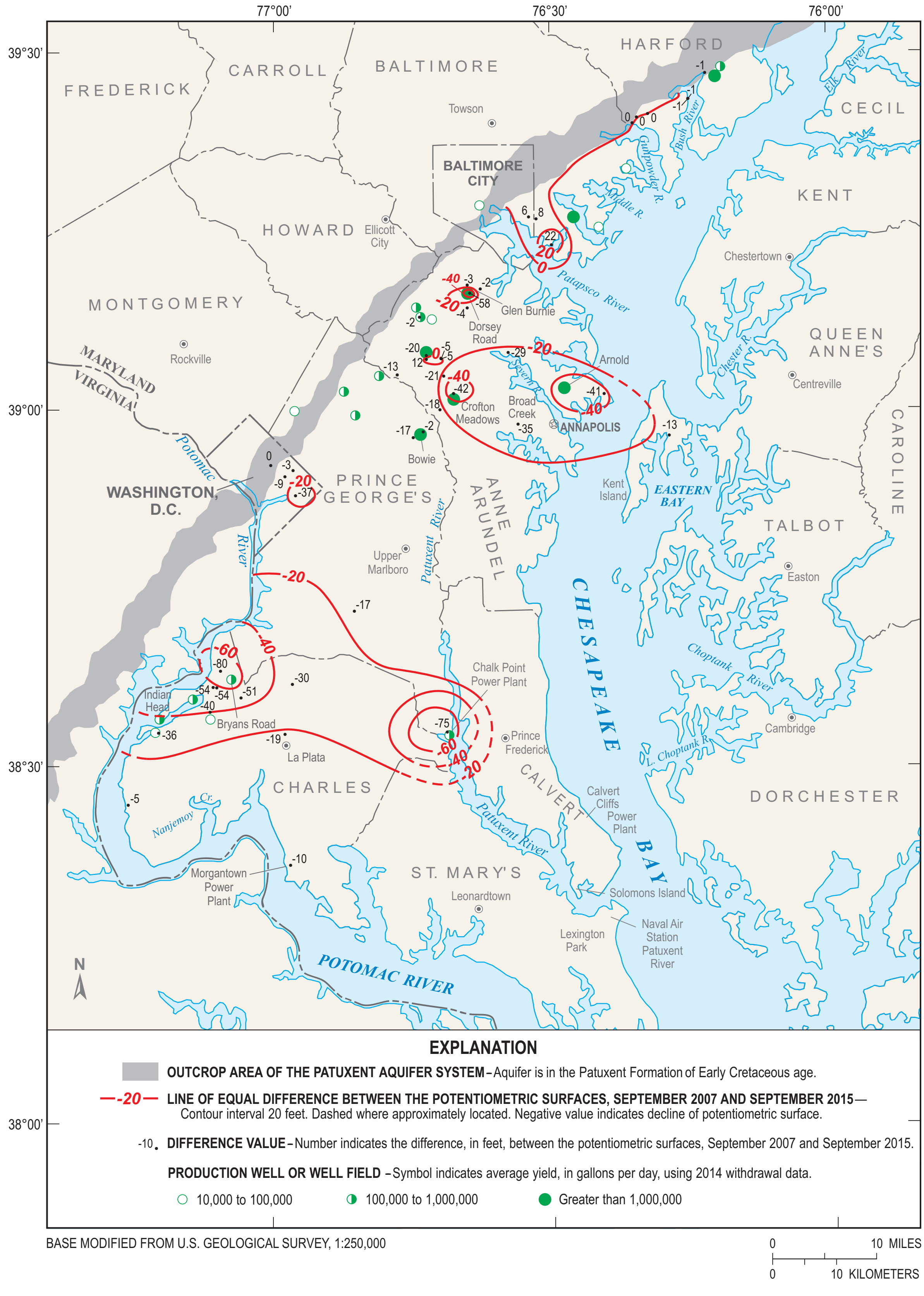

Figure 7b. The difference between the potentiometric surfaces of the Patuxent aquifer system in Southern Maryland and Maryland's Eastern Shore, September 2007 and September 2015.

SUMMARY AND CONCLUSIONS

Groundwater has been and is expected to continue to be a major source of freshwater supply for Southern Maryland and Maryland's Eastern Shore. The principal aquifers in the study area from which groundwater is withdrawn are the Aquia and Magothy aquifers, and Upper Patapsco, Lower Patapsco, and Patuxent aquifer systems. Groundwater withdrawals from these aquifers have increased substantially over the last several decades due to population growth but more so from increased use of water for irrigation, especially on the Eastern Shore.

In each aquifer the water levels tend to be lower in wells farther away from the outcrop areas where most of the aquifer recharge occurs. Water levels in the Aquia aquifer ranged from 53 ft above sea level to 164 ft below sea level in 2015, and declined by as much as 116 ft between 1982 and 2015. Withdrawals from the Aquia aquifer have increased from approximately 5 Mgal/d in 1982 (Wheeler and Wilde, 1989) to approximately 13 Mgal/d in 2014. Water levels in the Magothy aquifer ranged from 86 ft above sea level to 106 ft below sea level in 2015, and declined by as much as 99 ft between 1975 and 2015. Withdrawals from the Magothy aquifer increased from approximately 7 Mgal/d in 1975 (Wheeler and Wilde, 1989) to approximately 8 Mgal/d in 2014. Water levels in the Upper Patapsco aquifer system ranged from 115 ft above sea level to 115 ft below sea level in 2015, and declined by as much as 66 ft between 1990 and 2015. Water levels in the Lower Patapsco aquifer system ranged from 106 ft above sea level to 194 ft below sea level in 2015, and declined by as much as 83 ft between 1990 and 2015. Total withdrawals from the Upper and Lower Patapsco aquifer systems increased from approximately 29 Mgal/d in 1990 to approximately 37 Mgal/d in 2014. Most of the withdrawals in 2014 were from the Lower Patapsco aquifer system (approximately 24 Mgal/d). Withdrawals reported in 1990 were not differentiated between the Upper and Lower Patapsco aquifer systems. Water levels in the Patuxent aquifer system ranged from 165 ft above sea level to 171 ft below sea level in 2015, and declined by as much as 80 ft between 2007 and 2015. The withdrawal rates in the Patuxent aquifer system in the study area in 2007 and 2014 were approximately 18 and 24 Mgal/d, respectively.

