Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

REPORT OF INVESTIGATIONS NO. 72

HYDROGEOLOGY OF THE COASTAL PLAIN AQUIFER SYSTEM IN QUEEN ANNE'S AND TALBOT COUNTIES, MARYLAND, WITH EMPHASIS ON WATER-SUPPLY POTENTIAL AND BRACKISH-WATER INTRUSION IN THE AQUIA AQUIFER

by

David D. Drummond

Prepared in cooperation with
The Board of Commissioners of Queen Anne's County,
The Talbot County Council,
and
The Easton Utilities Commission

2001

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KEY RESULTS

Coastal Plain aquifers supply the majority of water needs in Queen Anne's and Talbot Counties (about 77 percent in 1997). Of these, the Aquia aquifer is perhaps the most important because of its wide extent, good water-bearing properties, and generally excellent water quality. However, because the Aquia aquifer is shallow in the vicinity of the Chesapeake Bay, and water levels have declined below sea level, brackish-water intrusion poses a threat to water quality in the Aquia aquifer.

Eight major aquifers are used for water supply in Queen Anne's and Talbot Counties:

- The Columbia aquifer is a surficial aquifer that extends over most of the study area. The Columbia aquifer supplies some older homes and farms, and is used for irrigation, but because it is shallow, it is vulnerable to contamination from surface sources, and to going dry during droughts.

- The Miocene aquifers underlie the Columbia aquifer in southeastern Queen Anne's and Talbot Counties, and are used for domestic, commercial, and irrigation supplies in that area.

- The Piney Point aquifer underlies the Miocene sediments in the southeastern part of the study area, but is absent in the northwest, and is a poor aquifer in some parts of the study area. It is used for domestic and commercial supplies where it is present, and for municipal supplies in neighboring Caroline and Dorchester Counties.

- The Aquia aquifer underlies the Piney Point and Columbia aquifers, and is used extensively throughout the study area, except for the southeastern part of Talbot County. Brackish water is present in the Aquia aquifer in a narrow strip along the Chesapeake Bay shore of Kent Island. Water levels in the Aquia aquifer have declined at a rate of about one-half foot per year since 1980, and may continue to decline as the region's population increases, and demand for irrigation water increases.

- The Matawan aquifer underlies the Aquia aquifer in western Queen Anne's County and possibly elsewhere. It is used for small domestic supplies in parts of Kent Island where it provides an alternative water source to the Aquia aquifer and deeper Cretaceous aquifers that have severe iron problems.

- The Magothy aquifer underlies the Matawan aquifer and may be hydraulically connected to it in places. It supplies water for domestic and commercial uses on Kent Island but water from the Magothy is very high in iron, and must be treated before use. The Magothy aquifer is also used for much of the municipal water supply at Easton, where iron concentrations do not pose a problem.

- The Upper Patapsco aquifer underlies the Magothy aquifer and supplies water for domestic, commercial, and municipal uses on Kent Island and eastward to Grasonville. Water from the Upper Patapsco aquifer also has a severe iron problem in the Kent Island area but becomes less severe to the east and south. The Upper Patapsco aquifer is also used for the municipal supply at Easton where iron concentrations do not pose a treatment problem.

- The Lower Patapsco aquifer underlies the Upper Patapsco aquifer on Kent Island, and probably elsewhere in the study area. It has been used for part of the public supply system on Kent Island since late 1999, but nowhere else on the Eastern Shore of Maryland south of Cecil County. Although water from the Lower Patapsco aquifer requires treatment for iron, concentrations are much lower than in the Magothy and Upper Patapsco aquifers. Aquifer tests have shown that the Lower Patapsco aquifer is very productive, and provides an excellent alternative to shallower aquifers, in spite of its great depth (1,445 feet below sea level at Stevensville).

- The Middle Patapsco and Patuxent aquifers are potential ground-water sources, but are not currently used for water supply in Queen Anne's and Talbot Counties, and have not been tested thoroughly.

- Bedrock underlying the Coastal Plain sediments is not considered a potential water supply.

Brackish-water intrusion poses a threat to water quality in the Aquia aquifer on Kent Island.

- Brackish water is present in the lower part of the Aquia aquifer in a narrow strip (about a quarter-mile wide) along the entire bay shore of Kent Island.

- Ground water with elevated chloride concentrations is present in the upper part of the Aquia aquifer on northern and southern Kent Island, and a narrow strip along the Chesapeake Bay on the central part of the island. At the northern tip of Kent Island, the entire section of the Aquia aquifer contains brackish water.

- Monitoring ground water in a network of wells on Kent Island since 1984 does not indicate an overall, consistent trend in chloride concentrations, but does identify an area where concentrations are generally increasing.

- Variations in water chemistry caused by sporadic but widespread pumping, fresh-water leakage from overlying aquifers, and prepumping invasion of brackish water from the Chester River and Eastern Bay may obscure an overall increase in chloride concentrations.

- Water with elevated chloride concentrations was detected in the Aquia aquifer in western Talbot County, but a widespread problem is not indicated. However, due to the lack of wells screened in the lower part of the Aquia aquifer in western Talbot County, it is uncertain if brackish water is present in the lower part of the aquifer, as it is on Kent Island.

Projected and hypothetical pumpage scenarios simulated with a ground-water flow model indicate water levels will decline in the Aquia aquifer as population and irrigation requirements increase.

- Water levels could decrease by as much as 90 feet in parts of the study area as a result of increased pumpage demands.

- Increasing irrigation pumpage by 300 percent in Queen Anne's and Talbot Counties could greatly increase the potential for brackish-water intrusion on Kent Island.

- Adding 0.5 MGD pumpage from the Aquia aquifer on easternmost Kent Island, increasing pumpage from the Aquia aquifer by 1 million gallons per day in the Grasonville area, and doubling irrigation pumpage in Queen Anne's and Talbot Counties would moderately increase the potential for brackish-water intrusion on Kent Island.

INTRODUCTION

From 1983 to 1986, the Maryland Geological Survey, in cooperation with the U. S. Geological Survey, conducted a study of the occurrence of brackish water in the Aquia aquifer on Kent Island. That study concluded that brackish water was present in at least part of the Aquia aquifer in a narrow strip within about a quarter mile of the Chesapeake Bay shore (Drummond, 1988). Brackish water occurred throughout the entire section of the aquifer on the northern tip of the island, but further south, the top part of the aquifer contained fresh water. Although no movement of the brackish-water interface was documented during that study, a solute-transport model estimated that under continued 1984 pumping conditions, the interface would move landward at a rate of about 21 feet per year (ft/yr). For this report, brackish water is defined as water with chloride concentrations between 1,000 mg/L and 10,000 mg/L (milligrams per liter).

In 1988 the Maryland Water Resources Administration (currently the Water Rights Division of the Maryland Department of the Environment) introduced a water-management strategy, in which all new ground-water users on Kent Island (Management area A on fig.1) requiring appropriation permits were prohibited from pumping from the Aquia aquifer. These users were directed to tap the deeper, Cretaceous aquifers. However, water from these deeper aquifers is generally very high in iron concentration (up to 34 mg/L), and requires expensive treatment to remove the iron. New appropriations for users of more than 1,000 gallons per day (gpd) east of Kent Island but west of the Wye River (Management area B on fig. 1) were also required to use aquifers deeper than the Aquia. New appropriations in excess of 10,000 gpd for users east and south of this area including Centreville, Easton, and Tilghman Island (Management area C on fig. 1) were scrutinized for potential contribution to brackish-water intrusion on Kent Island.

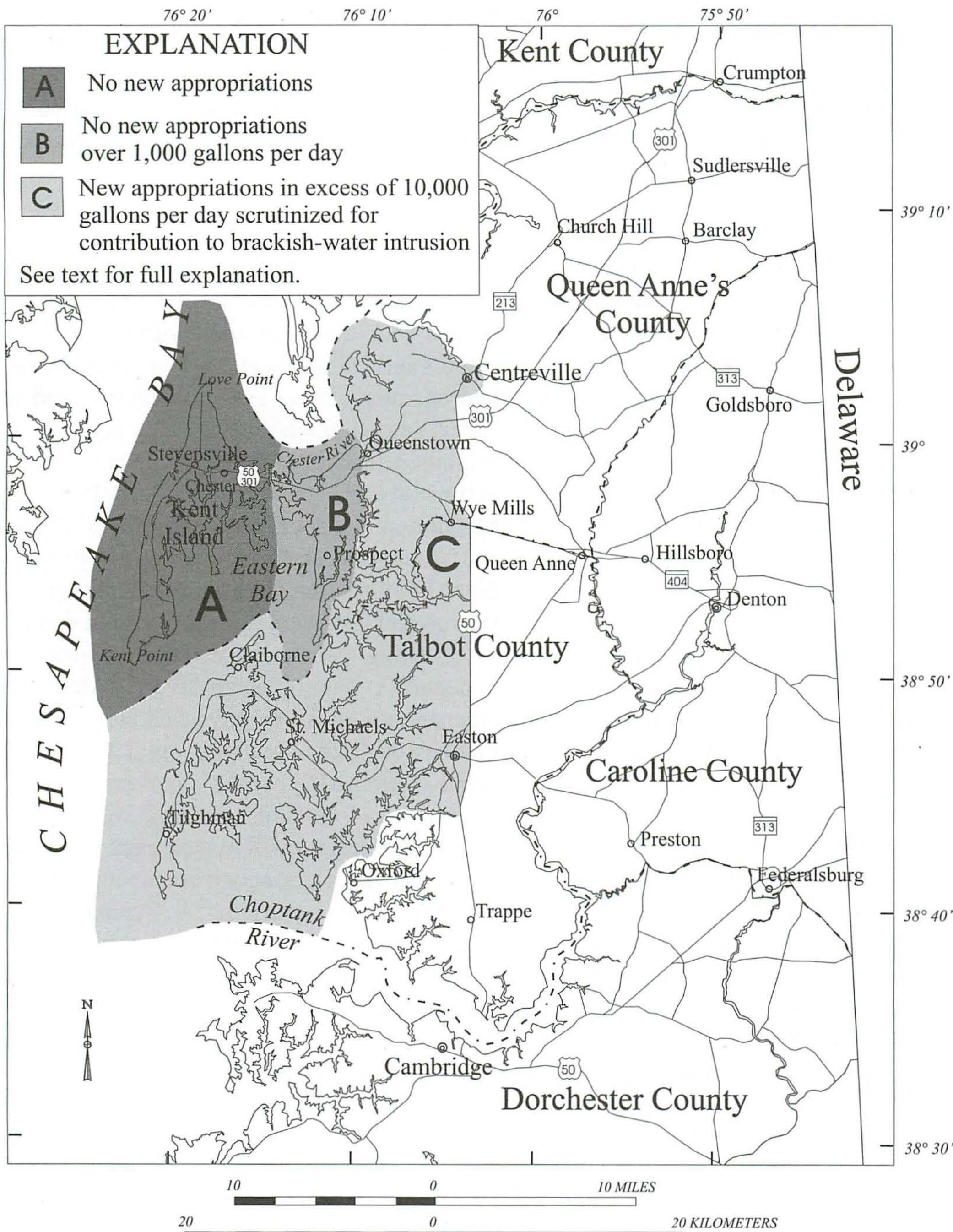
Since 1988, the Maryland Geological Survey, in cooperation with the U. S. Geological Survey, has continued to monitor chloride concentrations in a network of wells on Kent Island on an annual and semi-annual basis. The purpose of the monitoring is to determine trends in chloride concentrations, and to determine any movement in the brackish-water/fresh-water interface. The current study was conducted to analyze the monitoring data, update the historic-pumpage data base, and to estimate the effects of future pumpage increases. The results of this study are intended to help evaluate the need for continued ground-water use restrictions in the Aquia aquifer, and to explore alternatives to the current situation.

PURPOSE AND SCOPE

The purpose of this report is to present the results of a 3-year study of the hydrogeology of Queen Anne's and Talbot Counties. The study focused on the hydrogeology, water-supply potential, and brackish-water intrusion in the Aquia aquifer, but also examined the hydrogeology of the other aquifers used in the study area, including the Piney Point, Matawan, Magothy, and Upper Patapsco aquifers. The Columbia and Chesapeake aquifers, which are shallower than the Piney Point aquifer, were included in the ground-water flow model, but were not examined in detail.

Existing wells were inventoried during the study to document data on water levels, water quality, and pumpage amounts. Geophysical logs were obtained on four new wells, and compiled with 22 existing logs to create gamma-log cross sections. Ground-water samples were obtained from 30 wells for chemical analysis, in order to fill in data gaps in the Aquia and Piney Point aquifers, and to document water quality in the Cretaceous aquifers. A synoptic water-level measurement was conducted in the fall of 1997 to develop potentiometric surfaces for the Aquia and Piney Point aquifers, and to provide scattered head measurements in the Cretaceous aquifers. Monthly water-level measurements were taken in a network of wells screened in each of the major aquifers to document head changes caused by seasonal variations in recharge, evapotranspiration, and pumpage. Short-term water-level variations were documented by installing continuous water-level recorders on two wells in the Aquia aquifer. Field measurements were taken for chloride concentration and specific conductance on water from 18 wells, mostly in Talbot County, to determine if brackish-water intrusion was a problem south of Kent Island.

A ground-water flow model was developed to simulate water levels and flow rates in each of the major aquifers in the study area. The flow model was calibrated to historic water levels, and used to estimate future changes in ground-water levels as a result of



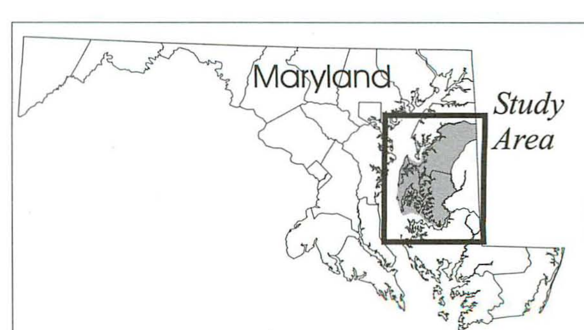


Figure 1. Location of study area with water-use restriction zones designated for the Aquia aquifer.

various projected-pumpage scenarios. The model was also used to estimate changes in ground-water flow at the brackish-water interface on Kent Island, which provides an indication of the potential for brackish-water intrusion for each of the pumpage scenarios. A particle-tracking routine was also used to estimate the potential for brackish-water intrusion.

LOCATION OF STUDY AREA

Queen Anne's and Talbot Counties are located on the central Eastern Shore of Maryland, and lie entirely within the Coastal Plain physiographic province (fig. 1). Queen Anne's County is bounded on the north by Kent County, on the east by Delaware and Caroline County, on the south by Talbot County, and on the west by the Chesapeake Bay. Talbot County is bounded on the north by Queen Anne's County, on the east by Caroline County, on the south by Dorchester County, and on the west by the Chesapeake Bay. Easton is located in the central part of Talbot County. Although the study area only includes Queen Anne's and Talbot Counties, data were also collected in the adjacent counties. Adjacent areas were also included in the ground-water flow model so that model boundaries could be placed some distance from the area of interest.

GROUND-WATER USE

Ground water is used on the central Eastern Shore for domestic, commercial, light industrial, agricultural, and public supply uses. All but domestic users are required to obtain a Ground-water Appropriation Permit (GAP) from the Maryland Department of the Environment, and large users (those users who pump more than 10,000 gpd) are required to report monthly pumpage amounts. Only ground water is used for human consumption in Queen Anne's and Talbot Counties, although surface water is used for irrigation and livestock watering.

Table 1 shows the pumpage amounts for each category between 1950 and 1997 for Queen Anne's and Talbot Counties (Wheeler and Wilde, 1987; Judith C. Wheeler, U. S. Geological Survey, written commun., 1999). Ground-water pumpage in Queen Anne's County has increased from about 1.3 million gallons per day (MGD) to about 7.8 MGD, and in Talbot County increased from 2.1 MGD to 6.0 MGD in that time period. Pumpage at Easton increased from about 0.49 MGD in the 1950's to 1.74 MGD in 1997. Irrigation was the largest use category in Queen Anne's County in 1997, while in Talbot County, public supply was the largest category.

All large ground-water users with current Ground-water Appropriation Permits in Queen Anne's and Talbot Counties were inventoried, and the data are displayed in table 14 (at the end of this report). Easton is the largest ground-water user in the study area, and pumped 1.74 MGD in 1997, from the Aquia, Magothy, and Upper Patapsco aquifers. Easton has reduced its pumpage from the Aquia aquifer from a high of 600,000 gpd in 1988 to 129,000 gpd in 1997, in part to reduce the impact of pumpage on brackish-water intrusion in the Kent Island area.

Projected population increases will produce increased demand on ground-water resources in Queen Anne's and Talbot Counties. The population of the region is not expected to increase dramatically; however, any increase in pumpage will produce decreases in water levels, which in turn may have impacts on brackish-water intrusion and regional water-level issues. Future ground-water pumpage was estimated from population projections for each election district (Alan L. Quimby, Queen Anne's County Department of Public Works, written commun., 1999; James W. Burns, Talbot County Department of Public Works, written commun., 1999). Domestic pumpage is assumed to increase proportionately with population increases. Pumpage from public-supply wells is also assumed to increase proportionately with projected population increases in the districts they serve. The population of Queen Anne's County is projected to increase from 33,586 in 1990 to 45,970 in 2010. The population of Talbot County is projected to increase from 30,549 in 1990 to 35,910 in 2010 and 38,350 in 2020.

Pumpage for irrigation has been increasing steadily since the 1950's, from 0.1 MGD to 3.3 MGD in Queen Anne's County, and from less than 0.1 MGD to 1.2 MGD in Talbot County (tab. 1). The trend is expected to continue, and irrigation may increase by as much as 300 percent from 1997 to 2020. Changes in water-use restrictions in the Kent Island area, and extensions of areas served by public water supplies may cause shifts in pumpage distribution between aquifers. Various scenarios for future pumpage were simulated in the ground-water flow model, and pumpage amounts are described in those sections of the report.

Table 1. Annual pumpage, by use category, for Queen Anne's and Talbot Counties

[modified from Judith C. Wheeler, U.S. Geological Survey, written commun., 1999]

Queen Anne's County	Pumpage, in million gallons per day (MGD)										
	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	1997
Public supply	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6	1.1	1.3
Domestic	0.9	1.0	1.1	1.1	1.3	1.5	1.6	1.9	2.4	2.6	2.3
Irrigation/Livestock	0.1	0.1	0.2	0.5	0.7	0.8	1.5	2.3	2.3	4.1	3.3
Commercial/Industrial	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.9	0.8	0.9
Total	1.3	1.4	1.8	2.1	2.6	3.1	4.0	5.2	6.2	8.6	7.8

Talbot County	Pumpage, in million gallons per day (MGD)										
	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	1997
Public supply	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.9	2.2	2.3	2.3
Domestic	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.2	1.4	1.6	1.5
Irrigation/Livestock	0.0	0.0	0.1	0.1	0.1	0.1	0.5	1.0	0.6	1.4	1.2
Commercial/Industrial	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.9	1.0	1.1	1.0
Total	2.1	2.4	2.7	2.8	2.9	3.1	3.6	4.9	5.2	6.4	6.0

METHODS OF INVESTIGATION

In order to evaluate the hydrogeology of Queen Anne's and Talbot Counties, an inventory was conducted of all ground-water users appropriated to pump 10,000 gpd or more (referred to as "large users"). All wells were inventoried for each user, and information was recorded for location, altitude, pumpage amounts, and well characteristics. Water levels were obtained where possible, and water samples for chemical analysis were collected from selected wells. Additional privately-owned wells were also inventoried to provide water-level, water-quality, and lithologic data. Most inventoried wells were in Queen Anne's and Talbot Counties, but a few wells were also inventoried in adjacent counties to provide data where needed. Historical pumpage data for large users were collected from files at the Maryland Department of the Environment, from published reports, and from interviews with water-system operators where necessary.

A water-level network was developed from the well inventory to construct potentiometric maps for each aquifer in the study area. Most wells on the water-level network were in the Aquia aquifer, as that is the focus of the study. Water levels in these wells were all measured within a 2-week period in the fall of 1997 to provide a synoptic measurement. Some wells were selected from the synoptic measurement for a monthly water-level network, and were measured approximately once a month from August 1997 to April 1999. Hydrographs were constructed that show seasonal water-level fluctuations in the wells on the monthly network. Hydrographs were also constructed showing long-term water-level fluctuations for wells in the state water-level network.

Water samples were collected from 18 wells in the study area to provide chemical analyses in areas where none previously existed. Water-quality analyses included field parameters, major ions, nutrients, iron and manganese, radon on selected wells, and pesticide screens on selected wells. Water-quality data for these wells, and previously sampled wells that included complete major-ion analyses were listed in table format, and plotted on Piper (trilinear) diagrams to show trends in water quality. Water samples were collected from an additional 12 wells screened in the Cretaceous aquifers on Kent Island and analyzed for dissolved iron and manganese to document the severe iron problem in that area.

Chloride concentrations of water from 38 monitoring wells on Kent Island were plotted against time to determine trends in chlorides. These data were used to evaluate the potential for increased brackish-water intrusion. Water samples were collected from an additional 18 wells in Talbot County, and field tests for chloride concentration and specific conductance were performed on the samples to determine if brackish-water intrusion has affected water in that area.

A ground-water flow model was developed to estimate future changes in water levels and flow rates caused by projected pumpage. Eleven hypothetical pumpage scenarios are discussed in the report. A proprietary program, Visual Modflow, was used for all simulations. This program provides pre-processing, post-processing, and visualization capabilities for MODFLOW (McDonald and Harbaugh, 1988), the U. S. Geological Survey modular ground-water flow model.

PREVIOUS INVESTIGATIONS

Darton (1896) first described the hydrogeology of the Maryland Coastal Plain, and provided brief descriptions of the confined aquifers in Queen Anne's and Talbot Counties. Clark, Mathews, and Berry (1918) wrote a comprehensive description of the surface and ground-water resources of Maryland and Delaware. They included descriptions of the major aquifers in use at the time, and characteristics of deep wells. Miller (1926a, 1926b) described the geology and physical characteristics of Talbot and Queen Anne's Counties, and listed a bibliography of early contributions to the geology of the area. Rasmussen and Slaughter (1957) provided the first comprehensive description of the ground-water resources of Talbot County, along with Caroline and Dorchester Counties. Overbeck and Slaughter (1958) provided a similar description of the ground-water resources of Queen Anne's County, along with Cecil and Kent Counties. These two publications give detailed descriptions of major aquifers in the study area, and ground-water quality, and provide tables of well characteristics.

Hansen (1968) constructed a cross-section network of Cretaceous sediments of Southern Maryland using geophysical logs. One cross section from that report extends across the Chesapeake Bay to the Eastern Shore, and helps correlate Cretaceous geology across the bay. Mack, Webb, and Gardner (1971) described the water resources of Dorchester and Talbot Counties, and made long-term predictions of the availability of ground water at Easton and

Cambridge. A user's guide for Coastal Plain aquifers was written by Hansen (1972). Cushing, Kantrowitz, and Taylor (1973) described the water resources of the Delmarva Peninsula. Hansen (1977) analyzed the stratigraphy of two core holes, one of which is located in northern Queen Anne's County, near Unicorn.

The shallow deposits of the northern and central Delmarva Peninsula were described by Owens and Minard (1979) and Owens and Denny (1979). Williams (1979) simulated changes in water levels in the Piney Point aquifer on the Eastern Shore and Southern Maryland. Mack (1983) provided an analysis of geohydrologic data from a cluster of test wells on Kent Island, the deepest of which was drilled to basement. Chapelle and Drummond (1983) described the hydrogeology and geochemistry of the Piney Point and Aquia aquifers in Southern Maryland, and included some data for those aquifers on the Eastern Shore. Bachman and Wilson (1984) described the hydrogeology of the Columbia aquifer on the Eastern Shore, and provided data on water levels, water quality, lithologic logs, and geophysical logs.

Drummond (1988) studied the hydrogeology of the Aquia aquifer on Kent Island, and assessed the brackish-water intrusion problem near the Chesapeake Bay shoreline. Andreasen and Hansen (1987) summarized the hydrogeologic data from a deep (1,725 ft) test well drilled in eastern Queen Anne's County.

Hansen (1992) analyzed the stratigraphy of a core hole drilled through Tertiary and Upper Cretaceous sediments near Chestertown, in Kent County. Tompkins, Cooper, and Drummond (1994) summarized ground-water and surface-water data in a basic data report for Kent County. Drummond (1998) described the hydrogeology, ground-water flow, and ground-water quality of the upper Coastal Plain aquifers in Kent County.

The U. S. Geological Survey publishes a series of annual reports which include water-level and water-quality data for many monitoring wells throughout Maryland.

ACKNOWLEDGMENTS

The project was funded through a cooperative agreement between the Maryland Geological Survey, Queen Anne's County, Talbot County, and the town of Easton. D. Steven Walls, Director, and Alan L. Quimby, Chief Sanitary Engineer of the Queen Anne's County Department of Public Works; William R. Runyan, County Engineer of the Talbot County Office of Public Works; and M. Gerald Adams, Water and Sewer Department Manager of the Easton Utilities Commission helped to initiate the project, provided data for public water-supply systems, and offered estimates of future ground-water demand. The author would like to thank the many homeowners, businesses, farmers, and public water-supply operators who allowed water-level measurements and water-quality samples from their wells. Earth Data Inc. provided hydrogeologic reports and data that were included in this study. Field work for the project was conducted by Erin Feehley, Sarah Frost, and Barbara Cooper, and typing and layout services were provided by Donajean Appel, all of the Maryland Geological Survey.

HYDROGEOLOGIC FRAMEWORK AND WATER QUALITY

The study area is underlain by Coastal Plain sediments which comprise multiple aquifers and confining layers. The Coastal Plain sediments are underlain by a complex assemblage of bedrock formations. Generally, the depth to bedrock increases to the southeast. Test wells and borings reached bedrock at 1,928 feet (ft) below sea level at Kingstown (Otton and Mandle, 1984), 2,504 ft below sea level at Chester (Mack, 1983), and 3,295 ft below sea level at Cambridge (Trappe and others, 1992). Bedrock is not used for water supply in the study area and is not considered a significant source of water.

The Coastal Plain hydrogeologic units are Quaternary, Tertiary, and Cretaceous in age, and generally become deeper and thicker to the southeast, as shown in the schematic cross section in figure 2. The major aquifers underlying the study area (from shallow to deep) are the Columbia aquifer, Miocene aquifers of the Chesapeake Group, Piney Point aquifer, Aquia aquifer, Matawan aquifer, Magothy aquifer, Upper Patapsco aquifer, and Lower Patapsco aquifer (fig. 2). The Miocene aquifers include the Frederica, Federalsburg, and Cheswold aquifers as defined by Cushing, Kantrowitz, and Taylor, (1973), in addition to sandy units in the Calvert Formation. These aquifers, although important sources of water in the southeastern part of the study area, are not the focus of this study. They are usually grouped together in this report, and referred to collectively as "the Miocene aquifers". All of the major aquifers are listed in table 2, along with approximate thickness, lithology, and water-bearing properties.

The hydrostratigraphy of the study area is illustrated in figures 3 and 4. Gamma radiation increases to the right on the logs and generally signifies increasing clay content. Sandy formations (aquifers) usually have lower gamma radiation than clayey formations (confining units). These figures show generalized lithologic types, top and bottom altitudes of aquifers, and selected well records typical of the two areas. The gamma logs displayed in figures 3 and 4 demonstrate that aquifer characteristics can vary from site to site in the study area.

Cretaceous sediments below the Aquia aquifer form several aquifers that are used in the Kent Island area and at Easton. Because of water-use restrictions on the Aquia aquifer on Kent Island, new large users are required to use the Cretaceous aquifers. Closely-spaced geophysical logs in the Kent Island area have allowed the correlation and differentiation of these units. Typically in the past, the first sandy unit below the Aquia aquifer has been designated the Magothy aquifer. However, stratigraphic correlation from the deep test well at Chester (QA Eb 110) indicates that three distinct aquifer units are present in this area that correlate with the Matawan Group, the Magothy Formation, and the upper part of the Patapsco Formation, all of which have been previously referred to as the Magothy aquifer. These units are defined here as the Matawan, Magothy, and Upper Patapsco

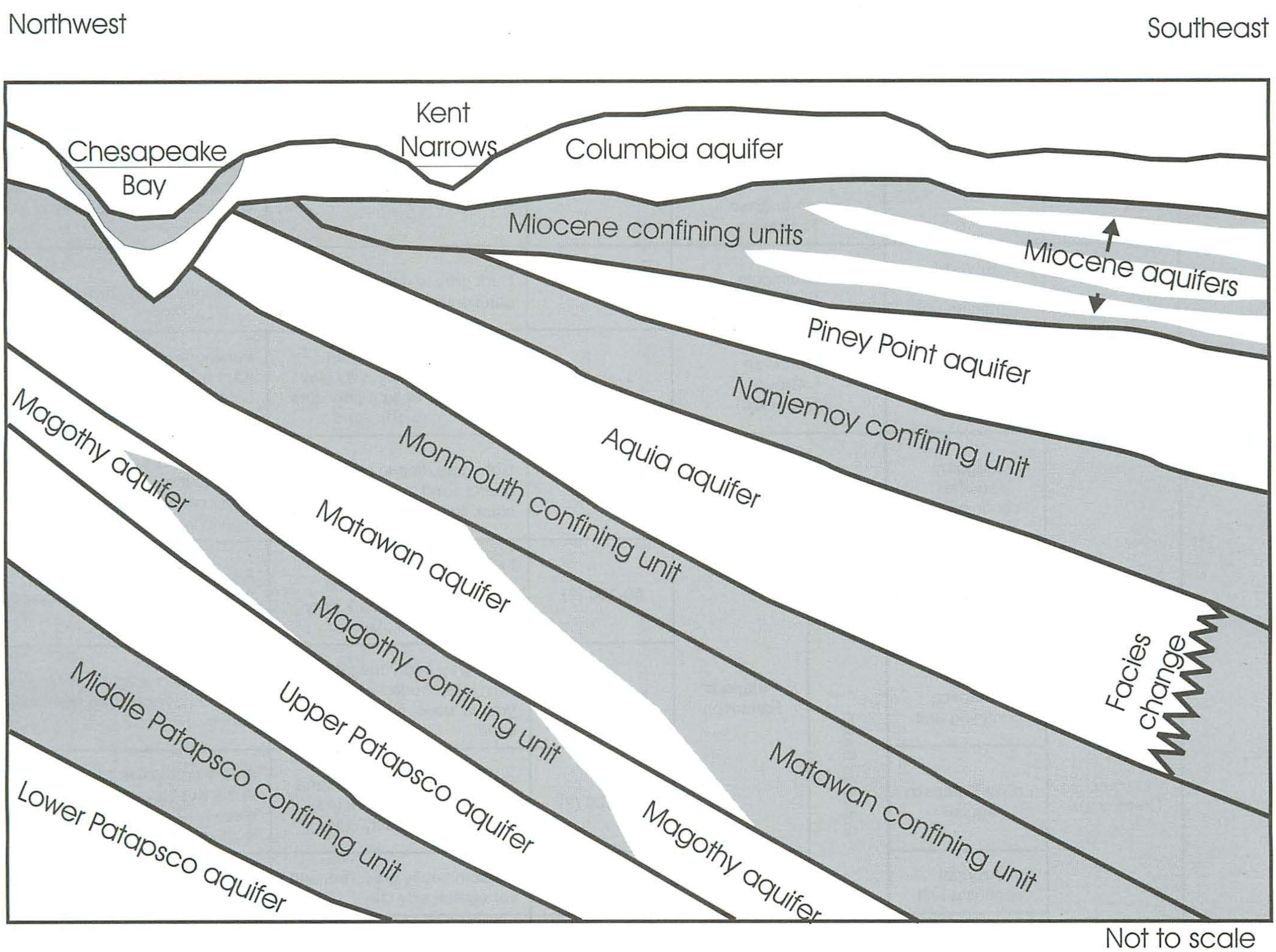


Figure 2. Schematic cross section showing the hydrogeologic units beneath Queen Anne's and Talbot Counties.

Table 2. Generalized hydrogeology and stratigraphy of Queen Anne's and Talbot Counties

System	Series	Hydrogeologic unit	Stratigraphic unit		Approximate thickness (feet)	Lithology	Water-bearing properties
Quaternary	Pleistocene	Columbia aquifer	Kent Island Formation		0-40	Loose, light-colored medium to coarse sand and dark-colored, massive silt clay.	Functions as an unconfined or semi-confined aquifer. Yields moderate amounts of water to shallow wells. Vulnerable to contamination from surface sources.
Tertiary	Pliocene (?) and/or Upper Miocene (?)	Columbia aquifer	Pensauken Formation		0-80	Orange to reddish brown, fine to coarse sand and gravelly sand.	Functions as an unconfined or semi-confined aquifer. Yields moderate amounts of water to shallow wells. Vulnerable to contamination from surface sources.
Tertiary	? Miocene	Miocene aquifers/ confining unit	Chesapeake Group	Choptank Formation	0-360	Gray quartz sand and dark gray silt with clay with abundant shell material.	Contains multiple aquifers in the southeastern part of the study area. Elsewhere functions as a leaky confining unit.
Tertiary	Miocene	Miocene aquifers/ confining unit	Chesapeake Group	Calvert Formation	0-360		
Tertiary	Eocene	Piney Point aquifer	Piney Point Formation		0-175	Green to gray, fine to coarse glauconitic quartz sand with abundant shell material.	An important confined aquifer in the southeastern part of the study area.
Tertiary	Eocene	Nanjemoy confining unit	Nanjemoy Formation		0-260	Green to gray glauconitic sandy silt and clay.	Functions as a leaky confining unit in all but the northwestern part of the study area.
Tertiary	Eocene	Aquia aquifer	Unnamed Lower Eocene sand		120-260	Green to gray, fine to medium, glauconitic quartz sand with abundant shell material and layers of calcite-cemented sand.	An important confined aquifer throughout most of the study area. Produces the majority of fresh water on the central Eastern Shore, for domestic, commercial, and public-supply wells. Contains brackish water along the bay shore of Kent Island.
Tertiary	Paleocene	Aquia aquifer	Aquia Formation				
Tertiary	Paleocene	Aquia aquifer	Hornerstown Formation				
Cretaceous	Upper Cretaceous	Severn/ Monmouth confining unit	Monmouth Formation		70-180	Dark gray to dark green glauconitic sandy, silty clay.	Functions as a tight confining unit.
Cretaceous	Upper Cretaceous	Matawan aquifer/ confining unit	Matawan Group (undivided)		100-150	Dark gray to dark green glauconitic sandy, silty clay with lenses of light gray, fine to medium quartz sand.	Functions as a poor aquifer in the Kent Island area, elsewhere as a confining unit. Produces water relatively low in iron.
Cretaceous	Upper Cretaceous	Magothy aquifer/ confining unit	Magothy Formation		100-120	Light gray, fine to coarse quartz sand and gray to black lignitic clay.	Functions as a confined aquifer in parts of the study area, elsewhere as a confining unit. Produces water high in iron.
Cretaceous	?	Upper Patapsco aquifer	Potomac Group	Patapsco Formation	50-150 (?)	Light gray to white fine to very coarse quartz sand. Interbedded with dark gray and variegated clay.	A productive confined aquifer throughout the study area; produces water high in iron.
Cretaceous	Lower Cretaceous	Middle Patapsco confining unit	Potomac Group	Patapsco Formation	800-900 (?)	Dark gray and variegated clay, interbedded with light gray to white, fine quartz sand.	Functions as a tight confining unit; may contain localized water-bearing zones.
Cretaceous	Lower Cretaceous	Lower Patapsco aquifer	Potomac Group	Patapsco Formation	150-180 (?)	Fine to medium quartz sand, interbedded with dark gray and variegated silty clay.	A very productive confined aquifer in the Kent Island area, and possibly elsewhere. Produces water relatively low in iron.
Cretaceous	Lower Cretaceous	Arundel confining unit	Potomac Group	Arundel Formation	~600	Predominantly gray, red, and variegated silty clay.	Functions as a very tight confining unit.
Cretaceous	Lower Cretaceous	Patuxent aquifer	Potomac Group	Patuxent Formation	~80	Fine to coarse, silty quartz sand with partially-pyritized lignite.	A poor aquifer in the Kent Island area, and possibly elsewhere.
Paleozoic	--	--	Basement Complex		–	Variable types of crystalline and sedimentary rocks.	Not used for water supply in the study area.

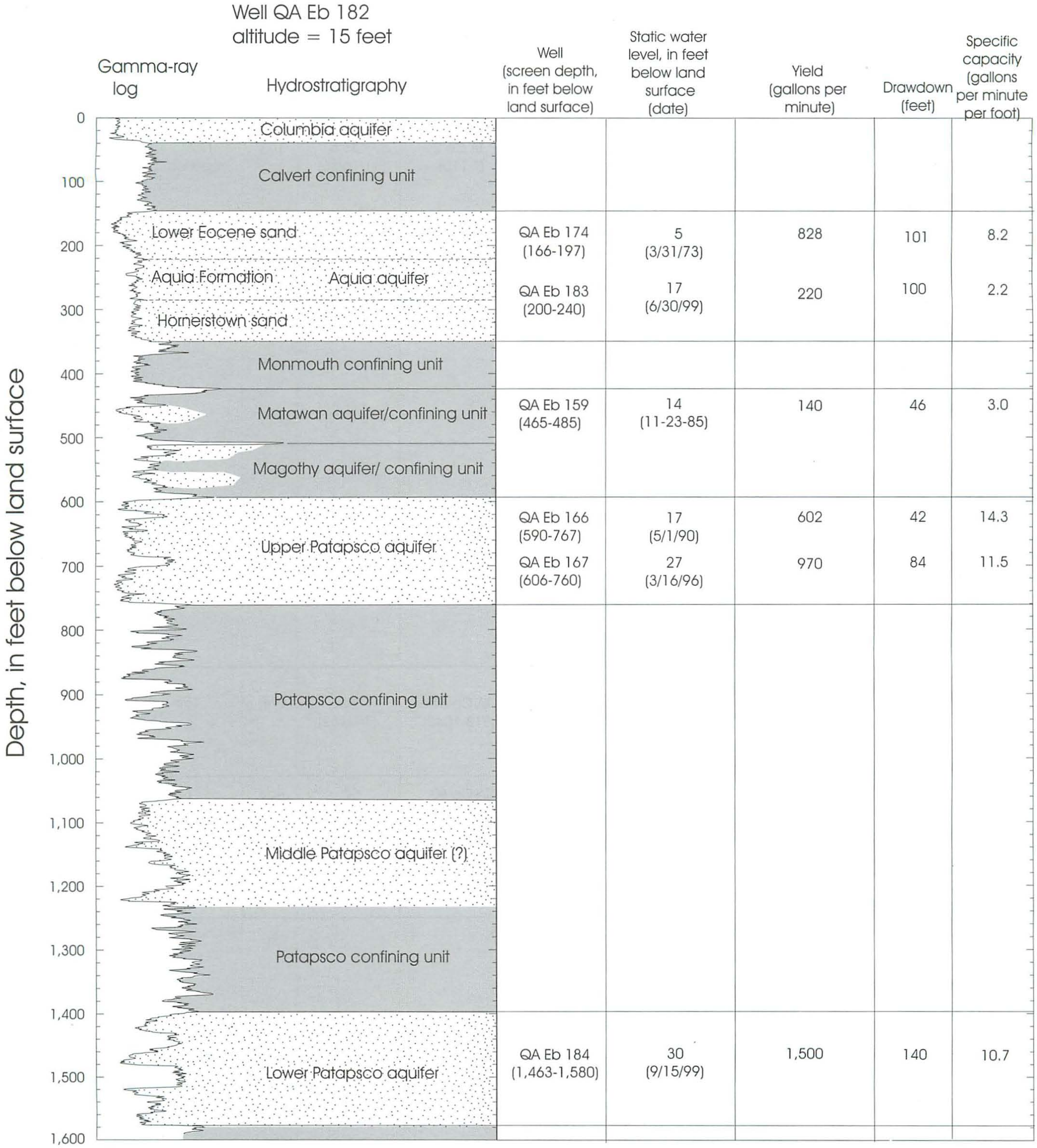
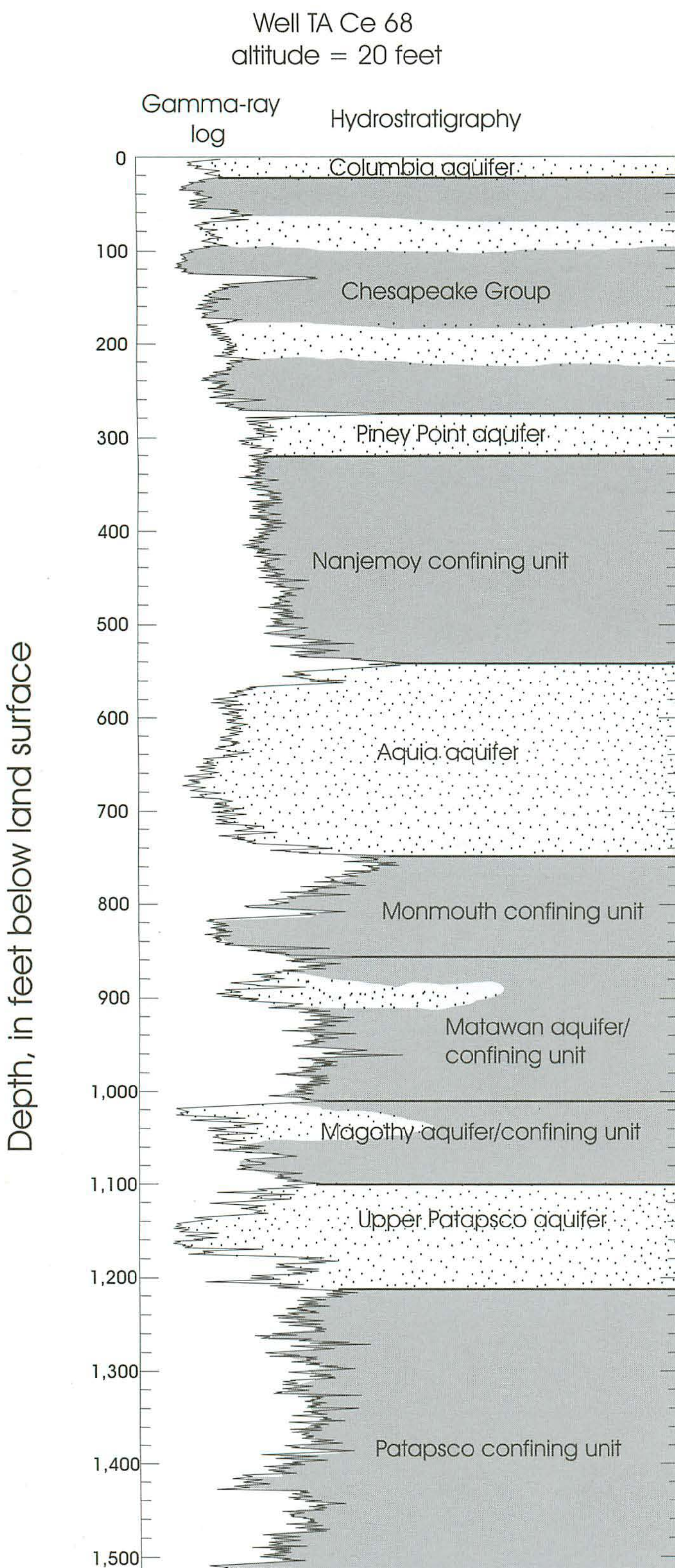


Figure 3. Gamma-radiation log, hydrostratigraphy, and selected well records in the vicinity of Stevensville.



Hydrostratigraphy	Well (screen depth, in feet below land surface)	Static water level, in feet below land surface (date)	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per foot)
Columbia aquifer					
Chesapeake Group	TA Ce 2 (?-110)	33.5 (1/16/56)	193	Not reported	Not reported
Piney Point aquifer					
Nanjemoy confining unit					
Aquia aquifer	TA Cd 55 (574-669)	41 (1/31/77)	530	181	2.9
Monmouth confining unit					
Matawan aquifer/confining unit	TA Ce 61 (918-1045)	94.6 (7/10/62)	494	158	3.1
Magothy aquifer/confining unit	TA Ce 60 (1,010-1,045)	43 (4/22/60)	463	82	5.6
Upper Patapsco aquifer	TA Ce 70 (1,143-1,184)	26 (8/17/88)	1,015	118	8.6
Patapsco confining unit					

Figure 4. Gamma-radiation log, hydrostratigraphy, and selected well records in the vicinity of Easton.

aquifers. The Matawan and Magothy units are spatially variable, and in some places form aquifers and in other places form confining units. The Upper Patapsco aquifer comprises several sandy units which vary spatially, but as a whole, seem to extend throughout the entire study area. In the flow-modeling section of this report, the Matawan and Magothy aquifers are simulated as a single hydraulic unit, and this unit is referred to as the "Matawan/Magothy aquifer".

Two wells were drilled into the Lower Patapsco aquifer at Stevensville for Queen Anne's County in 1999 (Earth Data Inc, 1999). A test well (QA Eb 182) was drilled to 1,717 ft below land surface, and indicated that a sandy interval between 1,460 ft and 1,580 ft, which correlates with the Lower Patapsco aquifer in well QA Eb 110 (Mack, 1983), would be very productive with significantly lower iron concentrations than the Upper Patapsco or Magothy aquifers. A production well (QA Eb 184) was then drilled and screened in this interval. During an aquifer test, the well was pumped at a rate of 1,507 gallons per minute (gpm) for 24 hours, with 140 ft of drawdown. The data indicate a 24-hour specific capacity of 10.74 gallons per minute per foot (gpm/ft), a transmissivity of 25,000 gallons per day per foot (gpd/ft) (3,300 feet squared per day [ft^2/d]), and a storativity of 0.0004 (Earth Data, 1999).

Another sandy interval is indicated in the log of well QA Eb 182 (fig. 3) between 1,065 and 1,225 ft below land surface. This interval has not been screened by any wells or tested, but it may be a water-bearing zone, and is referred to as the Middle Patapsco aquifer in figure 3 and table 2. It does not correlate with a sandy interval in well QA Eb 110 at Chester, about a mile and a half to the southeast.

The hydrogeologic framework is displayed in a series of cross sections, the locations of which are shown in figure 5. The cross sections are based on gamma-radiation logs and geologists' descriptions of drill cuttings and cores. Cross sections A-A$'$, B-B$'$, B$'$-B$''$ and C-C$'$ trend north and northeast, approximately parallel to regional strike. Cross sections D-D$'$ and D$'$-D$''$ trend east-west, approximately perpendicular to regional strike. Cross sections A-A$'$ and D-D$'$ show detailed hydrogeology on Kent Island, where more well control is available.

The aquifers and confining units are described in order of increasing depth. Although the focus of this report is on the Aquia aquifer, the other aquifers are also described briefly, as they form a hydrogeologic system.

COLUMBIA AQUIFER

The Columbia aquifer is a surficial series of sand, gravel, silt, and clay which blankets the entire study area. It comprises sediments of Pleistocene, Pliocene(?), and Miocene(?) age, including the Talbot Formation, the Kent Island Formation, and the Pensauken Formation (Owens and Denny, 1979). It is absent only along the shores of the Chester River and its tributaries, where erosion has removed it and exposed the underlying sediments. The hydrogeology of the Columbia aquifer was described in detail by Bachman and Wilson (1984). Bachman and Wilson (1984) excluded the Kent Island Formation from the Columbia aquifer, but in this report, the Kent Island Formation is included, so that the Columbia aquifer comprises all surficial sediments in the study area. The Columbia aquifer is underlain by Chesapeake Group sediments over most of the study area. Where the Chesapeake Group is absent in the northwestern part of Queen Anne's County, the Columbia is underlain by the Nanjemoy confining unit and the Aquia aquifer.

The Columbia aquifer is tapped by many dug wells at older farms and homes in the study area. Because of limited available drawdown in the Columbia, and its vulnerability to surface contamination, most modern wells used for potable-water supply are drilled into deeper aquifers. Many irrigation wells, however, withdraw water from the Columbia aquifer.

Water levels in the Columbia aquifer represent the water table, and ranged from sea level to about 65 ft above sea level in the study area in October 1980 (Bachman and Wilson, 1984, pl. 6). Although water levels in the Columbia aquifer exhibit a cyclic seasonal trend caused by evapotranspiration variations, they remain fairly constant over the long term. Hydrographs from three wells screened in the Columbia aquifer show no significant long-term trends in water levels (fig 12). Locations of wells with hydrographs and water-quality analyses are shown in figure 62, at the end of this report. The hydrograph for well TA Bf 74 shows a decline in water levels of about 5 ft between 1956 and 1990, perhaps due to increased irrigation pumpage from the Columbia aquifer and underlying Chesapeake aquifer.

Seasonal variations in the water table (fig. 13) are caused primarily by fluctuations in the evapotranspiration cycle. Irrigation pumpage may also cause declines during the summer months, especially in southern Talbot County, and Caroline and Dorchester

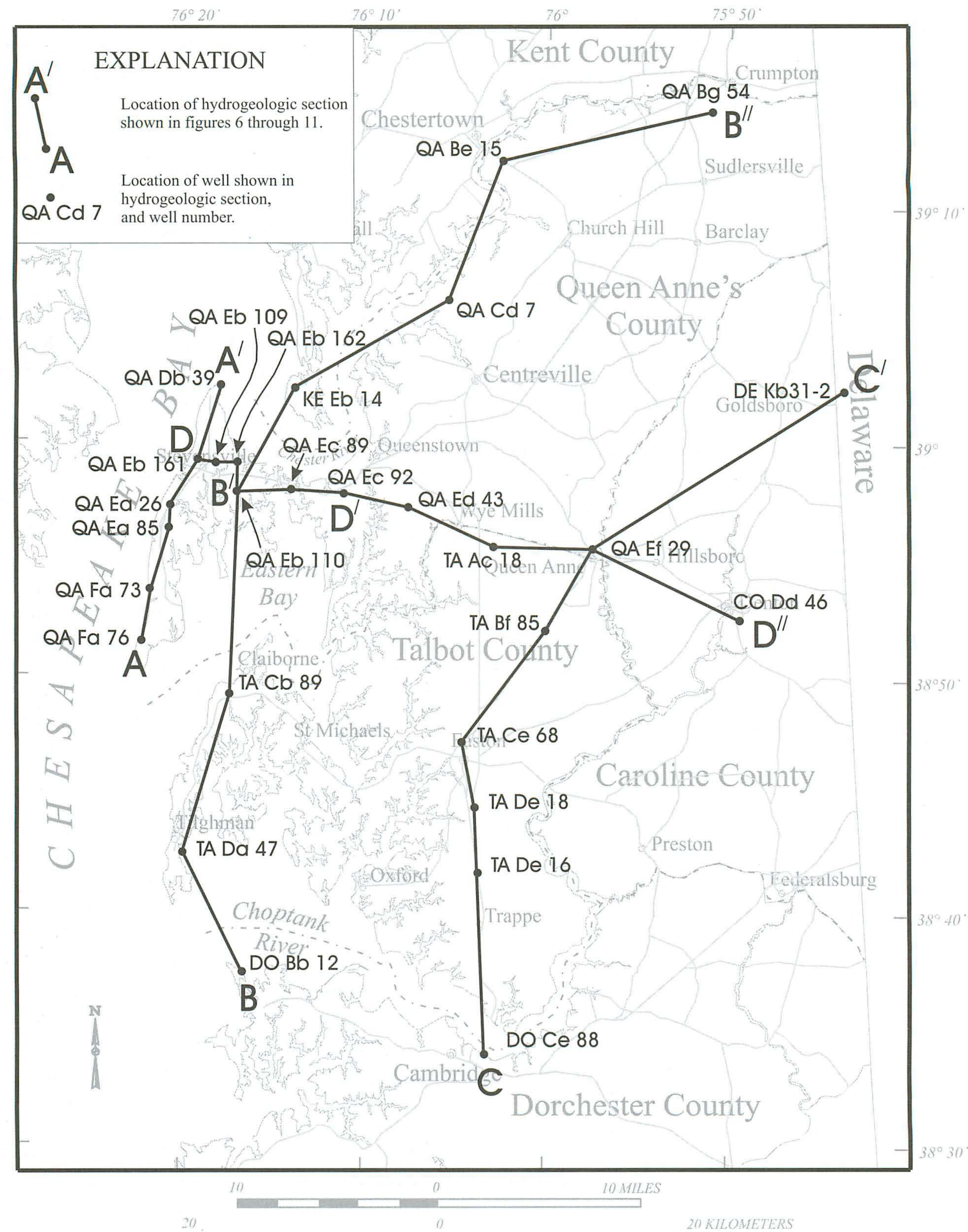
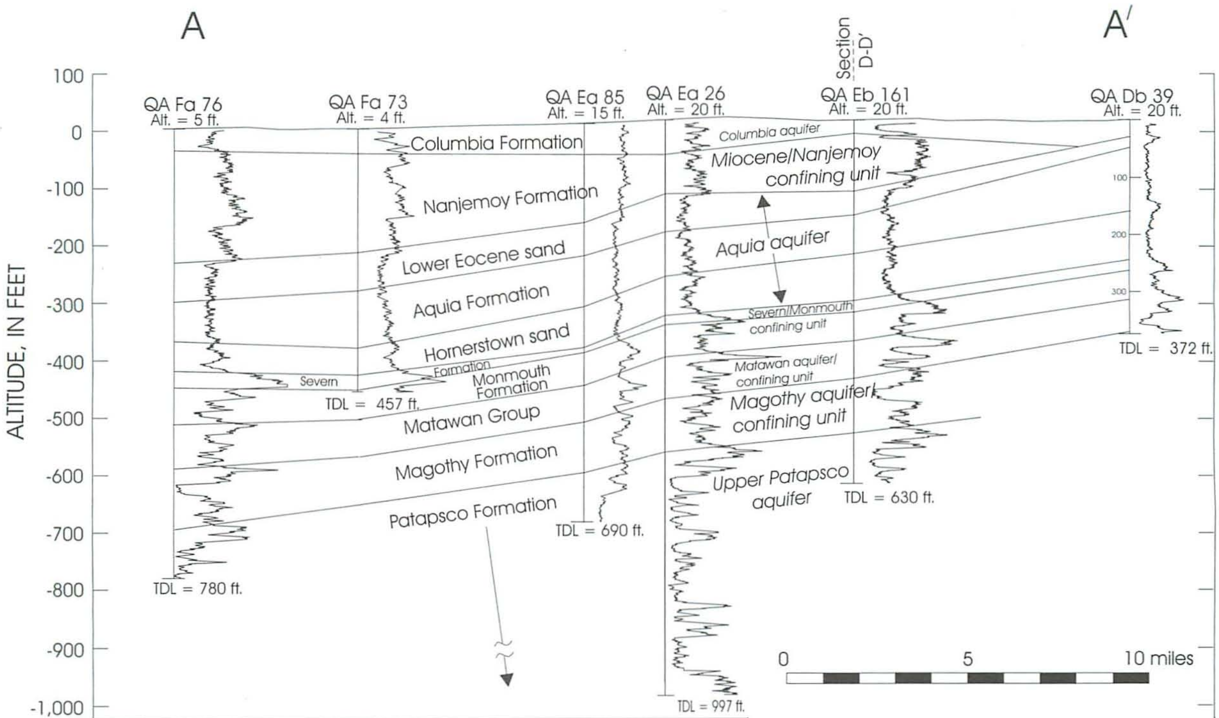


Figure 5. Locations of hydrogeologic sections.



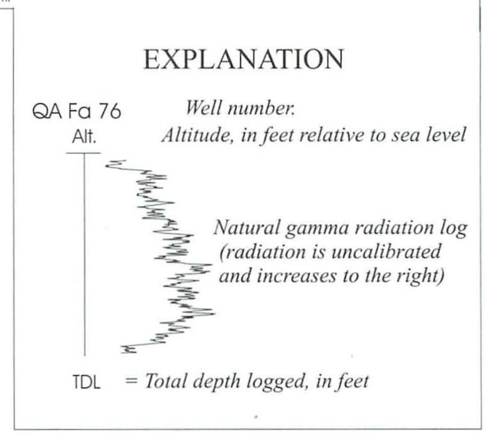


Figure 6. Hydrogeologic section A-A′ showing hydrogeologic units in Queen Anne's and Talbot Counties.

Counties, where the Columbia aquifer is used extensively for irrigation.

Water quality in the Columbia is quite variable, owing to the wide range of conditions in the aquifer. Table 15, at the end of this report, lists 23 chemical analyses of water from the Columbia aquifer. Because it is shallow, the Columbia aquifer is vulnerable to contamination from surface sources. Chloride concentrations are moderately high, with an average concentration of 32 mg/L, due to contamination from surface sources. Nitrate concentrations are also high, with an average of 8 mg/L, due to agricultural application of fertilizer, septic disposal, and high dissolved oxygen concentrations which prevent nitrate from degrading.

The plot of hydrochemical facies (fig. 14) shows that water in the Columbia aquifer has mixed cation and anion types, ranging from calcium and magnesium bicarbonate types, to sodium chloride and nitrate types. The only water type not exhibited by Columbia water is the sodium-potassium bicarbonate type.

MIOCENE AQUIFERS

Geologic units in the Chesapeake Group in Queen Anne's and Talbot Counties include the Calvert Formation and the Choptank Formation. The Calvert Formation is predominantly a silty clay, but includes some sandy lenses that yield small amounts of water to wells. The Choptank Formation comprises extensive layers of sand which form aquifers separated by layers of silt and clay. Cushing, Kantrowitz, and Taylor (1973) identified three sandy units in the Choptank Formation, and named them (from shallow to deep) the Frederica, Federalsburg, and Cheswold aquifers. In this report, however, these aquifers are undifferentiated, and are collectively referred to as the "Miocene aquifers". The Miocene aquifers are used extensively in the southeastern part of Queen Anne's County and the eastern part of Talbot County. Sandy units in the Calvert Formation are used by a few wells in the northwestern part of the study area, and are

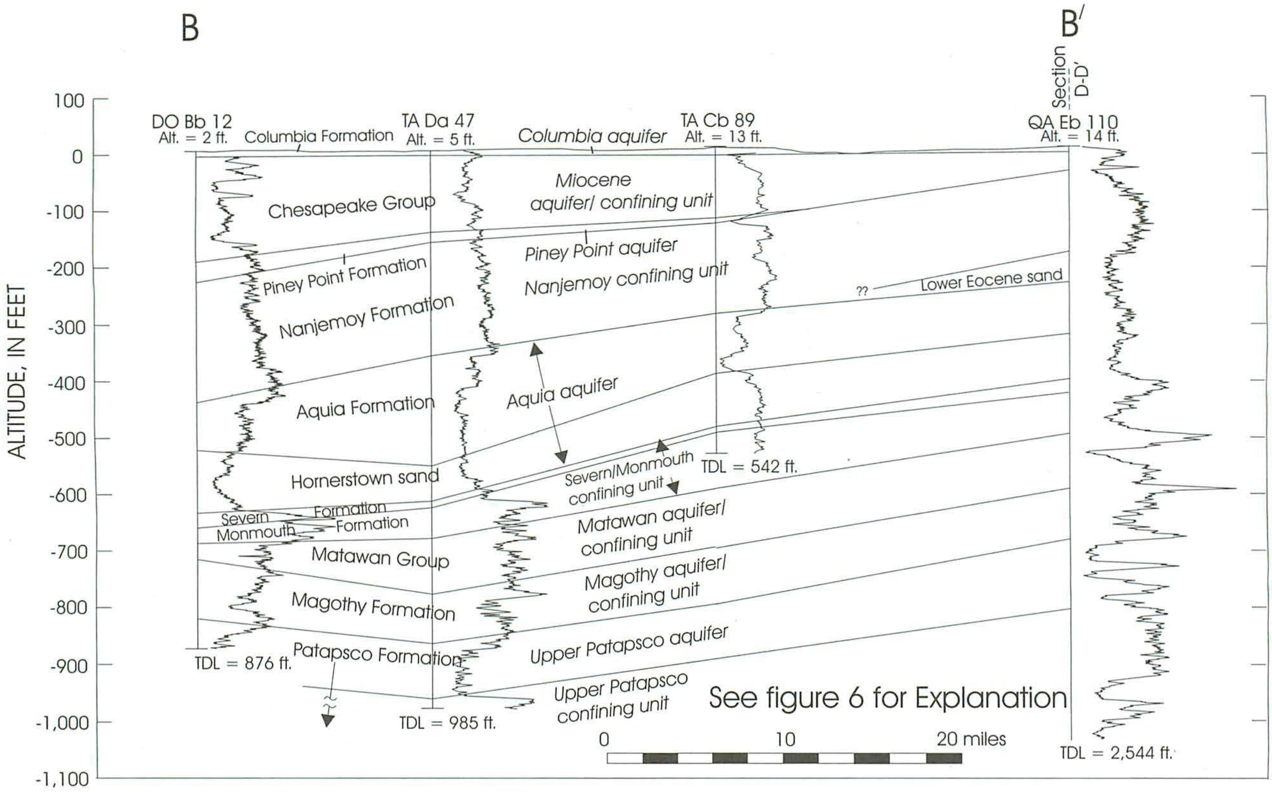


Figure 7. Hydrogeologic section B-B' showing hydrogeologic units in Queen Anne's and Talbot Counties.

included in the Miocene aquifers.

