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Recovery of Ground-Water Levels from 1988 to 2003 and Analysis of Effects of 2003 and Full-Allocation Withdrawals in Critical Area 2, Southern New Jersey

Scientific Investigations Report 2008–5142

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

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By Frederick J. Spitz and Vincent T. dePaul

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow rate	
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.646317	million gallons per day (Mgal/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	365.25	million gallons per year (Mgal/yr)
million gallons per day (Mgal/d)	0.0006944	gallons per minute (gal/min)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Recovery of Ground-Water Levels from 1988 to 2003 and Analysis of Effects of 2003 and Full-Allocation Withdrawals in Critical Area 2, Southern New Jersey

By Frederick J. Spitz and Vincent T. dePaul

Abstract

Water levels in the Potomac-Raritan-Magothy aquifer system within Water Supply Critical Area 2 in the southern New Jersey Coastal Plain have recovered as a result of reductions in ground-water withdrawals initiated in the early 1990s. The Critical Area consists of the depleted zone and the threatened margin. The Potomac-Raritan-Magothy aquifer system consists of the Upper, Middle, and Lower aquifers. Generally, ground-water withdrawals from these aquifers declined 5 to 10 Mgal/d (million gallons per day), and water levels recovered 0 to 40 ft (foot) from 1988 to 2003. In order to reevaluate water-allocation restrictions in Critical Area 2 in response to changes in the ground-water-flow system and demands for additional water supply due to increased development, the New Jersey Department of Environmental Protection (NJDEP) needs information about the effects of changes in those allocations. Therefore, the U.S. Geological Survey (USGS), in cooperation with the NJDEP, used an existing ground-water-flow model of the New Jersey Coastal Plain to evaluate the effects of withdrawal alternatives on hydraulic heads in the Potomac-Raritan-Magothy aquifer system in Critical Area 2.

The U.S. Geological Survey Regional Aquifer System Analysis model was used to simulate steady-state ground-water flow. Two withdrawal conditions were tested by using the model to evaluate hydraulic heads and differences in heads in these aquifers: 2003 withdrawals and full-allocation withdrawals (17.4 Mgal/d greater than 2003 withdrawals). Model results are presented using head maps and head-difference maps that compare 2003 to full-allocation withdrawals. Mandated hydrologic conditions for Critical Area protection are that the simulated -30-ft head contour not extend beyond the boundary of the depleted zone and (or) be at least 5 mi (miles) updip from the 250-mg/L (milligram per liter) isochlor in all three aquifers.

Simulation results indicate that, for 2003 withdrawals, the simulated -30-ft head contour in all three aquifers is generally within the boundary of the depleted zone, except in the Lower aquifer in northern Camden and northwestern Burlington Counties, and is generally 1 to 10 mi downdip from the 250-mg/L isochlor. (Corresponding observed data indicate that the -30-ft water-level contour extends beyond the southwest boundary of the depleted zone in the Upper and Middle aquifers, and is generally 5 to 20 mi downdip from the 250-mg/L isochlor in all three aquifers.) The area in which heads are below -30 ft ranges from 389 mi^2 (square miles) in the Middle aquifer to 427 mi^2 in the Lower aquifer. For full-allocation withdrawals, the simulated -30-ft head contour extends beyond the boundary of the depleted zone in all three aquifers in northern Camden and northwestern Burlington Counties and in the Upper aquifer in Gloucester and Salem Counties, and is generally 5 to 15 mi downdip from the 250-mg/L isochlor. The area in which heads are below -30 ft ranges from 616 mi^2 in the Upper aquifer to 813 mi^2 in the Lower aquifer. These results and observed data indicate that any increase in withdrawals from 2003 values would likely cause heads in the three aquifers to decline below the minimum values mandated by the NJDEP for the Critical Area.

Introduction

Ground-water development near large population centers in the New Jersey Coastal Plain has created large regional cones of depression in several Coastal Plain aquifers. In 1983, water levels in the Upper, Middle, and Lower aquifers of the Potomac-Raritan-Magothy aquifer system in southern New Jersey were 96, 89, and 94 ft below NGVD 29, respectively (Eckel and Walker, 1986). The continued decline of water levels in these confined aquifers posed a serious threat to the water supply in some areas, including the depletion of ground water, saltwater intrusion, and a reduction in ground-water flow to streams (New Jersey Department of Environmental Protection, 1996). To address these issues, the New Jersey Department of Environmental Protection (NJDEP) designated two Water Supply Critical Areas, defined in part as regions of the State where excessive water use presents undue stress or poses a significant threat to the integrity of a water-supply source (New Jersey Administrative Code, 2005).

> "The criteria upon which the NJDEP designates a Water Supply Critical Area include one or more of the following: (1) a shortage of surface water due to diversions from surface- or ground-water sources that leave insufficient surface water for permitted, certified, or registered diversions or for environmental protection purposes within a drainage area of at least 10 mi^2; and (2) a shortage of ground water due to diversions exceeding the long-term, safe, or dependable yield of an aquifer in an area of at least 10 mi^2. A shortage can be demonstrated by means of a verified mathematical ground-water model or, if such a model is unavailable, by one or more of the following hydrologic conditions: (a) a progressive lowering of ground water to the extent that existing wells of 50 ft or more in depth are threatened by declining water levels or rendered inoperative, and (b) a reduction in the average potentiometric surface in a confined aquifer such that the 30-ft contour below NGVD 29 is within 5 mi of saltwater or intersects the 250-mg/L isochlor (contour line of equal chloride concentration) within that aquifer." (New Jersey Administrative Code, 2005)

Water levels measured by the U.S. Geological Survey (USGS) in 1983 indicated that three aquifers—the Upper, Middle and Lower Potomac-Raritan-Magothy aquifers—were depleted in southern New Jersey and met the criteria for a Water Supply Critical Area. Specifically, it was determined that adverse conditions existed and special measures were required to ensure the integrity and viability of the water supply. Therefore, by administrative order, in January 1993, the NJDEP designated Water Supply Critical Area 2 in Burlington, Camden, Gloucester, and Atlantic Counties, and small parts of Ocean, Salem, and Cumberland Counties (fig. 1). The first three counties are the most dependent on the Potomac-Raritan-Magothy aquifer system in Critical Area 2 for water supply.

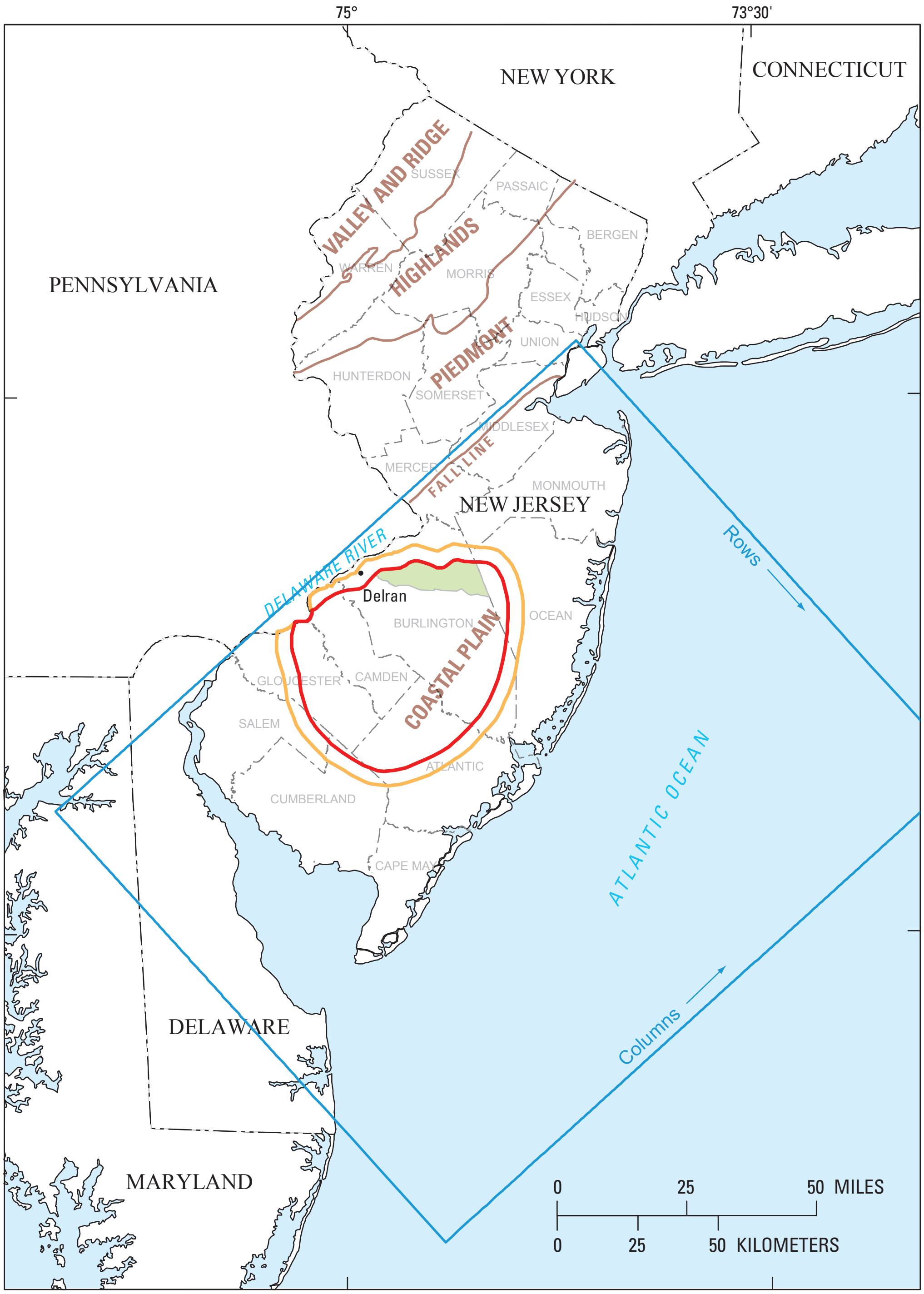
The boundary of the depleted zone (an area where ground-water levels have declined so substantially that the integrity of the water resource is of concern) of Critical Area 2 shown in figure 1 corresponds to a composite of the 1983 water-level contour 30 ft below NGVD 29 for each aquifer, as published by Eckel and Walker (1986) (Fred Sickles, New Jersey Department of Environmental Protection, written commun., 2008). The threatened margin (an area bordering the depleted zone where the decline of ground-water levels may accelerate saltwater intrusion) of Critical Area 2 is a 3-mi-wide area that surrounds the depleted zone (Hoffman and Lieberman, 2000).

In an effort to improve the management of ground-water resources in the Potomac-Raritan-Magothy aquifer system within these areas, Critical Area 2 was originally designated by NJDEP in 1986. Water users had the opportunity to interconnect with alternative water sources—shallower non-restricted aquifers, ground-water sources outside the Critical Area, surface-water sources, or the selected regional water purveyor. New water-supply allocations from the Potomac-Raritan-Magothy aquifer system were prohibited by the Water Supply Management Act (New Jersey Statutes Annotated, 1981), with the exception of temporary construction dewatering located in the credit receiving area in Burlington County (discussed below), base allocation transfers that meet mandated criteria (New Jersey Administrative Code, 2005), or ground-water remediation activities. Outside the Critical Area, water-supply development is less regulated, and water-quantity and -quality concerns may occur. Additionally, the NJDEP has denied allocation requests when new or increased withdrawals outside Critical Area 2 might adversely affect the aquifers within the Critical Area (Fred Sickles, New Jersey Department of Environmental Protection, written commun., 2007).

Due to a court challenge, Critical Area 2 was redesignated in 1991 and 1993. Actual reductions in withdrawals were implemented during and subsequent to this period. Within the depleted zone, ground-water withdrawals were reduced by an average of 22 percent in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers (Hoffman and Lieberman, 2000). Within the threatened margin, withdrawals were limited to an amount equal to the maximum annual rate between 1983 and 1991.

Additional water-supply measures initiated in Critical Area 2 included the Tri-County pipeline and Water Allocation Credit Receiving Area. The pipeline, a regional surface-water alternative operated by New Jersey American Water Company, provides water from the Delaware River to water users within and south of Critical Area 2. The high-capacity (more than 30 Mgal/d) water-treatment plant in Delran allows the service area to be expanded to supply additional water users. A Water Allocation Credit Receiving Area in northern Burlington County was included in the Critical Area statute to permit future withdrawals through the use of water-allocation credits, as established by formulae in the statute.

After implementation of the Critical Area, withdrawal reductions resulted in water-level recovery in the Potomac-Raritan-Magothy aquifer system and accompanying changes in the direction and rate of flow in the system. In response to the changes in the ground-water-flow system and demands for additional water supply, the NJDEP is reevaluating allocations within Critical Area 2 and the effects of possible changes in allocations. As part of this study, the USGS, in cooperation with the NJDEP, used an existing Regional Aquifer System Analysis (RASA) model of the New Jersey Coastal Plain (Voronin, 2004) to analyze the ground-water-flow system and provide needed information to water managers to make allocation decisions regarding the water supply. Model runs were made to evaluate the effects of (1) 2003 withdrawals and



Base from U.S. Geological Survey digital data, 1:100,000
Universal Transverse Mercator Projection, Zone 18, NAD 83

EXPLANATION

WATER ALLOCATION CREDIT RECEIVING AREA—From M.J. Torres (Burlington County Office of Resource Conservation, written commun., 2007)

REGIONAL AQUIFER SYSTEM ANALYSIS MODEL BOUNDARY

CRITICAL AREA 2—From New Jersey Department of Environmental Protection (unpublished). Boundary is approximate and should not be used for regulatory compliance purposes

Depleted zone

Threatened margin

Figure 1. Location of Water Supply Critical Area 2, southern New Jersey.