Table 2. Summary of water levels and water-level differences by aquifer through September, 2015. [Water altitudes are measured in feet from the North American Vertical Datum of 1988 (sea level).]

Aquifer (or aquifer system)	Deepest water-level altitude 2015 water level (ft)	Location	Greatest water-level difference 2015 difference (ft) [since]	Location
Aquia	-164	Lexington Park, St. Mary's Co.	-116 [1982]	Lexington Park, St. Mary's Co.
Magothy	-106	Easton, Talbot Co.	-99 [1975]	Waldorf, Charles Co.
Upper Patapsco	-115	Easton, Talbot Co.	-66 [1990]	Arnold, Anne Arundel Co.
Lower Patapsco	-194	Waldorf, Charles Co.	-83 [1990]	La Plata, Charles Co.
Patuxent	-171	Dorsey Road Well Field, Anne Arundel Co.	-80 [2007]	Bryans Road, Charles Co.

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REFERENCES

Achmad, Grufron, and Hansen, H.J., 2001, Ground-water levels and pumpage trends in the major Coastal Plain aquifers of Southern Maryland between 1970 and 1996: Maryland Geological Survey Open-File Report 2000-02-12, 149 p.

Andreasen, D.C., Staley, A.W., and Achmad, G., 2013, Maryland Coastal Plain aquifer information system: Hydrogeologic framework, Maryland Geological Survey Open-File Report 12-02-20, 121 p. (Also available online at *http://www.mgs.md.gov/publications/ report_pages/OFR_12-02-20.html)*

Mack, F.K., and Andreasen, D.C., 1991, Geohydrologic data for the Coastal Plain sediments underlying Broadneck Peninsula, Anne Arundel County, Maryland: Maryland Geological Survey Open-File Report No. 92-02-6, 70 p.

Soeder, D.J., Raffensperger, J.P., and Nardi, M.R., 2007, Effects of withdrawals on ground-water levels in Southern Maryland and the adjacent Eastern Shore, 1980-2005: U.S. Geological Survey Scientific Investigations Report 2007-5249, 82 p. (Also available online at *http://pubs.usgs.gov/sir/2007/5249*)

Staley, A.W., 2015, Hydrogeology of the Patuxent aquifer system in the Waldorf area, Charles County, Maryland: Maryland Geological Survey Open-File Report 15-02-01, 73 p. (Also available online at *http://www.mgs.md.gov/ publications/report_pages/OFR_15-02-01.html*)

Staley, A.W., **Andreasen, D.C., and Curtin, S.E.**, 2014, Potentiometric surface and water-level difference maps of selected confined aquifers in Southern Maryland and Maryland's Eastern Shore, 1975–2013: Maryland Geological Survey Open-File Report 14-02-02, 29 p. (Also available online at *http://www.mgs.md.gov/ publications/report_pages/OFR_14-02-02.html*)

Wheeler, J.C., and Wilde, F.D., 1989, Ground-water use in the Coastal Plain of Maryland, 1900-1980: U.S. Geological Survey Open-File Report 87-540, 173 p. (Also available online at *http://pubs.er.usgs.gov/publication/ofr87540*)

Appendix 1a. Water-level data for Southern Maryland and Maryland's Eastern Shore wells used in this report (Aquia aquifer).

[All depth and altitude measurements are in feet. Land and water altitudes are measured from the North American Vertical Datum of 1988 (NAVD88), same as sea level in this report. Latitude and longitude measured relative to the North American Datum of 1983 (NAD 83); --, no data; USGS, U.S. Geological Survey]

