Prepared in cooperation with the New Jersey Department of Environmental Protection

Simulated Effects of Allocated and Projected 2025 Withdrawals from the Potomac-Raritan-Magothy Aquifer System, Gloucester and Northeastern Salem Counties, New Jersey

Scientific Investigations Report 2011–5033

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per minute (ft/min)	0.3048	meter per minute (m/min)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per square mile [(gal/d)/mi^2]	0.001461	cubic meter per day per square kilometer [(m^3/d)/km^2]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [(Mgal/d)/mi^2]	1,461	cubic meter per day per square kilometer [(m^3/d)/km^2]
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Leakance	
foot per day per foot [(ft/d)/ft]	1	meter per day per meter
inch per year per foot [(in/yr)/ft]	83.33	millimeter per year per meter [(mm/yr)/m]

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.

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

Simulated Effects of Allocated and Projected 2025 Withdrawals from the Potomac-Raritan-Magothy Aquifer System, Gloucester and Northeastern Salem Counties, New Jersey

By Emmanuel G. Charles, John P. Nawyn, Lois M. Voronin, and Alison D. Gordon

Abstract

Withdrawals from the Potomac-Raritan-Magothy aquifer system in New Jersey, which includes the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, are the principal source of groundwater supply in northern Gloucester and northeastern Salem Counties in the New Jersey Coastal Plain. Water levels in these aquifers have declined in response to pumping. With increased population growth and development expected in Gloucester County and parts of Salem County over the next 2 decades (2005–2025), withdrawals from these aquifers also are expected to increase.

A steady-state groundwater-flow model, developed to simulate flow in the Potomac-Raritan-Magothy aquifer system in northern Gloucester and northeastern Salem Counties, was calibrated to withdrawal conditions in 1998, when groundwater withdrawals from the Potomac-Raritan-Magothy aquifer system in the model area were more than 10,100 Mgal/yr (million gallons per year). Withdrawals from water-purveyor wells accounted for about 63 percent of these withdrawals, and withdrawals from industrial self-supply wells accounted for about 32 percent. Withdrawals from agricultural-irrigation, commercial self-supply, and domestic self-supply wells accounted for the remaining 5 percent. Results of the 2000 baseline groundwater-flow simulation, incorporating average annual 1999–2001 groundwater withdrawals, indicate that the average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 31, 27, and 30 feet below the National Geodetic Vertical Datum of 1929 (NGVD 29), respectively, and the lowest simulated water levels are 77, 65, and 59 feet below NGVD 29, respectively.

In the full-allocation scenario, the maximum State-permitted (allocated) groundwater withdrawals totaled 16,567 Mgal/yr, an increase of 72 percent from the 2000 baseline simulation. Results of the full-allocation simulation indicate that the average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 49, 43, and 48 feet below NGVD 29, respectively, which are 18, 16, and 18 feet lower, respectively, than in the 2000 baseline simulation. The lowest simulated water levels are 156, 95, and 69 feet below NGVD 29, respectively, which are 79, 30, and 10 feet lower, respectively, than in the 2000 baseline simulation. Simulated net flow from the Potomac-Raritan-Magothy aquifer system to streams is 8,441 Mgal/yr in the 2000 baseline simulation but is 6,018 Mgal/yr in the full-allocation scenario, a decrease of 29 percent from the 2000 baseline simulation. Simulated net flow in the 2000 baseline simulation is 1,183 Mgal/yr from the aquifer system to the Delaware River but in the full-allocation scenario is 1,816 Mgal/yr from the river to the aquifer system.

Four other simulations were conducted that incorporated full-allocation conditions at water-purveyor wells in Critical Area 2 but increased or decreased withdrawals at selected water-purveyor wells outside Critical Area 2 and agricultural-irrigation and industrial-self-supply wells in the study area. The results of the four simulations also indicate net flow from the Delaware River to the Potomac-Raritan-Magothy aquifer system.

A growth scenario was developed to simulate future withdrawals in 2025 estimated from population projections for municipalities in the Salem-Gloucester study area. Simulated withdrawals for this scenario totaled 10,261 Mgal/yr, an increase of 6 percent from the 2000 baseline simulation. This total includes about 25 Mgal/yr withdrawn from the Englishtown aquifer system for domestic self-supply. This scenario incorporated full-allocation withdrawals at water-purveyor wells in Critical Area 2, and increased withdrawals at some water-purveyor wells outside Critical Area 2. Results of this simulation indicate that the average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 32, 29, and 32 feet below NGVD 29, respectively, which are 1, 2, and 2 feet lower, respectively, than in the 2000 baseline simulation. Simulated net flow from the Potomac-Raritan-Magothy aquifer system to streams in the 2025 scenario is 8,189 Mgal/yr, a decrease of 3 percent from the 2000 baseline simulation. Simulated net flow from the Potomac-Raritan-Magothy aquifer system to the Delaware River in this scenario is 1,010 Mgal/yr, a decrease of 15 percent from the 2000 baseline simulation.

An analysis of the sensitivity of water levels at key boundaries in the study area to withdrawals from a hypothetical well was completed for the Upper and Middle Potomac-Raritan-Magothy aquifers. These boundaries include the 250-mg/L (milligrams per liter) isochlor, the western boundary of Critical Area 2, the aquifer outcrop, and the southwestern boundary of the model area. This analysis indicated that water levels are affected less by withdrawals from the northern part of the study area than by withdrawals from the southern part.

Saline water has threatened the potability of groundwater supplies derived from the Potomac-Raritan-Magothy aquifer system in the study area. Four areas in the study area have experienced acute problems with saline water. Example pumped wells were simulated in each of the four areas, particle tracking was used to define groundwater flow paths, and a budget analysis of the withdrawal zones was conducted to assess the movement of saline water and the likelihood of continued saltwater intrusion. Water withdrawn from wells screened in the Upper Potomac-Raritan-Magothy aquifer in the Glassboro Borough area at average rates for 1999 to 2001 of the 2000 baseline simulation or the withdrawal rates of the adjusted full-allocation scenario will likely remain potable with respect to chloride for at least several hundred years. However, chloride concentrations in the wells closest to the 250-mg/L isochlor probably will continue to rise slowly. The elevated chloride concentrations observed in water from wells screened in the Upper Potomac-Raritan-Magothy aquifer in Harrison Township and the Middle Potomac-Raritan-Magothy aquifer in Woodstown Borough likely result from proximity of the wells to the 250-mg/L isochlor in each aquifer, rather than from substantial lateral updip movement of the saline water. The elevated chloride concentrations found in wells screened in the Lower Potomac-Raritan-Magothy aquifer in Oldmans Township are likely to persist because of the proximity of these wells to the 250-mg/L isochlor in this aquifer and the orientation of the contributing flow path that directs recharge water through saline areas.

Introduction

The Potomac-Raritan-Magothy aquifer system in New Jersey, which includes the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, is the principal source of groundwater supply in Salem and Gloucester Counties. With the exception of the Kirkwood-Cohansey aquifer system, the other aquifers within the study area do not yield sufficient quantities of water to provide a substantial supply. The Kirkwood-Cohansey aquifer system is present only in the southern part of the study area and is unconfined.

Large groundwater withdrawals from the Potomac-Raritan-Magothy aquifer system have resulted in regional water-level declines in these aquifers. In 1993, as a result of declining water levels in the Potomac-Raritan-Magothy aquifer system in the Coastal Plain of southern New Jersey, the State of New Jersey designated Water Supply Critical Area 2 (New Jersey Assembly, 1993) (fig. 1). Withdrawals from the Potomac-Raritan-Magothy aquifer system permitted by the New Jersey Department of Environmental Protection (NJDEP) Bureau of Water Allocation (BWA) are restricted within Critical Area 2 in an effort to mitigate the continuing decline in groundwater levels. Most of Gloucester County and a small portion of southeastern Salem County lie within Critical Area 2. Expected population growth over the next 2 decades (2005–2025) in parts of Salem and Gloucester Counties is likely to require increased groundwater withdrawals, which are likely to affect water levels in the study area.

The Potomac-Raritan-Magothy aquifer system in the study area is hydraulically connected to the Delaware River and its tributaries. This connection is more limited in Salem County than in Gloucester County (Navoy and others, 2005). Investigations by Barksdale and others (1958), Greenman and others (1961), Luzier (1980), and Vowinkel and Foster (1981) indicate that flow between the Potomac-Raritan-Magothy aquifer system and the Delaware River is substantial. Because parts of the tributaries and the river in contact with the aquifer system are tidally affected, saltwater may be a source of induced recharge into the aquifer system from pumping near the river. The degree of the hydraulic connection depends on the specific, local stratigraphy. Lewis and others (1991) and Barton and Kozinski (1991) indicate that flow between the Delaware River and the Potomac-Raritan-Magothy aquifer system is probably smaller in Logan Township than in bordering Greenwich Township to the northeast as a result of the presence of lower permeability sediments between the river and the aquifer system and because groundwater withdrawals in Logan Township are smaller.

Most of the updip parts of the Potomac-Raritan-Magothy aquifer system contain freshwater, but saline water (chloride concentration greater than or equal to 250 mg/L) is present in the deeper parts of the aquifer system in Salem and Gloucester Counties. The saline water either remains in the aquifer system from the time of deposition or has reentered the aquifers from the ocean after changes in sea level, or a combination of the two (Barksdale and others, 1958). The saline water may move toward water-purveyor wells in response to declining water levels from increased withdrawals. The induced movement of saline water could threaten the potable groundwater supply in this aquifer system.

Effective management of the water resources of the Potomac-Raritan-Magothy aquifer system in the study area requires quantification of the water-level declines and evaluation of the effects of withdrawals that may lead to vertical and horizontal movement of the deeper saline water. Therefore, the U.S. Geological Survey (USGS), in cooperation with the NJDEP, conducted a study to simulate various withdrawal scenarios and to evaluate the effects of increased withdrawals on water levels and on the movement of groundwater from areas in the Potomac-Raritan-Magothy aquifer system where chloride concentrations exceed 250 mg/L to areas that contain freshwater.

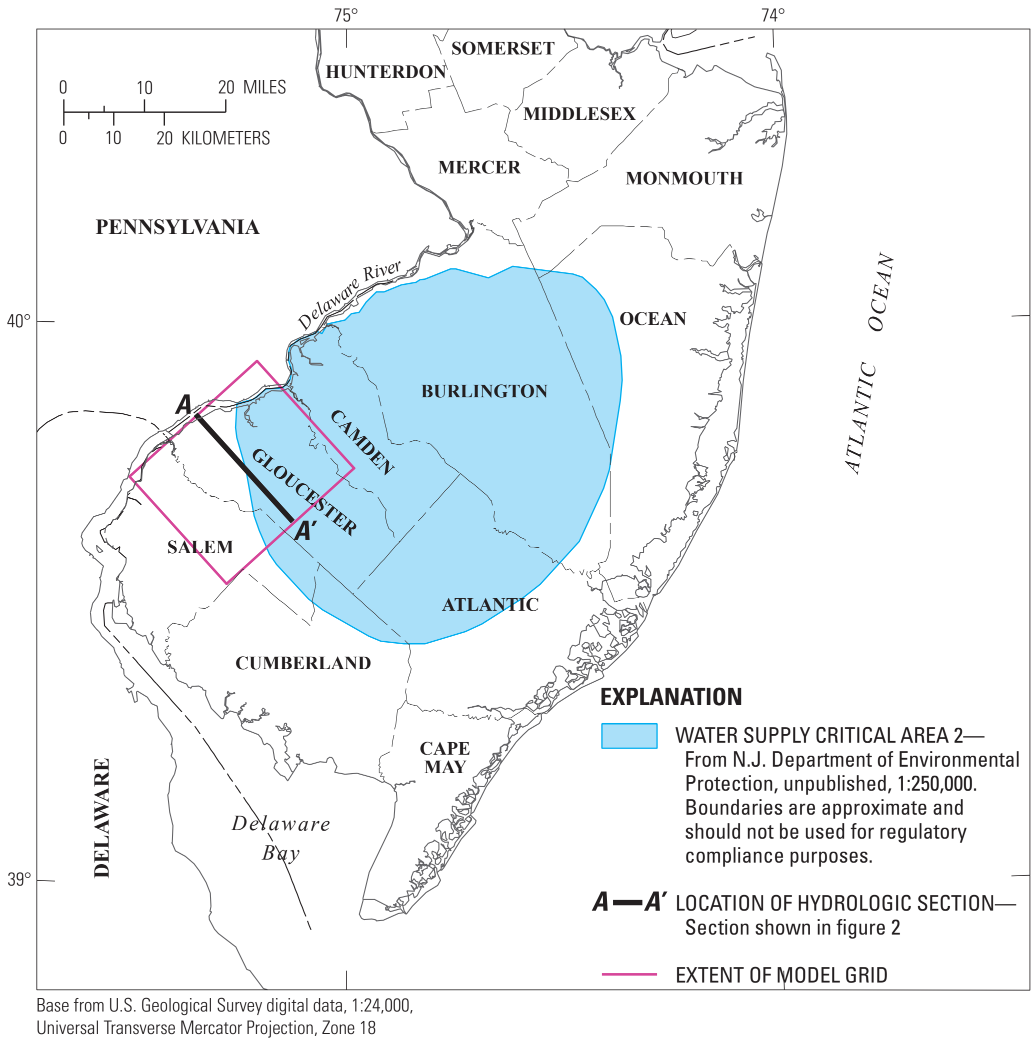


Figure 1. Location of model area and Water Supply Critical Area 2, southern New Jersey.

Purpose and Scope

This report evaluates the effects of groundwater withdrawals from the Potomac-Raritan-Magothy aquifer system in Gloucester and northeastern Salem Counties in New Jersey on groundwater levels, groundwater flow to streams, and movement of saline water in the aquifer system. A groundwater-flow model that includes the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, two intervening confining units, the Merchantville-Woodbury confining unit, and the Englishtown aquifer system was constructed and calibrated to 1998 withdrawal conditions and used to evaluate changes in simulated water levels under various groundwater-withdrawal conditions. A baseline simulation that incorporated average annual 1999–2001 withdrawals was evaluated. Six withdrawal scenarios were simulated: five scenarios involved simulating the maximum withdrawals from the Potomac-Raritan-Magothy aquifer system permitted by the State in 2006 and increasing or decreasing these withdrawals, and one scenario involved simulating withdrawals estimated from population-growth projections for 2025 for the study area. An analysis of the sensitivity of water levels at key boundaries to a hypothetical withdrawal was conducted to provide general guidance about the relative effect of the location of the withdrawal well. Particle-tracking analyses were conducted for the baseline simulation and for one of the groundwater-withdrawal scenarios to determine flow paths of groundwater to or from withdrawal wells located near the estimated locations of the 250-mg/L isochlors in the Potomac-Raritan-Magothy aquifer system in four parts of the study area.

The report discusses the hydrogeologic framework developed for the groundwater-flow model of the Salem-Gloucester study area. The effects of the withdrawals on simulated water levels in Critical Area 2 in each scenario also are evaluated.

Previous Investigations

The groundwater resources of Gloucester and Salem Counties in the lower Delaware River area were investigated by Barksdale and others (1958). The groundwater resources of Gloucester County were investigated by Hardt and Hilton (1969), and the groundwater resources of Salem County were investigated by Rosenau and others (1969). The regional hydrogeologic framework in the study area was described by Zapecza (1989). Lewis and others (1991) and Barton and Kozinski (1991) provide detailed descriptions of the hydrogeologic framework of the Potomac-Raritan-Magothy aquifer system in Logan and Greenwich Townships in Gloucester County, respectively.

Synoptic water-level data and contours in the study area for 1978, 1983, 1988, 1993, and 1998 are provided in Walker (1983), Eckel and Walker (1986), Rosman and others (1995), Lacombe and Rosman (1997), and Lacombe and Rosman (2001), respectively. Chloride concentrations in wells in the Potomac-Raritan-Magothy aquifer system in the New Jersey Coastal Plain are reported in Gill and Farlekas (1976), Schaefer (1983), Cauller and others (1999), and Lacombe and Rosman (2001). Navoy and others (2005) evaluated the vulnerability of withdrawal wells to contamination from induced infiltration of water containing high chloride concentrations from the Delaware River.

Luzier (1980) developed a one-layer groundwater-flow model of the New Jersey Coastal Plain. Martin (1998) developed an 11-layer groundwater-flow model of the New Jersey Coastal Plain, which was updated and rediscretized to a finer grid spacing by Voronin (2004). Table 1 summarizes the groundwater-flow models that include the Salem-Gloucester study area.

Well-Numbering System

The well-numbering system used in this report is based on the system used by the USGS, New Jersey Water Science Center, since 1978. It consists of a county-code prefix and the sequence number of the well. County codes used in this report are Camden (07), Gloucester (15), and Salem (33) in New Jersey and Philadelphia County in Pennsylvania (P). For example, well number 15-620 represents the 620th well inventoried in Gloucester County. Well-construction information is stored in the USGS Groundwater Site Inventory (GWSI) database.

Description of Study Area

The Salem-Gloucester study area consists of approximately 484 mi^2 and includes the northeastern part of Salem County, the northern part of Gloucester County, and a small area of Camden County on the northeastern border (fig. 1). The study area is characterized by industrial and high-density residential development along the Delaware River, suburban development in the northeastern area, and agricultural development in the southwestern area.

The study area is a region of low topography characterized by highly dissected sediments. The land surface slopes gently to the northwest throughout most of the study area, but a small part of the eastern corner of the study area slopes to the southeast. The Delaware River marks the northwestern boundary of the study area. Tidal marshes characterize the area within 1 to 5 mi of the Delaware River.

Hydrogeologic Framework

The Salem-Gloucester study area is entirely within the Coastal Plain Physiographic Province of New Jersey. The New Jersey Coastal Plain is a seaward-dipping wedge of unconsolidated sediments that range in age from Cretaceous to Quaternary (fig. 2). The Fall Line forms a hydrologic boundary on the northwestern side of the study area. The sedimentary wedge forms a complex groundwater system of aquifers composed of sands and gravels and confining units composed of silts and clays. The major aquifer system in the study area, the Cretaceous-age Potomac-Raritan-Magothy aquifer

Table 1. Summary of groundwater models incorporating the Salem-Gloucester study area, southern New Jersey.

[RASA, Regional Aquifer System Analysis]

Model area	Reference	Model calibration year	Minimum cell size (square miles)
New Jersey Coastal Plain (one layer)	Luzier (1980)	1973	0.25
North Atlantic Coastal Plain RASA	Leahy and Martin (1993)	1980	49.0
New Jersey Coastal Plain RASA	Martin (1998)	1978	6.25
New Jersey Coastal Plain SHARP[1] saltwater interface	Pope and Gordon (1999)	1988	6.25
Revised New Jersey Coastal Plain RASA	Voronin (2004)	1998	0.25
Salem-Gloucester study area	This report	1998	0.0087

[1]Essaid (1990)

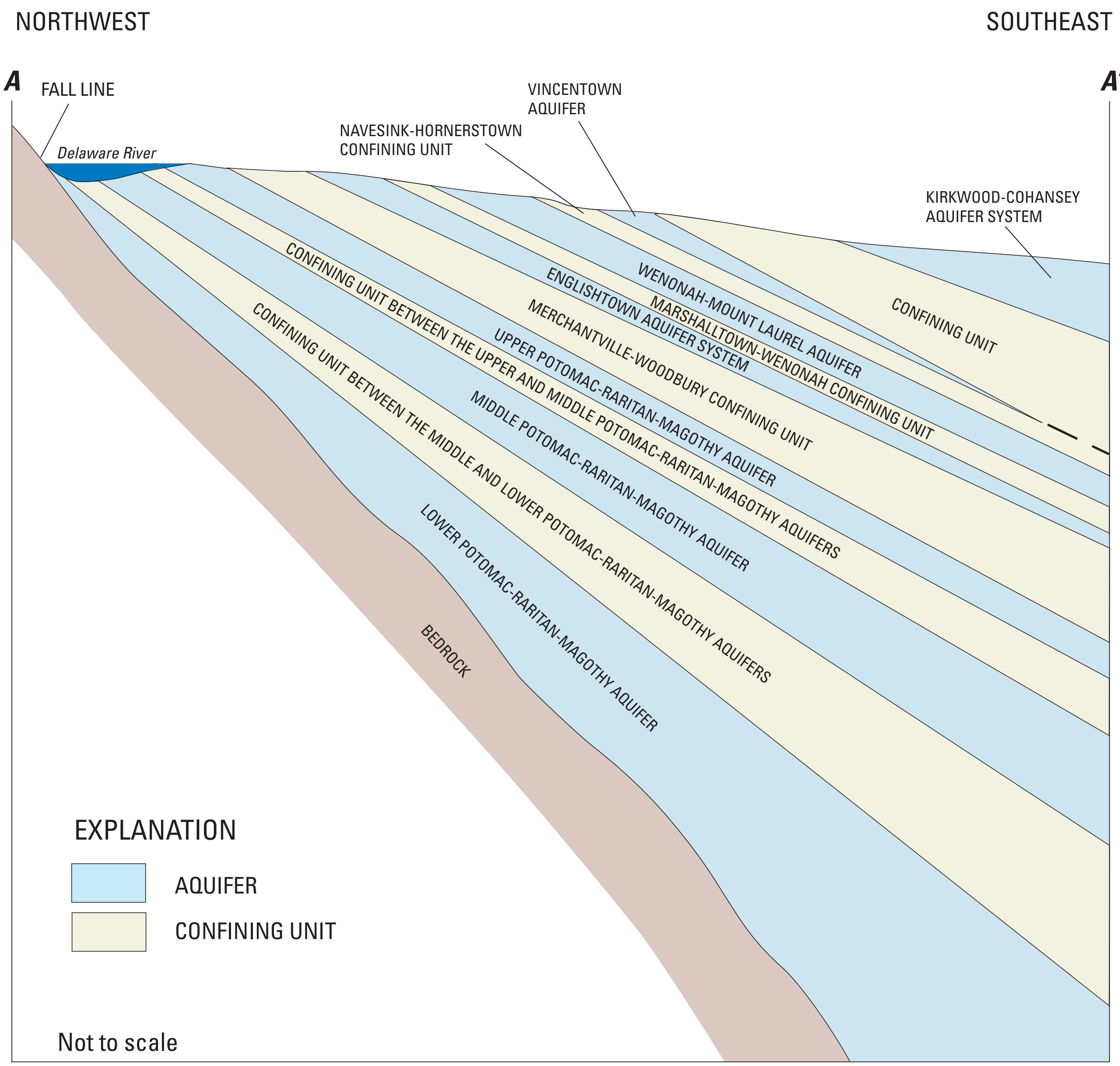


Figure 2. Generalized hydrogeologic section through New Jersey Coastal Plain aquifers and confining units in the Salem-Gloucester study area, southern New Jersey.

system, includes the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers. These aquifers are separated by two intervening confining units. The Englishtown aquifer system, a minor aquifer in the study area, is separated from the underlying Upper Potomac-Raritan-Magothy aquifer by the Merchantville-Woodbury confining unit. The Potomac-Raritan-Magothy aquifer system is underlain by relatively impermeable pre-Cretaceous bedrock.

The hydrogeologic and geologic units of the New Jersey Coastal Plain are described in Zapecza (1989). The hydrogeologic and geologic units that are the focus of the Salem-Gloucester study are listed in table 2. The hydrogeologic units overlying the Potomac-Raritan-Magothy aquifer system and the Englishtown aquifer system in the study area range from predominantly marine Upper Cretaceous to Miocene sediments, and mostly thin, relatively flat-lying fluvial Miocene to Holocene sediments. The thin, flat-lying sediments are not simulated as a separate layer in the groundwater-flow model developed during this study; where present, they are considered to be part of the adjacent model layer.

The depositional environment of the Potomac-Raritan-Magothy aquifer system is fluvial-deltaic-marginal marine (Farlekas and others, 1976) with a complex history of deposition (filling) and erosion (cutting). The result of this depositional environment is a complex hydrogeologic framework in which sand and clay layers can terminate abruptly, both vertically and horizontally.

To develop the hydrogeologic framework data for this study, 351 published geophysical-log interpretations were compiled from Zapecza (1989), Lewis and others (1991), and Barton and Kozinski (1991). This information was supplemented by 13 new gamma-log interpretations (table 3 and fig. 3), 7 of which were new interpretations of the framework and 6 of which were reinterpretations of existing logs. The 364 geophysical logs were used to define the aquifers and confining units of the hydrogeologic framework (figs. 4–11).

Water-Supply Issues

More than 11,000 Mgal/yr were withdrawn from the Englishtown and Potomac-Raritan-Magothy aquifer systems in the Salem-Gloucester study area in 1998. Areas of substantial groundwater withdrawals are present in the established industrial and residential areas in the corridor along the Delaware River. Since 1980, however, residential development has increased in certain central and southeastern parts of the study area. This growth is likely to cause an increase in demand for groundwater from the Potomac-Raritan-Magothy aquifer system. The increased demand could cause water levels to decline in the Salem-Gloucester study area, and also in Critical Area 2 in the eastern part of the study area.

Lacombe and Rosman (2001) tabulate water-level measurements made in the New Jersey Coastal Plain in 1978,

Table 2. Geologic and hydrogeologic units and model layers in the Salem-Gloucester study area, southern New Jersey.

[Modified from Martin (1998, table 2), Zapecza (1989, table 2), and Seaber (1965, table 3); shaded area indicates layer not modeled]

<table>
<tr><th>System</th><th>Series</th><th>Geologic Unit</th><th colspan="2">Hydrogeologic unit</th><th>Model layer (layer number)</th></tr>
<tr><td rowspan="8">Cretaceous</td><td rowspan="7">Upper Cretaceous</td><td>Englishtown Formation</td><td colspan="2">Englishtown aquifer system</td><td>Englishtown aquifer (1)</td></tr>
<tr><td>Woodbury Clay</td><td colspan="2" rowspan="2">Merchantville-Woodbury confining unit</td><td rowspan="2">Merchantville-Woodbury confining unit (2)</td></tr>
<tr><td>Merchantville Formation</td></tr>
<tr><td>Magothy Formation</td><td rowspan="5">Potomac-Raritan-Magothy aquifer system</td><td>Upper aquifer</td><td>Upper Potomac-Raritan-Magothy aquifer (3)</td></tr>
<tr><td rowspan="2">Raritan Formation</td><td>Confining unit</td><td>Confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers (4)</td></tr>
<tr><td>Middle aquifer</td><td>Middle Potomac-Raritan-Magothy aquifer (5)</td></tr>
<tr><td rowspan="2">Potomac Group</td><td>Confining unit</td><td>Confining unit between the Middle and Lower Potomac-Raritan-Magothy aquifers (6)</td></tr>
<tr><td>Lower Cretaceous</td><td>Lower aquifer</td><td>Lower Potomac-Raritan-Magothy aquifer (7)</td></tr>
<tr><td colspan="2">Pre-Cretaceous</td><td>Bedrock</td><td colspan="2">Bedrock confining unit</td><td></td></tr>
</table>

Table 3. Altitudes of land surface and tops of hydrogeologic units determined from new gamma-log interpretations, Salem-Gloucester study area, southern New Jersey.