(2) withdrawals increased to full (base) allocation, defined as a water user's portion of the safe or dependable yield of the water resource (New Jersey Administrative Code, 2005).

Purpose and Scope

This report presents the results of an analysis of the effects of an increase in water allocations after a reduction associated with the implementation of Critical Area 2 in southern New Jersey. The report also describes the hydrogeology of the study area and the recovery of the water levels in the Potomac-Raritan-Magothy aquifer system from 1988 to 2003. An existing regional ground-water-flow model is used to simulate the effects of 2003 and full-allocation withdrawals on water levels and examine them in relation to saltwater intrusion within Critical Area 2. The results of the two simulations are compared to each other, to observed water levels from 2003, and to the water-level criteria mandated for the Critical Area.

Description of Study Area

Critical Area 2 is located in the updip area of the New Jersey Coastal Plain in Burlington, Camden, Gloucester, and Atlantic Counties, in southern New Jersey and includes small parts of Ocean, Salem, and Cumberland Counties. The total area is approximately 1,657 mi^2. According to data from the U.S. Census Bureau, Burlington, Camden, Gloucester, and Atlantic Counties are the 11th, 8th, 14th, and 15th most populus counties, respectively, of the 21 counties in the State (New Jersey Department of Labor and Workforce Development, 2006). These counties contain about 40 percent of the total population of the State. In 2000, water use in these four counties was 126 Mgal/d, or 31 percent of the ground water withdrawn in New Jersey for public supply (Hutson and others, 2004).

The boundaries of Critical Area 2—the inner depleted zone and the outer threatened margin—are shown in figure 1. The threatened margin is a 3-mi-wide area surrounding the depleted zone. Characteristics of the aquifer system in the updip part of Critical Area 2 are interaction with the Delaware River and its tributaries, and contamination in aquifer outcrop areas. The aquifer system in the downdip part of Critical Area 2 is not likely to be used for water supply because of its depth and because it is subject to high chloride concentrations due to saltwater intrusion (Navoy and Carleton, 1995).

Hydrogeology

The New Jersey Coastal Plain is a seaward-dipping wedge of unconsolidated sediments that range in age from Cretaceous to Holocene. A detailed discussion of the hydrogeology of the New Jersey Coastal Plain is found in Zapecza (1989) upon which much of the discussion that follows is based. These sediments consist mainly of clay, silt, sand, and gravel and are divided into different hydrogeologic units. Hydrogeologic units that are mostly sand and gravel are permeable and are considered aquifers; those that are mostly silt and clay are relatively impermeable and are considered confining units (fig. 2). The total thickness of the sediments increases from less than 200 ft at the outcrop areas in Camden County to greater than 2,500 ft in Atlantic County. The sediments crop out at land surface in northeast-southwest-trending bands (strike) and dip to the southeast at 10 to 60 ft/mi.

The Potomac-Raritan-Magothy aquifer system includes the most productive aquifers in the New Jersey Coastal Plain. In order of increasing depth, they are the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers. The Merchantville-Woodbury confining unit, which overlies the Potomac-Raritan-Magothy aquifer system, typically ranges in thickness from 100 to greater than 225 ft and corresponds to the Merchantville Formation and Woodbury Clay. The confining unit effectively impedes vertical ground-water flow. The underlying Upper Potomac-Raritan-Magothy aquifer is the most areally extensive of the three aquifers and corresponds to the Magothy Formation. The Upper Potomac-Raritan-Magothy aquifer typically ranges in thickness from 50 ft to greater than 125 ft and consists mainly of permeable, coarse-grained sediments and thin, localized clay beds.

The confining unit below the Upper Potomac-Raritan-Magothy aquifer typically ranges in thickness from 50 to greater than 125 ft. The Middle Potomac-Raritan-Magothy aquifer underlying this confining unit typically ranges in thickness from less than 50 ft in the outcrop area to greater than 150 ft in downdip areas and corresponds to the Raritan Formation and Potomac Group. The percentage of sand in this aquifer in the updip area varies according to the fluvial depositional history. The confining unit is thought to be less permeable than the confining unit separating the Middle and Lower Potomac-Raritan-Magothy aquifers (Rosman and others, 1995).

The confining unit below the Middle Potomac-Raritan-Magothy aquifer typically ranges in thickness from 50 to greater than 100 ft. The Lower Potomac-Raritan-Magothy aquifer underlying this confining unit typically ranges in thickness from 50 to greater than 250 ft and also corresponds to the Raritan Formation and Potomac Group. The aquifer pinches out in updip areas and does not crop out. Due to a lack of data in downdip areas, this aquifer cannot be differentiated from the Middle Potomac-Raritan-Magothy aquifer, and therefore, is mapped with a limited areal extent. In contrast, the simulated aquifer (discussed farther on) extends northeast and represents the sand beds of the lower third of the undifferentiated Potomac-Raritan-Magothy aquifer system. The Potomac-Raritan-Magothy aquifer system is underlain by relatively impermeable bedrock.

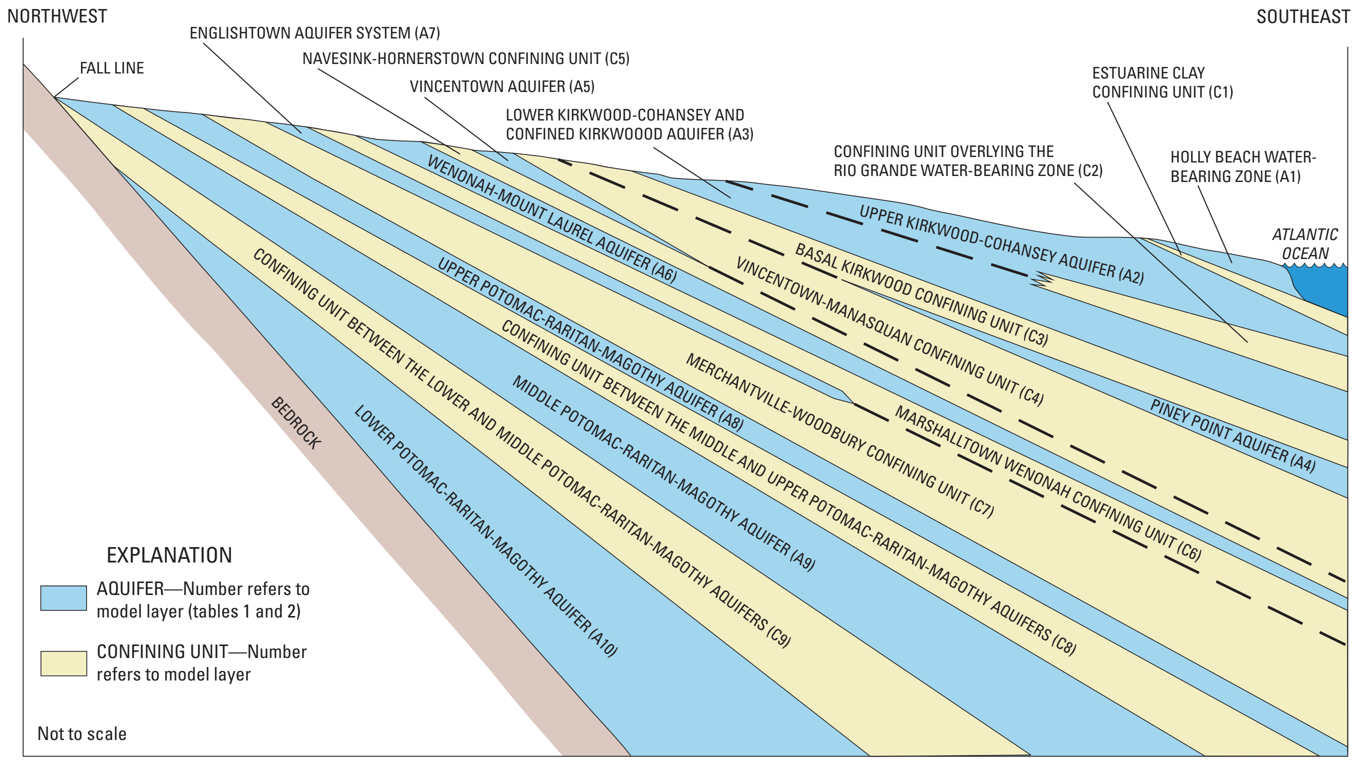


Figure 2. Generalized hydrogeologic section through the New Jersey Coastal Plain.

Previous Investigations

Various regional studies describe the hydrogeologic framework of, and ground-water flow in, the New Jersey Coastal Plain. Zapecza (1989) describes the hydrogeologic framework. Martin (1998) and Voronin (2004) describe ground-water flow. Synoptic water-level studies (for example, Lacombe and Rosman, 1997) have been conducted by the USGS for each of the major confined aquifers every 5 years since 1978. Water levels were measured during the fall for each study year, a time of year that typically represents annual average conditions. The most recent published work is the 2003 synoptic study by dePaul and others (2008). The studies show areas of decline (1978 to 1988) and recovery (1988 to 2003) of water levels in the Potomac-Raritan-Magothy aquifer system within Critical Area 2.

County-wide water-resource studies for Burlington, Camden, and Gloucester Counties were completed by Rush (1968), Farlekas and others (1976), and Hardt and Hilton (1969), respectively. Navoy and Carleton (1995) completed an updated ground-water study of Camden County that also included simulation of flow. Spitz and others (2007) conducted a related study of the recovery of ground-water levels and evaluation of water-supply management options in Critical Area 1, in east-central New Jersey. The boundaries of Critical Areas 1 and 2 overlap in Jackson and Manchester Townships in Ocean County.

Recovery of Ground-Water Levels

Reductions in withdrawals from the Potomac-Raritan-Magothy aquifer system in Critical Area 2 initiated in 1993 have decreased the stress on the ground-water-flow system and have resulted in recovery of water levels. The ground-water-flow system, and changes in ground-water withdrawals and water levels from 1988 to 2003, are described in this section.

Ground-water-flow system

A discussion of regional ground-water flow in the Camden area, which includes much of Critical Area 2, is presented in Navoy and Carleton (1995) and is summarized in this section. Flow in the New Jersey Coastal Plain aquifers is affected by variations in the hydraulic properties of the saturated sediments, and the amount and locations of ground-water recharge and discharge. The Potomac-Raritan-Magothy aquifer system is recharged mainly by precipitation on outcrop areas. Prior to water-supply development, recharge to these aquifers typically occurred in higher altitude outcrop areas in Mercer and Middlesex Counties. Water that entered the ground-water system followed long, arcuate flow paths to the southwest and discharged to the Delaware River and low-lying surface-water bodies in outcrop areas in Burlington, Camden, and Gloucester

Counties. Recharge to deeper hydrogeologic units in upgradient areas flowed downdip and eventually flowed back up into shallower units.

After water-supply development, the locations and amount of withdrawals controlled ground-water-flow paths in the Potomac-Raritan-Magothy aquifer system. Increased withdrawals lowered ground-water levels, causing large cones of depression. Long, arcuate flow paths from the northeast have been supplemented with intermediate flow paths from local downdip areas and short flow paths from local updip areas. As a result of lowering water levels in some areas below sea level, recharge and discharge areas have been redistributed. Ground-water discharge to streams has decreased, ground-water recharge from streams has increased, and flow between aquifers has changed magnitude and direction. Recharge has increased as a result of downward leakage from the water table and lateral ground-water flow under the Delaware River from Pennsylvania. Saline water from the Delaware River estuary has also recharged the aquifer system.

The Delaware River is hydraulically connected to the Potomac-Raritan-Magothy aquifer system in Critical Area 2. The nature and degree of the interaction depends on the riverbed materials and aquifer geometry, the difference between ground-water and surface-water levels, and the distance of withdrawals from the river. Because of the effective hydraulic connection between the Delaware River and the aquifer system, water levels near the river in the Middle and Lower Potomac-Raritan Magothy aquifers generally are only 5 to 10 ft below NGVD 29.

Changes in Withdrawals and Water Levels from 1988 to 2003

Ground-water withdrawals in the southern New Jersey Coastal Plain have increased steadily since the early 1900s. As a result, by the 1950s local cones of depression had begun to develop in the Potomac-Raritan-Magothy aquifer system in Camden County (Farlekas and others, 1976). In the 1970s and 1980s withdrawals stabilized, but water levels continued to decline, indicating that the aquifer system had not yet reached steady state. In 1983, withdrawals from wells in the Potomac-Raritan-Magothy aquifer system in the depleted zone of Critical Area 2 were 93.1 Mgal/d.

From 1983 to 1988, withdrawals from the Potomac-Raritan-Magothy aquifer system in Burlington, Camden, and Gloucester Counties decreased by about 5 percent, yet water levels continued to decline as much as 17 ft in Camden County (Rosman and others, 1995). Existing cones of depression broadened and deepened and localized cones developed due to new withdrawals. In 1988, the lowest observed water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in Critical Area 2 were 107 ft, 92 ft, and 103 ft below NGVD 29, respectively.