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1982-2015
AA Cf 98	390150076283003	39.030667	-76.474683	92.62	53.31	4.29
AA Cf 122	390149076261702	39.030611	-76.437389	19.20	0.83	-0.88
AA Cg 25	390127076240301	39.024278	-76.400514	16.53	0.35	-0.09
AA De 102	385512076331602	38.920028	-76.554194	48.77	8.06	-0.91
AA De 195	385628076323603	38.940936	-76.542900	36.20	0.85	--
AA Df 98	385550076292101	38.930778	-76.488778	10.49	0.81	0.24
AA Df 103	385623076274401	38.940306	-76.461889	25.69	2.90	--
AA Ed 45	385406076383901	38.902042	-76.643639	106.42	36.04	-7.52
AA Ed 49	385249076382101	38.888083	-76.639333	59.19	18.57	-6.71
AA Ee 67	385124076322001	38.856611	-76.538056	10.36	-9.69	-6.77
AA Fc 35	384833076415602	38.809528	-76.698750	50.48	-2.98	--
AA Fd 46	384727076382501	38.795683	-76.636811	138.09	-21.59	-24.77
AA Fe 46	384840076312801	38.811472	-76.524250	7.64	-23.83	-17.95
AA Fe 48	384508076334101	38.752444	-76.561194	84.20	-36.40	-26.53
AA Fe 60	384917076305802	38.821505	-76.515791	7.66	-19.64	--
AA Fe 92	384644076331201	38.778722	-76.552694	8.19	-35.24	--
CA Ba 11	384357076401601	38.732639	-76.670833	114.38	-38.98	-34.62
CA Ba 13	384231076412501	38.708583	-76.690056	55.07	-40.63	-41.05
CA Bb 27	384333076394701	38.726111	-76.663389	136.93	-43.29	-40.14
CA Bb 58	384222076380102	38.706111	-76.633611	109.07	-51.60	--
CA Bc 44	384243076320201	38.711889	-76.533528	6.77	-49.35	--
CA Cb 26	383837076381001	38.643528	-76.635611	114.36	-60.07	-56.94
CA Cb 32	383632076392701	38.609028	-76.656944	94.30	-67.66	-59.44
CA Cc 18	383940076314801	38.661417	-76.529722	110.5	-55.61	-47.52
CA Cc 57	383605076344601	38.601194	-76.579694	137.75	-65.06	-56.56
CA Cc 58	383924076341201	38.656833	-76.579056	121.62	-56.88	-52.10
CA Db 40	383053076382101	38.515278	-76.639722	22.51	-79.36	-64.11
CA Db 47	383239076354201	38.543556	-76.594667	139.54	-79.38	-63.15
CA Dc 29	383025076304701	38.507472	-76.510944	122.27	-73.43	-58.46
CA Ed 52	382549076260101	38.433250	-76.436944	9.14	-109.54	-79.88
CA Fd 54	382407076260301	38.402250	-76.434611	128.56	-111.92	-81.23
CA Fd 70	382155076254502	38.363694	-76.430472	107.67	-139.64	--
CA Gd 6	381952076270901	38.331944	-76.452139	11.74	-149.72	-103.28
CA Gd 61	381956076275301	38.332361	-76.464611	17.26	-146.36	--
CH Bg 11	383536076473601	38.593611	-76.793028	195.94	-48.25	-51.65
CH Ce 41	382225076591002	38.541028	-76.986944	193.43	-31.12	--
CH Ce 62	383348076595401	38.563167	-76.998167	194.19	-18.80	--
CH Ch 15	383043076404501	38.510139	-76.680528	8.90	-74.33	-63.46
CH Df 17	382800076530301	38.473722	-76.884000	160.10	-68.33	-68.09
CH Ff 59	381639076523201	38.273472	-76.875222	7.15	-52.84	-45.22
DO Db 19	382847076190901	38.480194	-76.319389	0.72	-71.87	--
KE Cb 100	391124076101004	39.189861	-76.168611	64.90	25.84	--

Appendix 1a (continued)

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1982-2015
KE Db 42	390909076122302	39.152944	-76.206306	24.19	10.13	--
KE Dc 91	390626076083302	39.107333	-76.142171	3.85	-0.58	--
PG Hf 35	383228076410601	38.541417	-76.684306	10.35	-72.62	-65.51
PG Hf 42	383348076411303	38.563389	-76.685306	26.89	-70.11	-63.88
QA Be 17	391203076024303	39.200943	-76.044945	24.21	13.61	1.27
QA Cf 78	390845075582302	39.145833	-75.973056	60	-14.15	--
QA Db 32	390201076182703	39.033722	-76.307178	17.21	0.79	--
QA Db 35	390119076191001	39.022056	-76.319123	6.72	0.78	--
QA Db 37	390023076174302	39.006501	-76.294955	6.32	-1.31	--
QA De 27	390251076034401	39.047612	-76.061889	9.42	-30.52	--
QA Ea 78	385718076211502	38.955113	-76.353845	11.02	-1.80	--
QA Ea 80	385757076200102	38.965946	-76.333289	7.72	-3.02	--
QA Eb 113	385748076172001	38.963446	-76.288565	10.57	-9.43	-3.52
QA Eb 155	385843076155302	38.978724	-76.264398	3.13	-7.64	--
QA Eb 156	385852076195201	38.981223	-76.330789	11.23	-2.69	--
QA Fc 7	385429076120201	38.908170	-76.200227	9.27	-29.68	-17.86
SM Bb 15	382838076470101	38.477556	-76.783222	164.43	-76.05	-72.41
SM Cc 8	382235076435801	38.377222	-76.732472	127.99	-70.06	--
SM Cc 22	382055076404601	38.348737	-76.679129	132.10	-69.89	-58.29
SM Ce 38	382222076304602	38.339750	-76.512583	15.08	-125.25	--
SM Ce 43	382012076332901	38.336667	-76.557806	87.13	-112.32	--
SM Dc 42	381648076421801	38.280128	-76.704687	12.63	-66.98	-42.65
SM Dc 59	381807076442801	38.302072	-76.740800	40.01	-65.93	-51.53
SM Dd 39	381834076381301	38.308833	-76.634722	106.57	-81.93	-45.38
SM Dd 49	381616076364702	38.270250	-76.613944	118.00	-81.06	-49.91
SM Dd 50	381807076380001	38.302500	-76.632639	98.47	-77.13	-45.93
SM Dd 68	381654076394502	38.281794	-76.662185	124.08	-71.70	-48.08
SM Dd 69	381923076372501	38.323861	-76.623250	124.09	-68.29	--
SM Dd 74	381616076384502	38.271111	-76.645833	19	-83.94	--
SM Df 1	381552076265001	38.264722	-76.447139	92.46	-154.39	--
SM Df 10	381715076261601	38.286791	-76.438007	45.14	-144.97	-92.96
SM Df 61	381604076271701	38.267889	-76.453528	107.97	-153.25	--
SM Df 62	381632076275301	38.275806	-76.467389	103.12	-163.50	-87.19
SM Df 71	381527076283101	38.256972	-76.475278	68.25	-143.64	-81.98
SM Df 80	381532076250101	38.259028	-76.416556	41.10	-135.22	--
SM Df 86	381548076272103	38.263250	-76.455639	111.20	-157.50	-83.63
SM Df 95	381617076263201	38.271444	-76.442000	79.12	-148.27	-116.39
SM Dg 10	381555076244801	38.265361	-76.413028	21.11	-140.51	-81.99
SM Dg 18	381607076241401	38.269389	-76.403278	17.11	-129.26	-104.77
SM Dg 19	381747076223901	38.296000	-76.376389	9.14	-130.12	--
SM Fe 31	380834076303402	38.142917	-76.509278	8.22	-81.81	-47.70
SM Ff 64	380821076255501	38.139417	-76.431444	9.06	-90.21	--
TA Cc 50	384707076133202	38.785500	-76.226583	7.22	-58.29	--
VA 54Q-21	382129077005801	38.358056	-77.016111	19.66	-28.74	--