Silty and clayey layers in the top of the Chesapeake Group generally act as a confining unit above the aquifer layers and prevent a direct hydraulic connection with the overlying Columbia aquifer. Similarly, silty and clayey layers in the lower part of the Chesapeake Group act as a confining unit below the aquifer layers. In some areas, the confining units may be absent, in which case the aquifer layers would be in direct contact with the overlying Columbia aquifer or the underlying Piney Point aquifer.

Cushing, Kantrowitz, and Taylor (1973) show generalized potentiometric surfaces for the Miocene aquifers that range from about 25 ft below sea level to 50 ft above sea level. Long term hydrographs of wells screened in the Chesapeake aquifer show water levels as deep as 60 ft below sea level at Easton in the 1960's, when the town derived part of its water supply from the Miocene aquifers (U. S. Geological Survey, 1999, p. 468). Water levels measured during the 1997 synoptic measurement range from 4 ft below sea level at Cambridge to 45 ft above sea level in northern Talbot County.

Rasmussen and Slaughter (1957) reported transmissivity values ranging from 170 to 470 ft²/d. Hansen (1977) reported a specific storage value of 6.0×10^{-5} per foot (1/ft) for a silt in the Calvert Formation from boring QA Bg 54. Drummond (1988) reported horizontal hydraulic conductivity values of 1.12×10^{-2} and 1.5×10^{-2} feet per day (ft/d) and vertical hydraulic conductivity values of 2.30×10^{-3} and 2.0×10^{-2} ft/d from core samples of the Calvert Formation on Kent Island.

Water quality in the Miocene aquifers is generally good in Queen Anne's and Talbot Counties. Although the Miocene aquifers are relatively shallow, they are generally overlain by low-permeability confining units, which prevent downward migration of contamination from surface sources. The seven analyses shown in table 15 show low chloride, nitrate, and iron concentrations. The hydrochemical facies shown in figure 15 are dominated by calcium and sodium bicarbonate types. This trend is caused predominantly by dissolution of shell material, which

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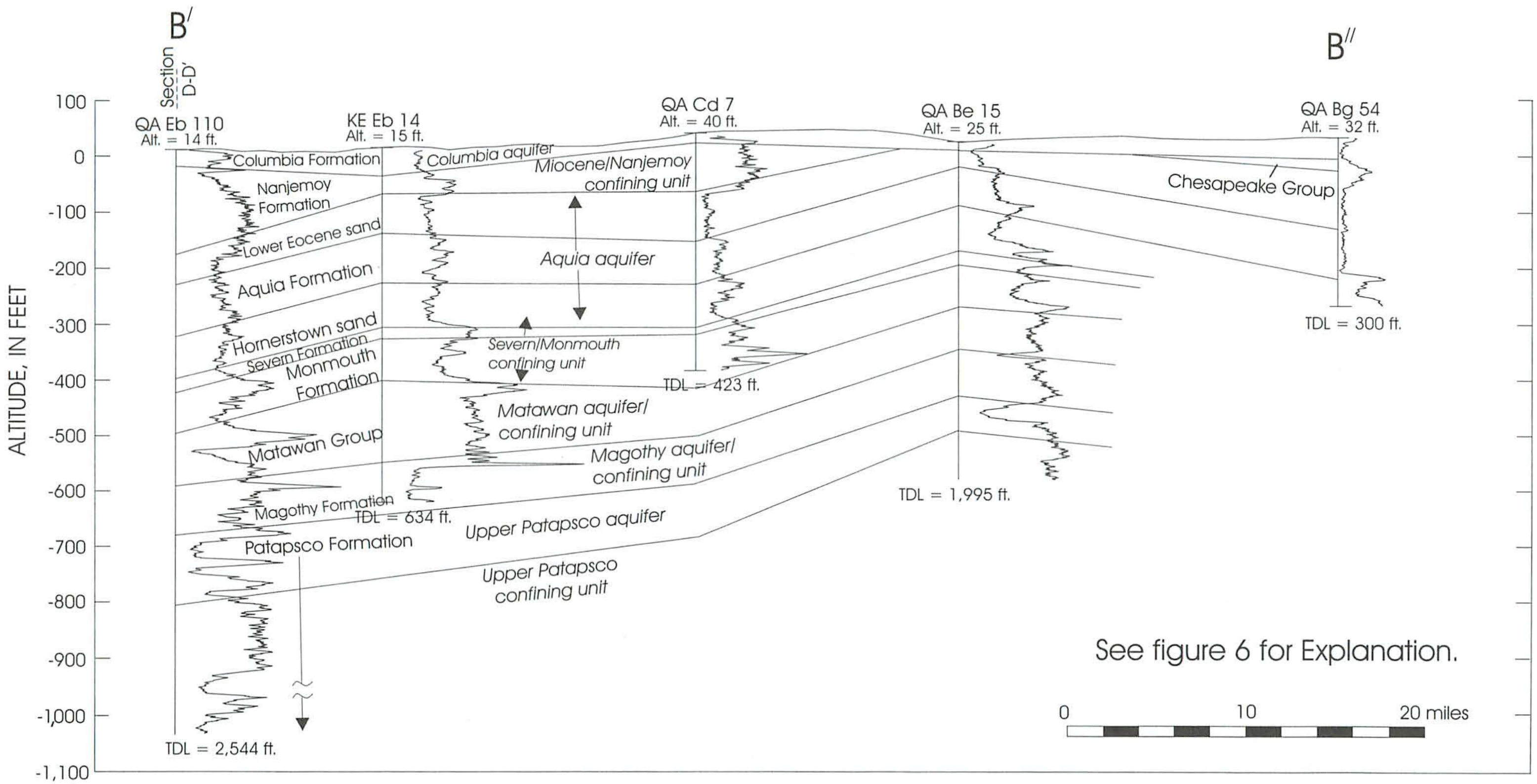

Figure 8. Hydrogeologic section B/-B// showing hydrogeologic units in Queen Anne's and Talbot Counties.

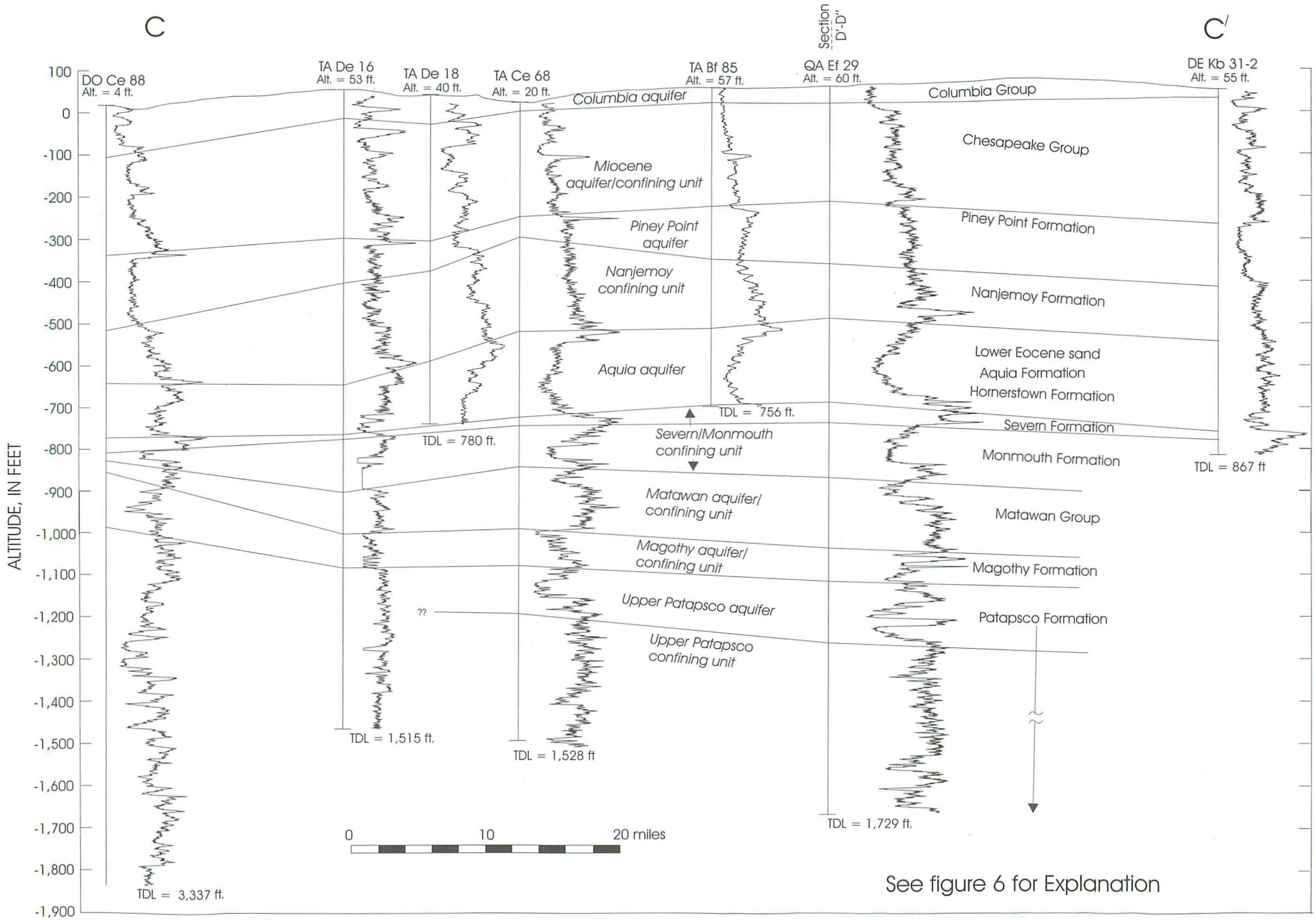

Figure 9. Hydrogeologic section C-C/ showing hydrogeologic units in Queen Anne's and Talbot Counties.

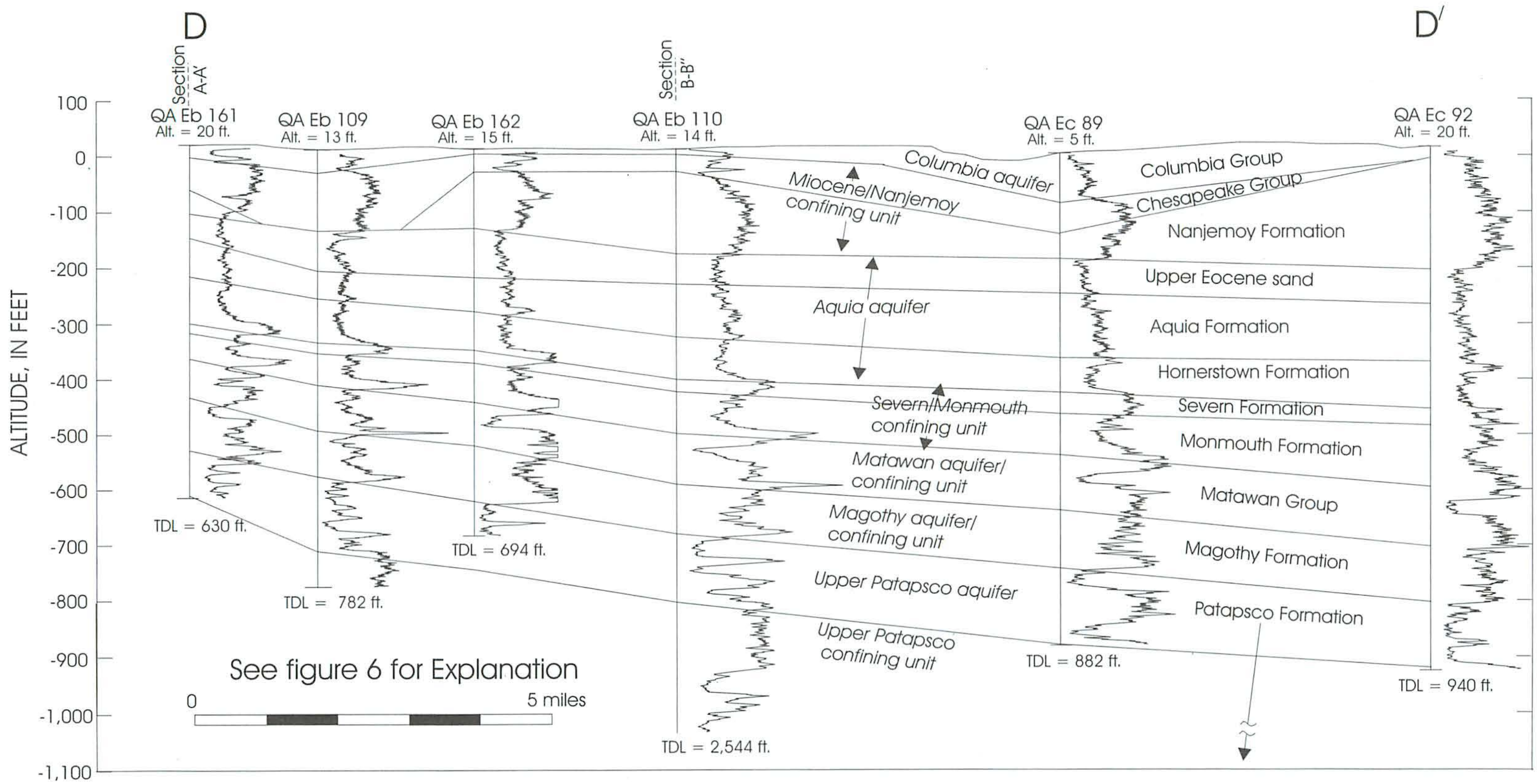

Figure 10. Hydrogeologic section D-D/ showing hydrogeologic units in Queen Anne's and Talbot Counties.

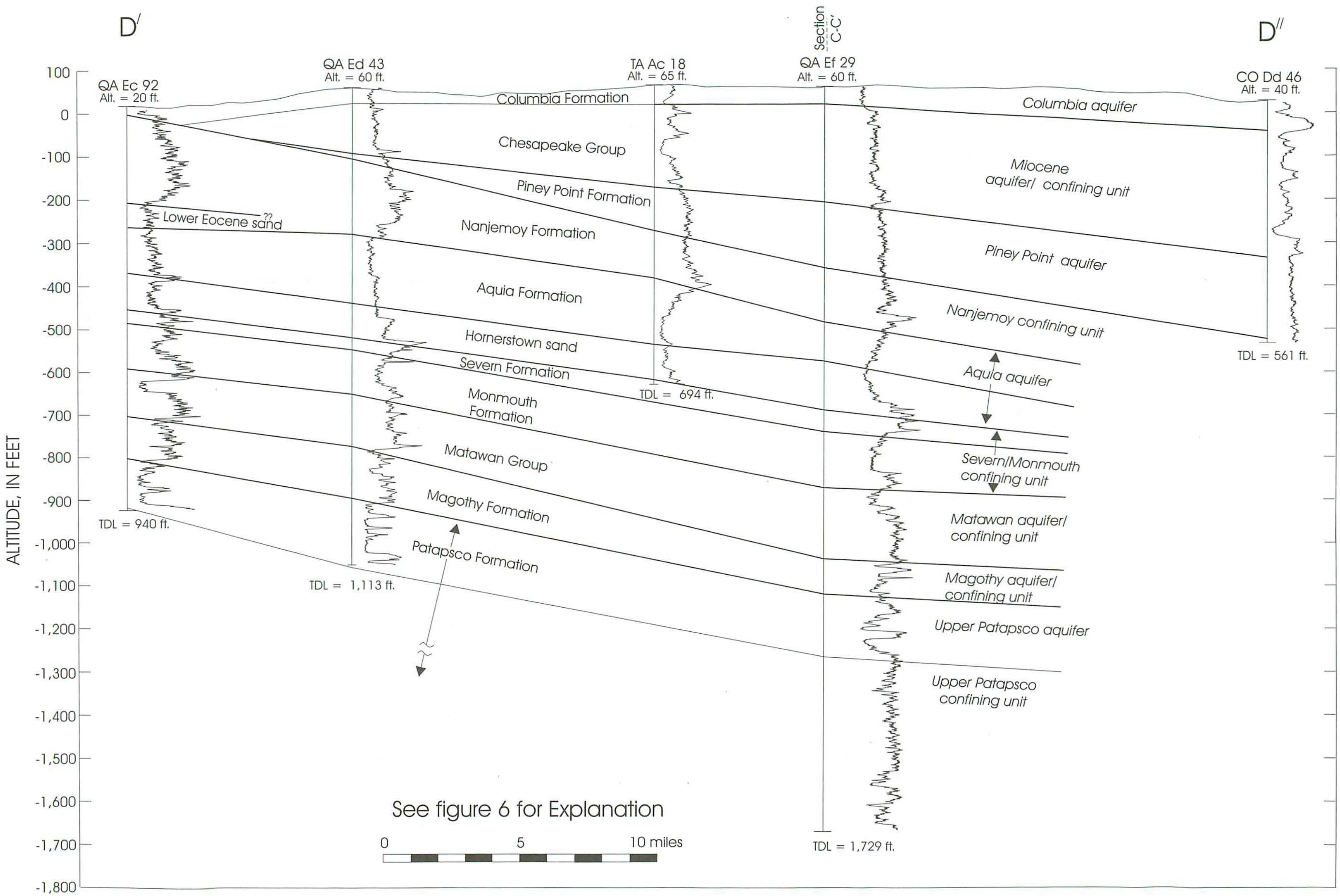

Figure 11. Hydrogeologic section D′-D″ showing hydrogeologic units in Queen Anne's and Talbot Counties.

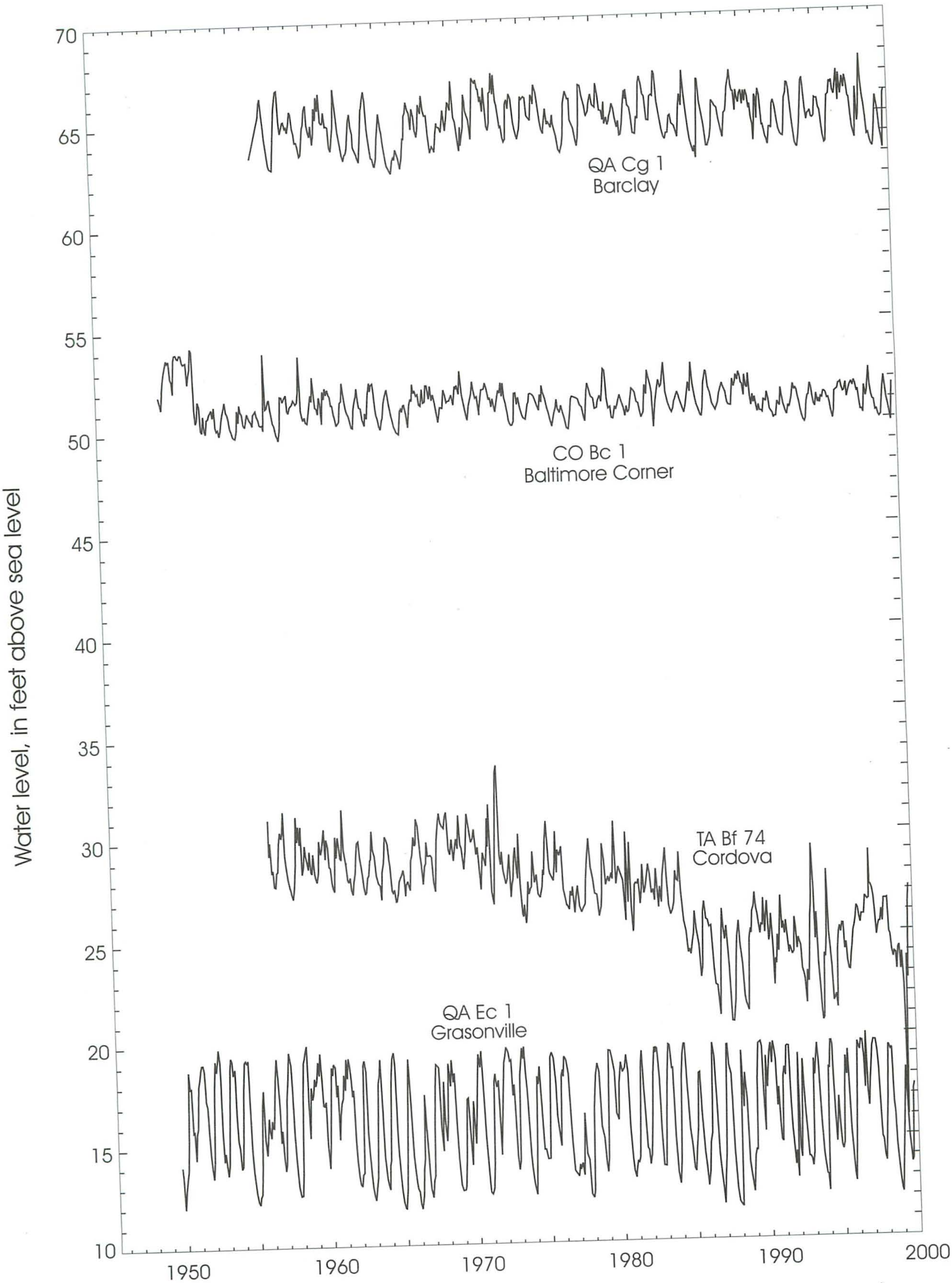

Figure 12. Hydrographs showing long-term water-level trends in the Columbia aquifer, 1943 to 1999.

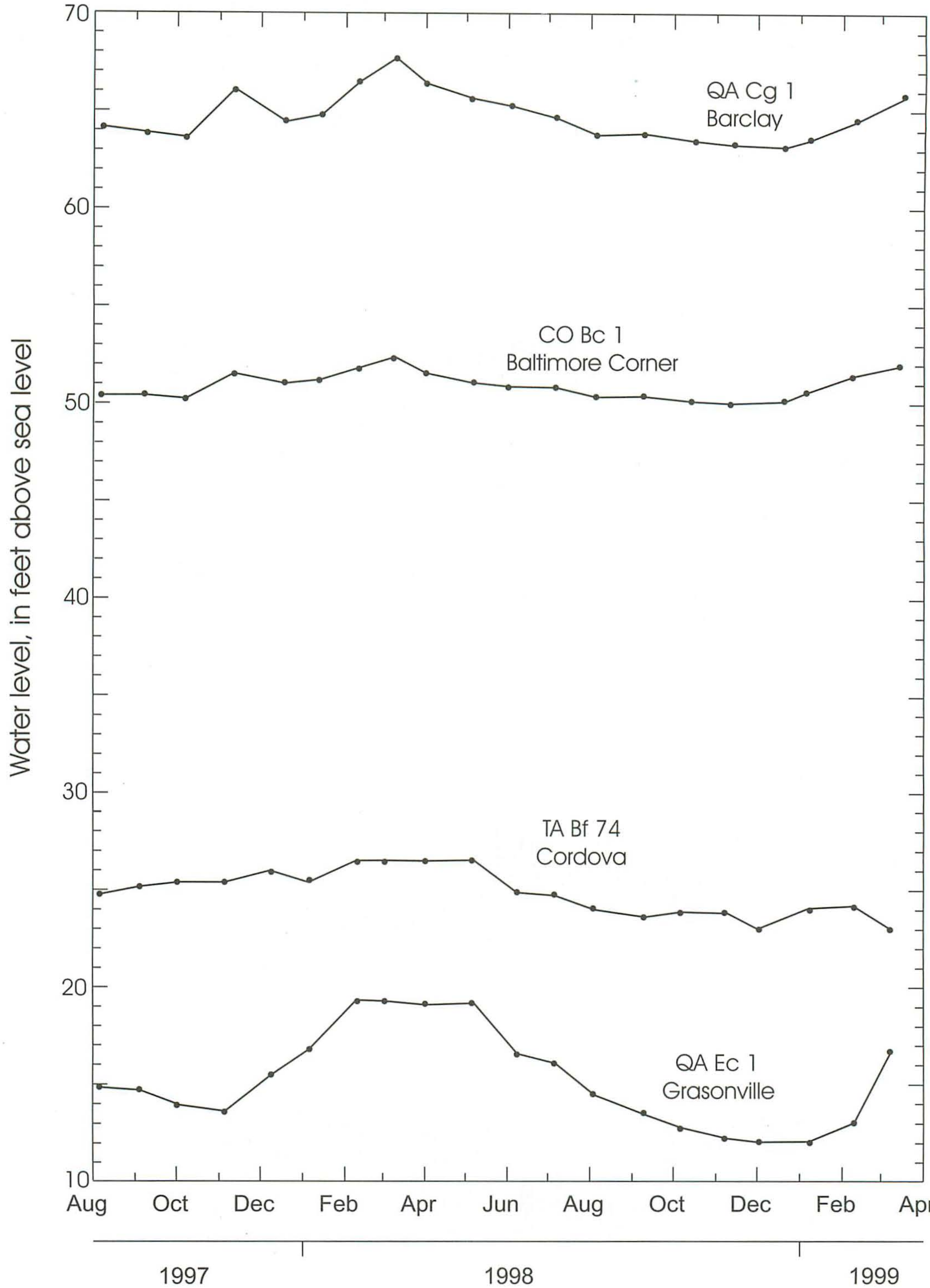

Figure 13. Hydrographs showing seasonal water-level trends in the Columbia aquifer, August 1997 to April 1999.

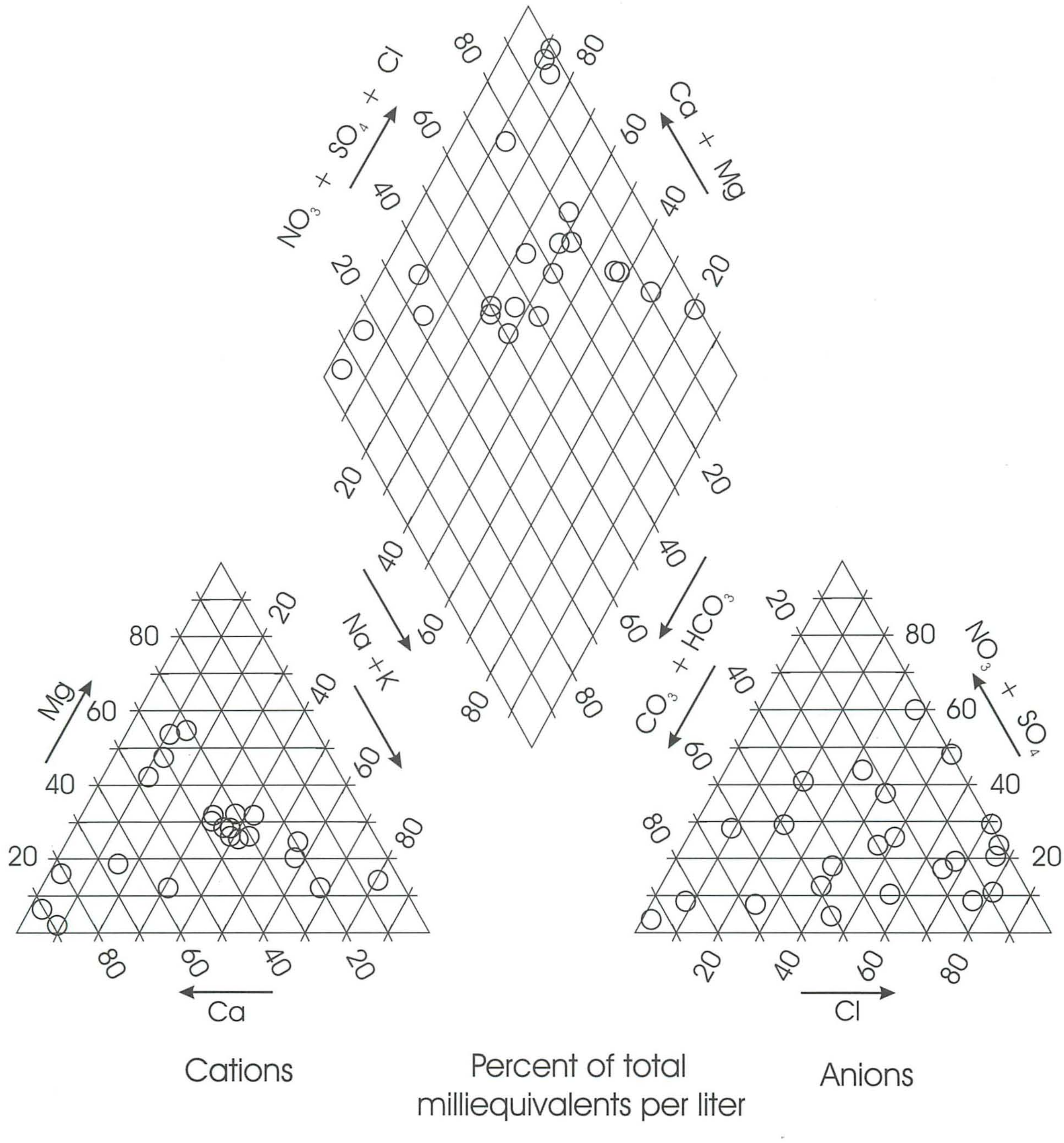

Figure 14. Hydrochemical facies in the Columbia aquifer.

is common in the Miocene aquifers, and cation exchange reactions.

PINEY POINT AQUIFER

The Piney Point aquifer is used extensively in the southeastern part of the study area, as well as in Dorchester and Caroline Counties, in Delaware, and in Southern Maryland. It is absent in the area northwest of a subsurface truncation line, which runs approximately through Sudlersville, Centreville, and Grasonville. The Piney Point aquifer does not crop out in Maryland. It is overlain by sediments of the Chesapeake Group, and underlain by the Nanjemoy Formation, which acts as a leaky confining unit between the Piney Point and Aquia aquifers.

The hydrogeology of the Piney Point aquifer on the Eastern Shore was described by Rasmussen and Slaughter (1957), Cushing, Kantrowitz, and Taylor (1973), and Williams (1979). Data were collected during this study on water levels and pumpage amounts for input to the ground-water flow model, but data on aquifer characteristics were derived from Williams (1979). The Piney Point aquifer is not easily distinguishable on gamma logs, and so the top and bottom altitudes shown in the cross sections (figs. 6-11) were derived from Williams (1979).

Water levels were measured in the Piney Point aquifer in the fall of 1997, and the potentiometric surface is shown in figure 16. The altitude of the potentiometric surface ranges from 60 ft below sea level near Cambridge to 45 ft above sea level near Queen Anne in southeastern Queen Anne's County. Comparison with the potentiometric surface from 1975 measured by Williams (1979) shows that water levels have recovered in the Cambridge area from 90 ft below sea level in 1976 to 60 ft below sea level in 1997. Water levels have declined in northern Talbot County from about 35 ft above sea level in 1976 to 25 ft above sea level in 1997. Elsewhere in the study area, water levels have remained about the same.

These trends are displayed in long-term hydrographs from wells in the Piney Point aquifer, shown in figure 17. Short-term hydrographs for wells in the Piney Point aquifer (fig. 18) show a modest seasonal fluctuation. Water levels in well QA Ee 24 show the greatest drop in the summer months of about 14 ft. All four wells with monthly measurements recovered to within 3 ft of the previous year's levels.

Water quality in the Piney Point aquifer is good throughout Queen Anne's and Talbot Counties. Because the Piney Point is confined and does not outcrop, it is not vulnerable to contamination from surface sources. The Piper diagram shown in figure 19 shows hydrochemical facies in the Piney Point aquifer. Cation water types range from sodium to mixed calcium and magnesium. Anion water types are exclusively bicarbonate. This pattern indicates evolution of water chemistry of dissolved shell material and cation exchange of calcium and magnesium for sodium, which is common in aquifers of the Atlantic Coastal Plain that consist of glauconitic, shell-rich marine deposits (Chapelle and Drummond, 1983).

AQUIA AQUIFER

The Aquia aquifer is the most widely used source of water in the study area. It is used for domestic, commercial, irrigation, and public supplies, and produces water of excellent chemical quality in most areas. Brackish-water intrusion is a potential problem in the Aquia along the Chesapeake Bay shore of Kent Island, and in a few low-lying areas in Kent County to the north of Queen Anne's County. The Aquia aquifer extends from its subcrop area in Kent County southeast to Trappe in Talbot County, where it becomes a silty sand and does not produce water. It also extends westward beneath the Chesapeake Bay into Southern Maryland (Chapelle and Drummond, 1983; Achmad and Hansen, 1997), and eastward into Delaware where it is referred to as the Rancocas aquifer (Sundstrom and Pickett, 1968; Woodruff, 1990).

The Aquia aquifer is overlain by the Nanjemoy confining unit where it exists, and by the Calvert confining unit where the Nanjemoy is absent. In a few areas of northern Queen Anne's County along the Chester River, and further north in Kent County, the Aquia aquifer is directly overlain by the Columbia aquifer where the Aquia subcrops. In northwestern Queen Anne's County, where the Piney Point aquifer is absent, it is difficult or impossible to distinguish the Calvert Formation from the Nanjemoy Formation in drillers' logs. This may be due to reworking of older glauconitic Nanjemoy sediments into the younger Calvert. For this reason, the two formations are undifferentiated in this area on the cross sections.

The Aquia aquifer was subdivided by Drummond (1988) into three units on Kent Island, an unnamed

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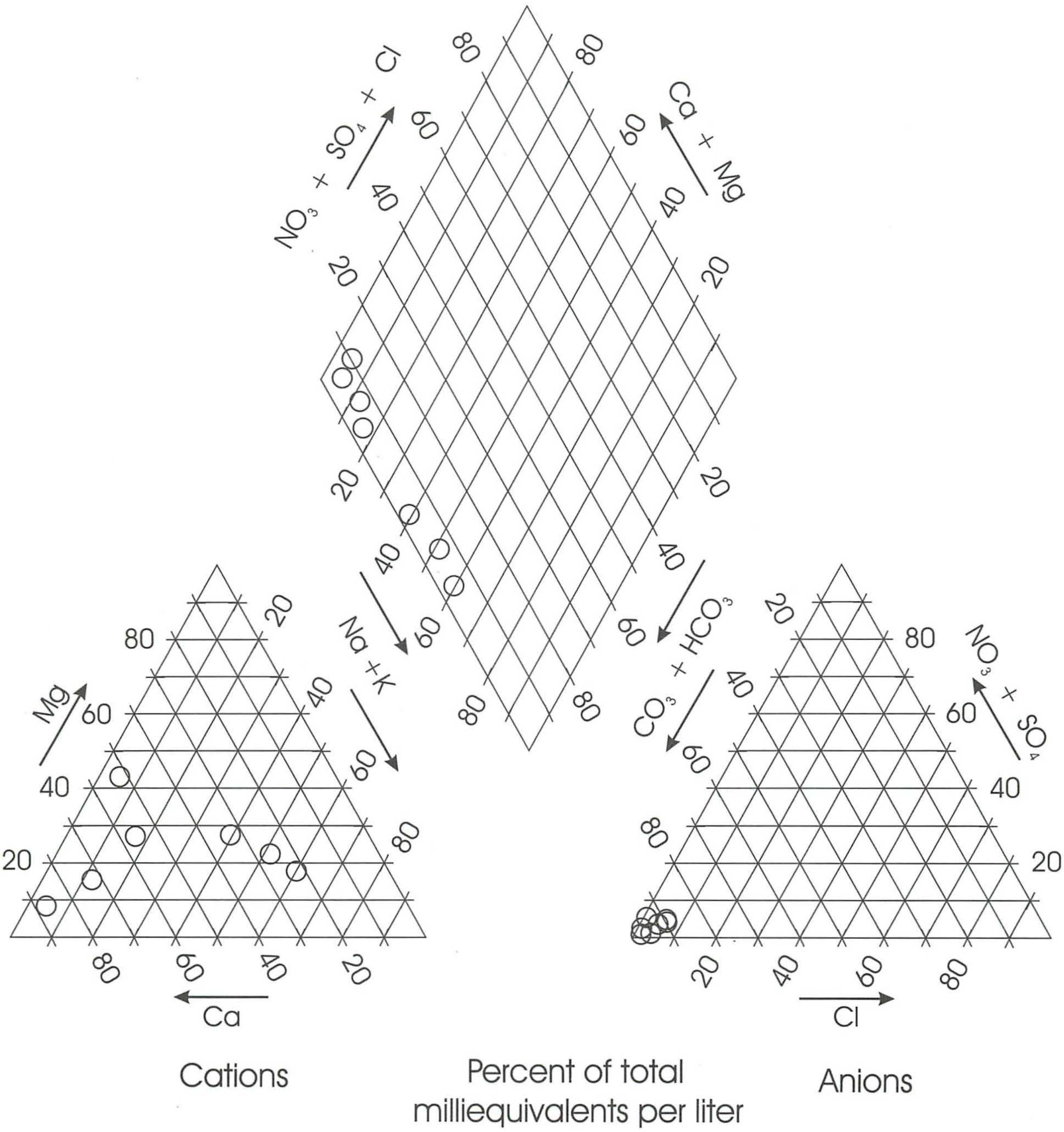

Figure 15 . Hydrochemical facies in the Miocene aquifers.

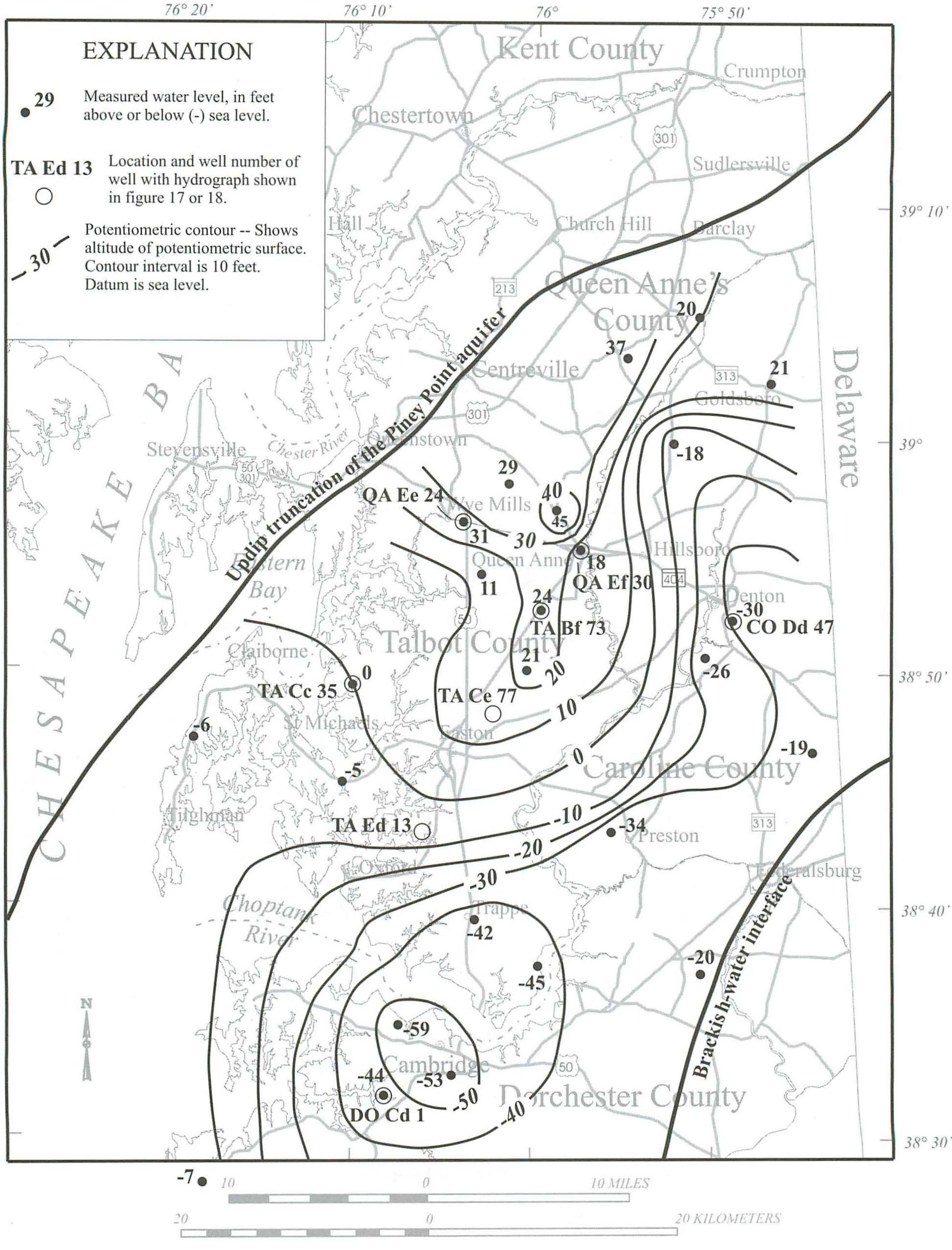

Figure 16. Potentiometric surface and measured water levels in the Piney Point aquifer, Fall 1997.

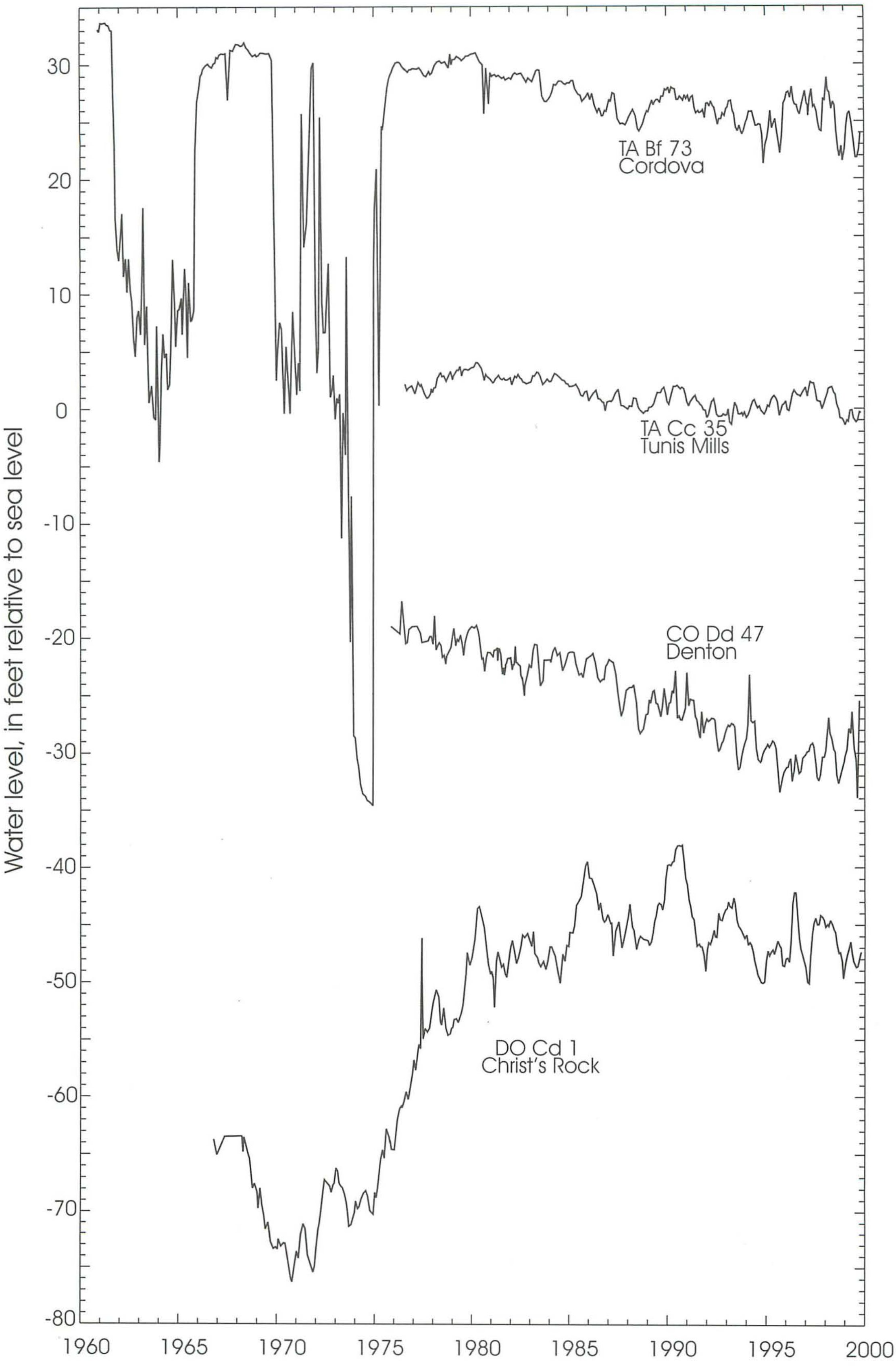

Figure 17. Hydrographs showing long-term water-level trends in the Piney Point aquifer, 1960 to 1999.

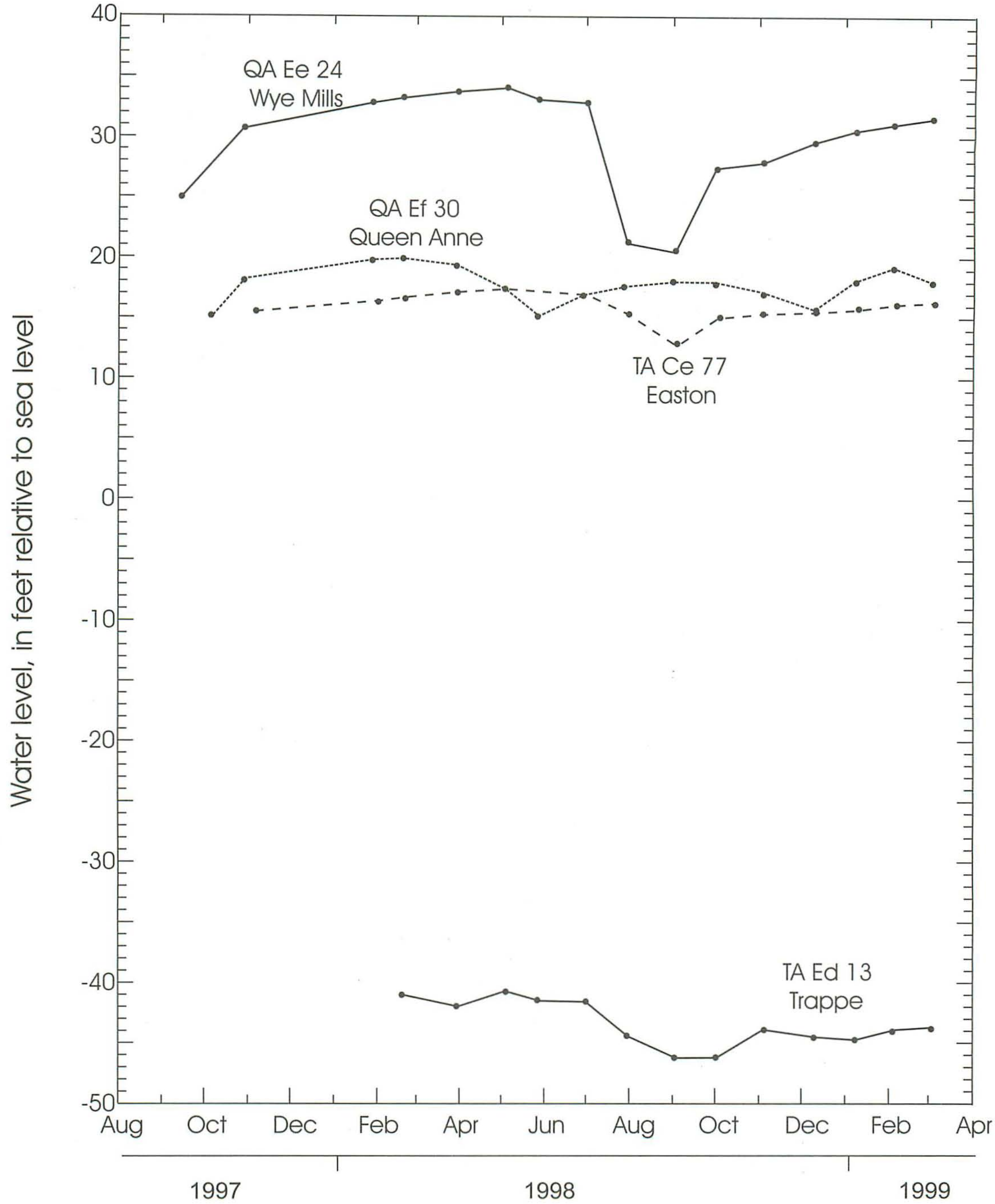

Figure 18. Hydrographs showing seasonal water-level trends in the Piney Point aquifer, September 1997 to March 1999.

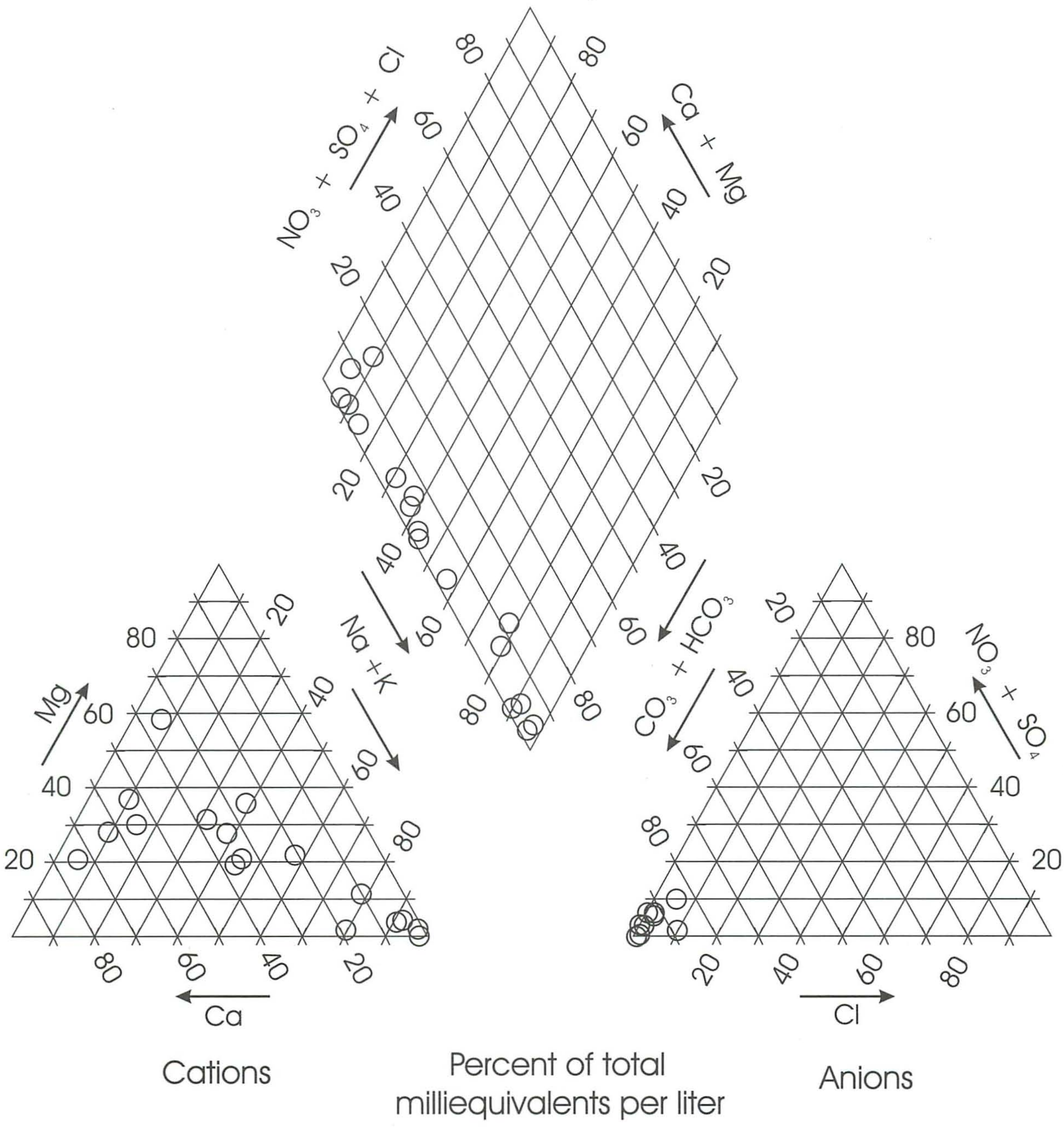

Figure 19. Hydrochemical facies in the Piney Point aquifer.

Lower Eocene sand, the Aquia Formation, and the Hornerstown sand. These units are not generally distinguishable in the rest of the study area, and are not used in this report. The Aquia aquifer is a medium to coarse, glauconitic sand which is interbedded locally with clayey layers and calcite-cemented sandstone.

The altitude of the top of the Aquia aquifer ranges from about sea level in northern Queen Anne's County to about 650 ft below sea level in southern Talbot County (fig. 20). The bottom of the Aquia ranges from about 250 ft below sea level in the northern part of Queen Anne's County to about 800 ft below sea level in southern Talbot County (fig. 21), and the thickness ranges from 120 to 250 ft.

Water levels were measured in the Aquia aquifer during the fall of 1997, and the resulting potentiometric map is shown in figure 22. Heads range from about 20 ft above sea level in northern Queen Anne's County to about 65 ft below sea level in the Easton area. Although heads are still above sea level in the northern part of Queen Anne's County and on the northern tip of Kent Island, they have declined below sea level in most of the study area. Regional head gradients indicate that ground water in the Aquia aquifer is moving from northern and western Queen Anne's County southward and eastward toward the cone-of-depression around Easton.

Hydrographs from wells QA Be 17, QA Eb 113, and QA Fc 7 show long-term trends in Aquia water levels (fig. 23). QA Be 17, near Kingstown, shows little change, or a slight increase in head from 1977 to present. The increase is probably a recovery after the nearby Chestertown water supply switched part of its withdrawals from the Aquia aquifer to the Magothy aquifer in the early 1980's. QA Eb 113, near Chester, shows a steady decline in head from about 3 ft below sea level in 1982 to about 10 ft below sea level in 1999. QA Fc 7 shows a decline from about 10 ft below sea level in 1980 to about 22 ft below sea level in 1999. The head declines in QA Eb 113 and QA Fc 7 are caused by increasing pumping rates in Queen Anne's and Talbot Counties.

Monthly water-level measurements taken from the fall of 1997 to the spring of 1999 indicate that heads in the Aquia aquifer fluctuate seasonally due to increased pumpage (mainly irrigation pumpage) during the summer, and evapotranspiration from spring through early fall (fig. 24). This seasonal fluctuation is most pronounced in western Queen Anne's County and central Talbot County where irrigation pumpage is heaviest. Heads decreased by as much as 35 ft from May 1998 through October 1998 in well TA Dd 58, which is just south of Easton. That well also showed the lowest head in the Aquia aquifer in the study area, at 91 ft below sea level in October 1998. Monthly water-level measurements were discontinued in March 1999, and by that time, water levels in most wells had not recovered to levels of the previous spring. Water levels are also affected by variations in precipitation, and the lack of full recovery of water levels may be partially due to the relatively dry spring of 1999.

Figure 25 shows the altitude of the 80-percent drawdown surface for the Aquia aquifer. The Maryland Department of the Environment prohibits drawdowns that exceed 80 percent of the depth from the prepumping water level to the top of the aquifer. If projected pumpage increases are expected to lower water levels to this surface, they should probably be directed to deeper aquifers. Comparison with figure 22 indicates that water levels were not exceeding or even approaching the 80-percent drawdown surface in 1997.

Water quality is good in the Aquia aquifer throughout most of the study area. The major exception is a narrow strip (about 1/4 mile) along the Chesapeake Bay shore of Kent Island where brackish-water intrusion has degraded water quality in the lower part of the Aquia aquifer. In this area, chloride concentrations are as high as 7,000 mg/L, total dissolved solids concentrations are as high as 13,000 mg/L, and iron concentrations are as high as 150 mg/L. The U. S. Environmental Protection Agency (U. S. EPA) Secondary Maximum Contaminant Levels (SMCL's) are 250 mg/L, 500 mg/L, and 0.3 mg/L, respectively, for these constituents. This water is unfit for human consumption and most other uses without expensive treatment. At Love Point, water in the upper part of the Aquia aquifer is also brackish, with a chloride concentration of 3,200 mg/L (Drummond, 1988), but elsewhere on Kent Island, the upper part of the Aquia is either fresh or slightly brackish.