[Well locations shown in figure 3. NJDEP, New Jersey Department of Environmental Protection; -, no data]

U.S. Geological Survey well number	Well name	NJDEP permit number	Altitude (in feet above National Geodetic Vertical Datum of 1929)								
						Potomac-Raritan-Magothy aquifer system					
			Land surface	Englishtown aquifer system	Merchantville-Woodbury confining unit	Upper aquifer	Confining unit between the Upper and Middle aquifers	Middle aquifer	Confining unit between the Middle and Lower aquifers	Lower aquifer	Bedrock
15-433	WASHINGTON TWP PW 9	31-17801	135	-	-	-336	-	-	-	-	-
15-1483	WOOLWICH MW-1	30-12606	104	63	41	-66	-125	-155	-239	-367	-522
15-1504	SOUTH JERSEY 3 OBS	30-12671	92	-2	-26	-142	-220	-306	-386	-516	-756
15-1528	PW5/OBS1	30-12878	45	-2	-22	-158	-242	-	-	-	-
15-1529	PW5	30-14503	51	-3	-25	-141	-201	-	-	-	-
15-1530	PW5/OBS3	30-13148	52	-11	-28	-143	-209	-272	-353	-511	-775
15-1531	PW5/OBS2	30-13147	59	-2	-20	-138	-190	-	-	-	-
15-1532	PW 1	30-13286	103	50	26	-66	-122	-	-	-	-
15-1533	PW 2	30-13285	104	46	24	-69	-133	-	-	-	-
15-1534	HS 3	30-15596	70	53	13	-92	-167	-	-	-	-
33-949	MW-20B	30-14800	15	-	-	-	15	-55	-97	-125	-
33-950	EHW-1R OLDMANS	30-09571	6	-	-	-	-4	-30	-40	-94	-
33-956	EFW-01 PENNS NECK	-	17	-	-6	-106	-	-	-	-	-

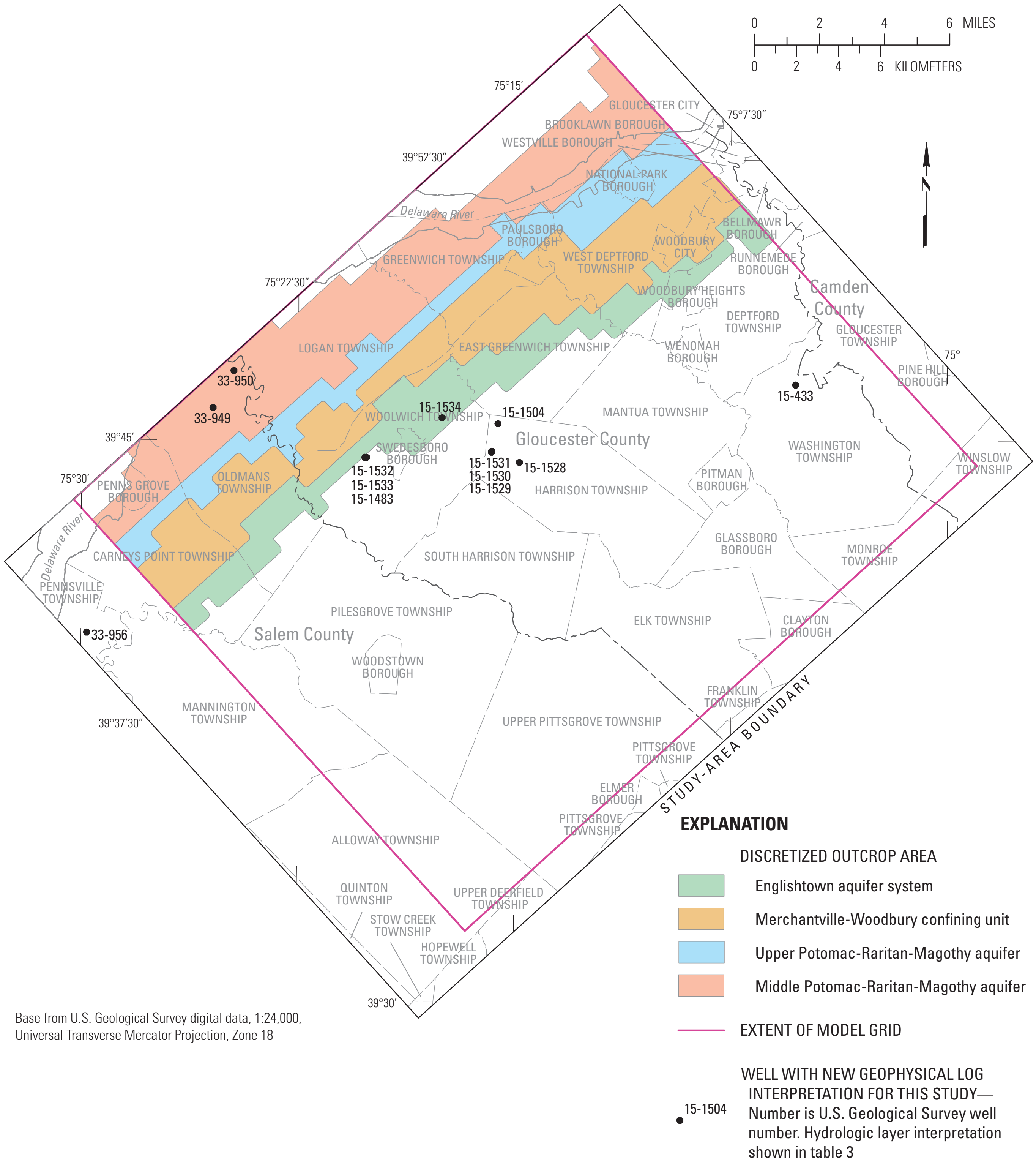


Figure 3. Discretized outcrop areas of hydrogeologic units represented in the model and wells with new geophysical interpretations, Salem-Gloucester study area, southern New Jersey.

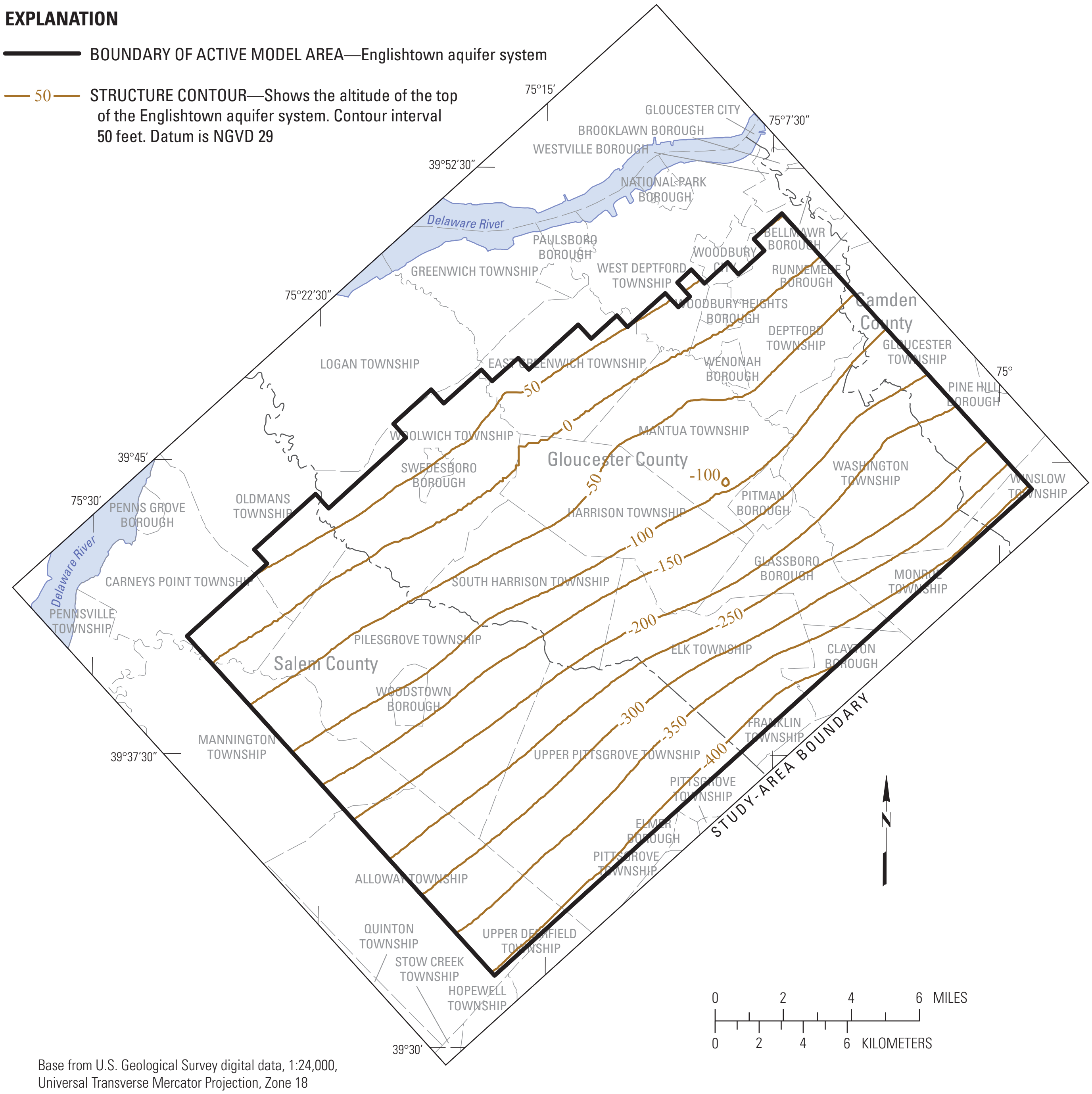


Figure 4. Altitude of the top of the Englishtown aquifer system, Salem-Gloucester study area, southern New Jersey.

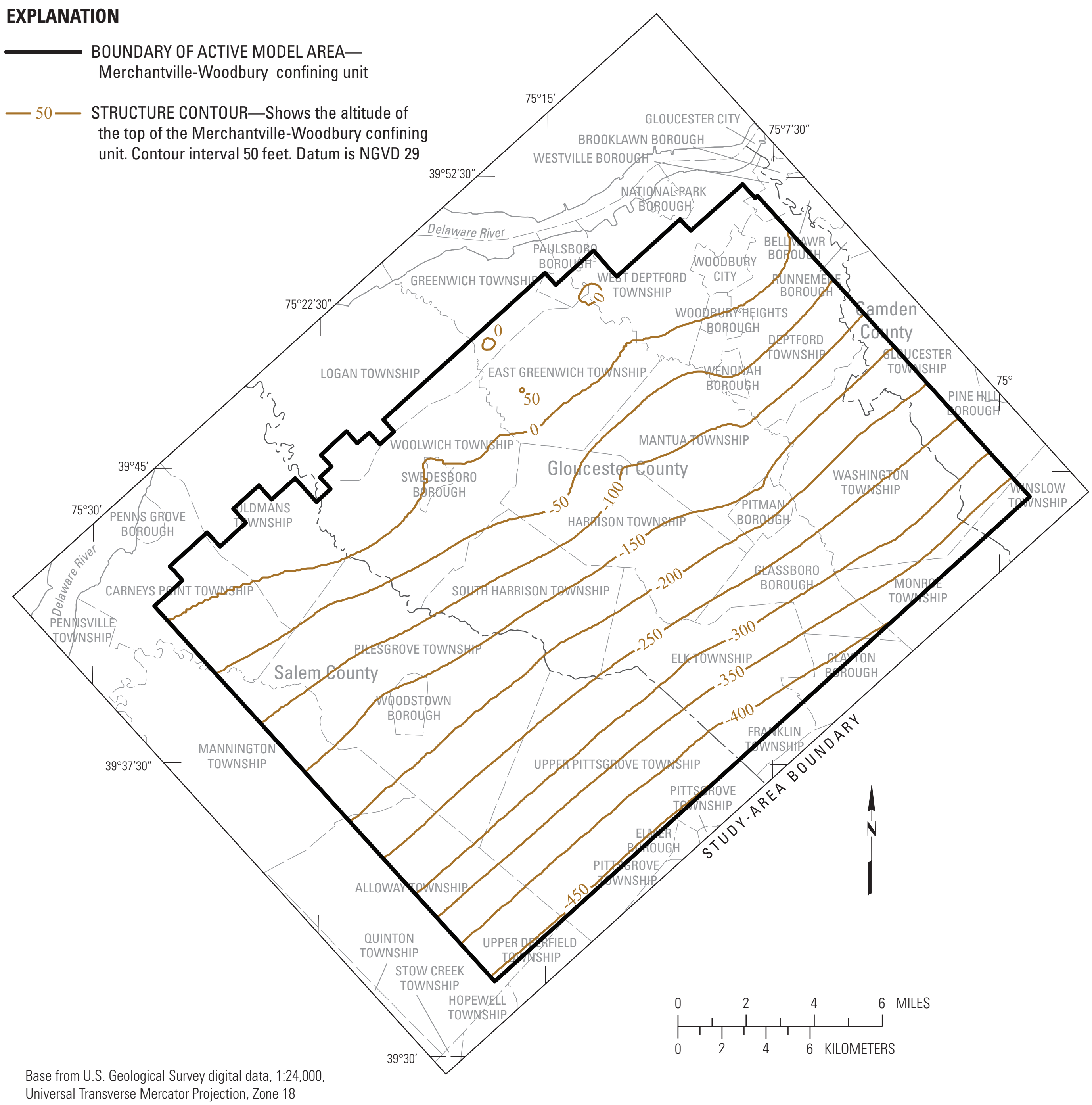


Figure 5. Altitude of the top of the Merchantville-Woodbury confining unit, Salem-Gloucester study area, southern New Jersey.

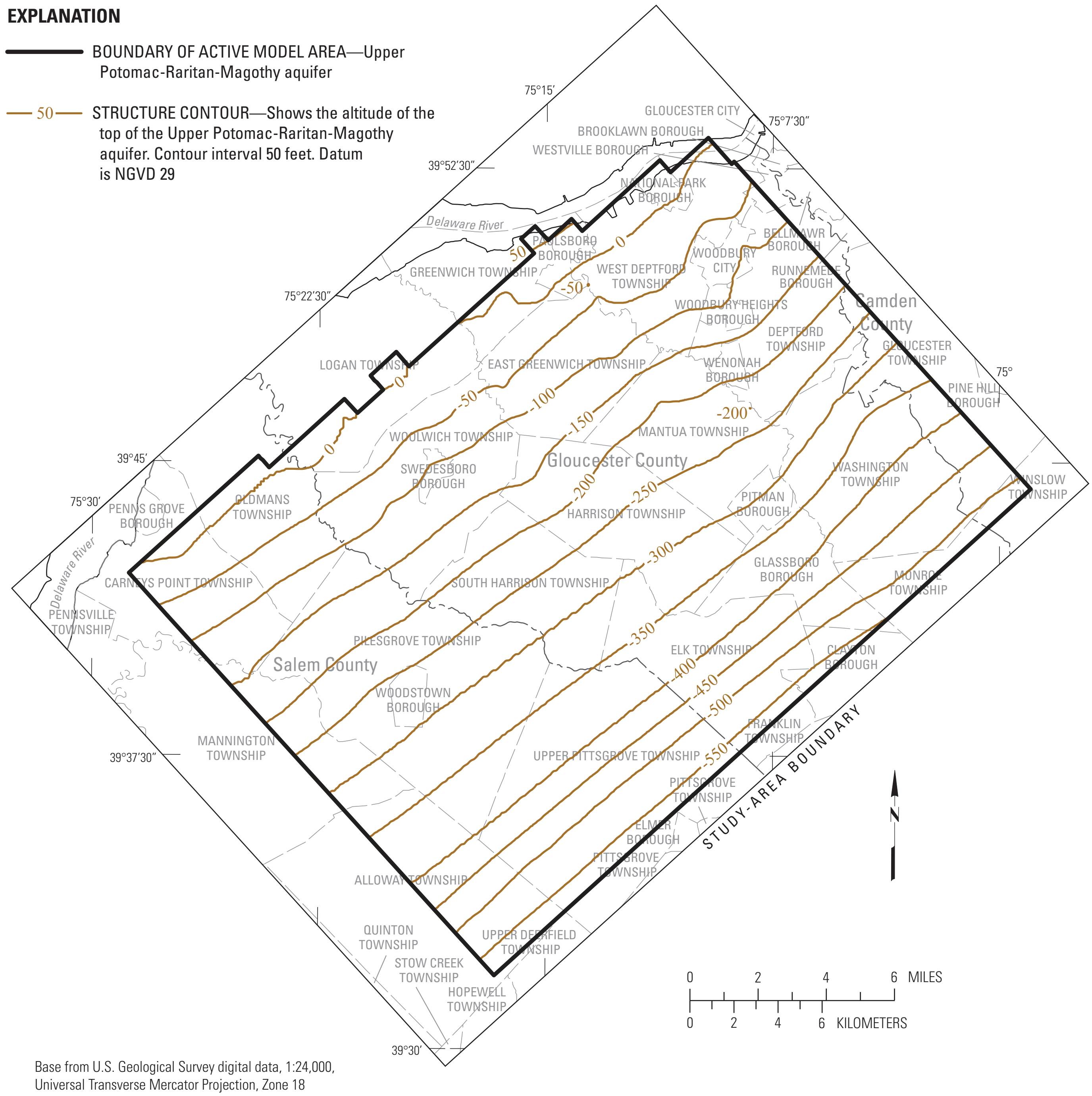


Figure 6. Altitude of the top of the Upper Potomac-Raritan-Magothy aquifer, Salem-Gloucester study area, southern New Jersey.

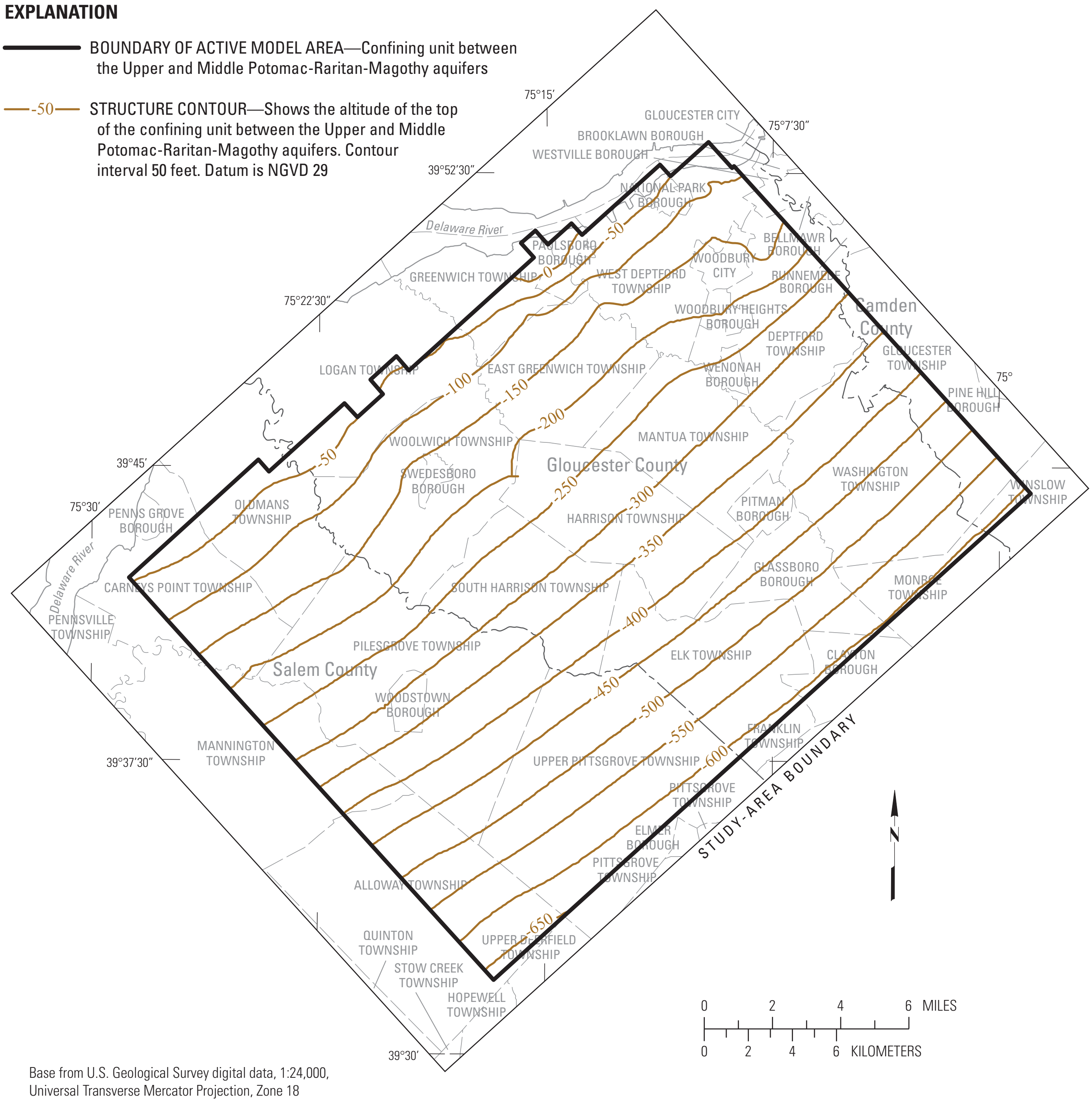
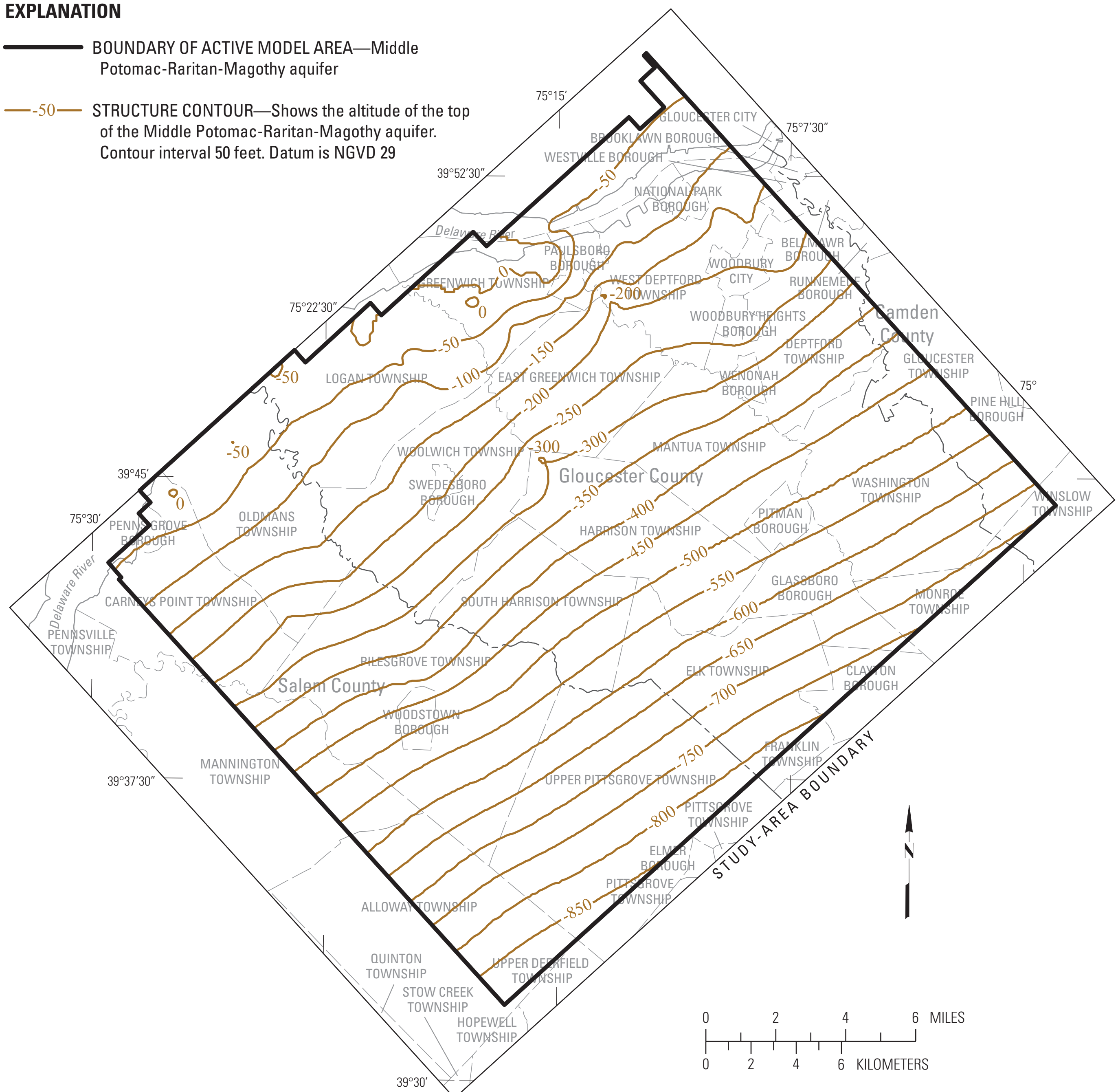


Figure 7. Altitude of the top of the confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

BOUNDARY OF ACTIVE MODEL AREA—Middle Potomac-Raritan-Magothy aquifer

-50 STRUCTURE CONTOUR—Shows the altitude of the top of the Middle Potomac-Raritan-Magothy aquifer. Contour interval 50 feet. Datum is NGVD 29



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 8. Altitude of the top of the Middle Potomac-Raritan-Magothy aquifer, Salem-Gloucester study area, southern New Jersey.

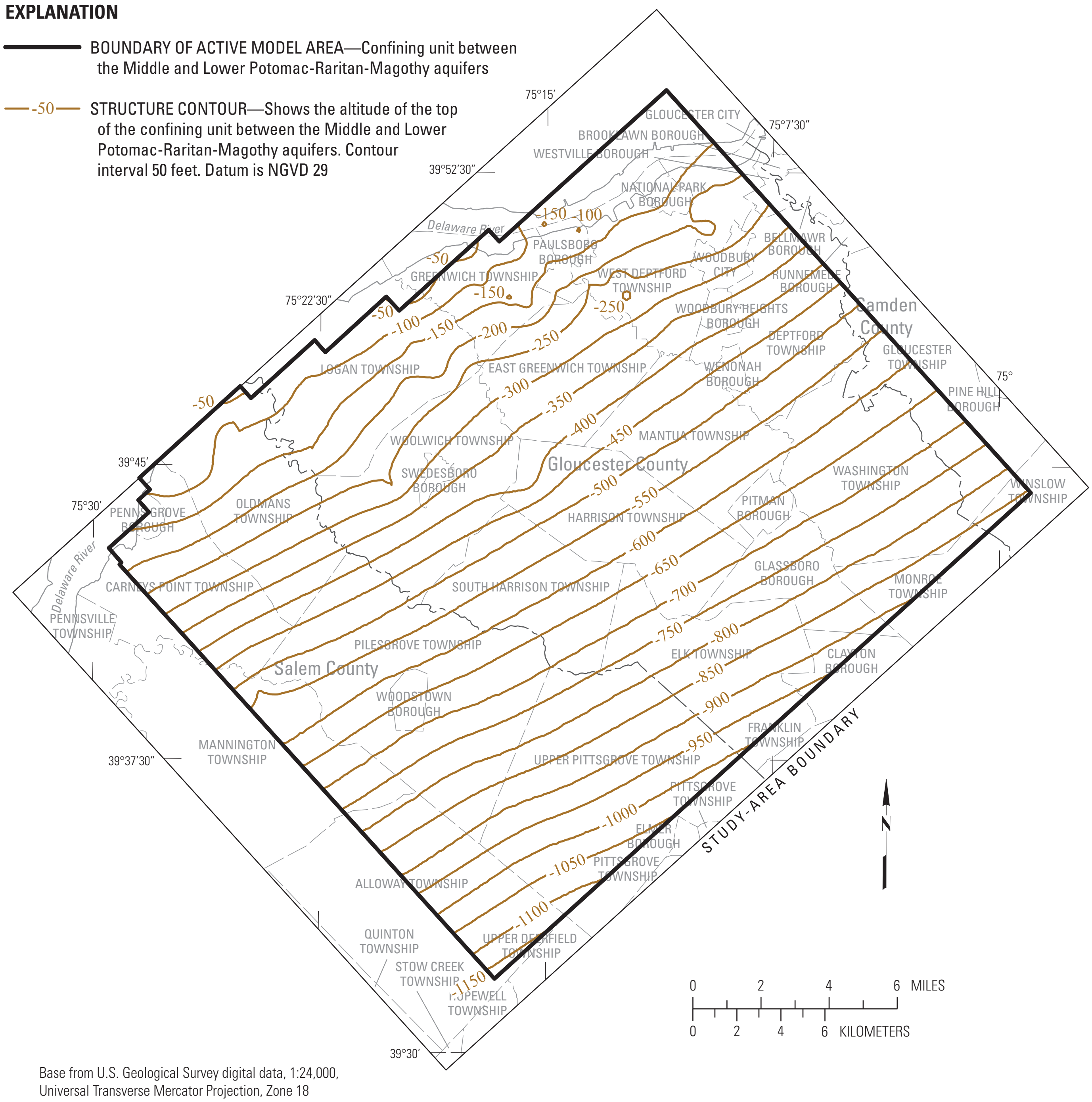


Figure 9. Altitude of the top of the confining unit between the Middle and Lower Potomac-Raritan-Magothy aquifers, Salem-Gloucester study area, southern New Jersey.