Appendix 1b. Water-level data for Southern Maryland and Maryland's Eastern Shore wells used in this report (Magothy aquifer).

[All depth and altitude measurements are in feet. Land and water altitudes are measured from the North American Vertical Datum of 1988 (NAVD88), same as sea level in this report. Latitude and longitude measured relative to the North American Datum of 1983 (NAD 83); --, no data; USGS, U.S. Geological Survey]

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1975-2015
AA Cc 95	390247076403501	39.046389	-76.676333	130.33	85.98	-2.88
AA Cc 117	390103076402603	39.017694	-76.673889	133.36	46.34	--
AA Cd 12	390124076361202	39.023500	-76.603083	98.03	11.28	-10.51
AA Cd 78	390238076373301	39.044139	-76.625639	128.04	39.14	-8.35
AA Cd 143	390000076364001	38.999917	-76.611222	102.21	3.78	-18.29
AA Ce 103	390214076342201	39.037278	-76.572556	58.40	1.07	-0.67
AA Ce 128	390404076300703	39.068000	-76.501167	6.33	-8.84	--
AA Ce 130	390148076325202	39.030222	-76.547389	1.88	-11.24	--
AA Ce 133	390410076302401	39.070250	-76.506361	14.34	-5.01	--
AA Ce 138	390049076322702	39.013611	-76.540722	68.20	-18.42	-18.13
AA Ce 151	390132076311401	39.025611	-76.520611	83.20	-19.55	-19.53
AA Cf 99	390150076283002	39.030667	-76.474683	92.90	-26.13	-25.79
AA Cf 104	390242076274501	39.045222	-76.462333	25.97	-26.94	-26.97
AA Cf 152	390121076253301	39.022578	-76.426258	24.64	-24.16	--
AA Cg 7	390123076241102	39.023167	-76.402736	16.20	-21.58	-23.34
AA Dc 20	385637076400802	38.943722	-76.668194	91.39	11.15	-18.04
AA Dd 37	385807076351901	38.968639	-76.588722	132.13	-12.58	-22.58
AA Dd 40	385511076373101	38.919861	-76.624889	134.99	-4.84	-25.43
AA Dd 42	385808076373502	38.969000	-76.626076	104.68	1.02	-21.57
AA De 1	385915076340401	38.971083	-76.567528	12.92	-37.52	-37.97
AA De 103	385512076331603	38.920028	-76.554139	48.87	-16.39	-27.21
AA De 124	385528076334601	38.924556	-76.562194	27.04	-16.59	-28.31
AA Df 20	385916076270702	38.988167	-76.451889	21.07	-23.96	-24.94
AA Df 79	385905076293601	38.984861	-76.493250	4.36	-22.79	-26.25
AA Df 82	385953076280201	38.998222	-76.467639	86.97	-25.35	-24.57
AA Df 84	385518076282701	38.921778	-76.474472	6.50	-29.69	-36.48
AA Df 87	385934076274301	38.992972	-76.461444	19.06	-23.70	--
AA Ed 39	385210076371002	38.869558	-76.619130	175.67	-11.09	-29.06
AA Ed 65	385406076383902	38.902119	-76.643617	108.83	-2.32	--
AA Fc 34	384833076415601	38.809472	-76.698722	50.18	-6.93	--
AA Fe 47	384843076312601	38.812361	-76.523861	5.52	-18.33	-31.79
AA Fe 51	384917076305801	38.821505	-76.515791	7.66	-19.04	--
AA Fe 93	384644076331202	38.778667	-76.552722	7.22	-21.39	--
CA Bb 10	384028076354201	38.674194	-76.594222	186.00	-39.68	-46.58
CA Bb 23	384458076375501	38.749278	-76.632972	145.96	-25.13	-38.03
CA Cc 56	383934076320001	38.659778	-76.533639	95.30	-41.06	-48.94
CA Dc 35	383050076305501	38.514194	-76.514417	90.76	-46.89	-55.35
CH Be 17	383502076565101	38.583361	-76.948500	203.46	-70.55	-63.78
CH Be 43	383819076555501	38.637778	-76.931389	216.03	-74.70	-83.47
CH Bf 98	383739076543001	38.627722	-76.907972	215.62	-72.62	-75.80
CH Bf 124	383750076540801	38.632194	-76.900444	207.02	-82.67	-91.47
CH Bf 133	383640076545901	38.611000	-76.915917	222.73	-79.38	--

Appendix 1b (continued)