Hydrochemical facies of water from the Aquia aquifer exhibit two distinct trends. The first trend reflects the evolution of the ground water from where it enters the aquifer as recharge, and flows generally southward toward discharge areas (fig. 26). This trend is similar to evolution of water chemistry in the Aquia aquifer in Southern Maryland, as explained by Chapelle and Drummond (1983). When water enters the aquifer, essentially as rain water, it contains low

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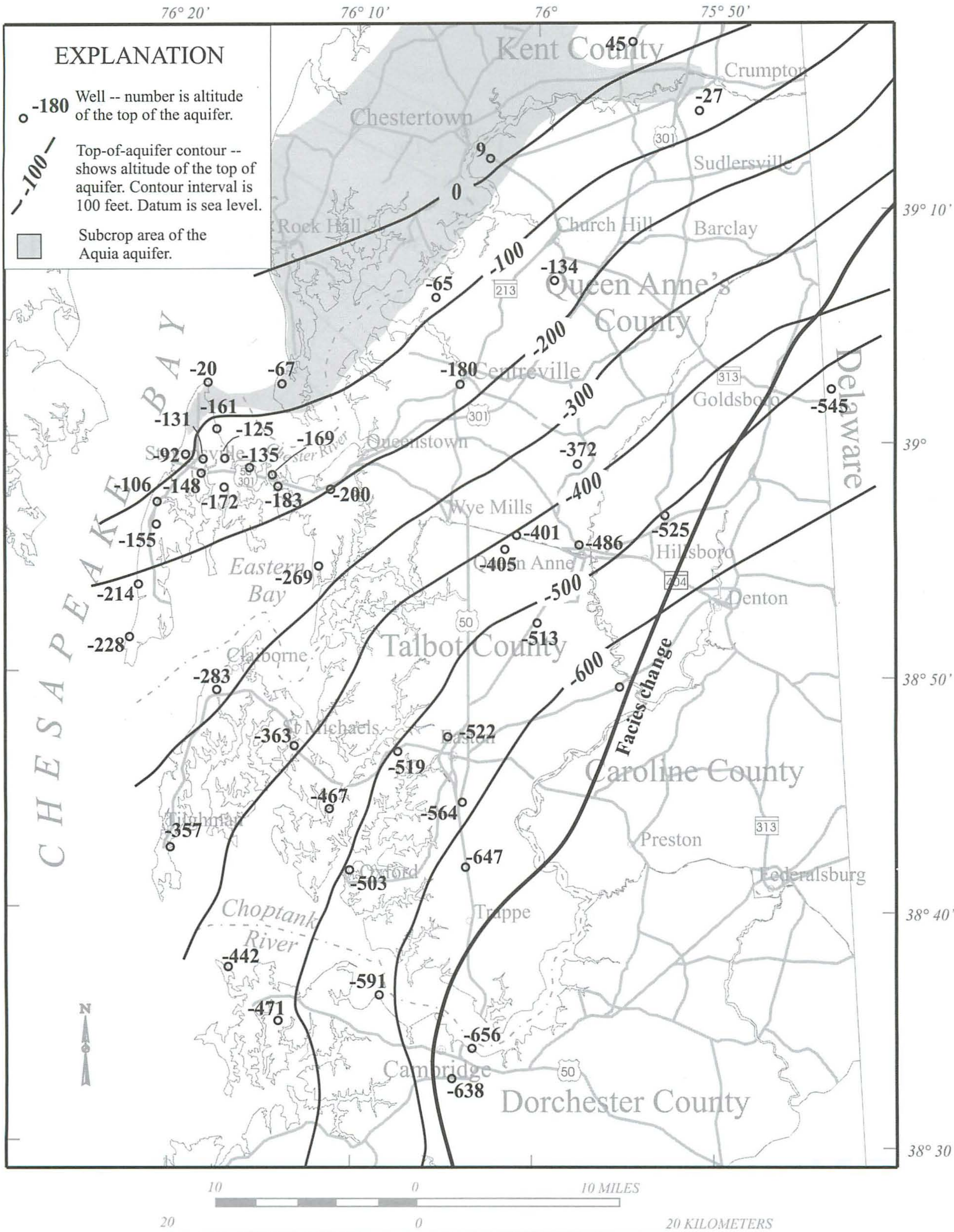


Figure 20. Altitude of the top of the Aquia aquifer.

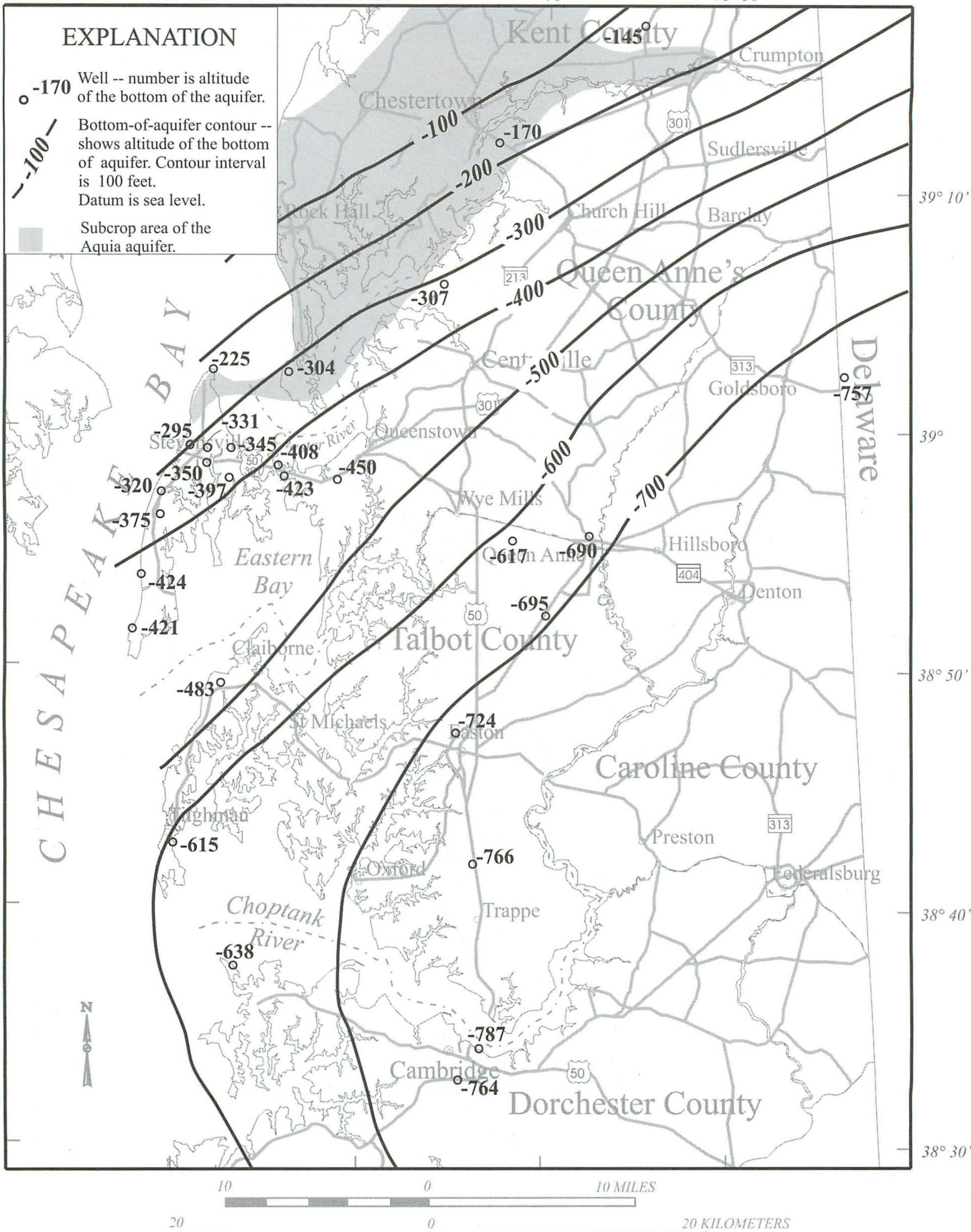


Figure 21. Altitude of the bottom of the Aquia aquifer.

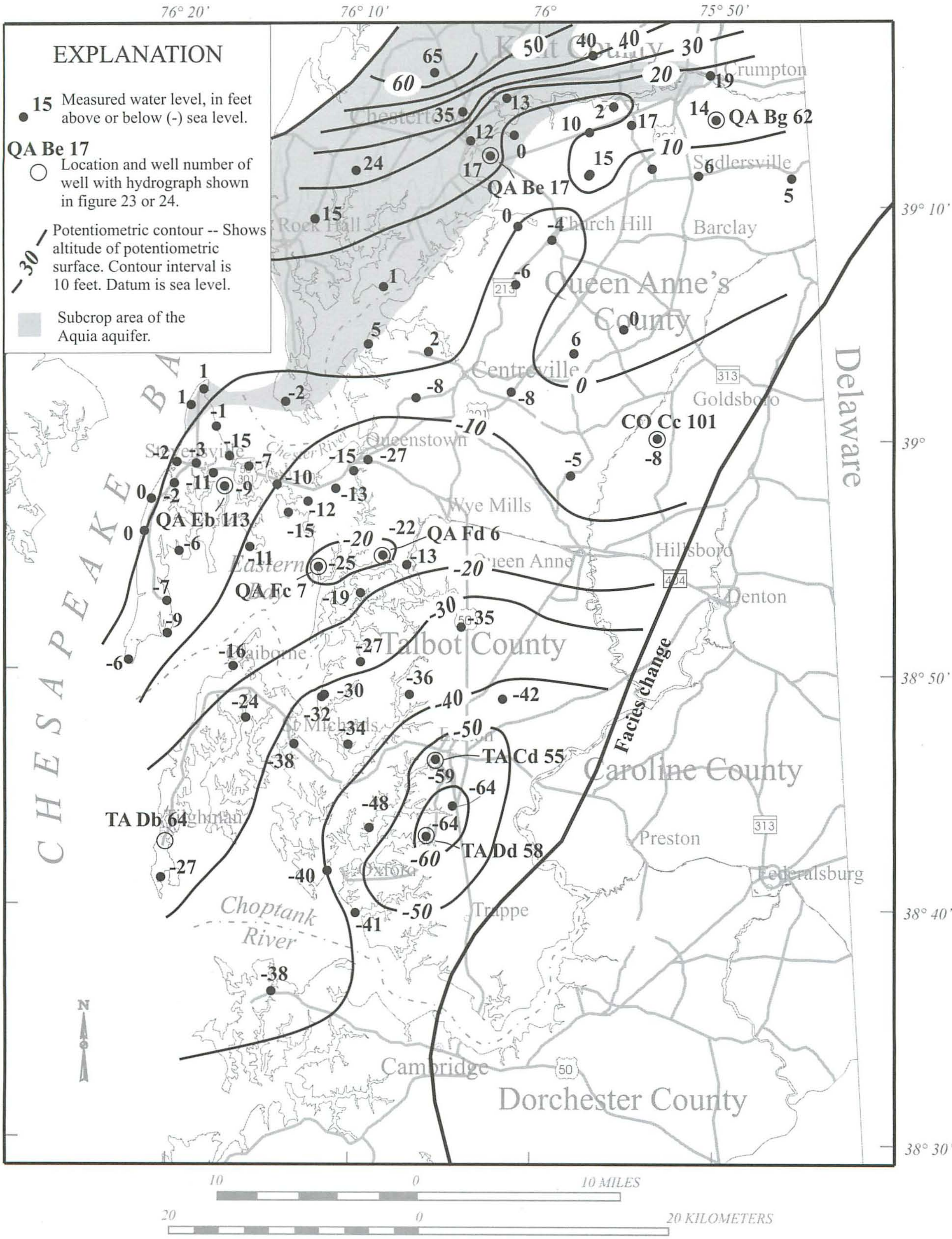


Figure 22. Potentiometric surface and measured water levels in the Aquia aquifer, Fall 1997.

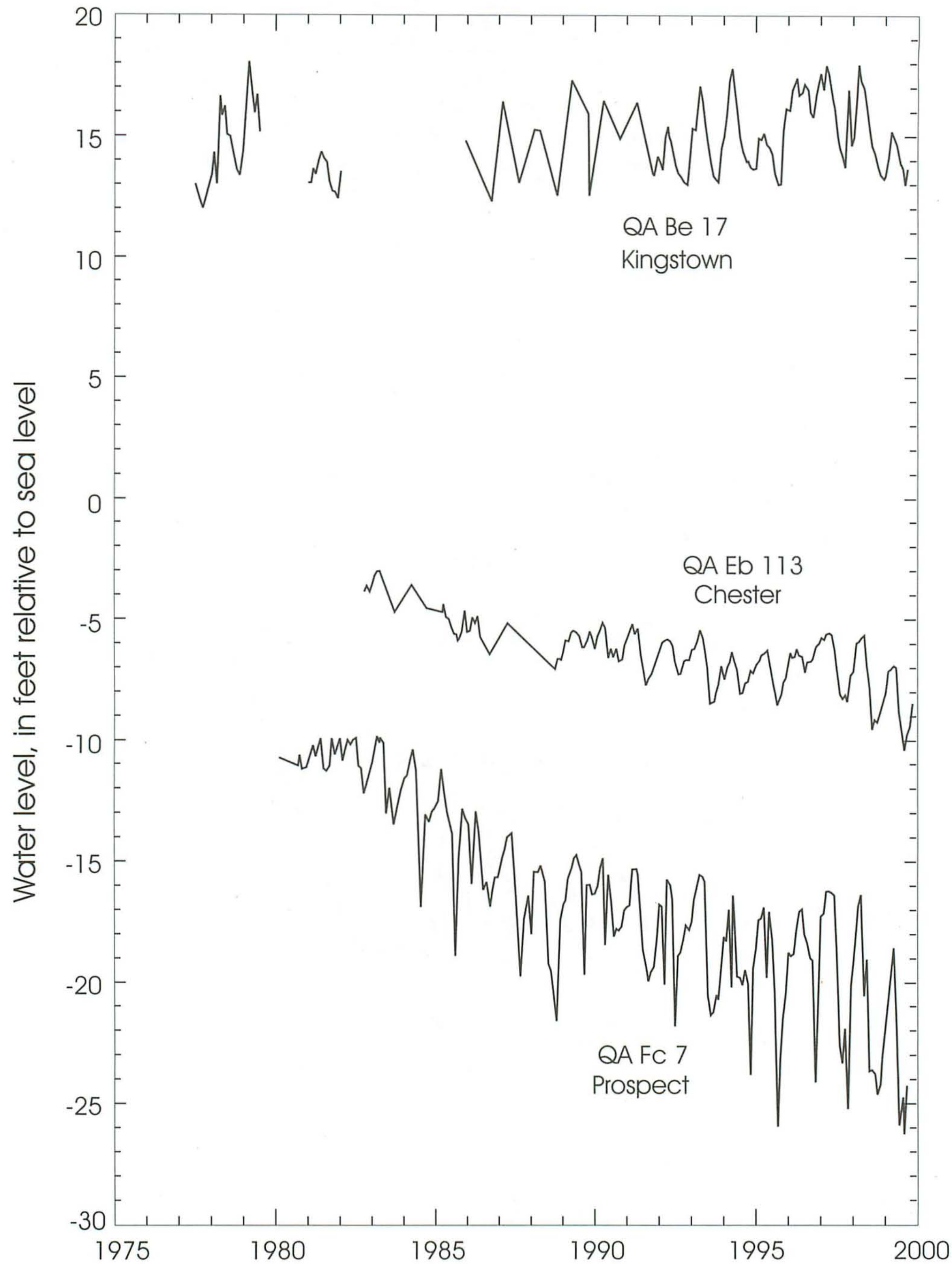


Figure 23. Hydrographs showing long-term water-level trends in the Aquia aquifer, 1976 to 1999.

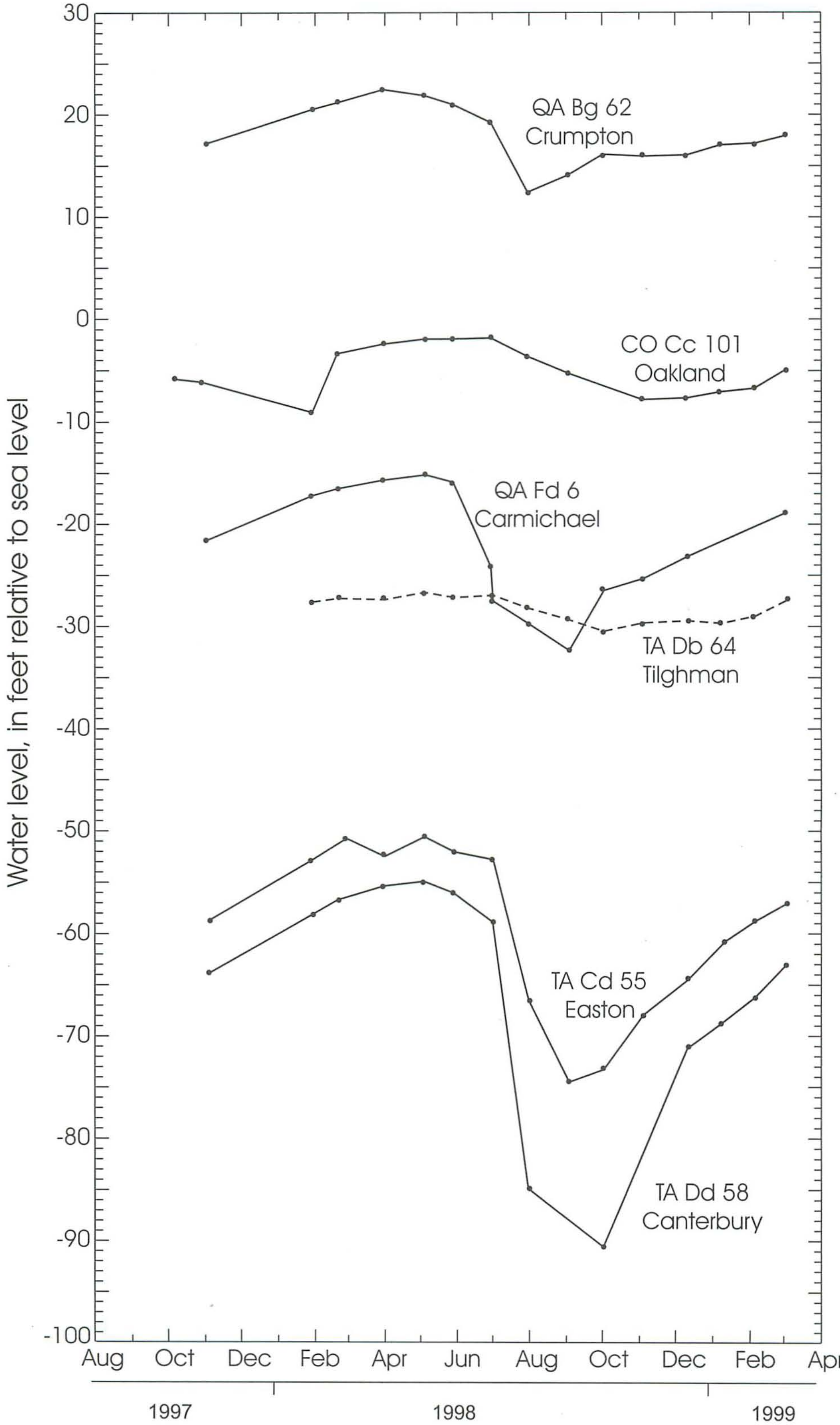


Figure 24. Hydrographs showing seasonal water-level trends in the Aquia aquifer, October 1997 to March, 1999.

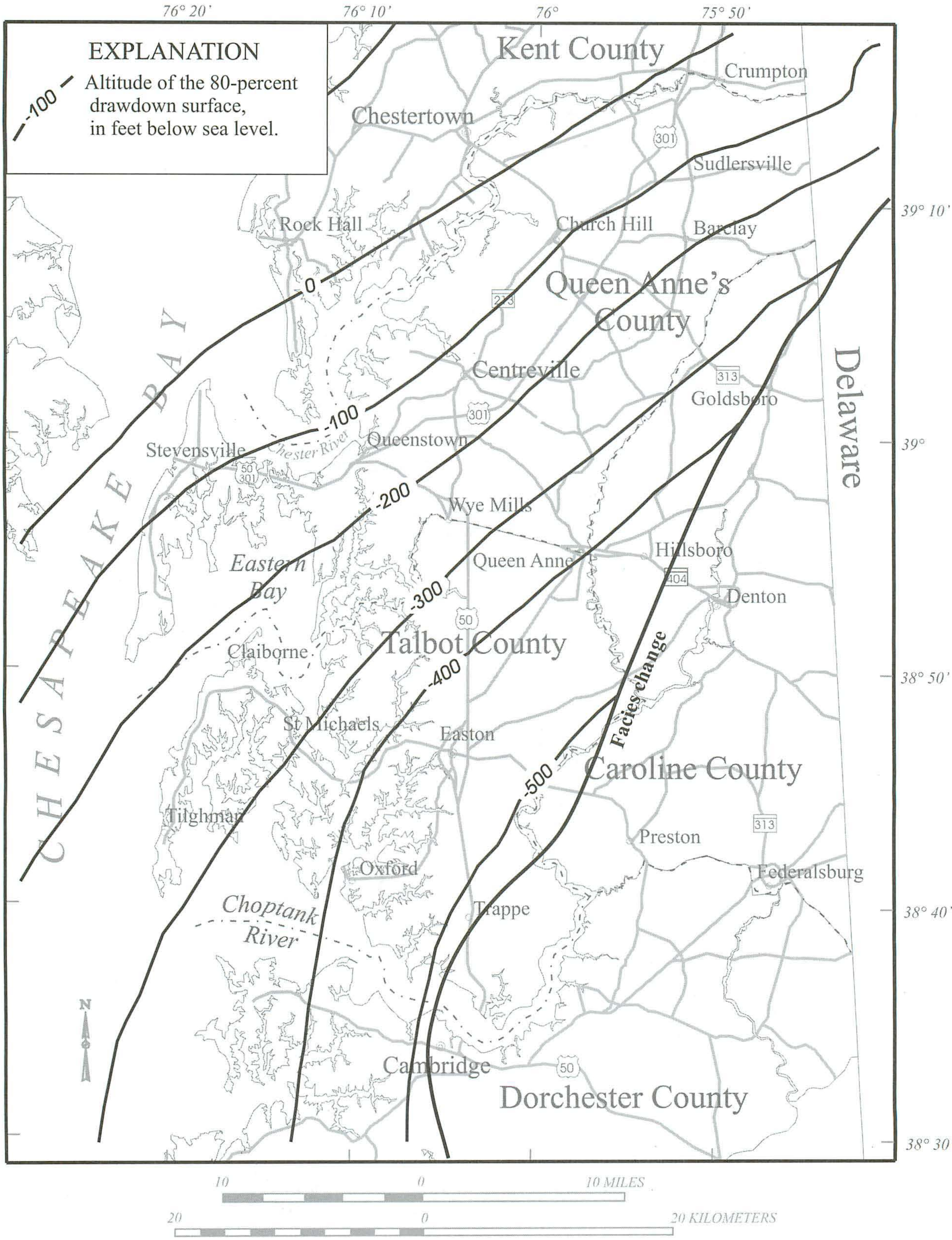


Figure 25. Altitude of the 80-percent drawdown surface in the Aquia aquifer.

dissolved solids and a high dissolved oxygen content. As the water flows downgradient, oxygen is consumed in reactions with organic matter, which produces carbonic acid. Next, the carbonic acid combines with shell material in the aquifer matrix to produce dissolved calcium, magnesium, and bicarbonate. Dissolved calcium and magnesium are then exchanged for sodium on exchange sites in glauconite in the aquifer matrix, producing a sodium bicarbonate water.

The second trend exhibited by water in the Aquia aquifer reflects brackish-water intrusion. Brackish water from the Chesapeake Bay (and possibly its tidal tributaries) mixes with fresh water near the bay shore of Kent Island to produce mixtures intermediate between those facies. These waters have cation types that are intermediate between sodium and calcium/magnesium, and anion types that are intermediate between bicarbonate and chloride. As sodium-rich bay water intrudes into the highly glauconitic Aquia aquifer, sodium is exchanged for calcium and magnesium, producing the calcium/magnesium chloride facies.

MATAWAN AQUIFER

The Matawan aquifer is formed by sands in the Upper Cretaceous Matawan Formation. Although the Matawan Formation is composed mainly of silt and clay, some areas contain enough sand to supply water to wells on Kent Island and further east on the mainland Eastern Shore. Many domestic wells on the southern part of Kent Island are screened in the Matawan aquifer, as well as the wells at the Queenstown Golf Course. No aquifer tests are available for the Matawan aquifer.

The top of the Matawan interval ranges from about 260 ft below sea level in northern Queen Anne's County to 1,000 ft below sea level in southeastern Talbot County. The bottom of the Matawan Group ranges from 350 ft below sea level in northern Queen Anne's County to 1,200 ft below sea level in eastern Talbot County. The thickness ranges from about 90 ft to 200 ft. The effective thickness of the Matawan aquifer (the water-bearing zone within the Matawan Group) is somewhat less than the thickness of the Matawan Group, and ranges up to about 35 ft near Queenstown. The aquifer part of the Matawan Group is described on drillers' reports as a brown or gray sand. The part of the Matawan Group that forms a confining unit is a silty, sandy, gray to green glauconitic clay.

The Matawan aquifer is overlain by the Monmouth Formation, which is chiefly a silty clay in most of the study area, and probably does not allow much leakage between the aquifers. In Kent County and northernmost Queen Anne's County, the Monmouth Formation contains abundant sandy layers and is a major aquifer (Drummond, 1998). The Matawan aquifer is underlain by confining beds within the Matawan Group and Magothy Formation. The lithology and thickness of these confining beds are variable, but probably allow significant leakage between the aquifer layers, at least locally. Two water levels for the Matawan aquifer on Kent Island are 9 ft below sea level and 23 ft below sea level (fig. 27). These relatively low water levels are probably the result of numerous domestic wells withdrawing from the Matawan on Kent Island, and the poor hydraulic characteristics of the aquifer.

No long-term hydrographs are available for the Matawan aquifer, but short-term hydrographs show steadily declining water levels in well QA Eb 159 on Kent Island, and a large seasonal fluctuation in well QA Ec 102 near Queenstown, where the Matawan is used for irrigation of a golf course (fig. 29).

The iron concentration in water from the Matawan aquifer is much lower than that in the deeper Magothy and Upper Patapsco aquifers. Thus the Matawan aquifer is desirable as a water source where water-use restrictions prohibit new wells from being installed in the Aquia aquifer. Table 3 lists specific conductance, and iron and manganese concentrations of water from Cretaceous aquifers in the Kent Island area. Because the Matawan aquifer probably has a relatively low transmissivity, excessive drawdown may become a problem as more wells are screened in it. Water levels in the Matawan aquifer should be monitored to assure that drawdowns do not become excessive.

The two water-quality analyses for water from the Matawan aquifer exhibit the sodium/calcium bicarbonate facies (fig 30), which reflects the mineralogy of the aquifer. Glauconite and shell material in the Matawan react with water in the aquifer in the same process seen in the Piney Point and Aquia aquifers.

MAGOTHY AQUIFER

The Magothy aquifer, as defined in this report, is the sandy interval within the Upper Cretaceous

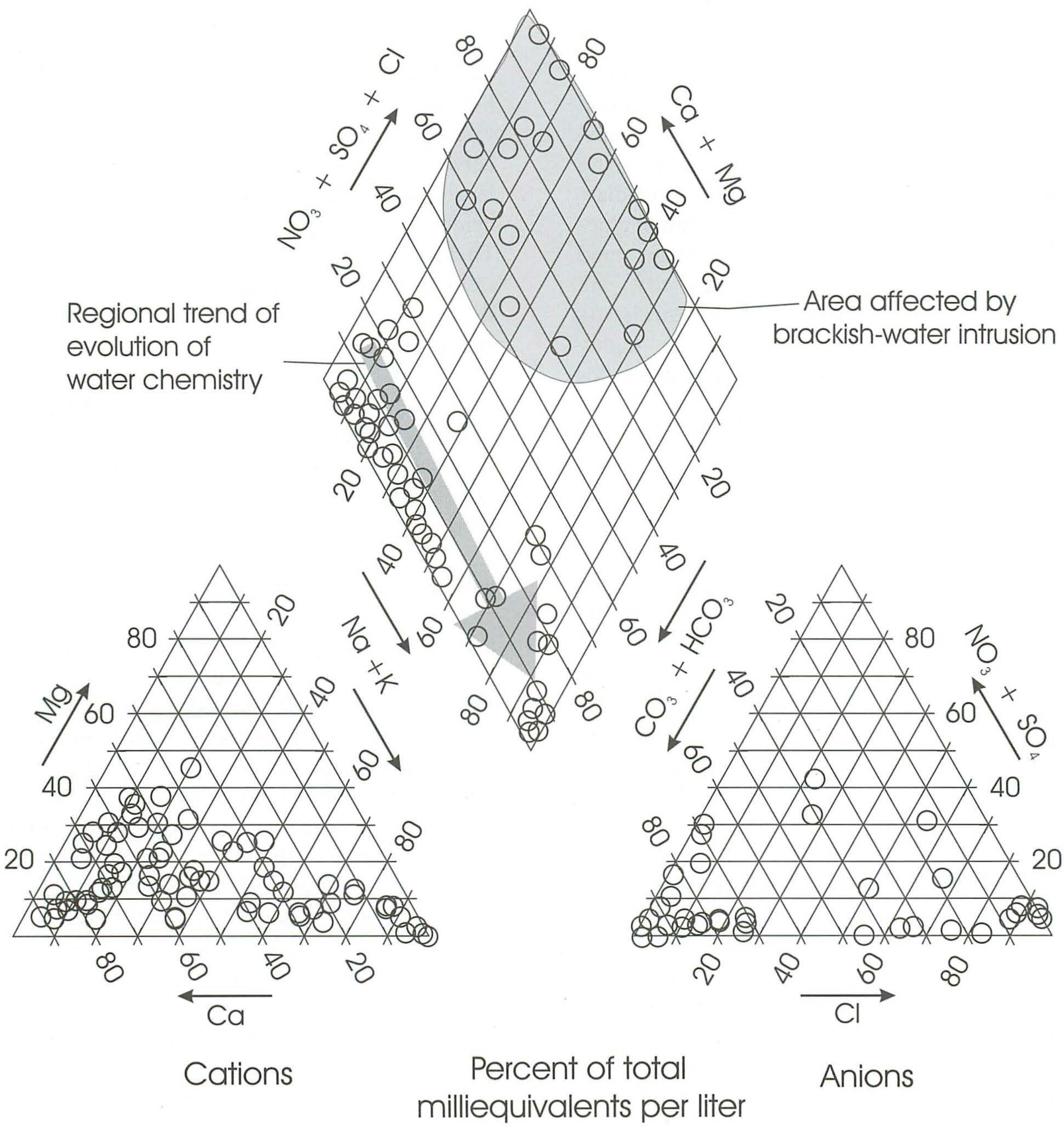


Figure 26. Hydrochemical facies in the Aquia aquifer.

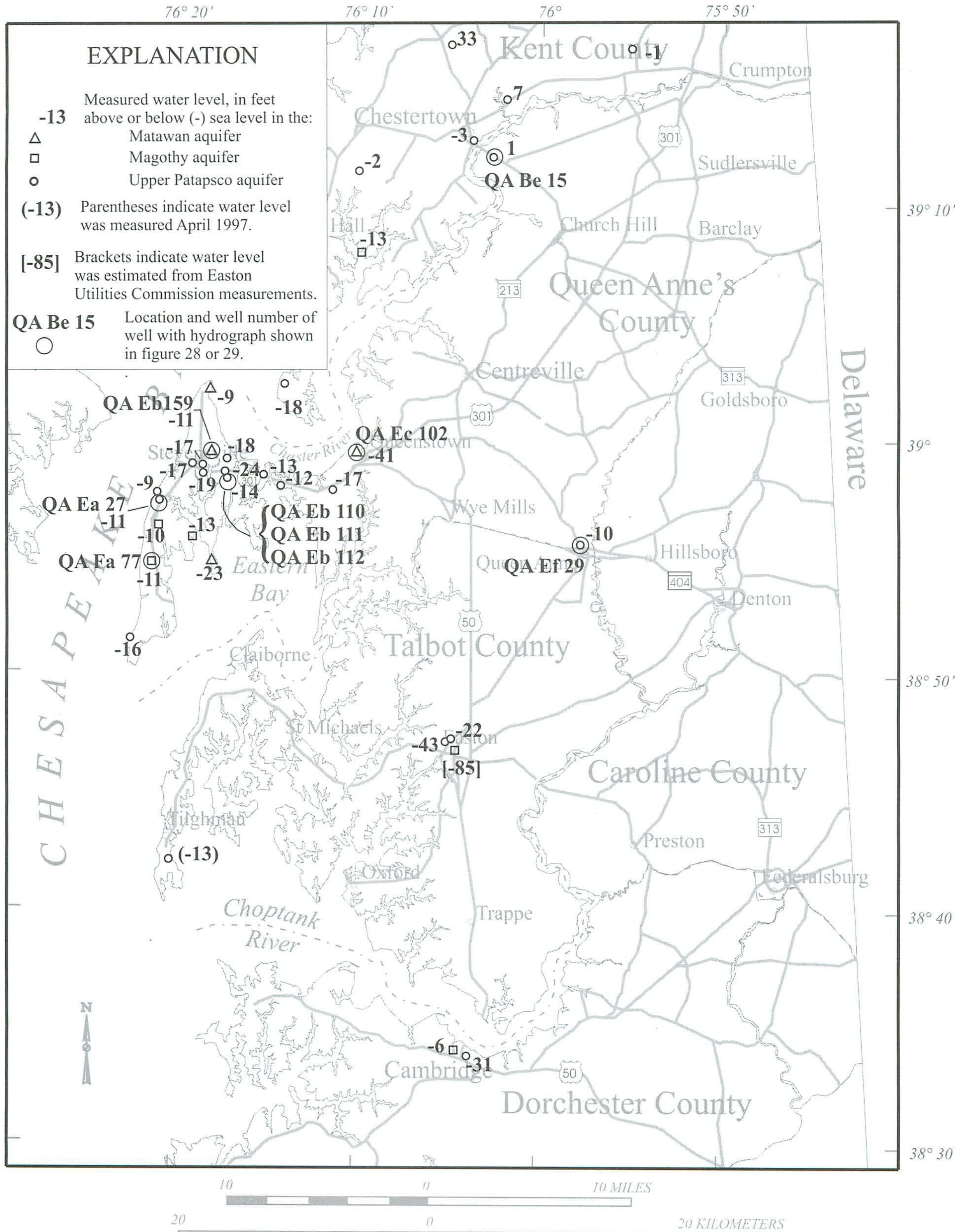


Figure 27. Measured water levels in the Cretaceous aquifers, Fall 1997.

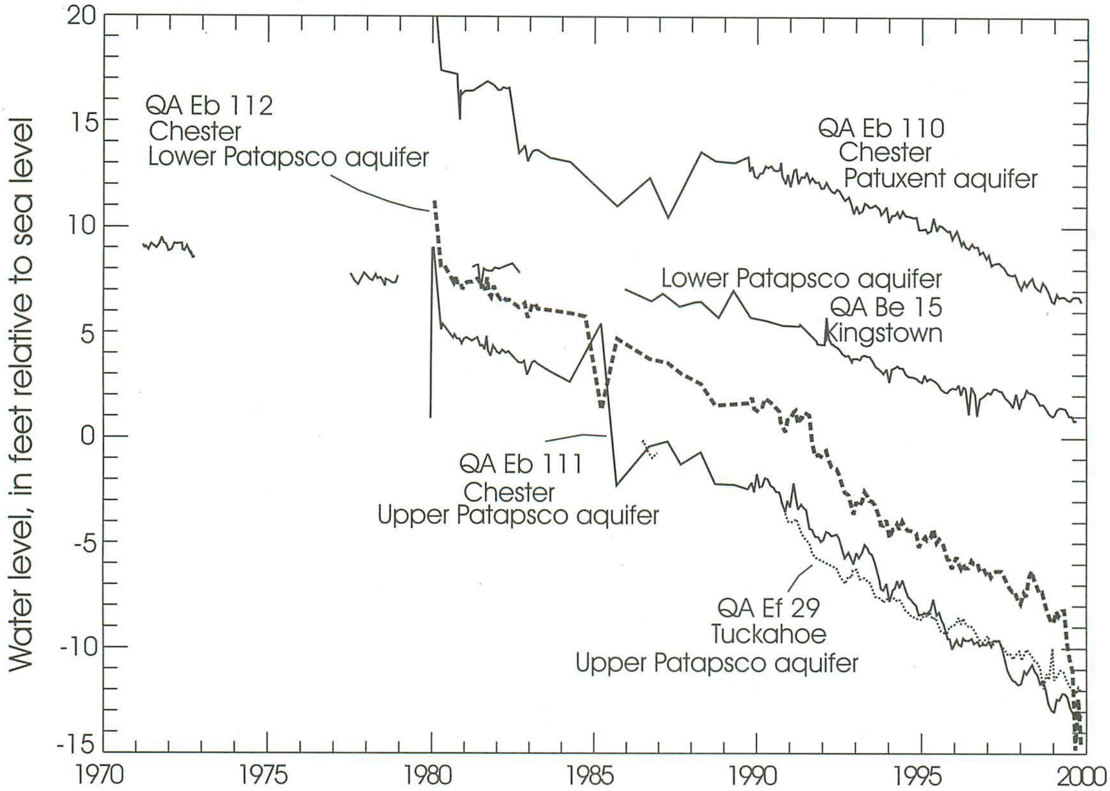


Figure 28. Hydrographs showing long-term water-level trends in the Cretaceous aquifers, 1970 to 1999.

Magothy Formation. Like the Matawan aquifer, the Magothy aquifer is not regionally extensive, but provides copious amounts of water where it exists. The Magothy aquifer is screened by production wells at the Chesapeake Bay Business Park (near Stevensville), the Blue Heron Golf Course (about 6 miles south of Stevensville), and the town of Easton. Domestic wells in some areas of Kent Island are also screened in the Magothy aquifer. Water from the Magothy is very high in iron in the Kent Island area and requires extensive treatment for most uses.

The top of the Magothy Formation ranges from about 350 ft below sea level in the northern part of Queen Anne's County (fig. 8) to 1,000 ft below sea level in the southeastern part of Talbot County (fig. 9). The bottom of the Magothy Formation ranges from about 400 ft below sea level in the northern part of Queen Anne's County (fig. 8) to 1,200 ft below sea level in the southeastern part of Talbot County (fig. 9). The aquifer portion of the Magothy Formation is variable, but ranges up to about 30 ft in thickness near Stevensville. Drillers' reports describe the Magothy aquifer as a fine to coarse, gray sand. The confining beds in the Magothy Formation are dark gray, silty clays.

The Magothy aquifer is overlain by silts and clays higher up in the Magothy Formation and in the Matawan Formation. It is underlain by confining beds deeper in the Magothy Formation, and clayey layers in the Patapsco Formation. These clayey layers form leaky confining units which probably allow some leakage between the aquifers.

Four water-quality analyses for the Magothy aquifer display similar characteristics to Magothy water in Kent County (Drummond, 1998): two hydrochemical facies, a sodium bicarbonate facies, and a calcium/magnesium sulfate facies. Unlike most of the shallower aquifers, the Magothy was deposited in a non-marine environment, and does not contain glauconite or shell material. Water in the Magothy does not undergo the same chemical reactions as the shallower marine aquifers, and displays different hydrochemical facies. The sodium bicarbonate facies is a result of dissolution of alumnosilicates, probably albite. The calcium/magnesium sulfate facies is probably the result of dissolution of anorthite and oxidation of pyrite.

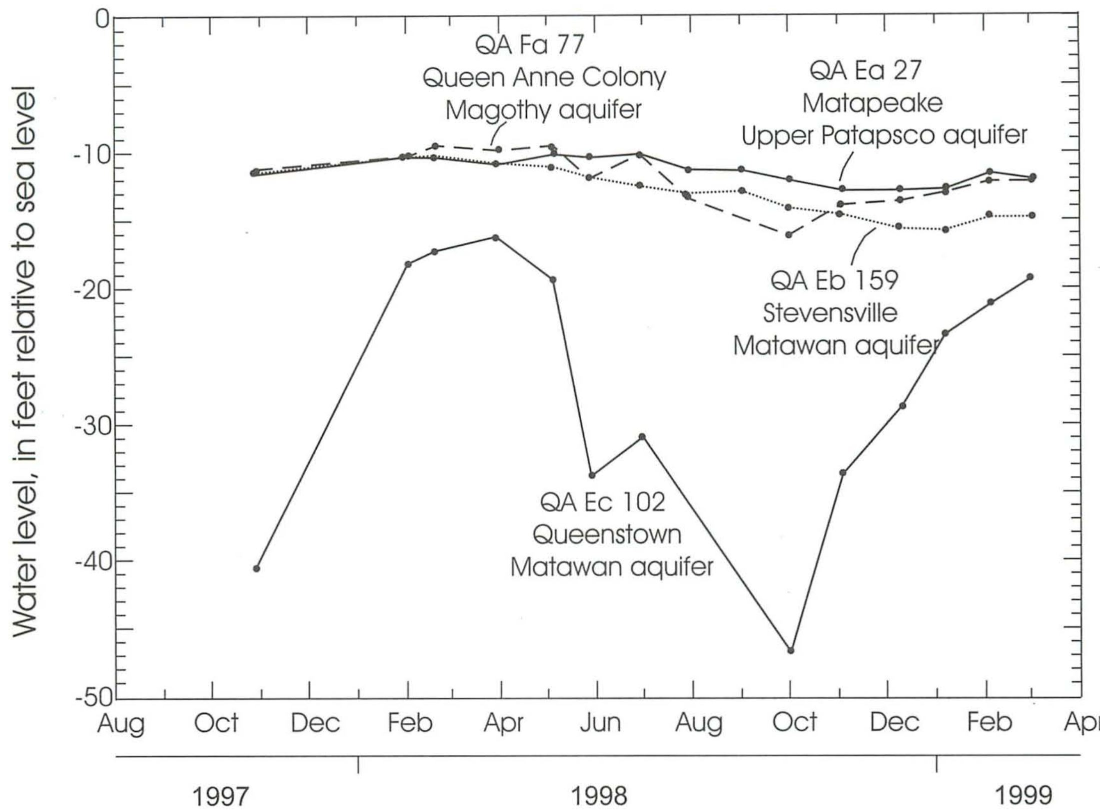


Figure 29. Hydrographs showing seasonal water-level trends in the Cretaceous aquifers, October 1997 to March 1999.

Most analyses of water from the non-marine Cretaceous aquifers (Magothy, Upper Patapsco, Lower Patapsco, and Patuxent) show the same trend, between sodium and calcium/magnesium for the cation type, and between bicarbonate and sulfate in the anion type (fig. 30). Although the Magothy and Upper Patapsco aquifers are probably hydraulically connected in places, they are not connected throughout the entire study area, and the similarity in water chemistry is due to similarities in aquifer mineralogy.

Two analyses of water from the Magothy aquifer on Kent Island indicate a severe problem with iron and manganese, similar to the problem in the Upper Patapsco aquifer. Iron concentrations in the Magothy aquifer are 23.8 mg/L and 33.9 mg/L, and manganese concentrations are 0.296 and 0.431 mg/L, respectively (fig. 31, table 3). A third analysis, from well QA Eb 177, which may be partially screened in the Matawan aquifer, has an iron concentration of 11.9 mg/L and a manganese concentration of 0.137 mg/L. Water from this well appears to be a mixture of water from the Matawan and Magothy aquifers.

UPPER PATAPSCO AQUIFER

The Upper Patapsco aquifer is formed by sandy layers in the upper part of the Patapsco Formation of Cretaceous age. Although individual sands are not areally extensive, the aquifer as a whole appears to extend throughout the entire study area. The Upper Patapsco aquifer is screened in numerous commercial, domestic, and public-supply wells on Kent Island, as well as public-supply wells at Grasonville and Easton. Wells screened in the Upper Patapsco aquifer generally have high yields, but the water is very high in iron concentration, and must be treated extensively for most uses.

The Upper Patapsco aquifer is overlain by the Magothy aquifer where it exists, and is generally separated from the Magothy aquifer by clayey units in the bottom of the Magothy Formation. These clay units may be absent in places, in which case the Magothy and Upper Patapsco aquifers act as a single hydraulic unit. The sands in the two aquifers are lithologically similar, and it is difficult or impossible to distinguish them on the basis of drillers' reports.

Table 3. Dissolved iron and manganese concentrations in water from wells screened in the Cretaceous aquifers in the Kent Island area

[µS/cm = microsiemens per centimeter; mg/L = milligrams per liter; µg/L = micrograms per liter]

Well number	Aquifer	Date	pH	Specific conductance (µS/cm)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (µg/L as Mn)
QA Ea 84[1]	Upper Patapsco	05-26-98	7.0	8,470	8.3	602
QA Ea 86	Upper Patapsco	05-26-98	6.4	241	20.1	298
QA Eb 110	Patuxent	03-04-80	7.2	225	0.9	70
	Patuxent	11-19-80			1.5	70
QA Eb 111	Upper Patapsco	02-06-80	6.5	154	14.0	240
QA Eb 112	Lower Patapsco	02-14-80	6.2	135	3.2	200
QA Eb 159	Matawan	05-21-98	7.8	368	0.22	7.3
QA Eb 162	Upper Patapsco	06-03-98	6.1	200	21.8	298
QA Eb 163[2]	Upper Patapsco	01-04-90	6.5	218	0.06	<1.0
	Upper Patapsco	01-04-90			0.07	–
QA Eb 164[3]	Upper Patapsco	06-03-98	8.2	308	0.1	34
QA Eb 167	Upper Patapsco	05-20-98	6.3	205	25.7	368
QA Eb 168	Upper Patapsco	05-26-98	6.7	224	15.2	206
QA Eb 169	Upper Patapsco	06-03-98	6.3	191	19.8	281
QA Eb 173	Upper Patapsco	05-20-98	6.2	205	23.5	340
QA Eb 175	Upper Patapsco	06-03-98	6.8	224	28.2	332
QA Eb 176	Upper Patapsco	05-21-98	6.2	224	26.4	357
QA Eb 177	Matawan	05-21-98	6.4	268	11.9	137
QA Eb 178	Upper Patapsco	05-21-98	6.1	220	24.0	361
QA Eb 179	Upper Patapsco	05-01-98	6.0	323	21.2	306
QA Eb 181	Magothy	05-20-98	6.0	216	33.9	431
QA Ec 89	Upper Patapsco	01-16-85	6.6	182	11.0	180
QA Ec 91	Upper Patapsco	04-02-98	6.5	147	7.7	130
QA Fa 78	Magothy	04-15-98	6.3	248	23.8	296

[1] Based on specific conductance and chloride concentrations, it appears the casing for this well has been corroded and the water sample affected by brackish-water contamination.
[2] Based on the anomalous water chemistry and an interview with the well operator, it appears that this water sample had passed through a water-softening system.
[3] Based on the anomalous water chemistry, it appears the casing for this well has corroded and the water sample affected by surface-water contamination.

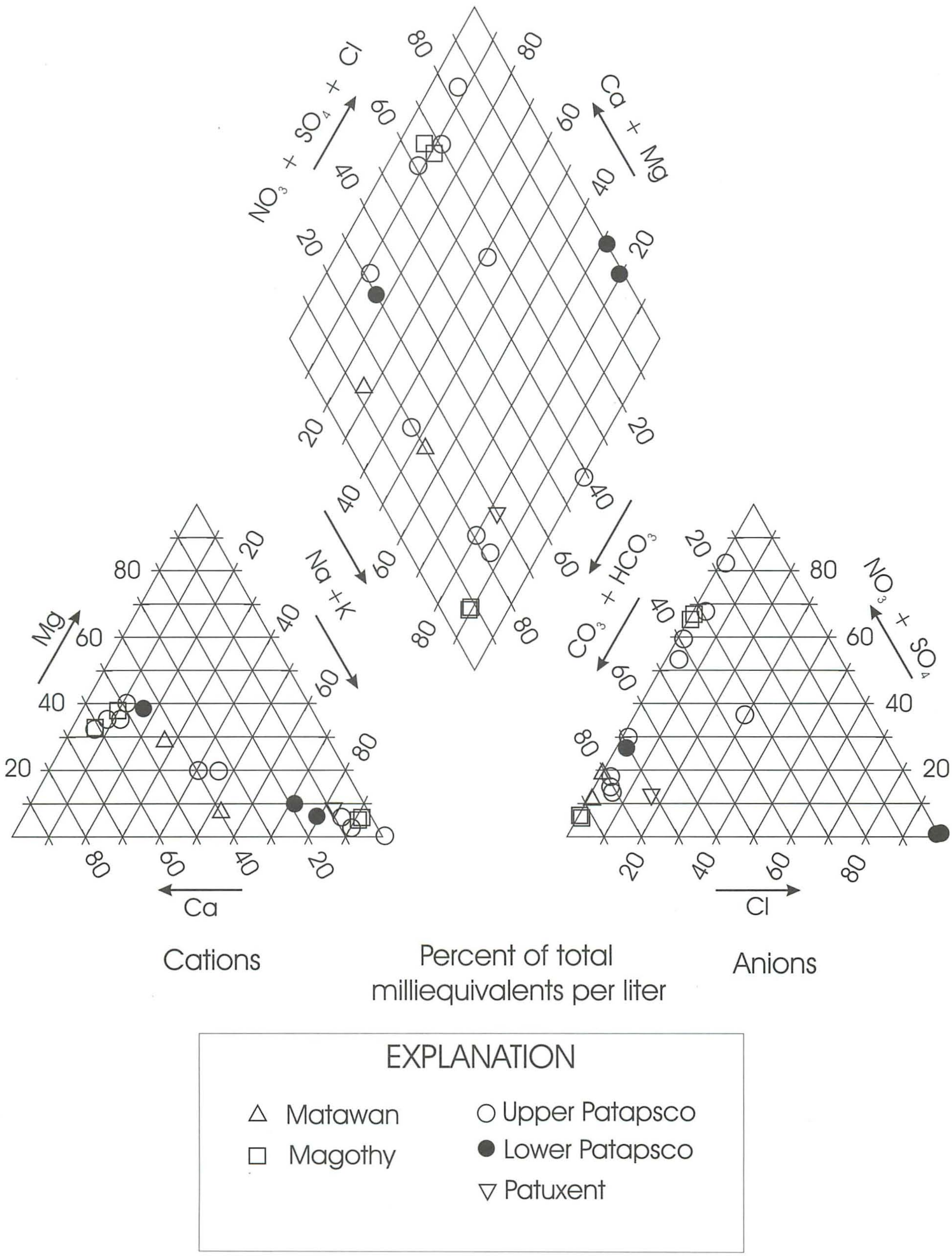


Figure 30. Hydrochemical facies in the Cretaceous aquifers.

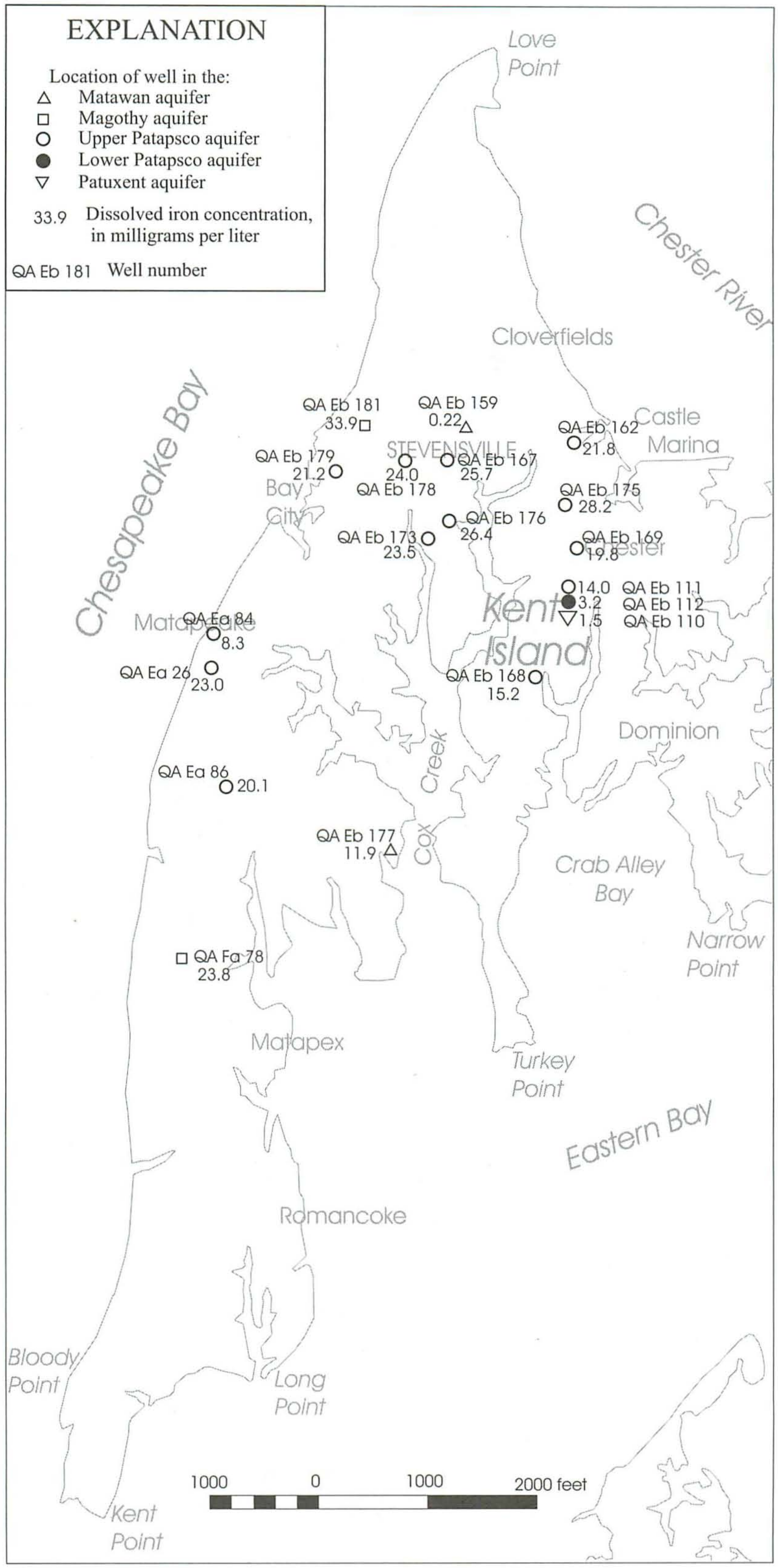


Figure 31. Distribution of dissolved iron in the Cretaceous aquifers in the Kent Island area.

The top of the Upper Patapsco aquifer ranges in altitude from about 400 ft below sea level in northern Queen Anne's County (fig. 8) to about 1,200 ft below sea level in eastern Talbot County (fig. 9). Only a few geophysical logs in the study area extend to the bottom of the Upper Patapsco aquifer, but based on those, the bottom ranges from about 500 ft below sea level in northern Queen Anne's County (fig. 8) to about 1,300 ft below sea level in eastern Talbot County (fig. 9). Because the Upper Patapsco is composed of individual sandy layers which have limited areal extent, the thickness is variable, but is generally between 100 and 150 ft.

Water quality in the Upper Patapsco aquifer is similar to water quality in the Magothy aquifer, due in part to similar mineralogy in the two aquifers. Similarity in water chemistry may also indicate hydraulic connection between the two aquifers.

A major water-quality problem in the Upper Patapsco aquifer is high concentrations of iron, particularly in the Kent Island area. High concentrations of manganese are associated with high iron concentrations and exacerbate the problem. Iron and manganese concentrations of 17 water samples from the Upper Patapsco aquifer in the Kent Island area are shown in table 3, along with analyses from the other Cretaceous aquifers in the area. Analyses for wells QA Ea 84, QA Eb 163, and QA Eb 164 are suspect, and probably do not represent ambient ground-water conditions. Iron concentrations in the other wells range from 7.7 mg/L to 28.2 mg/L. The two samples with the lowest iron concentrations, from wells QA Ec 89 (11.0 mg/L) and QA Ec 91 (7.7 mg/L) are east of Kent Island, and indicate that extremely high concentrations are restricted to Kent Island. A map showing the distribution of iron concentrations on Kent Island does not show any spatial trends in the Upper Patapsco aquifer, and the lowest iron concentration was 14.0 mg/L from well QA Eb 111.

Manganese concentrations in water from wells screened in the Upper Patapsco aquifer range from 0.206 mg/L to 0.368 mg/L on Kent Island, and down to 0.13 mg/L in well QA Ec 91, in Grasonville. All manganese concentrations from the Upper Patapsco aquifer on Kent Island exceed the SMCL of 0.05 mg/L. Manganese is removed from water by the same treatment process that removes iron, and does not pose a separate water-quality problem.

LOWER PATAPSCO AQUIFER

The Lower Patapsco aquifer is composed of sandy layers in the lower part of the Patapsco Formation. The sandy layers correlate well between the deep well cluster at Chester (QA Eb 110) and the new wells drilled into the Lower Patapsco aquifer at Stevensville (fig. 3). This indicates that the aquifer is fairly extensive, and may provide a significant source of good-quality ground water in other parts of the study area. Although water from wells at both of these sites requires treatment for the removal of iron, iron concentrations are significantly less than in water from the Upper Patapsco and Magothy aquifers. The Lower Patapsco aquifer is overlain by thick clay beds of the middle part of the Patapsco Formation, and underlain by clay beds of the Arundel Formation. These clays form very tight confining units which probably allow very little leakage to or from the Lower Patapsco aquifer.

The hydrograph for well QA Eb 112 at Chester shows a steady decline in water levels from about 11 ft above sea level in 1980 to about 15 ft below sea level in 1999 (fig. 28). This decline has occurred in spite of the fact that the Lower Patapsco aquifer had not been pumped anywhere on the Eastern Shore of Maryland south of Cecil County until the production well at Stevensville was installed in August 1999. The steep decline from 8 ft below sea level to 15 ft below sea level in mid-1999 was caused by testing and production of the new wells at Stevensville. The static water level at the Stevensville site was about 14 to 15 ft below sea level prior to the pumping test in September 1999 (Earth Data, 1999).

Transmissivity values determined from aquifer tests for the Lower Patapsco aquifer at the Chester and Stevensville sites were 4,000 ft/d (Mack, 1983) and 3,400 ft/d (Earth Data, 1999), respectively. Storativity at the Stevensville site was 0.0004 (Earth Data, 1999). These hydraulic data indicate that the Lower Patapsco aquifer is very productive, and could supply a significant portion of the water needed in the Kent Island area.

Water quality in the Lower Patapsco aquifer is good, based on chemical analyses from two wells (table 15; Earth Data, 1999). Water from well QA Eb 112 has a low total dissolved solids (TDS) concentration (75 mg/L) and a near-neutral pH (6.2). Although iron and manganese concentrations for this well (3.2 mg/L and 0.2 mg/L, respectively) are above the SMCL's, they are significantly lower than concentrations in water from the Magothy and Upper Patapsco aquifers on Kent Island.

Analyses of water from two separate intervals in the Lower Patapsco aquifer from well QA Be 15, near

Kingstown in northern Queen Anne's County, indicate the presence of brackish water, and poor water quality (Otton and Mandel, 1984). This brackish water is part of a regional body of brackish water that occupies the base of the Potomac Group beneath Kent County and parts of Queen Anne's County. Drummond (1998) attributes this body of brackish water to a previous high stand of sea level. Chloride concentrations were 473 and 2,580 mg/L from 1,135 and 1,335 ft below sea level respectively. It is uncertain how far southward into Queen Anne's County this brackish water extends, as there are no wells screened in the Lower Patapsco aquifer between Kingstown and Stevensville.

PATUXENT AQUIFER

The Patuxent aquifer is composed of sandy units in the Lower Cretaceous Patuxent Formation (Mack, 1983). It is screened by test well QA Eb 110 near Chester, but is not tapped for water supply anywhere in the study area. It is overlain by thick clay sequences higher in the Patuxent Formation, the Arundel Formation, and the lower part of the Patapsco Formation. At well QA Eb 110, the Patuxent aquifer directly overlies crystalline bedrock.