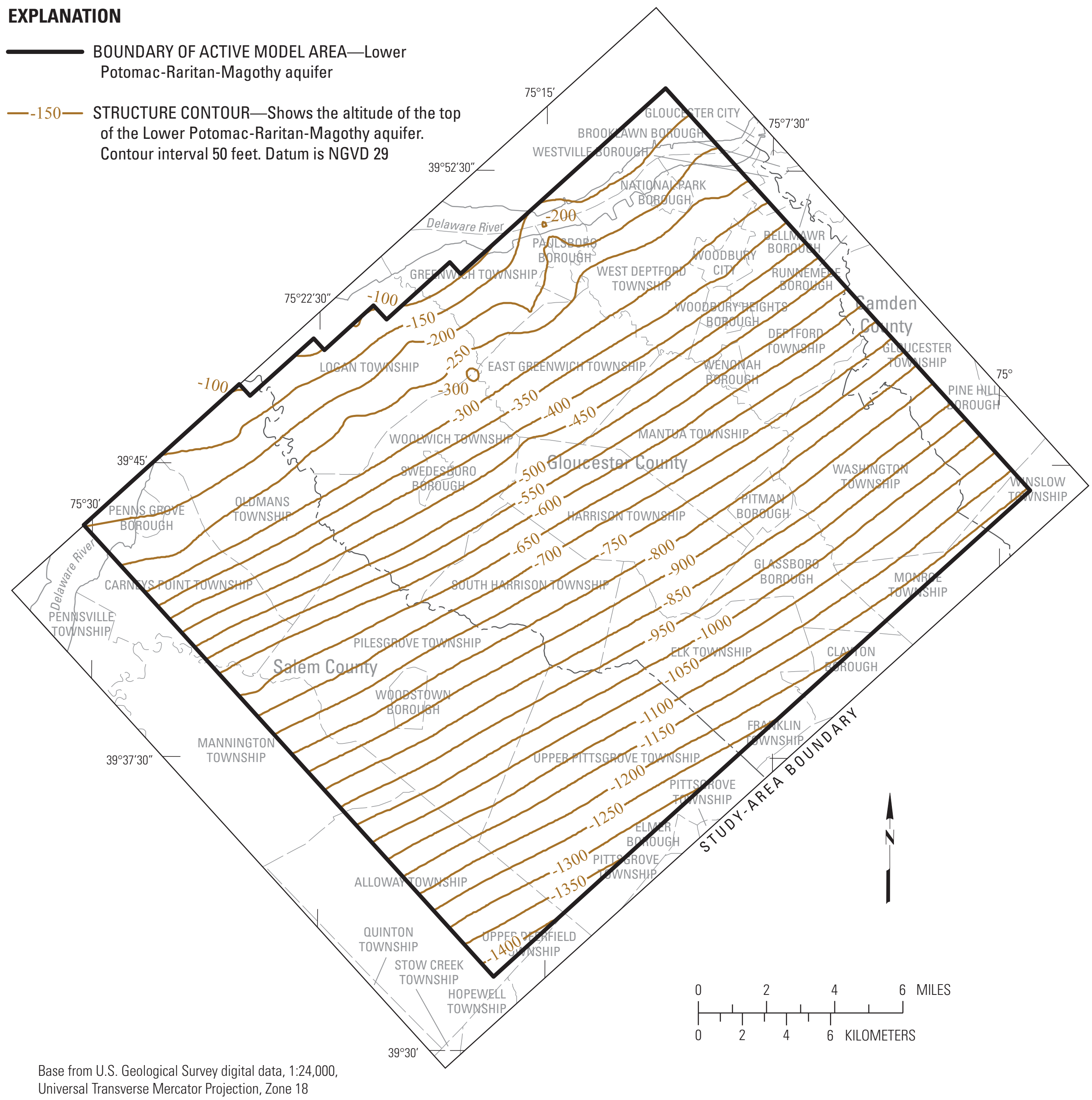


Figure 10. Altitude of the top of the Lower Potomac-Raritan-Magothy aquifer, Salem-Gloucester study area, southern New Jersey.

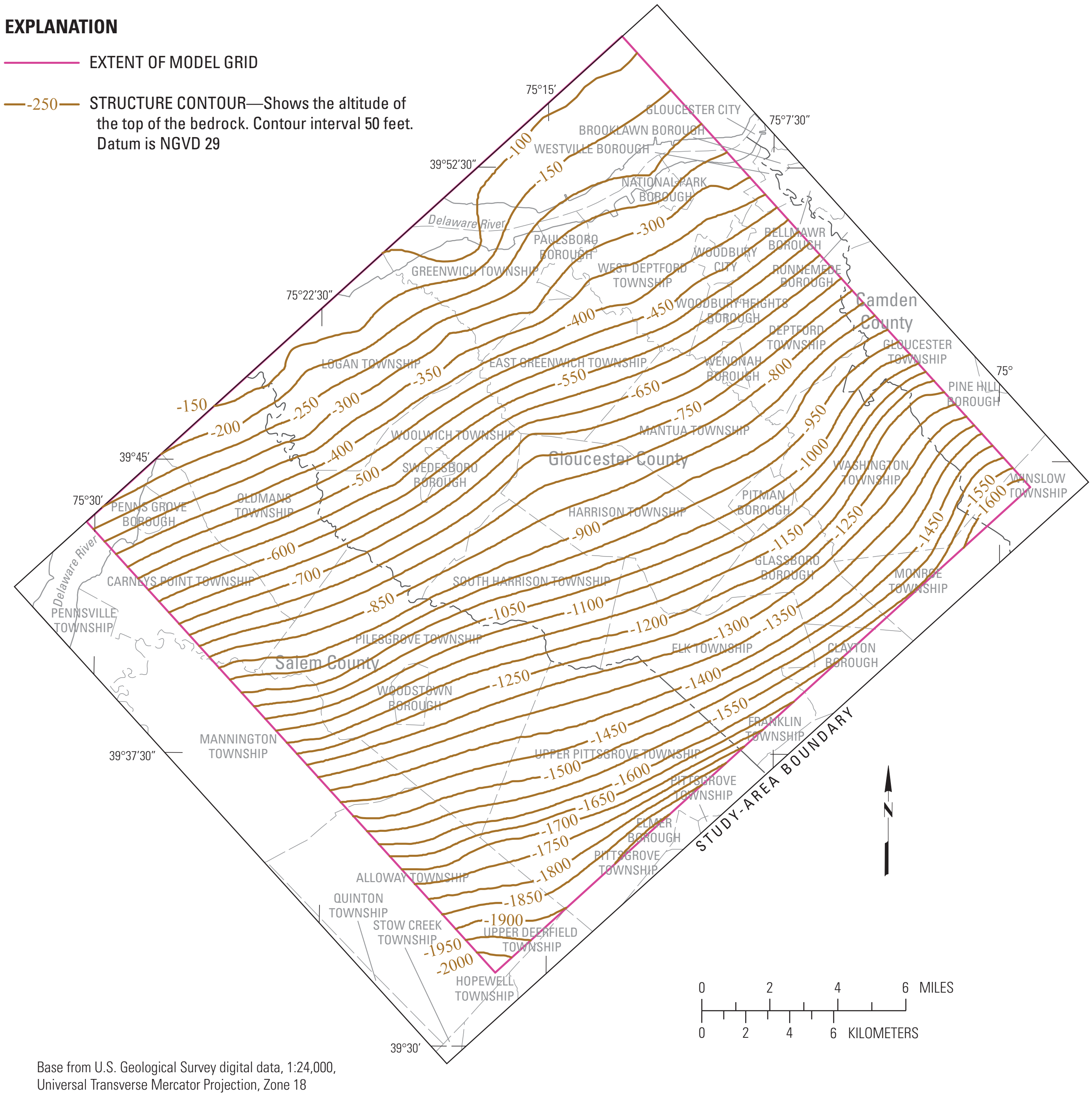


Figure 11. Altitude of the top of the bedrock, Salem-Gloucester study area, southern New Jersey.

1983, 1988, 1993, and 1998 and present water-level contours based on the 1998 water levels. They note that, in general, measured water levels in the Upper and Middle Potomac-Raritan-Magothy aquifers in the study area declined during 1978–93 but were recovering in 1998. The recovery occurred subsequent to the mandated withdrawal restrictions accompanying the designation of Critical Area 2 in 1993 (New Jersey Department of Environmental Protection, 2005). In the Lower Potomac-Raritan-Magothy aquifer, water levels declined during 1983–88, were relatively constant during 1988–93, and were generally recovering in 1998.

Saline water (chloride concentration greater than or equal to 250 mg/L) in the downdip parts of the Potomac-Raritan-Magothy aquifer system in the study area may move toward water-purveyor wells in response to declining water levels from pumping, posing a threat to the potable water supply. In addition to lateral flow, saline water potentially could flow vertically through the confining units between the Middle and Lower Potomac-Raritan-Magothy aquifers and between the Middle and Upper Potomac-Raritan-Magothy aquifers. Water-purveyor wells could also be affected by infiltration of saltwater from the Delaware River induced by pumping near the river. Navoy and Carleton (1995) note that the interface between freshwater and saline water in the Delaware River moves daily in response to tides and seasonally in response to variations in rainfall. The horizontal fluctuation of the interface location along the length of the Delaware River in response to tides is about 6 mi (Navoy and Carleton, 1995).

Cauller and others (1999) summarize trends in chloride concentrations from 1949 to 1996 in 496 wells (4,200 samples) in the Coastal Plain aquifers of Gloucester and Salem Counties. They conclude that chloride concentrations have increased in most of the sampled wells in the Potomac-Raritan-Magothy aquifer system, with typically greater median concentrations in samples from the Lower Potomac-Raritan-Magothy aquifer system.

Model Design

A three-dimensional, finite-difference groundwater-flow model was developed to evaluate the effects of groundwater withdrawals from the Potomac-Raritan-Magothy aquifer system in a 365 mi^2 area, which lies within the Salem-Gloucester study area. This model is referred to as the “local model” in this report. The groundwater flow system was simulated using MODFLOW-2000 (Harbaugh and others, 2000) with MFI2K used as the preprocessor (Harbaugh, 2002). An existing regional groundwater-flow model of the New Jersey Coastal Plain (Voronin, 2004), referred to as the “regional model” in this report, was used in this study solely to provide boundary flows and the initial values of hydraulic properties for the local model. Boundary flows were provided by using the Telescopic Mesh Refinement (MODTMR) package (Leake and Claar, 1999).

The local-model grid consists of 192 rows, 228 columns, and 7 layers (figs. 12 and 13). No model layer is present throughout the full extent of the model grid because of the dip of the hydrogeologic units. The model cell size is a uniform 492 ft on a side throughout the local-model area. The local-model grid is oriented with the regional model. The cell size of the regional model is variable but is 2,640 ft on a side within the study area (Voronin, 2004). The greater resolution of the local model provides a more detailed depiction of water levels and groundwater flow than is possible with the regional model.

Conceptual Model

The local model consists of seven layers, which represent the Englishtown aquifer system; the underlying Merchantville-Woodbury confining unit; and the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, which are separated by two intervening confining units (fig. 13). The hydrogeologic framework used in the local model is similar to that used in the regional groundwater-flow model of the New Jersey Coastal Plain (Voronin, 2004).

In the study area, groundwater generally enters the Potomac-Raritan-Magothy aquifer system in outcrop areas and discharges to streams, the Delaware River, or pumped wells. Recharge is derived primarily from precipitation on the outcrop areas but can be supplemented by infiltration from the Delaware River in areas of large groundwater withdrawals.

The aquifers represented in the local model are simulated as confined layers throughout the model extent. This representation is a simplification in the outcrop areas, which generally are considered to be unconfined areas, where changes in water levels cause changes in saturated thickness and transmissivity. (The saturated thickness and transmissivity of a confined layer do not change with changes in water levels.) In the local model, however, changes in water levels in outcrop areas generally are small compared to the saturated thickness. Also, the outcrop areas within several miles of the Delaware River are locally covered with relatively flat-lying fluvial sediments, which contain low-permeability layers, making such areas semi-confined or confined. In addition, the part of a layer that crops out is small compared to the confined part, and withdrawals are smaller in the outcrop areas than in the confined parts of the aquifers. Therefore, simulating the aquifer layers of the local model as confined is considered a good approximation.

Boundary Conditions

Four types of boundary conditions are used in the local model: (1) recharge in model cells representing outcrop areas of aquifers and one confining unit; (2) specified flow in model cells between the model and bordering hydrogeologic units; (3) no flow between the model and bordering confining units and also at the bottom of the model; and (4) head-dependent

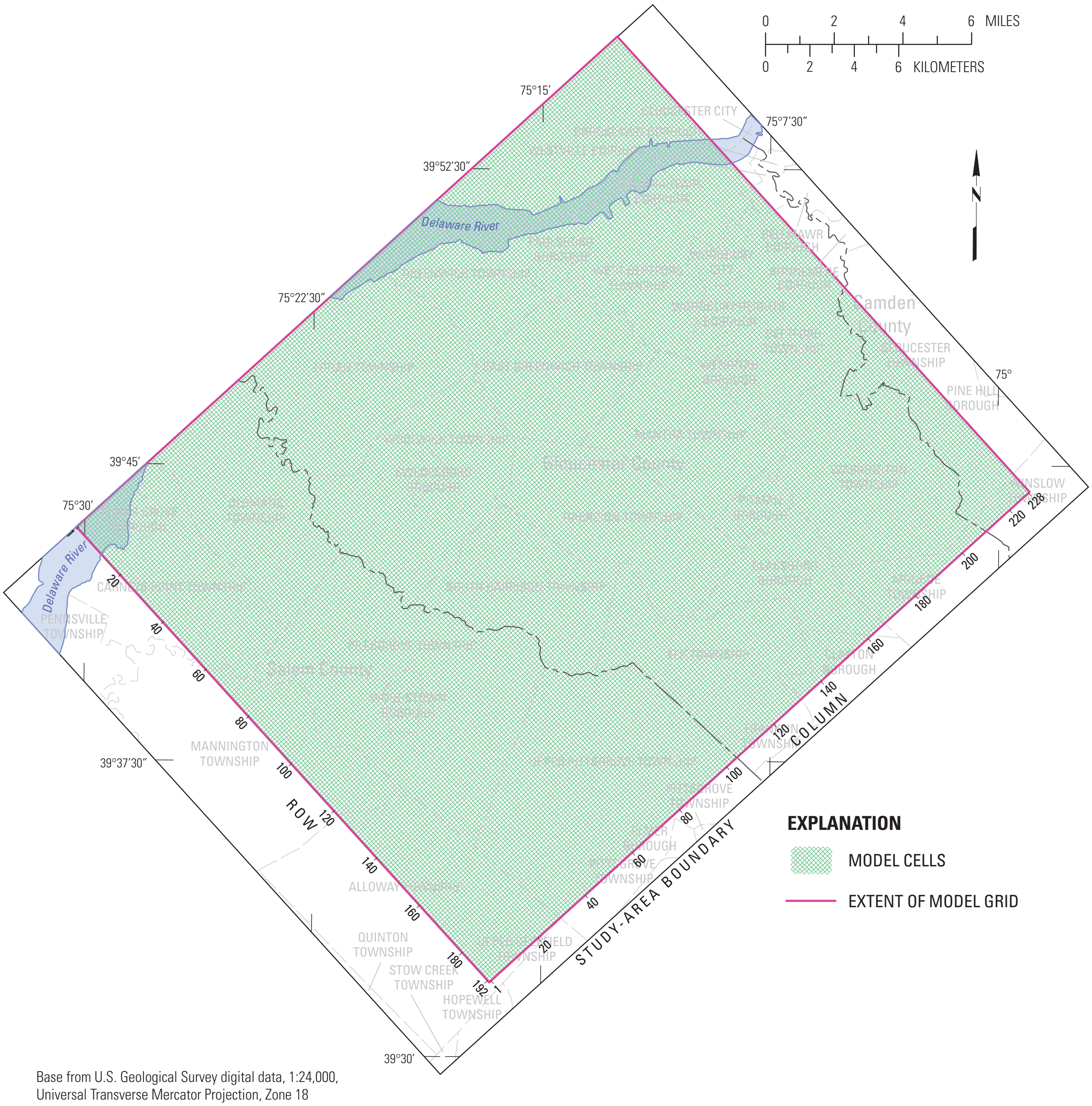


Figure 12. Finite-difference grid for the groundwater-flow model, Salem-Gloucester study area, southern New Jersey.

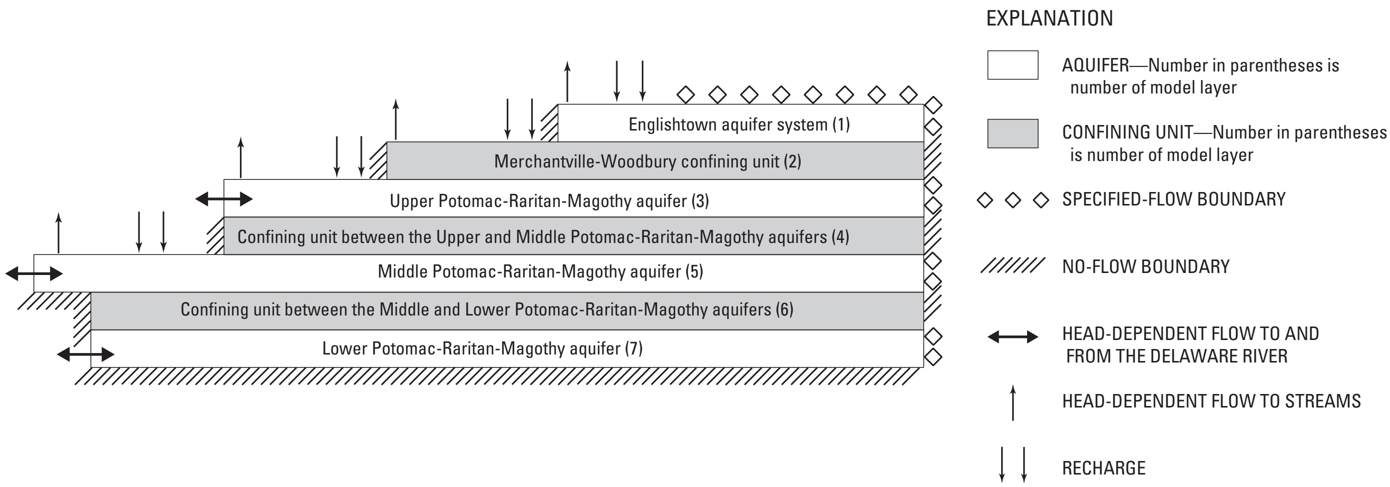


Figure 13. Schematic representation of model layers and boundary conditions used in the groundwater-flow model, Salem-Gloucester study area, southern New Jersey.

flow in model cells representing the Delaware River, streams (in this report, all streams other than the Delaware River), and wetlands. The upper surface of the model incorporates three of the boundary conditions in order to represent the connection with the Delaware River, or streams and wetlands; recharge from precipitation on outcrop areas; and vertical flow to and from the overlying Coastal Plain sediments.

Recharge to Outcrop Areas

The Recharge package of MODFLOW-2000 (Harbaugh and others, 2000) is used to simulate recharge at cells in the topmost layer of the model that represent the outcrop areas of aquifers and a confining unit in the study area. The recharge rate in the model represents long-term precipitation minus long-term evaporation and surface-water runoff. The recharge rates in the local model are the same as those used in the regional model and are uniform across the cells representing outcrop areas in the model. The outcrop areas are present only in the northern and western parts of the study and model areas, and include the outcrop areas of the Englishtown aquifer system, the Merchantville-Woodbury confining unit, and the Upper and Middle Potomac-Raritan-Magothy aquifers (fig. 3). Recharge of 6 in/yr and 15 in/yr is applied to cells representing outcrop areas of the Englishtown aquifer system and the Upper and Middle Potomac-Raritan-Magothy aquifers, respectively. The Lower Potomac-Raritan-Magothy aquifer does not crop out in New Jersey. A small amount of recharge (0.01 in/yr) is applied to the outcrop of the Merchantville-Woodbury confining unit. To be consistent with the regional model, the outcrop areas of the confining units between the Upper and Middle Potomac-Raritan-Magothy aquifers and between the Middle and Lower Potomac-Raritan-Magothy aquifers are not represented in the local model.

Specified Flow

Lateral boundaries that represent the connection between the aquifers in the model and the hydrogeologic units outside the model are modeled as specified-flow boundaries (fig. 13). A specified-flow boundary is also used to represent vertical flow between the confined Englishtown aquifer system and the overlying hydrogeologic units, which are not modeled.

The Telescopic Mesh Refinement (MODTMR) package (Leake and Claar, 1999) was used to calculate the specified flows at lateral boundaries into and out of the four layers in the local model (the Englishtown aquifer system and the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers) that have corresponding layers in the regional model. Evaluation of flows from the regional model at the boundaries of the local model indicates that groundwater flow along the northeastern boundary and southern two-thirds of the southeastern boundary of the local model in all four aquifers is predominantly out of the model area; along the southwestern boundary of the local model, however, groundwater flow is predominantly out of the model area only in the Middle and Lower Potomac-Raritan-Magothy aquifers.

No Flow

The boundary beneath the Lower Potomac-Raritan-Magothy aquifer represents the contact with the underlying impermeable weathered crystalline bedrock and is modeled as a no-flow boundary because flow between the bedrock and the Potomac-Raritan-Magothy aquifer system is assumed to be very small relative to other flows in the model. Boundaries that represent horizontal flow between the confining units in the model and the confining units outside the model are modeled as no-flow boundaries. Boundaries that represent the updip limit of the Englishtown aquifer system and the Merchantville-Woodbury confining unit are also modeled as no-flow boundaries.

Head-Dependent Flow to and from the Delaware River

The River package of MODFLOW-2000 (Harbaugh and others, 2000) is used to simulate the Delaware River. The River package simulates the river as a head-dependent flux boundary at which the direction and quantity of flow either into or out of the aquifer is determined by the difference in simulated water levels between the aquifer and the river. The model cells that represent the Delaware River in the River package of the local model (fig. 14) correspond to similar areas in the River package of the regional model where model cells represent the Delaware River.

Head-Dependent Flow to Streams

The Drain package of MODFLOW-2000 (Harbaugh and others, 2000) was used to simulate flow between the model layers and streams. The Drain package simulates groundwater discharge into a stream (drain) as a proportion of the difference between simulated groundwater levels in the model layer and the altitude of the base of the stream. If the water level in the hydrogeologic unit is below the base of the stream, simulated groundwater discharge to the stream is zero (McDonald and Harbaugh, 1984).

Seven principal streams that flow into the Delaware River—Big Timber Creek, Mantua Creek, Oldmans Creek, Raccoon Creek, Repaupo Creek, Salem River, and Woodbury Creek—and some minor tributaries are simulated in the model (fig. 14). It is assumed that broad areas of wetlands along the Delaware River are connected to streams and function as major areas of groundwater discharge; these areas are represented in the model as streams.

In the model and study areas, the downstream reaches of streams are in the outcrop areas (fig. 14). The cells in the Drain package that represent streams in the local model correspond to similar areas in the regional model. However, streams and wetlands in the outcrop of the Merchantville-Woodbury confining unit are represented differently in the local model than in the regional model because the regional model does not simulate confining units as model layers. Confining units in the regional model are represented by the vertical hydraulic conductivity between aquifer layers; therefore, model cells in the regional model that represent streams in the confining unit are included in the aquifer layer representing the Englishtown aquifer system.

Model Input

Initial input data for the local model were generated from the regional model (Voronin, 2004). The initial values are close approximations to the regional model values and distributions because of the differences in grid size and spacing between the two models. These data were modified as part of the calibration process. The modified data include horizontal and vertical hydraulic conductivity, streambed conductance of the streams, and riverbed conductance of the Delaware River.

The model input data for river stage and altitude of the bottom of the riverbed of the Delaware River were not changed from the regional model. River-stage values range from 0 to 2 ft above NGVD 29, and the altitudes of the bottom of the riverbed range from 3 to 5 ft below NGVD 29. The altitudes of the base of the streams in the local model also were not changed from the regional model and range from 0 to 40 ft above NGVD 29.

Hydraulic Properties of Aquifers, Confining Units, and Streambeds

Initial values of hydraulic properties in the local model were derived from corresponding values in the regional model for the Salem-Gloucester study area. Other values published in Martin (1998) and in Navoy and Carleton (1995) were also tested during the calibration process. The horizontal and vertical hydraulic-conductivity values determined for the seven model layers by model calibration are shown in figures 15–21.

Within each aquifer layer of the local model, zones of different horizontal hydraulic conductivity were delineated. The horizontal hydraulic conductivities for the aquifer layers range from 6 ft/d in a zone in the Englishtown aquifer system to 450 ft/d in a zone in the Middle Potomac-Raritan-Magothy aquifer (figs. 15, 17, 19, and 21). Vertical hydraulic conductivity for each aquifer layer is estimated using the horizontal conductivity value in each zone and a constant value of vertical anisotropy (the ratio of horizontal to vertical hydraulic conductivity) for the entire layer. The vertical anisotropy is 10 in the Upper and Middle Potomac-Raritan-Magothy aquifers and 200 in the Lower Potomac-Raritan-Magothy aquifer.