In 1993, withdrawals from the depleted zone were limited to 65 percent of the 1983 withdrawals plus the difference between the maximum withdrawal during 1983–91 and the 1983 withdrawals. The total reduction in withdrawals in the depleted zone can be computed as the difference between the 1988 withdrawals and the 1988 allocated withdrawals, which is estimated to be about 20 Mgal/d (Jennifer Myers, New Jersey Department of Environmental Protection, written commun., 2007). This difference is not a simple computation, however, because compliance of individual water users with Critical Area 2 regulations depended on when water users could obtain an alternative water source. For example, the New Jersey American Water Company Tri-County pipeline was not in service until April 1996. This source provided a relatively constant water supply of 18.9 Mgal/d from 1997 to 2003. Most water users were in compliance by 2007 (Jennifer Myers, New Jersey Department of Environmental Protection, written commun., 2007).

Observed water-level contours (dePaul and others, 2008) and locations of withdrawals in 2003 are shown in figure 3. Water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers along cross section B-B´ through the New Jersey Coastal Plain at different time intervals are shown in figures 4a, 5a, and 6a, respectively. The cross section, which is the same as that used in the synoptic water-level studies mentioned above, does not necessarily pass through the deepest parts of the cones of depression; therefore, some of the lowest water levels are not shown.

Average withdrawals (over the preceding 5 years) from the Upper Potomac-Raritan-Magothy aquifer increased slightly from about 28 Mgal/d in 1988 to about 29 Mgal/d in 1993, then decreased by about 9 Mgal/d, to about 19 Mgal/d, from 1993 to 2003 (fig. 4b). Based on the synoptic water-level data discussed previously, the lowest water levels in this aquifer declined about 10 ft from 1988 to 1993, then recovered about 50 ft from 1993 to 2003. The total 15-year (1988–2003) change in water levels in the Upper Potomac-Raritan-Magothy aquifer is shown in figure 4c. The recovery in Critical Area 2 was 10 to 20 ft in parts of Burlington, Camden, and Gloucester Counties, and was 20 to 40 ft in a 91.1-mi^2 area of the latter two counties.

Average withdrawals from the Middle Potomac-Raritan-Magothy aquifer increased slightly from about 16 Mgal/d in 1988 to about 17 Mgal/d in 1993, then decreased by nearly 5 Mgal/d, to about 12 Mgal/d, from 1993 to 2003 (fig. 5b). Based on the synoptic water-level data discussed previously, the lowest water levels in this aquifer remained stable from 1988 to 1993, then recovered about 30 ft from 1993 to 2003. The total 15-year (1988–2003) change in water levels in the Middle Potomac-Raritan-Magothy aquifer is shown in figure 5c. The recovery in Critical Area 2 was 10 to 20 ft in parts of Burlington, Camden, and Gloucester Counties, and was 20 to 35 ft in a 48.3-mi^2 area of Camden County.

Average withdrawals from the Lower Potomac-Raritan-Magothy aquifer decreased from about 30 Mgal/d to less than 24 Mgal/d from 1988 to 2003 (fig. 6b). Based on the synoptic water-level data discussed previously, the lowest water levels in this aquifer recovered about 20 ft from 1988 to 1993,

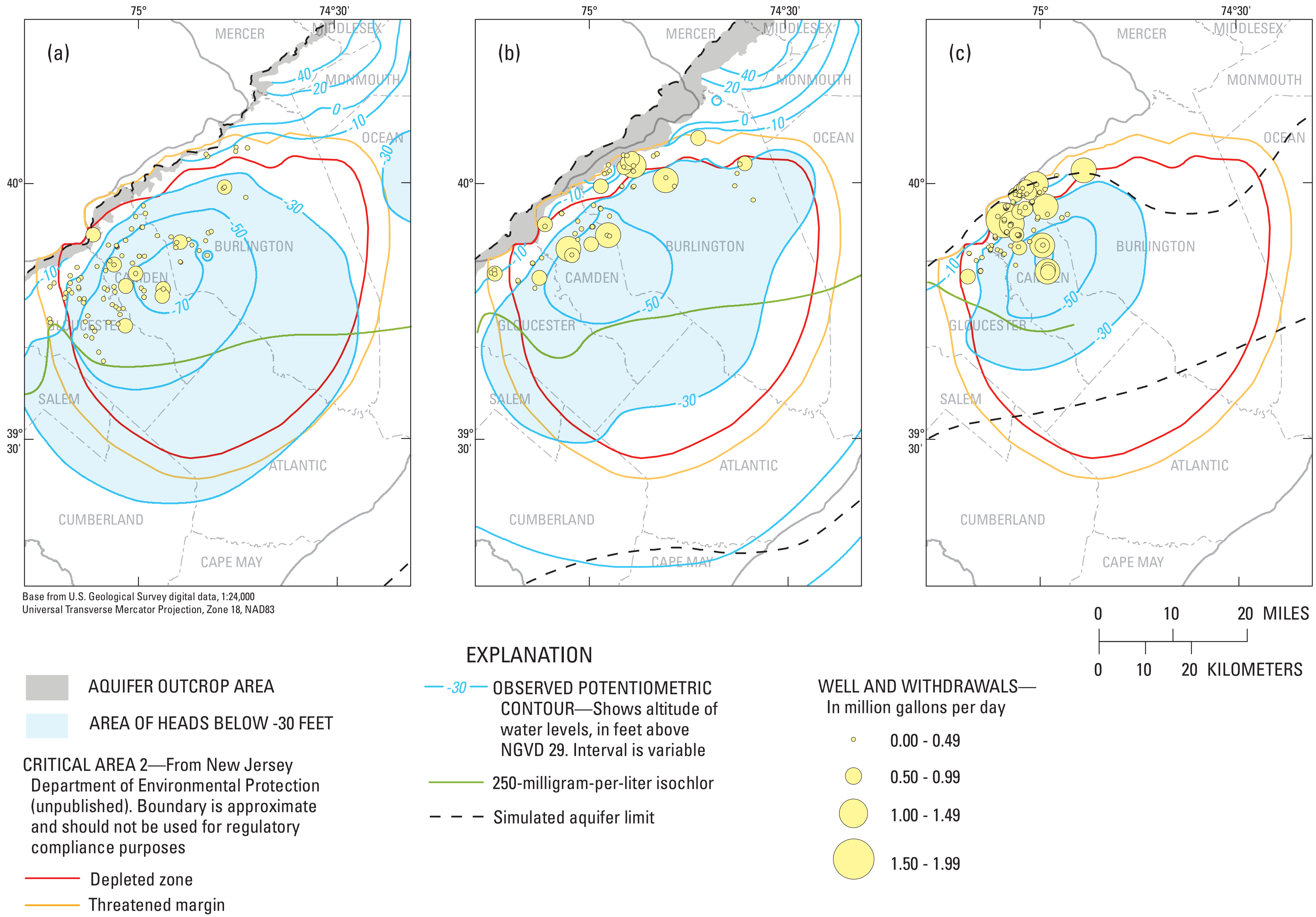


Figure 3. Observed potentiometric surfaces and distribution of withdrawals in 2003 in the (a) Upper, (b) Middle, and (c) Lower Potomac-Raritan-Magothy aquifers in Critical Area 2, southern New Jersey.

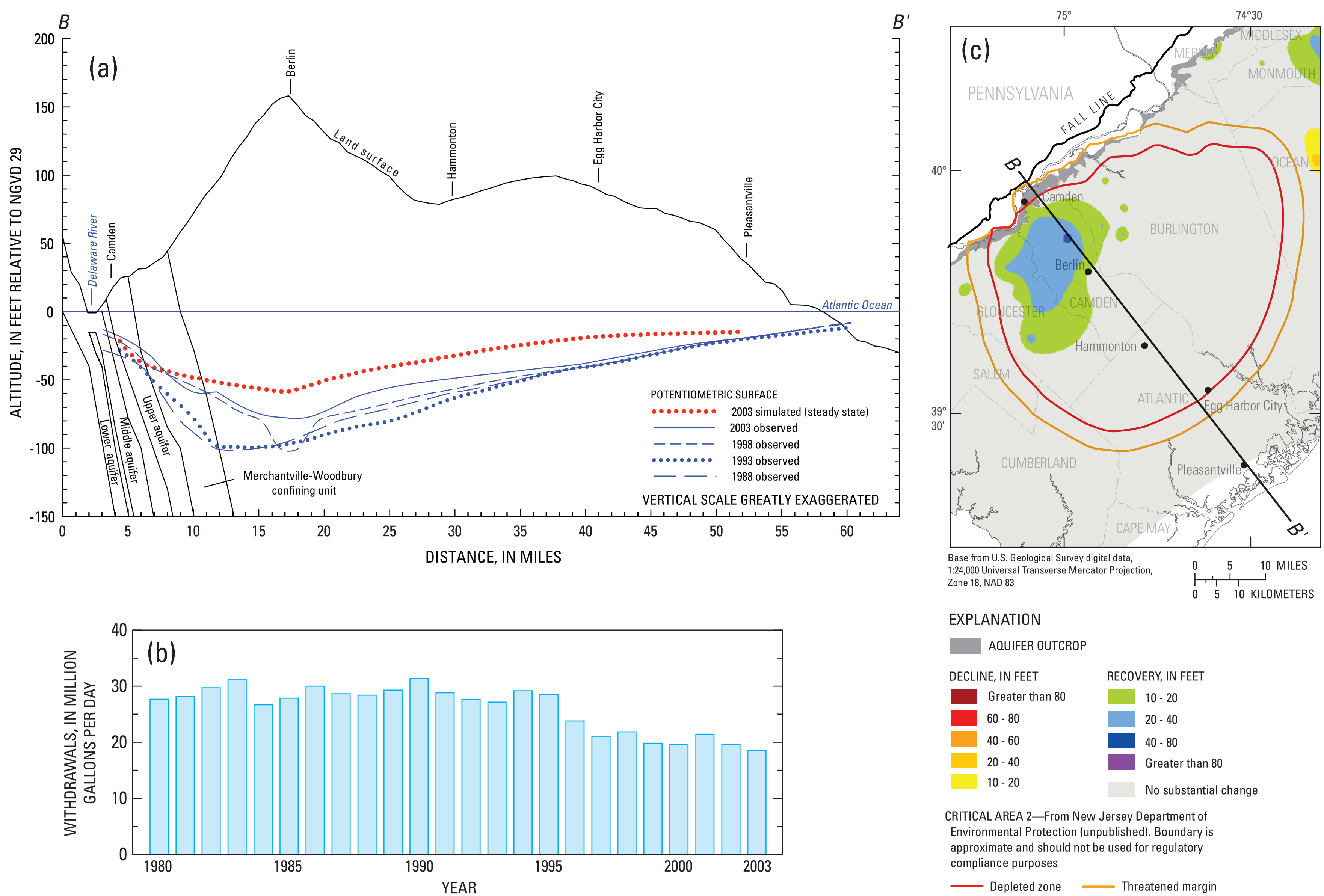


Figure 4. (a) Section showing potentiometric surfaces along section *B-B′*, 1988–2003; (b) graph showing withdrawals in the depleted zone of Critical Area 2, 1980–2003; and (c) map showing water-level changes in Critical Area 2, 1988–2003, in the Upper Potomac-Raritan-Magothy aquifer, southern New Jersey. (Potentiometric surfaces from Rosman and others (1995), Lacombe and Rosman (1997), Lacombe and Rosman (2001), and dePaul and others (2008))

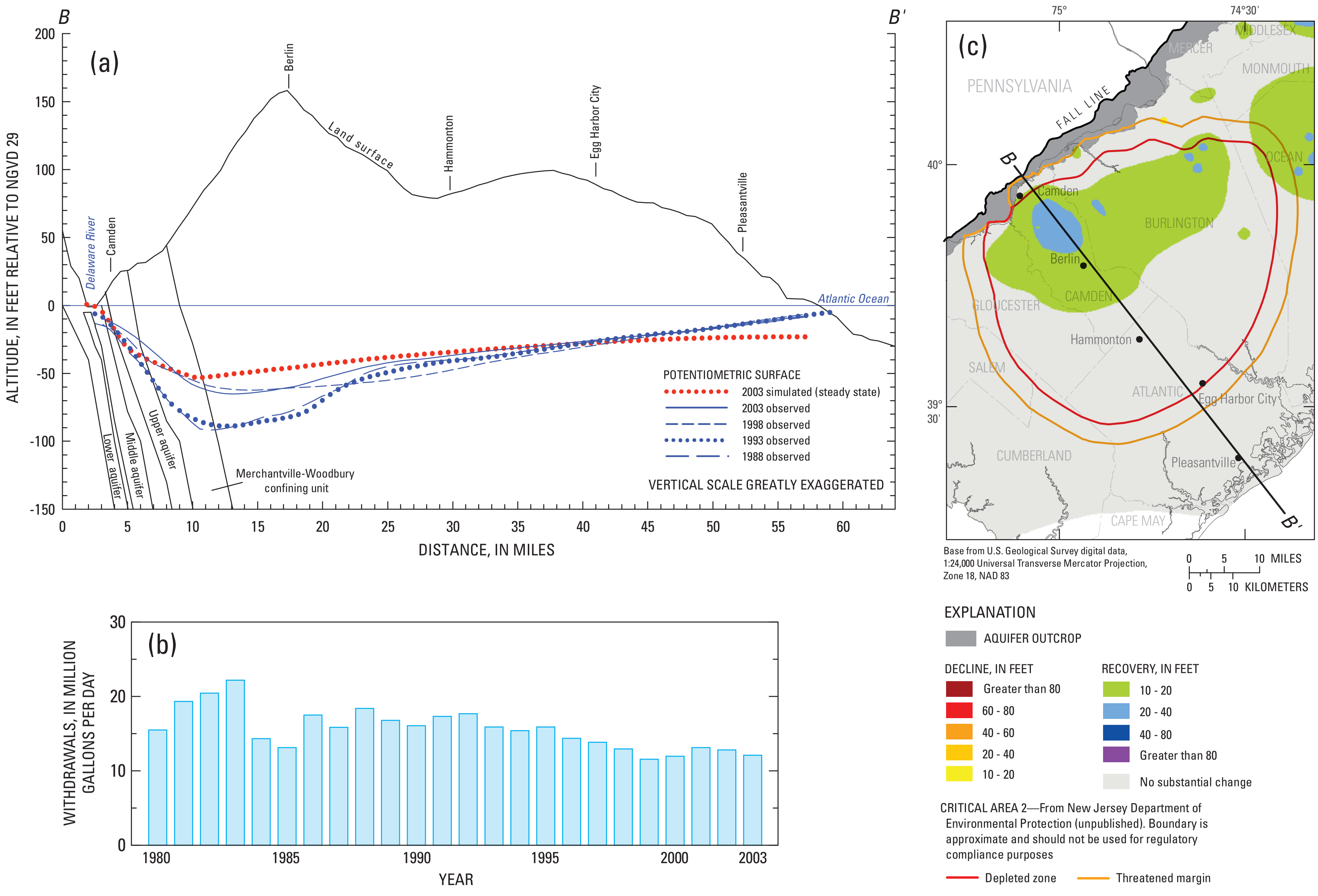


Figure 5. (a) Section showing potentiometric surfaces along section *B-B′*, 1988–2003; (b) graph showing withdrawals in the depleted zone of Critical Area 2, 1980–2003; and (c) map showing water-level changes in Critical Area 2, 1988–2003, in the Middle Potomac-Raritan-Magothy aquifer, southern New Jersey. (Potentiometric surfaces from Rosman and others (1995), Lacombe and Rosman (1997), Lacombe and Rosman (2001), and dePaul and others (2008))