The top of the Patuxent aquifer was reached at 2,360 ft below sea level in well QA Eb 110, and bedrock was reached at 2,504 ft below sea level. The transmissivity value of 800 ft^2/d determined by Mack (1983) is not very high, and indicates that the Patuxent is not a very good aquifer at that location, in that drawdown would be excessive. Elsewhere, the sands may be thicker and coarser, and might produce sufficient water to justify drilling to its great depth, but until the shallower aquifers are developed to their full potential, it is unlikely the Patuxent will be used for water supply. The hydrograph for well QA Eb 110 (fig. 28) shows that water levels have declined in the Patuxent aquifer from about 21 ft above sea level on January 21, 1980 (the well flowed when first completed) to about 7 ft above sea level in 1999. As there are no ground-water withdrawals from the Patuxent aquifer on the Eastern Shore of Maryland south of the C&D Canal, the decline in water level is probably caused by pumpage on the western shore of Maryland, chiefly in Anne Arundel County (Mack and Andreasen, 1991). The chemical analysis for well QA Eb 110 indicates that the Patuxent aquifer has good water quality, similar to that in the other Cretaceous aquifers, but with the lowest iron concentration (0.89 mg/L) of any of the aquifers in the Potomac Group.

BRACKISH-WATER INTRUSION IN THE AQUIA AQUIFER

Brackish-water intrusion is a potential threat to water quality in the Aquia aquifer in the Kent Island area of Queen Anne's County. Because there is no physical barrier, such as a clay layer, separating the brackish water from the rest of the Aquia aquifer, the movement of brackish water inland is controlled by head relations and density-dependent flow. This means that head declines in the Aquia aquifer could induce the movement of brackish water inland. As heads in the Kent Island area have declined from several feet above sea level before significant pumpage occurred, to 15 ft below sea level in 1997 (fig 22), the potential for the migration of brackish water is of great concern.

EXTENT

Drummond (1988) documented the occurrence of brackish water within about a quarter mile of the Chesapeake Bay shore from Love Point southward to Price Creek. An electrical resistance log obtained from well QA Fa 80 at Bloody Point (fig. 35) in the current study indicates that brackish water is present in the Aquia aquifer at least that far south, and probably all the way to Kent Point. At Love Point, the entire vertical section of the aquifer is brackish, but farther south along the bay shore, the lower part of the aquifer is brackish, and the upper part contains water with elevated chloride concentrations (10 to1,000 mg/L). The maximum chloride concentration was 7,400 mg/L at well QA Db 36 at Love Point.

The hydrologic conditions that led to brackish-water intrusion on Kent Island are also present in western Talbot County. Low-lying areas between Claiborne and Tilghman are exposed to brackish water of the Chesapeake Bay, and heads in the Aquia aquifer are at least 20 ft deeper in western Talbot County than on Kent Island. In order to determine if brackish water has intruded the aquifers of Talbot County, 18 wells screened in the Aquia, Piney Point, and Miocene aquifers were sampled for chloride and specific conductance in April 1997 (fig. 32). An attempt was made to resample wells that had been previously sampled in the 1950's and 1960's, but only three of those wells could be located. The results of this sampling are shown in table 4.

Chloride concentrations of water from wells sampled in Talbot County ranged from 1.5 mg/L to 63 mg/L, and specific conductance ranged from 214 μS/cm (microsiemens per centimeter) to 722 μS/cm (tab. 4). In the resampled wells, chloride concentrations decreased in TA Bb 4 from 53 to 45 mg/L, increased in TA Dc 52 from 36 to 62 mg/L, and remained the same in TA Da 36 at 2 mg/L. Although 7 of the 18 wells sampled for chloride show concentrations above background (10 mg/L), none were even close to the SMCL (250 mg/L), and a serious problem is not indicated in this area. It should be noted, however, that most wells are screened in the top part of the aquifers, and if brackish water were present in the bottom part of the aquifer, as on Kent Island, it would not have been detected by this sort of sampling program. In order to ascertain if brackish water is present in the bottom of the aquifers, test wells should be drilled and screened in the bottom interval, or multi-point resistivity logs obtained from uncased fully penetrating borings.

CHANGES WITH TIME

In 1985 and 1986, Drummond (1988) resampled 32 wells that had previously been sampled in 1982 and 1983, to determine if chloride concentrations had increased during the 3-year hiatus. He found that the average chloride concentration increased from 101.35 to 104.54 mg/L, or about 1 mg/L per year. The increase was not considered statistically significant. Since that time, the Maryland Geological Survey has continued monitoring a network of wells on Kent Island in order to identify changes in chloride concentration, and to track any movement of the brackish-water interface. A total of 49 wells have been sampled as a part of the monitoring program, although some wells were discontinued due to abandonment or accessibility problems.

The monitoring data do not show a clear, general trend of changes in chloride concentrations over the monitoring period (1982 to 1999). Most wells have shown considerable variation in concentrations, and some have increased while others have decreased. Figures 33 and 34 show graphs of chloride concentrations with time in selected wells screened in the upper and lower parts of the Aquia aquifer, respectively. Linear regressions were calculated for each well, and the regression coefficients are shown on the plots. The regression coefficients provide a statistical trend line for the chloride data, and indicate the slope of chloride data. A positive regression coefficient indicates increasing chloride concentrations and a negative coefficient indicates decreasing concentrations.

Chloride concentrations in wells screened in the upper part of the Aquia aquifer show several inconsistent trends. In well QA Db 32 at Love Point, concentrations are high (around 3,000 mg/L) and show a slight decreasing trend (R= -8.07). In well QA Db 34 at Cloverfields, chlorides are elevated (between 8 and 16 mg/L) and also show a slight decreasing trend. In wells QA Ea 48 at Bay City and QA Ea 60 at Matapeake Estates (both in the west-central part of Kent Island near the bay shore), chlorides are elevated (around 200 to 400 mg/L), and show a clear increasing trend. In well QA Ea 80 at Mowbray Park (just east of Bay City) chlorides are low (around 2 to 5 mg/L), and exhibit no trend. In well QA Fa 60 at Romancoke, chlorides are elevated (around 10 mg/L) and show a slight decreasing trend.

Chloride data and trends for the monitoring wells are summarized in table 5. The wells are grouped by well depth (upper or lower part of the Aquia aquifer), and by generalized areas (A, B, C, or D shown in figures 34 and 35) of similar chloride trends. Some wells in each area do not show the trend listed for that area. The table lists the area shown on figures 34 and 35, the maximum chloride concentration in mg/L, and the regression coefficient in mg/L/yr. Regression coefficients are greater for wells with higher chloride concentrations, and are not easily comparable. For this reason, the regression coefficient for each well was divided by the maximum chloride concentration to calculate values for comparison. These values were then multiplied by 100 mg/L to relate the trends to a typical reference well with chloride concentrations around 100 mg/L. Although these "unitized" values have no direct relationship to real chloride concentrations, they do provide an indication of where trends in chloride concentrations are most significant.

In the upper section of the Aquia aquifer, several areas were delineated that display differing characteristics in chloride concentrations (fig. 35). In the Love Point area (zone A), the upper part of the aquifer is brackish as well as the lower section. In this

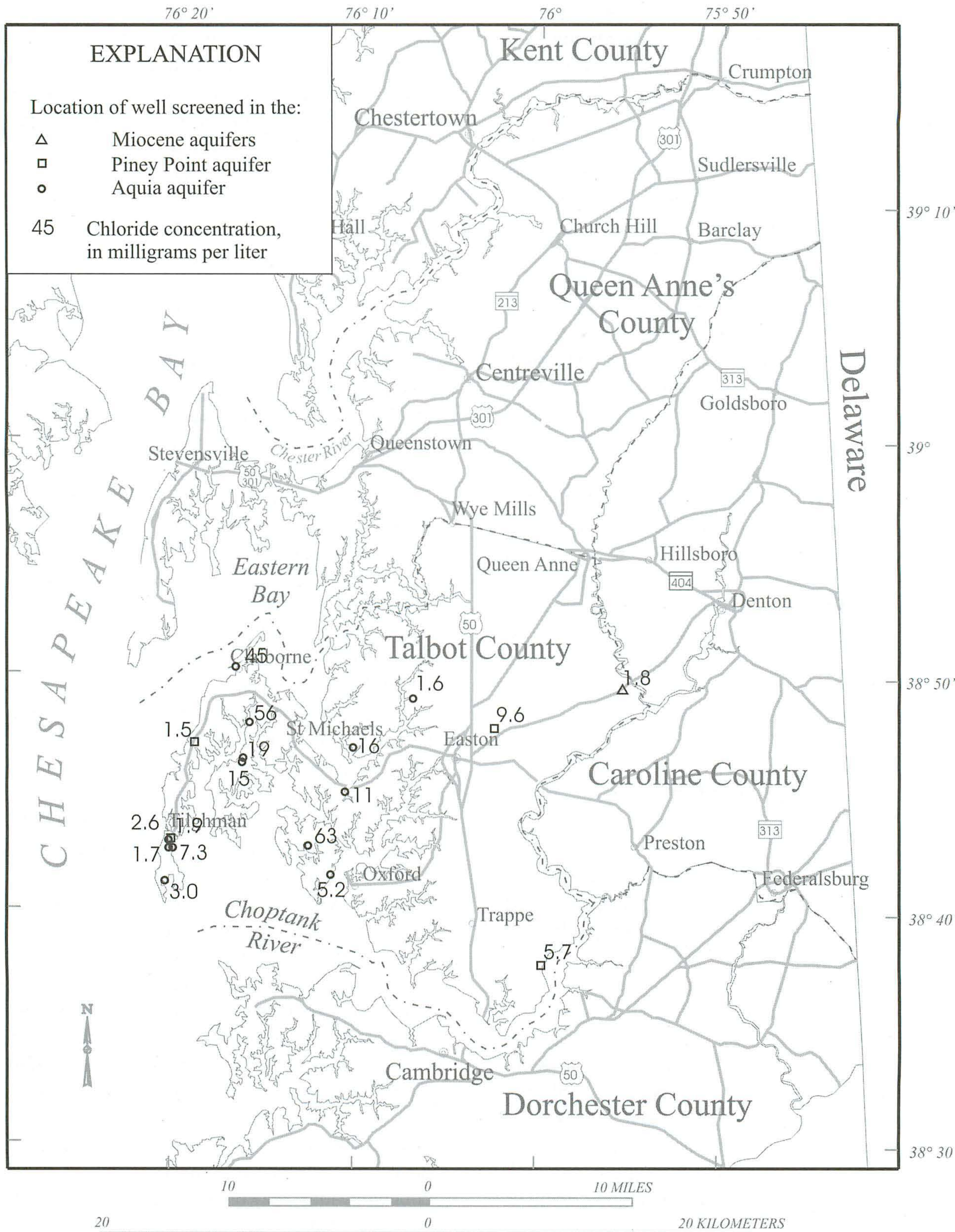


Figure 32. Field measurements of chloride concentration for water from selected wells in Talbot County, April 1997.

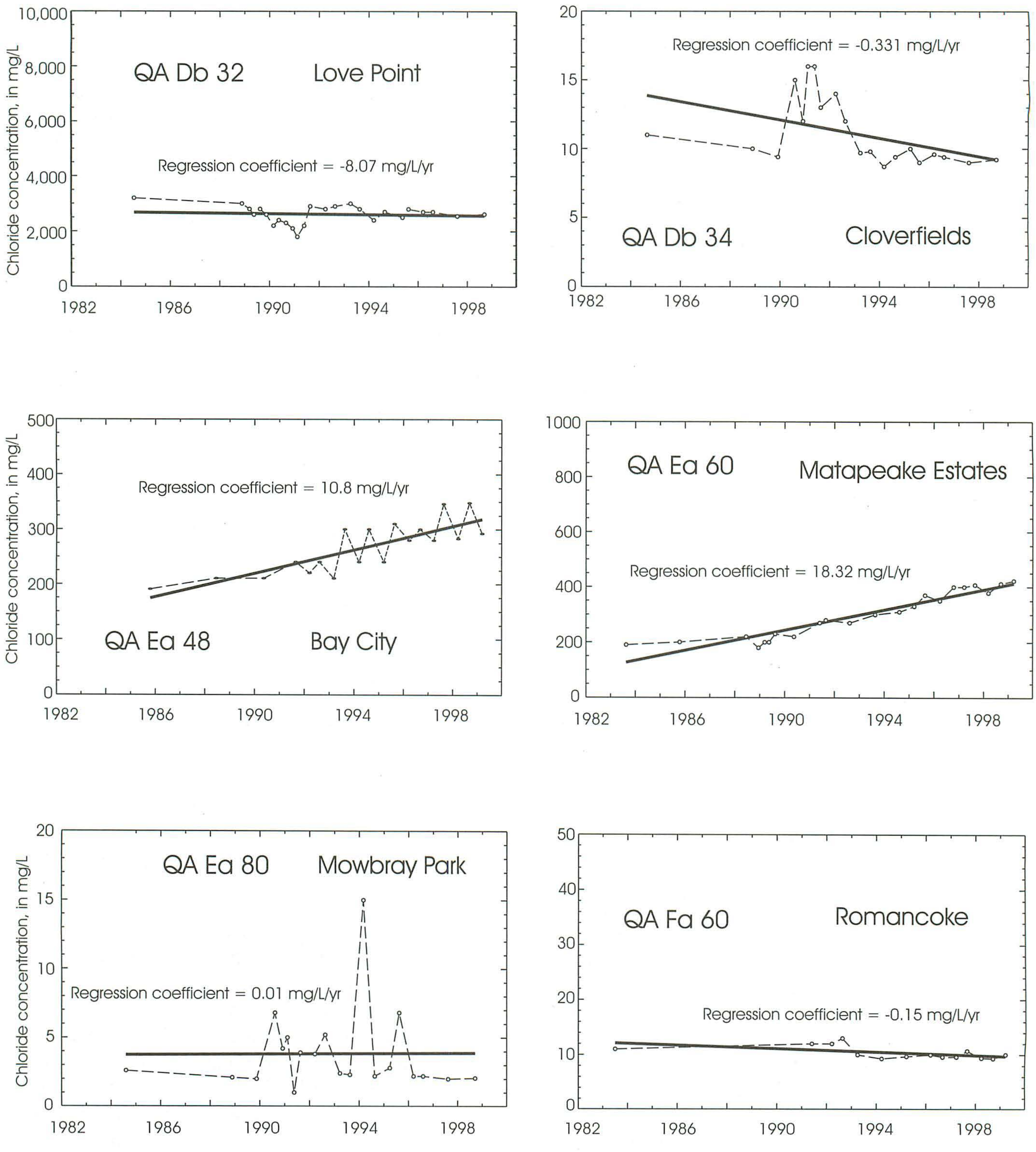
Table 4. Field measurements of chloride concentration and specific conductance in selected wells in Talbot County

[mg/L = milligrams per liter; µS/cm = microsiemens per centimeter]

Well number	Aquifer	Date	Chloride concentration (mg/L)	Specific conductance (µS/cm)	Date	Chloride concentration (mg/L)	Specific conductance (µS/cm)
TA Bb 4	Aquia	09/24/65	53	559	04/01/97	45	430
TA Cb 93	Piney Point	–	–	–	04/14/97	1.5	423
TA Cb 94	Aquia	–	–	–	04/14/97	56	451
TA Cb 97	Aquia	–	–	–	04/03/97	15	320
TA Cb 98	Aquia	–	–	–	04/10/97	19	354
TA Cc 47	Aquia	–	–	–	04/14/97	11	507
TA Cc 48	Aquia	–	–	–	04/14/97	16	386
TA Cd 63	Aquia	–	–	–	04/22/97	1.6	722
TA Ce 77	Piney Point	–	–	–	04/14/97	9.6	239
TA Cf 24	Miocene	–	–	–	04/15/97	1.8	333
TA Da 36	Piney Point	02/10/54	2	–	04/03/97	1.9	240
TA Da 42	Aquia	–	–	–	04/01/97	1.7	287
TA Da 44	Aquia	–	–	–	04/03/97	3.0	214
TA Da 45	Aquia	–	–	–	04/03/97	2.6	279
TA Da 46	Aquia	–	–	–	04/03/97	7.3	304
TA Dc 52	Aquia	10/26/65	36	406	04/02/97	63	287
TA Dc 55	Aquia	–	–	–	04/14/97	5.2	260
TA Ef 3	Piney Point	–	–	–	04/22/97	5.7	391

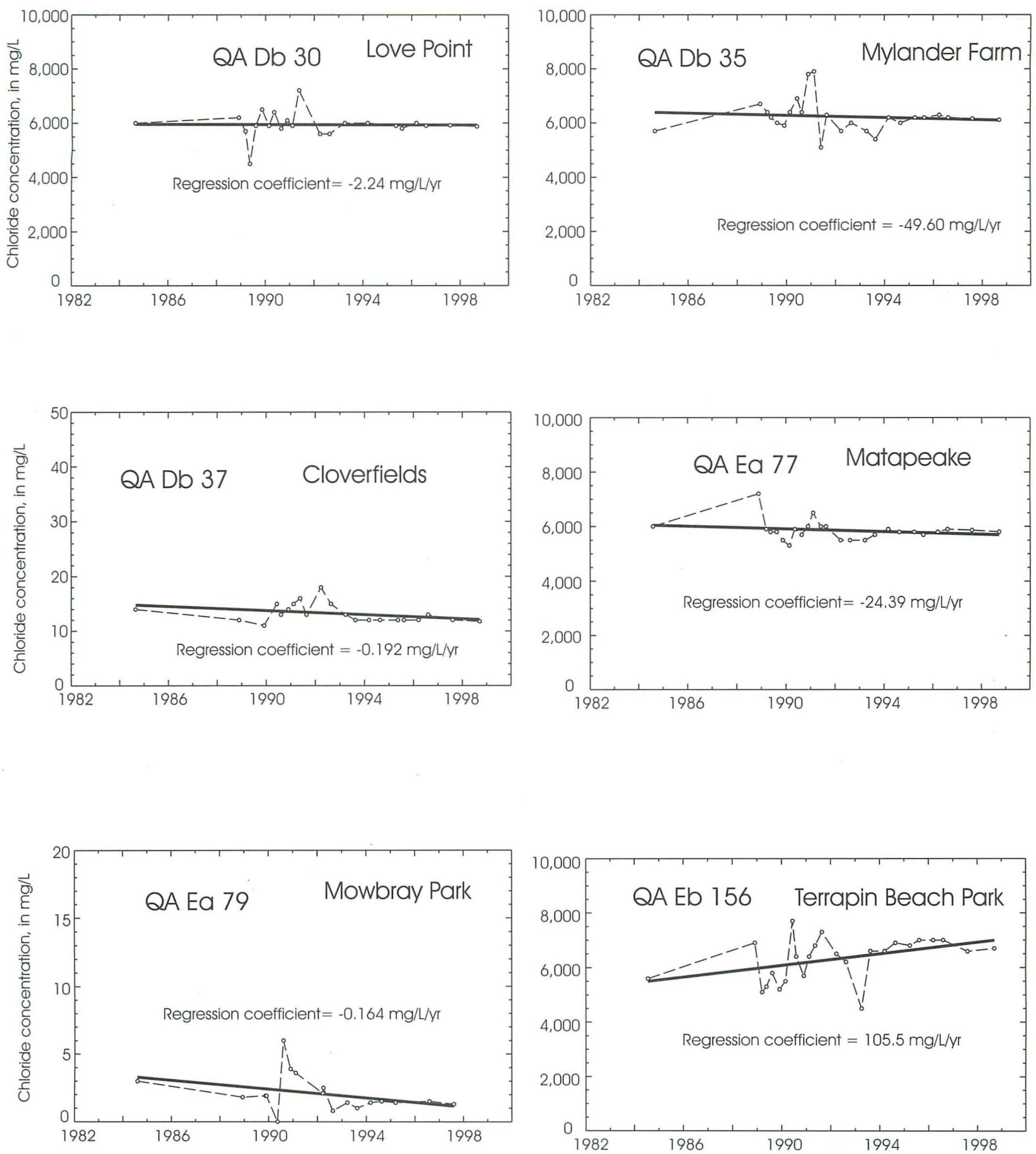
area, the entire Aquia aquifer is brackish. The regression line for well QA Db 32 shows a slope of -8.07 mg/L/yr (milligrams per liter per year), indicating decreasing chloride concentrations. South of Love Point, the upper section of the Aquia aquifer contains water with elevated chloride concentrations within a half mile of the bay shore in the central part of Kent Island, but extending east to Cloverfields in the north, and to Romancoke in the south (fig. 35). In the central portion of this area (zone C), chloride concentrations generally show a slight increasing trend, whereas in the northern(zone B1) and southern (zone B2) areas there is no trend or a slight decreasing trend. East of these areas of elevated chloride concentrations, the entire section of the Aquia aquifer is fresh, and there is no trend in concentrations.

In the lower part of the Aquia aquifer, water is brackish along the entire bay shore of Kent Island, within about a quarter mile of the shore (fig. 36). Although no chloride analyses are available for the lower part of the aquifer south of Matapeake, electrical resistivity logs obtained from bore holes at Prices Creek and Bloody Point indicate the presence of brackish water in the lower Aquia aquifer at those sites, and it is reasonable to assume that the same conditions exist over the additional mile south to Kent Point. East of this area, the lower part of the Aquia aquifer contains fresh water, although no chloride analyses or resistivity logs are available south of Mowbray Park. Of the four monitoring wells screened in the brackish part of the lower Aquia aquifer, one shows increasing chlorides (QA Eb 156 = 105.49



[mg/L = milligrams per liter, mg/L/yr = milligrams per liter per year]

Figure 33. Chloride concentrations and regression coefficients in water from the upper part of the Aquia aquifer on Kent Island, 1982 to 1998.



[mg/L = milligrams per liter, mg/L/yr = milligrams per liter per year]

Figure 34. Chloride concentrations and regression coefficients in water from the lower part of the Aquia aquifer on Kent Island, 1982 to 1998.

Table 5. Summary statistics of chloride concentrations from monitoring wells screened in the Aquia aquifer on Kent Island.

[mg/L = milligrams per liter; mg/L/yr = milligrams per liter per year; see figures 35 and 36 for well locations]

Well number	Generalized zone	Maximum chloride concentration (mg/L)	Regression coefficient of chloride concentrations (mg/L/yr)	Regression coefficient of unitized chloride concentrations (mg/L/yr)
		Upper Aquia aquifer		
QA Db 32	A	3,200	-8.07	-0.25
QA Db 14	B1	18	-0.09	-0.48
QA Db 15	B1	130	-0.97	0.75
QA Db 17	B1	77	0.28	0.36
QA Db 23	B1	33	-0.31	-0.94
QA Db 27	B1	340	-2.23	-0.66
QA Db 34	B1	16	-0.33	-2.07
QA Eb 157	B1	48	-1.26	-2.63
Average				-0.81
QA Fa 54	B2	20	-0.60	-2.99
QA Fa 58	B2	12	-0.21	-1.77
QA Fa 60	B2	13	-0.15	-1.17
QA Fa 66	B2	24	-0.38	-1.58
QA Fa 67	B2	15	-0.27	-1.77
QA Fa 72	B2	19	-0.28	-1.45
QA Fa 74	B2	17	-0.46	-2.71
QA Fa 75	B2	25	-0.50	-1.99
Average				-1.93
QA Ea 39	C	45	1.20	2.67
QA Ea 42	C	160	4.42	2.76
QA Ea 45	C	7	-0.03	-0.47
QA Ea 48	C	348	10.80	3.10
QA Ea 59	C	120	0.88	0.74
QA Ea 60	C	422	18.32	4.34

Table 5. Summary statistics of chloride concentrations from monitoring wells screened in the Aquia aquifer on Kent Island–Continued

Well number	Generalized zone	Maximum chloride concentration (mg/L)	Regression coefficient of chloride concentrations (mg/L/yr)	Regression coefficient of unitized chloride concentrations (mg/L/yr)
QA Ea 61	C	1,198	53.29	4.45
QA Ea 71	C	140	7.52	5.37
QA Ea 78	C	12	-0.13	-1.06
QA Ea 82	C	265	8.98	3.39
QA Ea 83	C	31	0.66	2.12
QA Fa 49	C	179	3.06	1.71
QA Fa 63	C	11	-0.39	-3.55
QA Fa 64	C	240	6.39	2.66
Average				2.02
QA Ea 80	D	15	0.01	0.06
		Lower Aquia aquifer		
QA Db 30	A	7,200	-2.24	-0.03
QA Db 35	A	7,900	-49.64	-0.63
QA Ea 77	A	7,200	-24.38	-0.34
QA Eb 156	A	7,700	105.49	1.37
Average				0.09
QA Db 37	B	18	-0.19	-1.07
QA Ea 79	D	6	-0.16	-2.74
QA Eb 155	D	11	0.01	0.07
Average				-1.33

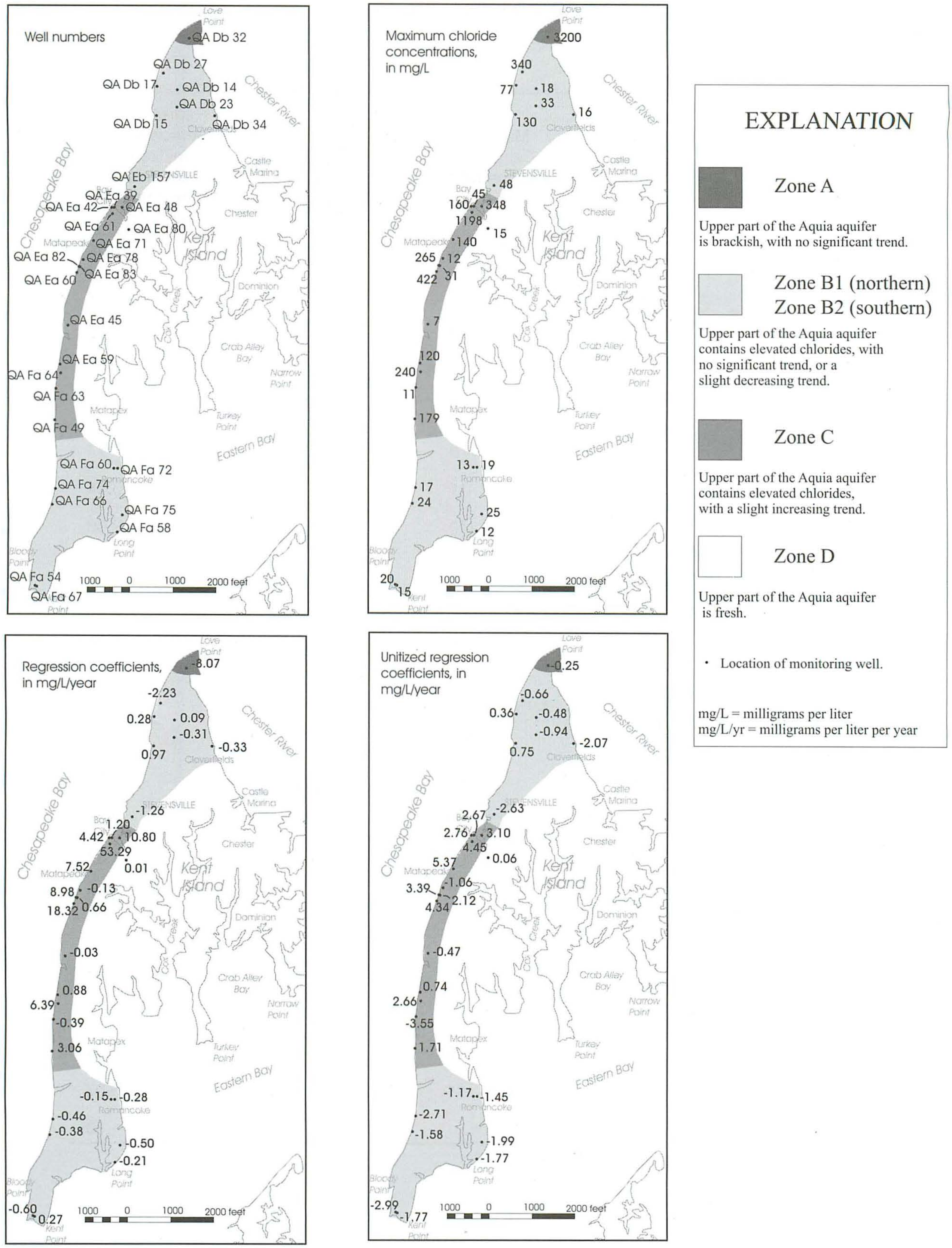


Figure 35. Maximum chloride concentrations, chloride regression coefficients, and unitized regression coefficients of chloride concentrations for wells screened in the upper part of the Aquia aquifer on Kent Island.

mg/L/yr), and the other three show decreasing chlorides (QA Db 30 = -2.24 mg/L/yr, QA Db 35 = -49.64 mg/L/yr and QA Ea 77 = -24.38 mg/L/yr). No general trends can be surmised from these data.

FACTORS CAUSING VARIATIONS IN CHLORIDE CONCENTRATIONS

Although chloride concentrations appear to be increasing in the near-shore part of central Kent Island, no general trend is apparent for the entire island. This inconsistency can be explained by three factors. The first factor is the presence of hundreds or thousands of pumping wells in the vicinity of the brackish zone. Pumpage from these wells is sporadic, and can create local head gradients that cause upconing and localized migration of brackish water in different directions. This can cause significant variations in chloride concentrations in monitoring wells.

A second factor in variations in chloride concentrations is increased fresh-water leakage from the water-table aquifer with declining heads in the Aquia aquifer. As heads decline in the Aquia aquifer, leakage of fresh water from the water-table aquifer into the Aquia will increase. The amount of increase at any location will depend on the local structure of the confining unit above the Aquia, the permeability of the confining unit, and the elevation of the water table at that location. Wells that are screened in the top of the brackish-water mixing zone may exhibit a decrease in chloride concentration caused by increased fresh-water leakage from above.

A third factor determining patterns and trends in chlorides in the Aquia aquifer is leakage of brackish water from the Chester River and Eastern Bay during prepumping conditions (fig. 37). Before there was much pumpage from the Aquia aquifer, heads in the Aquia were above sea level on the mainland Eastern Shore, and the regional head gradient was driving water westward toward the Chesapeake Bay. Brackish water from the Chester River and Eastern Bay would have leaked downward into the top part of the Aquia aquifer, mixed with fresh water already in the aquifer, and then flowed beneath the northern and southern parts of Kent Island. Water that leaked downward in the central part of Kent Island would have been fresh, and, as it mixed with fresh water already in the aquifer and flowed westward, would produce the fresh water seen in the central part of the island today.

As pumpage began and heads declined on the Eastern Shore, the regional head gradient was reversed, and water flowed eastward from the Chesapeake Bay toward the mainland Eastern Shore. Because slightly brackish water was already present in the northern and southern parts of Kent Island, this reversal of flow direction would cause no change in chloride concentrations, or perhaps even a decline, as fresh water leaked downward from the subaerial parts of the Columbia aquifer. In the central part of the island, however, the reversal in flow gradient caused the brackish-water interface and mixing zone to migrate slightly eastward, and chloride concentrations to slowly increase.

POTENTIAL FOR MIGRATION OF THE BRACKISH-WATER INTERFACE

Drummond (1988) evaluated the potential for migration of the brackish-water interface as a result of increased pumpage by developing a cross-sectional solute-transport model. The model simulated density-dependent flow, dispersion, and changes in head due to various pumping scenarios. Based on the best estimate of future pumpage in the Aquia aquifer, Drummond (1988) estimated that the brackish-water interface would migrate eastward at the rate of 21 ft/yr.

The future pumpage amounts used in that simulation were based on projected population increases in the Kent Island and Grasonville areas of 240 percent by 2000, and 274 percent by 2005. However, because of water-use restrictions on the Aquia aquifer and extension of the public water system, pumpage from the Aquia aquifer on Kent Island has remained fairly constant. The pumpage increases projected for the Grasonville area have not occurred, and future population increases in that area will probably be supplied by a public water system drawing from wells in the deeper Cretaceous aquifers. Significant increases in pumpage on the mainland Eastern Shore, however, have caused drawdowns on Kent Island of similar magnitude to those used for Drummond's best-estimate scenario.

The solute-transport model used by Drummond (1988) could be updated or redone to simulate the movement of brackish water in the Aquia aquifer using monitoring data collected since the previous study was completed. However, because the monitoring data do not show a consistent trend, and several factors that cause variations in chloride concentrations are not easily incorporated into a

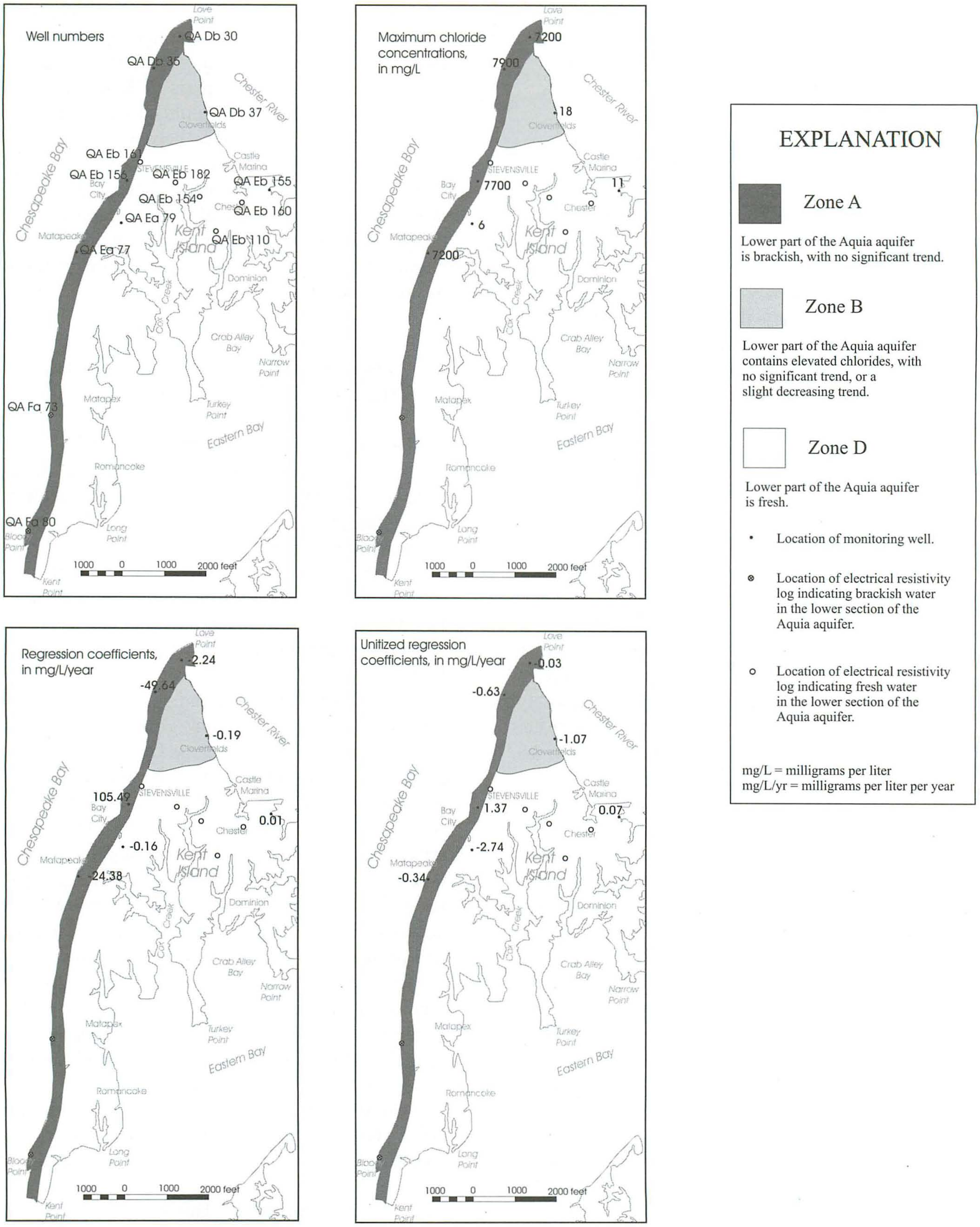


Figure 36. Maximum chloride concentrations, chloride regression coefficients, and unitized regression coefficients of chloride concentrations for wells screened in the lower part of the Aquia aquifer on Kent Island.

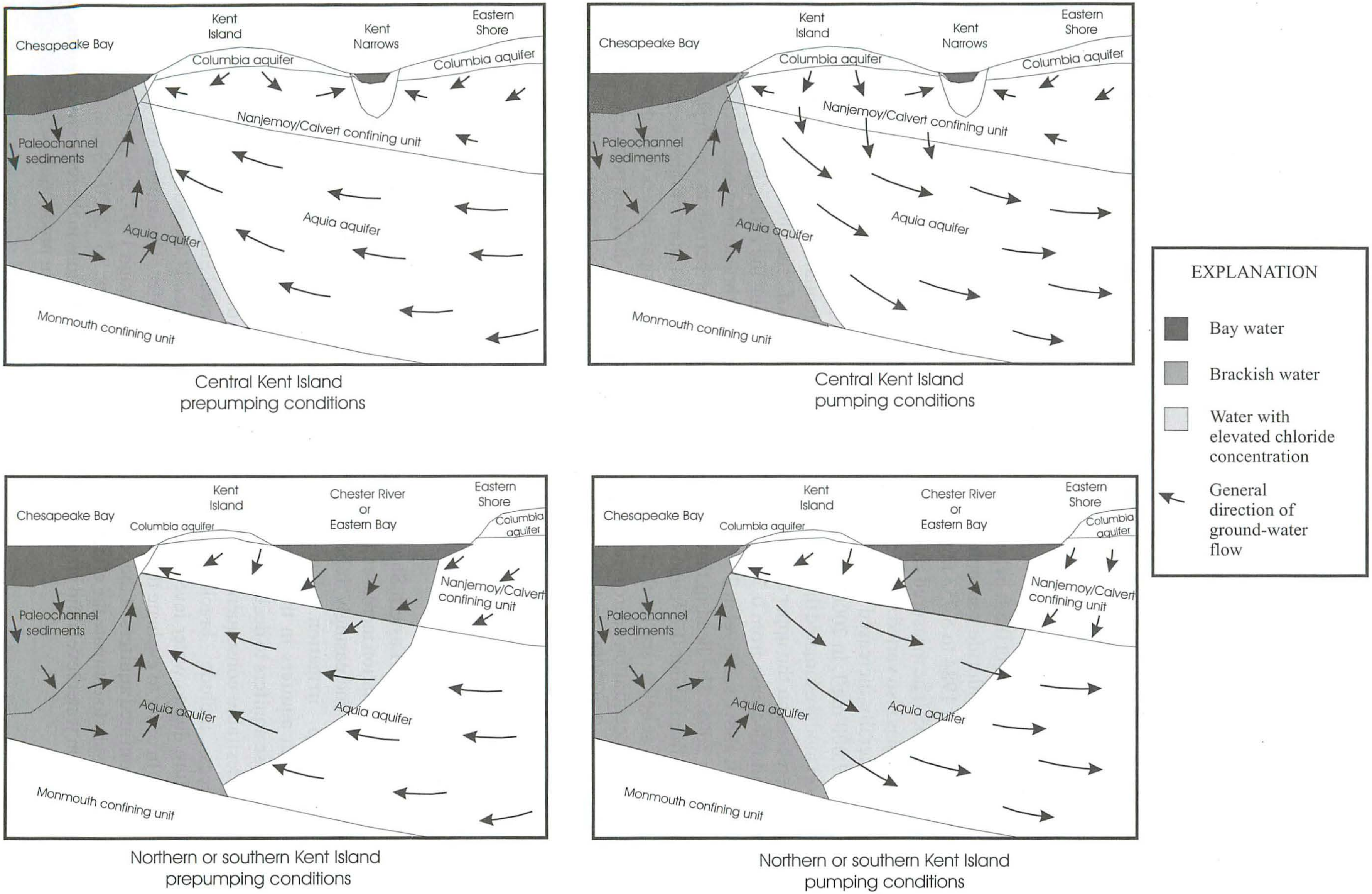


Figure 37. Schematic cross sections showing brackish-water distribution during prepumping and pumping conditions.

solute-transport model, the effort of redeveloping the model was not considered feasible. No additional data for the hydrogeologic framework in the Kent Island area were collected during this study, so the 1988 model could not be improved significantly.

It is worthwhile to evaluate the predictions made in the 1988 report. The solute-transport model estimated that the head in well QA Eb 156 (screened in the lower section of the Aquia aquifer) would decrease from 0.9 ft above sea level in 1984 to 0.3 ft above sea level in 2000, and 0.1 ft above sea level in 2005. The corrected head (corrected for the density of brackish water in the well bore) in that well has varied significantly, but has generally decreased from about 0.5 ft above sea level in 1984 to about 0.5 ft below sea level in 1999. The simulated chloride concentration increased from 5,619 mg/L in 1984 to 5,753 mg/L in 2000, and 5,795 mg/L in 2005. The measured chloride concentration in that well has also varied significantly in that time, but has generally increased from 5,600 mg/L in 1984 to about 7,000 mg/L in 2000.

The solute-transport model estimated that the head in well QA Eb 157 (screened in the upper section of the Aquia aquifer) would decrease from 0.7 ft above sea level in 1984 to 0.1 ft above sea level in 2000, and 0.1 ft below sea level in 2005. The head in that well has generally decreased from about 0.1 ft above sea level in 1984 to about 0.5 ft below sea level in 1999. The simulated chloride concentration decreased from 415 mg/L in 1984 to 408 mg/L in 2000, and 404 mg/L in 2005. Except for anomalously high values in 1984 (28 mg/L) and 1991 (48 mg/L), chloride concentrations in that well have generally remained the same, below 10 mg/L. The simulated decrease in chloride concentration at well QA Eb 157 can be attributed to increased fresh-water leakage from the overlying Nanjemoy confining unit.

The simulated head in well QA Eb 144 decreased from 3.1 ft above sea level in 1984 to 3.6 ft below sea level in 1995 and 4.3 ft below sea level in 2000, whereas the measured head decreased from 1.7 ft below sea level in 1984 to 3.2 ft below sea level in 1997. The simulated chloride concentration in well QA Eb 144 increased slightly from 3.1 mg/L in 1984 to 5.5 mg/L in 2000. Two measured chloride concentrations in that well remained essentially the same, at 6.3 mg/L in 1983 and 4.9 mg/L in 1999.

Although the simulated values differ from the measured values at these wells, the overall trends are reasonably similar. The transport model correctly predicted the increase in chloride concentrations at well QA Eb 156, but underestimated the rate of increase.

The potential for increased pumpage to induce movement of the brackish-water interface was evaluated using the calibrated flow model. Simulated flux across the brackish-water interface was calculated for each stress period in the historical calibration period, and each future simulation. These calculations were used to compare the potential for brackish-water movement for the different pumping scenarios, and are explained in the section entitled "Potential for Migration of the Brackish-Water Interface in the Aquia aquifer".

WATER-SUPPLY POTENTIAL OF THE AQUIA AQUIFER

The water needs of the central Eastern Shore are expected to increase as the population increases and as the agricultural community increasingly relies on ground water for crop irrigation. Increased withdrawals from artesian aquifers in the area will cause water levels in those aquifers to decline, which, in turn, may cause undesirable consequences. Some possible consequences include brackish-water intrusion and well failure due to water levels falling below the pump intake. In order to evaluate the water-supply potential of the confined aquifers of the central Eastern Shore, it is necessary to estimate the effects of increased pumping rates on water levels and brackish-water intrusion.

A ground-water flow model was developed to simulate flow and heads in the subsurface of the study area. Visual MODFLOW was used for these simulations, which provides pre-processing and post-processing capabilities for the MODFLOW model. MODFLOW (McDonald and Harbaugh, 1988) is a quasi-three dimensional flow model developed by the U. S. Geological Survey. The model includes aquifers from the surficial Columbia aquifer down to the Upper Patapsco aquifer. The calibration simulation was run from 1899 through 1997, and future simulations were run from 1998 to 2020. Simulated water levels represent conditions in the respective aquifers, and not pumping levels in production wells.

MODEL DESCRIPTION

Model Grid

The flow-model grid is 44 miles (mi) by 56 mi, and is oriented with its long dimension in the north-south direction. It contains 98 rows and 79 columns and includes 8 layers. Most of the cells are ½ mi square, but at the model edges, cell size was increased to as much as1.5 by 2.0 mi.

Figure 38 conceptually shows the layering scheme and boundary conditions for the flow model. Layer 1 represents the Columbia aquifer and the Chesapeake Bay and other tidal estuaries. Layer 2 represents the Chesapeake Group sediments, which include both sandy aquifer units, and clayey confining units. Layer 3 represents the Piney Point aquifer, which is truncated in the subsurface. Layer 4 represents the Nanjemoy confining unit, as well as Chesapeake Group sediments where the Piney Point aquifer is absent and the Nanjemoy and Chesapeake sediments are difficult to differentiate in well logs.

Layer 5 represents the Aquia aquifer, and layer 6 represents the Monmouth confining unit. Layer 7 represents the Matawan and Magothy aquifers, and layer 8 represents the Upper Patapsco aquifer. Although the Lower Patapsco and Patuxent aquifers are present below the Upper Patapsco aquifer, they are separated by at least 100 ft of silty clay, and it was assumed that leakage between the Upper and Lower Patapsco aquifers is insignificant.

Boundaries

Each side of the flow model is represented by boundary conditions which approximate real hydrologic conditions. The top surface of the model was assigned constant-head conditions in layer 1. The Chesapeake Bay and its tidal estuaries were assigned a head at sea level. The portions of the model over land were assigned heads of the water table in the Columbia aquifer, and were derived from Bachman and Wilson (1984). Water-table elevations vary seasonally with the evapotranspiration cycle, but remain fairly constant over the long term. If future pumpage from the Columbia aquifer (most likely irrigation pumpage) is shown to cause long-term regional declines in the water-table elevation, this assumption should be reconsidered.

The bottom surface of the model was simulated as a no-flow boundary. The thick, silty clay of the confining unit below the Upper Patapsco aquifer probably does not allow significant leakage between the Upper Patapsco aquifer and deeper aquifers in the Potomac Group. The lateral boundaries of confining units were also represented as no-flow boundaries, as horizontal flow in low-permeability sediments is expected to be minimal.

The lateral boundaries for aquifers were represented as head-dependent flux boundaries (General Head Boundaries). This boundary type allows flow into or out of the model, depending on the relative heads between model cells and boundary cells. Boundary heads vary with time, and were used to simulate head declines caused by pumpage outside the model area. Heads assigned to the aquifer boundaries were derived from previous publications (Cushing, Kantrowitz, and Taylor, 1973;Williams, 1979; Drummond, 1988; Fleck and Vroblesky, 1996) or estimated from the 1997 synoptic measurement conducted during this study. Boundary heads for future simulations are unknown, and so were not changed from 1997 conditions.

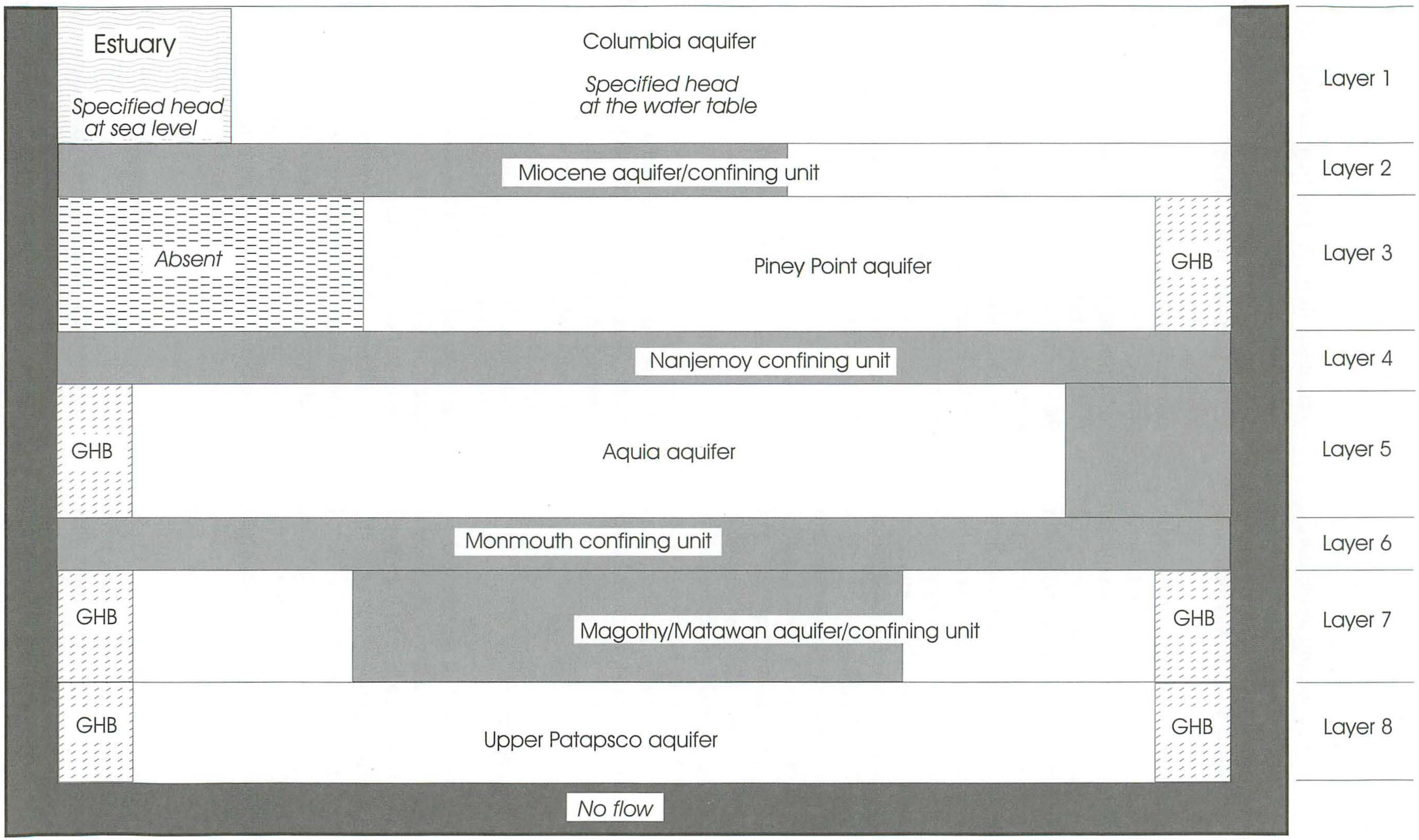
Time Discretization

The historic calibration simulation included the time period from 1900 to 1997, and was divided into five stress periods. Estimated pumpage and boundary heads were entered for each stress period, and remained constant during each stress period. Pumpage and boundary heads were varied from one stress period to the next to simulate changing hydrologic conditions. The stress periods ran from 1898 to1918, to 1952, to 1976, to 1984, to 1996, and to 1997. Each stress period was divided into five time steps, and heads and flows within the model were calculated at the end of each time step.

Future pumpage scenarios simulated the time period from 1998 to 2020, in two stress periods, 1998 to 2010 and 2011 to 2020. One scenario included extra stress periods in order to simulate the summer irrigation pumping cycle. These simulations are explained further in the relevant sections.

Pumpage

Historical ground-water pumpage for large users (withdrawals greater than 10,000 gpd) was derived from Wheeler and Wilde (1987), from pumpage reports kept on file at Maryland Department of the



[GHB = General Head Boundary]

Figure 38. Conceptualization of the ground-water flow model.

environment, and interviews with water-supply operators. A compilation of large users is shown in table 14 for Queen Anne's and Talbot Counties. Pumpage entered in the flow model is listed in table 6, and the locations of the pumping centers are shown in figure 39. Pumpage from the Columbia aquifer was not entered in the model because the Columbia (layer 1) was simulated as a constant-head boundary. Commercial pumpage for users pumping less than 10,000 gpd was also not included in the model simulations. These users are not required to report their pumpage, so their pumpage data are not available. This omitted pumpage is less than 10 percent of the total for the model area, and does not significantly affect model results.

Simulated pumpage for each aquifer is shown in table 7. For all simulations, most pumpage comes from the Aquia aquifer. Varying amounts of water are withdrawn from the Miocene, Piney Point, Matawan/Magothy, and Upper Patapsco aquifers, and a minor quantity is pumped from the Monmouth aquifer at one site in Kent County.

Domestic pumpage in Queen Anne's County for 1997 and future simulations was calculated from estimates of population served by individual wells by census tract (Alan L. Quimby, Queen Anne's County Department of Public Works, written commun., 1999) (tab. 8). The number of people supplied by individual wells was multiplied by a conversion factor of 67 gpd/person to determine domestic pumpage for each tract. The pumpage for each tract was then distributed into the aquifers that are generally used by domestic wells in that area. It was assumed that future increases in water usage on Kent Island would come from public supplies. Several wells were placed in the model in each census tract to represent domestic pumpage. Historical domestic pumpage was estimated from historical population figures and a similar distribution pattern to that used for 1997 estimates.

Domestic pumpage in Talbot County for historical conditions and 1997 was extrapolated from population figures of election districts for 1970 to 1990 (James W. Burns, Talbot County Department of Public Works, written commun., 1999) (tab. 9). The number of people served by public water-supply systems was subtracted from the total population of each district. The population for each district was then multiplied by a conversion factor of 67 gpd/person to determine domestic pumpage for that district. The pumpage for each district was distributed into the aquifers that are generally used by domestic wells in that district. Several wells were placed in the model in each election district to represent domestic pumpage.

Future domestic pumpage in Talbot County was estimated from population projections for the entire county (James W. Burns, Talbot County Department of Public Works, written commun., 1999), because projections for the individual election districts were not available. Population increase rates for 2010 and 2020 were applied to the 1990 domestic pumpage distribution to determine future domestic pumpage for each election district.

Model Input and Calibration

Although Visual MODFLOW uses MODFLOW to make model calculations, the data input structure is very different from that of MODFLOW. Data are entered irrespective of row and column numbers, and the program assigns row and column designations. Data are entered for each model layer for horizontal and vertical hydraulic conductivity, specific storage, and top and bottom elevations. Visual Modflow translates these data into transmissivity, storativity, and vertical conductance (Vcont) for input to Modflow

Hydrologic data were entered for each model layer based on published data where available, and estimates from sediment characteristics where published data were not available. The model inputs were adjusted during model calibration so that model-calculated heads matched measured heads. Model-calculated fluxes at boundaries and between layers was checked to ensure that the fluxes were reasonably close to estimated values. The model inputs adjusted during model calibration include horizontal hydraulic conductivity of aquifer layers, vertical hydraulic conductivity of confining layers, and heads at lateral boundaries. Ranges of simulated storativity and transmissivity for each aquifer are shown in table 10. Minimum values of 2.00 x 10^{-6} for storativity and 0.001 ft^2/d for transmissivity were generated by Visual MODFLOW in areas where the aquifers are very thin or absent. Emphasis was placed on the Aquia aquifer because it is the focus of this study.

The flow model was calibrated primarily using heads from the synoptic measurement conducted in the fall of 1997. This measurement produced the first regional map of heads in the Aquia aquifer on the Eastern Shore. Previous studies published head measurements for the Aquia aquifer in parts of the

(Text continued on p. 71.)