For the confining-unit layers in the local model, horizontal hydraulic conductivity is a fixed value for the entire layer: 6.0×10^{-3} ft/d for the Merchantville-Woodbury confining unit, 8.0×10^{-1} ft/d for the confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers, and 1.7×10^{-1} ft/d for the confining unit between the Middle and Lower Potomac-Raritan-Magothy aquifers. Within each confining-unit layer, zones of different vertical hydraulic conductivity were delineated (figs. 16, 18 and 20). Vertical hydraulic conductivity values for the confining layers range from 2.7×10^{-6} ft/d in a zone in the Merchantville-Woodbury confining unit to 8.0×10^{-1} ft/d in a zone in the confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers. Vertical anisotropy values for confining units range

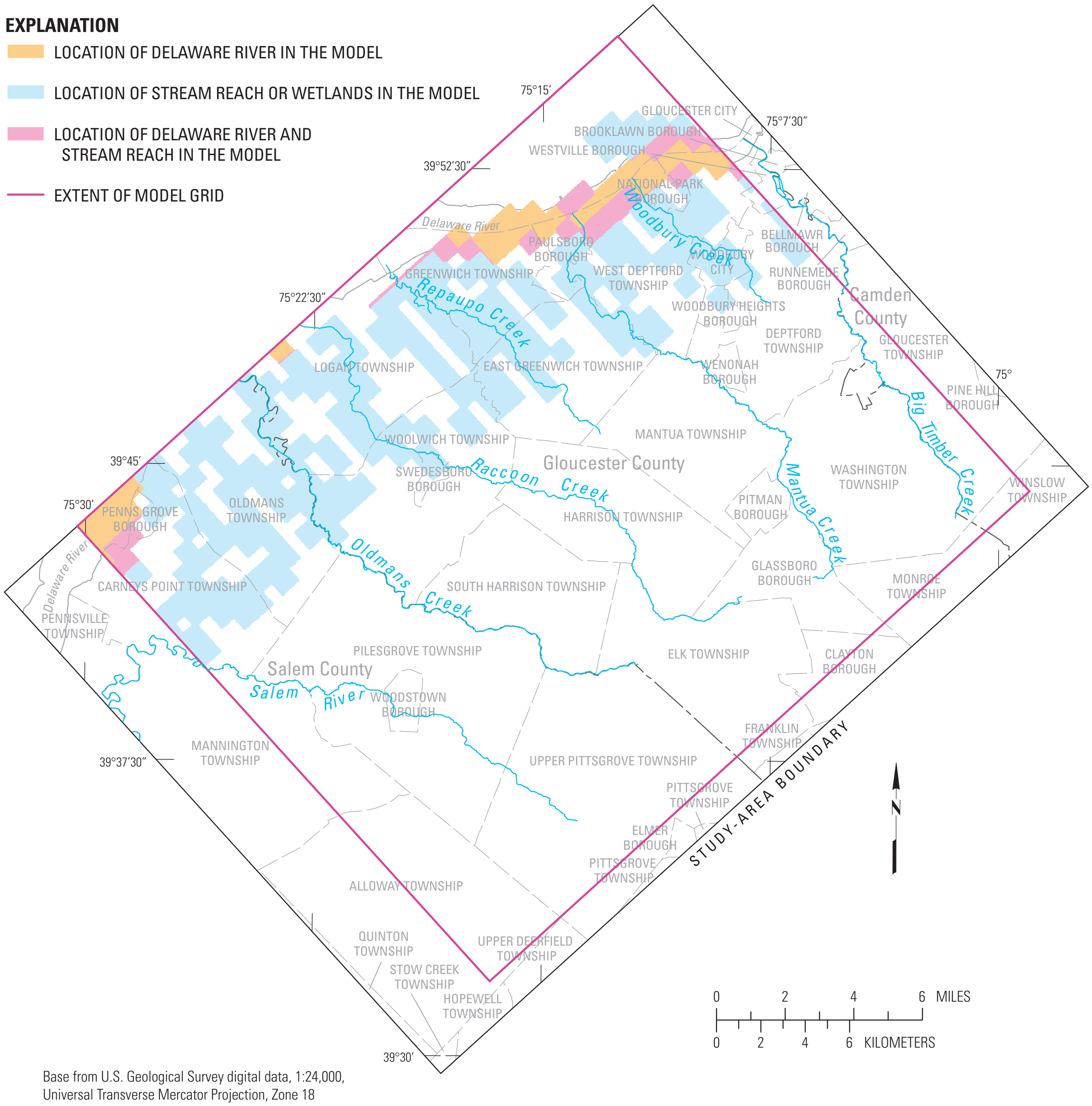


Figure 14. Model cells that represent stream reaches and wetlands in the outcrop areas and the Delaware River, Salem-Gloucester study area, southern New Jersey.

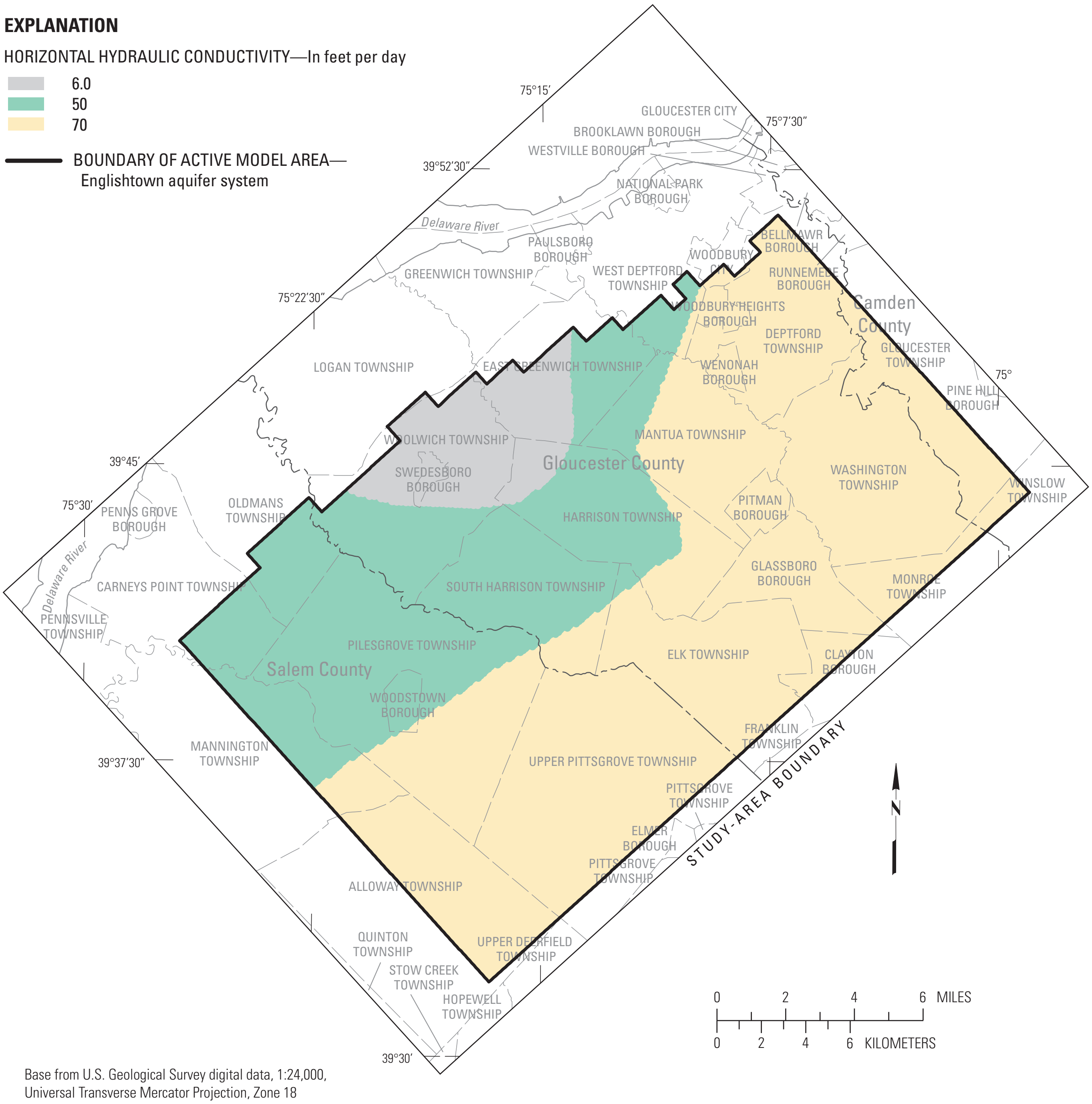


Figure 15. Horizontal hydraulic conductivity used in the model, Englishtown aquifer system, Salem-Gloucester study area, southern New Jersey.

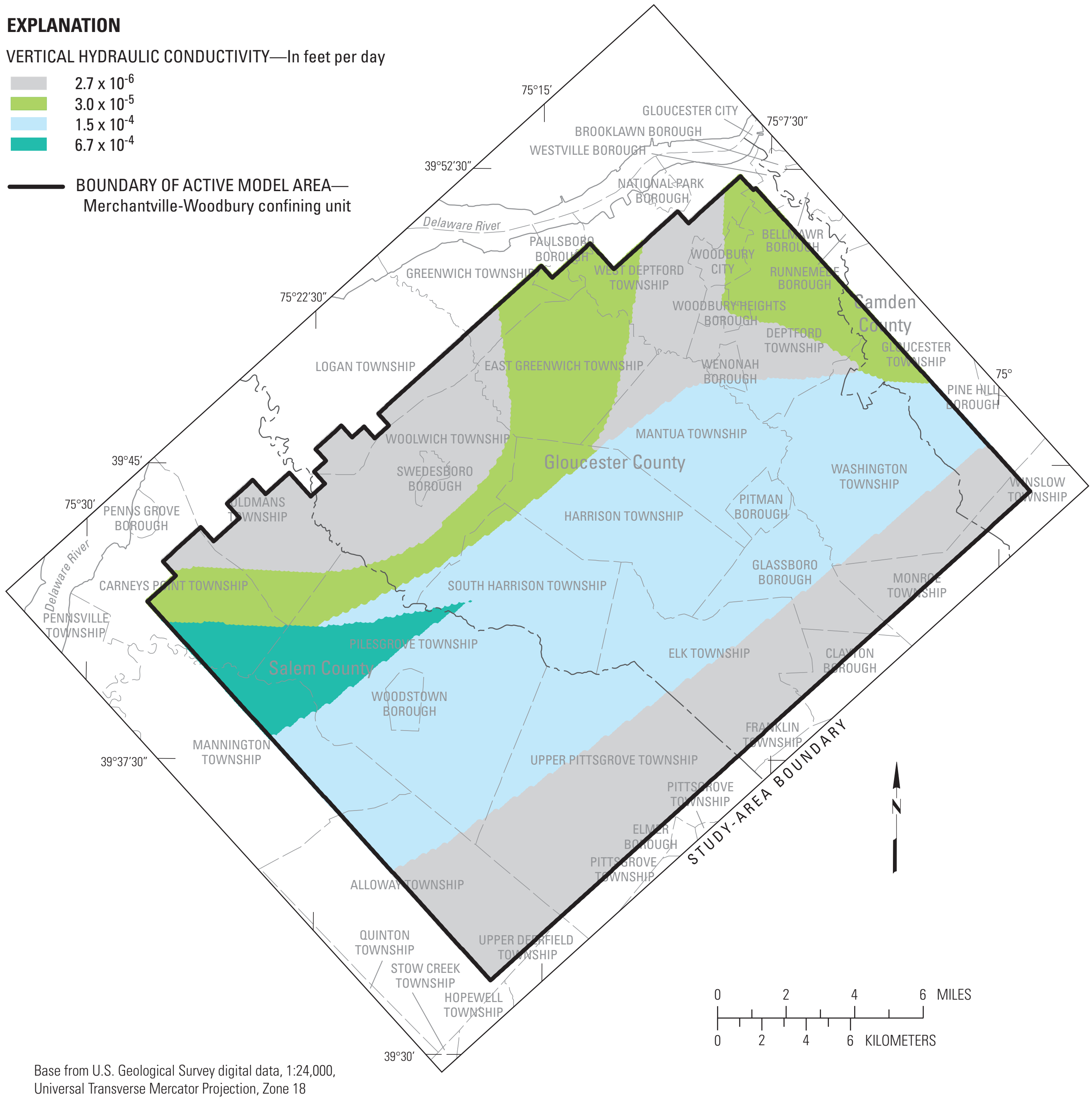


Figure 16. Vertical hydraulic conductivity used in the model, Merchantville-Woodbury confining unit, Salem-Gloucester study area, southern New Jersey.

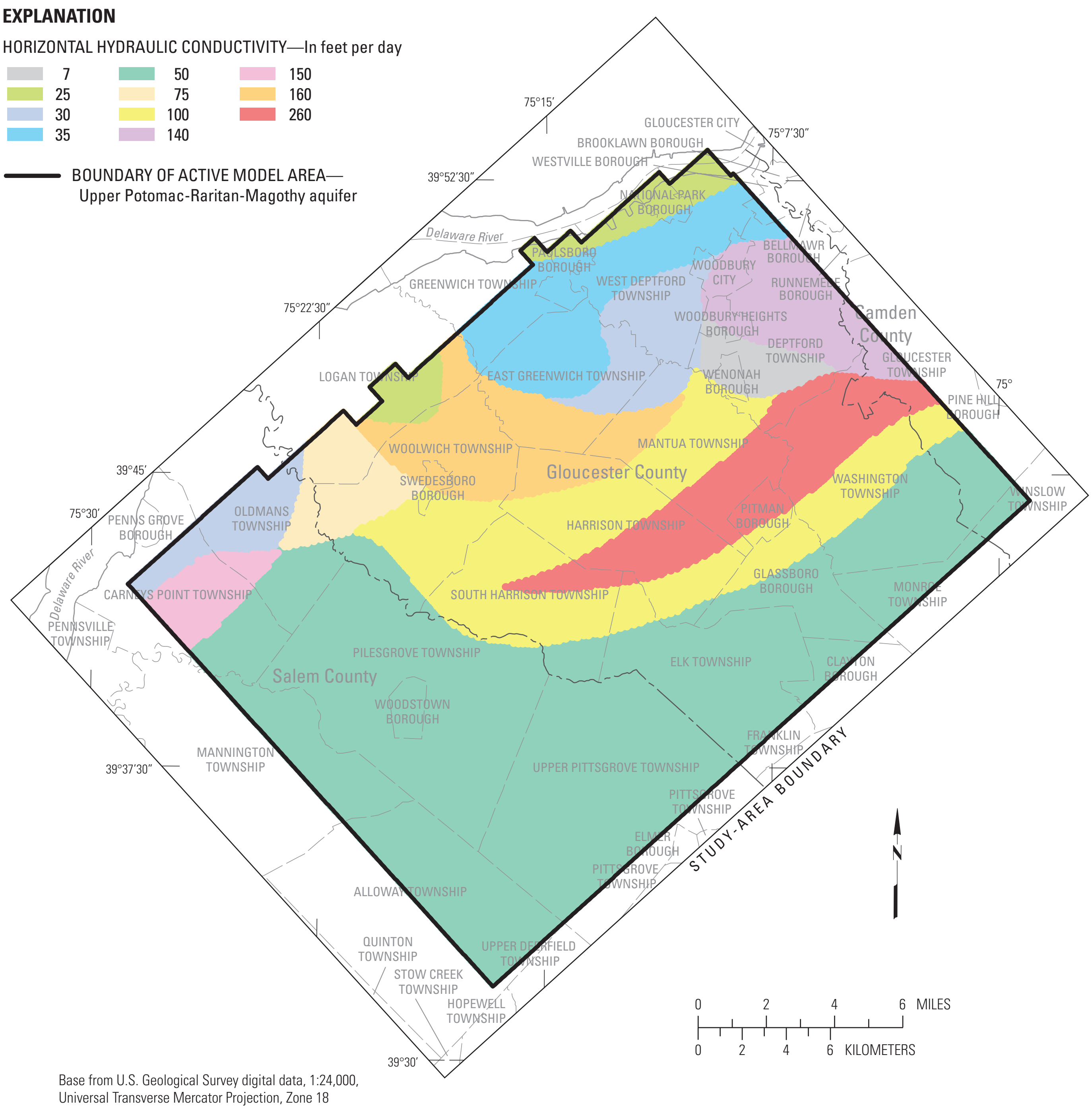


Figure 17. Horizontal hydraulic conductivity used in the model, Upper Potomac-Raritan-Magothy aquifer, Salem-Gloucester study area, southern New Jersey.

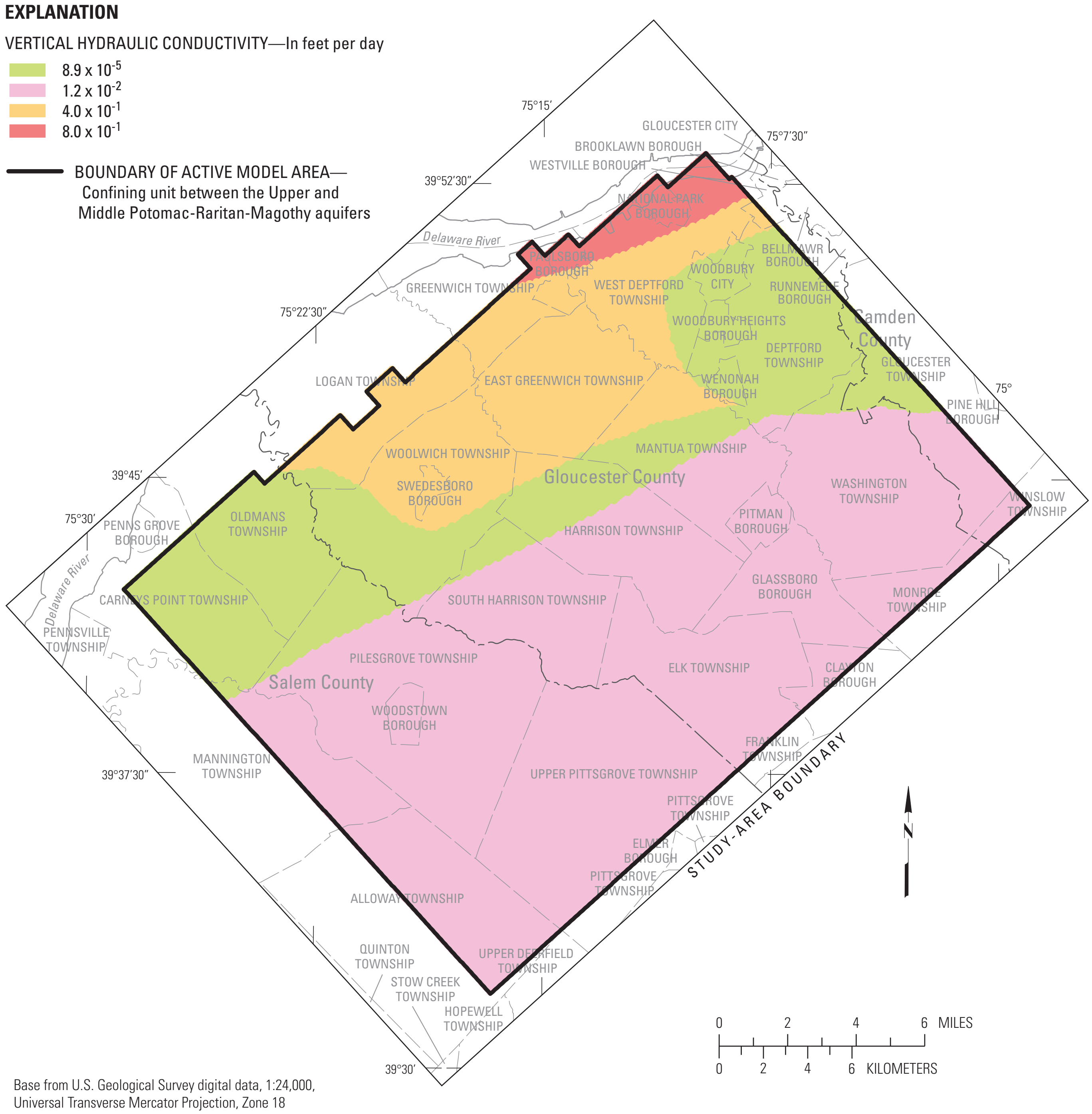


Figure 18. Vertical hydraulic conductivity used in the model, confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers, Salem-Gloucester study area, southern New Jersey.

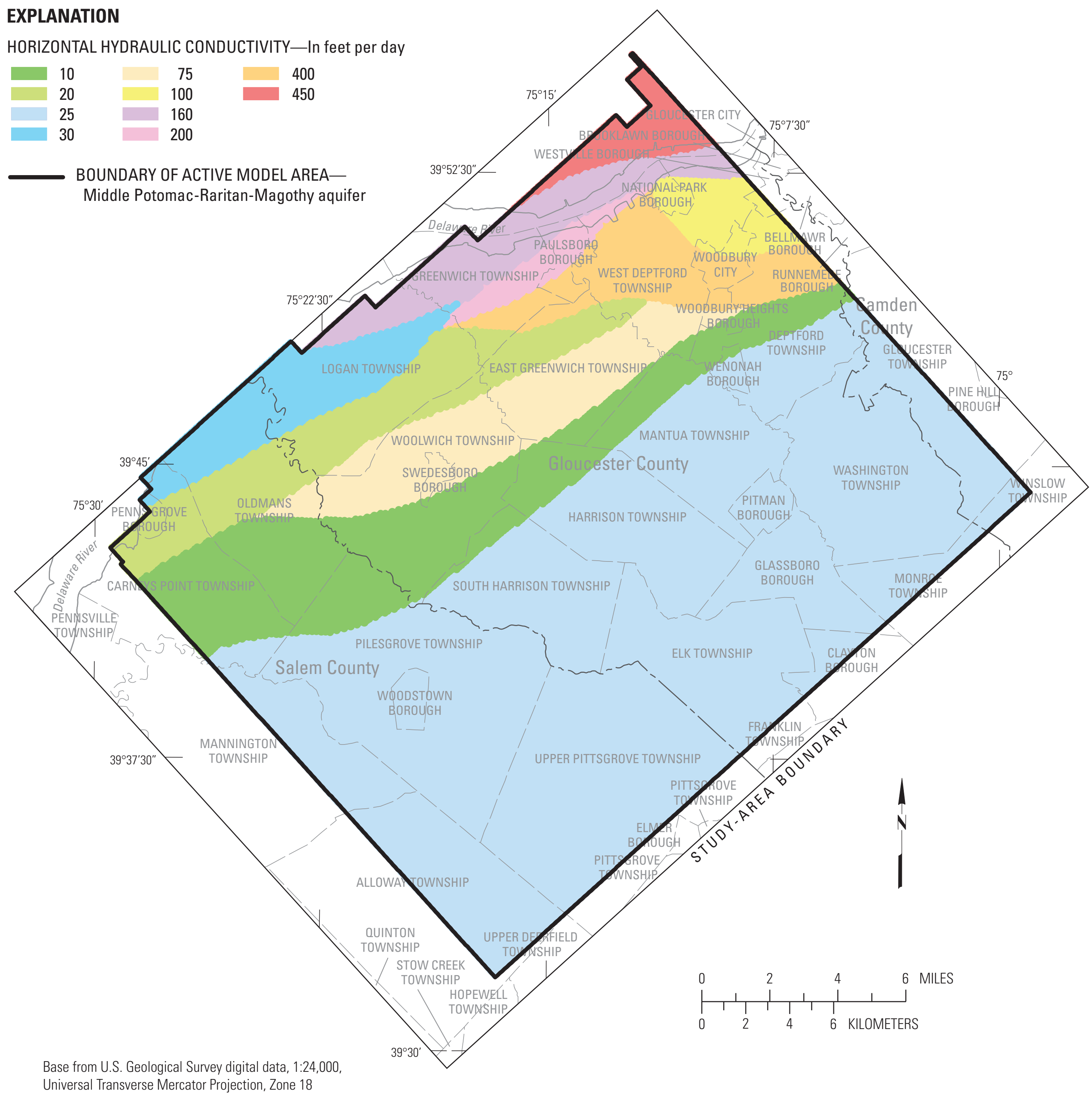


Figure 19. Horizontal hydraulic conductivity used in the model, Middle Potomac-Raritan-Magothy aquifer, Salem-Gloucester study area, southern New Jersey.

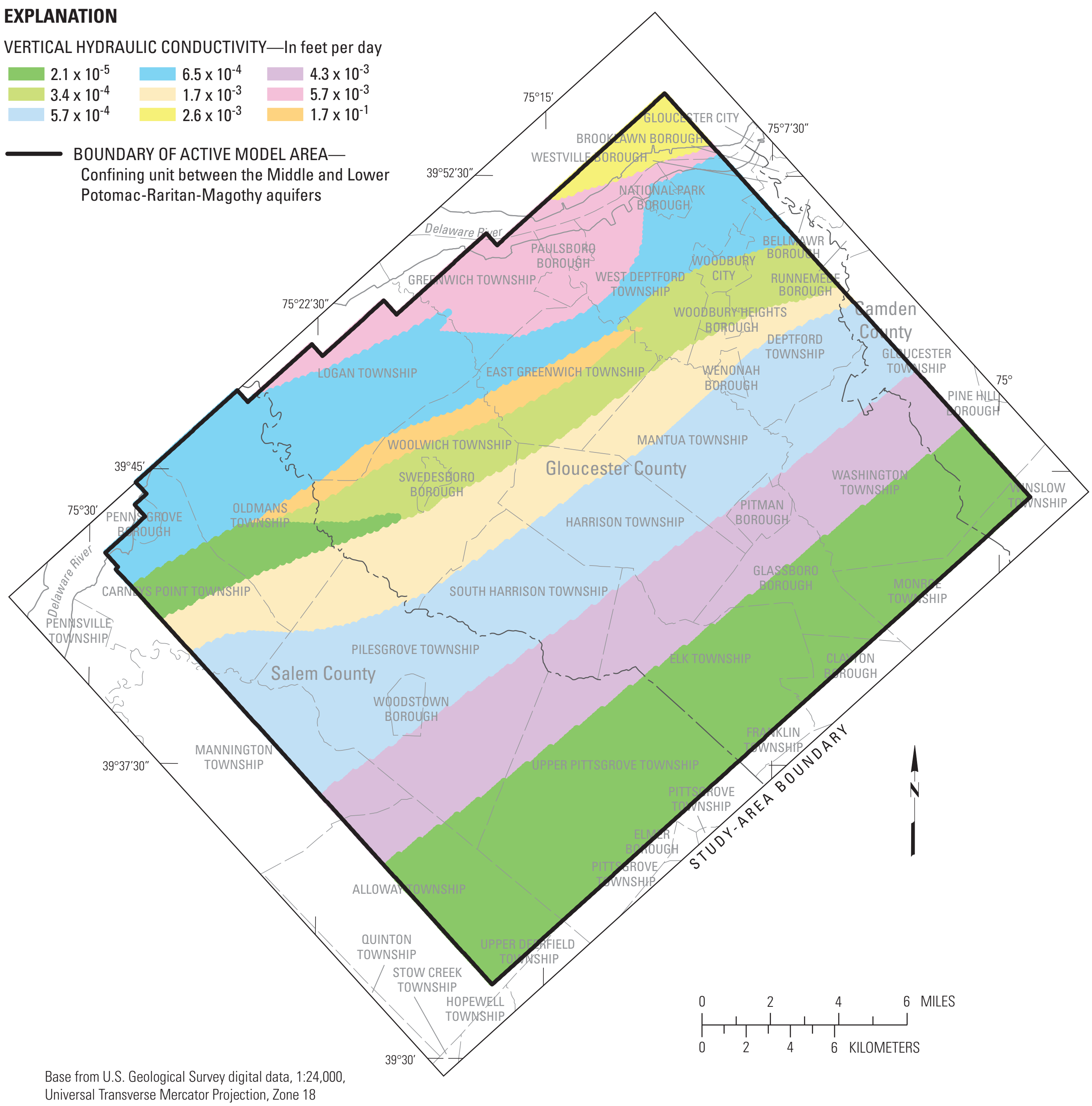


Figure 20. Vertical hydraulic conductivity used in the model, confining unit between the Middle and Lower Potomac-Raritan-Magothy aquifers, Salem-Gloucester study area, southern New Jersey.