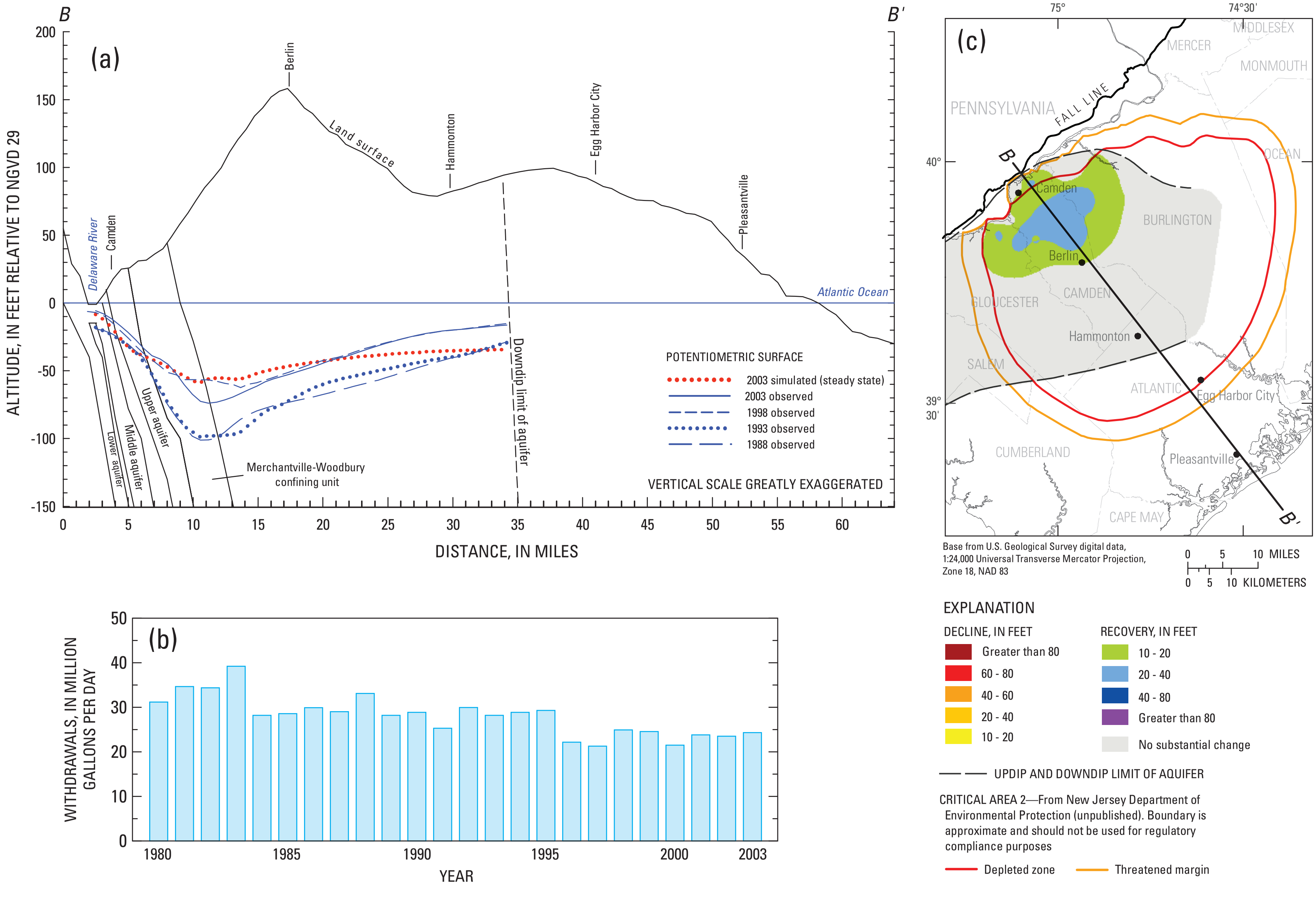


Figure 6. (a) Section showing potentiometric surfaces along section *B-B′*, 1988–2003; (b) graph showing withdrawals in the depleted zone of Critical Area 2, 1980–2003; and (c) map showing water-level changes in Critical Area 2, 1988–2003, in the Lower Potomac-Raritan-Magothy aquifer, southern New Jersey. (Potentiometric surfaces from Rosman and others (1995), Lacombe and Rosman (1997), Lacombe and Rosman (2001), and dePaul and others (2008))

recovered about 60 ft from 1993 to 1998, then remained stable from 1998 to 2003. The total 15-year (1988–2003) change in water levels in the Lower Potomac-Raritan-Magothy aquifer is shown in figure 6c. The recovery in Critical Area 2 was 10 to 20 ft in parts of Burlington, Camden, and Gloucester Counties, and was 20 to 30 ft in a 68.1-mi^2 area of these counties.

Although the Wenonah-Mount Laurel aquifer and Englishtown aquifer system overlying the Potomac-Raritan-Magothy aquifer system are not specifically regulated in Critical Area 2, some withdrawals were relocated to these aquifers after withdrawals from the Potomac-Raritan-Magothy aquifer system were reduced. This change caused water levels in the Wenonah-Mount Laurel aquifer to decline noticeably. As a result, a moratorium on new or increased withdrawals from this aquifer was issued in the mid-1990s (Jennifer Myers, New Jersey Department of Environmental Protection, written commun., 2007). The effect on the Englishtown aquifer system is less clear as a result of the lack of downdip water-level data.

Evaluation of Effects of 2003 and Full-Allocation Withdrawals

The Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in Critical Area 2 are hydraulically connected to aquifers and confining units beyond the extent of Critical Area 2. Therefore, to examine the effect of withdrawals on these aquifers in this area, the larger hydrologic system and associated stresses must be considered. Accordingly, a regional ground-water-flow model of the entire New Jersey Coastal Plain was used in this study. A description of this model is provided below. Results of simulations made using this model are provided in the following sections.

Ground-water-flow model

The USGS Regional Aquifer System Analysis (RASA) model has been widely used and has been shown to be an effective tool for simulating ground-water flow in the New Jersey Coastal Plain and provides reasonable estimates of the source of water to wells—for example, Gordon (2007). The input data for the RASA model were formatted for use with MODFLOW (Harbaugh and McDonald, 1996), a modular finite-difference ground-water-flow model. The original RASA model was developed by Martin (1998); the revised model (Voronin, 2004) includes (1) a rediscretization of original RASA model parameters using a finer grid size, (2) updated boundary fluxes, (3) a spatially variable recharge rate based on recharge rates determined as part of recent studies of the surficial aquifers of the Coastal Plain, and (4) updated ground-water withdrawals for 1981–98.

The following describes the revised model. The extent of the model is shown in figure 1. The model grid consists of 135 rows and 245 columns with a cell size of 0.25 mi^2 over most of Critical Area 2, 0.31 mi^2 elsewhere in the Coastal Plain, and up to 3.16 mi^2 in offshore areas (Voronin, 2004, plate 1). The ratio of the revised number of cells to the original number of cells is 25 to 1 in onshore areas. Rediscretization allows modeled withdrawals to be located more accurately, as withdrawals are simulated at the nodal center of each grid cell. Stress periods were changed from the original model to incorporate updated withdrawal data. The Coastal Plain was discretized vertically into 10 aquifers and 9 intervening confining units. All aquifers were modeled as confined layers with a constant saturated thickness. Some aquifers, including the Lower Potomac-Raritan-Magothy aquifer, are not continuous throughout the Coastal Plain.

The boundary conditions in the revised RASA model are the same as those used in the original RASA model. The northwestern limit of the Coastal Plain is the Fall Line (fig. 1), which is modeled as a no-flow boundary. (The Fall Line is the topographic boundary between physiographic provinces—the western margin of the Coastal Plain and the eastern margin of the Piedmont.) Flows at the northeastern and southwestern boundaries are computed from flows from larger areal models (Leahy and Martin, 1993; Pope and Gordon, 1999). Flows at the southwestern boundary of the Potomac-Raritan-Magothy aquifer system were updated on the basis of water-level declines to account for the large increases in withdrawals in Delaware from 1988 to 1998. The southeastern boundary in most aquifers is a no-flow boundary, representing the downdip limit of freshwater. This boundary in each aquifer, as delineated by chloride concentrations of 10,000 mg/L, can be found in Martin (1998).

Most of the Coastal Plain aquifers have outcrop areas that receive recharge from precipitation and are in direct contact with streams. The upper boundary in onshore grid cells that contain stream reaches is a head-dependent flow boundary (simulated using the River and Drain Packages of MODFLOW). The upper boundary in remaining onshore modeled areas is specified recharge. A spatially variable recharge rate equal to long-term precipitation minus long-term evapotranspiration and surface-water runoff was applied to these cells. The upper boundary in offshore modeled areas is a constant equivalent freshwater head. The lower boundary is crystalline bedrock and is modeled as a no-flow boundary.

Subsequent minor changes were made to the revised RASA model (M.K. Watt, U.S. Geological Survey, written commun., 2007): the vertical conductance of the Vincentown-Manasquan confining unit was modified to improve the representation of the hydrogeology, (2) the model was updated to include 1999–2003 withdrawal data, and a (3) more recent version of MODFLOW was used (Harbaugh and others, 2000). No additional calibration or sensitivity analysis was done. This model is on file at the USGS office in West Trenton, N.J.

To simplify the modeling process, the steady-state version of the RASA model was used. Steady-state conditions occur when there is no further change in simulated heads with time as a result of applied stresses, such as withdrawals. Simulated heads in the cones of depression in the Potomac-Raritan-Magothy aquifer system for 2003 from the steady-state RASA model were about 5 ft higher than heads from the transient RASA model (M.K. Watt, U.S. Geological Survey, written commun., 2007), and steady-state heads were about 10 to 20 ft higher than observed 2003 water levels. The difference between the steady-state and transient models is the result of aquifer-storage effects; the difference between the steady-state model and observed data is the result of the coarse model grid size. Given that an additional 40 years was necessary to reach steady-state conditions in the Potomac-Raritan-Magothy aquifer system when simulating estimated 2010 withdrawals (Gordon, 2007), heads simulated with the steady-state version of the RASA model may be higher than actual heads for periods shorter than 40 years.

Model Runs

In a related study of Critical Area 1 (Spitz and others, 2007), withdrawals were optimized in the RASA model to evaluate the effects of increased apportionment of allocations. Because withdrawals in Critical Area 2 are not near full allocation, an initial simulation was done to assess the effect of full-allocation withdrawals on water levels and saltwater intrusion to determine the appropriateness of conducting an optimization analysis. A simulation also was made to assess the effect of 2003 withdrawals for comparison.

Model results were evaluated in terms of satisfying the mandated hydrologic conditions for Critical Area protection with respect to the location of the simulated -30-ft head contour in each aquifer—that is, that the contour (1) not extend beyond the boundary of the depleted zone and (or) (2) be at least 5 mi updip from the 250-mg/L isochlor for each aquifer. Additional supporting conditions were evaluated, including the difference in heads between the two simulations. (The isochlor locations used in this study were modified from Gill and Farlekas (1976) and Lacombe and Rosman (2001) on the basis of water-quality data collected through 2006. The isochlor in the Lower Potomac-Raritan-Magothy aquifer is mapped with limited areal extent.)