Table 6. Pumpage simulated in the ground-water flow model

[KI = Kent Island; discrepancies due to rounding]

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
	Queen Anne's County															
							Large users									
1	QA56G001	0	93	1	175	175	210	140	350	150	175	175	175	175	175	175
2	QA56G101	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	QA61G005	0	0	0	0	0	0	0	0	123	0	0	0	0	0	0
4	QA63G002	0	8	16	36	36	44	29	73	35	36	36	36	36	36	36
5	QA63G004	0	2	2	11	11	13	9	22	16	11	11	11	11	11	11
6	QA65G004	0	0	7	6	6	7	5	12	96	6	6	6	6	6	6
7	QA67G002	243	333	166	412	512	614	410	1,024	355	512	512	512	512	512	512
8	QA69G003	0	2	18	68	68	82	54	136	50	68	68	68	68	68	68
9	QA70G102	0	10	20	194	170	204	136	340	92	170	170	170	170	170	170
10	QA71G002	0	0	0	19	19	23	15	38	35	19	19	19	19	19	19
11	QA71G007	19	60	1	62	62	75	50	125	123	62	62	62	62	62	62
12	QA74G001	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0
13	QA76G003	0	0	0	30	30	36	24	60	100	30	30	30	30	30	30
14	QA78G009	0	0	0	4	4	5	3	8	15	4	4	4	4	4	4
15	QA79G010	35	40	56	69	220	264	176	440	77	220	220	220	220	220	220
16	QA80G013	0	0	24	75	75	90	60	150	125	75	75	75	75	75	75
17	QA82G002	0	0	0	26	27	32	22	54	27	27	27	27	27	27	27
18	QA83G005	0	0	0	12	11	13	9	22	15	11	11	11	11	11	11
19	QA84G004	0	0	0	18	18	22	14	36	20	18	18	18	18	18	18
20	QA84G016	0	0	0	15	68	82	54	136	20	68	68	68	68	68	68
21	QA84G017	0	0	0	0	0	0	0	0	99	0	0	0	0	0	0
22	QA85G009	0	0	0	8	8	10	6	16	10	8	8	8	8	8	8
23	QA85G019	0	0	0	103	100	120	80	200	160	100	100	100	100	100	100
24	QA85G024	0	0	0	37	80	96	64	160	144	80	80	80	80	80	80
25	QA85G030	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0
26	QA87G035	0	0	0	315	315	378	252	630	400	315	315	315	315	315	315

Table 6. Pumpage simulated in the ground-water flow model–Continued

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
27	QA89G020	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0
28	QA89G022	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0
29	QA89G024	0	0	0	258	500	600	400	1,000	500	500	500	500	500	500	500
30	QA89G026	0	0	0	62	62	74	50	124	72	62	62	62	62	62	62
31	QA90G003	0	0	0	0	0	0	0	0	57	0	0	0	0	0	0
32	QA90G012	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0
33	QA90G021	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0
34	QA90G040	0	0	0	1	1	1	0	1	180	1	1	1	1	1	1
35	QA91G001	0	0	0	43	43	51	34	86	357	43	43	43	43	43	43
36	QA91G007	0	0	0	0	0	0	0	0	119	0	0	0	0	0	0
37	QA91G009	0	0	0	0	0	0	0	0	166	0	0	0	0	0	0
38	QA91G013	0	0	0	27	27	32	21	54	100	27	27	27	27	27	27
39	QA91G016	0	0	0	130	130	156	104	260	135	130	130	130	130	130	130
40	QA91G032	0	0	0	46	46	55	37	92	189	46	46	46	46	46	46
41	QA92G003	0	0	0	46	46	55	37	92	200	46	46	46	46	46	46
42	QA92G007	0	0	0	155	155	186	124	310	158	155	155	155	155	155	155
43	QA92G008	0	16	13	0	0	0	0	0	249	0	0	0	0	0	0
44	QA92G009	0	0	167	181	181	217	145	361	221	181	181	181	181	181	181
45	QA92G011	0	0	0	0	0	0	0	0	211	0	0	0	0	0	0
46	QA92G012	0	0	174	186	186	223	149	372	193	186	186	186	186	186	186
47	QA92G013	0	0	167	161	161	193	129	322	217	161	161	161	161	161	161
48	QA92G014	0	0	0	136	136	164	109	273	157	136	136	136	136	136	136
49	QA92G015	0	0	0	0	0	0	0	0	137	0	0	0	0	0	0
50	QA92G016	0	0	0	0	0	0	0	0	150	0	0	0	0	0	0
51	QA92G020	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
52	QA92G026	0	0	0	166	166	199	132	331	302	166	166	166	166	166	166
53	QA92G027	0	0	10	16	16	19	13	32	296	16	16	16	16	16	16
54	QA92G032	0	69	64	45	45	54	36	90	125	45	45	45	45	45	45
55	QA92G033	0	0	95	46	46	55	37	92	244	46	46	46	46	46	46
56	QA92G044	0	0	0	38	105	126	84	210	88	105	105	105	105	105	105

Table 6. Pumpage simulated in the ground-water flow model–Continued

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
57	QA92G047	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0
58	QA93G002	0	0	329	386	386	464	309	773	188	386	386	386	386	386	386
59	QA93G010	0	0	0	0	0	0	0	0	247	0	0	0	0	0	0
60	QA93G011	0	0	0	0	0	0	0	0	148	0	0	0	0	0	0
61	QA93G012	0	0	0	0	0	0	0	0	97	0	0	0	0	0	0
62	QA93G013	0	0	0	0	0	0	0	0	109	0	0	0	0	0	0
63	QA93G034	0	0	0	0	0	0	0	0	325	0	0	0	0	0	0
64	QA94G005	0	0	0	387	387	464	309	774	378	387	387	387	387	387	387
65	QA94G007	0	0	0	9	85	102	68	170	342	85	85	85	85	85	85
66	QA95G001	0	98	75	116	116	140	93	233	411	116	116	116	116	116	116
67	QA95G010	0	0	0	0	0	0	0	0	265	0	0	0	0	0	0
68	QA95G011	0	0	0	0	0	0	0	0	122	0	0	0	0	0	0
69	QA96G009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	QA97G003	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0
71	QA97G011	0	0	0	38	38	46	30	76	129	38	38	38	38	38	38
72	QA97G014	0	0	0	0	0	0	0	0	85	0	0	0	0	0	0
		Domestic pumpage														
73	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
74	Kent Island	0	52	75	15	15	18	12	30	15	15	15	15	15	15	15
75	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
76	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
77	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
78	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
79	Kent Island	0	52	75	15	15	18	12	30	15	15	15	15	15	15	15
80	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
81	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
82	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
83	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
84	Kent Island	0	52	75	75	75	90	60	150	75	75	75	75	75	75	75
85	Grasonville	0	22	37	75	105	126	84	209	105	105	105	105	105	105	105

Table 6. Pumpage simulated in the ground-water flow model–Continued

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
86	Grasonville	0	22	37	75	105	126	84	209	105	105	105	105	105	105	105
87	Queenstown	0	22	37	75	105	126	84	209	105	105	105	105	105	105	105
88	Queenstown	0	22	37	75	105	126	84	209	105	105	105	105	105	105	105
89	Queenstown	0	22	37	75	105	126	84	209	105	105	105	105	105	105	105
90	Crumpton	0	22	37	90	117	140	93	233	117	117	117	117	117	117	117
91	Crumpton	0	22	37	90	117	140	93	233	117	117	117	117	117	117	117
92	Sudlersville	0	22	37	82	115	138	92	230	115	115	115	115	115	115	115
93	Sudlersville	0	22	37	82	115	138	92	230	115	115	115	115	115	115	115
94	Church Hill	0	22	37	165	214	257	171	428	214	214	214	214	214	214	214
95	Church Hill	0	22	37	82	107	128	86	214	107	107	107	107	107	107	107
96	Centreville	0	22	37	90	144	172	115	287	144	144	144	144	144	144	144
97	Centreville	0	22	37	90	144	172	115	287	144	144	144	144	144	144	144
98	Queen Anne	0	22	37	105	136	163	109	272	136	136	136	136	136	136	136
							Hypothetical wells									
99	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
100	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
101	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
102	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
103	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
104	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
105	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
106	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
107	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
108	Grasonville	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
109	Eastern KI	0	0	0	0	0	0	0	0	0	250	0	0	0	0	0
110	Eastern KI	0	0	0	0	0	0	0	0	0	250	0	0	0	0	0
111	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
112	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
113	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
114	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0

Table 6. Pumpage simulated in the ground-water flow model–Continued

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
115	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
116	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
117	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
118	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
119	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
120	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
121	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
122	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
123	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
124	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
125	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	187	561	0
	Talbot County															
							Large users									
126	TA46G001	182	137	108	8	8	10	7	17	80	8	8	8	8	8	8
127	TA46G003	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0
128	TA46G005	16	19	27	70	108	129	86	215	70	108	108	108	108	108	108
129	TA57G004	0	44	98	0	0	0	0	0	175	0	0	0	0	0	0
130	TA57G104	0	23	20	0	0	0	0	0	50	0	0	0	0	0	0
131	TA62G002	0	1	13	8	8	9	6	15	12	8	8	8	8	8	8
132	TA70G002	55	96	132	125	134	161	107	268	140	134	134	134	134	134	134
133	TA71G002	0	10	24	58	58	69	46	115	65	58	58	58	58	58	58
134	TA71G205	0	0	0	1,042	1,594	1,913	1,275	3,189	704	1,594	1,594	1,594	1,594	1,594	1,594
135	TA71G105	330	324	290	129	197	237	158	395	260	197	197	197	197	197	197
136	TA71G005a	80	324	326	142	217	260	174	434	250	217	217	217	217	217	217
137	TA71G005b	80	324	326	142	217	260	174	434	250	217	217	217	217	217	217
138	TA71G005c	80	324	326	142	217	260	174	434	250	217	217	217	217	217	217
139	TA71G005d	80	324	326	142	217	260	174	434	250	217	217	217	217	217	217
140	TA73G001	0	0	0	13	13	15	10	25	45	13	13	13	13	13	13
141	TA73G101	0	0	0	13	13	15	10	25	10	13	13	13	13	13	13

Table 6. Pumpage simulated in the ground-water flow model–Continued

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
142	TA74G105	0	55	28	43	43	52	35	86	20	43	43	43	43	43	43
143	TA74G205	0	25	13	15	15	18	12	30	70	15	15	15	15	15	15
144	TA79G004	117	219	211	267	286	343	229	571	325	286	286	286	286	286	286
145	TA79G006	0	58	95	134	233	279	186	465	210	233	233	233	233	233	233
146	TA81G004	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0
147	TA81G101	0	0	0	7	7	9	6	14	10	7	7	7	7	7	7
148	TA82G008	0	0	0	5	5	6	4	9	15	5	5	5	5	5	5
149	TA88G031	0	0	0	0	0	0	0	0	70	0	0	0	0	0	0
150	TA89G004	0	0	0	0	0	0	0	0	46	0	0	0	0	0	0
151	TA89G021	0	348	275	284	284	341	227	568	300	284	284	284	284	284	284
152	TA90G005	0	0	0	10	10	12	8	21	50	10	10	10	10	10	10
153	TA91G016	0	0	241	559	559	671	448	1,119	473	559	559	559	559	559	559
154	TA91G019	0	0	0	104	104	125	83	208	245	104	104	104	104	104	104
155	TA92G004	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0
156	TA92G009	0	0	0	9	9	11	7	18	63	9	9	9	9	9	9
157	TA93G010	0	0	0	22	22	27	18	44	28	22	22	22	22	22	22
158	TA93G013	0	0	0	9	9	11	7	18	63	9	9	9	9	9	9
159	TA94G016	0	0	0	1	1	1	0	1	10	1	1	1	1	1	1
160	TA94G020	0	0	0	49	49	59	39	98	0	49	49	49	49	49	49
						Domestic pumpage										
161	Bay Hundred	0	52	75	75	86	103	69	172	86	86	86	86	86	86	86
162	Bay Hundred	0	52	75	75	86	103	69	172	86	86	86	86	86	86	86
163	St. Michaels	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
164	St. Michaels	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
165	St. Michaels	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
166	Trappe	0	37	60	75	86	103	69	172	86	86	86	86	86	86	86
167	Trappe	0	37	60	75	86	103	69	172	86	86	86	86	86	86	86
168	Chapel Point	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
169	Chapel Point	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
170	Chapel Point	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86

Table 6. Pumpage simulated in the ground-water flow model–Continued

Identifier (See fig. 39)	GAP or location (see tab. 14)	Simulated pumpage, in thousand gallons per day														
		Calibration				Future Simulations										
		1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
171	Easton	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
172	Easton	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
173	Easton	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
174	Easton	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
175	Easton	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
176	Easton	0	37	52	75	86	103	69	172	86	86	86	86	86	86	86
							Hypothetical wells									
177	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
178	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
179	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
180	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
181	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
182	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
183	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
184	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
185	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
186	Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	94	281	0
County Totals																
Caroline		1,681	1,831	2,646	4,643	4,643	5,572	3,714	9,286	6,998	4,643	4,643	4,643	4,643	4,643	4,643
Dorchester		4,296	3,077	3,352	5,015	5,015	6,018	4,012	10,030	5,389	5,015	5,015	5,015	5,015	5,015	5,015
Kent		741	1,370	1,279	1,558	1,558	1,870	1,247	3,117	2,586	1,558	1,558	1,558	1,558	1,558	1,558
Queen Anne's		338	1,676	2,830	6,400	7,560	9,072	6,048	15,120	12,893	8,060	8,560	7,560	10,365	15,975	7,560
Talbot		1,031	3,294	3,776	4,748	6,012	7,214	4,809	12,024	6,056	6,012	6,012	6,012	6,952	8,822	6,012
Simulation Totals		8,087	11,248	13,882	22,364	24,788	29,746	19,830	49,576	33,922	25,288	25,788	24,788	28,533	36,013	24,788

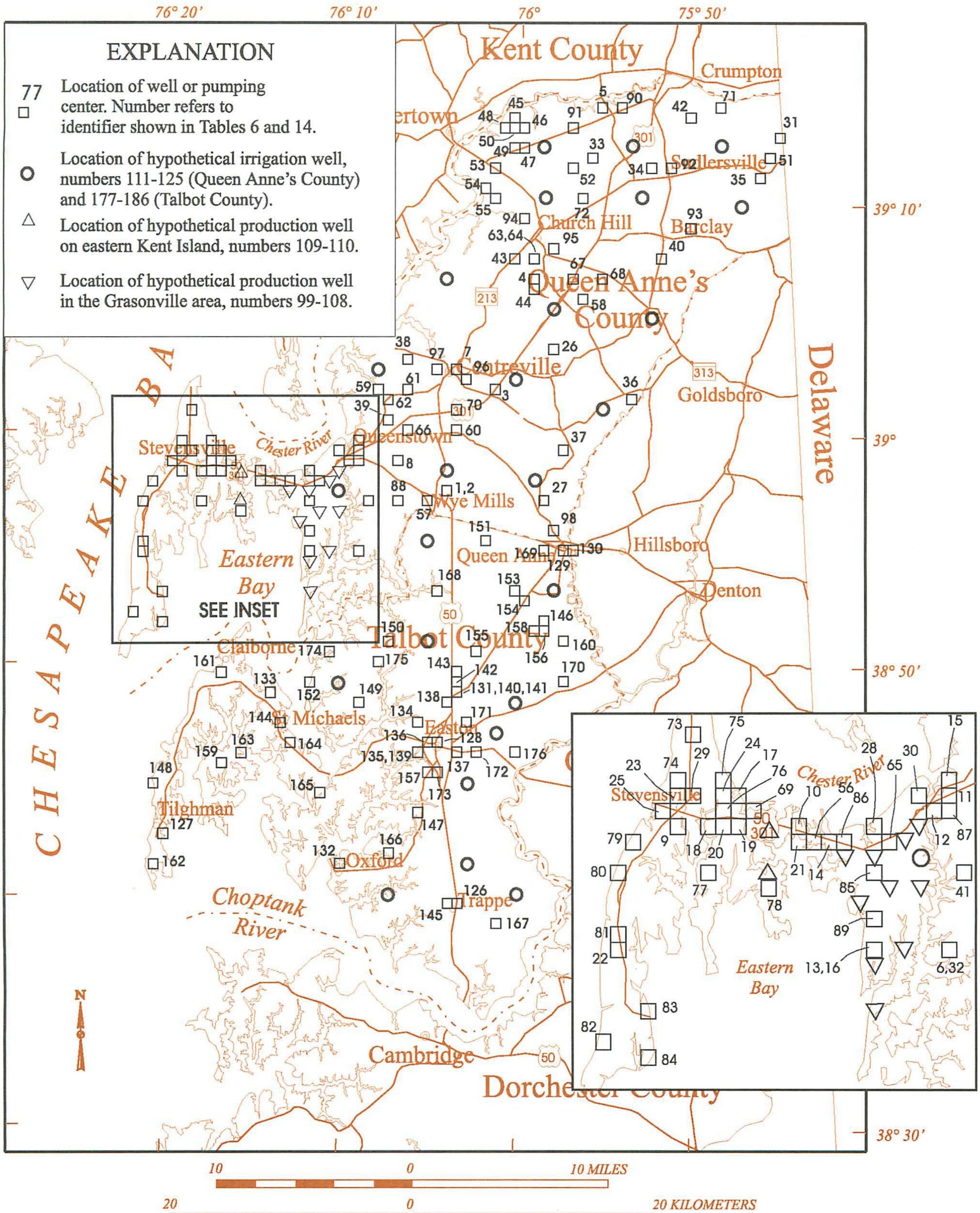


Figure 39. Locations of wells and pumping centers simulated in the flow model.

Table 7. Pumpage simulated in the ground-water flow model, by aquifer

[Discrepancies due to rounding]

Aquifer	Simulated pumpage, in thousand gallons per day														
	Calibration				Future simulations										
	1953	1976	1984	1997	1	2	3	4	5	6	7	8	9	10	11
Miocene	1,631	1,251	2,801	7,042	7,080	8,495	5,664	14,159	7,807	7,080	7,080	7,080	7,360	7,921	7,080
Piney Point	4,087	3,821	3,760	3,314	3,489	4,187	2,791	6,978	4,743	3,489	3,489	3,489	3,676	4,050	3,489
Aquia	1,214	3,940	5,164	8,467	9,430	11,321	7,548	18,869	14,693	9,935	10,435	8,011	12,707	19,252	9,435
Monmouth	0	88	59	41	41	49	33	82	100	41	41	41	41	41	41
Magothy	1,150	1,750	1,670	979	1,280	1,540	1,020	2,560	2,462	1,280	1,280	1,280	1,280	1,280	1,280
Upper Patapsco	0	396	437	2,521	3,451	4,141	2,761	6,902	4,247	3,451	3,451	4,888	3,451	3,451	3,451
Total	8,082	11,246	13,891	22,364	24,771	29,734	19,817	49,550	34,052	25,275	25,776	24,788	28,515	35,995	24,776

Table 8. Past and projected population for Queen Anne's County

[modified from Alan L. Quimby, Queen Anne's County Department of Public Works, written commun., 1999]

Area	Election district	Census tract	Population on individual wells			
			1995	2000	2010	2020
Sudlersville	1	8102	2,520	2,690	3,020	3,460
Church Hill	2	8103	3,580	3,800	4,220	4,780
Centreville	3	8104	2,790	3,100	3,720	4,550
Kent Island	4	8108	1,724	1,724	1,724	1,724
Kent Island	4	8109	5,880	5,880	5,880	5,880
Kent Island	4	8110	3,948	3,948	3,948	3,948
Queenstown	5	8106	3,860	4,130	4,660	5,350
Grasonville	5	8107	2,200	2,400	2,640	3,125
Ruthsburg	6	8105	1,550	1,700	1,980	2,420
Crumpton	7	8101	2,730	2,870	3,170	3,540
		1970	1980	1990	2000	2010
Total Population		18,113	25,169	33,586	39,820	45,970

study area, and for other aquifers, and these heads were also used for model calibration. Three long-term hydrographs for wells screened in the Aquia aquifer were used to calibrate transient effects of pumpage and storage. The simulated transmissivity distribution for the Aquia aquifer (layer 5) is shown in figure 40, along with measured transmissivity values. Measured transmissivities generally fall within ranges of simulated values, except where several disparate measured values fall within a relatively small area.

Figures 41 to 42 and 44 to 45 show simulated 1997 potentiometric maps for the Piney Point, Aquia, Matawan/Magothy, and Upper Patapsco aquifers, with measured heads for each aquifer. Results for the Columbia and Miocene aquifers are of marginal importance and are not shown.

Simulated heads in the Piney Point aquifer are generally within 10 ft of measured heads, with major exceptions in Caroline County, where pumpage amounts were not accurately documented. The simulated cone-of-depression at Cambridge matches measured heads fairly well, and the potentiometric high in central Queen Anne's County generally matches measured heads. The flow model does not accurately simulate the irregularities in the potentiometric surface (fig. 16), which may be caused by localized pumpage or localized variations in the leakance of overlying Miocene sediments.

The simulated potentiometric surface in the Aquia aquifer matches measured water levels quite well, with only a few exceptions. Most simulated water levels are within 5 ft of measured levels, with exceptions in the central part of Queen Anne's County, possibly caused by undocumented localized pumpage, or irregularities in the overlying confining unit. The cone-of-depression centered at Easton is accurately simulated, as are water levels on Kent Island. The cone-of-depression at Easton is caused by pumpage from the public-supply well and domestic pumpage in that area, and by a decrease in transmissivity in the Aquia aquifer near the facies change (fig. 40).

Table 9. Past and projected population for Talbot County

[modified from James W. Burns, Talbot County Department of Public Works, written commun., 1999; -- data not available]

Election district		1970	1980	1990	2000	2010	2020
Easton	total	11,167	12,166	15,470	--	--	--
	public supply	6,809	7,536	9,372	11,990	14,823	18,377
St. Michaels	total	4,413	4,654	5,298	--	--	--
	public supply	2,391	2,236	2,236	2,315	2,395	2,480
Trappe	total	3,366	3,510	4,071	--	--	--
	public supply	1,176	1,493	1,673	2,103	2,303	3,090
Chapel	total	2,761	3,347	3,755	--	--	--
	public supply	151	128	110	0	0	0
Bay Hundred	total	1,975	1,927	1,955	--	--	--
	public supply	0	0	0	0	0	0
Total Talbot County		23,682	25,604	30,549	33,700	35,910	38,350

Table 10 . Ranges of values for storativity and transmissivity simulated in the flow model

Aquifer	Storativity (dimensionless)	Transmissivity (feet squared per day)
Miocene	2.00×10^{-6} - 1.21×10^{-3}	0.001 - 3,020
Piney Point	2.00×10^{-6} - 5.48×10^{-4}	0.001 - 2,920
Aquia	2.00×10^{-6} - 5.93×10^{-4}	0.001 - 7,110
Magothy/Matawan	2.00×10^{-6} - 6.93×10^{-4}	0.001 - 6,670
Upper Patapsco	$2.00 \text{ X } 10^{-6}$ - 6.37×10^{-4}	10 - 10,600

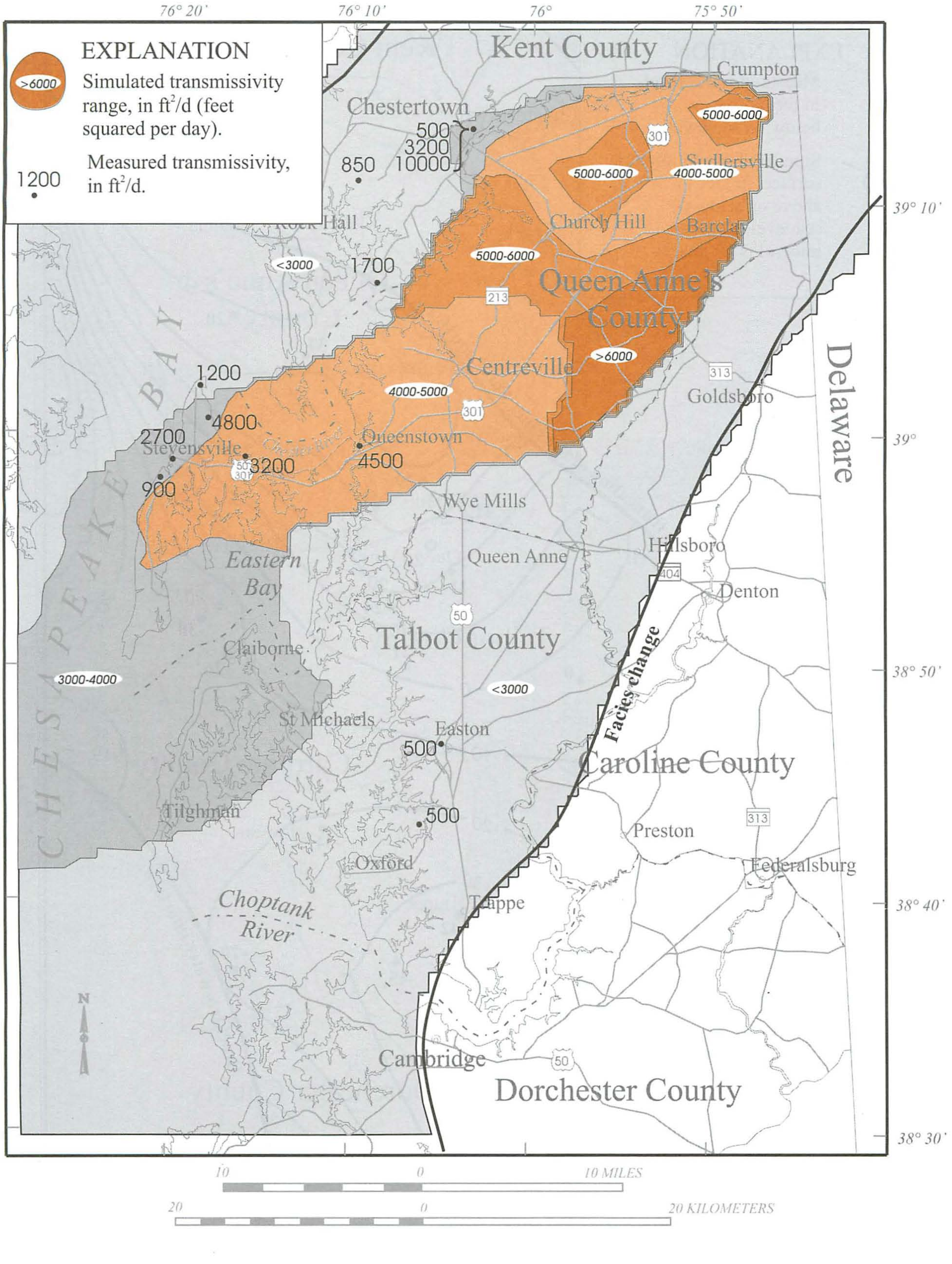


Figure 40. Simulated transmissivity ranges and measured transmissivities for the Aquia aquifer.

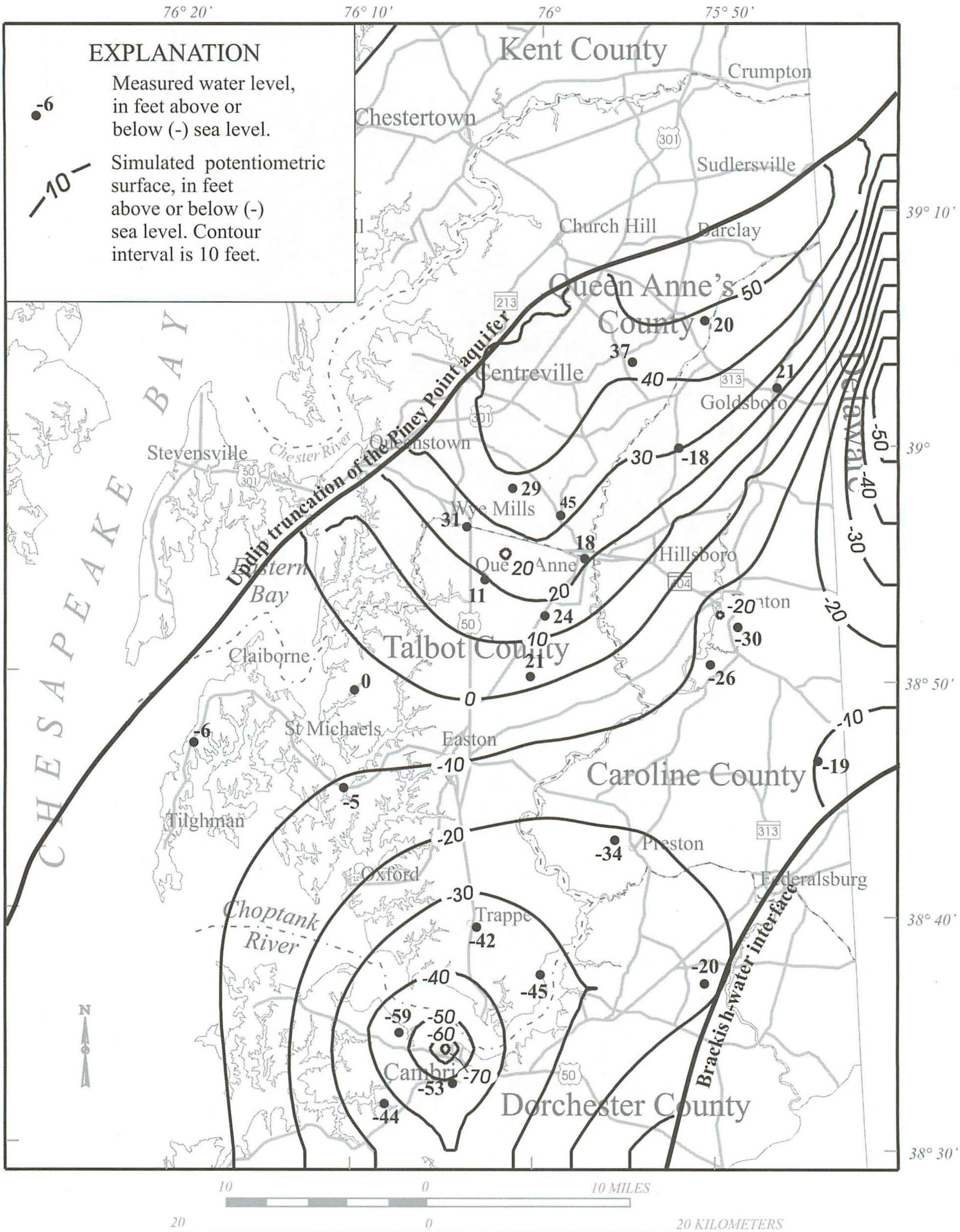


Figure 41. Simulated potentiometric surface and measured water levels in the Piney Point aquifer, 1997.

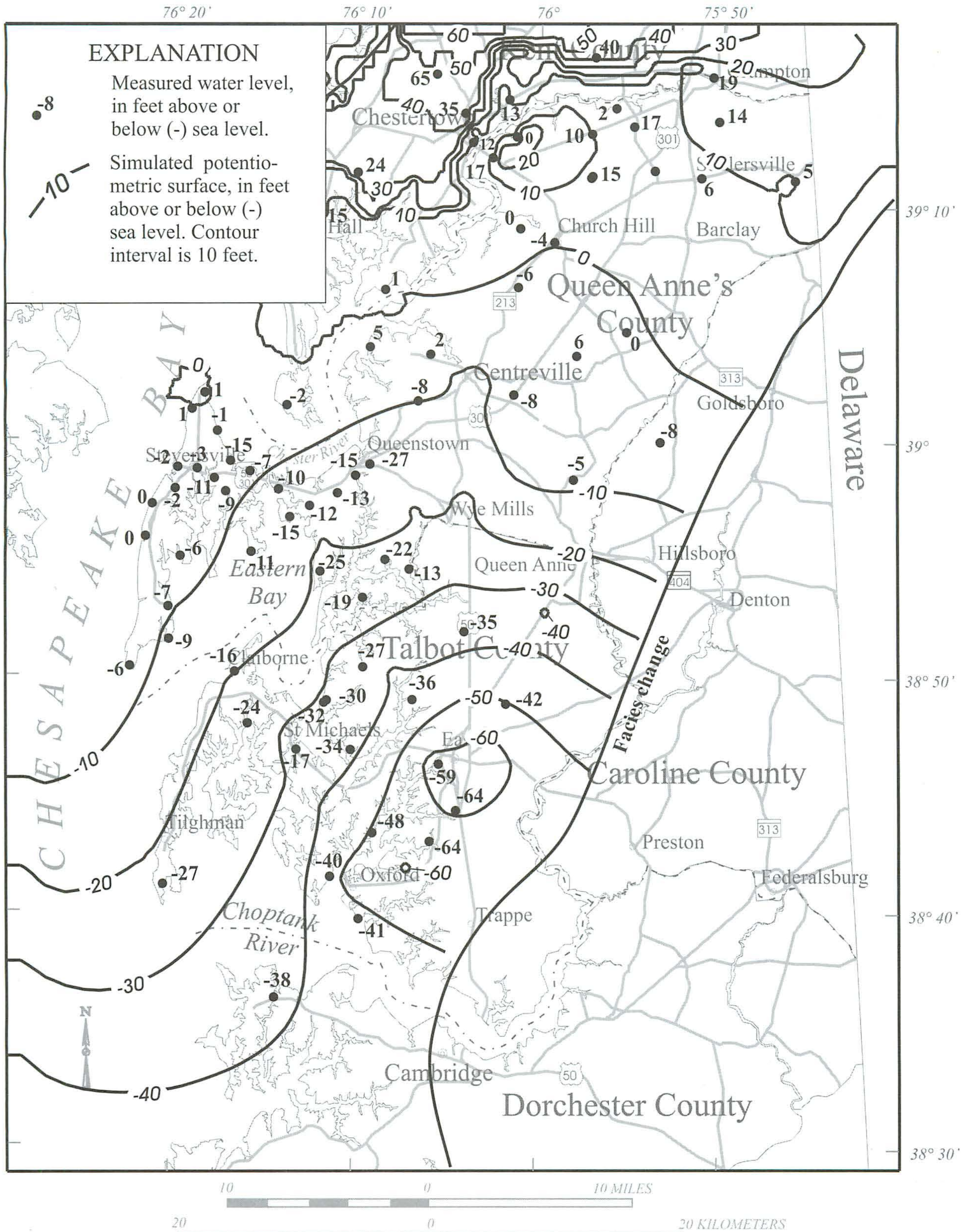


Figure 42. Simulated potentiometric surface and measured water levels in the Aquia aquifer, 1997.

Long-term hydrographs of simulated and measured heads in the Aquia aquifer are shown in figure 43. Measured water levels in well QA Be 17 show large fluctuations caused by pumping cycles at Chestertown, which is just across the Chester River, in Kent County. These pumping cycles were not simulated in the flow model, and the water-level fluctuations do not appear on the simulated hydrograph. The simulated head at this site is, however, consistent with an average water level at this site. Simulated hydrographs at wells QA Eb 113 and QA Fc 7 match measured water levels fairly accurately. Because the period of 1984 to 1997 was simulated as a single stress period and the entire pumpage increase was effected at the beginning of the period, simulated heads decline more rapidly at the beginning of the period than measured heads, but total declines for the period are consistent.

Calibration for the Matawan/Magothy aquifer (layer 7) and the Upper Patapsco aquifer (layer 8) was hindered by the lack of data in these deeper aquifers. Fewer wells are screened in these aquifers than in shallower aquifers, and so there are fewer aquifer tests and water levels available for calibration. Most data points for these aquifers are in the Kent Island area. Nevertheless, simulated heads match the few measured water levels reasonably well. Simulated heads on Kent Island are between 10 and 20 ft below sea level, and most measured heads fall within this range (fig. 44). Although no water levels were measured in the Magothy wells at Easton during the synoptic water-level measurement, water levels measured by the Easton water managers in February 1996 (67 to 93 ft below sea level)(M. Gerald Adams, Water and Sewer Department Manager of the Easton Utilities Commission, written commun., 1998) are within the range of simulated values (60 to 100 ft below sea level).

Simulated heads in the Upper Patapsco aquifer match measured heads reasonably well (fig. 45). Measured heads on Kent Island range from 9 to 24 ft below sea level, and simulated heads range from about 12 ft below sea level to 20 ft below sea level. Cones-of-depression at Easton and Cambridge are accurately simulated.

FUTURE SIMULATIONS

The calibrated flow model was used to evaluate the effects of future pumpage on water levels and brackish-water intrusion by entering a range of possible and hypothetical pumpage scenarios, and examining the calculated heads and flux values. Except for Simulation 11, all future simulations were run for the 23-year period from 1998 to 2020, and results were saved for 2010 and 2020. These times correlate with population projections supplied by the counties. Simulation 11 represents a one-year irrigation cycle. Most simulations involved changes in pumpage for the Aquia aquifer, which is the focus of the study, and results are generally described only for the Aquia.

Simulation 1

Simulation 1 represents pumpage increases due to projected population growth. Domestic pumpage from individual wells was increased in accordance with population projections in Queen Anne's and Talbot Counties. Pumpage from public-supply systems was also increased according to pumpage projections supplied by well-system operators if available, or according to population projections if pumpage projections were not available. Commercial and irrigation pumpage was kept at 1997 amounts for this simulation. All pumpage in Kent, Caroline, and Dorchester Counties was also kept the same as 1997 amounts (tab. 6).

The simulated potentiometric surface for the Aquia aquifer in 2020 indicates that the cone-of-depression at Easton will increase in depth to 80 ft below sea level (fig. 46), with a drawdown of 16 ft from the 1997 potentiometric surface (fig. 47). This drawdown is caused by increases in public-supply pumpage at Easton and domestic pumpage in the Easton area. Drawdown on eastern Kent Island was about 2 ft, due to increases in pumpage on the mainland Eastern Shore. Drawdown along the bay shore of Kent Island is near zero because the Chesapeake Bay acts as a recharge boundary. Drawdown in northern Queen Anne's County is near zero because this area is not projected for large growth in population.

Simulation 2

In Simulation 2, pumpage for the entire model was increased by 20 percent over pumpage used in Simulation 1 (tab. 6). Drawdown from the 1997 potentiometric surface in the Aquia aquifer for this simulation is about twice that in Simulation 1 (fig. 48).

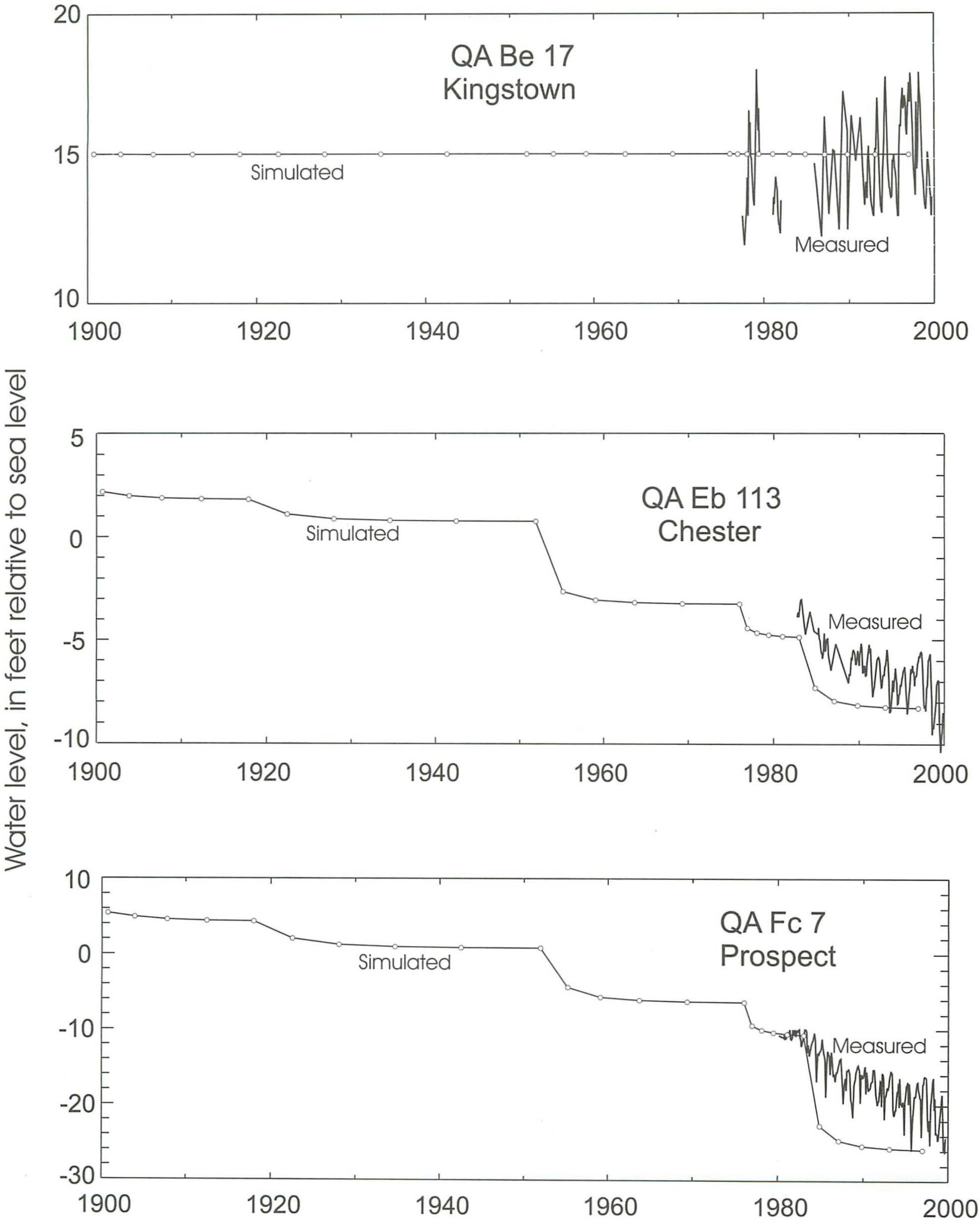


Figure 43. Hydrographs showing simulated and measured water levels in the Aquia aquifer.

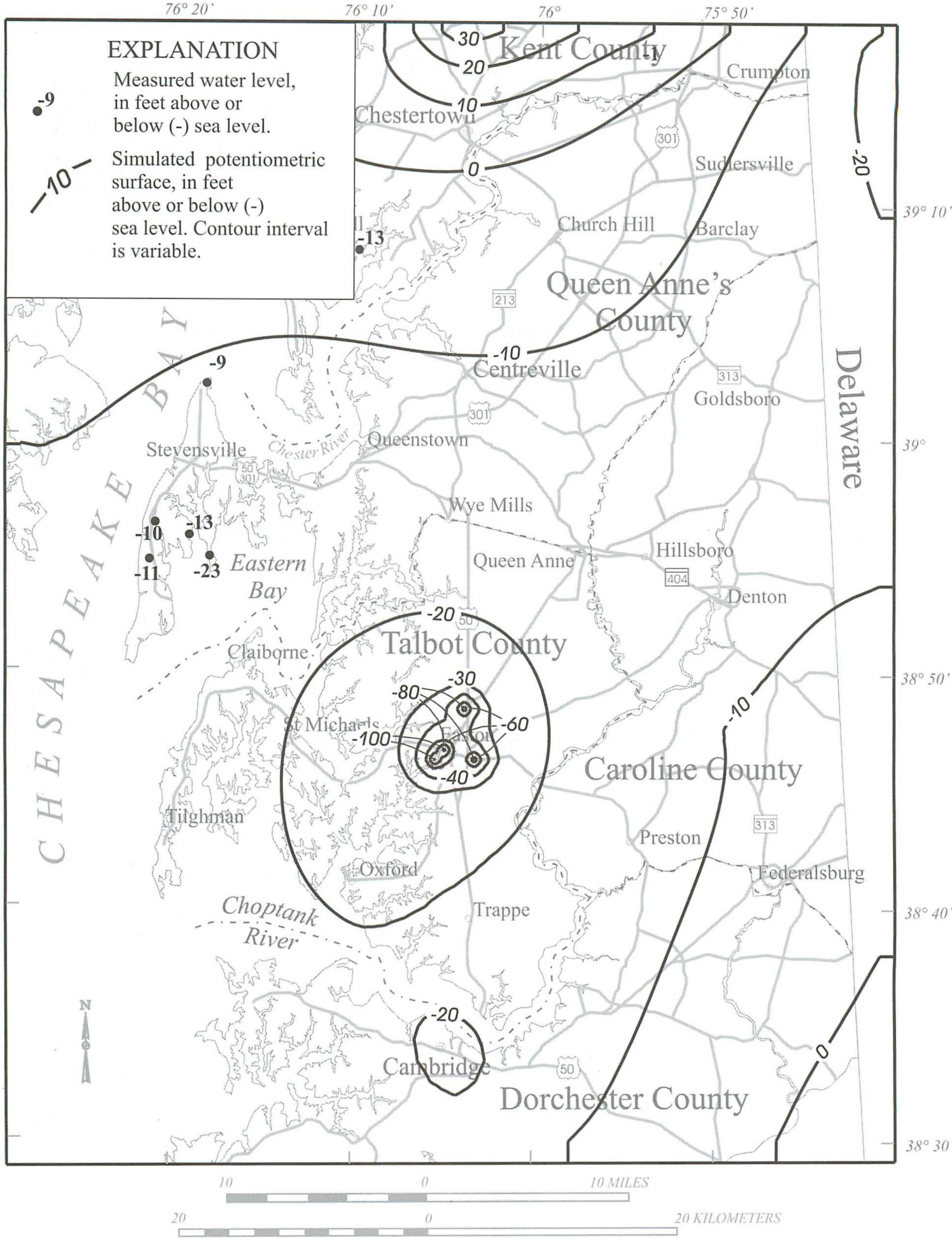


Figure 44. Simulated potentiometric surface and measured water levels in the Matawan/ Magothy aquifer, 1997.

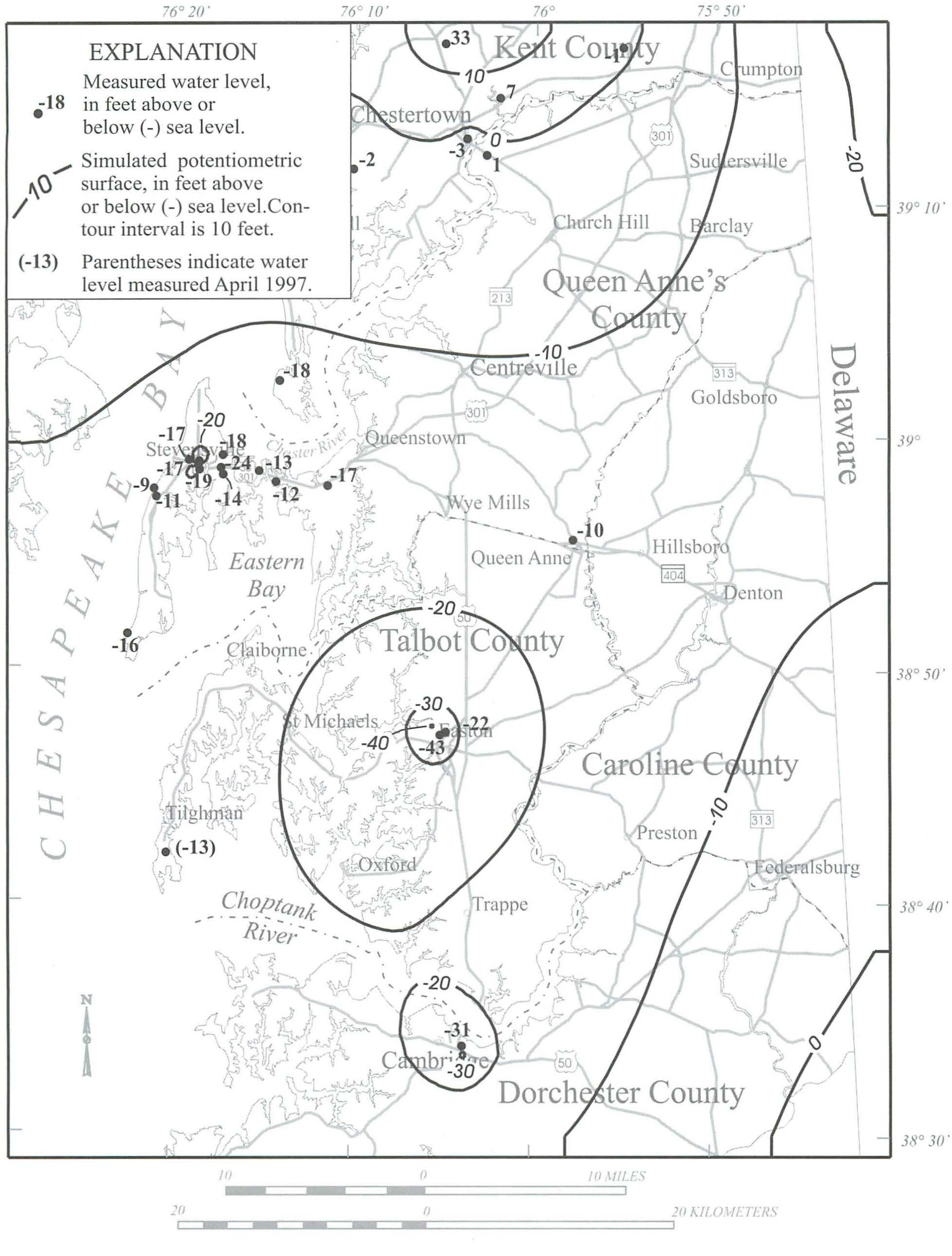


Figure 45. Simulated potentiometric surface and measured water levels in the Upper Patapsco aquifer, 1997.

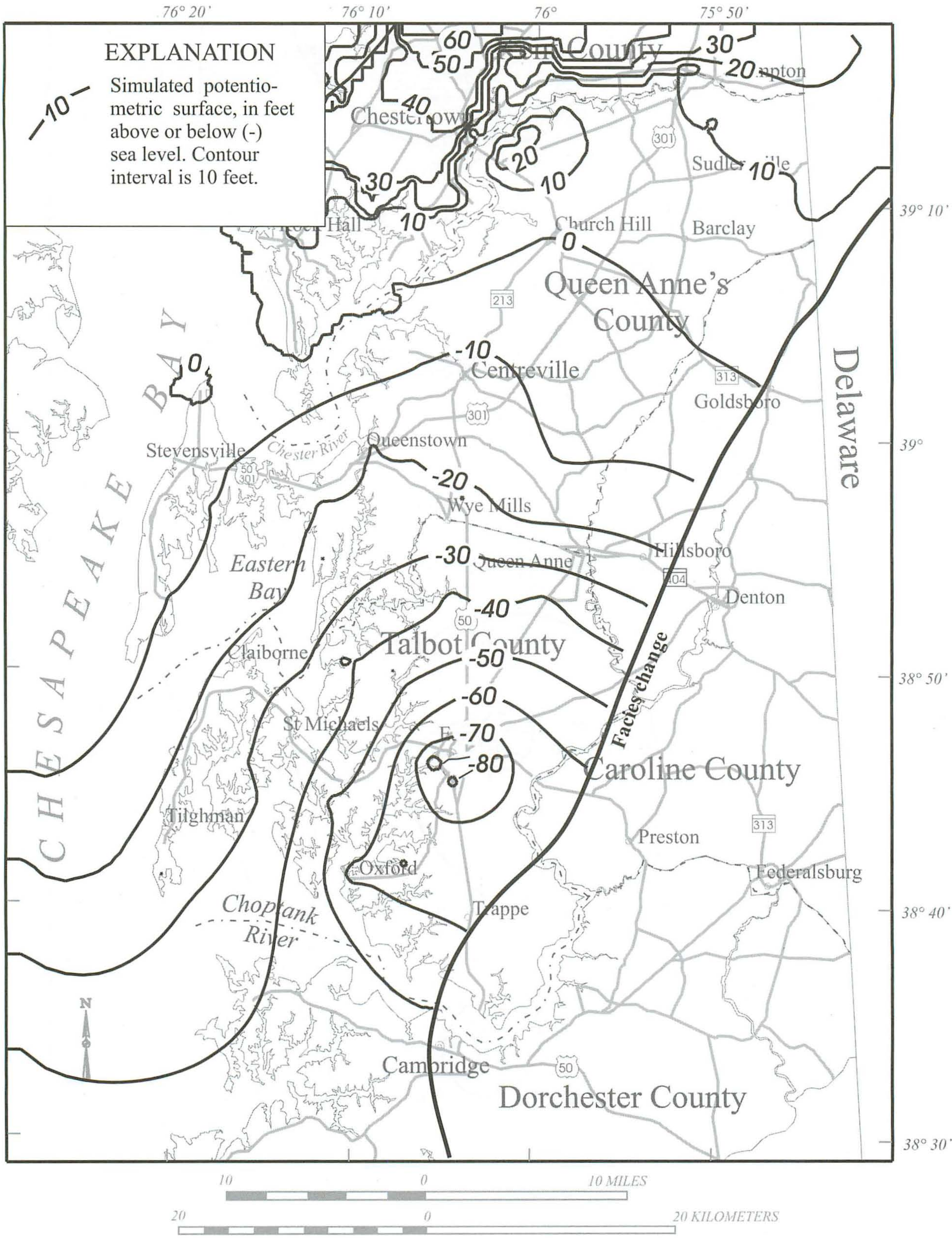


Figure 46. Simulated potentiometric surface in the Aquia aquifer for 2020, based on Simulation 1.

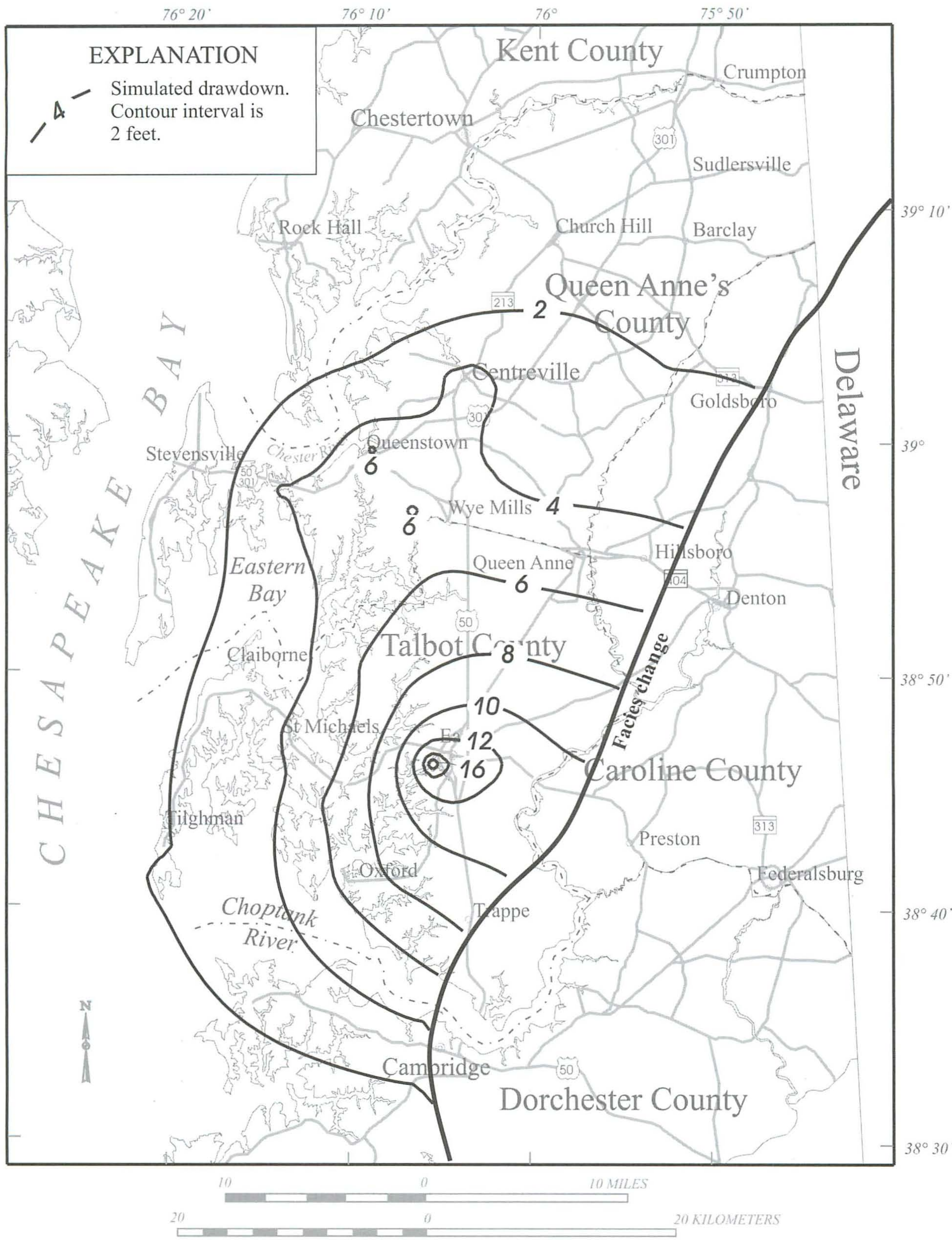


Figure 47. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 1.

The greatest drawdown is about 30 ft, centered at Easton.

Simulation 3

Simulation 3 is similar to Simulation 2, except that all pumpage in the entire model area was decreased by 20 percent from pumpage used in Simulation 1 (tab. 6). Drawdown in the Aquia aquifer for this simulation is negative in most of the model area, indicating that water levels are recovering from 1997 levels (fig. 49).

Simulation 4

In Simulation 4, all pumpage in the model area was increased by 100 percent over pumpage used in Simulation 1 (tab. 6). This condition is not at all likely to occur. The simulation could be considered an upper extreme of pumping conditions, which helps provide a perspective for the other, more realistic simulations.

Drawdown in the Aquia aquifer for this simulation is greater than 90 ft in the Easton area and 70 ft near Oxford (fig. 50). On eastern Kent Island drawdown is about 15 ft, and along the bay shore of Kent Island drawdown ranges from about 1 ft at Love Point to 6 ft at Kent Point.

Simulation 5

In Simulation 5, all major Ground-water Appropriation Permit (GAP) users (greater than 10,000 gpd) were pumped at their average yearly GAP appropriations (tab. 6). The average yearly GAP appropriation is the maximum pumpage allowed per year, expressed as a daily pumpage rate. Many users pump at rates well below their average GAP appropriations (some did not pump at all in 1997), so the total model pumpage in this simulation is much greater than the 1997 amount.

Drawdown in the Aquia aquifer is greater than 40 ft in northern Talbot County, 35 ft at Easton, and 30 ft in northern Queen Anne's County (fig. 51). Areas of greatest drawdown are centered at users that have large appropriations but were not pumping at appropriated capacity in 1997. Heads in the Aquia aquifer are as great as 100 ft below sea level for this simulation, centered at Easton (fig. 52). Heads in the Aquia aquifer on western Kent Island remain near sea level, because large users pumping from the Aquia aquifer in the Kent Island area were pumping at their appropriated capacities in 1997, and because the Chesapeake Bay acts as a recharge boundary.

Simulation 6

In Simulation 6, two hypothetical wells were added in the Aquia aquifer on easternmost Kent Island, pumping 250,000 gpd each (tab. 6). These wells represent an expansion of the public-supply system, and the locations were chosen to minimize the impact on brackish-water intrusion by placing them as far from the Chesapeake Bay shore as possible. The wells are in Water Management Zone A, and the addition would be prohibited under the current restrictions.

Drawdown around the hypothetical supply wells is about 10 ft, and drawdown along the Chesapeake Bay shore is about 1 ft (fig. 53). Drawdown elsewhere in the study area is about the same as in Simulation 1.

Simulation 7

In Simulation 7, pumpage was increased in Water Management Zone B (fig. 1) by 1 MGD by adding 10 hypothetical wells in the Aquia aquifer, each pumping 100,000 gpd (tab. 6). All other pumpage in the model area was identical to Simulation 1. The purpose of this simulation is to evaluate the impact on brackish-water intrusion of allowing a significant amount of additional pumpage in the area where water-use restrictions currently prohibit new pumpage appropriations over 1,000 gpd. Although state and county officials do not currently have plans to implement these changes, this hypothetical scenario would ease restrictions in an area that may not affect brackish-water intrusion as severely as areas farther west.

Drawdown in the Aquia aquifer is as much as 25 ft in the Grasonville area and 20 ft at Easton (fig. 54). This simulation indicates drawdowns at Easton about 4 ft greater than in Simulation 1, and drawdowns on eastern Kent Island about 3 ft greater than in Simulation 1. Drawdown along the bay shore of Kent Island is about 1 ft.

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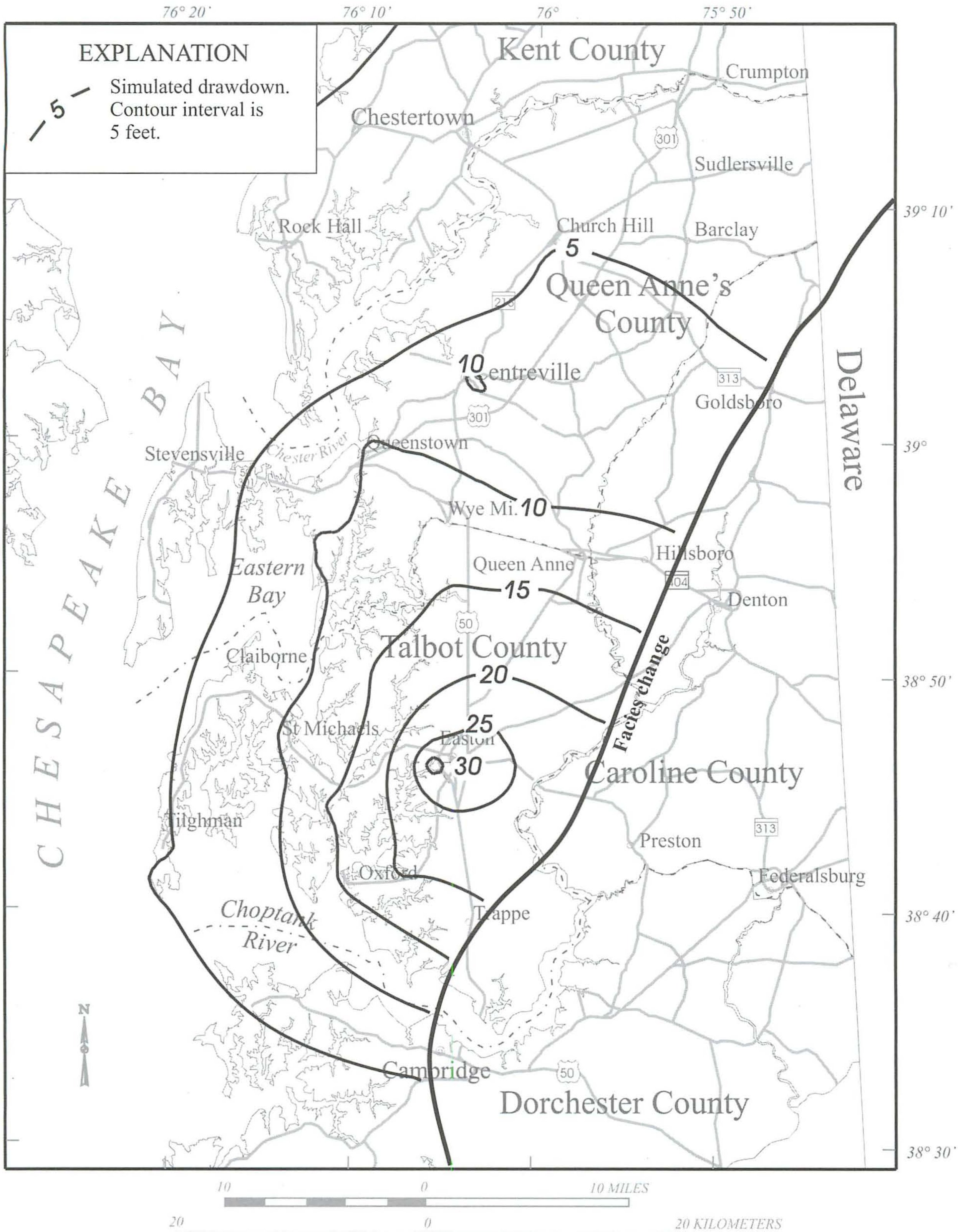

Figure 48. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 2.