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1975-2015
CH Bf 134	383728076531701	38.625056	-76.887778	201.32	-93.80	-99.46
CH Bf 135	383814076500301	38.637528	-76.832722	207.03	-62.18	-75.95
CH Bf 143	383918076522201	38.655444	-76.905806	205.83	-70.63	--
CH Cf 29	383219076503502	38.539806	-76.843194	177.21	-69.47	--
CH Cf 39	383259076531001	38.549678	-76.886294	138.82	-73.36	--
DO Ce 15	383408076042402	38.569056	-76.072889	5.23	-16.83	-8.06
KE Be 43	391823075594701	39.306722	-75.995056	64.21	34.42	--
PG Cf 33	385806076435303	38.968333	-76.731750	114.62	45.16	--
PG De 21	385130076465501	38.858833	-76.781611	94.89	30.62	-18.27
PG De 32	385323076471801	38.889835	-76.788025	131	48.33	-13.07
PG Ed 50	384715076522001	38.787778	-76.871667	240.11	4.46	--
PG Ef 34	384623076424001	38.773167	-76.711139	38.32	-12.47	-32.12
PG Ef 40	384847076440401	38.813167	-76.733806	79.03	-2.43	--
PG Fd 32	384148076510901	38.696783	-76.852193	225	-43.91	-67.04
PG Fd 39	384410076502501	38.735444	-76.839806	232.66	-19.98	-45.09
PG Fe 30	384453076482101	38.748056	-76.805694	236.82	-15.82	-43.16
PG Ge 15	383940076461301	38.661229	-76.769968	209.68	-41.36	-58.07
PG Gf 35	383832076414701	38.642139	-76.696861	34.05	-39.02	-52.05
PG Hf 41	383348076411302	38.563389	-76.685389	27.43	-53.38	-40.51
QA Ea 27	385718076205501	38.954002	-76.348011	17.49	-21.98	-27.92
TA Ce 80	384644076044602	38.778889	-76.079444	14	-106.38	--

Appendix 1c. Water-level data for Southern Maryland and Maryland's Eastern Shore wells used in this report (Upper Patapsco aquifer system).

[All depth and altitude measurements are in feet. Land and water altitudes are measured from the North American Vertical Datum of 1988 (NAVD88), same as sea level in this report. Latitude and longitude measured relative to the North American Datum of 1983 (NAD 83); --, no data; USGS, U.S. Geological Survey]

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1990-2015
AA Bd 159	390737076374402	39.127083	-76.629083	74.69	38.24	2.48
AA Be 102	390559076312602	39.100056	-76.524250	35.56	9.66	0.84
AA Bf 100	390629076273601	39.108364	-76.459517	44.9	16.19	--
AA Cc 43	390422076414501	39.072725	-76.695953	175.3	114.52	-6.00
AA Ce 120	390303076344301	39.050889	-76.578444	161.00	5.67	-3.05
AA Ce 137	390043076345402	39.012908	-76.582667	57.88	-3.60	--
AA Cf 118	390207076292802	39.035278	-76.490278	119.76	-72.75	-66.27
AA Cf 128	390149076261703	39.030389	-76.437738	13.20	-24.22	-8.22
AA Cf 134	390121076270501	39.021889	-76.449889	23.20	-28.90	-14.56
AA Cg 24	390123076241603	39.023167	-76.404125	11.88	-20.87	-13.71
AA De 95	385853076333001	38.981722	-76.557778	72.41	-22.61	-16.26
AA De 128	385530076334701	38.924889	-76.562611	27.51	-15.49	-17.01
AA De 199	385753076310801	38.964303	-76.519386	37.05	-21.98	-13.22
AA De 219	385915076335303	38.987611	-76.564408	119.21	-22.10	--
AA De 230	385627076322901	38.940764	-76.541389	35.37	-19.07	--
AA Df 19	385921076270701	38.989556	-76.451944	15.04	-25.59	-16.18
AA Df 89	385934076274302	38.993000	-76.461861	19.78	-29.02	-14.17
AA Df 100	385905076293603	38.984861	-76.493250	4.36	-21.53	-13.37
AA Ec 12	385125076404801	38.856944	-76.679472	54.21	-5.33	--
CA Cc 55	383934076320201	38.659972	-76.532861	104	-17.20	-14.53
CA Db 96	383244076354201	38.545889	-76.589639	151.56	-48.68	--
CE Ce 56	393026075523101	39.507611	-75.874917	37.22	5.97	-1.89
CE Ee 29	392403075521801	39.401472	-75.871528	74.20	-17.25	-19.24
CH Be 60	383706076575604	38.617778	-76.963889	212.02	-61.20	-38.29
CH Bf 151	383508076540703	38.585833	-76.901000	192.03	-72.31	-32.60
CH Bf 157	383637076545803	38.610917	-76.916000	224.23	-73.53	-28.06
CH Bf 158	383732076531902	38.625639	-76.888194	192.23	-63.46	-32.71
CH Cd 31	383222077004401	38.539565	-77.011919	129.19	-94.45	--
CH Cd 54	383346077000901	38.562806	-77.002472	179.18	-107.16	--
CH Ce 16	383217076590201	38.537642	-76.983231	186.65	-110.57	-31.63
CH Ce 50	383420076592501	38.572322	-76.989578	201.37	-72.58	-21.73
CH Cg 24	383254076481401	38.548778	-76.803389	171.04	-62.78	--
CH Da 21	382659077152401	38.449528	-77.256667	89.20	-16.38	-11.87
CH Dd 33	382607077002601	38.419278	-77.000222	98.98	-49.85	-39.57
CH Dd 38	382925077010101	38.499203	-77.016678	76.4	-82.35	--
CH Fe 5	381803076550801	38.301333	-76.917806	11.16	-64.07	--
KE Ac 20	392007076075501	39.334917	-76.131500	6.19	-1.66	-5.33
KE Cb 36	391400076101401	39.233167	-76.170611	39.20	-6.41	-8.18
KE Cb 103	391124076101005	39.189861	-76.168361	64.81	-10.06	--
KE Db 40	390837076140401	39.143778	-76.234167	14.19	-11.49	-11.47
PG Cf 31	385757076442001	38.965750	-76.738861	146.22	37.15	-4.90
PG De 33	385323076471802	38.889444	-76.797861	102.83	51.80	-6.15