2003 Withdrawals

Withdrawals in 2003 from wells in the depleted zone of Critical Area 2 are listed by well in table 1 (at end of report). Steady-state simulated head contours from the RASA model based on these withdrawals are shown in figure 7. The simulated -30-ft head contour in all three Potomac-Raritan-Magothy aquifers generally is located within the boundary of the depleted zone, except in northern Camden and northwestern Burlington Counties in the Lower Potomac-Raritan-Magothy aquifer. The area of heads below -30 ft ranges from 389 mi^2 in the Middle Potomac-Raritan-Magothy aquifer to 427 mi^2 in the Lower Potomac-Raritan-Magothy aquifer. The -30-ft head contour in all three aquifers generally is located 1 to 10 mi downdip from the 250-mg/L isochlor, depending on the flow gradient.

Full-Allocation Withdrawals

The RASA model was used to simulate full-allocation withdrawals from all wells in the depleted zone of Critical Area 2 (as identified by NJDEP) and proximal wells in Salem and Gloucester Counties (as identified by USGS). The procedure used to determine full-allocation withdrawals in the depleted zone is presented first. NJDEP provided allocation permit numbers and current full allocations. Well permit numbers associated with each allocation permit number were determined by USGS. Recent withdrawals for each well associated with an allocation were used to prorate the full-allocation withdrawals. Average withdrawals from the transient RASA model for 2001–03 (M.K. Watt, U.S. Geological Survey, written commun., 2007) were used in the proration.

Withdrawals within the Burlington County Water Allocation Credit Receiving Area (fig. 1) included those by water users who had already received credit transfers. Unassigned credits were not included in the model. Full-allocation withdrawals in Salem and Gloucester Counties were equivalent to adjusted full-allocation withdrawals determined as part of a concurrent USGS study (E.G. Charles, U.S. Geological Survey, written commun., 2007). Full-allocation withdrawals for 154 wells in the depleted zone and 124 wells in Salem and Gloucester Counties were greater than 2003 withdrawals, and total full-allocation withdrawals exceed 2003 withdrawals by 17.4 Mgal/d.

Individual wells and associated withdrawals in Salem and Gloucester Counties are listed in table 2 (at end of report). Differences between 2003 withdrawals and full-allocation withdrawals for individual wells can be determined from tables 1 and 2. Steady-state simulated heads from the RASA model based on full-allocation withdrawals are shown in figure 8. The simulated -30-ft head contour extends beyond the boundary of the depleted zone in all three Potomac-Raritan-Magothy aquifers in northern Camden and northwestern Burlington Counties; the contour also extends beyond the boundary in the Upper Potomac-Raritan-Magothy aquifer in Gloucester and Salem Counties. If unassigned Burlington County Water Allocation Credits had been included in the model, the -30 ft contour might have reached the boundary of the depleted zone in the Middle Potomac-Raritan-Magothy aquifer in the Credit Receiving Area. The area of heads below -30 ft ranges from 616 mi^2 in the Upper Potomac-Raritan-Magothy aquifer to 813 mi^2 in the Lower Potomac-Raritan-Magothy aquifer. The -30-ft head contour in all three Potomac-Raritan-Magothy aquifers generally is located 5 to 15 mi downdip from the 250-mg/L isochlor.

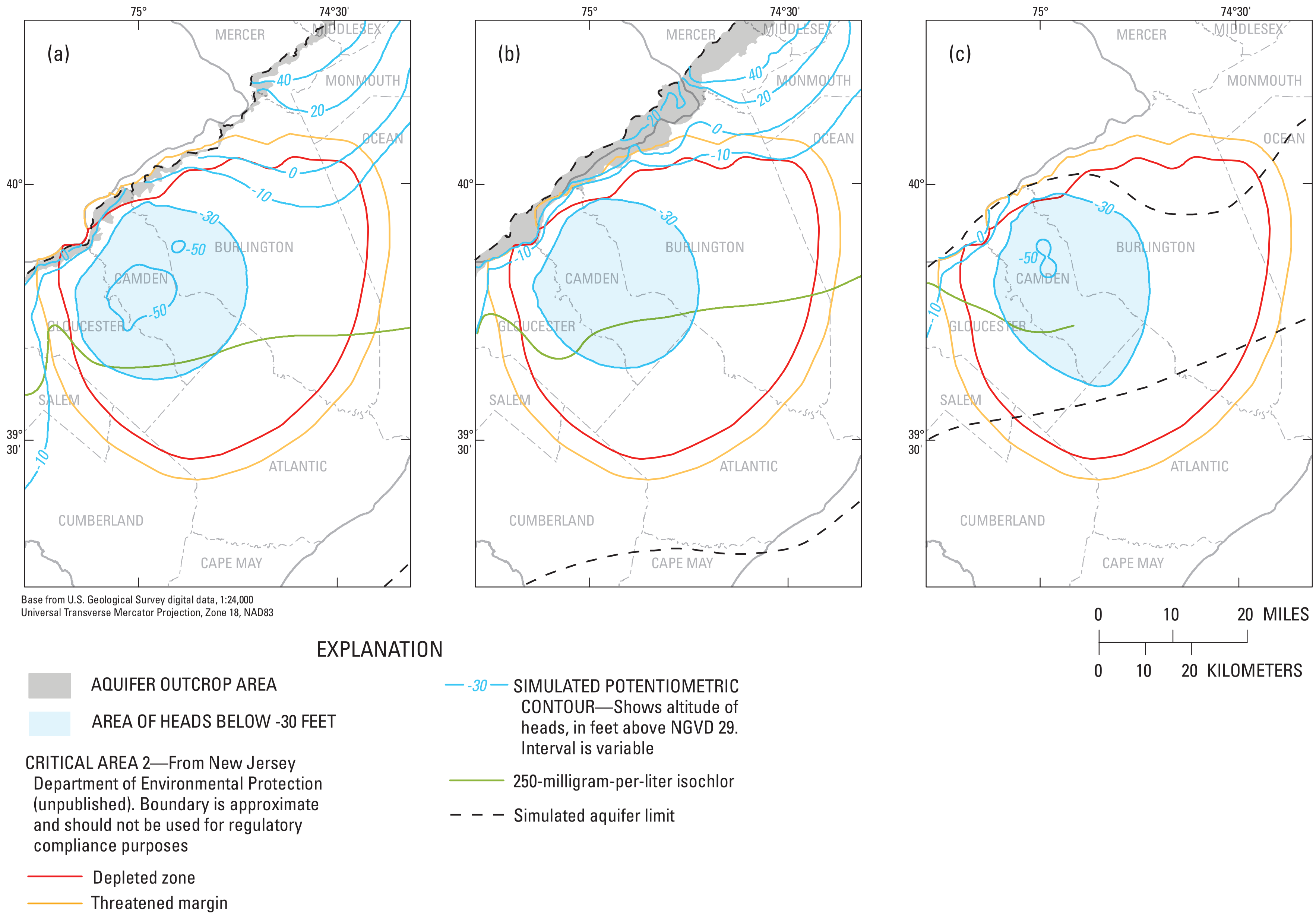


Figure 7. Simulated potentiometric surface for 2003 withdrawals in the (a) Upper, (b) Middle, and (c) Lower Potomac-Raritan-Magothy aquifers in Critical Area 2, southern New Jersey.

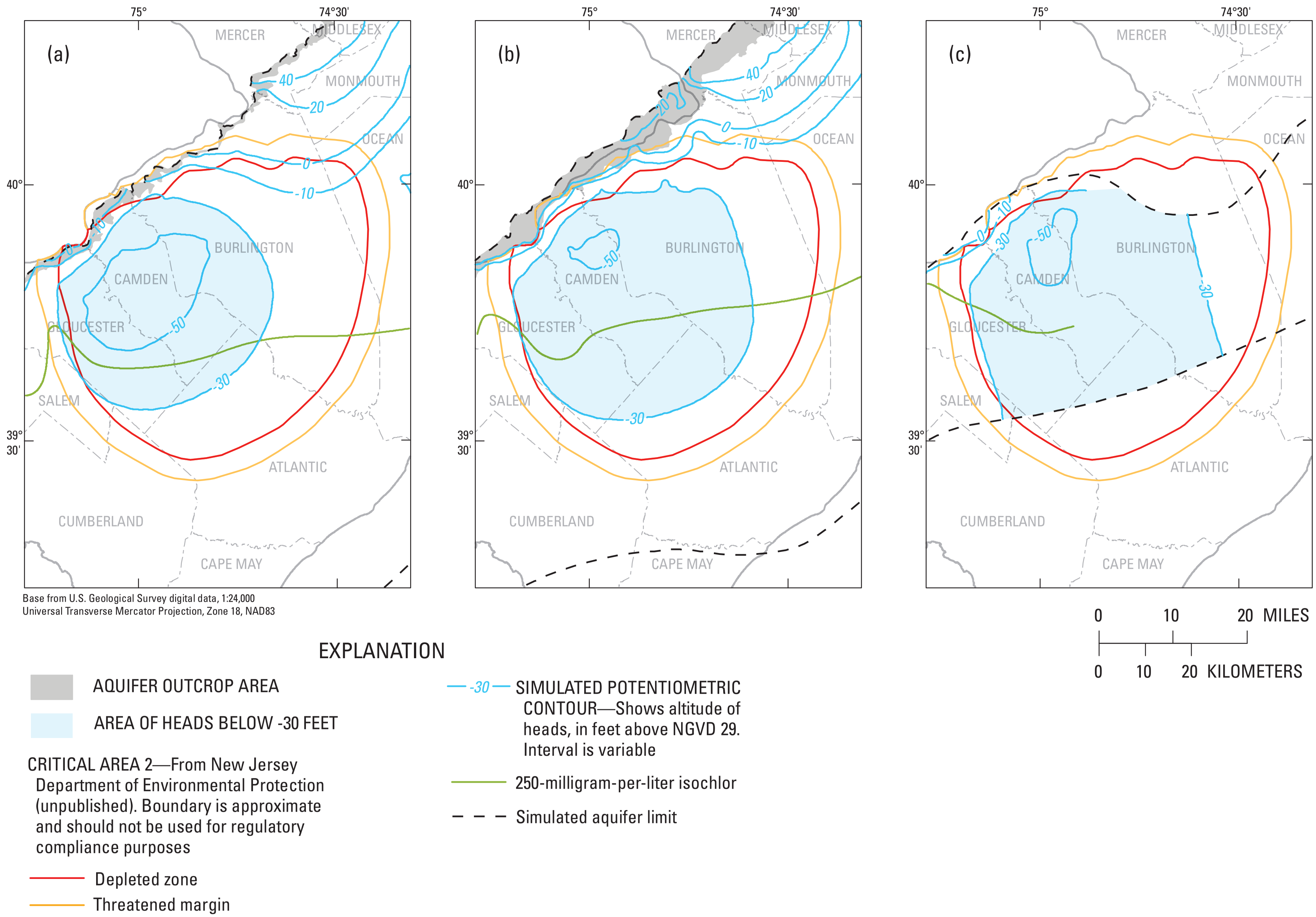


Figure 8. Simulated potentiometric surface for full-allocation withdrawals in the (a) Upper, (b) Middle, and (c) Lower Potomac-Raritan-Magothy aquifers in Critical Area 2, southern New Jersey.

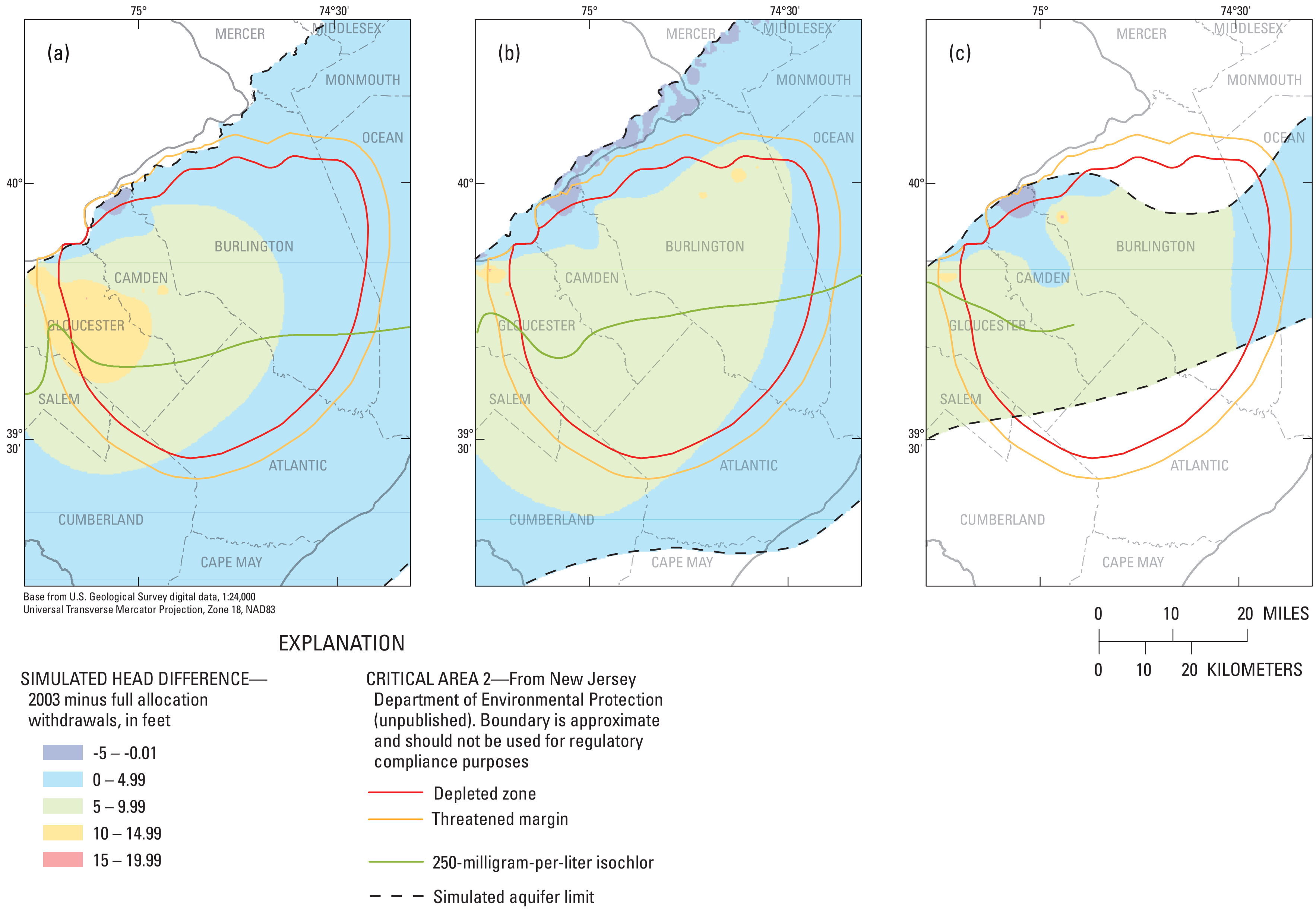


Figure 9. Simulated head difference between 2003 and full-allocation withdrawals in the (a) Upper, (b) Middle, and (c) Lower Potomac-Raritan-Magothy aquifers in Critical Area 2, southern New Jersey.