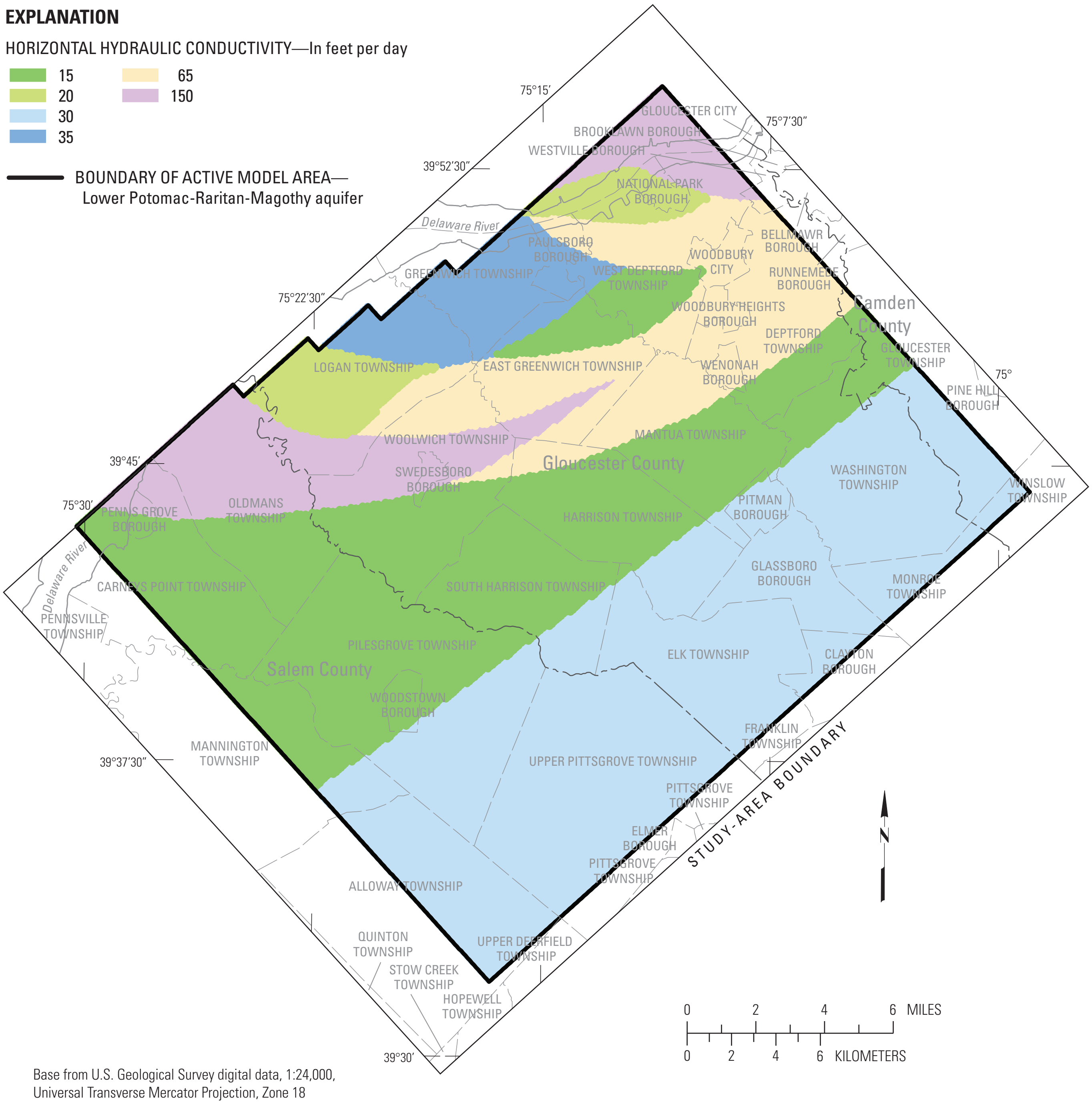


Figure 21. Horizontal hydraulic conductivity used in the model, Lower Potomac-Raritan-Magothy aquifer, Salem-Gloucester study area, southern New Jersey.

from 1 in select zones in the confining units between the Upper and Middle Potomac-Raritan-Magothy aquifers and the Middle and Lower Potomac-Raritan-Magothy aquifers to 9,000 in a zone in the confining unit between the Upper and Middle Potomac-Raritan-Magothy aquifers.

Riverbed conductance values for the Delaware River were adjusted during calibration. The values in the calibrated local model range from 3.5 x 10^{-1} ft^2/d to 4.3 x 10^4 ft^2/d in river cells. Streambed conductance values also were adjusted during calibration. The values in the calibrated model range from 2.6 x 10^{-3} ft^2/d to 6.7 x 10^3 ft^2/d in stream (drain) cells.

Groundwater Withdrawals

Groundwater-withdrawal data (except domestic self-supply withdrawals) for wells screened in the Potomac-Raritan-Magothy aquifer system in the study area were obtained from the USGS Site-Specific Water Use Data System (SWUDS) database. SWUDS contains withdrawal data reported to the NJDEP BWA. The BWA regulates all groundwater and surface-water diversions throughout the State. The regulation can take the form of a permit, certification, registration, or permit-by-rule. A water allocation or certification is the authority to withdraw surface or groundwater for use, pursuant to a permit issued under the Water Supply Allocation rules or the Agricultural, Aquacultural or Horticultural Water Usage Certification rules (New Jersey Administrative Code, 2005). The withdrawal data from SWUDS were divided into four separate categories of water users: water-purveyor, industrial self-supply, low-volume, and agricultural-irrigation. A water purveyor is any person who owns or operates a public-water supply (New Jersey Administrative Code, 2005). Industrial self-supply includes withdrawals made directly by the industry, not water supplied by a water purveyor. The water-purveyor and industrial self-supply withdrawals are made by users with permitted allocations greater than 100,000 gal/d, whereas low-volume withdrawals are made by users with allocations less than 100,000 gal/d. Low-volume withdrawals can be made from water-purveyor, industrial self-supply, nonagricultural-irrigation, or commercial self-supply wells. There are no reported withdrawals from the Englishtown aquifer system in the study area for these withdrawal categories. Domestic self-supply withdrawals from the Potomac-Raritan-Magothy and Englishtown aquifer systems were estimated from census data (Delaware Valley Regional Planning Commission, 2002; U.S. Censuses of Population and Housing, 2006).

Withdrawals simulated in the local model totaled about 10,100 Mgal/yr in 1998. Withdrawals from water-purveyor wells accounted for 63 percent of withdrawals from the Potomac-Raritan-Magothy aquifer system; industrial self-supply wells, 32 percent; agricultural-irrigation wells, more than 2 percent; and domestic self-supply wells, about 2 percent. Low-volume users accounted for less than 1 percent of the total withdrawals from these aquifers in 1998.

As previously mentioned in the “Conceptual Model” section, water was withdrawn from wells screened in the outcrop (unconfined) areas of the Englishtown aquifer system (domestic self-supply only) and the Upper and Middle Potomac-Raritan-Magothy aquifers. These withdrawals are included in the simulation because they may affect the water levels in the confined part of these aquifers.

Water-Purveyor, Industrial Self-Supply, Low-Volume, and Agricultural-Irrigation

Withdrawals from the Potomac-Raritan-Magothy aquifer system by water purveyors were divided into wells located in Critical Area 2 (table 4 at end of report) and wells located outside the Critical Area 2 boundary (table 5 at end of report). Withdrawals by low-volume users are shown in table 5. Withdrawals from industrial self-supply wells are shown in tables 6 and 7 (at end of report), and withdrawals from agricultural-irrigation wells are shown in table 7. The location of wells in the local model from which withdrawals were made in 1998 is shown in figure 22.

Estimated Domestic Self-Supply

Domestic self-supply withdrawals from the Englishtown and Potomac-Raritan-Magothy aquifer systems in the study area are estimated to be small, about 2 percent of the total withdrawals from these aquifers. These withdrawals are included in the model to simulate local effects of these withdrawals on water levels. The Groundwater Site Inventory (GWSI) database, the site-information component of the National Water Information System (NWIS), the USGS national water-data storage and retrieval system, was used to determine the proportion of domestic self-supply wells in each aquifer and municipality in the database. Several municipalities in the study area had only a small number of wells in the GWSI database from which to determine the domestic self-supply withdrawals from the Englishtown or Potomac-Raritan-Magothy aquifer system. Therefore, these municipalities were assigned the same proportion as a neighboring municipality that had more wells in the GWSI database.

The shallowest productive aquifers in the southern part of the model area are the Kirkwood-Cohansey aquifer system and the Wenonah-Mount Laurel aquifer (fig. 2). Most domestic self-supply withdrawals are from these aquifers because shallow wells are the most economical to install. (The Upper Potomac-Raritan-Magothy aquifer is more than 400 ft below land surface in this area.)

Most of the domestic self-supply wells in the study area were considered to be screened in the confined part of the Englishtown and Potomac-Raritan-Magothy aquifer systems, but some wells were considered to be screened in the unconfined part of the Upper and Middle Potomac-Raritan-Magothy aquifers. Whether the well was in the confined or unconfined part of the Upper and Middle Potomac-Raritan-Magothy aquifers was determined by the location of the well in the model and was based on the model framework.

Withdrawals from wells in the confined aquifers are assumed to be 100 percent consumptive—that is, none of

EXPLANATION

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

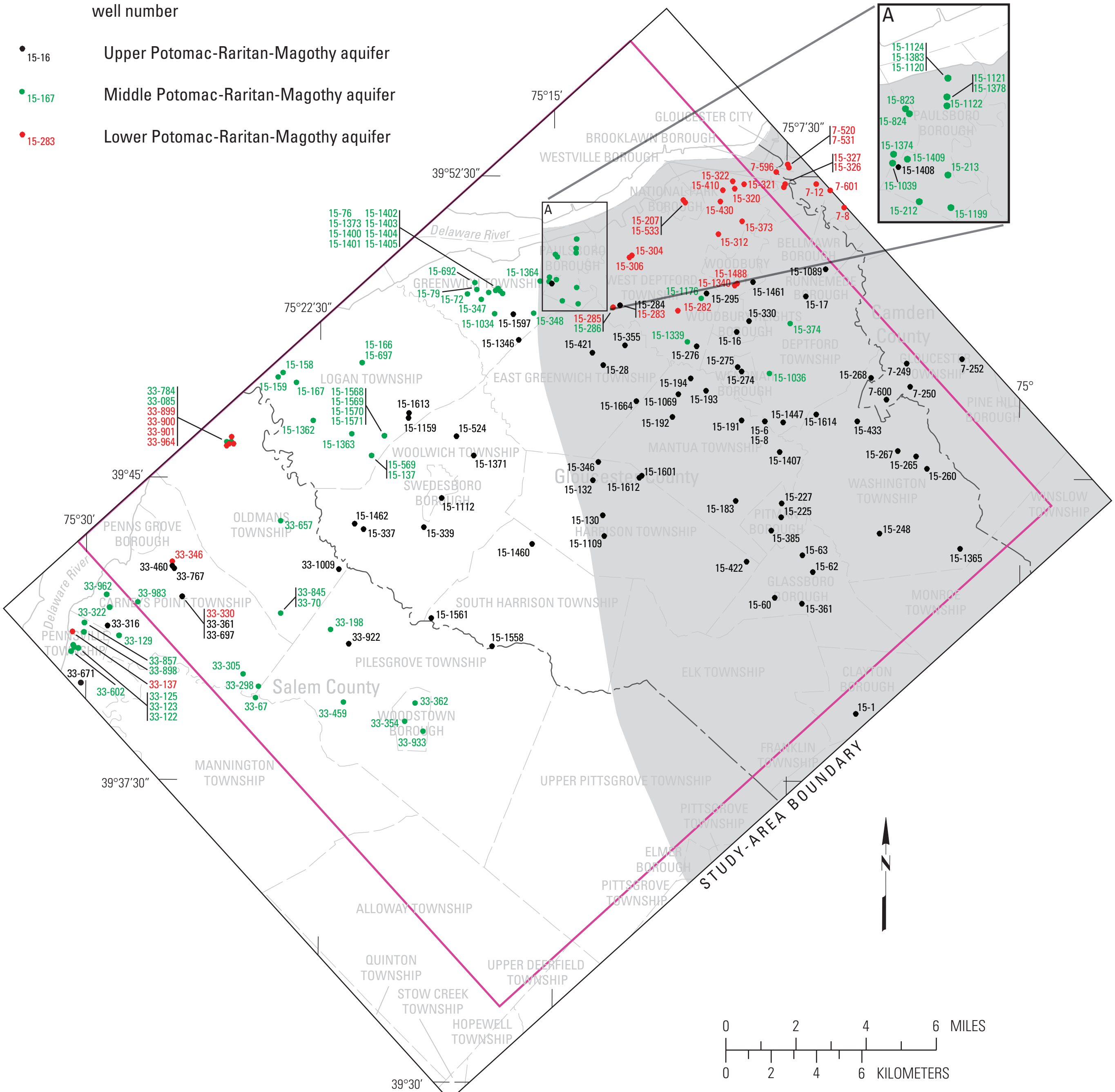
EXTENT OF MODEL GRID

LOCATION OF WITHDRAWAL WELL—Number is U.S. Geological Survey well number

15-16 Upper Potomac-Raritan-Magothy aquifer

15-167 Middle Potomac-Raritan-Magothy aquifer

15-283 Lower Potomac-Raritan-Magothy aquifer



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 22. Location of withdrawal wells and wells simulated as boundary flows in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers for the 1998 calibration simulation, Salem-Gloucester study area, southern New Jersey.

the withdrawals are returned to the same aquifer by way of a septic system. Withdrawals from domestic self-supply wells screened in the unconfined Upper and Middle Potomac-Raritan-Magothy aquifers in the study area are assumed to be about 15 percent consumptive. The consumptive-use coefficient was modified from the consumptive-use coefficient determined for domestic self-supply withdrawals in Camden County (Nawyn, 1997). The remaining 85 percent of the pumped water is assumed to return to the aquifer from which it was withdrawn by way of a septic system.

To estimate the annual domestic self-supply withdrawals from wells in the Englishtown and the Potomac-Raritan-Magothy aquifer systems in 1998, the population in each municipality in the study area was obtained from 2000 census data (U.S. Censuses of Population and Housing, 2006). The population served by public-water supply for each municipality in the study area was determined from data reported quarterly to the NJDEP and on file at the USGS New Jersey Water Science Center in West Trenton, New Jersey. The reported population served in each municipality was subtracted from total population for each municipality and the difference was the estimated population served by domestic self-supply for that municipality (table 8). It is assumed that there was little change between the 2000 population served by domestic self-supply and the 1998 population served by domestic self-supply.

The population served by domestic self-supply was multiplied by the percentage of the municipality in the study area and of the domestic wells in an aquifer (table 8). This value was multiplied by the consumptive-use coefficient for either a confined (1.0) or unconfined (0.15) aquifer. The resulting value was multiplied by 365 (days per year), and then multiplied by 80 gal/d, which is an average per capita usage estimated by Solley and others (1998) for domestic self-supply. This calculation yielded a consumptive-water-use value in gallons per day for each municipality in the study area assumed to have domestic self-supply withdrawals. This value is given in million gallons per year in table 8. The consumptive-water-use value was divided equally among the model cells in those municipalities that have domestic self-supply wells.

Model Calibration and Simulation of 2000 (Baseline) Withdrawals

The local groundwater-flow model was calibrated to 1998 withdrawal conditions using a steady-state simulation. The model was calibrated to 1998 conditions because synoptic water levels were measured in 1998 and the steady-state regional model, which provided the boundary flows for the local model, was calibrated to 1998 withdrawal conditions. A steady-state simulation for this analysis is valid because (1) water-level changes resulting from mandated withdrawal restrictions for Critical Area 2 after 1993 generally have stabilized and (2) a steady-state analysis is consistent with the NJDEP regulatory policy which grants a water-allocation permit with a term of 10 years (New Jersey Department of Environmental Protection, 2005, N.J.A.C. 7:19-2:14) and the permits are routinely extended (New Jersey Statutes Annotated, 2008, N.J.S.A. 58:1A-7b). Therefore, a steady-state analysis is a useful measure of the full-allocation withdrawal condition.

Calibration was done by a trial-and-error process. Initial estimates of the model input values for streambed and riverbed conductance, horizontal hydraulic conductivity, and vertical hydraulic conductivity were adjusted to achieve an acceptable match of model results to observed water-level data. Adjustments were made to the streambed conductance used in the Drain package of MODFLOW-2000 (Harbaugh and others, 2000). Values of riverbed conductance in a few model cells near the Delaware River were adjusted to improve the match between simulated and measured water levels. During model calibration, results of the local model simulation were compared to (1) simulated water levels and groundwater discharge to streams in the regional model, (2) 1998 synoptic-water-level contours (Lacombe and Rosman, 2001), and (3) water levels measured in 104 wells in 1998 (Lacombe and Rosman, 2001).

Model calibration did not include a comparison of simulated groundwater discharge to streams with base flow estimated from measured streamflow. These data are not available because many stream reaches in the study area are influenced by tides, and there are no continuous stream-discharge gages in the study area. During model calibration, groundwater discharge simulated with the local model was compared to groundwater discharge simulated with the regional model. Groundwater discharge simulation with the calibrated local model is within 2 percent of that of the regional model.

The 1998 water levels simulated with the calibrated local model for the confined Englishtown and Potomac-Raritan-Magothy aquifer systems are shown in figures 23 to 26. Simulated water levels are not shown for the three confining units because measured water levels for those units are not available for comparison. In general, the simulated water levels in a given confining unit fall between the simulated water levels in the aquifers above and below that confining unit.

The MODFLOW-2000 Observation package (Hill and others, 2000) was used to compare and calculate the differences between simulated water levels and water levels measured at 104 wells (Lacombe and Rosman, 2001). The Observation package interpolates simulated water levels to the actual location of the measured water levels between model nodes, thereby improving the accuracy of water-level comparisons. The difference between simulated and measured water levels was minimized primarily by adjusting the zones of horizontal and vertical hydraulic conductivity in the aquifers and confining units during model calibration. The differences (residuals) between simulated and measured water levels are shown in figures 23 to 26.

An acceptable match between simulated water levels and water levels measured in 1998 at 104 wells was achieved

Table 8. Estimated consumptive use of groundwater for domestic self-supply in 2000 by municipality, Salem-Gloucester study area, southern New Jersey.

[Mgal/yr, million gallons per year; - -, not applicable]

Municipality	Estimated population served by domestic self-supply in 2000[1]	Proportion of municipality in study area	Proportion of municipality's domestic self-supply wells in aquifer[2]							Consumptive water use for domestic self-supply in 2000, by aquifer (Mgal/yr)[3]			
			Confined Englishtown aquifer system	Potomac-Raritan-Magothy aquifer system					Other Coastal Plain aquifers	Englishtown aquifer system	Potomac-Raritan-Magothy aquifer system		
				Confined Upper aquifer	Unconfined Upper aquifer	Confined Middle aquifer	Unconfined Middle aquifer	Confined Lower aquifer			Upper aquifer	Middle aquifer	Lower aquifer
Camden County													
Gloucester Township	19	0.377	0.242	0.091	- -	- -	- -	- -	0.667	0.051	0.019	- -	- -
Winslow Township	10,706	0.019	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Gloucester County													
Clayton Borough	581	0.289	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Deptford Township	950	0.891	0.111	0.222	- -	- -	- -	- -	0.667	2.744	5.487	- -	- -
East Greenwich Township	206	1.000	0.077	0.846	- -	- -	- -	- -	0.077	0.463	5.089	- -	- -
Elk Township	3514	0.912	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Glassboro Borough	265	0.984	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Greenwich Township	64	1.000	- -	0.750	- -	0.250	- -	- -	- -	- -	1.402	0.467	- -
Harrison Township	3302	1.000	- -	0.125	- -	- -	- -	- -	0.875	- -	12.052	- -	- -
Logan Township	818	1.000	- -	0.250	0.200	0.350	0.050	0.100	0.050	- -	6.688	8.539	2.389
Mantua Township	2657	1.000	0.143	0.429	- -	- -	- -	- -	0.429	11.095	33.284	- -	- -
Monroe Township	7457	0.090	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
National Park Borough	0	1.000	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Paulsboro Borough	55	1.000	- -	0.750	- -	0.250	- -	- -	- -	- -	1.205	0.402	- -
Pitman Borough	17	1.000	- -	0.125	- -	- -	- -	- -	0.875	- -	0.062	- -	- -
South Harrison Township	2358	1.000	- -	0.333	- -	- -	- -	- -	0.667	- -	22.928	- -	- -
Swedesboro Borough	52	1.000	0.056	0.944	- -	- -	- -	- -	- -	0.085	1.433	- -	- -
Washington Township	4564	1.000	- -	0.087	- -	- -	- -	- -	0.913	- -	11.594	- -	- -
Wenonah Borough	28	1.000	0.111	0.222	- -	- -	- -	- -	0.667	0.091	0.182	- -	- -
West Deptford Township	267	0.960	0.048	0.810	- -	0.095	- -	- -	0.048	0.359	6.062	0.711	- -
Westville Borough	58	0.298	- -	1.000	- -	- -	- -	- -	- -	- -	0.505	- -	- -
Woodbury City	0	1.000	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Woodbury Heights Borough	35	1.000	0.111	0.222	- -	- -	- -	- -	0.667	0.113	0.227	- -	- -
Woolwich Township	1459	1.000	0.043	0.739	- -	- -	- -	- -	0.217	1.832	31.483	- -	- -
Salem County													
Alloway Township	2,753	0.421	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Carneys Point Township	1,236	0.780	- -	0.476	0.143	0.286	- -	- -	0.095	- -	14.004	8.051	- -
Mannington Township	1,474	0.220	0.118	- -	- -	0.059	- -	- -	0.824	1.117	- -	0.559	- -
Oldmans Township	657	1.000	- -	0.476	0.143	0.286	- -	- -	0.095	- -	9.544	5.487	- -
Penns Grove Borough	64	1.000	- -	- -	- -	0.700	0.100	0.200	- -	- -	- -	1.336	0.374
Pilesgrove Township	3,160	1.000	0.057	0.029	- -	0.029	- -	- -	0.886	5.260	2.676	2.676	- -
Upper Pittsgrove Township	3,089	0.788	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Woodstown Borough	35	1.000	- -	- -	- -	- -	- -	- -	1.000	- -	- -	- -	- -
Total[4]										23.210	165.926	28.228	2.763

[1]Estimated using data from U. S. Censuses of Population and Housing (2006) and data reported quarterly to the N.J. Department of Environmental Protection on municipal population served by public water supply.

[2]Estimated from U.S. Geological Survey Ground-Water Site Inventory database.

[3]Confined-aquifer domestic self-supply withdrawals are considered 100-percent consumptive. Unconfined-aquifer domestic self-supply withdrawals are considered 15-percent consumptive, a value modified from Nawyn (1997) for domestic self-supply consumptive use in Camden County. Population estimated to use 80 gallons per day per person for domestic self-supply (Solley and others,1998).

[4]Total domestic self-supply withdrawals may not equal simulated totals for each aquifer as a result of rounding.

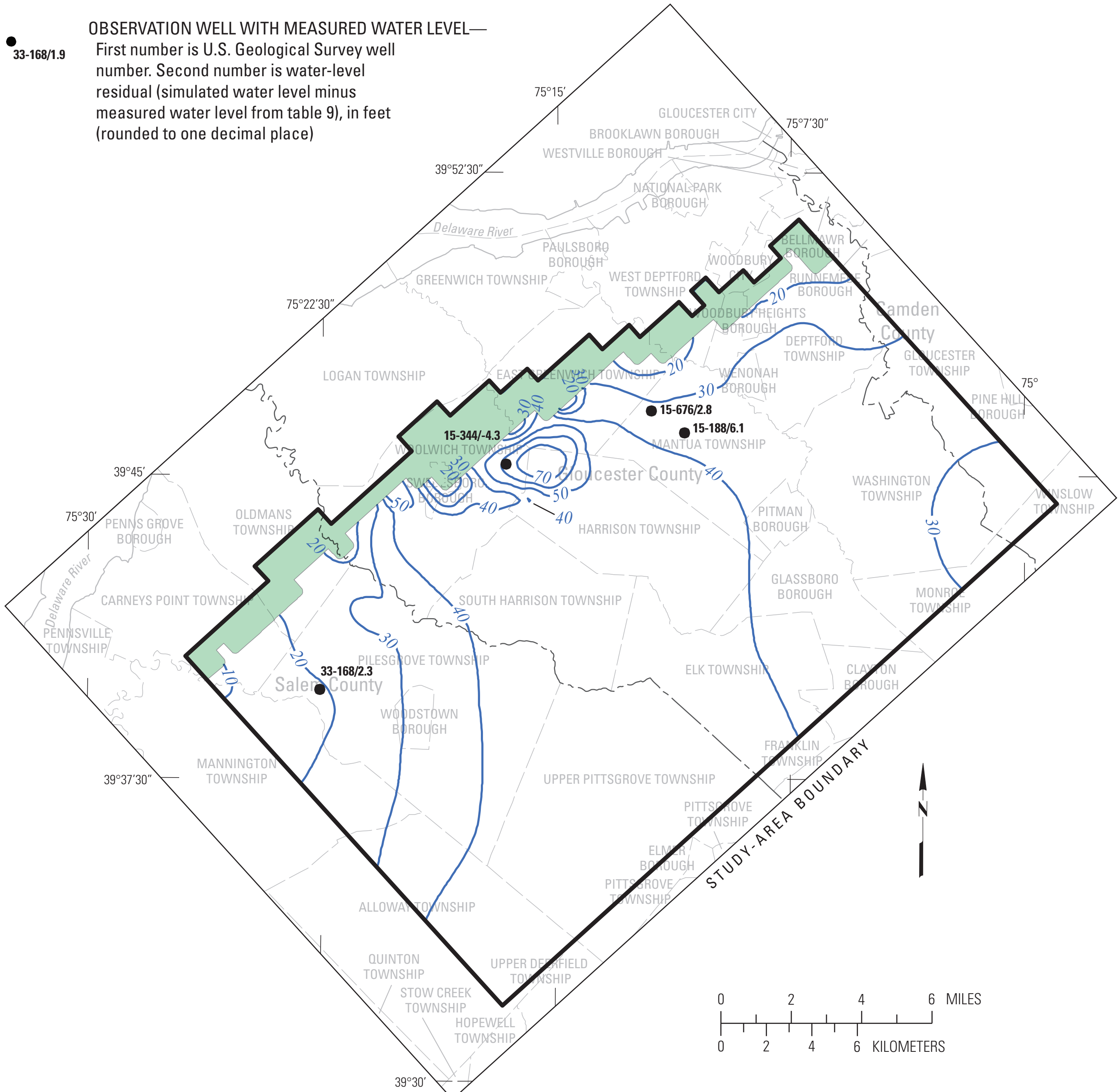
EXPLANATION

DISCRETIZED OUTCROP AREA OF THE ENGLISHTOWN AQUIFER SYSTEM

BOUNDARY OF ACTIVE MODEL AREA—Englishtown aquifer system

— *50* — SIMULATED POTENTIOMETRIC CONTOUR—Shows the simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

● 33-168/1.9 OBSERVATION WELL WITH MEASURED WATER LEVEL—First number is U.S. Geological Survey well number. Second number is water-level residual (simulated water level minus measured water level from table 9), in feet (rounded to one decimal place)



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 23. Steady-state potentiometric surface in the confined Englishtown aquifer system for the 1998 calibration simulation, Salem-Gloucester study area, southern New Jersey.