Appendix 1c (continued)

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1990-2015
PG Fb 36	384423077004501	38.739778	-77.012167	77.19	-29.49	-24.53
PG Hf 40	383348076411301	38.563500	-76.685333	27.11	-53.15	-29.60
PG Hf 44	383250076405304	38.547344	-76.681074	9.58	-74.63	-51.09
QA Be 16	391203076024302	39.200943	-76.044945	24.21	-24.10	-27.06
QA Eb 111	385751076171601	38.964279	-76.287454	13.26	-22.55	-19.24
QA Eb 167	385850076183601	38.980556	-76.310000	14	-20.83	--
QA Ef 29	385534075573601	38.927336	-75.960772	60.92	-24.25	-17.82
SM Bc 41	382621076445301	38.439111	-76.747889	159.14	-64.45	--
SM Dc 64	381559076400201	38.266667	-76.666667	32.08	-67.01	--
SM Dd 78	381827076350402	38.307500	-76.584167	129.08	-86.25	--
SM Dd 79	381834076381303	38.308833	-76.634722	112	-88.06	--
SM Dd 80	381616076384503	38.271111	-76.645833	26	-71.43	--
SM Dd 81	381509076351401	38.256111	-76.584722	113	-68.97	--
SM Dd 83	381621076364701	38.272500	-76.613056	119.06	-63.35	--
SM De 52	381753076310001	38.298056	-76.518056	109.11	-80.19	--
SM De 59	381914076331002	38.320000	-76.552778	150	-80.19	--
SM Df 84	381548076272102	38.263111	-76.456056	107.50	-70.99	-52.08
SM Df 88	381955076293901	38.333139	-76.496306	19.16	-69.99	--
SM Df 100	381721076264801	38.289167	-76.446528	20.14	-65.77	--
SM Ef 94	381440076271701	38.244444	-76.454722	79.09	-78.22	--
SM Ff 36	380724076251901	38.122611	-76.421667	5.06	-50.04	-36.02
SM Ff 65	380823076255501	38.139861	-76.432083	9.06	-50.57	--
TA Cd 57	384709076050301	38.785949	-76.083831	11.23	-114.79	--

Appendix 1d. Water-level data for Southern Maryland and Maryland's Eastern Shore wells used in this report (Lower Patapsco aquifer system).

[All depth and altitude measurements are in feet. Land and water altitudes are measured from the North American Vertical Datum of 1988 (NAVD88), same as sea level in this report. Latitude and longitude measured relative to the North American Datum of 1983 (NAD 83); --, no data; USGS, U.S. Geological Survey]

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1990-2015
4S2E- 7	391456076345002	39.248947	-76.580686	7.02	2.21	--
5S2E- 26	391349076354401	39.230378	-76.595711	68.74	25.25	--
AA Ad 102	391032076385904	39.175861	-76.649167	75.93	68.13	-0.86
AA Ad 108	391032076385906	39.175889	-76.649056	77.52	71.12	-0.53
AA Ad 109	391006076380101	39.168000	-76.634056	34.99	40.19	2.27
AA Ae 47	391124076331201	39.190056	-76.553194	35.45	4.24	--
AA Bc 215	390700076412601	39.116889	-76.690722	123.24	44.19	0.93
AA Bd 37	390848076363601	39.147222	-76.609444	37.40	24.60	9.18
AA Bd 56	390950076384001	39.163917	-76.644139	60.81	54.19	5.52
AA Bd 91	390950076391101	39.163917	-76.652722	81.85	70.25	42.73
AA Bd 101	390855076373402	39.149000	-76.626556	54.21	41.71	15.84
AA Bd 152	390821076365401	39.139639	-76.615028	52.49	30.18	6.90
AA Bd 155	390938076383701	39.161167	-76.643139	56.71	49.35	8.26
AA Bd 156	390922076371001	39.155833	-76.619083	68.19	36.10	14.70
AA Bd 157	390737076374401	39.127111	-76.629139	74.96	38.81	3.02
AA Bd 158	390744076390001	39.129194	-76.649722	107.47	60.53	5.18
AA Bd 160	390908076394402	39.152556	-76.661833	87.22	76.47	3.99
AA Bd 181	390839076385702	39.144219	-76.649408	176.7	56.34	--
AA Bf 99	390654076283601	39.114861	-76.476972	39.19	-20.78	--
AA Cc 40	390423076432001	39.073500	-76.722111	136.17	87.17	-0.54
AA Cc 82	390422076414505	39.072897	-76.696006	177.96	49.59	-9.88
AA Cc 89	390010076415703	39.001861	-76.699444	51.99	-10.67	-41.12
AA Cc 115	390103076402601	39.017694	-76.673889	133.60	-43.22	-51.99
AA Cc 116	390103076402602	39.017694	-76.673889	133.57	-18.48	-43.55
AA Cc 137	390126076402901	39.024278	-76.674278	114.57	-35.63	--
AA Cd 128	390327076363701	39.057461	-76.610711	109.22	14.40	--
AA Ce 94	390450076343503	39.080665	-76.576075	89.20	-91.13	-48.18
AA Ce 124	390303076344303	39.050639	-76.578694	159.20	-24.14	-24.21
AA Ce 136	390043076345401	39.012961	-76.582711	59.4	-21.57	--
AA Cf 137	390205076292702	39.034556	-76.490111	123.50	-80.42	-78.75
AA Cf 167	390154076282802	39.031544	-76.474381	105.89	-64.25	--
AA Cg 23	390123076241602	39.023167	-76.404125	11.77	-40.76	-38.24
AA De 206	385833076332801	38.976167	-76.557222	80.95	-62.97	--
AA De 232	385915076335304	38.987500	-76.564722	118.21	-35.45	--
CA Db 99	383311076350301	38.553056	-76.584167	159.14	-29.52	--
CA Fd 85	382236076255401	38.376472	-76.431972	105.98	-30.33	--
CH Bc 24	383633077083001	38.609639	-77.141278	71.17	-113.90	-25.69
CH Bc 76	383754077051201	38.631917	-77.086528	170.17	-116.78	-24.95
CH Bc 81	383709077061002	38.619194	-77.102694	155.63	-113.55	-26.65
CH Bd 33	383844077040701	38.647028	-77.065583	179.19	-113.69	6.52
CH Bd 51	383715077014901	38.620556	-77.029583	184.19	-131.35	--
CH Be 58	383706076575602	38.617833	-76.964000	211.72	-173.84	--