Comparison of Results

The difference in simulated heads between 2003 and full-allocation withdrawals is shown in figure 9. Generally, head differences were 0 to 10 ft lower in all the Potomac-Raritan-Magothy aquifers along the depleted-zone boundary and 250-mg/L isochlor for each aquifer. Head differences were up to 15 ft lower in the Upper Potomac-Raritan-Magothy aquifer over a large area centered on Gloucester County and in the Middle and Lower Potomac-Raritan-Magothy aquifers in isolated areas of Gloucester and Burlington Counties. The area of heads below -30 ft in the three aquifers was 227 to 386 mi^2 greater for full allocation than for 2003 withdrawals. In outcrop areas, the difference in simulated heads was generally less than 5 ft but as much as 15 ft in parts of Gloucester County. Results of these model runs indicate that withdrawals at full-allocation levels would cause the -30-ft head contour to extend beyond the boundary of the depleted zone and the 250-mg/L isochlor for each aquifer in several areas; therefore, evaluation of the effects of withdrawals greater than full allocation was unnecessary.

Comparison with Observed Data

Because observed 2003 water levels (fig. 3) are generally lower than simulated 2003 heads (fig. 7), actual conditions may be more acute than simulated conditions. The observed 2003 water-level data indicate that the -30-ft water-level contour in all three Potomac-Raritan-Magothy aquifers reaches or extends beyond the boundary of the depleted zone and is located 5 to 20 mi downdip from the 250-mg/L isochlor (dePaul and others, 2008). An implication of both the simulated results and observed data discussed in this section is that optimization analysis for Critical Area 2, as was done for Critical Area 1, is not necessary.

Limitations of the Analysis

The results of this study should be evaluated in terms of the limitations and assumptions associated with the model and input data. Data error may include inaccuracies in interpreted potentiometric surfaces, locations of observed 250-mg/L isochlors, and withdrawal data. For example, withdrawal data used in this study are derived from values reported to the NJDEP by water users. These data represent the best information available, although the associated accuracy is not always known.

Limitations and assumptions of the MODFLOW model are discussed in Harbaugh and others (2000). Limitations and assumptions of the RASA model are discussed in Martin (1998) and Voronin (2004). Some differences between simulated heads and observed water levels could not be resolved during RASA model calibration. Nevertheless, the RASA model has proven to be a good predictor in previous hydrologic studies, particularly at a regional scale. The assumption of steady-state conditions indicates that there is no further change in simulated heads with time as a result of withdrawal stresses. As described earlier, results of previous simulations of projected 2010 withdrawals indicate that steady-state conditions are not reached for more than 40 years; therefore, heads from simulation of steady-state conditions may be higher than heads from simulation of shorter duration. The analysis documented herein is considered reasonable given these limitations.

Summary and Conclusions

Water levels in the Upper, Middle, and Lower aquifers of the Potomac-Raritan-Magothy aquifer system in Water Supply Critical Area 2 in the southern New Jersey Coastal Plain have recovered since the early 1990s as a result of NJDEP-mandated reductions in ground-water withdrawals in the Critical Area. Critical Area 2 is located in Burlington, Camden, Gloucester, and Atlantic Counties and small parts of Ocean, Salem, and Cumberland Counties. Maximum withdrawals in 1993 were mandated to be 22 percent less than those in 1988 in the depleted zone of the Critical Area, and were limited to the maximum annual rate during 1983–91 in the threatened margin in order to mitigate adverse effects on the sustainability of the ground-water supply. Recent increased water demand as a result of development in Critical Area 2 prompted the NJDEP to evaluate the possibility of revising current water-use allocations.

Average withdrawals in the depleted zone of Critical Area 2 from 1993 (when reductions were implemented) to 2003 were about 23 Mgal/d from the Upper aquifer, 14 Mgal/d from the Middle aquifer, and 25 Mgal/d from the Lower aquifer. During that period, water levels recovered as much as 40 ft in these aquifers, with much of that recovery occurring in Camden County. In Critical Area 2 and surrounding areas, the area of recovery was most extensive in the Middle aquifer, but the magnitude of recovery was greatest in the Upper and Lower aquifers. The recovery in the Upper aquifer was 10 to 20 ft in parts of Burlington, Camden, and Gloucester Counties and 20 to 40 ft in a 91.1-mi^2 area of the latter two counties. The recovery in the Middle aquifer was 10 to 20 ft in parts of the three counties and 20 to 35 ft in a 48.3-mi^2 area of Camden County. The recovery in the Lower aquifer was 10 to 20 ft in parts of the three counties and 20 to 30 ft in a 68.1-mi^2 area of the counties.

An existing regional ground-water flow model of the New Jersey Coastal Plain, the U.S. Geological Survey Regional Aquifer System Analysis (RASA) model, was used to simulate steady-state ground-water flow in the Potomac-Raritan-Magothy aquifer system to determine the effects of ground-water withdrawals on heads in Critical Area 2. Two withdrawal options were simulated—2003 withdrawals and full-allocation withdrawals (17.4 Mgal/d greater than 2003 withdrawals). The effects of these two withdrawal options in each of the three aquifers were evaluated by examining simulated heads and the difference in simulated heads (1) within the Critical Area, (2) at the boundary of the depleted zone, and (3) at the 250-mg/L isochlor for each aquifer. Observed 2003 water levels also were considered in the evaluation.

Simulation results indicate that, for 2003 withdrawals, the simulated -30-ft head contour in all three aquifers is generally within the boundary of the depleted zone, except in the Lower aquifer in northern Camden and northwestern Burlington Counties, and is generally 1 to 10 mi downdip from the 250-mg/L isochlor. (Corresponding observed data indicate that the -30-ft water-level contour extends beyond the southwest boundary of the depleted zone in the Upper and Middle aquifers and is generally 5 to 20 mi downdip from the 250-mg/L isochlor in all three aquifers.) The area in which heads are below -30 ft ranges from 389 mi^2 in the Middle aquifer to 427 mi^2 in the Lower aquifer. For full-allocation withdrawals, the simulated -30-ft head contour extends beyond the boundary of the depleted zone in all three aquifers in northern Camden and northwestern Burlington Counties and in the Upper aquifer in Gloucester and Salem Counties, and is generally 5 to 15 mi downdip from the 250-mg/L isochlor. The area in which heads are below -30 ft ranges from 616 mi^2 in the Upper aquifer to 813 mi^2 in the Lower aquifer. These simulation results and the analysis of observed water-level recoveries indicate that any increase in withdrawals from 2003 values in Critical Area 2 would likely cause heads in the three aquifers to decline below the minimum values mandated by the NJDEP.

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Table 1. Withdrawals from and model locations of production wells in the depleted zone of Critical Area 2, southern New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; MUA, Municipal Utilities Authority; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal (Mgal/d)
Aqua New Jersey	Blackwod div 7	479	437	479	5007	3108176	0.517	070250	8	27	94	0.421
	Blackwod div 6	480	407	477	do.	3105581	0.649	070252	8	28	97	0.624
	Blackwod div 3	447	426	447	do.	3102703	0.299	070249	8	26	95	0.369
	H 4	453	405	453	5007	3108539	0.321	070600	8	27	93	0.372
Bellmawr Borough WD	WD 4	557	380	557	5223	3104969	0.363	070008	10	17	98	0.312
	Bellmawr Ps	557	458	557	do.	3112315	0.270	070523	10	17	99	0.238
	PW 6	381	330	381	do.	3119218	0.172	070601	10	16	98	0.173
	Bellmawr PW 3	359	334	359	do.	3102687	0.161	070012	10	15	98	0.134
Berlin Borough WD	Berlin PW 9	713	650	713	5044	3102079	0.982	070018	8	35	104	0.682
	Berlin PW 11	745	675	745	do.	3106208	0.511	070015	8	36	103	0.539
Brooklawn Borough WD	5(OW 3)	320	300	320	5030	3114471	0.114	070531	10	13	97	0.118
	PW 4	293	263	293	do.	3119765	0.039	070596	10	13	97	0.027
	PW 3	327	307	327	do.	3104325	0.135	070520	10	13	97	0.076
Clayton Borough WD	Clayton P-3	800	746	800	5244	3102889	0.119	150001	8	39	79	0.050
	4-1973	740	670	740	do.	3106676	0.333	150003	8	36	80	0.128
Clementon Borough WD	Clementon PW 10	629	600	629	5168	3112301	0.292	070521	8	31	100	0.155
Collingswood WD	PW 4	304	274	304	5209	5100030	0.230	070177	10	12	105	0.193
	7(B)	313	224	313	do.	3104797	0.325	070171	10	13	103	0.257
	PW 2R	278	248	278	do.	3104053	0.009	070176	10	12	105	0.003
	PW 3	287	257	287	do.	3104054	0.018	070178	10	12	105	0.025
	PW 5	278	248	278	do.	5100031	1.538	070179	10	12	106	1.454
	Collingswood PW 1R	306	266	306	do.	3100079	0.008	070175	10	12	105	0.001
Deptford Township MUA	Deptford PW 7	324.42	259.42	319.42	5336	3122504	0.474	151036	9	21	89	0.320
	Deptford PW 4	345	282	345	do.	3105513	0.090	150024	9	16	96	0.151
	Booster Sta 8	261	198	258	do.	3137705	0.237	151089	8	19	95	0.053
	Deptford PW 6	489	430	486	do.	3113385	0.727	150374	9	20	91	0.753
	PW 1	273	252	273	do.	3102416	0.122	150016	8	18	89	0.073

Table 1. Withdrawals from and model locations of production wells in the depleted zone of Critical Area 2, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; MUA, Municipal Utilities Authority; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal (Mgal/d)
Evesham Township MUA	PW 6	550	458	550	5004	3107453	0.501	050757	8	30	118	0.465
	Mlwc 5/Emua 9	463	416	463	do.	3109595	0.531	050795	8	29	116	0.507
	Evesham PW 7	441	405	441	do.	3114627	0.426	050707	8	26	115	0.458
	PW 8	435	375	435	do.	3120373	0.181	050824	8	28	115	0.269
	Kgwc 2/Emua 11	591	545.08	591	do.	3106841	0.146	050820	8	33	113	0.103
	Evesham 4	500	464	500	do.	3105458	0.355	050165	8	29	114	0.427
	Kgwc 1/Emua 10	593	546.5	593	do.	3106840	0.136	050755	8	33	113	0.091
	Evesham 5	555	478	548	do.	3107883	0.349	050167	8	32	118	0.161
Glassboro WD	PW 2	602	562	602	5135	5100042	0.193	150062	8	31	83	0.178
	Glassboro PW 4	599	549	599	do.	3104176	0.630	150063	8	30	83	0.491
	Glassboro PW 3	612	562	612	do.	3102358	0.330	150060	8	31	80	0.223
Gloucester City WD	PW 41	265	225	265	5010	3127737	0.677	070902	8	12	100	0.503
	PW 40	262	221	261	do.	3104306	0.074	070220	10	12	100	0.015
	PW 43	260	219.5	260	do.	3118822	0.472	070516	10	12	100	0.390
	PW 42	306	---	---	do.	3105242	0.195	070210	10	12	100	0.168
Haddon Township WD	Rhoades Ave 3A	475	418	470	5235	3128896	0.240	070723	10	16	105	0.177
	1-R	480	---	---	do.	3105243	0.327	070291	10	16	105	0.072
	Haddon PW 5	450	355	445	do.	3159128	0.445	071085	10	15	105	0.710
Haddonfield Borough WD	PW 1A	249	206	246	5152	3102570	0.168	070997	8	19	106	0.098
	Hwd 8/Hwd 7	550	500	550	do.	3109694	0.579	070525	10	19	106	0.493
	Rulon	572	523	572	do.	3102130	0.258	070302	10	19	106	0.231
Inversand Co	Ind 2	355	---	---	2391P	3102558	0.091	151407	9	25	86	0.123
Johnson, Peter & William	Irr 2	445	---	---	BU0087	5100157	0.103	051485	8	28	123	0.038
Laurel Creek Country Club	Irr 1R	305	285	305	2385P	3152021	0.000	051548	9	18	125	0.001
	PW 3	283	257	277	do.	3147958	0.004	051522	9	19	127	0.003
	PW 2	280	260	280	do.	3148385	0.001	051523	9	19	127	0.000
Mantua Township MUA	Mantua PW 4	265	230	265	5314	3105309	0.150	150194	8	18	85	0.157
	PW 5	337	315	337	do.	3102987	0.173	150192	8	19	83	0.148
	PW 3	317	295	317	do.	3101140	0.075	150193	8	19	85	0.085
	PW 2	368	336	368	do.	3104791	0.160	150191	8	22	86	0.145