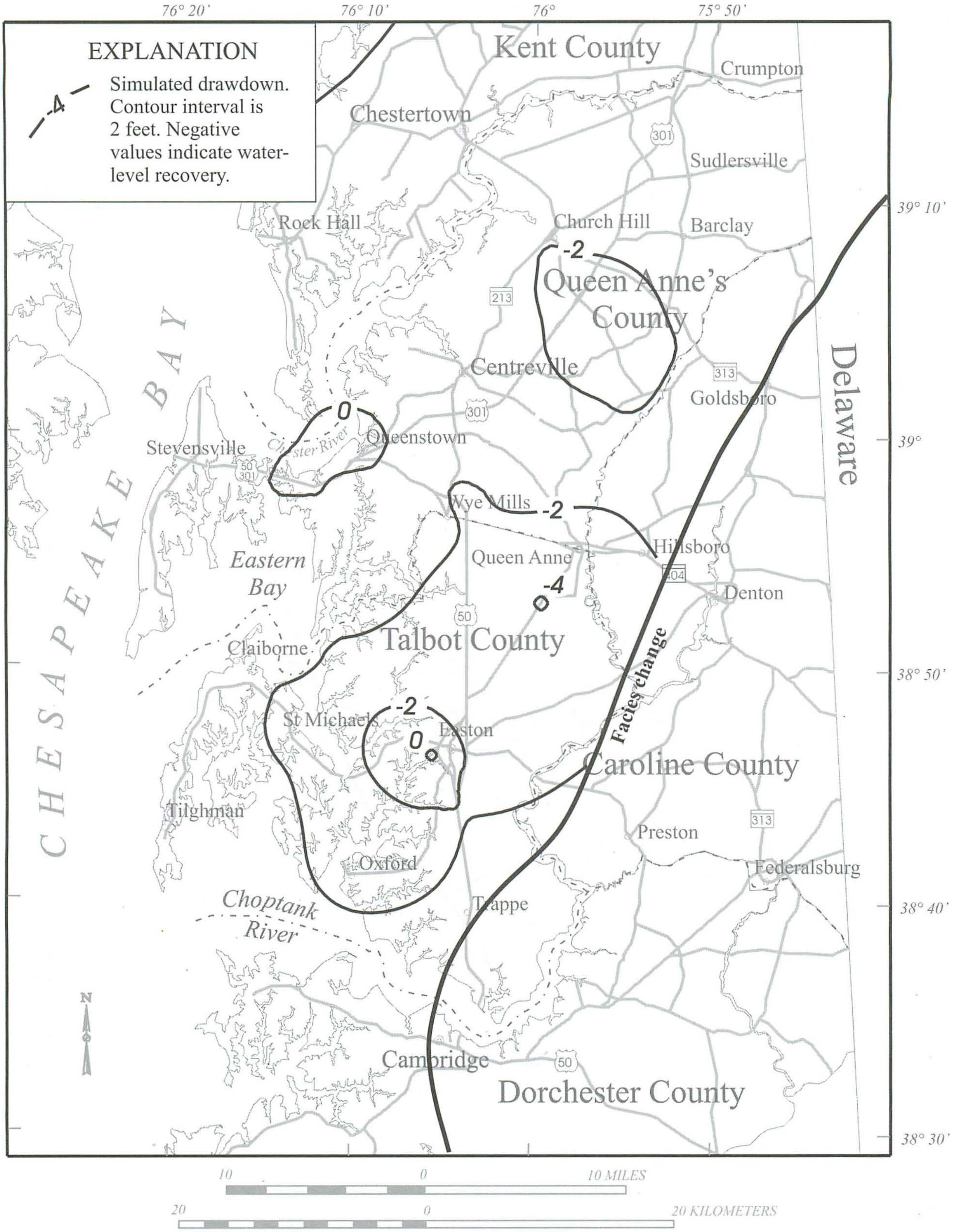

Figure 49. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 3.

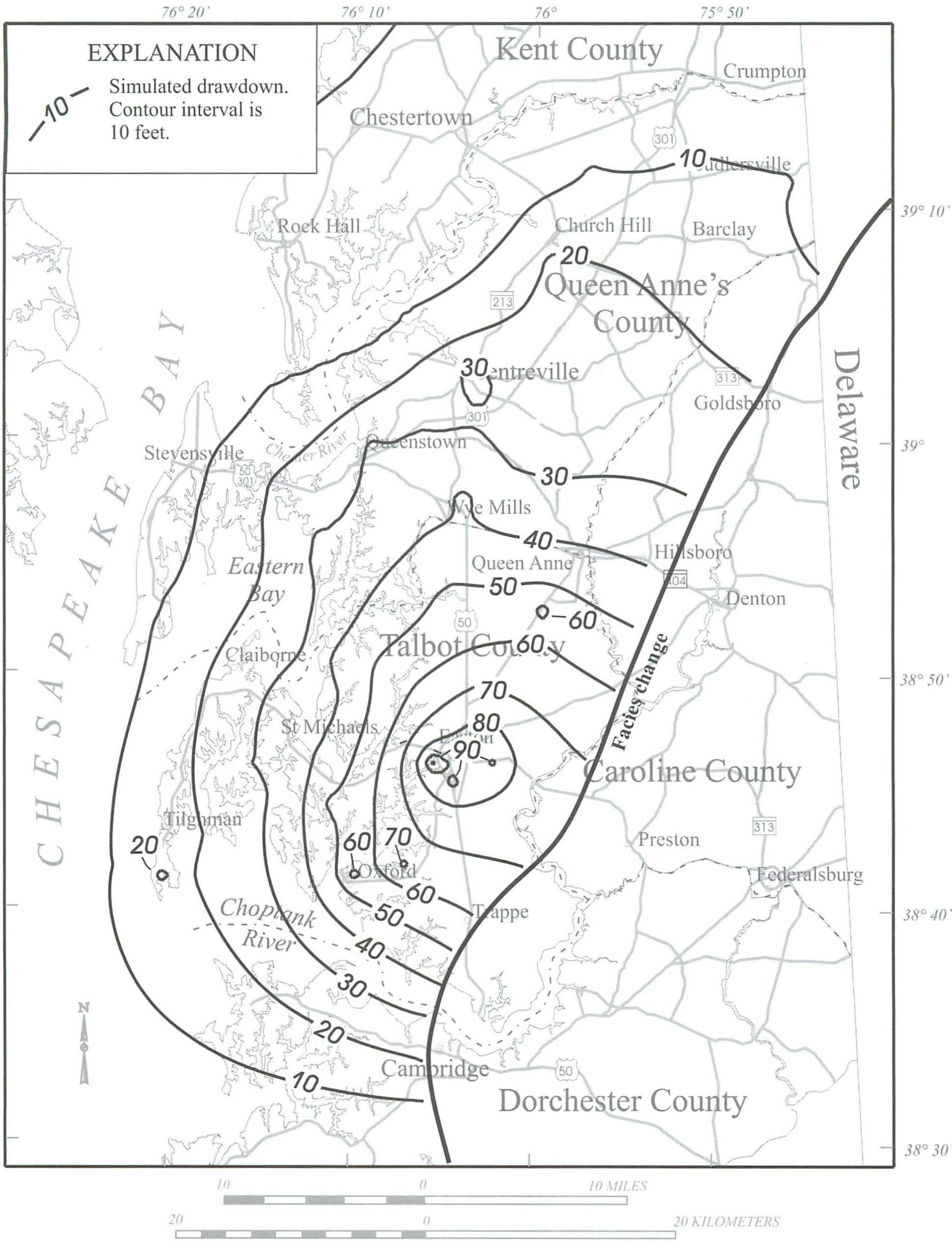

Figure 50. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 4.

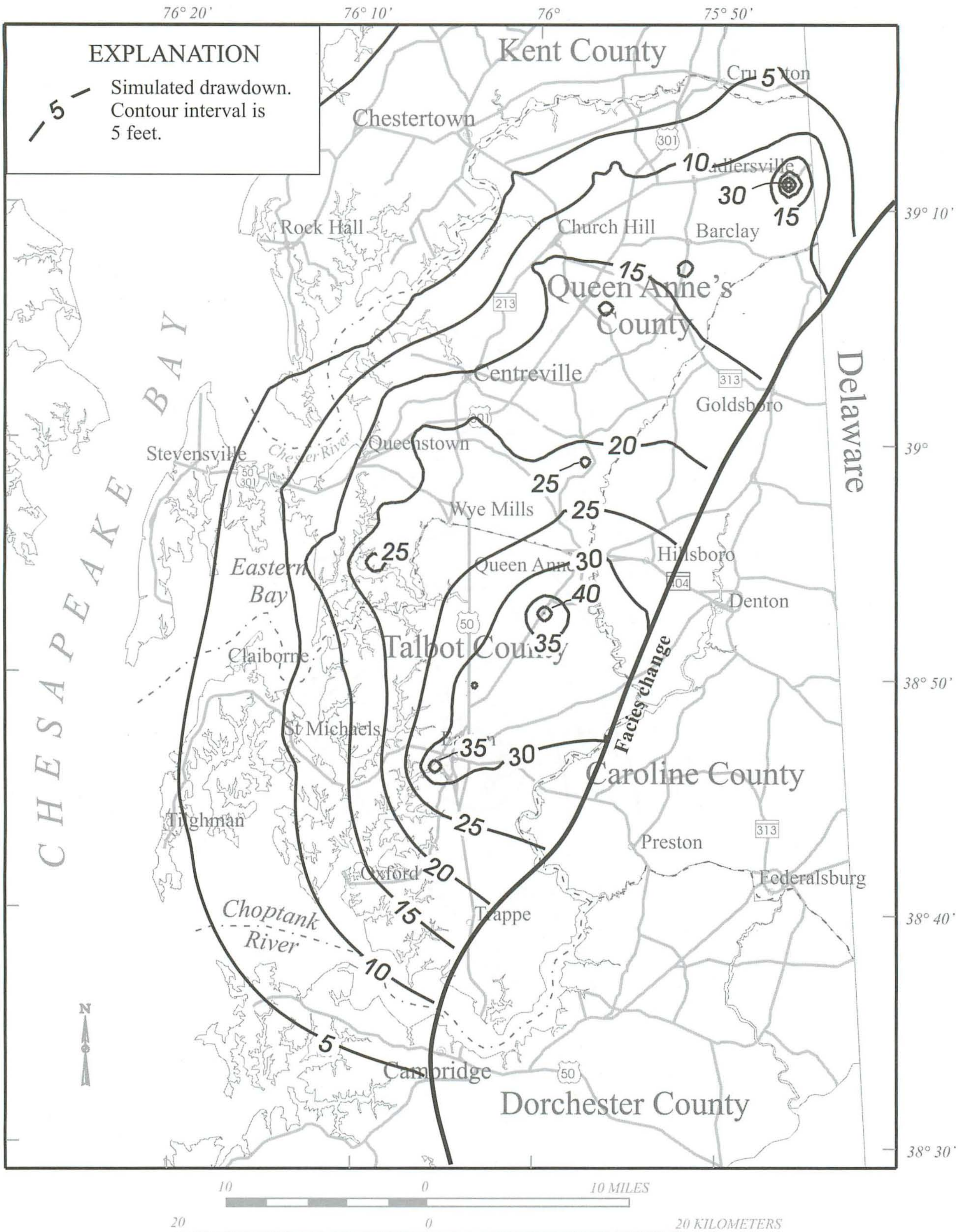

Figure 51. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 5.

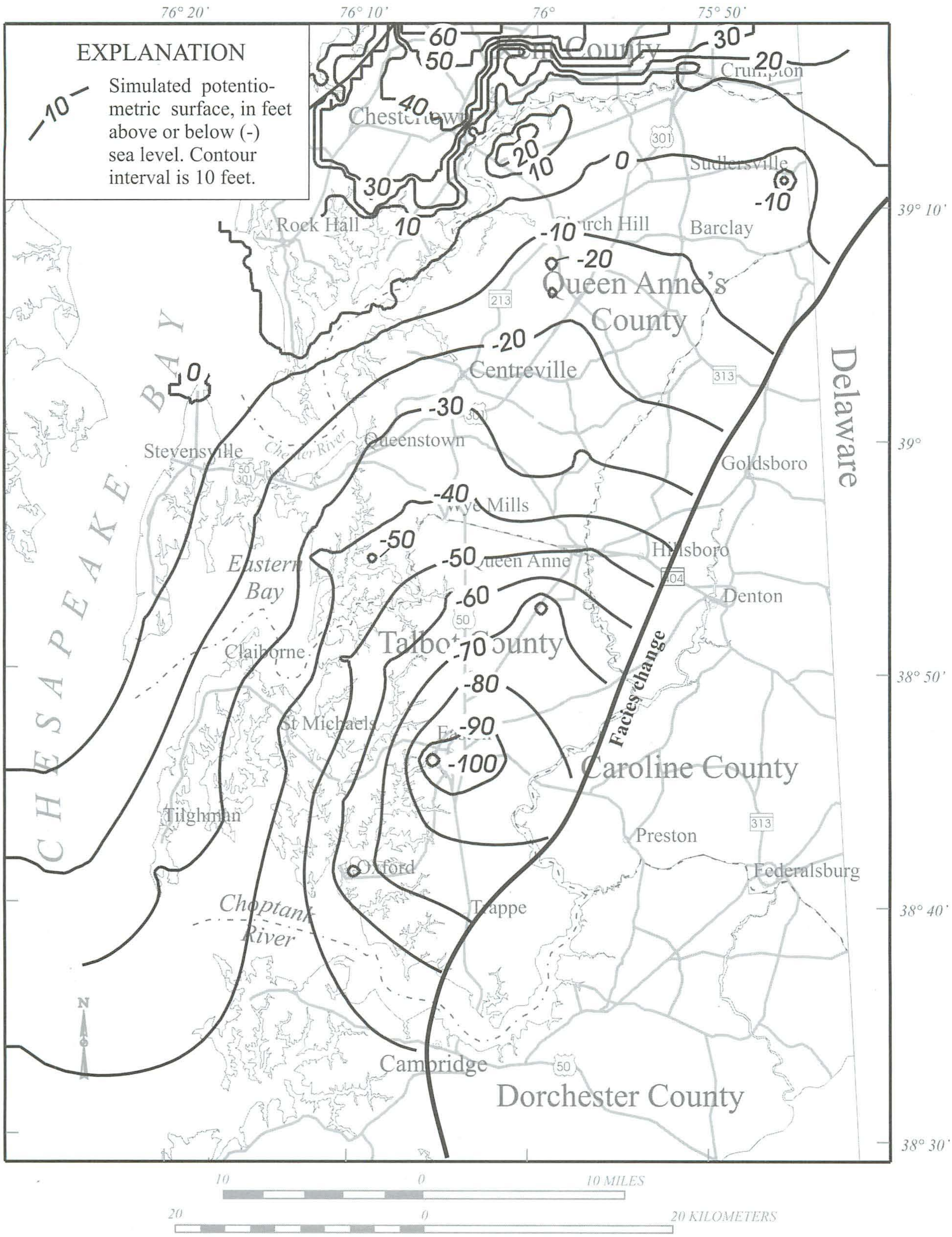

Figure 52. Simulated potentiometric surface in the Aquia aquifer for 2020, based on Simulation 5.

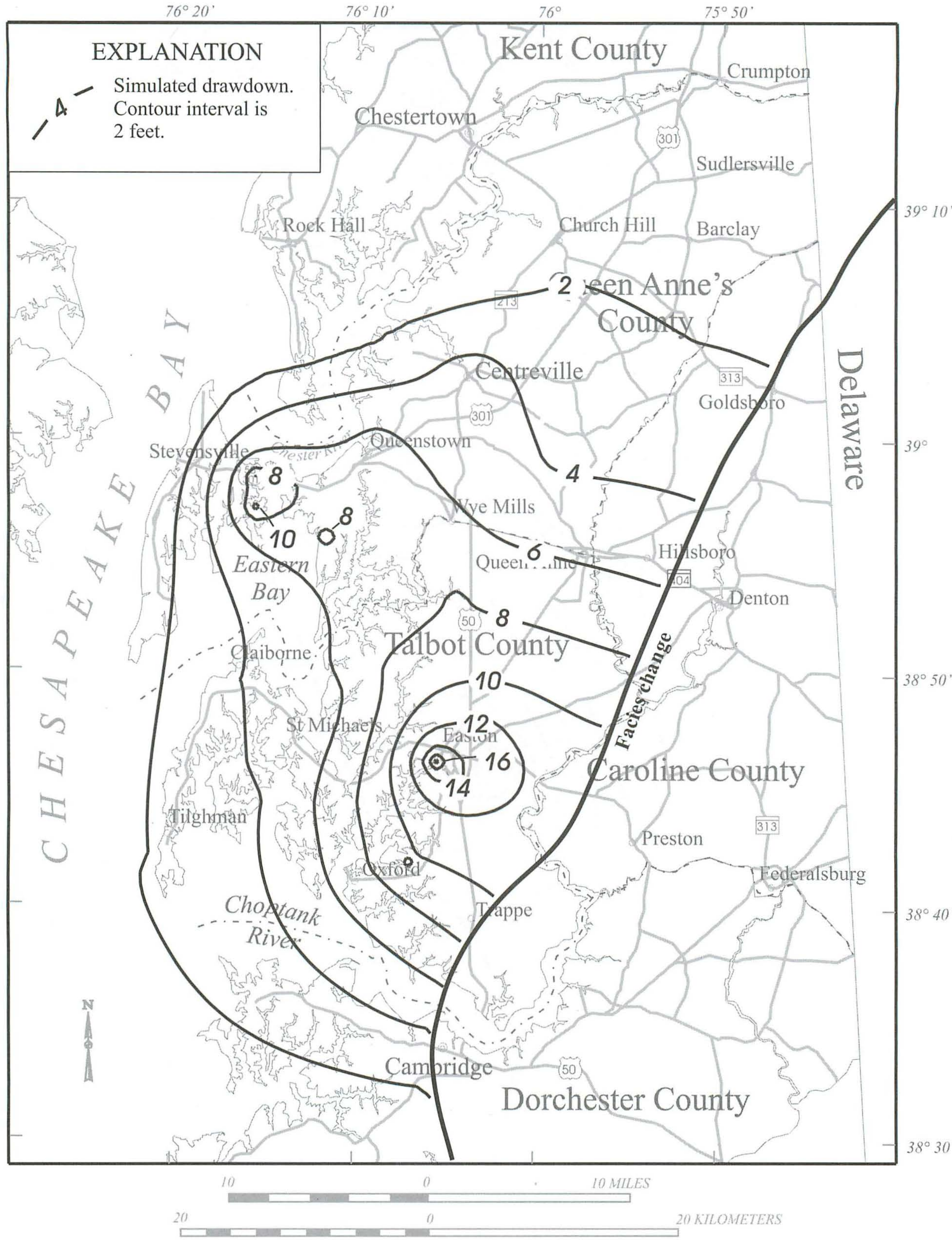

Figure 53. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 6.

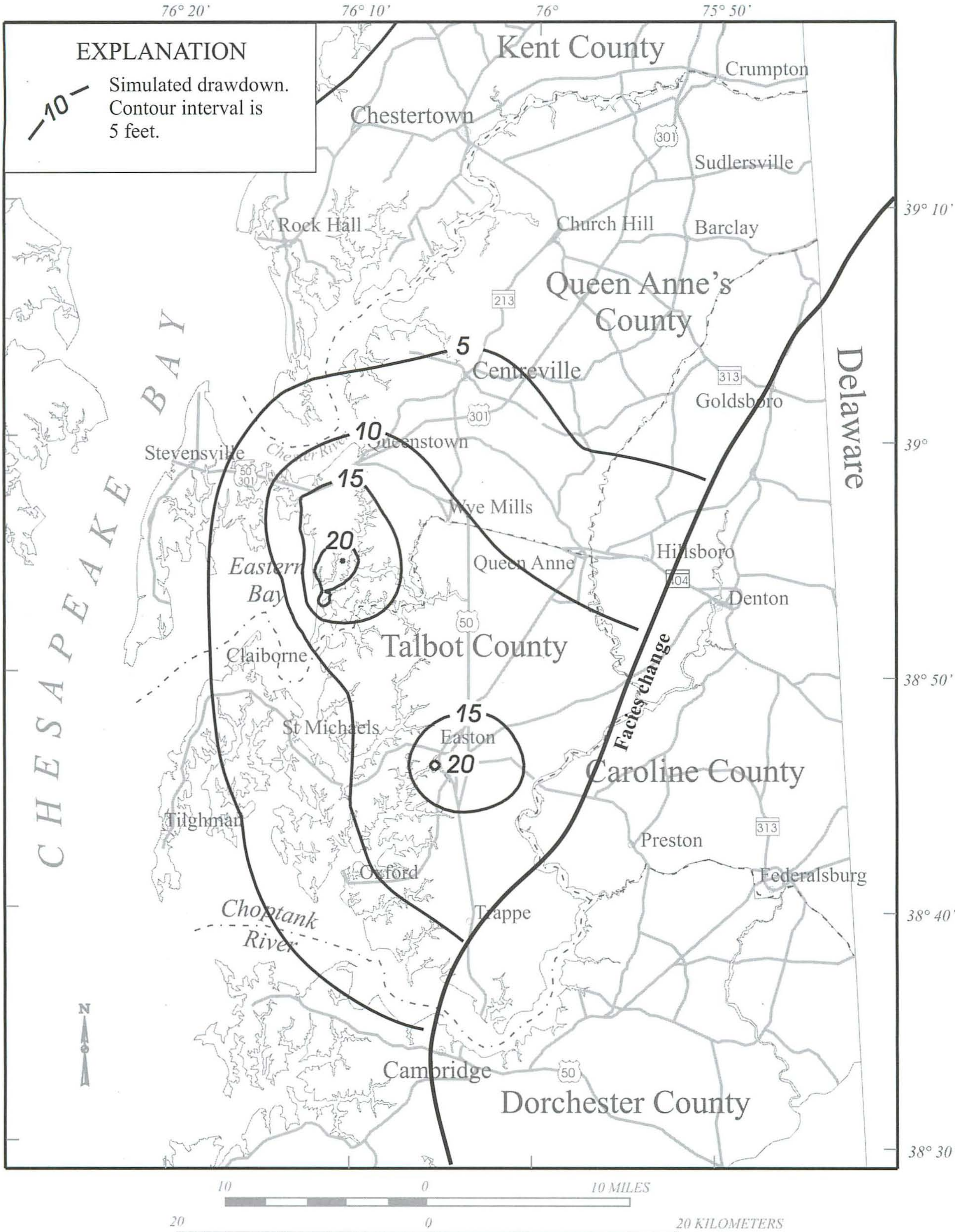

Figure 54. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 7.

Simulation 8

In Simulation 8, the public-supply withdrawals at Easton, St. Michaels, Oxford, Centreville, Queenstown, and Prospect Plantation were shifted from the Aquia aquifer to the Upper Patapsco aquifer (tab. 6). Although water-system operators at these sites do not intend to make these shifts, the simulation is useful to evaluate the influence of the region's major Aquia users on brackish-water intrusion. If it became necessary to reduce pumpage from the Aquia aquifer, it would be more economically feasible overall to shift pumpage to deeper aquifers for a few major users than for numerous smaller users.

Drawdown in the Aquia aquifer in most of the study area is negative, which indicates that water levels are recovering from 1997 conditions (fig. 55). Water-level recovery is about 20 ft at Easton and Oxford, 10 ft at St. Michaels, and 5 ft at Prospect and Centreville. Drawdown at Queenstown is near zero, because increases in domestic pumpage in the area offset the decrease for the town supply.

Drawdown in the Upper Patapsco aquifer is about 15 ft at Easton and 20 ft at Centreville (fig. 56). The area in which drawdown is greater than 5 ft in the Upper Patapsco aquifer encompasses most of western Queen Anne's and Talbot Counties.

Simulation 9

In Simulation 9, all irrigation pumpage in Queen Anne's and Talbot Counties was doubled over pumpage used in Simulation 1 (an increase of 100 percent) (tab. 6). Pumpage at farms, golf courses, and nurseries was considered irrigation for this simulation. All other pumpage (including irrigation pumpage in Caroline, Kent, and Dorchester Counties) was identical to that in Simulation 1. The additional pumpage was distributed among 15 new sites (fig. 39) in Queen Anne's County pumping 187,000 gpd and 10 new sites in Talbot County pumping 93,500 gpd. The new sites do not represent real farms, but an attempt was made to locate them in agricultural areas. The hypothetical withdrawals were placed in the Aquia aquifer except in southern Talbot County where the Aquia is absent; in this area the withdrawals were placed in the Piney Point or Miocene aquifers.

Drawdown in the Aquia aquifer is as much as 35 ft in northeastern Talbot County, and 30 ft in southeastern Queen Anne's County (fig. 57). Drawdowns are greatest around the hypothetical irrigation wells, but generally, drawdowns are 5 to 20 ft greater than in Simulation 1. Drawdown is about 5 ft on eastern Kent Island and 1 ft along the bay shore of Kent Island.

Simulation 10

Simulation 10 is similar to Simulation 9, except that irrigation pumpage in Queen Anne's and Talbot Counties was quadrupled over pumpage used in Simulation 1 (an increase of 300 percent) (tab. 6). Locations and aquifer designations for hypothetical production wells is the same as in Simulation 9, but wells in Queen Anne's County pumped at a rate of 561,000 gpd and wells in Talbot County pumped at a rate of 280,500 gpd.

Drawdown exceeds 90 ft in northeastern Talbot County, and 80 ft south of Oxford and southeastern Queen Anne's County (fig. 58). As in Simulation 9, drawdowns are greatest around the hypothetical irrigation wells. In general, drawdowns are 40 to 60 ft greater in this simulation than in Simulation 1. Drawdown is greater than 10 ft on western Kent Island and 2 to 4 ft along the bay shore.

The simulated potentiometric surface for the Aquia aquifer is shown in figure 59. Heads are as much as 120 ft below sea level at several hypothetical pumping sites in Talbot County and 100 ft below sea level in southeastern Queen Anne's County. Heads have declined to 10 ft below sea level along the southern bay shore of Kent Island. Heads are below sea level in the entire study area, except for extreme northern Queen Anne's County, near the Chester River, where the Aquia aquifer subcrops and water-table conditions prevail.

Comparison with figure 25 shows that, even with very high pumpage rates and extreme drawdowns, water levels simulated by the model do not exceed or even approach the 80-percent drawdown limits. An additional 330 ft of drawdown is available in the Easton area, 80 ft at Centreville, and 70 ft at Stevensville.

Simulation 11

Simulation 11 is a 1-year simulation that simulates the yearly irrigation cycle. It is divided into three stress periods, from January to May, June to August, and September to December. The first (11a) and third (11c) stress periods include all pumpage from the

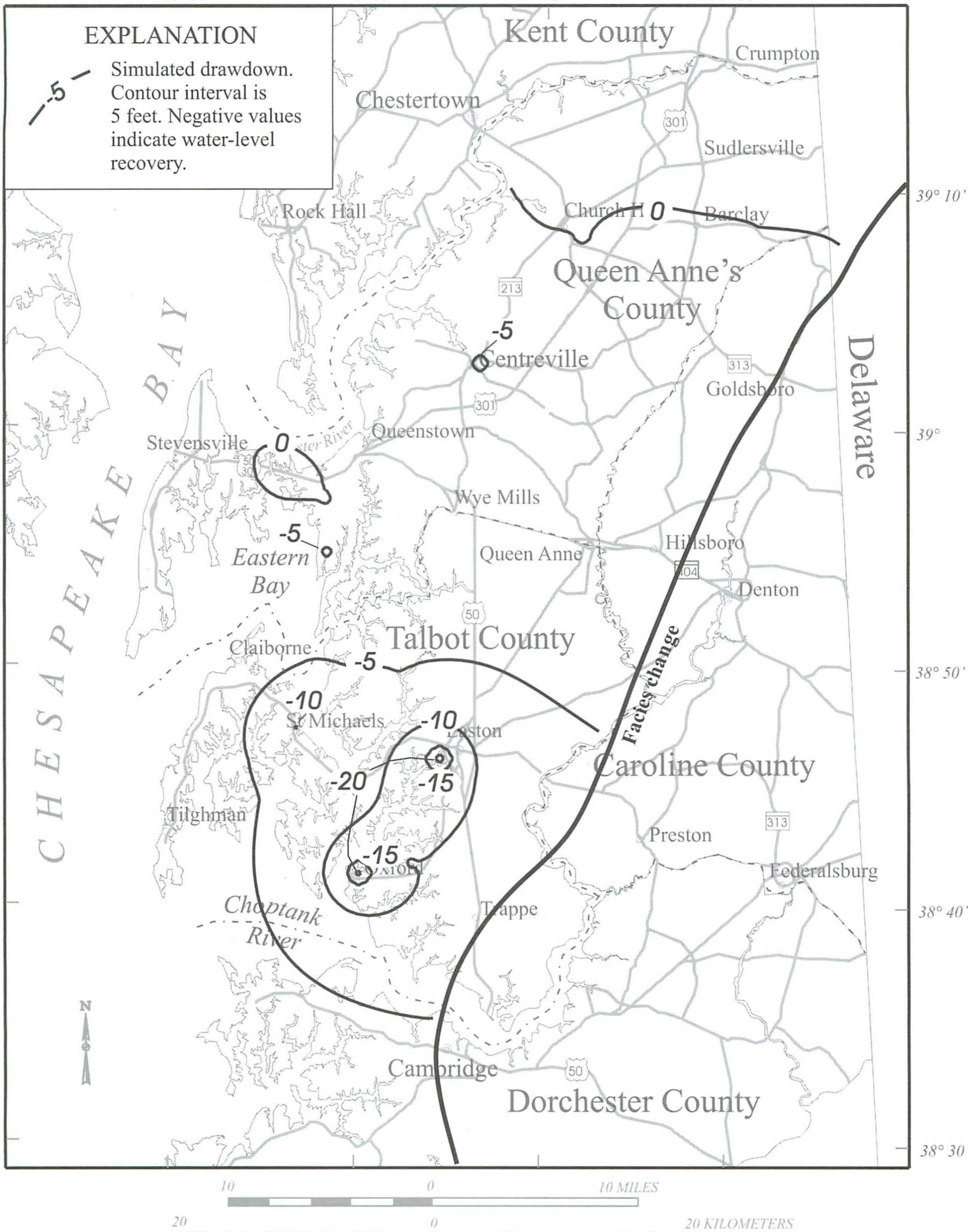

Figure 55. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 8.

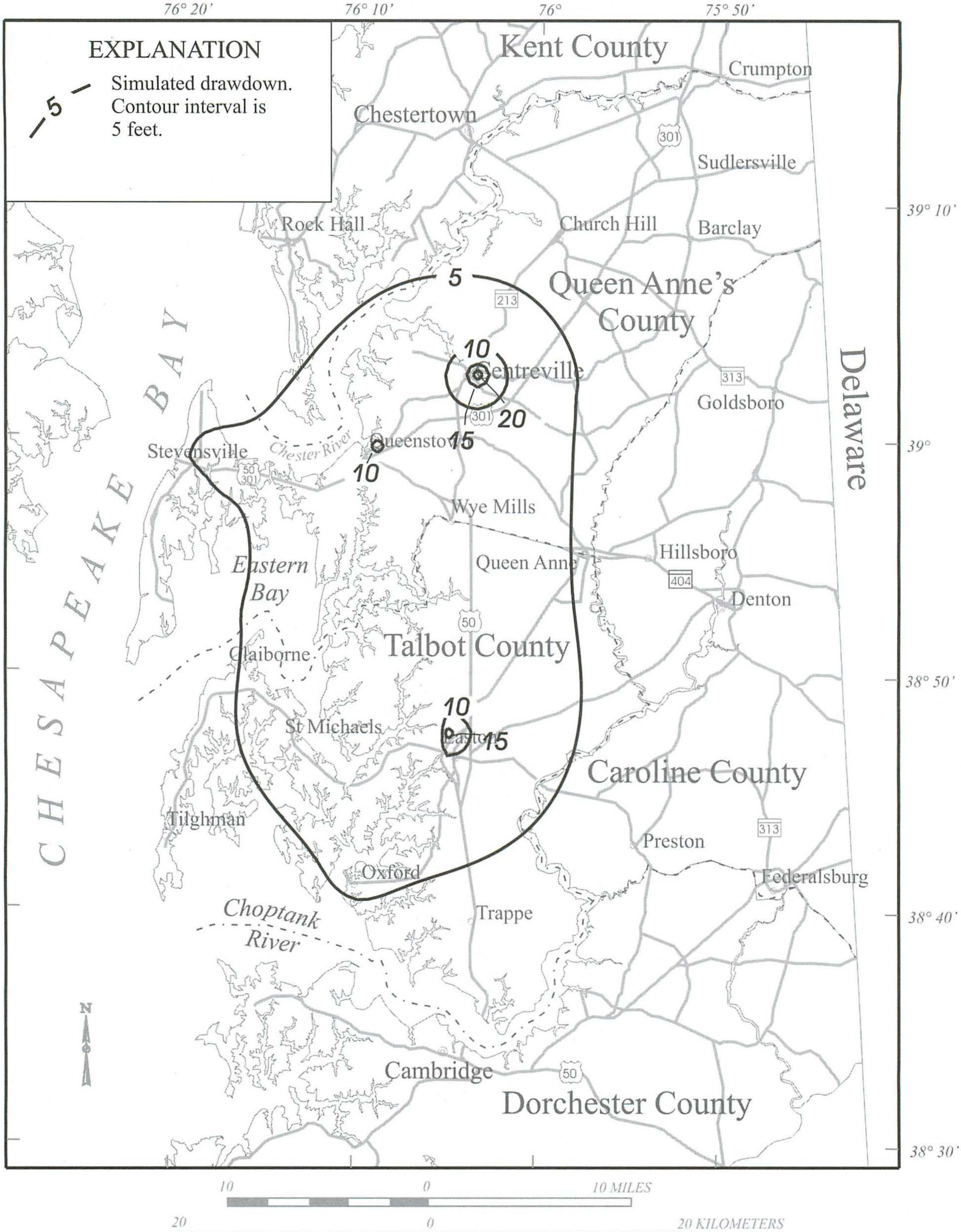

Figure 56. Simulated drawdown in the Upper Patapsco aquifer, 1997 to 2020, based on Simulation 8.

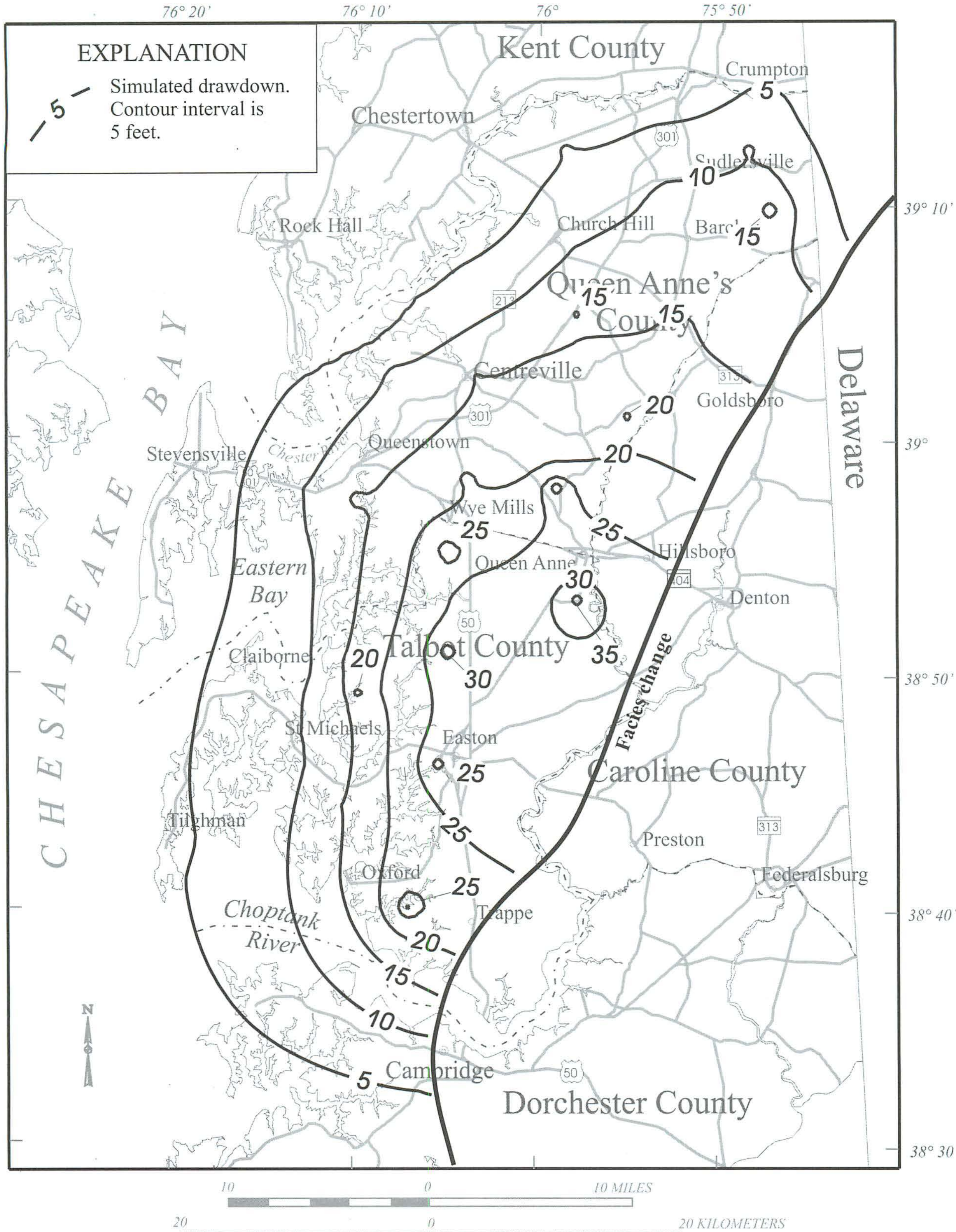

Figure 57. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 9.

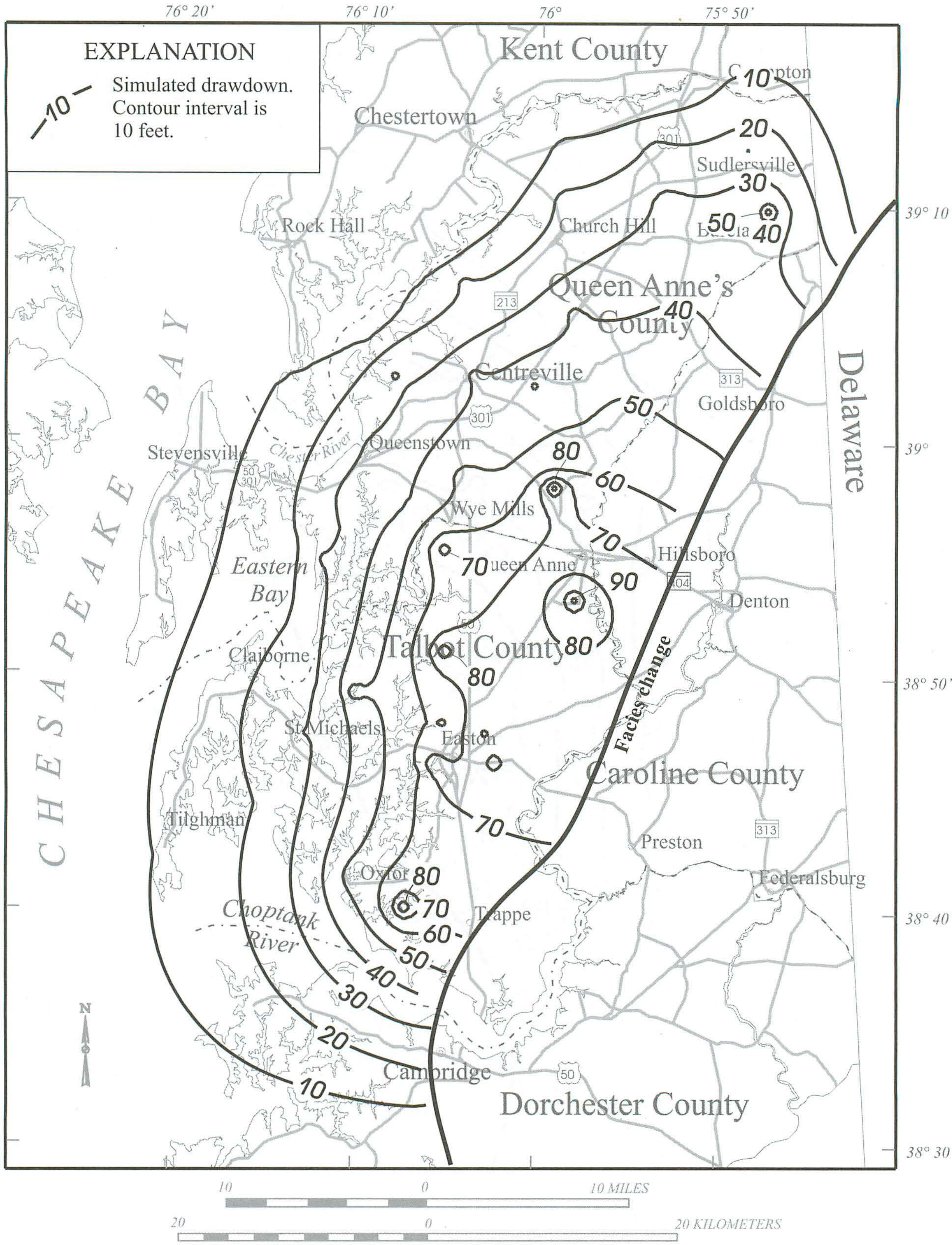

Figure 58. Simulated drawdown in the Aquia aquifer, 1997 to 2020, based on Simulation 10.

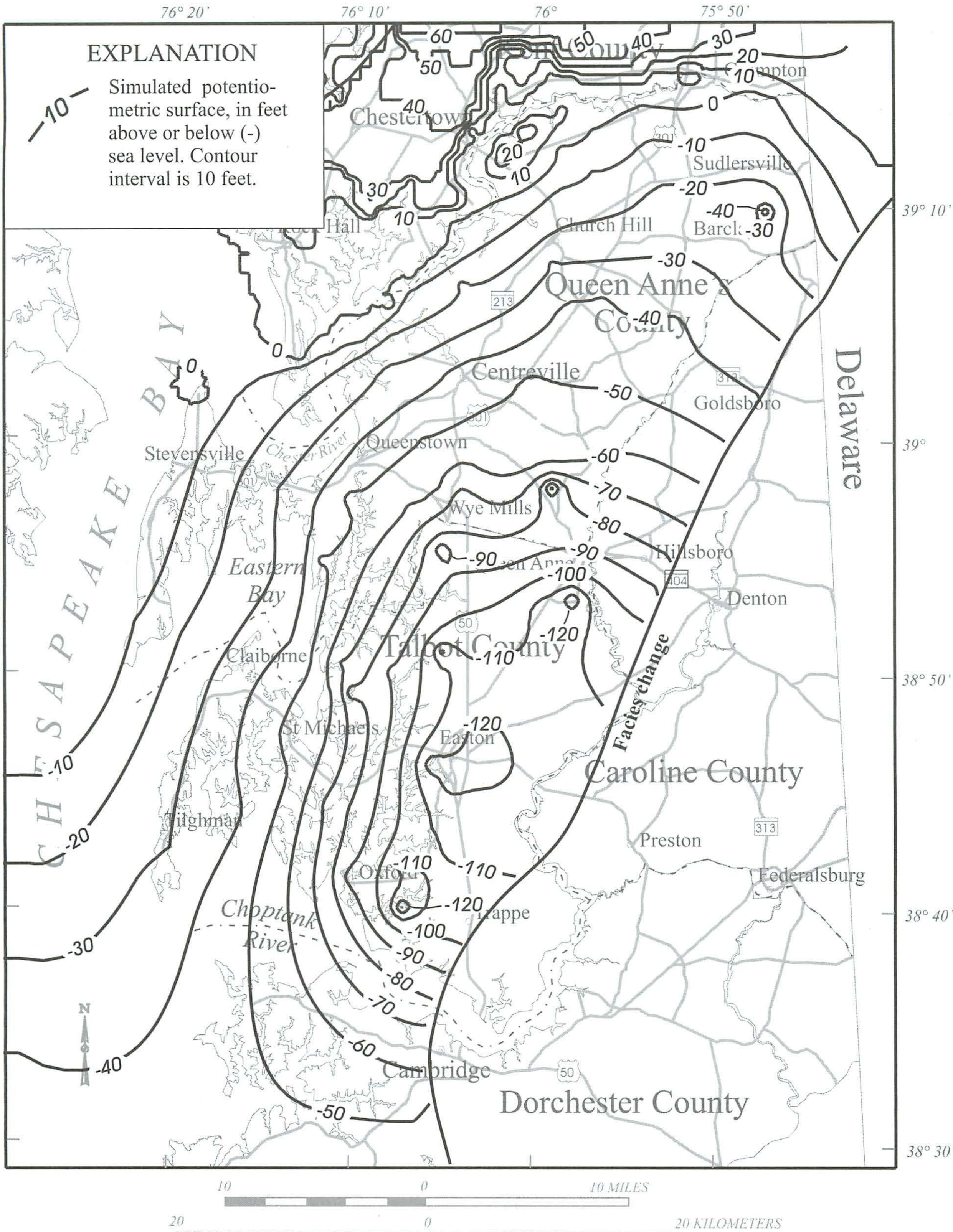

Figure 59. Simulated potentiometric surface in the Aquia aquifer for 2020, based on Simulation 10.

1997 calibration run, but exclude irrigation pumpage. The second stress period (11b) includes all pumpage from the 1997 calibration run, with the total reported irrigation pumpage withdrawn in the 3-month period. Yearly averages for 1997 irrigation pumping rates were multiplied by four to obtain correct rates during the irrigation season.

Drawdown in the Aquia aquifer at the end of the irrigation season is as much as 35 ft in southern Queen Anne's County, and 25 ft in central Queen Anne's County. Drawdown in the Aquia aquifer is less than 5 ft in Talbot County, because most of the irrigation pumpage in Talbot County is from shallower aquifers. By the end of the simulation (one year) water levels had recovered to within 2 ft of heads at the beginning of the simulation. The potentiometric surface is 60 ft below sea level at Wye Mills and Easton, but is well above the 80-percent management surface (fig. 25).

POTENTIAL FOR MIGRATION OF THE BRACKISH-WATER INTERFACE IN THE AQUIA AQUIFER

The potential for increased pumpage to induce movement of the brackish-water interface in the Aquia aquifer was evaluated using the calibrated flow model. Simulated flux across the brackish-water interface was calculated for each stress period in the historical calibration period, and each future simulation. The simulated flux values for the future simulations were compared with each other to determine the relative potential for each pumping scenario to cause brackish-water movement. The flow model does not simulate solute transport, so cannot be used directly to determine encroachment rates of the brackish-water interface. Assuming that the brackish-water interface will move inland in response to increasing head gradients in that direction, the flux calculations provide a qualitative means of comparing the potential impact of various future pumping scenarios.

The brackish-water interface on Kent Island was divided into three sections (fig. 61) which correspond to the three zones (fig. 35) delineated along the shoreline for brackish-water trends. Zone 1 is the northern section, Zone 2 is the central section, and Zone 3 is the southern section. The cross-sectional area of each section is shown in table 11. The advective flow velocity was calculated using the following equation:

$$v = \frac{q}{An}$$

where,

v = velocity (L/T)
q = flux (L^3/T)
A = area (L^2)
n = porosity (dimensionless)

Simulated flux for each section was divided by cross-sectional area, and by an estimated porosity value of 0.25 (Drummond, 1988) to calculate flow velocity for inland movement of ground water. Flow velocities for each section, and weighted average velocity for the entire interface, may be compared for each model simulation to assess the potential for brackish-water intrusion. These velocity estimates are for average or "Darcian" flow, and do not directly indicate velocity of movement of the brackish-water interface.

Simulated flow velocities range from -2.6 ft/yr for Zone 1 in the pre-pumping calibration period to 29.6 ft/yr for section 2 in Simulation 4. Negative flow velocities indicate water moving westward, from Kent Island toward the Chesapeake Bay. Average velocities for the entire interface range from -1.9 ft/yr for the prepumping calibration period to 24.5 ft/yr for Simulation 4.

All future simulations produce positive flux values, which indicates that ground water will move inland in all of the pumpage scenarios. Even Simulation 3, in which projected pumpage values (Simulation 1) were reduced by 20 percent, produced landward flow. Simulation 2, which simulated 20 percent more pumpage than Simulation 1, produced about 21 percent more flux than Simulation 1. Simulations 2, 5, 7, and 9 produced about the same amount of flux (between 190,000 and 216,000 ft^3/d). This indicates that adding 1 MGD pumpage from the Aquia aquifer at Grasonville would have about the same impact on movement of the brackish-water interface as doubling the irrigation pumpage in Queen Anne's and Talbot Counties (an increase of 3.7 MGD). Although the increase in pumpage in Simulation 9 was almost four times as great as in Simulation 5, the pumpage is farther from the interface, and some is withdrawn from other aquifers besides the Aquia.

Quadrupling irrigation pumpage (Simulation 10) in Queen Anne's and Talbot Counties (an increase of 11.2 MGD) would have a far greater impact on any

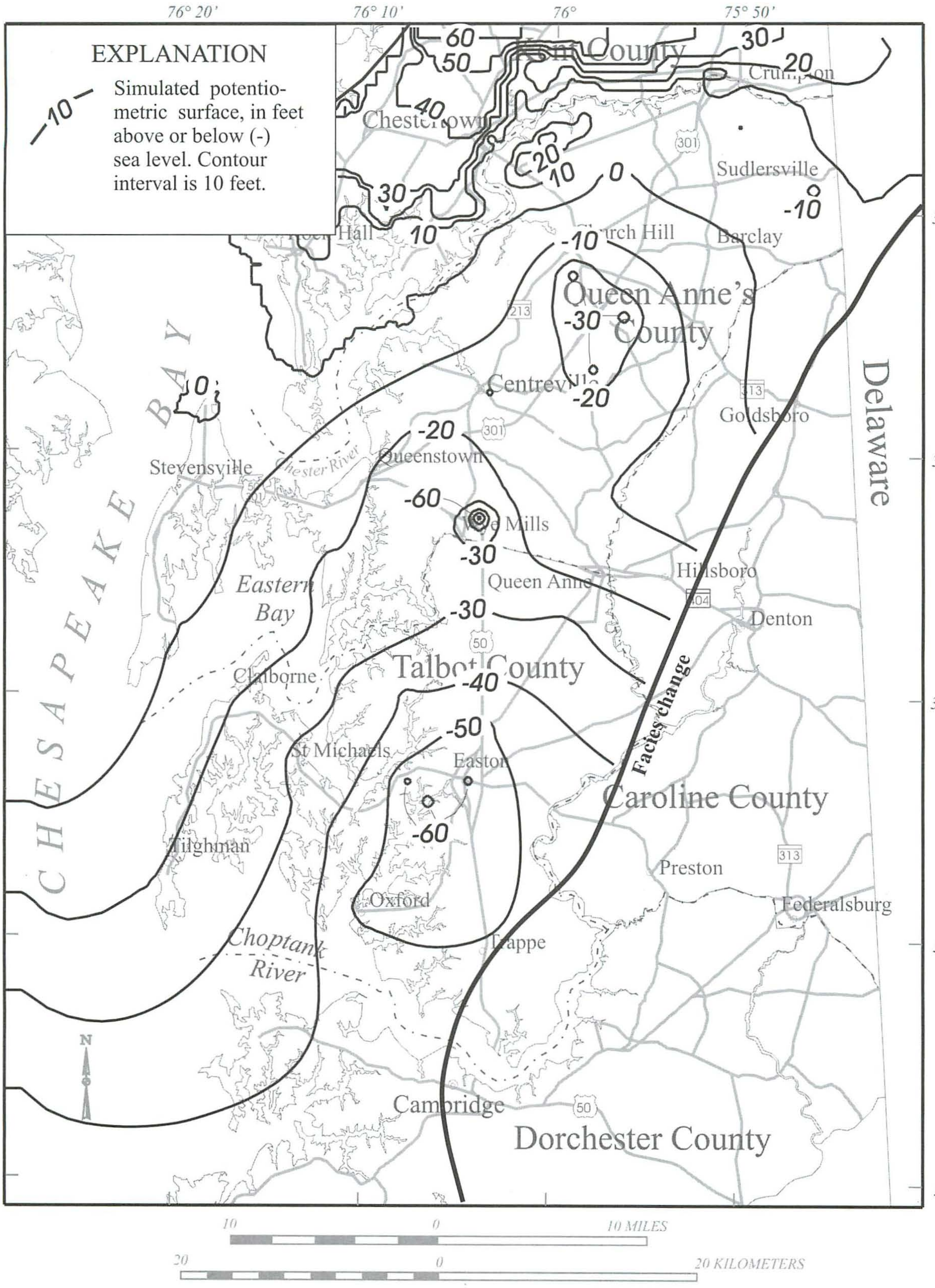

Figure 60. Simulated potentiometric surface in the Aquia aquifer at the end of the irrigation cycle, based on Simulation 11b.

Table 11. Flux rates for flow-model simulations in the Aquia aquifer

[ft^3/d = cubic feet per day; ft^2 = feet squared]

Historical calibration

Zone	Area (x 10^6 ft^2)	Flux rate, in thousand ft^3/d				
		1918	1953	1976	1984	1997
1	5.84	-10.39	-7.90	-7.53	13.64	21.09
2	9.12	-12.09	-1.57	46.16	68.17	84.92
3	5.01	-4.06	3.97	22.79	34.93	46.74
Total	19.97	-26.54	-5.5	61.42	116.75	152.74

Future simulations

Zone	Flux rate, in thousand ft^3/d												
	1	2	3	4	5	6	7	8	9	10	11a	11b	11c
1	25.31	32.20	16.74	55.44	32.24	30.96	33.55	20.74	31.10	42.66	19.36	22.67	22.13
2	96.18	116.35	71.44	185.2	119.62	107.91	117.88	80.09	111.21	141.26	81.96	87.14	87.06
3	51.97	61.67	40.15	94.84	62.20	52.73	59.27	41.39	58.80	72.45	46.2	46.96	47.23
Total	173.46	210.22	128.33	335.47	216.05	191.59	210.70	142.22	201.10	256.37	147.52	156.77	156.42

Table 12. Flow velocities and total pumpage for flow-model simulations in the Aquia aquifer

[ft/yr = feet per year; MGD = million gallons per day]

Historical calibration

Zone	Flow velocity, in ft/yr				
	1918	1953	1976	1984	1997
1	-2.60	-1.98	-1.88	3.41	5.27
2	-1.94	-0.25	7.39	10.91	13.59
3	-1.18	1.16	6.64	10.18	13.62
Average	-1.94	-0.40	4.49	8.54	11.17
Pumpage (MGD)	0.00	8.08	11.25	13.88	22.36

Future simulations

Zone	Flow velocity, in ft/yr												
	1	2	3	4	5	6	7	8	9	10	11a	11b	11c
1	6.33	8.05	4.19	13.86	8.56	7.74	8.39	5.18	7.77	10.67	4.84	5.67	5.53
2	15.40	18.63	11.44	29.65	19.15	17.28	18.87	12.82	17.80	22.61	13.12	13.95	13.94
3	15.15	17.97	11.70	27.64	18.12	15.37	17.27	12.06	17.13	21.11	13.46	13.69	13.76
Average	12.68	15.37	9.38	24.53	15.80	14.01	15.40	10.40	14.70	18.74	10.78	11.46	11.44
Pumpage (MGD)	24.79	29.75	19.83	49.58	33.92	25.29	25.79	24.79	28.53	36.01	12.67	51.68	12.67

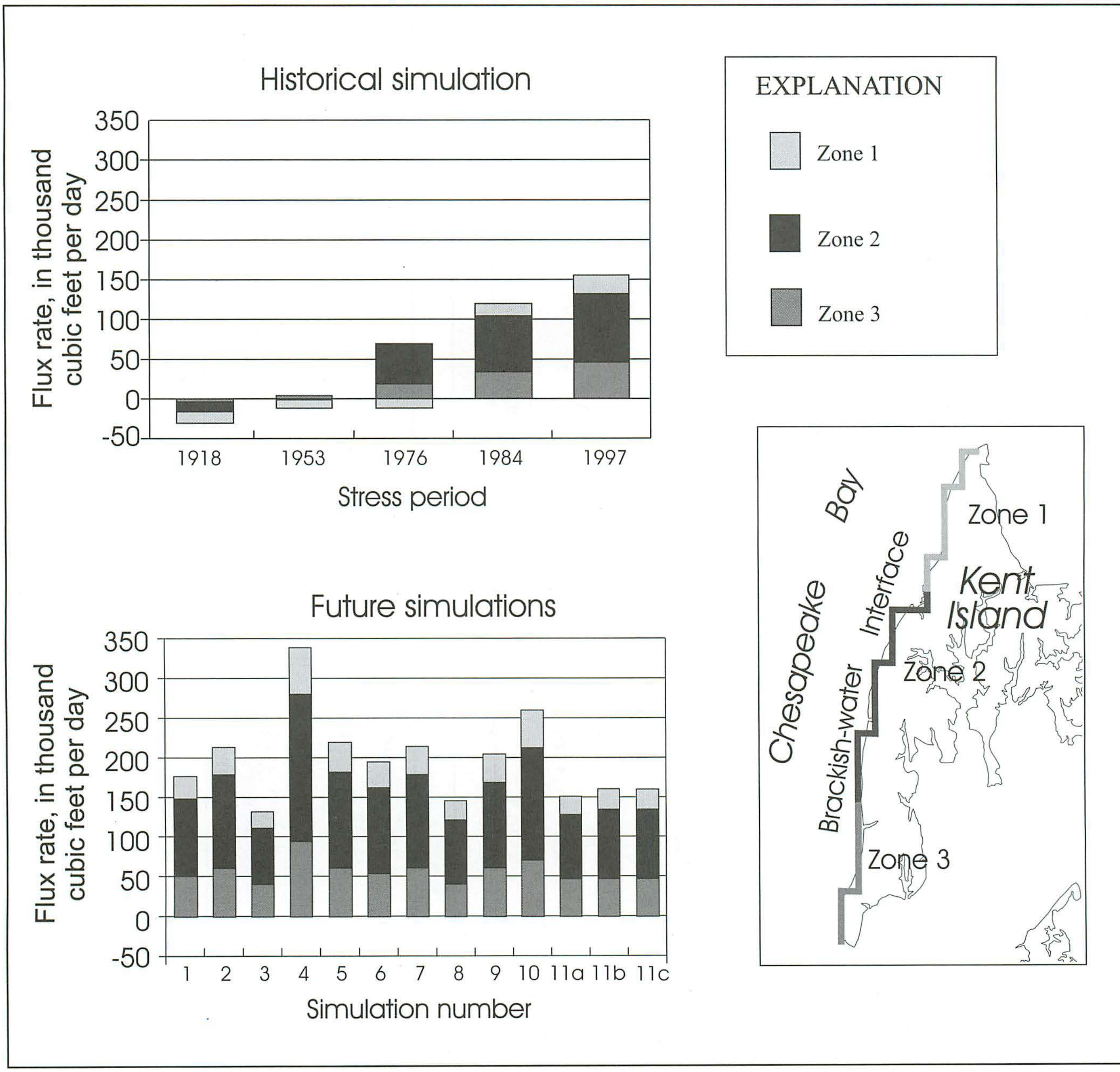

Figure 61. Simulated flux rates across the brackish-water interface on Kent Island for the historical calibration period and future simulations.

brackish-water movement (flux = 256,000 ft^3/d) than other simulations except doubling all pumpage in the model area. Shifting pumpage from the Aquia aquifer to deeper aquifers at six major pumping centers (Simulation 8) would significantly decrease the potential for brackish-water movement (decrease in flux of 18 percent).