Appendix 1d (continued)

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 1990-2015
CH Be 64	383553076562002	38.599167	-76.939972	208.22	-193.80	-50.95
CH Be 72	383903076594301	38.650833	-76.995278	109.23	-122.35	--
CH Bf 146	383508076540701	38.585889	-76.900833	192.03	-138.20	-42.90
CH Bf 150	383901076524301	38.650361	-76.878111	214.24	-103.95	--
CH Bg 17	383706076475401	38.618452	-76.798024	199.16	-65.74	--
CH Cb 7	383422077114601	38.572861	-77.195722	35.18	-19.49	30.00
CH Cb 28	383315077131401	38.554444	-77.220222	4.18	-42.27	1.65
CH Cb 38	383328077114201	38.557898	-77.194702	3.19	-53.83	--
CH Cb 42	383328077111702	38.558806	-77.185444	4.19	-73.46	--
CH Cc 31	383455077074401	38.582083	-77.128361	34.19	-87.05	--
CH Cd 42	383256077015301	38.548942	-77.036122	187.62	-102.54	--
CH Cd 53	383340077000901	38.560944	-77.002778	159.18	-152.40	--
CH Ce 35	383111076584801	38.520189	-76.979736	172.37	-124.13	-41.89
CH Ce 37	383236076563901	38.543454	-76.943861	184.18	-150.00	-83.38
CH Ce 53	383420076592504	38.572194	-76.989472	201.55	-116.04	--
CH Ce 56	383251076583901	38.547306	-76.977139	195.69	-144.25	--
CH Da 20	382654077152701	38.448222	-77.256472	89.20	-17.91	-12.22
CH De 52	382752076593601	38.464722	-76.995278	165	-84.71	--
CH Ee 70	382154076574801	38.364139	-76.960278	21.99	-92.19	-30.31
CH Ee 78	382240076582801	38.376528	-76.973944	74.16	-91.30	-23.63
CH Ff 60	381806076545401	38.298861	-76.911917	11.15	-63.81	-40.54
PG Be 14	390226076481001	39.040969	-76.802311	149.7	105.66	-6.17
PG Cf 32	385806076435302	38.968417	-76.731694	114.62	2.45	-34.48
PG Cf 76	385757076440402	38.965833	-76.734861	126.83	2.32	-36.79
PG Cf 77	385757076442002	38.965750	-76.738861	146.22	2.13	-35.15
PG Cf 80	385816076434502	38.962667	-76.747444	149.22	23.75	-28.07
PG Ed 34	384933076530001	38.825806	-76.884472	269.21	-8.74	-28.14
PG Fb 57	384056077015501	38.682339	-77.031643	169.16	-110.92	--
PG Gd 6	383958076520601	38.666333	-76.868167	216.24	-102.32	--
PG Hf 32	383250076405303	38.549533	-76.681406	9.58	-53.25	-41.11
QA Be 15	391203076024301	39.200943	-76.044945	24.21	-8.22	-12.78
QA Eb 112	385751076171602	38.964279	-76.287454	13.15	-31.91	-32.47
QA Eb 182	385850076183501	38.980556	-76.309444	13	-48.43	--
SM Bc 39	382605076430201	38.434750	-76.716778	161.54	-46.67	--
SM Dd 72	381626076393401	38.274000	-76.659611	109.99	-37.85	--
VA 54R-2	382341077032401	38.394722	-77.056667	69.19	-79.20	-29.59

Appendix 1e. Water-level data for Southern Maryland and Maryland's Eastern Shore wells used in this report (Patuxent aquifer system).