Table 1. Withdrawals from and model locations of production wells in the depleted zone of Critical Area 2, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; MUA, Municipal Utilities Authority; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal (Mgal/d)
Maple Shade WD	Maple Shade 8	270	210	270	5190	3106020	0.250	050232	9	15	115	0.157
	Maple Shade 10	500	440	500	do.	3108923	0.141	050228	10	17	114	0.141
	Maple Shade 9	200	160	200	do.	3108922	0.063	050229	8	17	114	0.165
	PW 11	450	389	450	do.	3112925	1.373	050746	10	15	115	1.180
Medford Leas	1-1972	471	447	471	5323	3106056	0.001	050253	8	32	124	0.000
	2-1977	471	451	471	do.	3110560	0.072	050254	8	32	124	0.064
Medford Township WD	Medford PW 6	672	593	672	5039	3116976	0.237	050759	8	36	119	0.253
	Medford 3/1	544	523	541	do.	3105282	0.076	050249	8	34	118	0.122
	1(3)/MWC 8	536	506	536	do.	3102752	0.352	050252	8	32	123	0.304
	4(1968)	536	506	536	do.	3105301	0.291	050251	8	33	121	0.235
Merchantville-Pennsauken Water Co	Woodbine 2	226	196	226	5173	3114563	0.534	070560	10	11	109	0.959
	National Hwy 2	206	182	206	do.	3119207	0.461	070602	10	9	115	0.831
	Park Ave 1	270	240	270	do.	3100010	0.101	070349	10	12	114	0.174
	Park Ave 3	275	240	275	do.	3103534	0.478	070348	10	12	114	0.397
	1R/Browning 1A	152	132	152	do.	3105641	0.274	070319	9	11	108	0.396
	Browning 2A/Browning 1	140	110	140	do.	3104836	0.041	070329	9	11	108	0.229
	Park Ave 2	257	232	257	do.	5100064	0.141	070350	10	11	114	0.397
	4R-A/Park Ave 6	270	240	270	do.	3114564	0.141	070530	10	12	113	0.397
	Woodbine 1	285	245	285	do.	3104642	0.308	070320	10	11	109	0.395
	Marion 1	278	243	278	do.	3102915	0.218	070335	10	11	111	0.493
	Marion 2	258	223	258	do.	3104641	0.406	070332	10	12	111	0.836
	Browning Wtp 3A	185.3	107.7	180.3	do.	3143933	0.099	070904	9	11	108	0.153
	Park Ave 5	288	248	288	do.	3100011	0.141	070345	10	12	114	0.397
Moorestown Township WD	PW 5	288	248	288	5121	3104663	0.569	050264	9	17	116	0.210
	PW 3	299	269	299	do.	5100041	0.507	050266	9	17	116	0.196
Mount Laurel MUA	PW 6	590	499	590	5193	3119212	1.964	050819	10	20	117	0.343
National Park Borough WD	PW 6	272	240	272	5153	3117938	0.295	150533	10	11	92	0.264
	NPWd 2/NPWd 5	282	241	282	do.	3102555	0.010	150207	10	10	92	0.007

Table 1. Withdrawals from and model locations of production wells in the depleted zone of Critical Area 2, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; MUA, Municipal Utilities Authority; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal (Mgal/d)
NJ/American WC	Highland & Walnut OW-64	545	452	535	5197	3140817	0.717	070733	9	21	102	0.601
	Haddon 30	275	224	275	do.	3104798	0.112	070279	8	18	103	0.028
	Haddon 15	594	452	594	do.	3102434	0.704	070278	10	18	103	0.840
	Haddon 20	275	236	267	do.	3103375	0.410	070275	8	19	103	0.308
	Magnolia 33	348	271	348	do.	3105100	0.411	070316	8	21	102	0.268
	Runnemede 19	339	297	339	do.	3103307	0.239	070404	8	20	99	0.268
	Somerdale 14	441	---	---	do.	3102360	0.052	070410	8	24	103	0.041
	Otterbrook 39	349	269	349	do.	3105226	0.779	070274	8	21	99	0.735
	Otterbrook 34	377	---	---	do.	3105041	0.493	070272	8	22	99	0.281
	Otterbrook 29	712	612	712	do.	3104756	0.332	070273	10	21	99	0.294
	Trenton & Second OW-63	509	333	499	do.	3140970	1.408	070734	9	19	103	1.337
	Laurel 15	473	395	442	5200	3104723	0.154	070311	8	27	102	0.556
	PW 43	1,011	923	1,011	do.	3105951	0.895	070183	10	28	104	0.711
	Laurel 13	456	394	456	do.	3101363	0.467	070310	8	27	102	0.437
	Gibbsboro 41	1,099	1,022	1,097	do.	3105949	0.571	070189	10	28	105	0.915
	Gibbsboro 42	998	934	986	do.	3105950	0.664	070188	10	28	104	1.040
	Old Orchard 37	488	454	488	5203	3105219	0.586	070134	9	24	113	0.365
	Old Orchard 38	493	443	493	do.	3105218	1.086	070135	9	24	113	1.396
	Old Orchard 36	349	299	349	do.	3105217	0.396	070133	8	24	113	0.429
	Browning 65	759	695	754	do.	3138319	0.090	070739	10	22	108	0.163
	Browning 45	626	483	626	do.	3107020	0.564	070124	9	22	108	0.581
	Browning 44	741	684	741	do.	3107021	1.258	070122	10	22	108	1.444
	Browning 46	735	664	735	do.	3107019	0.825	070123	10	22	108	0.801
	Murray Ave Asr-1	353	236	350	do.	3140911	0.188	070994	9	15	109	0.389
	Mansfield PW-2	527	439	522	5025X	2835141	0.622	051410	9	20	149	0.483
	Mansfield PW-4	536	447	533	do.	2835937	0.444	051411	9	20	149	0.525
	Mansfield PW-3	536	449	531	do.	2835936	0.564	051409	9	20	149	0.492
	Wtr Sys	530	437	525	do.	2835140	0.543	051408	9	20	149	0.583
Pine Hill MUA	Pine Hill 2-1972	698	668	698	5335	3106646	0.165	070398	8	32	100	0.136
	Pine Hill PW 4	670	590	665	do.	3137826	0.401	070824	8	33	99	0.412

Table 1. Withdrawals from and model locations of production wells in the depleted zone of Critical Area 2, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; MUA, Municipal Utilities Authority; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal (Mgal/d)
Pitman Borough WD	Pitman PW P3	487	447	487	5137	3104061	0.088	150227	8	27	84	0.010
	PW P4	520	---	---	do.	5100018	0.572	150385	8	28	83	0.216
Pitman Country Club	Irr	408	378	408	2280P	3105060	0.010	150183	8	25	82	0.004
Ramblewood Country Club	Pond Well	425	---	---	2108P	3107140	0.013	050749	9	23	117	0.009
Sunoco Inc	Ind 1	288	248	288	2205P	3100007	0.368	150320	10	12	94	0.358
	Eagle Point 5	277	237	277	do.	3100028	1.126	150321	10	12	95	0.614
	Ind 3	288	258	288	do.	3100008	0.167	150322	10	12	94	0.243
	Eagle Point 6A	331	256	328	2205P	3117788	0.567	150430	10	12	93	0.168
Sybron Chemical Inc	Ind 4	829	773	824	2181P	3202387	0.519	050382	9	33	139	0.171
	Ind 5	828	747	823	do.	3203778	0.560	050385	9	32	139	0.344
Tavistock Country Club	Irr	247	219	247	2299P	3105248	0.013	070411	8	21	105	0.007
US Air Force	McGuire D	1,075	1,012	1,075	2236P	2800797	0.267	050335	9	36	153	0.348
	McGuire A	1,055	992	1055	do.	2800796	0.565	050337	9	34	153	0.670
	McGuire C	1089	1036	1,089	do.	2800795	0.448	050336	9	37	155	0.019
US Army	Fort Dix 5	1,104	1,064	1,104	5303	4800269	1.145	050332	9	35	150	0.411
Washington Township MUA	PW 4	417	369	417	5194	3106133	0.172	150268	8	25	93	0.202
	Washington Township TW20	711	616	703	do.	3162302	0.022	151543	8	34	89	0.017
	Washington Township PW 5	618	559	618	do.	5100029	0.370	150248	8	32	87	0.281
	Washington Township PW 15	712	628	712	do.	3145998	0.907	151365	8	36	90	0.735
	8(Bels Lk Wc2)	620	544	620	do.	3105206	0.276	150260	8	31	92	0.315
	PW 3	640	575	640	do.	3106050	0.453	150267	8	29	91	0.468
	Washington Township PW 9	552	512	552	do.	3117801	0.502	150433	8	26	91	0.467
	PW 2	577	543	573	do.	3104849	0.180	150265	8	30	92	0.173
Wenonah WD	PW 1	320	273	310	5192	5100065	0.096	150274	8	20	88	0.088
	Wenonah PW 2	310	268	310	do.	3100170	0.101	150275	8	20	88	0.079
West Deptford Township WD	8-1981 Pkvlle Rd	312	252	309	5304	3117811	0.363	151339	9	17	87	0.115
	5 Kings Hiway	450	388	450	do.	3107056	0.281	150282	10	15	87	0.748
	6 Red Bank Ave	372	322	372	do.	5100063	0.496	150312	10	13	92	0.018
	West Deptford PW 4	289	242	289	do.	3104567	0.531	150276	8	17	87	0.486
	PW 7	366	323	363	do.	3117452	0.185	150373	10	14	93	0.201

Table 1. Withdrawals from and model locations of production wells in the depleted zone of Critical Area 2, southern New Jersey.—Continued

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					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal (Mgal/d)
Westville WD	PW 6	317	265	317	5319	3117923	0.000	150434	10	14	97	0.000
	PW 5	277	243	277	do.	3105689	0.596	150326	10	14	96	0.412
	PW 4	319	286	313	do.	3103418	0.089	150327	10	14	97	0.111
Westwood Golf Club	Deep 1	188	174	184	2257P	3143251	0.002	151176	9	15	89	0.002
	Irr	140	120	140	do.	3106200	0.036	150295	8	15	89	0.028
Woodbury City WD	Sewell 1A	311	263	308	5347X	3105174	0.700	150006	8	23	87	0.371
	Sewell 2A	307	244	307	do.	5100101	0.579	150008	8	23	87	0.275
Woodbury Heights Borough	1 Helen Ave	235	190	235	5159	3106356	0.229	150330	8	18	90	0.209
Wrightstown MUA	Wrightstown PW 3	732	692	726	5169	2808443	0.103	050726	9	33	152	0.067

[1] Model layer is assigned on the basis of aquifer code if open interval is not available.

[2] Annual current (2003) allocation (Jan Gheen, NJDEP, written commun., 2004). Prorated on the basis of 2001–03 reported use; therefore, value is based on multiple years.

[3] Number of wells associated with BWA permit is based on Regional Aquifer System Analysis model data (Voronin, 2004).

[4] Certain model cells may contain more than one well. Layer 8 is the Upper Potomac-Raritan-Magothy aquifer, layer 9 is the Middle or undifferentiated Potomac-Raritan-Magothy aquifer, and layer 10 is the Lower Potomac-Raritan-Magothy aquifer (fig. 2).