Comparison of flow velocities in the three zones shows some differences, but the differences do not account for the trends in chloride concentrations in monitoring wells on Kent Island (tab. 12). Generally, flow velocities in Areas 2 and 3 are about the same, but velocities in Area 1 are somewhat less than in the other two areas. Velocities in Area 1 are less than in the other areas because of the water-table conditions in the Aquia aquifer at Love Point and a consequent potentiometric high which diverts the landward movement of ground water. Areas 1 and 2 are also closer to the regional cone-of-depression centered around Easton, and thus are affected by steeper head gradients. Because flow velocities in Areas 1 and 2 are about equal in the historical pumping periods, head gradients cannot account for the generally increasing trend in chloride concentrations in Area 2 and decreasing trend in Area 3 (fig. 35).

Flux rates and flow velocities for Simulation 11 show small differences between the stress periods. The total flux rate for the pre-irrigation period is about 3 percent lower than the 1997 calibration rate, and the flux rate for the irrigation period is about 3 percent higher than the 1997 calibration rate. The total flux rate for the post-irrigation period (11c) is only slightly lower than the irrigation rate. This simulation indicates that the yearly cycle in irrigation pumpage does not cause large variations in brackish-water movement.

RECOMMENDATIONS FOR FUTURE STUDY

Water-levels in the Aquia aquifer were measured in numerous privately-owned wells during this study to document the potentiometric surface in 1997. Tracking water-level declines in the future, as pumpage increases, will be of critical importance to the sound management of ground-water resources in Queen Anne's and Talbot Counties. Although there are observation wells in the northern and western part of Queen Anne's County, there are none in the eastern part of the county where future increases in irrigation pumpage would produce the greatest declines in water levels. Likewise, there are no observation wells screened in the Aquia aquifer at all in Talbot County. It is therefore recommended that four observation wells should be drilled, two in each county, and the water levels in those wells measured on a monthly basis.

Water from the Piney Point aquifer and the upper part of the Aquia aquifer was sampled in Talbot County for chloride concentrations to determine if brackish water has intruded the aquifers in that area. It was not determined, however, if brackish water is present in the lower part of the Aquia aquifer in western Talbot County, as it is on Kent Island, because no existing wells are screened in the lower section of the aquifer. It is recommended that at least two wells be drilled near the Chesapeake Bay shore between Claiborne and Tilghman, and water samples collected and analysed for chloride and other major ions. Electrical resistance logs should be run on the uncased boreholes to provide salinity information for the entire section. These wells should be sampled periodically (similar to the monitoring network on Kent Island) to determine trends in chloride concentrations.

SUMMARY AND CONCLUSIONS

The aquifer system beneath Queen Anne's and Talbot Counties supplies most of the water needs of the residents of the two counties. Although several aquifers are used in the area, the Aquia aquifer supplies the majority of water, and in many respects, is the most important. The presence of brackish water in the Aquia aquifer on the Chesapeake Bay shore of Kent Island, and the decline in water levels in the Aquia aquifer has led to concern that increased pumpage may induce the landward movement of brackish water. Declining water levels due to population increases and increased irrigation may also cause problems with wells going dry, and drawdowns exceeding state-mandated limits.

The major aquifers used for water supply in Queen Anne's and Talbot Counties include (from shallow to deep) the Columbia, several Miocene aquifers, the Piney Point, Aquia, Matawan, Magothy, Upper Patapsco, and Lower Patapsco aquifers. The Middle Patapsco and Patuxent aquifers may also be productive aquifers, but are not presently being developed. Bedrock, which underlies the Coastal Plain aquifers is not used for water supply, and is not considered a feasible water source.

The Columbia aquifer is a surficial, unconfined aquifer which extends throughout the entire study area, and supplies water for irrigation and for a few older farms and homes. The Miocene aquifers, which include the Calvert, Frederica, Federalsburg, and Cheswold aquifers, are shallow and moderately productive aquifers which are used primarily in the southeastern part of the study area. The Piney Point aquifer is confined and very productive in parts of Talbot County, but absent in most of Queen Anne's County.

The Aquia aquifer is a very productive, confined aquifer that is used extensively throughout most of the study area, but is absent in southeastern Talbot County. The top of the Aquia aquifer ranges in depth from about sea level in northeastern Queen Anne's County to about 650 ft below sea level in southern Talbot County. At Love Point and along parts of the Chester River, the Aquia aquifer subcrops beneath the Columbia aquifer, but elsewhere is separated from the overlying Miocene and Piney Point aquifers by the Nanjemoy confining unit, or by clayey units in the Chesapeake Group. The Aquia is separated from the underlying Matawan aquifer by the Monmouth confining unit.

A synoptic water-level measurement conducted in the fall of 1997 indicates that heads in the Aquia aquifer range from about 20 ft above sea level in northern Queen Anne's County to about 65 ft below sea level near Easton, and heads are below sea level throughout most of the study area. Head gradients indicate that ground water is moving eastward from the Chesapeake Bay, and southward from northern Queen Anne's County toward a regional cone-of-depression centered at Easton. Long-term hydrographs from wells at Chester and Prospect indicate that heads in the Aquia aquifer are decreasing at a rate of about 0.5 ft/y. Short-term hydrographs indicate that heads in the Aquia aquifer fluctuate seasonally by as much as 35 ft, due to irrigation pumpage and increased evapotranspiration during the summer months.

Water quality in the Aquia aquifer is good throughout most of the study area, except for a narrow strip along the Chesapeake Bay shore of Kent Island, where brackish-water intrusion has degraded water quality, and rendered the water unfit for drinking. Hydrochemical facies for the Aquia aquifer include calcium bicarbonate, sodium bicarbonate, sodium chloride, and calcium chloride types.

The Matawan aquifer provides modest quantities of water for domestic supplies on parts of Kent Island and the Queenstown Golf Course. Elsewhere in the study area its presence and production capacity are uncertain. The Magothy aquifer is used for water supply on Kent Island and at Easton, but in some places is not a productive aquifer. It is difficult to distinguish the Magothy and Matawan aquifers in drillers' logs, and they may be hydraulically connected in places. High iron and manganese concentrations (as high as 34 and 0.4 mg/L, respectively) in the Kent Island area render water from the Magothy aquifer unfit for most purposes without treatment.

The Upper Patapsco aquifer is used extensively for water supply on Kent Island and at Easton. It is lithologically similar to the Magothy aquifer, and difficult to distinguish from the Magothy in drillers' logs. Although the Upper Patapsco is a very productive aquifer, high iron and manganese concentrations (as high as 28 and 0.4 mg/L, respectively) require treatment for most purposes. The Lower Patapsco aquifer has supplied the public water system at Stevensville since September, 1999, but is not used elsewhere on the Eastern Shore of Maryland south of Cecil County. Iron and manganese concentrations, although above the SMCL's, are significantly lower in the Lower Patapsco aquifer (3.2 and 0.2 mg/L, respectively, at the Stevensville well) than in the Upper Patapsco or Magothy aquifers. Moderate iron and manganese concentrations, coupled with the very high production capability and large available drawdown, make the Lower Patapsco aquifer an attractive source for public supplies on Kent Island, and possibly elsewhere in the study area.

Brackish-water intrusion is a potential threat to water quality in the Aquia aquifer in the Kent Island area of Queen Anne's County. Brackish water (chloride concentration greater than 1,000 mg/L) is present in the lower part of the Aquia aquifer within about a quarter mile of the entire bay shore of Kent Island. Water with elevated chloride concentrations (10 to 1,000 mg/L) is present in the upper part of the Aquia aquifer along the bay shore, and the northern and southern sections of Kent Island. Sampling of 18 wells in western Talbot County showed elevated chloride concentrations in a few wells screened in the Aquia aquifer, but do not indicate a widespread problem in that area. If, however, brackish water was present in the lower part of the Aquia aquifer, this sampling program would not have detected it.

Monitoring of 49 wells screened in the Aquia aquifer on western Kent Island from 1982 to 1999 does not show a clear, consistent trend in chloride concentrations. Concentrations in some wells have increased, and some have decreased, and almost all wells have shown considerable variation. Some trends, however, have been identified which generally explain the variations. In the central area of the island, concentrations in the upper part of the Aquia aquifer are generally elevated and increasing in a narrow strip (within a quarter mile of the shore), but farther inland, the entire section is fresh. In the northern and southern areas of the island, extending to the Chester River and Eastern Bay, concentrations in the upper part of the Aquia are elevated, but show a slight decreasing trend or no trend. At the northern tip of Kent Island, the entire section of the Aquia is brackish, and concentrations show no discernable trend.

Variations in chloride concentrations are explained by several factors:

1) Hundreds or thousands of domestic and commercial wells are pumping from the Aquia aquifer in the vicinity of the brackish-water interface, and create sporadic migration and mixing of fresh and brackish water. Because many of the monitoring wells are domestic wells, they will be particularly affected by sporadic pumping patterns.
2) Elevated chloride concentrations in the northern and southern parts of Kent Island were probably caused by leakage and mixing of brackish water from the Chester River and Eastern Bay during prepumping times when regional ground-water flow was from east to west. Reversal of the regional head gradient would not cause increases in chloride concentrations in these areas, and may cause decreases.
3) Downward leakage of fresh water from the Columbia aquifer to the Aquia aquifer would increase as fresh-water heads in the Aquia decrease. Depending on the local hydraulic characteristics of the confining unit and water-table elevation, increased fresh-water leakage could cause a decrease in chloride concentration even though the interface is generally moving inland.

Although the projected pumpage conditions used in the 1988 solute-transport model have not occurred, heads used for boundary conditions in that model are close to present-day heads, and evaluation of the solute-transport model results is useful. Trends in heads and chloride concentrations predicted by the model are generally consistent with measured trends, but are not entirely accurate.

A ground-water flow model was used to estimate heads and drawdowns in the Aquia aquifer in response to various future pumping scenarios. The model was also used to estimate ground-water flow across the brackish-water interface on Kent Island, which in turn was used to estimate the relative impact of the future pumpage scenarios on brackish-water intrusion. Although the major focus of flow modeling was the Aquia aquifer, the Coastal Plain aquifer system from the Columbia aquifer down to the Upper Patapsco aquifer was simulated. The model area included southern Kent County, Caroline County, and northern Dorchester County to minimize boundary effects.

Model results indicate that pumpage increases caused by projected population growth between 1997 and 2020 will cause water levels in the Aquia aquifer to decrease by about 2 ft on eastern Kent Island and 16 ft at Easton. Water levels on western Kent Island did not change appreciably because the Chesapeake Bay acts as a recharge boundary, keeping water levels near sea level. Increasing projected pumpage throughout the model area by 20 percent caused about twice as much drawdown as the projected pumpage simulation, and decreasing projected pumpage by 20 percent caused water levels to recover somewhat from 1997 levels.

Doubling projected pumpage in the model area caused drawdowns in the Aquia aquifer of 90 ft at Easton, 70 ft at Oxford, and 15 ft on eastern Kent Island. Drawdown on western Kent Island ranged from about 1 ft at Love Point, and 6 ft at Kent Point for this simulation. A simulation in which all major users pumped at their maximum yearly allowable rates in addition to projected population increases caused drawdowns of about 40 ft in northern Talbot County, 35 ft at Easton, and 30 ft in northern Queen Anne's County.

A simulation in which two hypothetical production wells were added in western Kent Island to supplement the public-water-supply system caused drawdowns of 10 ft in the vicinity of the hypothetical wells, and about 1 ft on western Kent Island. A simulation in which 1 MGD of pumpage from the Aquia aquifer was added in Management Area B (fig.

1) indicated drawdowns of 25 ft at Grasonville, and about 1 ft on western Kent Island. Shifting pumpage from the Aquia aquifer to the Upper Patapsco aquifer at six major public-supply well fields caused recoveries of about 20 ft at Easton and Oxford.

A simulation in which irrigation pumpage in Queen Anne's and Talbot Counties was doubled caused drawdowns of 35 ft in northeastern Talbot County and 30 ft in southeastern Queen Anne's County. Quadrupling irrigation pumpage (an increase of 300 percent) caused drawdowns of 90 ft in northeastern Talbot County, 80 ft in southeastern Queen Anne's County, and 2 to 4 ft along the bay shore of Kent Island. A 1-year simulation of the irrigation cycle indicated drawdowns in the Aquia aquifer of 35 ft in southern Queen Anne's County, and 25 ft in central Queen Anne's County.

Simulated flux values and flow velocities across the brackish-water interface were used to estimate the relative impact of various pumpage simulations on movement of the interface. The flow model does not simulate solute transport or density-dependent flow, and cannot calculate rate of movement of the brackish-water interface. Simulated flow velocities ranged from -2.6 ft/yr (negative velocities indicate westward flow toward the bay) for prepumping conditions to 29.6 ft/yr when all pumpage in the model area was doubled. All future simulations produced landward flow, but reducing pumpage by 20 percent, and shifting pumpage from the Aquia aquifer to deeper aquifers at six major public-supply facilities reduced flow velocities appreciably. Increasing irrigation pumpage by 300 percent in Queen Anne's and Talbot Counties caused an increase in flow velocity of 68 percent across the brackish-water interface.

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SUPPLEMENTAL DATA

This section contains data for the selected-well inventory (tab. 13), ground-water appropriation permits (tab. 14), and selected water-quality analyses (tab. 15). It also includes a map showing 5-minute quadrangles used to designate well numbers, and locations of water-quality analyses, and hydrographs for the Columbia aquifer (fig. 62).

Table 13. Data for selected wells in Queen Anne's and Talbot Counties

[See table 14 and figure 39 for locations of wells]

Well number	Permit number	Ground-water appropriation number	Owner	Driller	Altitude of land surface (feet above sea level)	Completion date	Hole depth (feet below land surface)	Well depth (feet below land surface)	Diameter of screen (inches)
QA Be 22	QA-88-1537	QA92GAP014	Chino Farms, Inc.	Lifetime Well Drilling Co.	37	06-11-92	180	180	12 / 6
QA Be 23	QA-94-0627	QA92GAP014	Chino Farms, Inc.	A C Schultes of DE, Inc.	38	01-09-97	180	175	6
QA Be 25	QA-73-1823	QA92GAP027	Peter G. Sheaffer	Edward Kelley	51	06-17-77	161	160	12
QA Be 26	QA-73-1889	QA92GAP027	Peter G. Sheaffer	Edward Kelley	55	06-10-77	160	160	12
QA Be 27	QA-73-2255	QA92GAP033	Neff & Son, Inc.	Edward Kelley	45	05-18-78	178	178	16
QA Be 28	QA-73-3047	QA92GAP033	Neff & Son, Inc.	Edward Kelley	42	02-08-80	252	250	16
QA Bf 35	QA-88-2182	QA92GAP026	Van Land Farms, Inc.	White Drilling Corporation	65	02-02-94	328	261	4
QA Bf 37	QA-73-2594	QA92GAP013	Chino Farms, Inc.	Edward Kelley	54	11-02-78	201	195	4
QA Bf 38	QA-73-2593	QA92GAP013	Chino Farms, Inc.	Edward Kelley	38	--	--	--	--
QA Bf 39	QA-73-3074	QA92GAP013	Chino Farms, Inc.	Edward Kelley	57	12-13-79	180	180	16
QA Bf 40	QA-73-3075	QA92GAP013	Chino Farms, Inc.	Edward Kelley	58	12-21-79	191	191	16
QA Bf 41	QA-81-2161	QA92GAP026	Van Land Farms, Inc.	Delmarva Drilling Co.	80	06-09-87	180	180	12
QA Bf 42	QA-81-2162	QA92GAP026	Van Land Farms, Inc.	Delmarva Drilling Co.	80	04-20-87	210	200	4
QA Bf 44	QA-88-0752	QA90GAP021	Goose Valley Fish Farms	American Water Well Sy.	68	07-16-90	195	138	16
QA Bg 59	QA-73-0057	QA73GAP001	Ches. 7th Day Adventist	George Kelley	50	09-11-72	160	160	4
QA Bg 62	QA-73-3818	--	QA Co. Parks & Rec.	Paul McCreary	60	05-26-82	100	100	4
QA Bg 63	QA-88-0958	QA90GAP040	Paul E. Schlosser	Lifetime Well Drilling Co.	71	02-20-91	210	210	4
QA Bg 69	QA-88-1656	QA92GAP007	Moore Brothers, Inc.	White Drilling Corporation	61	02-24-93	262	260	12
QA Bg 70	QA-88-1449	QA92GAP007	Moore Brothers, Inc.	Lifetime Well Drilling Co.	62	03-23-92	243	233	6
QA Bh 48	QA-88-1176	QA91GAP001	Bell Nursery Farm, Inc.	Shannahan Artesian Well	64	09-18-91	426	375	4
QA Bh 49	QA-88-1491	QA92GAP020	Charles Haines	White Drilling Corporation	61	06-03-92	355	346	4.5
QA Bh 50	QA-81-2111	QA92GAP020	Charles Haines	Delmarva Drilling Co.	47	04-01-87	334	332	10
QA Bh 53	QA-94-0785	QA97GAP011	Allen M. Weaver, Jr.	Lifetime Well Drilling Co.	64	06-05-97	300	300	6
QA Ce 37	QA-73-0131	--	QA Co. Soil Conservation	Kelley Well Drilling	40	11-24-72	220	220	--
QA Cf 65	QA-81-0007	--	C & P Telephone Co.	Kelley Well Drilling	35	01-17-83	170	170	4
QA Cf 66	QA-88-1622	QA63GAP002	MD Dept. of Corrections	A C Schultes of DE, Inc.	60	08-19-92	310	248	4
QA Cf 67	QA-88-1623	QA63GAP002	MD Dept. of Corrections	A C Schultes of DE, Inc.	58	08-26-92	280	254	4
QA Cf 68	QA-05-0363	QA63GAP002	MD Dept. of Corrections	Shannahan Artesian Well	60	02-17-63	194.7	194.7	12 / 6
QA Cf 74	QA-02-0269	QA92GAP008	A. A. MacGlashan, III	Sam Shannahan Well Co.	67	10-20-55	290	290	–
QA Cf 75	QA-92-0432	QA94GAP005	Michael Bostic	A C Schultes of DE, Inc.	61	03-23-95	400	385	16
QA Cg 62	QA-81-1592	--	Daniel Farrell	Fisher Well Drilling	58	05-10-86	235	230	2
QA Cg 65	QA-02-9634	QA91GAP032	Charles A. Taff	Cecil M. Cannon	73	05-10-58	85	85	17
QA Dd 27	QA-65-0186	QA95GAP001	Central Sod Farms of MD	Sam Shannahan Well Co.	69	12-05-64	440	440	–
QA Dd 28	QA-88-1103	QA95GAP001	Central Sod Farms of MD	Lifetime Well Drilling Co.	55	06-20-91	265	265	6
QA Dd 29	QA-81-1614	QA91GAP016	Ball & Burlap Nursery	Collier's Well Drilling, Inc.	58	05-22-86	305	305	4
QA Dd 30	QA-81-1127	QA91GAP016	Ball & Burlap Nursery	Collier's Well Drilling, Inc.	60	10-07-85	305	305	6
QA Dd 31	QA-81-2454	--	Peter G. Shaeffer	Lifetime Well Drilling Co.	12	08-19-87	140	140	4
QA Dd 32	QA-81-1140	--	Peter G. Shaeffer	Lifetime Well Drilling Co.	7	07-08-85	140	140	4

Table 13.–Continued

Screen or open interval (feet below land surface)	Aquifer	Pumping test data: Static water level depth (feet below land surface)	Date reported	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per feet)	Duration of test (hours)	Remarks	Well number
20-180	Aquia	18	06-11-92	400	17	23.53	5		QA Be 22
135-175	Aquia	11	01-09-97	35	49	0.71	4	Test well	QA Be 23
80-160	Aquia	38	06-17-77	495	55	9	4		QA Be 25
80-160	Aquia	38	06-10-77	495	55	9	4		QA Be 26
98-178	Aquia	22	05-18-78	480	81	5.93	3		QA Be 27
155-250	Aquia	20	02-08-80	525	110	4.77	4		QA Be 28
121-261	Aquia	51.5	02-02-94	32	3	10.67	2	WL; test well	QA Bf 35
135-195	Aquia	29	11-02-78	35	37	0.95	3		QA Bf 37
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133-180	Aquia	27	12-13-79	500	71.7	6.97	4		QA Bf 39
125-191	Aquia	26	12-21-79	500	113	4.42	4		QA Bf 40
50-180	Aquia	24	06-09-87	530	58	9.14	4		QA Bf 41
120-200	Aquia	62	04-20-87	84	35	2.4	4	Test well	QA Bf 42
58-138	Aquia	32	07-16-90	100	78	1.28	2	Unused	QA Bf 44
140-160	Aquia	35	09-11-72	45	65	0.69	2	WL; WQ	QA Bg 59
80-100	Aquia	44	05-26-82	25	22	1.14	10	WL; WQ	QA Bg 62
180-210	Aquia	40	02-20-91	100	80	1.25	5	Test well	QA Bg 63
140-260	Aquia	43	02-24-93	500	67	7.46	4		QA Bg 69
133-233	Aquia	40	03-23-92	250	80	3.13	5	Destroyed	QA Bg 70
295-375	Aquia	58	09-18-91	58	17	3.41	1	Test well	QA Bh 48
226-346	Aquia	38	06-03-92	300	46	6.52	4		QA Bh 49
232-332	Aquia	26.3	04-01-87	489	83.7	5.84	8		QA Bh 50
160-300	Aquia	47	06-05-97	300	53	5.66	2		QA Bh 53
100-220	Aquia	35	11-24-72	75	45	1.67	2	WL; WQ; Open hole	QA Ce 37
160-170	Aquia	30	01-17-83	20	40	0.5	3	WL	QA Cf 65
220-245	Aquia	69	08-19-92	96	21	4.57	8	Well 2	QA Cf 66
226-251	Aquia	70.5	08-26-92	95	22.5	4.22	5	Well 3	QA Cf 67
186.3-192.2	Aquia	54	02-17-63	87	43	2.02	24	Well 1	QA Cf 68
151-290	Aquia	38	10-20-55	500	90	5.56	10	Open hole	QA Cf 74
150-385	Aquia	53	03-23-95	1,000	67	14.93	8		QA Cf 75
185-230	Piney Point	22	05-10-86	10	58	0.17	4	WQ	QA Cg 62
29-85	Columbia	6	05-10-58	1,300	51	25.49	24		QA Cg 65
--	Aquia	68	12-05-64	1,500	115	13.04			QA Dd 27
205-265	Aquia	56	06-20-91	300	64	4.69	5		QA Dd 28
290-305	Aquia	40	05-22-86	30	20	1.5	7		QA Dd 29
265-305	Aquia	70	10-07-85	300	30	10	6		QA Dd 30
120-140	Aquia	9	08-19-87	100	16	6.25	5	WL	QA Dd 31
130-140	Aquia	15	07-08-85	50	10	5	5	WQ	QA Dd 32

Table 13. Data for selected wells in Queen Anne's and Talbot Counties–Continued

Well number	Permit number	Ground-water appropriation number	Owner	Driller	Altitude of land surface (feet above sea level)	Completion date	Hole depth (feet below land surface)	Well depth (feet below land surface)	Diameter of screen (inches)
QA De 27	--	QA67GAP002	Town of Centreville	Shannahan Artesian Well	10	1899	665 ?	530 ?	10
QA De 28	--	QA67GAP002	Town of Centreville	Shannahan Artesian Well	10	00-00-15	530 ?	480 ?	8
QA De 29	QA-03-3814	QA67GAP002	Town of Centreville	Shannahan Artesian Well	15	06-15-59	450	450	--
QA De 30	QA-67-0030	QA67GAP002	Town of Centreville	Shannahan Artesian Well	60	09-30-66	481	481	--
QA De 34	QA-73-3999	QA61GAP005	Tidewater Publishing Corp.	Shannahan Artesian Well	60	12-22-82	441	441	4
QA De 35	QA-73-4000	QA61GAP005	Tidewater Publishing Corp.	Shannahan Artesian Well	82	12-15-82	457	383	4
QA De 36	QA-94-0130	QA61GAP005	Tidewater Publishing Corp.	Shannahan Artesian Well	82	10-03-95	398	390	4
QA De 37	QA-04-4935	QA67GAP002	Town of Centreville	M. A. Pentz, Jr.	62	03-22-62	263	263	
QA De 40	QA-94-1069	QA97GAP003	James Schillinger, Sr.	A C Schultes of DE, Inc.	44	04-17-98	483	460	8
QA De 41	QA-94-1070	QA97GAP003	James Schillinger, Sr.	A C Schultes of DE, Inc.	55	02-18-98	480	470	4
QA De 42	QA-94-1068	QA97GAP003	James Schillinger, Sr.	A C Schultes of DE, Inc.	41	04-27-98	455	455	8
QA De 43	QA-94-1213	QA67GAP002	Town of Centreville	Shannahan Artesian Well	50	07-03-98	747	500	4
QA De 44	QA-94-1390	QA67GAP002	Town of Centreville	Shannahan Artesian Well	50	11-19-98	400	385	6
QA Df 56	QA-81-3038	QA87GAP035	Conard-Pyle Co.	Delmarva Drilling Co.	70	03-30-88	442	430	12
QA Df 57	QA-92-0420	QA87GAP035	Conard-Pyle Co.	A C Schultes of DE, Inc.	61	02-16-95	360	340	4
QA Df 58	QA-94-0468	--	William E. Chambers	Queenstown Well Drilling	70	07-18-96	340	340	2
QA Dg 41	QA-67-0123	QA91GAP007	Ashley Hunt Ray Farms	E R Kauffman	45	05-02-67	65	65	17
QA Dg 42	QA-81-0313	--	Sara Clark	Lifetime Well Drilling Co.	74	11-12-83	203	203	4
QA Ea 27	--	--	USACE - Bay Model	US Army Corps of Eng.	18.27	03-20-72	670	661	6
QA Ea 84	QA-81-0401	QA68GAP011	Diocese of Easton	Shannahan Artesian Well	17	02-27-84	632	632	3
QA Ea 85	QA-94-0759	QA97GAP025	QA Co. Parks & Rec.	A C Schultes of DE, Inc.	15	07-14-97	703	703	4
QA Eb 146	QA-81-0152	QA82GAP002	QA Co. Sanitary District	Delmarva Drilling Co.	5	07-25-83	320	280	4
QA Eb 150	QA-81-0153	QA82GAP002	QA Co. Sanitary District	Delmarva Drilling Co.	5	06-23-83	300	280	4
QA Eb 154	QA-81-0446	QA83GAP005	QA Co. Sanitary District	Delmarva Drilling Co.	10	04-04-84	340	288	4
QA Eb 159	QA-81-0872	QA84GAP028	QA Co Parks & Rec.	Collier's Well Drilling, Inc.	12	11-23-85	485	485	4
QA Eb 161	--	QA85GAP019	QA Co. Sanitary District	Delmarva Drilling Co.	15	04-24-86	603	--	--
QA Eb 162	QA-81-1753	QA85GAP024	QA Co. Sanitary District	Shannahan Artesian Well	15	11-06-86	684	684	4
QA Eb 164	QA-81-2079	QA85GAP026	EWH Associates	Delmarva Drilling Co.	5	01-16-87	745	740	4
QA Eb 166	QA-88-0686	QA89GAP024	QA Co. Sanitary District	Delmarva Drilling Co.	15	05-01-90	783	767	6
QA Eb 167	QA-94-0318	QA89GAP024	QA Co. Sanitary District	A C Schultes of DE, Inc.	15	03-16-96	775	760	6
QA Eb 168	QA-81-2673	QA87GAP028	QA Co. Sanitary District	Queenstown Well Drilling	15	04-23-88	740	740	3
QA Eb 169	QA-88-1490	QA84GAP016	QA Co. Sanitary District	Shannahan Artesian Well	15	07-07-92	718	718	4
QA Eb 170	QA-81-1232	QA84GAP016	QA Co. Sanitary District	Shannahan Artesian Well	15	09-22-85	712	712	4
QA Eb 171	QA-81-1778	QA85GAP024	QA Co. Sanitary District	Shannahan Artesian Well	15	11-10-86	716	666	4
QA Eb 172	QA-81-0540	QA82GAP002	QA Co. Sanitary District	Delmarva Drilling Co.	10	06-05-84	300	282	8
QA Eb 173	QA-81-0893	QA70GAP102	QA Co. Sanitary District	Shannahan Artesian Well	5	02-20-85	693	693	4
QA Eb 174	QA-73-0215	QA70GAP002	QA Co. Sanitary District	Kelley Well Drilling	5	03-31-73	213	197	10
QA Eb 175	QA-81-2006	QA86GAP006	Island Professional Assoc.	Queenstown Well Drilling	10	01-16-87	710	710	2

Table 13. Continued

Screen or open interval (feet below land surface)	Aquifer	Pumping test data: Static water level depth (feet below land surface)	Date reported	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per feet)	Duration of test (hours)	Remarks	Well number
170-378	Aquia	17	04-06-55	750	32	23.44	--	Open hole; well 1[1]	QA De 27
--	Aquia	26	08-25-58	190	15	12.67	--	Well 2; destroyed	QA De 28
--	--	29	06-15-59	692	60	11.53	4	Open hole; well 3	QA De 29
269.8-481	Aquia	57	09-30-66	211	16	13.19	20	Open hole; well 4	QA De 30
311-441	Aquia	63	12-22-82	17	1	17	1		QA De 34
312-383	Aquia	81	12-15-82	20	2	10	2		QA De 35
360-390	Aquia	95	10-03-95	15	5	3	1		QA De 36
171-263	Aquia	60	03-22-62	90	30	3	8	WL; Open hole	QA De 37
350-460	Aquia	59	04-17-98	315	32	9.84	4	Well 1	QA De 40
360-470	Aquia	63	02-18-98	96	22	4.36	4	Test well 1	QA De 41
315-455	Aquia	61	04-27-98	318	44	7.23	4	Well 2	QA De 42
250-500	Aquia	67	07-03-98	23	2	11.5	6	Test well	QA De 43
228-385	Aquia	66	11-19-98	365	33	11.06	24		QA De 44
380-430	Aquia	65	03-30-88	900	65	13.85	24		QA Df 56
310-340	Aquia	65	02-16-95	150	19	7.89	4		QA Df 57
320-340	Aquia	77	07-18-96	30	23	1.3	3	WQ	QA Df 58
29-65	Columbia	15	05-02-67	720	29	24.83	2	Unused	QA Dg 41
183-203	Piney Point	38	11-12-83	15	82	0.18	5	WQ	QA Dg 42
625-661	Upper Patapsco	--	--	--	--	--	--	WL; Test well 2	QA Ea 27
610-626	Upper Patapsco	19	02-27-84	15	9	1.67	1	WQ	QA Ea 84
680-703	Upper Patapsco	26.6	07-14-97	110	33.6	3.27	2	WQ	QA Ea 85
180-280	Aquia	19	07-25-83	300	45	6.67	24	Well 1	QA Eb 146
180-280	Aquia	17	06-23-83	25	2	12.5	4	Test hole; destroyed	QA Eb 150
188-288	Aquia	17	04-04-84	30	3	10	3		QA Eb 154
465-485	Matawan	14	11-23-85	140	46	3.04	8	WL; WQ	QA Eb 159
--	Magothy	--	--	--	--	--	--	Test hole; destroyed	QA Eb 161
652-684	Upper Patapsco	17	11-06-86	225	65	3.46	12	WQ; Bayside #1	QA Eb 162
720-740	Magothy	6	01-16-87	30	6	5	8	WL; WQ	QA Eb 164
596-767	Upper Patapsco	17	05-01-90	602	42	14.33	24	Stevensville #1	QA Eb 166
606-760	Upper Patapsco	26.53	03-16-96	970	83.93	11.56	24	WQ; Stevensville #2	QA Eb 167
720-740	Upper Patapsco	18	04-23-88	100	72	1.39	20	WQ	QA Eb 168
688-718	Upper Patapsco	24	07-07-92	242	122	1.98	8	WQ; Bridgepointe #2	QA Eb 169
682-712	Upper Patapsco	18	09-22-85	205	83	2.47	36	Bridgepointe #1	QA Eb 170
639-712	Upper Patapsco	18	11-10-86	225	130	3.07	36	Bayside #2	QA Eb 171
182-282	Aquia	17	06-05-84	200	43	4.65	12	Queens Landing #2	QA Eb 172
658-693	Upper Patapsco	8	02-20-85	245	41	5.98	12	WQ	QA Eb 173
166-197	Aquia	5	03-31-73	828	101	8.2	5	Destroyed	QA Eb 174
670-710	Upper Patapsco	15	01-16-87	100	105	0.95	2	WQ	QA Eb 175

[1] Geophysical logs on 03-27-98 shows casing down to 270 ft and hole obstruction at 378 ft.

Table 13. Data for selected wells in Queen Anne's and Talbot Counties–Continued

Well number	Permit number	Ground-water appropriation number	Owner	Driller	Altitude of land surface (feet above sea level)	Completion date	Hole depth (feet below land surface)	Well depth (feet below land surface)	Diameter of screen (inches)
QA Eb 176	QA-81-2131	QA85GAP029	Champion Realty, Inc.	East Coast Well & Pump	10	04-21-87	702	702	2
QA Eb 177	QA-88-1492	--	Cornelius R. Love	Shannahan Artesian Well	10	06-11-92	587	576	2
QA Eb 178	QA-88-0073	QA88GAP022	Island Medical Center	Shannahan Artesian Well	8	01-31-89	645	645	2
QA Eb 179	QA-81-2870	QA85GAP030	Bay Bridge Marina	Collier's Well Drilling, Inc.	20	10-04-88	640	640	2
QA Eb 180	QA-81-1227	QA84GAP004	Kent Island Joint Venture	East Coast Well & Pump	17	00-00-85	--	--	--
QA Eb 181	QA-81-1494	QA85GAP019	QA Co. Sanitary District	Delmarva Drilling Co.	15	04-24-86	495	485	6
QA Eb 182	QA-94-1444	QA97GAP050	QA Co. Sanitary District	Layne Atlantic	14	04-01-99	1,717	1,580	4
QA Eb 183	QA-94-1701	QA70GAP002	QA Co. Sanitary District	A C Schultes of DE, Inc.	6	06-30-99	250	240	6
QA Eb 184	QA-94-1702	QA97GAP050	QA Co. Sanitary District	A C Schultes of MD, Inc.	14	09-15-99	1,613	1,590	10
QA Ec 85	QA-81-0128	QA71GAP002	Mears Point Marina	CZ Enterprises, Inc.	5	10-29-83	440	412	6
QA Ec 89	QA-81-0873	QA84GAP017	QA Co. Sanitary District	Branham Contractors	5	12-19-84	782	780	4
QA Ec 90	QA-81-1493	QA84GAP017	QA Co. Sanitary District	CZ Enterprises, Inc.	10	04-30-86	793	793	4
QA Ec 91	QA-92-0457	QA94GAP007	QA Co. Sanitary District	A C Schultes of MD, Inc.	18	04-29-95	982	952	6
QA Ec 92	QA-92-0465	QA94GAP007	QA Co Sanitary District	A C Schultes of MD, Inc.	20	05-24-95	941	930	6
QA Ec 94	QA-88-2093	QA92GAP044	QA Co. Sanitary District	Shannahan Artesian Well	10	01-03-94	266	250	4
QA Ec 100	QA-88-0732	QA89GAP026	Queenstown Harbor Golf	Shannahan Artesian Well	23	06-18-90	655	649	6
QA Ec 102	QA-88-0996	QA90GAP026	Queenstown Harbor Golf	Shannahan Artesian Well	18	05-09-91	648	644	2
QA Ec 103	QA-73-2433	QA78GAP009	Bay View at Kent Narrows	Douglas Middleton	5	05-05-78	215	215	2
QA Ec 104	QA-71-0040	QA71GAP002	Mears Point Marina	Alfred Hudson	5	09-17-70	225	225	2
QA Ec 105	QA-94-0401	QA71GAP002	Mears Point Marina	Collier's Well Drilling, Inc.	4	04-08-96	440	440	4
QA Ed 34	--	QA71GAP007	S. E. W. Friel	–	19	00-00-25	260	260	--
QA Ed 35	--	QA71GAP007	S. E. W. Friel	–	19	00-00-45	260	260	--
QA Ed 36	--	QA79GAP010	Queenstown Commission	–	15	00-00-31	320	320	--
QA Ed 42	QA-04-9856	QA79GAP010	Queenstown Commission	William Crouch Sr.	20	12-10-62	290	290	--
QA Ed 43	QA-88-1728	QA79GAP010	Queenstown Commission	Shannahan Artesian Well	15	03-25-93	296	278	4
QA Ed 44	QA-88-1726	QA74GAP010	Queenstown Commission	Shannahan Artesian Well	15	03-25-93	296	275	2
QA Ed 46	QA-81-0485	QA71GAP007	S. E. W. Friel	Queenstown Well Drilling	19	08-10-84	260	260	--
QA Ed 47	QA-73-0803	QA71GAP007	S. E. W. Friel	William Crouch Sr.	19	02-03-75	260	260	--
QA Ed 48	QA-69-0179	QA69GAP003	Con Agra Poultry Co.	Shannahan Artesian Well	61	09-06-69	381	359	4
QA Ed 49	QA-94-0300	QA69GAP003	Con Agra Poultry Co.	A C Schultes of DE, Inc.	64	03-29-96	373	368	6
QA Ed 51	QA-81-2860	QA92GAP003	Pintail Point Partnership	American Water Well Sy.	20	09-07-88	351	347	4
QA Ee 24	QA-73-0550	--	Fisher Norman	Shannahan Artesian Well	41	04-10-74	214	214	2
QA Ee 30	QA-94-0004	QA56GAP001	S. E. W. Friel	Collier's Well Drilling, Inc.	45	05-26-95	440	440	4
QA Ee 31	QA-73-1146	QA56GAP001	S. E. W. Friel	Queenstown Well Drilling	50	05-13-76	435	435	--
QA Ef 30	QA-81-1806	QA86GAP024	Dept. of Natural Resources	Collier's Well Drilling, Inc.	58	09-06-86	300	300	2
QA Ef 31	QA-88-1734	QA89GAP020	Herschell B. Claggett	Lifetime Well Drilling Co.	65	11-30-92	560	560	2
QA Ef 32	QA-88-1736	QA92GAP040	Dan Shortall	Lifetime Well Drilling Co.	52	11-12-92	500	500	2
QA Fa 77	QA-81-1498	QA85GAP009	QA Co. Dept. Parks & Rec.	Collier's Well Drilling, Inc.	10	04-08-86	620	620	4

Table 13. Continued

Screen or open interval (feet below land surface)	Aquifer	Pumping test data: Static water level depth (feet below land surface)	Date reported	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per feet)	Duration of test (hours)	Remarks	Well number
680-702	Upper Patapsco	15	04-21-87	100	35	2.86	12	WQ	QA Eb 176
546-576	Matawan	24	06-11-92	22	75	0.29	1	WQ	QA Eb 177
625-645	Upper Patapsco	20	01-31-89	16	29	0.55	1	WQ	QA Eb 178
610-640	Upper Patapsco	16	10-04-88	300	80	3.75	10	WL; WQ; well 1; unused	QA Eb 179
--	Aquia	--	--	--	--	--	--		QA Eb 180
455-485	Magothy	14	04-24-86	250	73	3.42	24	WQ	QA Eb 181
1,460-1,580	Lower Patapsco	29.2	04-01-99	90	18.43	4.88	8	Stevensville test well	QA Eb 182
200-240	Aquia	17	06-30-99	220	100	2.2	4		QA Eb 183
1,463-1,580	Lower Patapsco	30	09-15-99	1,500	140	10.71	24	Stevensville # 3	QA Eb 184
392-412	Aquia	10.25	10-29-83	68	133.25	0.51	11	Test well; destroyed	QA Ec 85
750-780	Upper Patapsco	5	12-19-84	150	53	2.83	5	WL; Oyster Cove # 1	QA Ec 89
753-793	Upper Patapsco	4	04-30-86	151	49	3.08	8	Oyster Cove # 2	QA Ec 90
826-952	Upper Patapsco	33	04-29-95	750	84	8.93	24	WQ; Grasonville # 1	QA Ec 91
824-930	Upper Patapsco	33	05-24-95	754	73	10.33	24	Grasonville # 2	QA Ec 92
220-250	Aquia	15	01-03-94	175	29	6.03	8	Oyster Cove # 3	QA Ec 94
617-649	Matawan	30	06-18-90	350	78	4.49	24		QA Ec 100
624-644	Matawan	35	05-09-91	23	9	2.56	2	WL; WQ	QA Ec 102
195-215	Aquia	10	05-05-78	25	9	2.78	5		QA Ec 103
190-225	Aquia	6	09-17-70	30	–	–	2	Open hole; destroyed	QA Ec 104
430-440	Aquia	14	04-08-96	90	46	1.96	8		QA Ec 105
--	Aquia	--	--	--	--	--	--	Open hole	QA Ed 34
250-260	Aquia	--	--	--	--	--	--	Open hole	QA Ed 35
186-320	Aquia	--	--	--	--	--	--	Open hole; well 1[2]	QA Ed 36
210-290	Aquia	20	12-10-62	200	40	5	8	Open hole; well 2	QA Ed 42
232-278	Aquia	30	03-25-93	251	45	5.58	24	Well 3	QA Ed 43
260-275	Aquia	29	03-25-93	25	13	1.92	1	WL; observation well	QA Ed 44
210-260	Aquia	32	08-10-84	500	88	5.68	2	Open hole; well 1	QA Ed 46
220-260	Aquia	25	02-03-75	200	10	20	10	Open hole; well 4	QA Ed 47
328-359	Aquia	63	09-06-69	49	6	8.17	10		QA Ed 48
338-368	Aquia	74	03-29-96	84	20	4.2	3		QA Ed 49
327-347	Aquia	34	09-07-88	80	16	5	9		QA Ed 51
194-214	Piney Point	17	04-10-74	40	18	2.22	6	WL; unused	QA Ee 24
400-440	Aquia	48	05-26-95	250	48	5.21	10	Well 5	QA Ee 30
405-435	Aquia	50	05-13-76	150	20	7.5	6	Open hole; well 6	QA Ee 31
280-300	Piney Point	66	09-06-86	30	15	2	7	WL	QA Ef 30
520-560	Aquia	70	11-30-92	100	50	2	5		QA Ef 31
480-500	Aquia	25	11-12-92	25	60	0.42	5	WQ	QA Ef 32
580-620	Magothy	11	04-08-86	100	8	12.5	7	WL	QA Fa 77

[2] Data from Overbeck and Slaughter, 1958; open hole

Table 13. Data for selected wells in Queen Anne's and Talbot Counties–Continued

Well number	Permit number	Ground-water appropriation number	Owner	Driller	Altitude of land surface (feet above sea level)	Completion date	Hole depth (feet below land surface)	Well depth (feet below land surface)	Diameter of screen (inches)
QA Fa 78	--	--	QA Co. Dept. Parks & Rec.	–	–	--	--	--	--
QA Fc 7	QA-73-2191	QA76GAP003	Prospect Bay Golf Course	Conrad J. Zittinger	10	05-26-78	420	356	2
QA Fc 8	QA-73-2192	QA76GAP003	Prospect Bay Golf Course	Conrad J. Zittinger	10	08-00-78	362	356	10
QA Fc 9	QA-73-2193	QA76GAP003	Prospect Bay Golf Course	Conrad J. Zittinger	19.64	08-23-78	360	329	10
QA Fc 10	QA-73-2938	QA80GAP013	QA Co. Sanitary District	Charles L. Collier	14	10-10-79	300	300	2
QA Fd 6	QA-73-2744	QA79GAP003	Univ. of MD-Wye R & E Ctr	William Wood	15	03-09-79	368	368	2
QA Fd 7	QA-73-3930	QA65GAP004	Univ. of MD-Wye R & E Ctr	Delmarva Drilling Co.	15	09-23-82	383	360	6
QA Fd 8	QA-81-1884	QA65GAP004	Univ. of MD-Wye R & E Ctr	Lifetime Well Drilling Co.	15	11-21-86	380	380	4
QA Fd 9	QA-88-0731	QA90GAP012	Univ. of MD-Wye R & E Ctr	Shannahan Artesian Well	10	06-20-90	396	383	6

EXPLANATION

Remarks
WL - Monthly water level site
WQ - Water quality site

Owner abbreviations
MD - Maryland
QA Co. - Queen Anne's County
Univ. of MD-Wye R & E Ctr - University of MD-Wye Research and Education Center
USACE - US Army Corps of Engineers

Drillers abbreviations
DE - Delaware

Table 13. Continued

Screen or open interval (feet below *land surface*)	Aquifer	Pumping test data: Static water level depth (feet below land surface)	Date reported	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per feet)	Duration of test (hours)	Remarks	Well number
--	Magothy	--	--	--	--	--	--	WQ	QA Fa 78
336-356	Aquia	20	05-26-78	75	70	1.07	4	Observation well	QA Fc 7
336-356	Aquia	19	08-00-78	201	103	1.95	24	Prospect #2	QA Fc 8
309-329	Aquia	24	08-23-78	257	63	4.08	8	Prospect #1	QA Fc 9
280-300	Aquia	15	10-10-79	50	17	2.94	6		QA Fc 10
338-368	Aquia	25	03-09-79	20	75	0.27	6	WL; well 2	QA Fd 6
340-360	Aquia	20.5	09-23-82	4	3.5	1.14	1	Well 3	QA Fd 7
355-380	Aquia	26	11-21-86	50	94	0.53	5	Well 5	QA Fd 8
352-383	Aquia	25	06-20-90	251	61	4.11	8		QA Fd 9

Table 13. Data for selected wells in Queen Anne's and Talbot Counties–Continued

Well number	Permit number	Ground-water appropriation number	Owner	Driller	Altitude of land surface (feet above sea level)	Completion date	Hole depth (feet below land surface)	Well depth (feet below land surface)	Diameter of screen (inches)
TA Ae 19	TA-73-0297	TA89GAP021	Pahlman Farm Enterprises	Edward Kelley	65	02-02-74	700	–	–
TA Ae 20	TA-73-0336	TA89GAP021	Pahlman Farm Enterprises	Edward Kelley	65	05-08-74	195	175	12
TA Ae 21	TA-73-0888	TA89GAP021	Pahlman Farm Enterprises	Edward Kelley	65	04-23-77	–	195	15
TA Af 10	TA-04-1413	TA57GAP104	Fox Canning Co.	Shannahan Artesian Welll	10	07-12-61	876	845	5
TA Af 12	TA-02-6797	TA57GAP004	Fox Canning Co.	Shannahan Artesian Well	10	05-23-57	240	240	–
TA Bd 25	TA-88-0483	TA89GAP004	Louis Foehrkolb	Lifetime Well Drilling Co.	15	10-15-90	490	490	4
TA Be 80	TA-73-0198	--	Samuel Fike	William Wood	55	08-01-73	350	350	4
TA Be 86	TA-94-0221	TA96GAP009	Johnson Logging	Lifetime Well Drilling Co.	50	11-18-96	620	620	2
TA Be 87	TA-73-1400	TA91GAP016	Ernie Fuchs	William Wood	55	07-18-79	62	62	4
TA Be 88	TA-81-0480	TA91GAP016	Ernie Fuchs	Lifetime Well Drilling Co.	55	10-24-83	66	66	12
TA Be 89	TA-73-1122	TA91GAP016	Ernie Fuchs	Edward Kelley	55	04-21-78	83	83	15
TA Bf 72	TA-01-6235	TA54GAP002	Allen Family Foods, Inc.	Shannahan Artesian Well	50	09-22-54	65	52	10
TA Bf 85	TA-88-0640	TA91GAP019	Allen Family Foods, Inc.	CZ Enterprises, Inc.	57	08-26-92	762	730	5
TA Bf 86	TA-81-0501	TA54GAP002	Allen Family Foods, Inc.	Delmarva Drilling Co.	45	01-23-84	78	75	12
TA Bf 88	TA-81-1054	TA54GAP002	Allen Family Foods, Inc.	David Tull Drilling & Pp.	50	02-10-86	292	292	2
TA Bf 89	TA-88-1553	TA93GAP013	Chesapeake Sod Farm	Lifetime Well Drilling Co.	55	11-06-93	200	200	4
TA Bf 90	TA-88-1552	TA92GAP009	Chesapeake Sod Farm	Lifetime Well Drilling Co.	55	11-06-93	40	40	4
TA Bf 91	TA-88-1551	TA92GAP009	Chesapeake Sod Farm	Lifetime Well Drilling Co.	55	11-06-93	40	40	4
TA Bf 93	TA-81-2074	TA81GAP004	Campbell & Ferrara Nurs.	Fisher Well Drilling	55	10-04-88	55	53	4
TA Bf 94	TA-73-1777	TA81GAP004	Campbell & Ferrara Nurs.	Lifetime Well Drilling Co.	55	05-06-81	131	131	2
TA Bf 95	TA-73-0498	TA89GAP023	Hutchison Brothers	Robert D. Maloney	45	03-03-75	140	140	4
TA Bf 96	TA-73-1729	TA89GAP023	Hutchison Brothers	Paul S. McCreary	45	08-11-81	140	140	4
TA Bf 97	TA-81-0479	TA91GAP016	Ernie Fuchs	Lifetime Well Drilling Co.	50	10-20-83	63	63	12
TA Cc 29	--	TA79GAP004	Town of St. Michaels	Shannahan Artesian Well	10	1928	–	455	8
TA Cc 32	TA-65-0050	TA79GAP004	Town of St. Michaels	Shannahan Artesian Well	10	02-15-65	465	458	8
TA Cc 34	TA-71-0042	TA71GAP002	Martingham Utilities	Shannahan Artesian Well	10	10-27-70	208	208	--
TA Cc 37	TA-72-0143	TA71GAP002	Martingham Utilities	Shannahan Artesian Well	10	08-04-72	395	395	4
TA Cc 42	TA-88-0497	--	Franz Burda	Shannahan Artesian Well	7	12-12-90	442	442	2
TA Cc 44	TA-88-1019	TA90GAP005	Franz Burda	Shannahan Artesian Well	7	06-08-90	220	220	4
TA Cc 49	TA-72-0142	TA71GAP002	Martingham Utilities	Shannahan Artesian Well	10	07-18-72	406	406	4
TA Cc 50	TA-81-2002	TA79GAP004	Town of St. Michaels	Shannahan Artesian Well	8	07-20-88	485	445	2
TA Cc 51	TA-81-2105	TA79GAP004	Town of St. Michaels	Shannahan Artesian Well	8	01-05-89	446	446	5
TA Cd 55	TA-71-0080	TA71GAP105	Easton Utilities Comm.	Shannahan Artesian Well	15	01-13-71	669	669	8
TA Cd 56	TA-81-1091	TA71GAP005	Easton Utilities Comm.	Shannahan Artesian Well	15	04-21-87	1,073	1,040	6
TA Cd 58	TA-92-0090	TA93GAP010	Easton Club	Shannahan Artesian Well	15	05-06-95	128	127	4
TA Cd 59	TA-92-0041	TA93GAP010	Easton Club	Shannahan Artesian Well	15	11-08-94	125	115	4
TA Ce 9	TA-00-0957	TA46GAP005	Tidewater Inn	Shannahan Artesian Well	38	12-07-46	160	160	--
TA Ce 10	TA-00-0957	TA46GAP005	Tidewater Inn	Shannahan Artesian Well	38	12-21-46	160	160	--
TA Ce 60	TA-03-7628	TA71GAP005	Easton Utilities Comm.	Shannahan Artesian Well	15	04-22-60	1,051	1,045	8

Table 13. Continued

Screen or open interval (feet below land surface)	Aquifer	Pumping test data: Static water level depth (feet below land surface)	Date reported	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per feet)	Duration of test (hours)	Remarks	Well number
–	--	–	–	–	–	–	–	Test hole only	TA Ae 19
168-175	Piney Point	19	05-08-74	401	82	4.89	4		TA Ae 20
135-195	Piney Point	20	04-23-77	500	92	5.43	2		TA Ae 21
610-840	Aquia & Matawan	6	07-12-61	325	201	1.62	24		TA Af 10
--	--	Flowing	05-23-57	180	--	--	8		TA Af 12
430-490	Aquia	51	10-15-90	100	49	2.04	5		TA Bd 25
250-350	Piney Point	35	08-01-73	10	55	0.18	2	WQ	TA Be 80
600-620	Aquia	60	11-18-96	30	60	0.5	2	WQ and WL	TA Be 86
52-62	Miocene	4	07-18-79	15	46	0.33	6		TA Be 87
21-66	Miocene	12	10-24-83	60	4	15	5		TA Be 88
33-83	Miocene	10	04-21-78	450	35	12.86	1		TA Be 89
31-52	Miocene	11	09-22-54	175	14	12.5	4	Well 1	TA Bf 72
539-730	Aquia	70	08-26-92	170	136	1.25	24	Well 3	TA Bf 85
35-75	Miocene	9.5	01-23-84	100	6.5	15.38	8	Well 6	TA Bf 86
277-292	Piney Point	12	02-10-86	27	88	0.31	6		TA Bf 88
140-200	Miocene	70	11-06-93	20	50	0.4	5	Well 1	TA Bf 89
30-40	Miocene	15	11-06-93	15	20	0.75	5	Well 2	TA Bf 90
30-40	Miocene	15	11-06-93	25	20	1.25	5	Well 3	TA Bf 91
33-53	Miocene	8	10-04-88	60	17	3.53	4		TA Bf 93
112-131	Miocene	20	05-06-81	20	80	0.25	5		TA Bf 94
130-140	Miocene	18	03-03-75	22	11	2	3		TA Bf 95
130-140	Miocene	28	08-11-81	30	38	0.79	2		TA Bf 96
23-63	Miocene	5	10-20-83	100	4	25	5	Replacement well	TA Bf 97
–	Aquia	8	1928	250	–	–	–	Well 1; not in use	TA Cc 29
408-458	Aquia	16.3	05-21-65	265	35.6	7.44	10	Well 2	TA Cc 32
168-208	Piney Point	16	10-27-70	34	11	3.09	15		TA Cc 34
374-395	Aquia	22	08-04-72	132	31	4.26	8	Well 1	TA Cc 37
432-442	Aquia	35	12-12-90	30	20	1.5	1	WQ	TA Cc 42
180-220	Piney Point	16	06-08-90	73	30	2.43	2		TA Cc 44
385-406	Aquia	20	07-18-72	104	25	4.16	8	Well 2	TA Cc 49
400-445	Aquia	41	07-20-88	30	10	3	1	WL	TA Cc 50
399-446	Aquia	40	01-05-89	402	67	6	24	Well 3	TA Cc 51
575-669	Aquia	41	01-31-71	530	181	2.93	24	Well 9 & WL	TA Cd 55
1,012-1,040	Magothy	137	04-21-87	146	233	0.63	14	Well 10	TA Cd 56
97-127	Miocene	24	05-06-95	27	42	0.64	6		TA Cd 58
85-115	Miocene	19	11-08-94	22	60	0.37	8		TA Cd 59
116-160	Miocene	78	12-07-46	200	48	4.17	6.5	Well 1; open hole	TA Ce 9
114-160	Miocene	78	12-21-46	200	48	4.17	6.5	Well 2; open hole	TA Ce 10
1,010-1,045	Magothy	43	04-22-60	463	82	5.65	24	Well 6	TA Ce 60

Table 13. Data for selected wells in Queen Anne's and Talbot Counties–Continued

Well number	Permit number	Ground-water appropriation number	Owner	Driller	Altitude of land surface (feet above sea level)	Completion date	Hole depth (feet below land surface)	Well depth (feet below land surface)	Diameter of screen (inches)
TA Ce 61	TA-04-6762	TA71GAP005	Easton Utilities Comm.	Shannahan Artesian Well	40	07-10-62	1,091	1,057	8
TA Ce 67	TA-66-0012	TA71GAP005	Easton Utilities Comm.	Shannahan Artesian Well	45	09-20-65	1,099	1,092	8
TA Ce 70	TA-81-1967	TA71GAP205	Easton Utilities Comm.	Delmarva Drilling Co.	25	08-17-88	1,225	1,189	10
TA Ce 72	TA-73-0488	TA74GAP004	Talbot Co. Park Bd.	Shannahan Artesian Well	50	11-29-75	648	648	2
TA Ce 73	TA-81-1027	TA73GAP101	Jensen's, Inc	Shannahan Artesian Well	65	08-27-86	666	666	4
TA Ce 74	TA-88-1512	TA93GAP010	Easton Club	Shannahan Artesian Well	15	12-23-93	266	130	4
TA Ce 75	TA-04-7331	TA62GAP002	Talbot Trailer Park, Inc.	Shannahan Artesian Well	65	07-03-62	194	175	2
TA Ce 77	TA-81-1565	--	Michael Feehley	Shannahan Artesian Well	55	08-18-87	245	239	4
TA Ce 78	TA-94-0352	--	Linda Gaulden	Shannahan Artesian Well	45	07-25-97	680	680	2
TA Da 48	TA-81-0707	TA82GAP008	Tilghman Island Sewer Plt.	Shannahan Artesian Well	8	11-16-84	403	403	4
TA Db 37	TA-00-0294	TA46GAP003	Tilghman Packing Co.	Albert L. Wilson	5	03-22-46	200	200	--
TA Db 38	TA-00-5555	TA46GAP003	Tilghman Packing Co.	Shannahan Artesian Well	5	05-06-50	442	422	--
TA Db 41	TA-00-0215	TA46GAP003	Tilghman Packing Co.	Shannahan Artesian Well	5	03-25-46	418	416	--
TA Db 42	--	TA46GAP003	Tilghman Packing Co.	John Wilson & Sons	5	00-00-36	--	--	--
TA Db 43	TA-00-7563	TA46GAP003	Tilghman Packing Co.	Albert L. Wilson	5	03-17-51	210	210	--
TA Db 44	--	TA46GAP003	Tilghman Packing Co.	--	5	--	--	400	--
TA Db 45	--	TA46GAP003	Tilghman Packing Co.	--	5	--	--	--	--
TA Db 60	TA-02-6262	TA46GAP003	Tilghman Packing Co.	Sam Shannahan Well Co	5	00-00-57	216	206	--
TA Db 64	TA-94-0244	TA99GAP001	MD Dept. of Transp.	Shannahan Artesian Well	10	01-21-98	410	410	2
TA Dc 54	TA-70-0109	TA70GAP002	Town of Oxford	George Kelley	5	03-24-70	630	600	--
TA Dc 56	TA-81-0271	TA70GAP002	Town of Oxford	Shannahan Artesian Well	5	07-11-83	578	578	5
TA Dd 53	TA-05-3609	TA81GAP101	Talbot Country Club	Shannahan Artesian Well	10	09-20-63	640	640	5
TA Dd 58	TA-88-0829	TA56GAP004	Talbot Country Club	Shannahan Artesian Well	10	01-24-92	645	645	2
TA Ed 13	TA-81-0548	TA84GAP003	Dickerson Boat Builders	Shannahan Artesian Well	8	10-02-84	333	333	4
TA Ee 7	TA-00-0212	TA46GAP001	Trappe Canning Co.	Shannahan Artesian Well	55	03-26-46	423	360.6	6
TA Ee 8	TA-00-0895	TA46GAP001	Trappe Canning Co.	Shannahan Artesian Well	55	06-12-46	1,245	948	10/8
TA Ee 41	TA-67-0099	TA79GAP006	Town of Trappe	Shannahan Artesian Well	52	05-01-67	433	410	4
TA Ee 42	TA-70-0134	TA79GAP006	Town of Trappe	Shannahan Artesian Well	52	12-08-70	429	421	--