[All depth and altitude measurements are in feet. Land and water altitudes are measured from the North American Vertical Datum of 1988 (NAVD88), same as sea level in this report. Latitude and longitude measured relative to the North American Datum of 1983 (NAD 83); --, no data; USGS, U.S. Geological Survey]

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 2007-2015
2S5E- 1	391617076322001	39.271583	-76.538472	27.39	2.18	5.87
4S2E- 6	391456076345001	39.248933	-76.580756	6.88	-0.19	--
AA Ad 29	391015076373501	39.171122	-76.625872	35.65	-59.82	-1.86
AA Ad 90	391032076385902	39.176000	-76.649222	77.06	-84.32	-3.43
AA Bb 67	390538076453001	39.094639	-76.757306	132.26	-0.61	--
AA Bb 87	390826076454802	39.140556	-76.763333	268.55	140.50	--
AA Bb 88	390756076464201	39.132222	-76.778333	174.11	136.45	--
AA Bb 90	390657076462601	39.115833	-76.773889	162.76	103.62	--
AA Bc 163	390524076442501	39.089972	-76.741056	134.37	-1.53	--
AA Bc 240	390752076441001	39.131500	-76.735444	259.25	22.90	-1.60
AA Bd 57	390952076384102	39.164722	-76.644417	69.21	-170.87	-58.37
AA Bd 182	390839076385703	39.144264	-76.649339	178.06	-29.50	-4.18
AA Cb 1	390303076463201	39.050111	-76.775750	128.35	20.37	-13.07
AA Cc 80	390422076414503	39.072897	-76.696006	177.99	43.97	4.61
AA Cc 81	390422076414504	39.072897	-76.696006	177.98	37.65	-5.42
AA Cc 102	390004076420001	39.001361	-76.699472	53.18	-32.90	-18.46
AA Cc 113	390256076413101	39.049008	-76.691806	150.73	-28.85	-20.56
AA Cc 119	390437076432302	39.077667	-76.723361	138.25	-21.36	-19.94
AA Cc 124	390419076432301	39.072014	-76.722833	126.87	8.08	11.75
AA Cc 135	390126076403001	39.024306	-76.674333	114.04	-69.21	-41.69
AA Ce 117	390450076343402	39.080889	-76.576000	85.20	-37.02	-29.42
AA Cf 166	390154076282801	39.031558	-76.474467	105.93	-102.96	--
AA Cg 22	390123076241601	39.023167	-76.404125	11.81	-48.99	-40.68
AA De 203	385854076333202	38.981361	-76.558772	92.59	-47.11	-35.44
BA Fe 19	391607076312901	39.268594	-76.524300	11.7	-21.68	7.69
BA Gf 11	391356076293501	39.232167	-76.492556	12.72	-6.73	21.76
CH Bc 75	383645077062401	38.613028	-77.105944	123.77	-90.15	-53.77
CH Bc 77	383644077055501	38.612111	-77.099333	95.82	-90.83	-54.15
CH Bc 78	383809077053401	38.636056	-77.092389	20.13	-113.03	-79.91
CH Bd 52	383553077032401	38.598333	-77.056111	46.68	-86.81	-51.31
CH Be 57	383706076575601	38.617778	-76.963889	211.48	-44.99	-30.15
CH Be 73	383903076594302	38.650833	-76.995417	106	-49.30	--
CH Bf 166	383846076512001	38.646250	-76.855611	211	-22.59	--
CH Bf 167	383556076505201	38.598972	-76.847833	182	-27.98	--
CH Bg 18	383621076462801	38.605744	-76.774492	187.16	-35.11	--
CH Cb 45	383255077121201	38.548583	-77.203222	126	-117.33	-35.64
CH Cc 34	383441077063901	38.578444	-77.110722	41.01	-86.60	-39.70
CH Ce 57	383250076584001	38.547250	-76.977611	192.68	-31.68	-19.21
CH Ce 66	383445076551301	38.578806	-76.919861	179.00	-29.43	--
CH Da 18	382654077152501	38.448333	-77.256444	89.10	-12.61	-4.86
CH Ee 96	382151076580901	38.364342	-76.967453	22.16	-34.76	-9.66
HA De 181	392606076145801	39.435109	-76.249122	11.34	4.29	-0.61

Appendix 1e (continued)

Well number	USGS site identification number	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation	Water-level altitude 2015	Water-level difference 2007-2015
HA De 183	392606076145803	39.435109	-76.249122	11.65	2.48	-0.69
HA De 197	392819076130901	39.472054	-76.218844	18.21	6.57	-1.19
HA Ec 11	392435076203301	39.409830	-76.342181	10.88	9.68	0.49
HA Ec 46	392408076210101	39.402330	-76.349959	22.35	7.47	-0.16
HA Ed 47	392455076192101	39.415386	-76.322180	89.68	19.94	-0.22
HO Df 60	390830076473902	39.141667	-76.794167	210.68	165.43	--
PG Cf 66	385745076445201	38.962750	-76.747167	149.29	-25.58	-17.44
PG Cf 81	385745076445202	38.970889	-76.729583	116.57	-26.10	-1.85
PG Fd 62	384309076511401	38.719556	-76.853278	227.85	-22.09	-17.37
PG Hf 43	383300076411601	38.550033	-76.687386	44.17	-98.04	-75.07
QA Eb 110	385751076171603	38.964279	-76.287454	13.21	-10.19	-12.55
WE Ba 11	385649076584201	38.946889	-76.978444	87.43	75.33	--
WE Ca 35	385429076583601	38.908111	-76.976667	150.05	20.72	-8.88
WE Ca 36	385460076574801	38.916639	-76.963194	42.71	33.14	-3.06
WE Ca 39	385241076580901	38.878281	-76.969419	15.45	-41.78	--
WE Cb 8	385252076572801	38.881194	-76.957778	58.79	-16.97	-36.94
WW Bc 9	385527077000701	38.924389	-77.002139	133.6	115.33	-0.40
WW Cc 38	385257077001101	38.882472	-77.003131	60.61	-2.00	--

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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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