Table 2. Withdrawals from and model locations of production wells outside the depleted zone of Critical Area 2 in Salem and Gloucester Counties, New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; WSC, Water Supply Company; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal[5] (Mgal/d)
Allied Energy	No-1 1977	101	71	91	10762W	3001616	0.102	150399	9	5	76	0.000
	Auburn 2	204	184	204	do.	3011400	0.102	330920	8	13	63	0.012
Aqua New Jersey	PW 1	225	190	220	5383	3013286	0.010	151532	8	12	68	0.096
	PW 2	229	184	224	do.	3013285	0.010	151533	8	12	68	0.104
B F Goodrich Co	Ind 3	195	180	195	2166P	5000079	0.002	330432	10	4	64	0.001
	6 (PW-2)	129	109	129	do.	3001141	1.071	330085	9	3	63	0.631
BP Oil Co	R-6-A	72	6	72	2401P	3007032	0.255	151120	9	8	86	0.083
	R-9-A	90	45	90	do.	3007015	0.159	151122	9	8	85	0.101
	R-8-A	85	39	85	do.	3007014	0.132	151121	9	8	85	0.086
	R-7-A	40	9.5	40	do.	3007012	0.203	151124	9	8	86	0.085
BP Oil Co-Paulsboro Terminal	R-4A	82	11	82	2401P	3006920	0.182	151378	9	8	85	0.079
	R-10A	39	9	39	do.	3007028	0.070	151383	8	8	86	0.035
Catalano, Sam	Irr 1	230	210	230	SA0124	3010178	0.268	330922	8	16	61	0.019
Clendining, Jean	Irr	110	87	107	GL0092	3007814	0.086	151566	8	10	73	0.004
Colella, Anthony	Irr 1	191	171	191	SA0151	3005648	0.049	331009	8	13	63	0.000
Conectiv Atl Mickleton Gen Stn	Well IND 2	313	293	313	11230W	3016779	0.102	151691	10	13	80	---
Del Monte Corp	Swedesboro Ind 9	231	190	231	10469W	3000973	0.102	150240	8	13	71	0.000
Dubois Brothers	Irr 74	362	337	362	SA0014	3001383	0.055	330198	9	15	60	0.008
E I Dupont	Irr P1	591	445	591	2122P	3001081	0.037	330067	9	15	55	0.000
	Course Land P2	637	385	525	do.	3001082	0.038	330298	9	15	55	0.000
	Course Land P3	457	381	457	do.	3001083	0.092	330305	9	13	55	0.000
	Interceptor 46	136	96	136	2251P	3003594	0.746	150692	9	6	80	0.415
	Repauno 6	109	84	109	do.	3001145	0.104	150079	9	6	80	0.076
	Repauno 3	101	91	101	do.	3000037	0.628	150072	9	6	79	0.274
East Greenwich Township WD	East Greenwich PW 3	246	205	245	5142	3001426	0.306	150355	8	14	84	0.191
	East Greenwich PW 2	216	191	216	do.	3000432	0.181	150028	8	14	82	0.184
EM Diagnostic Systems Inc	Irr-1985	90	60	90	10472W	3003764	0.102	151346	8	10	79	0.000
Ferro Corp	PW4	108	60	105	2099P	3013712	0.541	151554	9	3	70	0.000
G & G Stecher	Irr1	230	200	220	GL0216	3009279	0.031	151565	8	12	68	0.000
Gibbstown Soccer Association	Irr 1	123	103	123	11028W	3012748	0.102	151597	8	9	80	0.000
Gloucester Co Solid Waste	2 Fire Protect	379	359	379	10506W	3004336	0.004	151370	8	18	70	0.000
	Com 1	377	357	377	do.	3004335	0.098	151105	8	19	69	0.008
Grasso, J S	Ind 1	267	247	267	2423P	3001161	0.085	150339	8	14	68	0.028

Table 2. Withdrawals from and model locations of production wells outside the depleted zone of Critical Area 2 in Salem and Gloucester Counties, New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; WSC, Water Supply Company; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal[5] (Mgal/d)
Greenwich Township WD	PW 6	138	105	135	5253	3001776	0.210	150348	9	9	81	0.206
	Memorial Ave 4R	171	98	166	do.	3009345	0.280	151364	9	8	83	0.219
	5 (2-A)	122	82	117	do.	3001545	0.463	150347	9	7	79	0.395
Gunn, Kevin	Irr	170	150	170	SA0166	3014084	0.040	330996	8	13	57	---
Harrison Township	Irr 1	397	372	397	11088W	3013781	0.102	151598	8	20	77	0.002
Hercules Chemical	4 1970	120	90.5	120.5	2227P	3001224	0.137	150076	9	7	80	0.047
	MW 19B	68	48	68	do.	3003372	0.022	150647	9	7	81	0.000
	PW-9	44	13.65	43.65	do.	3004317	0.068	151402	9	7	80	0.027
	MW-6	49	34	49	do.	3003264	0.005	151401	9	7	81	0.000
	PW-7B	95	55	95	do.	3003650	0.035	151404	9	7	81	0.011
	PW-8B	69.5	29.5	69.5	do.	3003651	0.031	151403	9	7	81	0.007
	PW 11	120	90	120	do.	3004319	0.281	151034	9	8	79	0.113
	PW-8	19.87	9.87	19.87	do.	3003649	0.012	151405	8	8	81	0.005
Huntsman Polypropylene Corp	Shell 1	360	328	358	2215P	3000898	0.112	150285	10	12	85	0.000
	Shell 3	384	358	383	do.	3000900	0.393	150283	10	12	85	0.000
	Shell Ind 2	290	273	288	do.	3000899	0.388	150286	9	12	85	0.000
Kingsway Reg High School District	Ath Field Irr	195	180	195	10441W	3003041	0.102	151371	8	13	73	0.002
Logan Generating Co LP	PW 1A	97	75	95	4059PS	3008635	0.003	151527	10	3	70	0.000
	PW 1B	97	75	95	do.	3008633	0.000	151526	10	3	70	0.000
Maccarone, Samuel	Irr-1	165	---	---	GL0033	5000097	0.105	151159	8	9	72	0.013
	Irr 2	160	---	---	do.	3010793	0.060	151613	9	9	72	0.016
Marino Bros	Irr1	350	330	350	GL0214	3012585	0.164	151558	8	22	67	0.047
Maugeri, Sal	Irr S1	152	128	148	GL0107	3000431	0.033	150337	8	12	66	0.021
Monsanto Chem	Bridgeport E1	81	56	81	2099P	3000872	0.310	150159	9	3	68	0.139
	Bridgeport W2	82	57	82	do.	3000873	0.322	150158	9	2	68	0.507
	Ind 1	96	64	94	do.	3001170	0.179	150167	9	3	68	0.133
Muscumeci, Frank	2-Dom	155	125	155	GL0097	3001078	0.220	150524	8	12	73	0.000
Musumeci, Anthony	Irr	130	115	130	SA0011	3014087	0.088	331010	9	9	63	---
Nicolosi Brothers Farm	Irr 1	170	130	170	GL0021	3012217	0.110	151462	8	12	66	0.014
NJ/American WC	Lwwc Birch Ck Rd 4	96	56	91	5003	3009444	0.481	151362	9	6	68	0.008
	PW 3	201	161	201	do.	3002405	0.359	150569	9	9	69	0.296
	Pure 2(3-1973)	208	158	208	do.	3001371	0.191	150137	9	9	69	0.039
	Lwwc Pureland Wtp 1A	156	121	155	do.	3005212	0.043	151363	9	8	69	0.000
Nolte, Carl	Irr	180	60	180	CU199R	3001042	0.049	150421	8	13	82	0.000
Noveon Inc	Iw	201	161	198	11036W	3012821	0.102	330984	10	4	64	0.000

Table 2. Withdrawals from and model locations of production wells outside the depleted zone of Critical Area 2 in Salem and Gloucester Counties, New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; USGS, U.S. Geological Survey; BWA, Bureau of Water Allocation; ft, foot; Mgal/d, million gallons per day; WD, Water Department; WC, Water Company; WSC, Water Supply Company; NJ, New Jersey; Co, Company; Inc, Incorporated; ---, not available]

					NJDEP			USGS				
Well owner	Local well name	Well depth (ft)	Depth to top of open interval[1] (ft)	Depth to bottom of open interval (ft)	BWA permit number	Well permit number	Full allocation[2] (Mgal/d)	Local well number[3]	Model layer[4]	Model row	Model column	2003 withdrawal[5] (Mgal/d)
Paulsboro WD	PW 4	220	192	220	5130	3000069	0.014	150212	9	10	83	0.004
	Paulsboro PW 5	175	135	175	do.	3000602	0.046	150213	9	10	84	0.004
	Replacement 7	272	201	269	do.	3011403	0.925	151199	9	11	83	0.685
Pedricktown Cogeneration Ltd	PW-1	247.5	207	247.5	2421P	3007176	0.202	330901	10	3	63	0.176
	PW-3	205	170	195	do.	3008172	0.239	330899	10	4	63	0.091
	PW-2	245	215	235	do.	3007824	0.025	330900	10	3	63	0.009
Penns Grove WSC	Rf2B	68	50	65	5328	3008511	0.270	330767	8	6	56	0.218
	Layton 11	394	---	---	do.	5000098	0.183	330330	10	8	55	0.223
	PW 4	64	44	54	do.	3001815	0.038	330361	8	8	55	0.000
	Rf 3A	56	36	56	do.	3003535	0.000	330750	8	6	56	0.000
	1A/Rf2A	61	41	61	do.	3003310	0.245	330460	8	6	56	0.204
	PW 1	357	317	357	do.	3000563	0.611	330346	10	6	56	0.433
	Layton 2	76	47	62	do.	3001113	0.378	330697	8	8	55	0.260
	Bridgeport Backup-2	84	69	84	5375	3003332	0.062	150697	9	5	72	0.052
	Bridgeport 2	88	65.4	85.4	do.	3000410	0.081	150166	9	5	72	0.034
Penns Grove-Carneys Point Bd Ed	Irr 2	50	30	50	11018W	3012668	0.051	331007	9	6	56	0.001
	Irr 1	50	30	50	do.	3012665	0.051	331006	9	6	56	0.000
	Irr 1	65	45	65	11019W	3012666	0.015	331012	9	4	56	0.000
	Irr 2	65	45	65	do.	3012667	0.087	331011	9	4	56	0.000
Pennwalt Corp	418	290	237	289	2234P	3001173	0.009	150304	10	11	87	0.001
	417	278	234	276	do.	3001174	0.816	150306	10	11	87	0.809
Polyone Corporation	Ind 9A	134.58	94	134.58	2166P	3010864	0.095	330964	10	3	63	0.024
	Bfg Shallow 10	105	76	102	2166P	3006023	0.271	330784	9	3	63	0.119
Richman Ice Crm	Ind 1A	457	414	457	10673W	3003336	0.051	330459	9	18	58	0.000
	Ind 2	446	---	---	do.	5000104	0.051	330164	9	19	58	0.006
Rollins Environmental Services	35D	76	61	76	2530P	3009785	0.147	151571	9	9	70	---
	15D	85	65	85	do.	3009789	0.147	151568	9	9	70	---
	24D	77	65	77	do.	3009787	0.147	151570	9	9	70	---
	21D	82.4	61.5	81.5	do.	3009788	0.147	151569	9	9	70	---
S & J Leone Farms Inc	Well 1	300	---	---	GL0127	5000101	0.175	151664	9	17	82	0.004
Sakima Country Club	Irr	140	108	138	10687W	3008190	0.102	330983	9	6	54	0.000
Sorbella, Thomas & Frank	Irr1	270	260	270	GL0101	3008495	0.120	151561	8	18	65	0.000
Sorbello, Alfio	Irr	280	270	280	GL0046	3000829	0.049	151460	8	19	72	0.045

Table 2. Withdrawals from and model locations of production wells outside the depleted zone of Critical Area 2 in Salem and Gloucester Counties, New Jersey.—Continued

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South Jersey Water Supply	PW5	253	198	248	5183	3014503	0.039	151529	8	17	74	0.425
	PW 3	265	234	265	do.	3000210	0.224	150130	8	21	76	0.101
	PW 6	353	308	348	do.	3008859	0.073	151109	8	22	76	0.041
State of NJ-Turnpike Auth	Fenwick Srvc Area	388	327	383	5381	3009813	0.001	330845	9	11	58	0.000
	Service 1N-2	330	---	---	do.	3000229	0.087	330070	9	13	59	0.036
Stecher, Emily F	Irr 3	110	90	110	GL0216	3012655	0.013	151603	8	10	68	0.001
Swedesboro WD	PW 2	244	217	240	5105	5000036	0.002	150238	8	14	70	0.005
	PW 4	285	207	280	do.	3008730	0.381	151112	8	14	70	0.219
Tomarchio, Alfred S	Irr	343	267	343	GL0007	3001565	0.049	150346	8	18	72	0.000
Valero Refining Corp-NJ	RW-5A	65	---	---	2204P	3012907	0.363	151541	8	8	84	0.158
	PW-50	152	94	152	2204P	3011162	0.547	151409	9	9	83	0.176
	RW-61/1	23	3	23	do.	3010019	0.078	151414	8	8	86	0.000
	48 Dwta	153	100	153	do.	3005060	0.625	151039	9	9	83	0.281
	RW-22	64	14	59	do.	3011178	0.522	151408	8	9	83	0.211
	RW-6	53.5	13.5	48.5	do.	3001905	0.332	150824	9	8	84	0.177
	RW-19	60.67	15	55.67	do.	3005642	0.686	151374	9	8	83	0.000
	RW-1	23	3	23	do.	3009959	0.139	151415	8	8	86	0.210
Vasalli, Joseph	Irr 1	385	355	385	GL0028	3001258	0.115	150132	8	19	77	0.035
Woodstown Borough	Woodstown PW 5	675	535	670	5167	3013120	0.185	330933	9	23	60	0.215
	PW 2	705	670	705	do.	5000038	0.083	330354	9	22	60	0.018
	PW 3	712	692	712	do.	3001441	0.059	330362	9	22	61	0.015
Woolwich Township	Irr 1	246	226	246	11233W	3013711	0.051	151610	8	13	70	---
	PW	255	240	250	do.	3012350	0.051	151609	8	14	69	---

[1] Model layer is assigned on the basis of aquifer code if open interval is not available.

[2] Annual current (2003) allocation. Prorated on the basis of 1999-2001 reported use; therefore, value is based on multiple years. Full-allocation values were adjusted for some wells because these withdrawals are much greater than reported withdrawals (E.G. Charles, U.S. Geological Survey, written commun., 2007).

[3] More than one well may be associated with one BWA permit.

[4] Certain model cells may contain more than one well. Layer 8 is the Upper Potomac-Raritan-Magothy aquifer, layer 9 is the Middle or undifferentiated Potomac-Raritan-Magothy aquifer, and layer 10 is the Lower Potomac-Raritan-Magothy aquifer (fig. 2).

[5] Not simulated by model if withdrawal data are not available.

For additional information, write to:
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or visit our Web site at:
http://nj.usgs.gov/

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Spitz and dePaul—**Recovery of Ground-Water Levels and Analysis of Withdrawals in Critical Area 2, New Jersey**—Scientific Investigations Report 2008–5142