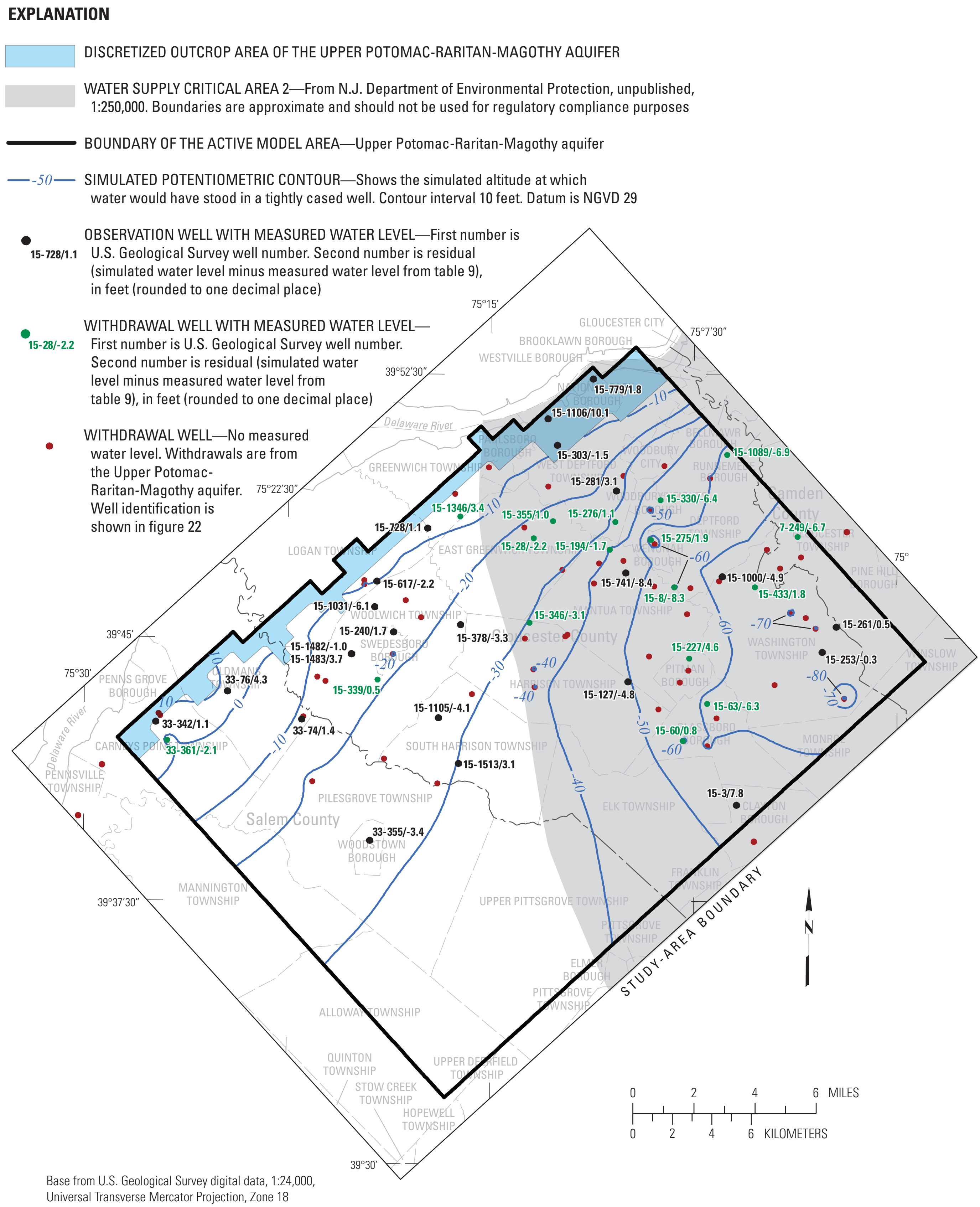


Figure 24. Steady-state potentiometric surface in the confined Upper Potomac-Raritan-Magothy aquifer for the 1998 calibration simulation, Salem-Gloucester study area, southern New Jersey.

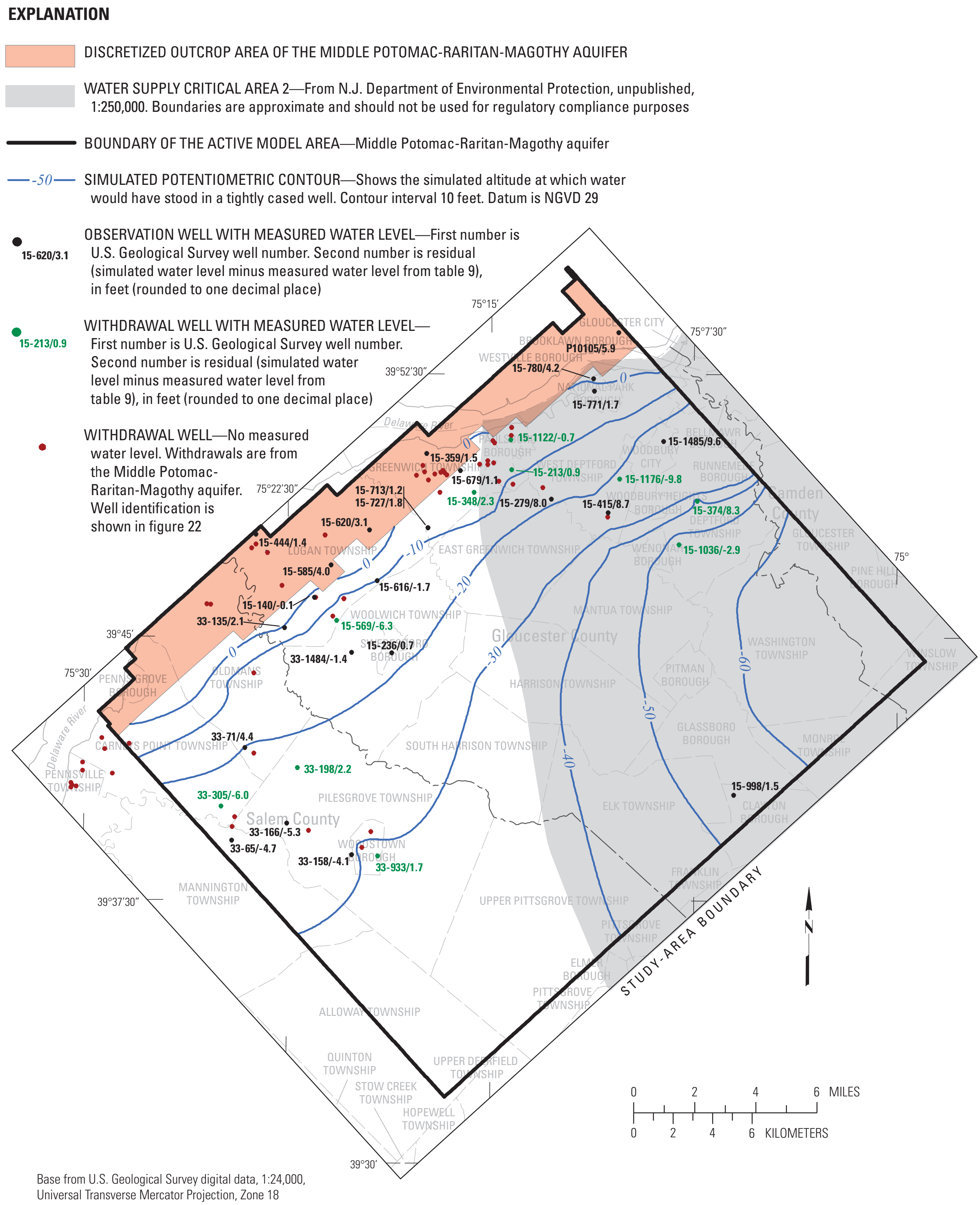


Figure 25. Steady-state potentiometric surface in the confined Middle Potomac-Raritan-Magothy aquifer for the 1998 calibration simulation, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

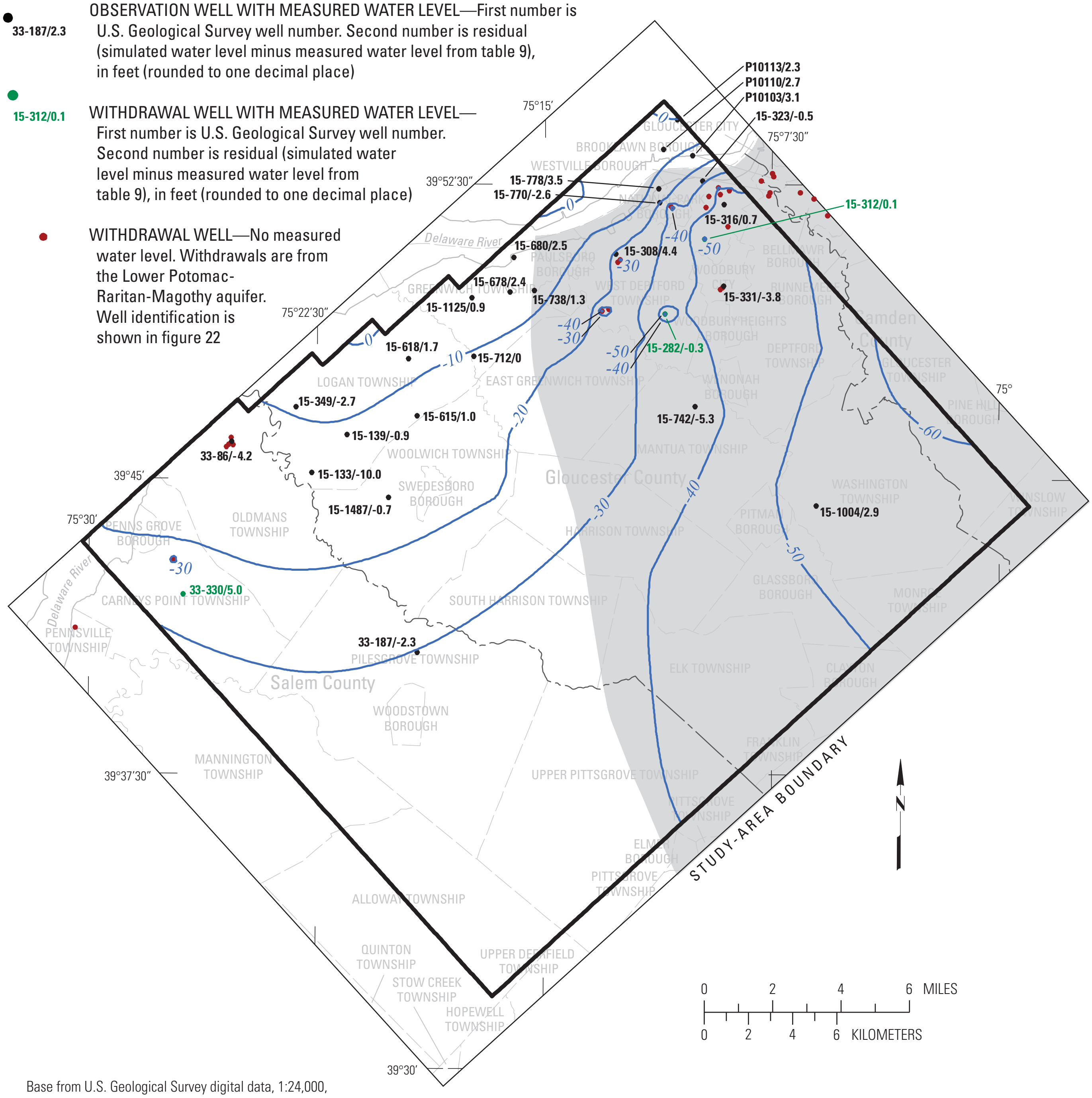
BOUNDARY OF ACTIVE MODEL AREA—Lower Potomac-Raritan-Magothy aquifer

-50 SIMULATED POTENTIOMETRIC CONTOUR—Shows simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

33-187/2.3 OBSERVATION WELL WITH MEASURED WATER LEVEL—First number is U.S. Geological Survey well number. Second number is residual (simulated water level minus measured water level from table 9), in feet (rounded to one decimal place)

15-312/0.1 WITHDRAWAL WELL WITH MEASURED WATER LEVEL—First number is U.S. Geological Survey well number. Second number is residual (simulated water level minus measured water level from table 9), in feet (rounded to one decimal place)

WITHDRAWAL WELL—No measured water level. Withdrawals are from the Lower Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 22



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 26. Steady-state potentiometric surface in the Lower Potomac-Raritan-Magothy aquifer for the 1998 calibration simulation, Salem-Gloucester study area, southern New Jersey.

through model calibration (table 9 at end of report). The root mean square error for residuals is 4.14 ft. Simulated water levels match measured water levels within +/-5 ft for 82 of the 104 wells (79 percent). The maximum negative residual (-9.96 ft) and maximum positive residual (10.14 ft) are similar in magnitude. The overall distribution of the residuals (60 (58 percent) greater than zero and 44 (42 percent) less than zero) indicates that the simulated water levels have neither a strong high bias nor a strong low bias.

1998 Calibration Simulation Flow Budget

Components of inflow in the local model flow budget are recharge to the outcrop areas, boundary flows, and, in some instances, flow from the Delaware River where it is hydraulically connected to the aquifer and withdrawals from the aquifer near the river are large. Components of outflow in the flow budget are groundwater withdrawals, boundary flows, discharge to streams and wetlands, and depending on the magnitude of the withdrawals, discharge to the Delaware River. All flow-budget values are rounded to the nearest integer.

In the calibrated local model, simulated withdrawals total about 44 percent (10,144 Mgal/yr) and simulated groundwater discharge to streams and wetlands is about 35 percent (8,242 Mgal/yr) of outflow in 1998. Specified flows at bordering hydrogeologic units (including the confined Englishtown aquifer system at the top of the model) are about 18 percent of inflow (4,120 Mgal/yr) and account for about 12 percent of outflow (2,838 Mgal/yr). Simulated recharge is about 77 percent of inflow (17,937 Mgal/yr). Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (5 percent) and outflow (9 percent) and is a net flow from the Potomac-Raritan-Magothy aquifer system to the river of about 4 percent (833 Mgal/yr).

Sensitivity Analysis

A sensitivity analysis provides a measure of the uncertainty in model input parameters by showing the effects on water levels and flows simulated by the model of changes in selected model input parameters. A relatively small change in model input parameter that has a relatively large effect on model results indicates the model is highly sensitive to that parameter. For the local model, the sensitivity of simulated water levels and groundwater discharge to streams and the Delaware River was determined for a uniform change in (1) recharge, (2) boundary flows, (3) conductance of streambeds, (4) conductance of the riverbed of the Delaware River, (5) aquifer horizontal hydraulic conductivity, and (6) confining-unit vertical hydraulic conductivity. Only one parameter was changed in each sensitivity-analysis simulation. Input parameters were varied by one or two orders of magnitude.

Evaluating model assumptions and model input data through use of a sensitivity analysis is limited in several ways. In this study, the sensitivity analysis was done for selected input parameters, and the parameter values were changed throughout the entire area of the local model. Localized changes to any input parameters were not evaluated.

To examine the sensitivity of simulated water levels to changes in a model input parameter: (1) the simulated water levels in 104 observation wells used in the model calibration were averaged, (2) the simulated water levels obtained for each sensitivity analysis for these wells were averaged, and (3) the difference between the average produced for a sensitivity run and the model calibration average was obtained. The highest and lowest recorded difference for a range of changes to a model input parameter was then subtracted (table 10). In this study, model sensitivity was high if this difference was less than -50 ft or greater than 50 ft; low if the difference was between -10 ft and 10 ft; and moderate if the difference was between these values.

To examine the sensitivity of simulated groundwater discharge to changes in a model input parameter, the total groundwater discharge to streams (drains) for each sensitivity analysis was recorded. The lowest recorded discharge was then subtracted from the highest recorded discharge for a range of changes to a model input parameter, and the result was recorded in table 10. Model sensitivity was high if this difference was less than -50 ft^3/s and greater than 50 ft^3/s in response to a range of changes to a model input parameter; low if the difference was between -5 ft^3/s and 5 ft^3/s; and moderate if the difference was between these values.

Average simulated water levels showed high sensitivity to decreases in aquifer horizontal hydraulic conductivity. Simulated total groundwater discharge to streams showed high sensitivity to changes in recharge and increases in boundary flows (table 10). Simulated water levels and groundwater discharge showed low to moderate sensitivity to changes in the other parameters tested—that is, changes in the average simulated water level and groundwater discharge were small relative to the changes made to the model input data, indicating that additional adjustments to the value of streambed conductance, conductance of the riverbed of the Delaware River, or confining-unit vertical hydraulic conductivity most likely would not significantly improve the simulation results.

Model Limitations

Limitations of the local model can be attributed to uncertainties in the model input data, inaccuracies in measured water levels, and the limitations and assumptions related to the model design. Assessing limitations of the model generated by uncertainties in model input data is limited to determining the sensitivity of simulated water levels and groundwater discharge to changes in model input data. The model shows high sensitivity to boundary flows, aquifer horizontal hydraulic conductivity, and recharge, but it is less sensitive to the hydraulic conductance of streambeds and the vertical hydraulic conductivity of the confining units.

Table 10. Sensitivity of groundwater-flow model output to changes in model input parameters, Salem-Gloucester study area, southern New Jersey.

[--, Water-level difference and discharge difference were not calculated for the indicated range of multiplication factors; na, not applicable

Model input parameter[1]	Range of multiplication factors[2]	Simulated water level: Water-level difference calculated over the range of multiplication factors[3] (feet)	Simulated water level: Sensitivity[4]	Simulated discharge to streams: Discharge difference calculated over the range of multiplication factors[5] (cubic feet per second)	Simulated discharge to streams: Sensitivity[6]
Recharge	0.2 to 2.2	27.22	Moderate	95.58	High
Boundary flows	0.1 to 10	-4.43	Low	--	na
	10 to 20	-16.18	Moderate	--	na
	0.1 to 1	--	na	4.09	Low
	1 to 20	--	na	96.36	High
Streambed conductance	0.1 to 100	-4.70	Low	12.19	Moderate
Delaware River riverbed conductance	0.1 to 100	2.35	Low	-0.44	Low
Aquifer horizontal hydraulic conductivity	0.1 to 1	135.54	High	--	na
	1 to 100	22.26	Moderate	--	na
	0.1 to 100	--	na	-4.13	Low
Confining-unit vertical hydraulic conductivity	0.1 to 100	30.31	Moderate	-6.91	Moderate

[1] In each sensitivity analysis, one parameter was varied at a time. Aquifer horizontal hydraulic conductivity and confining-unit vertical hydraulic conductivity of all layers were varied at the same time.

[2] Not all multiplication factors within these ranges were analyzed.

[3] The simulated water levels in 104 observation wells used in the model calibration were averaged. The simulated water levels for these wells produced during a sensitivity run were also averaged. The difference between the average produced for a sensitivity run and the model calibration average was recorded. The highest recorded difference was subtracted from the lowest recorded difference and the result is recorded in this table.

[4] Sensitivity was high if the difference in water level was less than -50 feet or greater than 50 feet; low if the difference was between -10 feet and 10 feet; and moderate if the difference was between these values.

[5] The highest recorded difference was subtracted for the lowest recorded difference, and the result is recorded in this table.

[6] Sensitivity was high if the difference in discharge was less than -50 cubic feet per second or greater than 50 cubic feet per second; low if the difference was between -5 cubic feet per second and 5 cubic feet per second; and moderate if the difference was between these values.

The accuracy of the withdrawal data input to the model is difficult to assess because of uncertainties inherent in collecting, recording, and reporting the data to the State. Results of the local-model simulation could be improved with more accurate agricultural-irrigation withdrawal data and more accurate estimates of domestic self-supply withdrawals for the various municipalities. The accuracy of domestic self-supply withdrawal values is difficult to assess because of uncertainties inherent in estimating the population served by domestic self-supply and the per capita water use associated with domestic self-supply.

Results of the local-model simulation could be improved with more accurate water-level altitudes. Uncertainties exist in the 104 observed water-level measurements that were used to calibrate the model. Table 9 shows that the accuracy of these water-level altitudes ranges from +/- 0.01 ft to +/- 5 ft, depending on whether the altitude of the measuring point at the well was determined by surveying (accuracy of +/- 0.01 ft) or by estimation from a topographic map (accuracy of +/- 5 ft). This limitation led to the selection of the +/- 5-ft value as the water-level calibration criterion.

The resolution of the hydrogeologic framework, both vertically and horizontally, is a limitation of the local-model design. All models are an approximation of the actual flow system. A groundwater-flow model is generally based on a conceptual model that is a simplification of a natural system that is inherently variable and complex and for which it is not feasible to reconstruct every detail (Anderson and Woessner, 1992). Because of the complicated depositional history of the Potomac-Raritan-Magothy aquifer system, the complexity of the hydrogeologic framework cannot be fully reproduced with the resolution used in the model; however, an acceptable calibration was achieved with the discretization used.

Estimates of groundwater discharge in the outcrop area of the local model were not available for comparison with groundwater discharge simulated during model calibration; therefore, the simulated groundwater discharge to streams in the outcrop areas of the local model was compared to simulated values for streams in the regional model.

The aquifers in the local model were simulated as confined, although the Upper and Middle Potomac-Raritan-Magothy aquifers and the Englishtown aquifer system generally are unconfined where they crop out. As previously stated, however, the change in water levels in the outcrop areas of these aquifers generally was small compared to the saturated thickness. This simplification does not substantially diminish the usefulness of the model for examining the effects of withdrawals from the confined parts of the Potomac-Raritan-Magothy aquifers on water levels and groundwater discharge to streams.

Despite these limitations, the results of the local-model calibration and sensitivity analysis indicate that the model simulates groundwater flow in the confined part of the Potomac-Raritan-Magothy aquifer system adequately for the objectives of the study—to assess the effect of changes in withdrawals on water levels and on the movement of groundwater from source areas with chloride concentrations greater than or equal to 250 mg/L.

2000 Baseline Simulation and Results

The 2000 baseline steady-state simulation incorporates the average annual 1999–2001 withdrawals from the Potomac-Raritan-Magothy aquifer system by water purveyor, from industrial self-supply and agricultural-irrigation wells, and by low-volume users. Reported withdrawals (except domestic self-supply withdrawals) for 1999, 2000, and 2001 were obtained from the SWUDS database. Because agricultural-irrigation demand can vary widely from year to year depending on the rainfall and temperatures during growing season, average annual withdrawals from 1992 to 2001, depending on reported usage, were input for these wells (table 7). Domestic self-supply withdrawals were the same as those input for the 1998 calibration simulation. The types of withdrawal data used in this simulation are summarized in table 11.

Withdrawals from wells in the Potomac-Raritan-Magothy aquifer system input to the local model are shown in tables 4 to 7. Included in these tables are withdrawals from 25 wells located outside, but adjacent to, the local-model boundary. There are 11 industrial self-supply wells in Pennsville and Carneys Point Townships in Salem County. There are four water-purveyor wells in Gloucester County (one in Deptford Township, one in Clayton Borough, and two in Westville Borough), seven water-purveyor wells in Camden County (one in Gloucester Township, three in Bellmawr Borough, and three in Brooklawn Borough), and three water-purveyor wells in Pennsville Township in Salem County. To simulate the effect of withdrawals from the wells, all withdrawals for this simulation were first input to the regional model using the MODTMR package (Leake and Claar, 1999). This task was accomplished by changing the withdrawals in the model cells in the Salem-Gloucester study area in the regional model to the 2000 baseline withdrawals. Withdrawals from the wells located outside the local-model area were also changed to the 2000 baseline withdrawals. Withdrawals from the other wells in the regional model were not changed and remained at 1998 withdrawal values. The MODTMR output was input into the local model to obtain the boundary flows for the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers and the Englishtown aquifer system.

The 2000 baseline simulation was chosen as the baseline for comparison with the scenario results of the full-allocation and adjusted full-allocation scenarios and the 2025 scenario. The withdrawal data were more current than the 1998 withdrawals used in the calibration simulation, and the 2000 census data (Delaware Valley Regional Planning Commission, 2002; U.S. Census Bureau, 2006) were used to project withdrawals for the 2025 population-growth scenario (discussed later in this report). Withdrawal wells in the

Table 11. Type and amount of groundwater withdrawals in the Salem-Gloucester study area, southern New Jersey, for the 1998 calibration simulation, the 2000 baseline simulation, and the six groundwater-withdrawal scenarios.

[Withdrawals shown in parentheses are in million gallons per year and are rounded to the nearest integer; CA2, Critical Area 2]

Type of withdrawal	1998 calibration simulation[1]	2000 baseline simulation[1]	Allocation scenario: Full-allocation	Allocation scenario: Adjusted full-allocation[2]	Allocation scenario: Adjusted full-allocation plus Woolwich request	Allocation scenario: Adjusted full-allocation plus all requests	Allocation scenario: Adjusted full-allocation plus adjusted requests	2025 population projection scenario
Domestic self-supply	Based on 2000 population and per capita water-use data[3] (220)							2025 population and[3] per capita water-use projection (233)
Water-purveyor	Reported average 1998 (7,275)	Average annual reported 1999–2001 (7,307)	Full-allocation[4] (7,919)		Full-allocation[4] plus Woolwich request (8,028)	Full-allocation[4] plus all requests (8,762)	Full-allocation[4] plus adjusted requests (8,276)	Full-allocation inside CA2, 2025 population estimate outside CA2 (7,788)
Industrial self-supply	Reported average 1998 (3,932)	Average annual reported 1999–2001 (3,612)	Full-allocation[4] (10,510)	Adjusted full allocation (6,754)				Average reported 1999–2001 (3,612)
Agricultural-irrigation	Reported average 1998 (236)	Average annual reported 1992–2001 (191)	Full-allocation[5] (3,301)	Adjusted full-allocation (766)		Adjusted full-allocation plus all requests (1,238)	Adjusted full-allocation plus adjusted requests (984)	Average reported 1992–2001 (191)
Low-volume[6]	Reported average 1998 (27)	Average annual reported 1999–2001 (41)	Full-allocation[4] (670)	Average annual reported 1999–2001 (73)				[7]Average reported 1999–2001 (54)
Total withdrawals[8]	(11,690)	(11,371)	(22,620)	(15,732)	(15,841)	(17,047)	(16,307)	(11,878)

[1]Reported withdrawal data from U.S. Geological Survey Site-Specific Water Use Data System (unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.)