Owner abbreviations
MD - Maryland
Plt - Plant
Nurs - Nursery (or Nurseries)

Table 13. Continued

Screen or open interval (feet below land surface)	Aquifer	Pumping test data: Static water level depth (feet below land surface)	Date reported	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per feet)	Duration of test (hours)	Remarks	Well number
918-1,057	Magothy	94.6	07-10-62	494	158.4	3.12	24	Well 7	TA Ce 61
850-1,092	Magothy	69	09-20-65	500	202	2.48	50	Well 8	TA Ce 67
1,143-1,184	Upper Patapsco	26	08-17-88	1015	118	8.6	24	Well 11	TA Ce 70
618-648	Aquia	68	11-29-75	20	31	0.65	6		TA Ce 72
638-666	Aquia	91	08-27-86	70	68	1.03	4		TA Ce 73
90-130	Miocene	11	12-23-93	95	55	1.73	24		TA Ce 74
133-143	Miocene	42	07-03-62	15	58	0.26	6		TA Ce 75
229-239	Miocene	45	08-18-87	12	81	0.15	1	WL	TA Ce 77
660-680	Aquia	95	07-25-97	12	15	0.8	1	WQ	TA Ce 78
378-403	Aquia	22	11-16-84	89	41	2.17	2		TA Da 48
100-200	Piney Point	6	03-22-46	12	9	1.33	4	Open hole	TA Db 37
391-421	Aquia	9	05-06-50	100	46	2.17	10		TA Db 38
391-416	Aquia	2	03-25-46	100	103	0.97	24		TA Db 41
--	--	--	--	--	--	--	--		TA Db 42
108-210	Piney Point	7	03-17-51	18	11	1.64	4	Open hole	TA Db 43
--	--	--	--	--	--	--	--		TA Db 44
--	--	--	--	--	--	--	--		TA Db 45
197-206	Piney Point	2	04-00-57	100	61	1.64	6		TA Db 60
400-410	Aquia	36	01-21-98	22	15	1.47	8	WL	TA Db 64
570-600	Aquia	16	03-24-70	300	89	3.37	12	Well 1	TA Dc 54
538-578	Aquia	30	07-11-83	275	79	3.48	8	Well 2	TA Dc 56
590-640	Aquia	32	09-20-63	200	151	1.32	8		TA Dd 53
615-645	Aquia	71	01-24-92	20	14	1.43	1	WL	TA Dd 58
316-333	Piney Point	52	10-02-84	19	14	1.36	1	WL	TA Ed 13
360-420	Piney Point	80	03-26-46	80	30	2.67	--	Open hole	TA Ee 7
407-925	Piney Point & Matawan	68	06-12-46	240	178	1.35	1.5		TA Ee 8
370-410	Piney Point	105	05-01-67	47	29	1.62	8	Well 4	TA Ee 41
369-421	Piney Point	118	12-08-70	48	26	1.85	20	Well 5	TA Ee 42

Remarks
WL = Monthly-water-level site
WQ = Water-quality site

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties

[MGS = Maryland Geological Survey; USGS = U.S. Geological Survey; QA Co = Queen Anne's County; MD = Maryland; TA Co = Talbot County]

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
QA56G001	S. E. W. Friel - Wye Mills Cannery (1)	Ee 18	None	150,000	Aquia	Destroyed
		Ee 19	None			Destroyed
		Ee 20	02-3333			Destroyed
		Ee 30	94-004			Well 5
		Ee 31	73-1146			Well 6
QA56G101	S. E. W. Friel - Wye Mills Cannery (2)	Ee 12	None	0	Piney Point	Destroyed
QA61G005	Tidewater Publishing Corporation (3)	De 34	73-3999	123,000	Aquia	
		De 35	73-4000			
		De 36	94-0130			
		None	04-4920			Destroyed
QA63G002	MD Department of Corrections (4)	Cf 66	88-1622	35,000	Aquia	Well 2
		Cf 67	88-1623			Well 3
		Cf 68	05-0363			Well 1
QA63G004	Arthur S. Hock, Jr. -Pine Springs Trailer Park (5)	None	81-1372	16,000	Aquia	Unable to locate wells in the field
		None	92-0309			
QA65G004	Univ of MD-Wye Research & Education Center (6)	Fd 6	73-2744	96,000	Aquia	Well 2
		Fd 7	73-3930			Well 3
		Fd 8	81-1884			Well 5
		None	73-0946			Well 1
QA67G002	Town of Centreville (7)	De 27	None	355,000	Aquia	Well 1; unused
		De 28	None			Well 2; destroyed
		De 29	03-3814			Well 3
		De 30	67-0030			Well 4
		De 37	04-4935			
		De 43	94-1213			Test hole for QA De 44
		De 44	94-1390			
QA69G003	Con Agra Poultry Company (8)	Ed 48	69-0179	50,000	Aquia	
		Ed 49	94-0300			
QA70G002	QA Co. Sanitary District - Thompson Creek North (9)	Eb 174	73-0215	92,000	Aquia	Destroyed
		Eb 183	94-1701			Replaced QA Eb 174
QA70G102	QA Co. Sanitary District - Thompson Creek (9)	Eb 173	81-0893	5,000	Upper Patapsco	
QA71G002	Mears Point Marina (10)	Ec 85	81-0128	35,000	Aquia	Test well; destroyed
		Ec 104	71-0040			Destroyed
		Ec 105	94-0401			
QA71G007	S. E. W. Friel - Queenstown Cannery (11)	Ed 34	None	123,000	Aquia	
		Ed 35	None			
		Ed 46	81-0485			Well 1
		Ed 47	73-0803			Well 4
QA74G001	Queenstown Properties (12)	None	None	0	Aquia	

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties–Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
QA76G003	Prospect Bay Golf Course (13)	Fc 7 Fc 8 Fc 9	73-2191 73-2192 73-2193	100,000	Aquia	Observation well Well 2 Well 1
QA78G009	Jack Dietrich - Bay View at Kent Narrows (14)	Ec 103	73-2433	15,000	Aquia	
QA79G010	Queenstown Commission (15)	Ed 36 Ed 42 Ed 43 Ed 44	None 04-9856 88-1728 88-1726	77,000	Aquia	Well 1 Well 2; backup well Well 3 Observation well
QA80G013	QA Co. Sanitary District - Prospect Plantation (16)	Fc 10	73-2938	125,000	Aquia	
QA82G002	QA Co. Sanitary District - Queens Landing Condominiums (17)	Eb 146 Eb 150 Eb 172	81-0152 81-0153 81-0540	27,000	Aquia	Well 1 Test well; destroyed Well 2
QA83G005	QA Co. Sanitary District - Harborview Subdivision (18)	Eb 154	81-0446	15,000	Aquia	
QA84G004	Kent Island Joint Venture (19)	Eb 180	81-1227	20,000	Aquia	
QA84G016	QA Co. Sanitary District - Bridgepointe Townhouses (20)	Eb 169 Eb 170	88-1490 81-1232	20,000	Upper Patapsco	Well 2 Well 1
QA84G017	QA Co. Sanitary District - Oyster Cove (21)	Ec 89 Ec 90	81-0873 81-1493	99,000	Upper Patapsco	Well 1 Well 2
QA85G009	QA Co. Dept. Parks & Rec. - Blue Heron Golf Course (22)	Fa 77	81-1498	10,000	Magothy	
QA85G019	QA Co. Sanitary District - Chesapeake Bay Business Park (23)	Eb 161 Eb 181	None 81-1494	160,000	Magothy	Test well; destroyed
QA85G024	QA Co. Sanitary District - Bayside Marina Condos. (24)	Eb 162 Eb 171	81-1753 81-1778	144,000	Upper Patapsco	Well 1 Well 2
QA85G030	Bay Bridge Marina (25)	Eb 179 None	81-2870 71-0294	28,000	Upper Patapsco	Well 1 Destroyed ?
QA87G035	Conard-Pyle Company (26)	Df 56 Df 57 None	81-3038 92-0420 81-2373	400,000	Aquia	 Test hole; destroyed
QA89G020	Herschell B. Claggett (27)	Ef 31 None	88-1734 88-0984	11,000	Aquia	 Owner - not drilled
QA89G022	John E. Gerber III (28)	None	None	12,000	Aquia	
QA89G024	QA Co. Sanitary District - Stevensville (29)	Eb 166 Eb 167	88-0686 94-0318	50,000	Upper Patapsco	Well 1 Well 2

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties–Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
QA89G026	Washington Brick & Terracotta - Queenstown Harbor Golf Course (30)	Ec 100	88-0732	72,000	Matawan	
QA90G003	Charles & John Haines (31)	None	None	57,000	Aquia	
QA90G012	University of MD - Wye Research & Education Center (32)	Fd 9	88-0731	50,000	Aquia	
QA90G021	Goose Valley Fish Farms (33)	Bf 44	88-0752	200,000	Aquia	Unused
QA90G040	Paul E. Schlosser (34)	Bg 63	88-0958	180,000	Aquia	
QA91G001	Bell Nursery Farm, Inc. (35)	Bh 48	88-1176	347,000	Aquia	Test well
QA91G007	Ashley Hunt Ray Farms (36)	Dg 41	67-0123	119,000	Columbia	Unused; Owner - water comes from pond
QA91G009	Ashley Hunt Ray Farms (37)	None	None	166,000	Aquia	Owner - water comes from pond
QA91G013	Central Sod Farms of MD (38)	None	65-0186	100,000	Aquia	
QA91G016	Ball & Burlap Nursery (39)	Dd 29 Dd 30	81-1614 81-1127	135,000	Aquia	
QA91G032	Charles A. Taff (40)	Cg 65	02-9634	189,000	Columbia	
QA92G003	Louis Shaeffer / Pintail Point Partnership (41)	Ed 51 None	81-2860 81-0321	200,000	Aquia	
QA92G007	Moore Brothers, Inc. (42) (Stanley & John)	Bg 69 Bg 70	88-1656 88-1449	158,000	Aquia	 Destroyed
QA92G008	A. A. MacGlashan III (43)	Cf 74	02-0269	249,000	Aquia	
QA92G009	Dorsey Patchett (44)	None	None	221,000	Aquia	
QA92G011	Chino Farms, Inc. (45)	None	88-1918	221,000	Aquia	Test well
QA92G012	Chino Farms, Inc. (46)	None	None	193,000	Aquia	
QA92G013	Chino Farms, Inc. (47)	Bf 37 Bf 38 Bf 39 Bf 40	73-2594 73-2593 73-3074 73-3075	217,000	Aquia	
QA92G014	Chino Farms, Inc. (48)	Be 22 Be 23	88-1537 94-0627	157,000	Aquia	 Test well
QA92G015	Chino Farms, Inc. (49)	None None	73-2591 73-2592	137,000	Aquia	Unable to locate wells in the field
QA92G016	James O'Neill (50)	None	None	150,000	Magothy	

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties–Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
QA92G020	Charles & Frances Haines (51)	Bh 49 Bh 50	88-1491 81-2111	30,000	Aquia	
QA92G026	Van Land Farms, Inc. (52)	Bf 35 Bf 41 Bf 42	88-2182 81-2161 81-2162	302,000	Aquia	Test well Test well
QA92G027	Peter G. Sheaffer (53)	Be 25 Be 26	73-1823 73-1889	296,000	Aquia	
QA92G032	Clovelly Family Partnership (54)	None	None	125,000	Aquia	
QA92G033	Neff & Son, Inc. (55)	Be 27 Be 28	73-2255 73-3047	244,000	Aquia	
QA92G044	QA Co. Sanitary District - Oyster Cove (56)	Ec 94	88-2093	88,000	Aquia	Well 3
QA92G047	Gordon Drummer (57)	None	None	50,000	Aquia	
QA93G002	Michael R. Bostic (58)	None	None	188,000	Aquia	
QA93G010	Temple Rhodes, Jr. (59)	None	None	247,000	Aquia	
QA93G011	Temple Rhodes, Jr. (60)	None	None	148,000	Aquia	
QA93G012	Temple Rhodes, Jr. (61)	None	None	97,000	Aquia	
QA93G013	Temple Rhodes, Jr. (62)	None	None	109,000	Aquia	
QA93G034	Chino Farms, Inc. (63)	None	94-0326	325,000	Aquia	Test hole
QA94G005	Michael Bostic -Raymond Farm (64)	Cf 75 None	92-0432 92-0424	378,000	Aquia	 Test hole; destroyed
QA94G007	QA Co. Sanitary District - Grasonville (65)	Ec 91 Ec 92	92-0457 92-0465	342,000	Upper Patapsco	Well 1 Well 2
QA95G001	Central Sod Farms of MD (66)	Dd 27 Dd 28 None	65-0186 88-1103 94-0338	411,000	Aquia	
QA95G010	Richard Smith -Bourdon Farm (67)	None	None	265,000	Aquia	
QA95G011	Richard Smith - Smith Farm (68)	None	None	122,000	Aquia	
QA96G009	U. S. Links, Inc - Kent Island Golf Course (69)	None	None	0	Upper Patapsco	

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties–Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
QA97G003	James Schillinger, Sr. (70)	De 40 De 41 De 42	94-1069 94-1070 94-1068	75,000	Aquia	Well 1 Test well 1 Well 2
QA97G011	Allen M. Weaver, Jr. (71)	Bh 53	94-0785	129,000	Aquia	
QA97G014	Chino Farms, Inc. (72)	None	None	85,000	Aquia	
QA97G050	QA Co. Sanitary District - Stevensville (-)	Eb 182 Eb 184	94-1444 94-1702	750,000	Lower Patapsco	Test well Well 3

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties--Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
TA46G001	Trappe Canning Company (126)	TA Ee 7	00-0212	80,000	Piney Point	TA Ee 8 is also screened in the Matawan Formation
		TA Ee 8	00-0895			
TA46G003	Tilghman Packing Co. (127)	TA Db 37	00-0294	0	Piney Point	
		TA Db 38	00-5555		Aquia	
		TA Db 41	00-0215		Aquia	
		TA Db 43	00-7563		Piney Point	
		TA Db 60	02-6262		Piney Point	
		None	00-5173			
		TA Db 40	none			Abandoned
		TA Db 42	none			Abandoned
		TA Db 44	none			Abandoned
		TA Db 45	none			Abandoned
TA46G005	Tidewater Inn (128)	TA Ce 9	00-0957	70,000	Miocene	Both wells drilled under the one permit
		TA Ce 10	00-0957			
TA57G004	Fox Canning Company (129)	TA Af 12	02-6797	175,000		
		None	72-0087			
TA57G104	Fox Canning Company (130)	TA Af 10	04-1413	50,000	Aquia and Matawan	
		None	04-0517			
TA62G002	Talbot Trailer Park, Inc. (131)	TA Ce 75	04-7331	12,000	Miocene	
TA70G002	Town of Oxford (132)	TA Dc 54	70-0109	140,000	Aquia	Well 1
		TA Dc 56	81-0271			Well 2
		TA Dc 2	none			Abandoned
TA71G002	Martingham Utilities (133)	TA Cc 37	72-0143	65,000	Aquia	
		TA Cc 49	72-0142			
		TA Cc 34	71-0042		Piney Point	Abandoned
		None	71-0008			Test hole
		None	71-0042		Piney Point	Abandoned

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties-Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
TA71G005	Easton Utilities Commission (136, 137, 138, 139)	TA Cd 56 TA Ce 60 TA Ce 61 TA Ce 67 TA Ce 50 TA Ce 1 TA Ce 2 TA Ce 3 TA Ce 4 TA Ce 5 TA Ce 6 TA Ce 68 TA Ce 69 None None	81-1091 03-7628 04-6762 66-0012 00-8836 none none none none none none 81-1709 81-1514 71-0041 66-0012	740,000	Magothy	Well 10 Well 6 Well 7 Well 8 Abandoned Abandoned Abandoned Abandoned Abandoned Abandoned Test hole Test hole Test hole Abandoned
TA71G105	Easton Utilities Commission (135)	TA Cd 55	71-0080	260,000	Aquia	Well 9
TA71G205	Easton Utilities Commission (134)	TA Ce 70	81-1967	1,000,000	Upper Patapsco	Well 11
TA73G001	Jenson's, Inc / Hyde Mobile Home Park (140)	None None	73-0027 73-1214	45,000	Miocene	Unable to locate wells
TA73G101	Jenson's, Inc / Hyde Mobile Home Park (141)	TA Ce 73	81-1027	10,000	Aquia	
TA74G105	TA Co Park Board / Hog Neck Golf Club (142)	None None	73-0328 73-0442	20,000	Miocene	Unable to locate wells
TA74G205	TA Co Park Board / Hog Neck Golf Club (143)	TA Ce 72 None None	73-0488 73-0329 88-0032	70,000	Aquia	Unable to locate the other wells
TA79G004	Town of St. Michaels (144)	TA Cc 32 TA Cc 51 TA Cc 29	65-0050 81-2105 none	325,000	Aquia	 Well 3 Well 1
TA79G006	Town of Trappe (145)	TA Ee 41 TA Ee 42 TA Ee 1 TA Ee 29	67-0099 70-0134 none 01-4034	210,000	Piney Point	 Abandoned Abandoned
TA81G004	Campbell & Ferrara Nurseries Corp. (146)	TA Bf 93 TA Bf 94	81-2074 73-1777	42,000	Miocene	
TA81G101	Talbot Country Club (147)	TA Dd 53 TA Dd 58 None	05-3609 88-0829 73-0328	10,000	Aquia	 Standby Test hole
TA82G008	Tilghman Island Sewer Plant (148)	TA Da 48	81-0727	15,000	Aquia	
TA88G024	Wildlife International, Ltd. (-)	None	88-0042	20,000	Miocene	Test well; unable to locate well

Table 14. Ground-water appropriation permits for users greater than 10,000 gallons per day in Queen Anne's and Talbot Counties-Continued

Groundwater appropriation permit (GAP) number	Owner - location (map identifier number. See figure 39)	MGS/USGS well number	Well permit number	Permit average appropriated (gallons per day)	Aquifer or Formation	Remarks
TA88G031	Robert Pascal (149)	None None	88-0054 88-0055	70,000	Miocene	Owner denied access
TA89G004	Louis Foehrkolb, Inc. (150)	TA Bd 25	88-0483	46,000	Aquia	
TA89G021	Pahlman Farm Enterprises, Inc. (151)	TA Ae 19 TA Ae 20 TA Ae 21	73-0297 73-0336 73-0888	300,000	Piney Point	
TA89G023	Hutchinson Brothers (-)	TA Bf 96 TA Bf 95	73-1729 73-0498	75,000	Miocene	
TA90G005	Franz Burda (152)	TA Cc 44	88-1019	50,000	Piney Point	
TA91G016	Ernie Fuchs (153)	TA Be 87 TA Be 88 TA Be 89 TA Bf 97 None	73-1400 81-0480 73-1122 81-0479 81-0422	473,000	Miocene	Replaces TA 81-0422 Destroyed
TA91G019	Allen Family Foods, Inc. (154)	TA Bf 85	88-0830	245,000	Aquia	
TA92G004	Campbell & Ferrara Nurseries Corp. (155)	None	none	29,000	Miocene	Unable to locate wells
TA92G009	Chesapeake Sod Farm (156)	TA Bf 90 TA Bf 91	81-1552 81-1551	63,000	Miocene	Well 2 Well 3
TA93G010	Easton Club (157)	TA Cd 58 TA Cd 59 TA Ce 74	92-0090 92-0041 88-1512	28,000	Miocene	
TA93G013	Chesapeake Sod Farm (158)	TA Bf 89	88-1553	63,000	Miocene	Well 1
TA94G016	Pete Pappas (159)	None	none	10,000	Aquia	No information on wells
TA94G020	Chesapeake Sod Farm (160)	None None None None	92-0288 92-0289 92-0290 88-1599	107,000	Miocene	Unable to locate wells

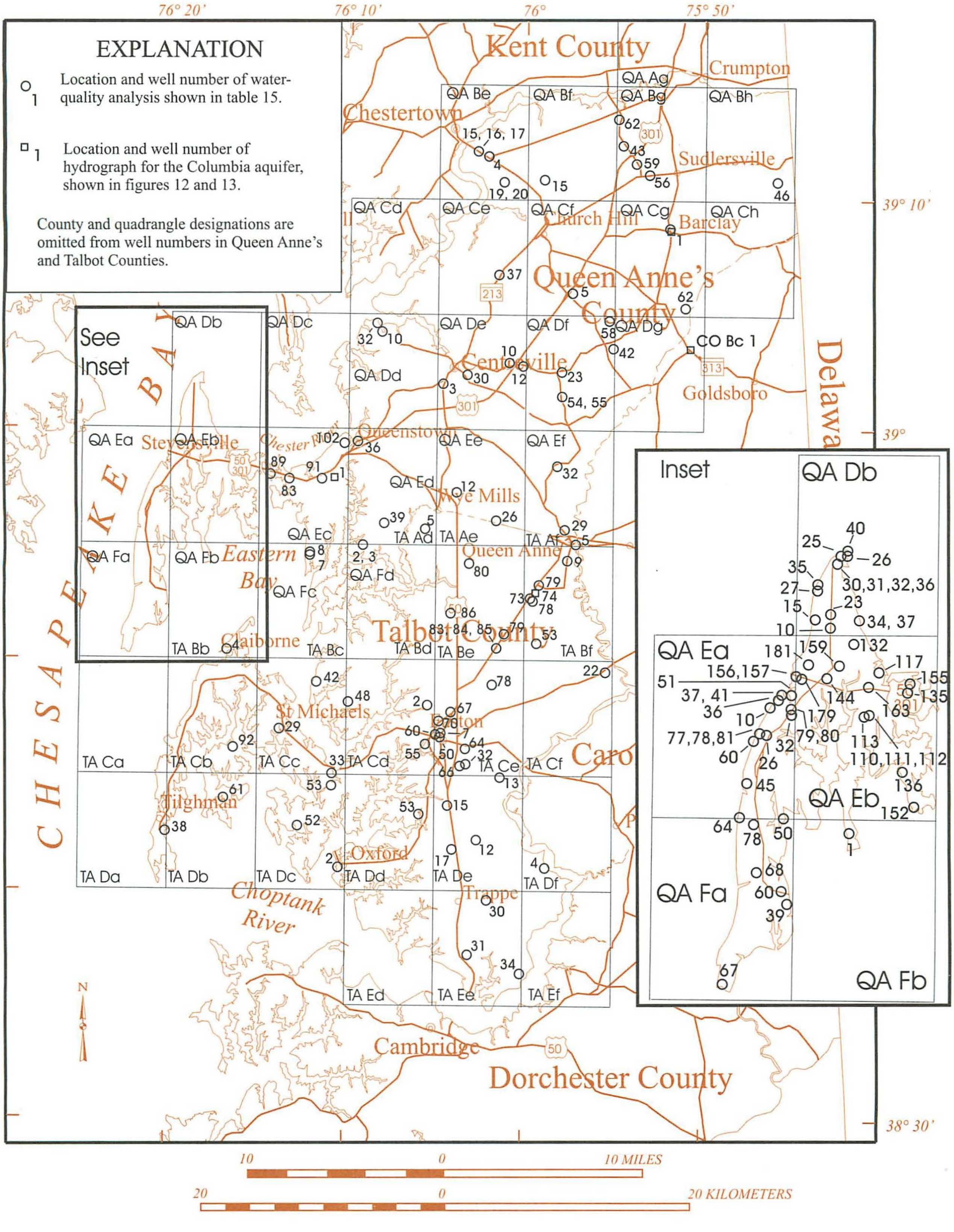

Figure 62. Map of 5-minute quadrangles used to designate well numbers, showing locations of selected water-quality analyses and hydrographs for the Columbia aquifer in Queen Anne's and Talbot Counties.

Table 15. Selected water-quality analyses from wells in Queen Anne's and Talbot Counties

[°C = degrees Celsius; μS/cm = microsiemens per centimeter; mg/L = milligrams per liter; pCi/L = picocuries per liter; see figure 62 for locations of wells]

Well number	Date	pH	Temperature (°C)	Specific conductance (μS/cm	TDS (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sulfate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)
					COLUMBIA AQUIFER							
QA Be 19	07-13-88	6.6	15.6	459	270	3.5	1.9	76.0	9.1	11.0	220	12
QA Be 20	07-11-90	4.1	13.4	194	-	2.6	4.3	1.2	11.0	<1.0	0.0	20
QA Bf 15	05-06-81	6.7	13.7	276	175	2.2	1.6	52.0	2.2	4.7	171	2.6
QA Bg 56	04-09-81	5.2	14.3	192	101	13	2.3	13.0	6.5	6.8	29.3	28
QA Cf 5	09-29-54	6.9	14.0	87	73	7.5	1.4	5.7	2.8	0.6	19.5	8.9
QA Cg 1	02-20-91	5.7	15.4	185	87	12	6.3	9.4	4.3	12.0	14.6	17
QA Db 40	07-25-88	4.2	14.6	506	308	77	1.1	4.6	7.1	42.0	2.4	110
QA De 10	05-08-81	5.8	11.4	409	224	25	50.0	15.0	7.9	59.0	72.0	21
QA De 12	01-10-55	6.7	11.0	805	536	16	49.0	46.0	33.0	42.0	59.8	48
QA Df 23	01-10-55	6.0	8.5	150	100	10	6.8	5.5	4.0	6.2	9.8	11
QA Df 54	07-12-88	5.6	20.3	138	118	12	1.4	10.0	4.9	0.5	25.6	13
QA Df 55	07-12-88	5.3	19.4	173	111	13	1.3	9.1	4.2	0.6	13.4	12
QA Ed 39	06-29-89	4.6	13.9	107	-	7	1.6	5.0	3.2	<1.0	6.1	13
QA Ee 26	05-04-81	4.5	12.9	93	74	9.6	2.1	9.6	5.1	2.0	29.3	15
QA Fd 2	07-11-89	7.1	14.8	347	252	7.6	1.0	65.0	0.9	48.0	137	12
QA Fd 3	07-11-89	4.0	22.4	658	-	13	5.9	47.0	26.0	78.0	0.0	80
TA Be 83	07-20-88	5.0	13.6	259	-	33	1.6	8.7	3.1	<0.2	8.5	44
TA Be 84	07-19-88	5.0	15.6	188	125	21	1.2	7.2	3.9	2.1	8.5	24
TA Be 85	06-29-89	4.6	14.5	162	132	4.1	2.1	12.0	11.0	36.0	2.4	19
TA Bf 9	05-07-81	5.4	14.8	782	424	92	31.0	28.0	21.0	27.0	59.8	180
TA Bf 53	05-07-81	5.7	11.8	222	105	13	12.0	21.0	2.6	18.0	39.0	9.7
TA Bf 78	09-16-65	6.5	13.3	126	67	3.8	1.9	14.0	2.4	2.5	29.3	6.4
TA Ce 32	05-06-81	4.1	14.0	280	101	7.2	1.9	14.0	15.0	12.0	2.4	33
					MIOCENE AQUIFERS							
TA Af 5	12-21-54	8.1	11.5	363	231	30	9.8	22.0	11.0	2.0	207	2.1
TA Ce 7	08-09-93	8.0	16.3	362	243	14	5.6	41.0	12.0	2.9	217	2.7
TA Ce 64	09-17-65	7.9	15.0	373	240	4.5	1.1	72.0	4.0	8.5	224	9.5

Table 15.--Continued

Bromide (mg/L)	Iodide (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Man-ganese (mg/L)	Nitrate (mg/L)	Phos-phorus (mg/L)	Carbon (mg/L)	Silica (mg/L)	Oxygen (mg/L)	Radon (pCi/L)	Well number
COLUMBIA AQUIFER											
-	-	<0.1	0.36	0.22	8.5	<0.01	1.1	9.4	0.4	830	QA Be 19
0.04	-	0.1	0.006	0.27	13	0.03	0.8	14	6.7	-	QA Be 20
-	-	0.2	1.0	0.07	-	-	-	24	-	-	QA Bf 15
-	-	<0.1	0.24	0.11	-	-	-	17	-	-	QA Bg 56
-	-	0.1	-	-	4.1	-	-	18	-	-	QA Cf 5
-	-	<0.1	0.14	0.06	-	-	-	19	2.9	-	QA Cg 1
-	-	<0.1	0.26	0.12	6.3	0.01	1.7	36	0.6	500	QA Db 40
-	-	<0.1	0.17	0.05	-	-	-	11	-	-	QA De 10
-	-	0.2	-	-	59	-	-	11	-	-	QA De 12
-	-	<0.05	-	-	9.5	-	-	9.5	-	-	QA Df 23
-	-	0.1	0.005	0.01	9.8	0.02	0.8	20	7.8	560	QA Df 54
-	-	0.2	<.003	0.03	9.8	0.03	1.1	20	7.1	530	QA Df 55
0.02	-	<0.1	<.003	0.04	4.6	<0.01	0.5	12	6.7	2,400	QA Ed 39
-	-	<0.1	0.16	0.12	-	-	-	16	-	-	QA Ee 26
0.03	-	0.3	0.43	0.02	0.1	0.11	1.0	49	0.4	200	QA Fd 2
0.08	-	1.6	0.033	0.16	29	0.07	1.4	40	5.2	-	QA Fd 3
-	-	<0.1	0.009	0.01	10	0.01	1.3	27	5.5	210	TA Be 83
-	-	<0.1	0.14	0.19	9.2	<0.01	1.6	20	3.8	200	TA Be 84
0.01	-	<0.1	0.091	0.09	6.7	<0.01	0.6	16	7.4	180	TA Be 85
-	-	<0.1	0.03	0.04	-	-	-	16	-	-	TA Bf 9
-	-	<0.1	0.06	0.02	-	-	-	9.5	-	-	TA Bf 53
-	-	0.2	-	-	-	-	-	22	-	-	TA Bf 78
-	-	<0.1	0.04	0.08	-	-	-	17	-	-	TA Ce 32
MIOCENE AQUIFERS											
-	-	0.4	-	-	0.2	-	-	51	-	-	TA Af 5
-	-	0.3	0.11	0.01	<0.05	<0.01	-	57	0.1	-	TA Ce 7
-	-	0.2	-	-	0.0	-	-	30	-	-	TA Ce 64

Table 15. Selected water-quality analyses from wells in Queen Anne's and Talbot Counties–Continued

Well number	Date	pH	Temperature (°C)	Specific conductance (µS/cm	TDS (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sulfate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)
TA Ce 66	09-14-65	8.5	16.1	347	258	11	6.3	56.0	7.2	9.7	224	2.0
TA De 15	09-17-65	7.5	16.1	281	208	3.6	2.8	32.0	16.0	5.0	181	2.5
TA Df 4	09-23-65	7.9	16.7	418	307	64	5.7	21	10.0	6.2	278	2.1
TA Ee 34	09-23-65	8.0	16.1	571	395	74	12.0	33	17.0	4.2	370	9.1
					PINEY POINT AQUIFER							
QA Bh 46	09-21-89	7.9	14.8	340	-	34	11.0	23	8.5	<1.0	211	1.0
QA Cg 62	04-15-98	8.2	15.2	503	-	107.9	6.8	6.6	2.6	<0.1	312	1.3
QA Dg 42	03-26-98	7.8	14.3	342	232	32.2	10.6	24	7.6	2.3	198	1.0
QA Ee 12	06-20-66	7.7	14.4	389	262	13	16.0	42	14.0	3.4	253	1.6
TA Be 79	09-17-65	7.8	17.2	353	250	32	9.2	19	16.0	4.3	232	2.2
TA Be 80	03-20-98	7.8	15.0	299	189	18.7	11.9	19.8	10.3	4.0	171	1.4
TA Bf 73	01-24-90	7.8	15.4	365	271	49	12.0	16	10.0	2.0	253	2.4
TA Bf 79	06-03-71	8.2	-	574	381	140	8.0	2.8	0.5	8.4	365	1.5
TA Cb 92	10-26-65	8.0	14.4	464	278	7.2	22.0	32	33.0	0.0	306	3.6
TA Cd 2	10-14-65	7.9	14.4	310	213	6.5	3.4	40	11.0	15.0	171	6.9
TA Cf 22	10-05-76	8.4	-	845	580	210	5.8	3.8	2.0	5.4	653	2.8
TA Dc 53	10-26-65	7.9	16.1	533	327	99	15.0	12	7.8	3.4	311	21
TA De 12	09-15-65	7.8	18.3	277	215	3.7	2.8	45	7.7	8.5	171	2.6
TA De 13	09-17-65	7.8	17.2	395	271	9.2	8.6	45	19.0	5.4	265	0.8
TA De 17	09-17-65	7.9	17.8	286	215	25	8.9	20	9.7	8.1	182	0.7
TA Ee 30	09-22-65	7.8	17.8	392	275	75	8.2	16	1.0	12.0	246	1.1
TA Ee 31	09-23-65	8.3	17.8	717	473	174	9.2	7.3	4.4	7.2	481	4.6
					AQUIA AQUIFER							
QA Be 4	12-21-54	6.7	12.0	92	65	2.9	1.1	11	0.4	0.1	37.8	2.5
QA Be 17	09-21-70	7.2	14.5	233	154	2.6	2.4	46	1.6	13.0	132	3.3
QA Bg 43	01-10-55	7.5	13.0	142	118	3.4	3.2	16	4.5	11.0	70.8	0.7
QA Bg 59	03-26-98	7.8	14.0	284	168	6.2	6.3	34.9	8.0	4.0	165	1.0
QA Bg 62	02-26-98	5.1	14.7	86	57	2.7	3.1	4.0	3.2	1.7	3.4	7.6
QA Ce 37	04-15-98	7.9	15.1	307	178	3.8	8.2	40.5	10.4	1.7	182	1.3

Bromide (mg/L)	Iodide (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Man-ganese (mg/L)	Nitrate (mg/L)	Phos-phorus (mg/L)	Carbon (mg/L)	Silica (mg/L)	Oxygen (mg/L)	Radon (pCi/L)	Well number
-	-	0.3	-	-	0.0	-	-	55	-	-	TA Ce 66
-	-	0.2	-	-	0.0	-	-	57	-	-	TA De 15
-	-	0.7	-	-	0.0	-	-	61	-	-	TA Df 4
-	-	0.2	-	-	0.1	-	-	63	-	-	TA Ee 34
PINEY POINT AQUIFER											
0.01	-	0.9	0.20	0.01	<0.1	0.02	1.4	39	0.4	780	QA Bh 46
-	-	1.73	0.036	<.004	<0.05	0.07	0.9	36	0.0	719	QA Cg 62
-	-	0.42	0.08	<.004	<0.05	0.02	0.4	46.6	0.1	502	QA Dg 42
-	-	0.3	-	-	-	-	-	48	-	-	QA Ee 12
-	-	0.3	-	-	0.1	-	-	53	-	-	TA Be 79
-	-	0.4	0.046	<.004	<0.05	0.03	0.4	32	0.1	-	TA Be 80
0.01	-	0.3	0.11	0.02	<0.1	0.02	0.7	54	0.4	470	TA Bf 73
-	-	2.3	-	-	0.2	-	-	37	-	-	TA Bf 79
-	-	0.3	-	-	-	-	-	29	-	-	TA Cb 92
-	-	0.3	-	-	-	-	-	46	-	-	TA Cd 2
-	-	1.7	0.22	<.01	-	-	-	28	-	-	TA Cf 22
-	-	1.0	-	-	-	-	-	15	-	-	TA Dc 53
-	-	0.2	-	-	0.0	-	-	60	-	-	TA De 12
-	-	0.3	-	-	0.0	-	-	52	-	-	TA De 13
-	-	0.4	-	-	0.0	-	-	53	-	-	TA De 17
-	-	0.7	-	-	-	-	-	40	-	-	TA Ee 30
-	-	1.1	-	-	0.1	-	-	28	-	-	TA Ee 31
AQUIA AQUIFER											
-	-	0.1	-	-	1.9	-	-	20	-	-	QA Be 4
-	-	0.1	-	-	-	-	-	20	-	-	QA Be 17
-	-	0.3	-	-	0.1	-	-	44	-	-	QA Bg 43
-	-	0.48	0.197	<.004	<0.05	0.04	0.5	20.3	0.0	465	QA Bg 59
-	-	<0.1	0.021	0.05	5.4	0.01	-	9.2	-	280	QA Bg 62
-	-	0.24	0.333	<.004	<0.05	0.04	0.6	17	0.0	-	QA Ce 37

Table 15. Selected water-quality analyses from wells in Queen Anne's and Talbot Counties–Continued

Well number	Date	pH	Temper-ature (°C)	Specific conduct-ance (µS/cm	TDS (mg/L)	Sodium (mg/L)	Potas-sium (mg/L)	Calcium (mg/L)	Mag-nesium (mg/L)	Sulfate (mg/L)	Bicar-bonate (mg/L)	Chloride (mg/L)
QA Db 10	08-16-83	7.2	16.0	1,060	696	43	3.9	150	17	230	244	88
QA Db 15	07-08-83	>7.2	16.6	960	659	23	5.6	170	9.4	170	268	100
QA Db 23	07-06-83	7.4	15.5	440	286	7.7	3.9	81	4.6	7.9	244	21
QA Db 25	07-06-83	5.7	15.0	370	201	45	0.7	9.9	4.8	19	32	66
QA Db 26	07-06-83	6.6	18.0	3,450	2,025	460	7.6	200	50	82	171	1,100
QA Db 27	07-14-83	7.2	14.5	-	748	13	4.4	210	17	17	268	320
QA Db 30	08-27-84	6.8	17.0	15,900	10,588	2,100	27	1,400	140	670	0.0	6,000
QA Db 31	07-13-84	7.0	15.0	19,200	12,476	2,800	18	1,500	160	740	145	7,100
QA Db 32	07-16-84	6.7	15.0	9,400	5,711	790	9.4	1,100	55	390	227	3,200
QA Db 34	08-29-84	7.4	15.0	518	330	30	4.0	61	8.6	0.5	318	11
QA Db 35	08-23-84	7.0	15.0	14,900	9,719	1,200	22	2,000	200	470	43	5,700
QA Db 36	09-12-84	6.8	14.9	18,600	13,248	3,400	17	1,300	160	810	138	7,400
QA Db 37	08-28-84	7.5	16.0	570	373	20	4.1	84.0	8.8	58.0	279	14
QA Dd 10	12-21-54	7.8	9.0	359	212	20	8.4	39	9.1	2.7	223	3.3
QA Dd 32	02-26-98	7.2	14.1	376	259	6.6	3.3	66.4	2.4	0.5	221	3.6
QA De 3	12-21-54	7.8	13.5	279	173	3.6	9.0	38	8.3	6.0	170	1.5
QA De 30	11-14-89	8.0	15.7	296	187	17	13.0	29.0	10.0	5.0	184	0.9
QA Df 58	04-14-98	7.9	15.1	281	158	5.4	12.4	26.5	11.1	5.8	160	1.1
QA Ea 10	12-20-54	7.5	12.0	297	183	4.1	4.6	43	7.5	0.1	187	3.1
QA Ea 32	03-19-85	7.8	15.0	350	231	33	3.8	37	7.2	15.0	223	3.8
QA Ea 36	07-05-83	7.4	15.5	2,050	1,043	56	4.4	270	19.0	8.0	195	560
QA Ea 37	07-05-83	7.6	17.0	350	201	8.1	2.0	54	3.9	1.9	195	4.4
QA Ea 41	08-18-83	7.3	17.0	1,580	766	40	3.1	210	15.0	9.7	195	360
QA Ea 45	08-17-83	7.4	17.0	360	230	15	6.8	48	7.7	2.1	232	4.7
QA Ea 51	08-17-83	7.6	19.0	350	223	12	2.4	48	8.1	9.5	232	3.1
QA Ea 60	08-18-83	7.6	18.0	860	466	44	5.8	91	15	9.4	183	190
QA Ea 77	08-01-84	7.0	15.0	15,400	9,447	510	29	2,100	300	430	34.2	6,000
QA Ea 78	06-12-90	7.6	15.9	309	-	12	3.5	44	7.3	<1.0	200	7.9

Table 15.--Continued

Bromide (mg/L)	Iodide (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Man-ganese (mg/L)	Nitrate (mg/L)	Phos-phorus (mg/L)	Carbon (mg/L)	Silica (mg/L)	Oxygen (mg/L)	Radon (pCi/L)	Well number
-	-	0.3	4.8	0.03	<0.1	<0.01	5.5	39	0.0	-	QA Db 10
-	0.02	<0.1	4.2	0.02	<0.1	<0.01	2.5	45	0.0	-	QA Db 15
-	<0.01	0.1	0.89	0.01	<0.1	0.02	1.2	39	0.1	-	QA Db 23
-	<0.01	0.1	0.073	0.07	2.9	0.06	1.0	27	0.5	-	QA Db 25
-	<0.01	0.2	3.7	5.70	<0.1	<0.01	1.0	31	0.0	-	QA Db 26
-	-	0.2	4.5	0.15	<0.1	<0.01	4.0	30	0.0	-	QA Db 27
-	0.06	0.2	150	0.93	<0.1	<0.01	1.8	20	0.0	-	QA Db 30
-	0.063	<0.1	23.000	0.08	<0.1	<0.01	2.1	25	0.0	-	QA Db 31
-	0.042	<0.1	13	0.17	<0.1	<0.01	1.3	18	0.0	-	QA Db 32
-	0.013	0.1	-	-	<0.1	0.13	3.4	46	0.0	-	QA Db 34
-	0.056	0.6	44	0.17	<0.1	<0.01	1.0	18	0.0	-	QA Db 35
-	0.1	<0.1	25	0.05	<0.1	<0.01	1.3	29	0.0	-	QA Db 36
-	0.007	<0.1	0.940	0.04	<0.1	0.02	2.5	31	0.0	-	QA Db 37
-	-	0.4	-	-	0.1	-	-	19	-	-	QA Dd 10
-	-	0.67	1.405	0.04	<0.05	0.19	-	57.9	-	162	QA Dd 32
-	-	0.2	-	-	0.4	-	-	21	-	-	QA De 3
0.01	-	0.5	0.21	0.00	<0.1	0.02	0.6	18	0.5	220	QA De 30
-	-	0.56	0.146	0.00	<0.05	0.04	0.4	11.6	0.0	278	QA Df 58
-	-	0.2	-	-	0.3	-	-	27	-	-	QA Ea 10
<0.01	0.001	0.2	0.28	0.01	<0.1	<0.01	1.9	21	0.4	-	QA Ea 32
-	0.01	0.1	4.6	0.07	<0.1	<0.01	1.6	24	0.1	-	QA Ea 36
-	<0.01	0.2	0.6	0.01	<0.1	0.03	1.9	30	-	-	QA Ea 37
-	-	<0.1	3.4	0.10	<0.1	<0.01	1.8	29	0.3	-	QA Ea 41
-	-	0.2	0.66	0.00	<0.1	0.03	3.3	31	0.0	-	QA Ea 45
-	-	<0.1	0.64	0.00	<0.1	0.02	2.4	25	0.2	-	QA Ea 51
-	-	<0.1	1.1	0.01	<0.1	<0.01	3.3	20	0.0	-	QA Ea 60
-	0.013	<0.1	15	0.63	<0.1	<0.01	0.6	19	0.0	-	QA Ea 77
-	-	0.2	1.1	0.03	-	-	-	24	-	-	QA Ea 78

Table 15. Selected water-quality analyses from wells in Queen Anne's and Talbot Counties–Continued

Well number	Date	pH	Temperature (°C)	Specific conductance (µS/cm	TDS (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sulfate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)
QA Ea 78	07-31-84	7.6	15.0	302	205	11	3.6	41	7.3	12.0	189	4.1
QA Ea 79	08-08-84	9.3	17.0	380	249	63	7.4	18	1.9	45	144	3
QA Ea 80	08-08-84	7.7	15.0	335	211	27	4.3	34	6.8	0.4	206	2.6
QA Ea 81	07-30-84	7.7	15.0	640	363	70	5.4	45	6.2	38	144	110
QA Eb 113	01-15-80	7.5	15.5	360	193	6.5	5.6	43.0	13.0	0.0	220	2.5
QA Eb 117	07-13-83	7.8	15.5	480	290	100.0	1.3	0.7	0.2	8.6	281	7.9
QA Eb 132	08-16-83	7.5	17.0	500	311	38.0	4.0	60.0	9.1	2.2	329	9.3
QA Eb 135	07-13-83	7.9	15.5	370	199	15.0	9.5	33.0	12.0	0.4	220	2.0
QA Eb 136	07-14-83	7.9	16.5	460	265	100.0	0.9	0.4	0.2	5.5	281	2.5
QA Eb 144	07-13-83	7.8	16.0	440	262	38.0	2.4	48.0	6.0	7.6	268	6.3
QA Eb 152	03-22-85	7.7	15.0	382	246	48.0	10.0	25.0	9.3	4.5	263	1.5
QA Eb 155	08-20-84	7.8	15.5	330	201	8.8	9.9	35.0	13.0	2.7	213	2.2
QA Eb 156	07-23-84	7.1	15.0	14,800	8,821	160.0	26.0	2,100.0	450.0	410.0	28.1	5,600
QA Eb 157	07-25-84	7.5	15.0	332	237	6.5	1.7	55.0	3.7	10.0	209	28.0
QA Ec 83	09-29-54	7.8	15.0	435	261	41.0	12.0	31.0	12.0	1.4	290	4.0
QA Ed 36	12-20-54	7.8	12.0	322	189	11.0	12.0	34.0	11.0	5.0	199	1.3
QA Ef 32	05-01-98	8.1	15.8	782	467	181.2	7.5	2.5	1.2	3.5	464	3.6
QA Fa 39	12-20-54	7.8	15.5	507	305	85.0	6.2	23.0	4.7	7.0	289	18
QA Fa 50	07-07-83	7.9	17.0	320	157	30.0	5.4	30.0	6.0	0.9	134	2.9
QA Fa 60	07-07-83	7.9	15.5	415	254	68.0	4.4	21.0	3.7	5.3	244	11
QA Fa 64	07-07-83	7.6	17.0	725	375	52.0	6.5	62.0	14.0	1.2	183	130
QA Fa 67	07-07-83	>7.7	16.5	345	207	20.0	7.1	37.0	9.7	5.2	195	15.0
QA Fa 68	08-18-83	7.6	17.0	465	265	22.0	6.6	51.0	11.0	17.0	268	4.3
QA Fb 1	07-14-83	7.9	15.5	420	219	44.0	10.0	21.0	6.3	0.9	244	2.2
QA Fc 7	01-25-90	7.8	16.1	306	191	32.0	13.0	16.0	9.0	4.0	196	1.4
QA Fc 8	08-01-78	6.8	16.0	10	185	32.0	12.0	20.0	9.6	2.6	195	1.6
TA Ad 5	09-22-65	7.7	17.2	332	204	56.0	9.8	13.0	3.8	2.5	213	1.1
TA Bb 4	09-24-65	7.8	15.6	559	325	48.0	13.0	41.0	17.0	3.8	263	53

Table 15.--Continued

Bromide (mg/L)	Iodide (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Man-ganese (mg/L)	Nitrate (mg/L)	Phos-phorus (mg/L)	Carbon (mg/L)	Silica (mg/L)	Oxygen (mg/L)	Radon (pCi/L)	Well number
-	0.008	0.1	1.5	0.03	<0.1	0.04	1.1	23	0.0	-	QA Ea 78
-	0.004	0.3	0.03	0.00	<0.1	<0.01	0.9	14	-	-	QA Ea 79
-	0.008	0.1	0.52	0.01	<0.1	0.05	2.2	17	0.5	-	QA Ea 80
-	0.004	0.2	0.84	0.06	<0.1	<0.01	0.7	14	-	-	QA Ea 81
-	-	0.2	0.63	0.00	-	-	-	14	-	-	QA Eb 113
-	-	0.2	0.021	<.001	<0.1	0.07	2.3	33	0.3	-	QA Eb 117
-	-	<0.1	0.56	0.01	<0.1	0.06	3.3	26	0.0	-	QA Eb 132
-	-	1.0	0.37	0.00	<0.1	0.01	1.5	18	0.2	-	QA Eb 135
-	-	1.0	0.007	0.00	<0.1	0.01	1.4	17	0.1	-	QA Eb 136
-	-	0.2	0.44	0.00	<0.1	0.05	1.9	21	0.6	-	QA Eb 144
<0.01	0.001	0.9	0.22	0.16	<0.1	<0.01	1.8	16	0.3	-	QA Eb 152
-	0.011	0.8	0.41	0.00	<0.1	<0.01	-	16	1.0	-	QA Eb 155
-	0.018	<0.1	15	0.05	<0.1	<0.01	0.7	22	0.0	-	QA Eb 156
-	0.008	0.2	1.4	0.01	<0.1	0.05	1.8	30	0.0	-	QA Eb 157
-	-	0.3	-	-	0.3	-	-	15	-	-	QA Ec 83
-	-	0.5	-	-	0.1	-	-	16	-	-	QA Ed 36
-	-	3.92	<.01	<.004	<0.05	0.12	0.9	13	0.1	-	QA Ef 32
-	-	1.1	-	-	0.1	-	-	18	-	-	QA Fa 39
-	<0.01	0.5	0.19	0.00	<0.1	0.05	2.1	15	0.2	-	QA Fa 50
-	0.01	1.1	0.35	0.00	<0.1	0.03	1.0	19	0.6	-	QA Fa 60
-	<0.01	0.3	0.77	0.01	<0.1	<0.01	2.1	18	0.2	-	QA Fa 64
-	<0.01	0.3	0.3	0.01	<0.1	<0.01	1.3	16	0.0	-	QA Fa 67
-	-	0.2	0.36	0.01	<0.1	0.03	1.9	21	0.1	-	QA Fa 68
-	-	0.8	0.3	0.00	<0.1	0.02	1.3	14	-	-	QA Fb 1
<0.01	-	1.1	0.14	0.00	0.5	0.03	1.1	14	0.3	240	QA Fc 7
-	-	1.0	0.21	<.01	-	-	-	13	-	-	QA Fc 8
-	-	1.9	-	-	0.0	-	-	11	-	-	TA Ad 5
-	-	0.2	-	-	0.0	-	-	19	-	-	TA Bb 4

Table 15. Selected water-quality analyses from wells in Queen Anne's and Talbot Counties–Continued

Well number	Date	pH	Temperature (°C)	Specific conductance (µS/cm	TDS (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sulfate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)
TA Be 86	03-20-98	8.3	17.0	795	466	174.5	9.1	3.8	2.3	14.3	453	6.6
TA Cc 29	08-02-67	8.5	17.0	536	306	88.0	15.0	12.0	7.6	8.4	232	48
TA Cc 33	10-26-65	8.0	17.8	569	356	126.0	11.0	5.7	3.9	11.0	309	32
TA Cc 42	04-14-98	8.2	15.6	677	385	127.6	13.6	8.9	6.1	11.9	304	41.6
TA Cd 48	10-28-65	8.4	16.1	702	432	151.0	12.0	7.7	7.1	12.0	392	35
TA Cd 55	03-21-85	8.4	20.0	810	517	200.0	7.1	2.6	2.2	12.0	551	3.0
TA Ce 50	04-01-65	8.1	20.6	838	513	196.0	8.6	4.0	2.4	12.0	550	2.1
TA Ce 78	04-23-98	8.3	19.0	831	513	204.3	7.1	2.3	1.1	11.7	486	2.2
TA Db 38	04-09-65	7.8	16.7	281	166	10.0	14.0	24.0	12.0	3.5	176	1.5
TA Db 61	10-26-65	7.7	16.7	281	167	16.0	14.0	22.0	10.0	7.4	171	1.7
TA Dc 2	03-03-65	8.0	20.0	607	373	136.0	8.4	6.6	0.9	12.0	368	13
TA Dc 52	10-26-65	7.6	16.1	406	246	70.0	12.0	10.0	5.6	9.8	181	36
TA Dd 53	09-24-65	8.4	20.6	915	599	245.0	9.2	3.2	1.5	11.0	626	1.6
MATAWAN AQUIFER												
QA Eb 159	05-21-98	7.8	17.0	368	226	44.0	4.4	28.5	3.3	34.2	185	1.8
QA Ec 102	04-02-98	8.0	17.7	219	127	12.6	6.7	17.7	7.0	11.2	112	1.6
MAGOTHY AQUIFER												
QA Eb 181	05-20-98	6.0	17.5	216	147	2.0	3.0	9.1	4.1	65.0	40.3	0.7
QA Fa 78	04-15-98	6.3	16.7	248	155	1.9	4.1	15.8	5.1	69.6	45.1	0.6
TA Ce 60	04-01-65	7.6	23.9	379	239	81.0	9.4	6.0	1.2	12.0	234	1.6
TA Ce 67	09-16-65	7.5	24.4	363	235	81.0	7.0	4.0	2.4	13.0	232	1.6
UPPER PATAPSCO AQUIFER												
QA Be 16	09-23-70	7.1	16.0	146	88	14.0	5.6	9.1	3.2	10.0	73.2	2.9
QA Ea 26	04-11-72	6.8	18.0	150	95	2.1	2.8	16.0	5.2	54.0	13.4	0.8
QA Eb 111	02-06-80	6.5	21.0	154	75	1.9	3.1	7.2	3.5	27.0	14.6	0.9
QA Eb 163	01-04-90	6.5	17.3	218	137	49.0	0.4	0.0	0.0	49.0	50.0	2.5
QA Eb 179	05-01-98	6.0	17.7	323	169	19.6	3.0	16.7	5.1	51.8	61.6	30.3
QA Ec 89	01-16-85	6.6	20.0	162	93	2.1	3.7	12.0	4.7	36.0	29.3	0.7
QA Ec 91	04-02-98	6.5	19.0	147	81	2.7	4.1	10.8	4.5	19.9	57.3	0.9
QA Ef 29	06-27-86	6.2	25.1	197	125	36.0	5.0	3.2	1.0	18.0	96.4	2.0

Table 15.--Continued

Bromide (mg/L)	Iodide (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Man-ganese (mg/L)	Nitrate (mg/L)	Phos-phorus (mg/L)	Carbon (mg/L)	Silica (mg/L)	Oxygen (mg/L)	Radon (pCi/L)	Well number
-	-	3.0	<.01	<.004	<0.05	0.10	0.6	13.4	0.1	-	TA Be 86
-	-	0.5	-	-	0.1	-	-	12	-	-	TA Cc 29
-	-	0.7	-	-	-	-	-	14	-	-	TA Cc 33
-	-	0.53	0.022	<.004	<0.05	0.04	0.6	12.8	0.1	302	TA Cc 42
-	-	1.4	-	-	-	-	-	13	-	-	TA Cd 48
<0.01	0.018	3.8	0.019	0.00	<0.1	0.02	1.8	13	0.1	-	TA Cd 55
-	-	3.7	-	-	-	-	-	14	-	-	TA Ce 50
-	-	3.05	<.01	<.004	0.1	0.11	0.5	19.1	0.1	-	TA Ce 78
-	-	0.2	-	-	0.1	-	-	14	-	-	TA Db 38
-	-	0.3	-	-	-	-	-	12	-	-	TA Db 61
-	-	1.6	-	-	0.0	-	-	14	-	-	TA Dc 2
-	-	0.4	-	-	-	-	-	13	-	-	TA Dc 52
-	-	4.2	-	-	0.1	-	-	14	-	-	TA Dd 53
					MATAWAN AQUIFER						
-	-	0.21	0.217	0.01	<0.05	0.02	0.5	15.9	0.0	-	QA Eb 159
-	-	0.2	0.052	0.02	<0.05	0.02	0.3	11.5	0.1	149	QA Ec 102
					MAGOTHY AQUIFER						
-	-	0.18	33.88	0.43	<0.05	<0.01	0.3	9	0.0	-	QA Eb 181
-	-	0.13	23.82	0.30	0.1	0.36	0.4	9.9	0.0	29	QA Fa 78
-	-	0.8	-	-	-	-	-	12	-	-	TA Ce 60
-	-	0.2	-	-	-	-	-	12	-	-	TA Ce 67
					UPPER PATAPSCO AQUIFER						
-	-	0.3	-	-	-	-	-	7.4	-	-	QA Be 16
-	-	0.4	-	-	-	-	-	7.4	-	-	QA Ea 26
-	0.01	0.2	14	0.24	0.0	0.16	-	9.7	0.0	-	QA Eb 111
<0.01	-	0.3	0.056	<.001	<0.1	0.52	0.9	9	1.7	190	QA Eb 163
-	-	0.28	21.237	0.31	<0.05	0.06	0.3	7.6	0.0	-	QA Eb 179
-	-	0.3	11	0.18	-	-	-	8.3	-	-	QA Ec 89
-	-	0.28	7.706	0.13	<0.05	0.34	0.3	8.5	0.0	91	QA Ec 91
0.02	0.002	0.2	-	-	<0.1	0.27	-	11	0.0	-	QA Ef 29

Table 15. Selected water-quality analyses from wells in Queen Anne's and Talbot Counties–Continued

Well number	Date	pH	Temper-ature (°C)	Specific conduct-ance (µS/cm	TDS (mg/L)	Sodium (mg/L)	Potas-sium (mg/L)	Calcium (mg/L)	Mag-nesium (mg/L)	Sulfate (mg/L)	Bicar-bonate (mg/L)	Chloride (mg/L)
TA Ce 70	01-30-90	6.9	25.2	167	109	27.0	6.5	3.1	1.7	14.0	85.4	2.3
LOWER PATAPSCO AQUIFER												
QA Be 15	07-28-70	6.2	18.0	1,640	799	242.0	16.0	40.0	10.0	5.4	9.8	473
QA Be 15	08-06-70	6.8	19.0	7,830	4,174	1,160	39.0	272	86	26	3.7	2,580
QA Eb 112	02-14-80	6.2	25.0	135	75	3.6	6.5	8.6	4.5	13.0	42.7	1.1
PATUXENT AQUIFER												
QA Eb 110	03-04-80	7.2	24.5	225	136	36.0	7.2	3.6	1.8	13.0	92.7	13

Table 15.--Continued

Bromide (mg/L)	Iodide (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Man-ganese (mg/L)	Nitrate (mg/L)	Phos-phorus (mg/L)	Carbon (mg/L)	Silica (mg/L)	Oxygen (mg/L)	Radon (pCi/L)	Well number
0.02	-	0.2	0.98	0.03	<0.1	0.02	0.7	11	1.2	<80	TA Ce 70
LOWER PATAPSCO AQUIFER											
-	-	0.2	-	-	0.1	-	-	7.5	-	-	QA Be 15
-	-	0.2	-	-	0.3	-	-	8.1	-	-	QA Be 15
-	0.01	0.2	3.2	0.20	0.0	0.02	-	12	0.0	-	QA Eb 112
PATUXENT AQUIFER											
-	0	0.2	0.89	0.07	0.0	0.03	-	14	-	-	QA Eb 110