[2]Adjusted full-allocation scenario includes decreased full-allocation withdrawals for wells whose full-allocation withdrawals far exceed 1998 withdrawals. At one well, withdrawals were increased.

[3]2000 population from U.S. Censuses of Population and Housing (2006). 2025 population from U.S. Census Bureau (2006) and Delaware Valley Regional Planning Commission (2002). Per capita water use for domestic self-supply from Solley and others (1998).

[4]Full allocation is the maximum withdrawal permitted by the N.J. Department of Environmental Protection for a water-allocation permit in 2006.

[5]Full allocation refers to the agricultural certification or registration.

[6]Low-volume users withdraw less than 100,000 gallons per day; includes water-purveyor, industrial self-supply, nonagricultural-irrigation, and commercial self-supply withdrawals.

[7]Although permit number 10792W is for a low-volume user and withdrawals for low-volume users were generally not increased from the 2000 baseline value to the 2025 scenario, withdrawals in 2025 were increased from the 2000 baseline value because of projected growth.

[8]Total withdrawals are the sum of simulated withdrawals from wells in tables 4 to 7, which includes the large withdrawals adjacent to the model grid simulated as boundary conditions. This value may not add to totals in these tables as a result of rounding.

Potomac-Raritan-Magothy aquifer system used in the 2000 baseline simulation are shown in figure 27. Simulated water levels in the confined part of the Potomac-Raritan-Magothy aquifer system are shown; however, simulated water levels in the confined part of the Englishtown aquifer system are not shown because withdrawals from this aquifer system in the study area are small and this aquifer is not the focus of the study.

Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation range from about 10 ft above NGVD 29 in Oldmans Township near the outcrop area of the aquifer to more than 70 ft below NGVD 29 in a small cone of depression around a water-purveyor well (15-1365) in Washington Township in Critical Area 2 (fig. 28A). In Carneys Point Township, two small cones of depression centered on water-purveyor wells (33-767 and 33-460, and 33-361, respectively) are observed. Small cones of depression are also observed in West Deptford Township (water-purveyor well 15-276), and in Wenonah (water-purveyor wells 15-274 and 15-275) and Glassboro (water-purveyor well 15-63) Boroughs. A small cone of depression also is observed in Pilesgrove Township (agricultural-irrigation well 33-922). The average and lowest simulated water levels for the 2000 baseline simulation in the Upper Potomac-Raritan-Magothy aquifer are 31 and 77 ft below NGVD 29, respectively (table 12 at end of report).

Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation range from about 10 ft above NGVD 29 in Oldmans Township near the outcrop area of the aquifer to more than 60 ft below NGVD 29 in Critical Area 2 in the Washington Township area (fig. 28B). Cones of depression are observed in Deptford (water-purveyor well 15-374) and in Oldmans Townships (water-purveyor well 33-070). The average and lowest simulated water levels in the Middle Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation are 27 and 65 ft below NGVD 29, respectively (table 12).

Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation range from about NGVD 29 in the western updip limit of the aquifer to more than 50 ft below NGVD 29 in the Washington Township area (fig. 28C). A small cone of depression is centered on a water-purveyor well (33-346) in Carneys Point Township. In West Deptford Township, a small cone of depression is centered on an industrial self-supply well (15-321) and a larger cone of depression is centered on a water-purveyor well (15-312). A cone of depression is also observed in National Park Borough (water-purveyor well 15-533). The average and lowest simulated water levels in the Lower Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation are 30 and 59 ft below NGVD 29, respectively (table 12).

Simulated withdrawals total about 42 percent (9,644 Mgal/yr), and simulated groundwater discharge to streams and wetlands is about 37 percent (8,441 Mgal/yr) of outflow. Specified flows at bordering hydrogeologic units (including the confined Englishtown aquifer system at the top of the model) account for about 18 percent of inflow (4,077 Mgal/yr) and account for about 12 percent of outflow (2,747 Mgal/yr). Simulated recharge is 78 percent of inflow (17,937 Mgal/yr) and was not changed from the 1998 calibration simulation. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (4 percent) and outflow (9 percent) and is a net flow from the Potomac-Raritan-Magothy aquifer system to the river of about 5 percent (1,183 Mgal/yr). Simulated flow-budget components for streams and the Delaware River in the local model for the 2000 baseline simulation are summarized in table 12. All flow-budget values are rounded to the nearest integer.

Simulated Effects of Allocated Withdrawals

As mentioned previously, groundwater withdrawals from wells screened in the Potomac-Raritan-Magothy aquifer system in the study area were divided into five separate water-user categories: water-purveyor, industrial self-supply, low-volume, agricultural-irrigation, and domestic self-supply. The water-purveyor and industrial self-supply withdrawals are by users with allocations exceeding 100,000 gal/d permitted by the State, and low-volume withdrawals are by users with allocations less than 100,000 gal/d. Water users in New Jersey who divert 100,000 gal/d or more of ground and (or) surface water are required to obtain a water-allocation permit from the NJDEP, water users who withdraw less than 100,000 gal/d are issued well registrations, and agricultural/horticultural users are issued agricultural certifications (greater than 70 gal/min and greater than or equal to 3.1 Mgal/month) or agricultural registrations (greater than 70 gal/min and less than 3.1 Mgal/month). Although a single water-allocation permit, well registration, or agricultural certification or registration may cover multiple groundwater and surface-water sources, the withdrawals considered in this report are only those attributed to the Potomac-Raritan-Magothy aquifer system. The maximum permitted withdrawals per water-allocation permit, well registration, or agricultural certification or registration (referred to as “full allocation” in this report) used in these scenarios reflect information listed in NJDEP BWA files as of March 2006.

Description of Allocation-Based Scenarios

Five scenarios were simulated using the permitted allocation withdrawals and increases or decreases to these withdrawals (table 11). The first scenario, referred to in this report as the full-allocation scenario, simulated full-allocation conditions, the maximum withdrawal amounts permitted by the NJDEP with those wells with a water-allocation permit, well registration, or agricultural certification or registration (tables 4–7). A second scenario, referred to as the adjusted full-allocation

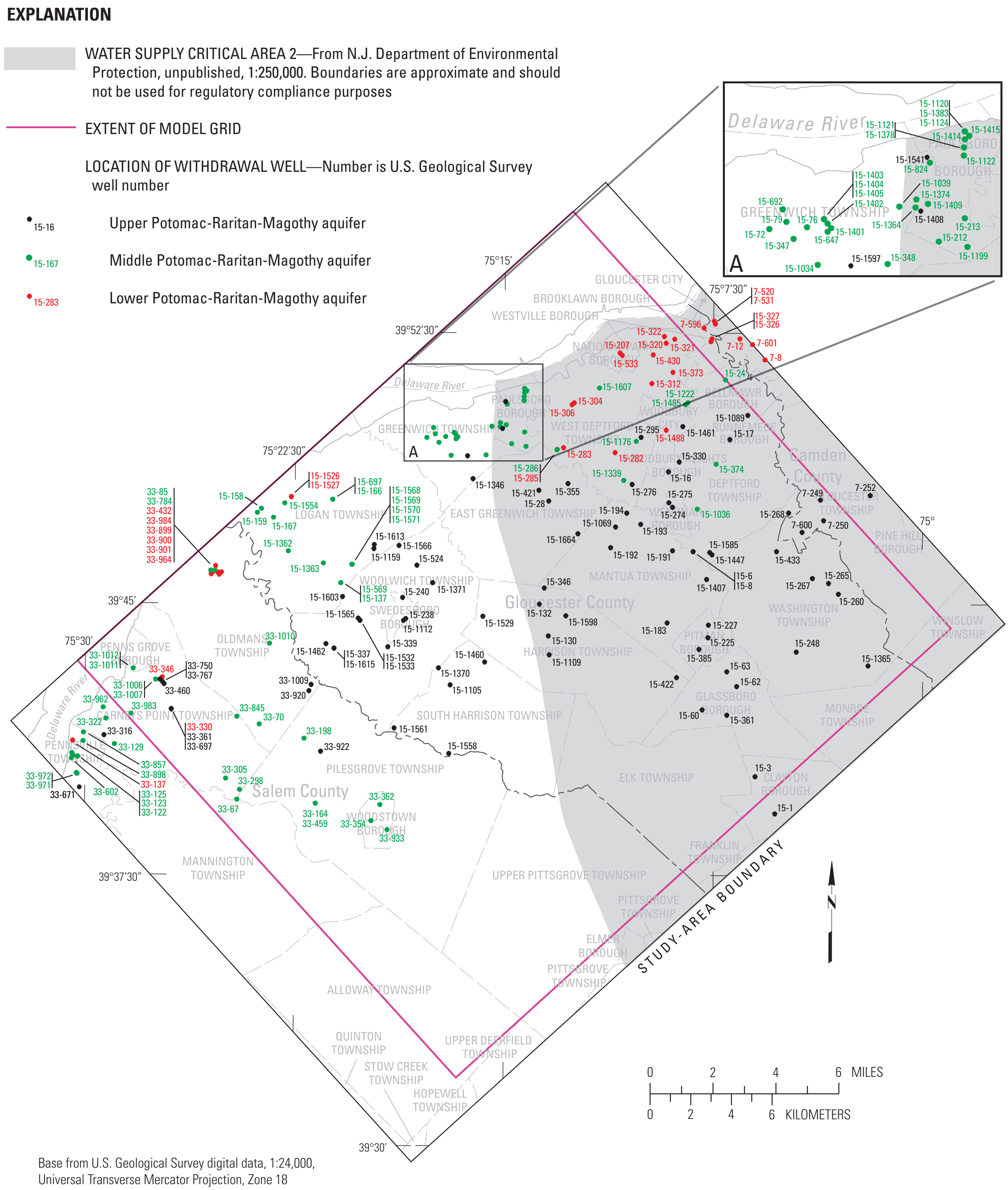


Figure 27. Location of withdrawal wells and wells simulated as boundary flows in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers for the 2000 baseline simulation and 2025 scenario, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

DISCRETIZED OUTCROP AREA OF THE UPPER POTOMAC-RARITAN-MAGOTHY AQUIFER

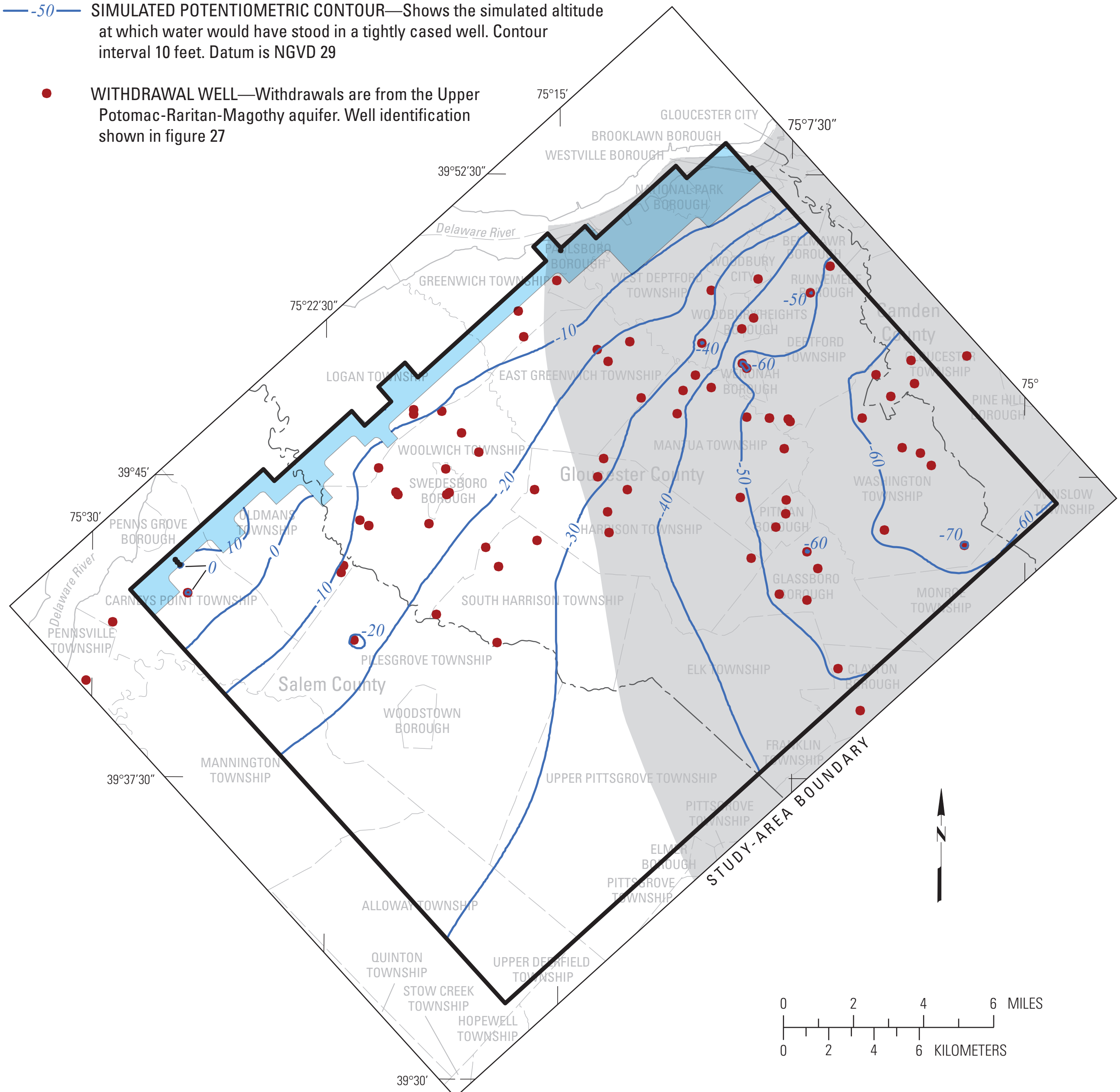
WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Upper Potomac-Raritan-Magothy aquifer

-50 SIMULATED POTENTIOMETRIC CONTOUR—Shows the simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

WITHDRAWAL WELL—Withdrawals are from the Upper Potomac-Raritan-Magothy aquifer. Well identification shown in figure 27

A



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 28. Steady-state potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation, Salem-Gloucester study area, southern New Jersey.

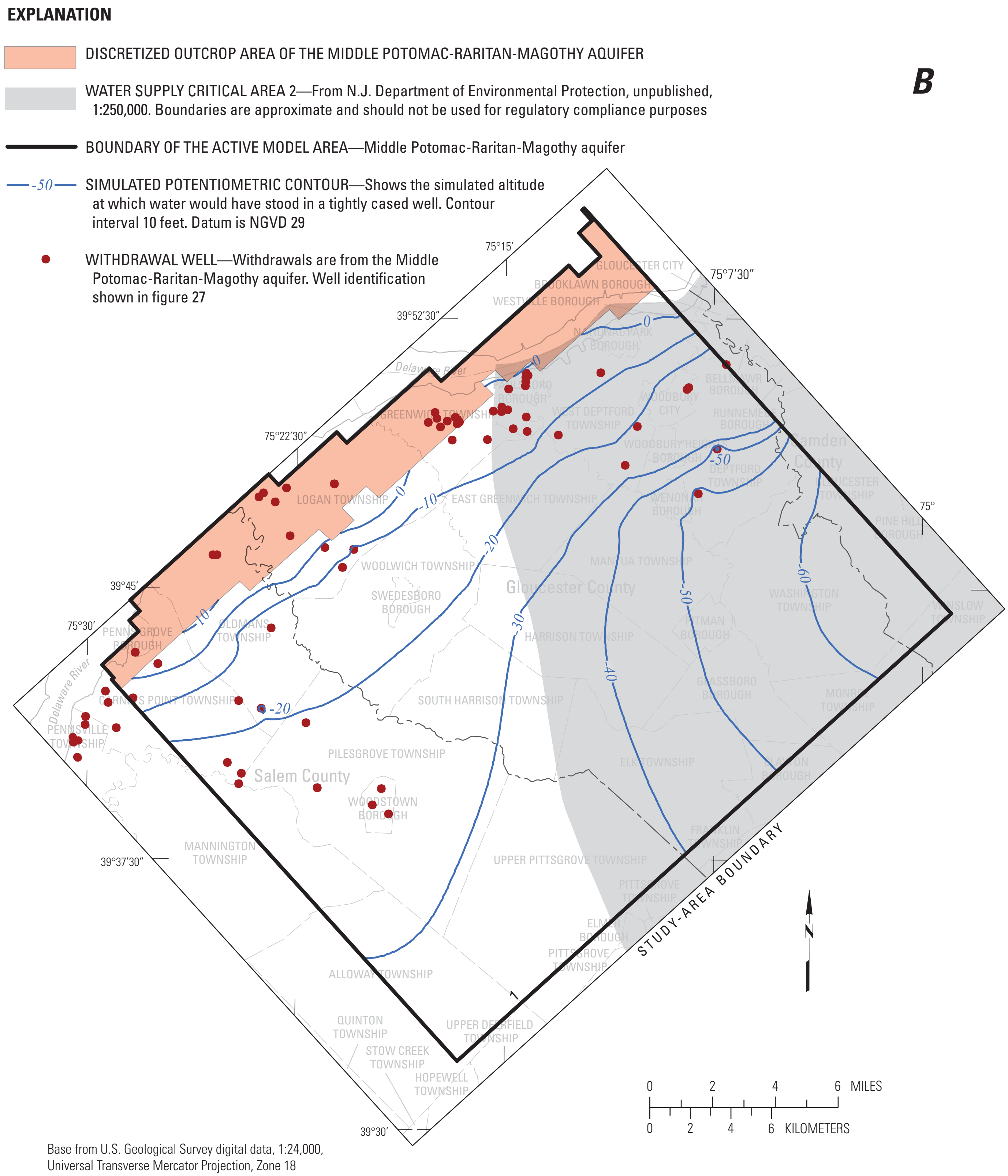


Figure 28. Steady-state potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation, Salem-Gloucester study area, southern New Jersey.—Continued

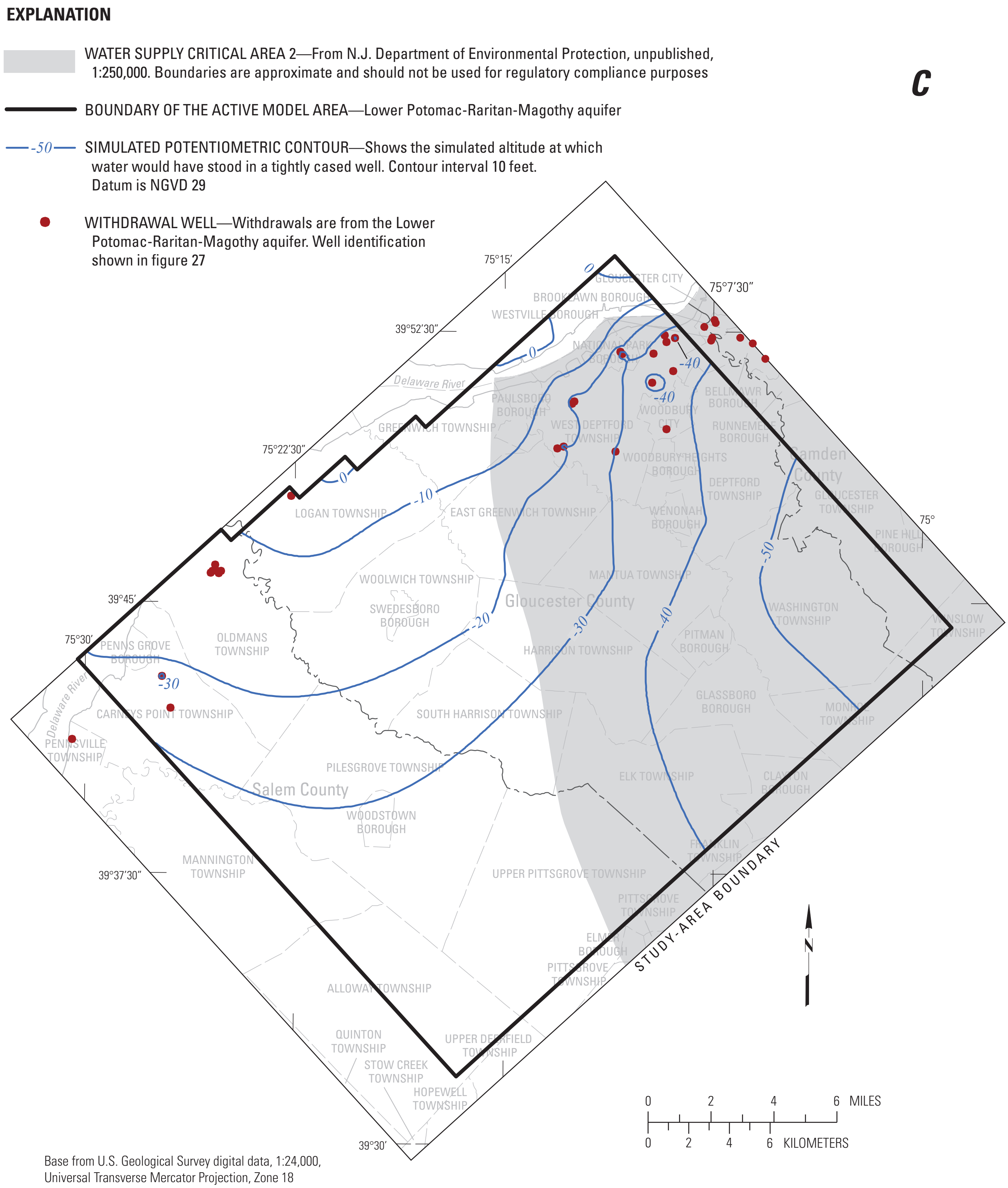


Figure 28. Steady-state potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the 2000 baseline simulation, Salem-Gloucester study area, southern New Jersey.—Continued

scenario, simulated a decrease in the full-allocation amount for one industrial self-supply user and 12 agricultural-irrigation users that withdrew an amount of water far less than the permitted amount (table 7). Also, one agricultural-irrigation well simulated an increase in the full-allocation amount. In this scenario, withdrawals from other wells were the same as those under full-allocation conditions. Because a certification amount commonly includes withdrawals from both groundwater and surface-water sources, this allocation can exceed withdrawals from groundwater; therefore, the full-allocation amounts for the 13 agricultural-irrigation users were assigned by using one or more of the following criteria: reported historical use; the well's pump capacity; and, for some agricultural-irrigation wells, four times the monthly certification amount (to represent the growing season). A third scenario, referred to as the adjusted full-allocation plus Woolwich request scenario, included the same wells as those in the second scenario but withdrawals from two water-purveyor wells in Woolwich Township were increased (table 5). A fourth scenario, referred to as the adjusted full-allocation plus all requests scenario, used the same withdrawals as in the second scenario except that withdrawals were increased at wells for four water purveyors and six agricultural-irrigation users (tables 5 and 7). A fifth scenario, referred to as the adjusted full-allocation plus adjusted requests scenario, incorporated a decrease in the requested withdrawals for the four water-purveyor and one of the agricultural-irrigation wells for which withdrawals were increased in the fourth scenario. Only withdrawals from existing wells in the study area were used in these scenarios.

The withdrawals from wells included in these scenarios are shown in tables 4 to 7. These tables also include withdrawals from 26 wells (tables 4-7) located outside, but adjacent to, the local-model boundary, including the 25 wells included in the 2000 baseline simulation and an additional agricultural-irrigation well in Mannington Township in Salem County. To simulate the effect of withdrawals from these wells, all withdrawals for this scenario were first input to in the regional model using the MODTMR package (Leake and Claar, 1999). In the regional model, only these 26 wells and the wells within the Salem-Gloucester study area were assigned the withdrawals used in the scenarios; withdrawals from all other wells in the regional model remained at 1998 values. The MODTMR output for each scenario was input into the local model to obtain the boundary flows for the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers and the Englishtown aquifer system for that scenario.

Withdrawals

Water-purveyor, industrial self-supply, low-volume, and agricultural-irrigation withdrawals from the Potomac-Raritan-Magothy aquifer system and domestic self-supply withdrawals from the Potomac-Raritan-Magothy and Englishtown aquifer systems were input into the local model. Allocated withdrawals for water purveyors and for industrial self-supply users are designated by NJDEP water-allocation permits (tables 4–7). Allocated withdrawals for low-volume users are designated by NJDEP water registrations (table 5). Allocated withdrawals for agricultural-irrigation users are designated by NJDEP agricultural/horticultural certifications or registrations (table 7). Each permit, registration, or certification may cover the total annual withdrawal from one or more wells, or, in the case of agricultural-irrigation users, surface-water sources also (see "Simulated Effects of Allocated Withdrawals"). To estimate the allocation for each well under one water-allocation permit, a percentage of the withdrawals from 1999 to 2001 from all wells designated by one permit was calculated for each well associated with that permit. This percentage was applied to all wells associated with that permit, registration, or certification, except where noted in tables 4 to 7. In the case of low-volume users, where only monthly allocations are available, annual full-allocation amounts were estimated by multiplying the monthly allocation (3.1 Mgal/month) by 12.

Water-Purveyor and Industrial Self-Supply

Full-allocation withdrawals were used for water-purveyor and industrial self-supply wells in the full-allocation scenario (tables 4–7). The same withdrawals were used in the adjusted full-allocation scenario, except for one industrial self-supply user whose full-allocation withdrawal was substantially greater than the reported withdrawals. The withdrawals for this one user were decreased (table 7).

Low-Volume

For the full-allocation scenario, a withdrawal of 37.2 Mgal/yr was assigned to each low-volume user in table 5. For the adjusted full-allocation scenario, the 2000 baseline simulation withdrawals were used, except one water purveyor was assigned the full-allocation withdrawals.

Agricultural-Irrigation

The model includes 25 agricultural-irrigation users (table 7). In the full-allocation scenario, the agricultural certification amounts were used as the withdrawals for these wells. In the adjusted full-allocation scenario, 12 of the 25 agricultural-irrigation users were assigned a decreased certification amount because the certification amounts are much larger than the reported withdrawals and one well was assigned an increased certification amount. The remaining 12 agricultural-irrigation users were assigned the same agricultural certification or registration amount used in the full-allocation scenario.

Domestic Self-Supply

The domestic self-supply withdrawals used in the model were the same as those used in the 1998 calibration and 2000 baseline simulations (table 8).

Scenario Results

Simulated steady-state water levels for the confined part of the Upper and Middle Potomac-Raritan-Magothy aquifers and the Lower Potomac-Raritan-Magothy aquifer are presented in this section. A flow budget is presented for each scenario. Results for the Englishtown aquifer system are not presented because withdrawals from this aquifer in the study area are small and are only from domestic self-supply wells.

The area in which water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are lower than 30 ft below NGVD 29 but above 30 ft below NGVD 29 in either the 2000 baseline simulation or the adjusted full-allocation scenario are shown for the five scenarios. The location of the 30 ft below NGVD 29 water-level contour in these aquifers in Camden, Gloucester, and Burlington Counties shown in Eckel and Walker (1986) became a groundwater-withdrawal management criterion used by the NJDEP in Critical Area 2 (New Jersey Administrative Code, 2005).

Full-Allocation Scenario

Withdrawal wells in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers used in the full-allocation scenario are shown in figure 29. In six municipalities, water purveyors pumped less in the full-allocation scenario than in the 2000 baseline simulation because they pumped more than their permitted allocations during 1999–2001 (table 4). Simulated withdrawals from wells in the full-allocation scenario are given in tables 4 to 7. Results of this scenario are compared to results of the 2000 baseline simulation.

Simulated water levels in the confined Upper and Middle and Lower Potomac-Raritan-Magothy aquifers for the full-allocation scenario are shown in figure 30, and the change in simulated water levels from the 2000 baseline simulation to the full-allocation scenario are shown in figure 31. Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer in the full-allocation scenario range from NGVD 29 at the outcrop area of the aquifer near the Delaware River in Oldmans and Carneys Point Townships to more than 80 ft below NGVD 29 in four small cones of depression observed around water-purveyor wells (15-248, 15-260, 15-267, and 15-1365, respectively) in Washington Township in Critical Area 2, and more than 150 ft below NGVD 29 in a cone of depression centered on an agricultural-irrigation well (15-1664) in East Greenwich Township (fig. 30A). The agricultural-irrigation well exhibited the greatest water-level decline (128 ft) from the 2000 baseline simulation (table 12). The full-allocation withdrawal for this well is much larger than the withdrawal in the 2000 baseline simulation (table 7). The water-level decline at this well was large because the full allocation for the water-allocation permit was simulated in one well, although the water-allocation permit is a combined surface-water and groundwater permit and a portion of the allocation could be from surface-water sources. When compared to the 2000 baseline simulation (fig. 28A), two cones of depression centered on two agricultural-irrigation wells (15-337 and 15-1462, respectively) developed in Woolwich Township, and a cone of depression developed around an agricultural-irrigation well (15-1561) in South Harrison Township. Simulated water levels declined from the 2000 baseline simulation about 60 ft in Woolwich Township as a result of the increase in withdrawals from these two agricultural-irrigation wells (fig. 31A). Simulated water levels in this aquifer in Woolwich Township are lower than those in the underlying Middle Potomac-Raritan-Magothy aquifer in the area of these wells; therefore, groundwater flows upward from the Middle to the Upper aquifer. The average simulated water level in the Upper Potomac-Raritan-Magothy aquifer for the full-allocation scenario is 49 ft below NGVD 29, 18 ft lower than in the 2000 baseline simulation (table 12).

Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer in the full-allocation scenario range from NGVD 29 at the outcrop area of the aquifer to more than 90 ft below NGVD 29 in a cone of depression in East Greenwich Township caused by the large withdrawal from an agricultural-irrigation well (15-1664) in the overlying Upper Potomac-Raritan-Magothy aquifer (fig. 30B, table 7). When compared to the 2000 baseline simulation, the largest water-level decline simulated in the Middle Potomac-Raritan-Magothy aquifer in this scenario was more than 65 ft at this well (fig. 31B, table 12). When compared to the 2000 baseline simulation (fig. 28B), cones of depression are observed at a water-purveyor well (33-933) in Woodstown Borough, an agricultural-irrigation well (33-198) in Pilesgrove Township, and an industrial self-supply well (33-305) in Carneys Point Township. The average simulated water level in the Middle Potomac-Raritan-Magothy aquifer for the full-allocation scenario is 43 ft below NGVD of 1929, 16 ft lower than in the 2000 baseline simulation (table 12).

Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer in the full-allocation scenario range from about NGVD 29 in the northern updip limit of the aquifer to more than 60 ft below NGVD 29 in the eastern part of the model area in Critical Area 2, and in the western part of the model area in Carneys Point Township (fig. 30C). When compared to the 2000 baseline simulation (fig. 28C), a cone of depression is observed around a cluster of five industrial self-supply wells (33-899, 33-900, 33-901, 33-964, and 33-984) in Oldmans Township. The largest water-level decline in this aquifer in this scenario was about 36 ft below NGVD 29 in Carneys Point Township near the model boundary (fig. 31C, table 12). The average simulated water level in the Lower Potomac-Raritan-Magothy aquifer for the full-allocation scenario is 48 ft below NGVD of 1929, 18 ft lower than the 2000 baseline simulation (table 12).

The areas in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in which simulated water levels are lower than 30 ft below NGVD 29 in the full-allocation scenario but above 30 ft below NGVD 29 in the 2000 baseline simulation are shown in figure 30. These areas increased in size from the area in the 2000 baseline simulation by

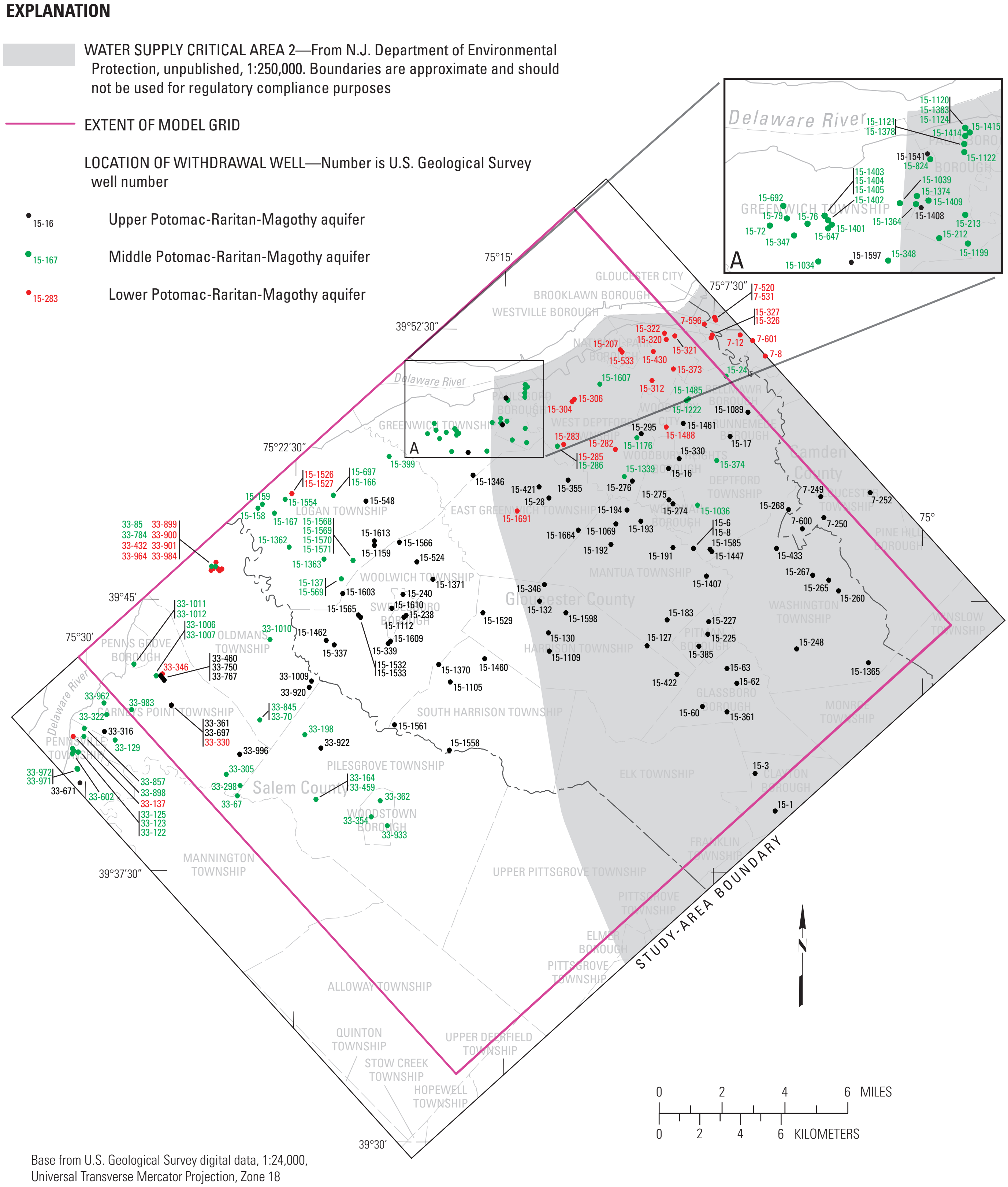


Figure 29. Location of withdrawal wells simulated in the model and wells simulated as boundary flows in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers for the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.

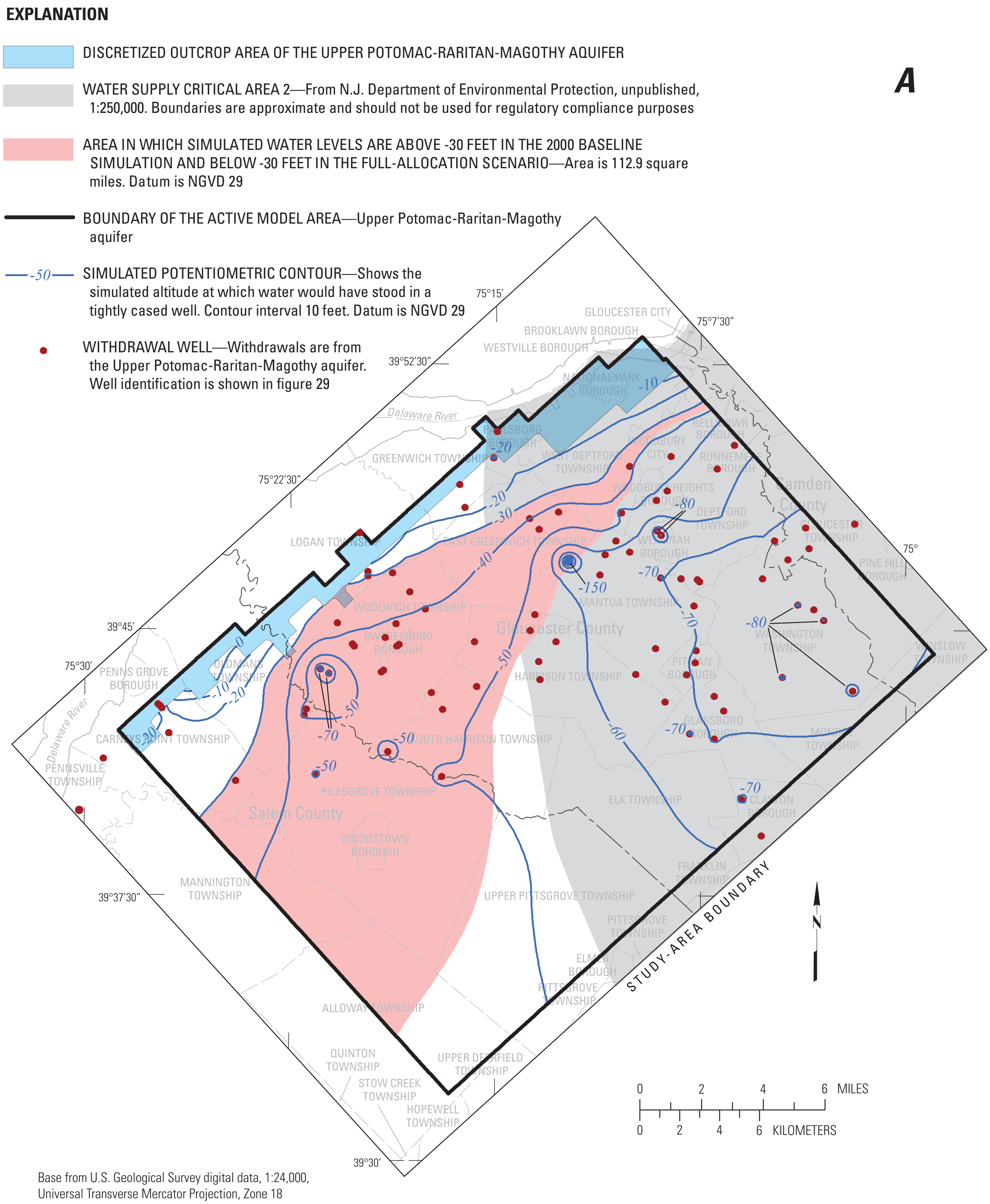


Figure 30. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.

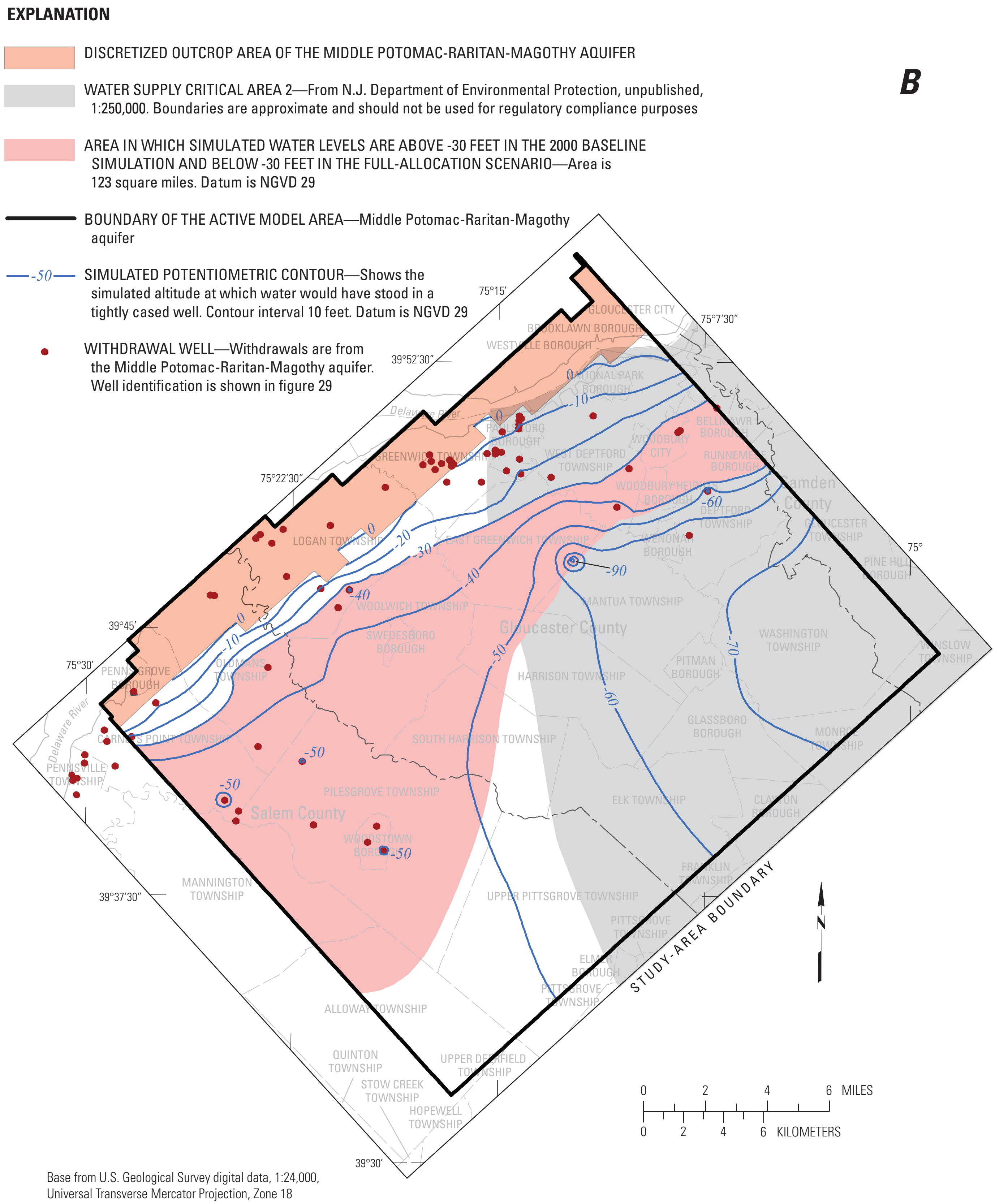


Figure 30. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

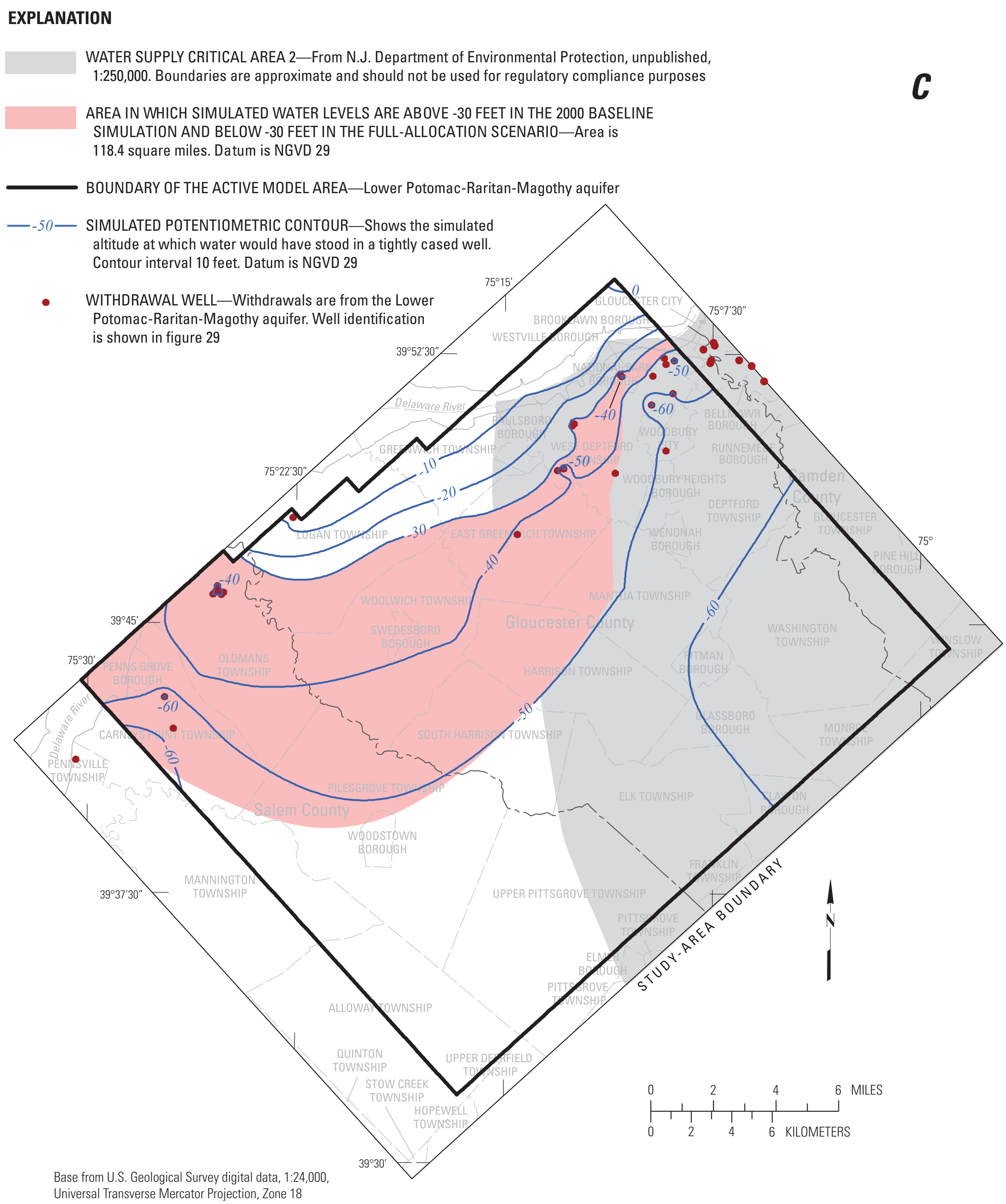


Figure 30. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

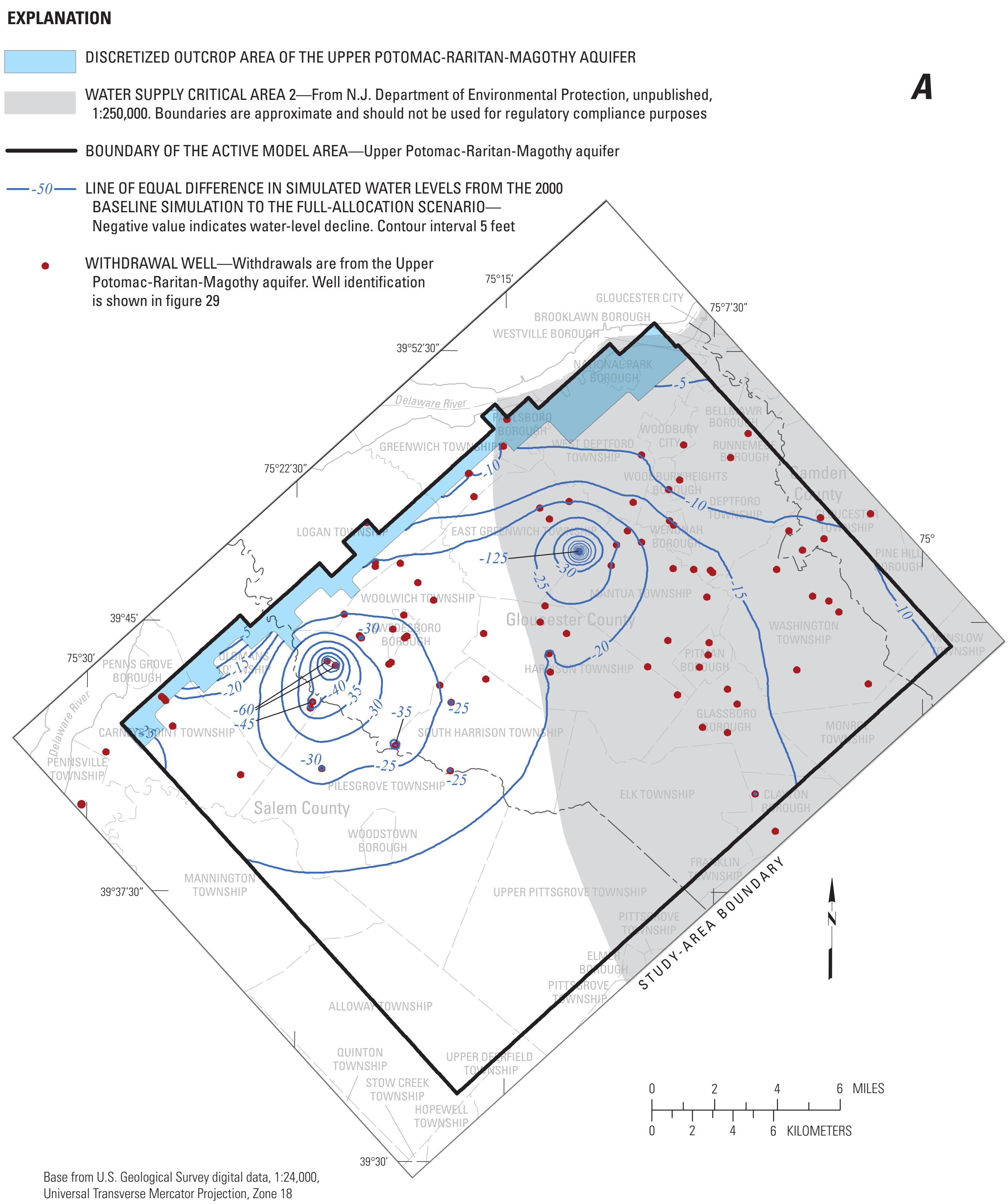


Figure 31. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

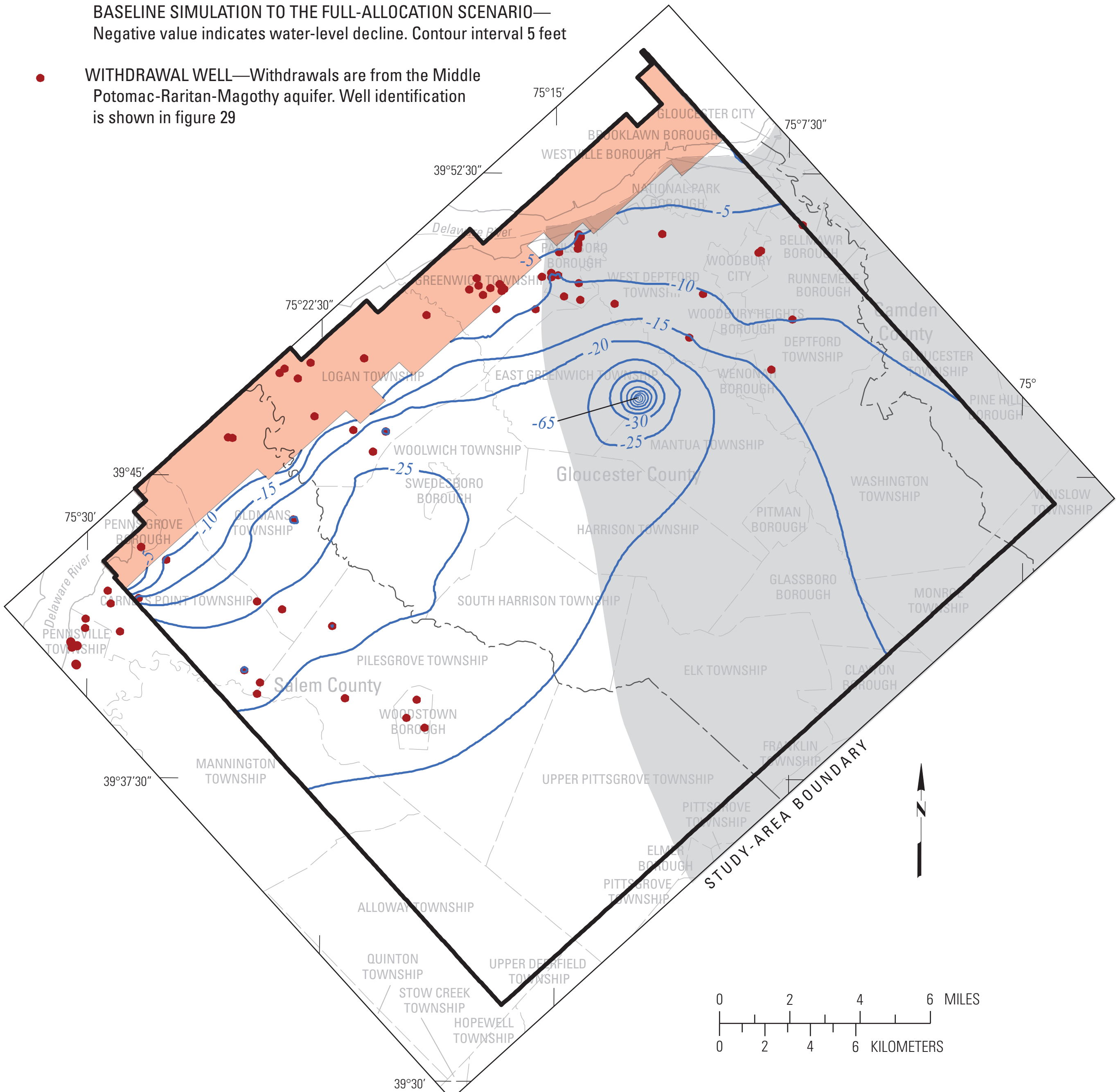
DISCRETIZED OUTCROP AREA OF THE MIDDLE POTOMAC-RARITAN-MAGOTHY AQUIFER

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Middle Potomac-Raritan-Magothy aquifer

-50 LINE OF EQUAL DIFFERENCE IN SIMULATED WATER LEVELS FROM THE 2000 BASELINE SIMULATION TO THE FULL-ALLOCATION SCENARIO—Negative value indicates water-level decline. Contour interval 5 feet

WITHDRAWAL WELL—Withdrawals are from the Middle Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 29



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 31. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

EXPLANATION

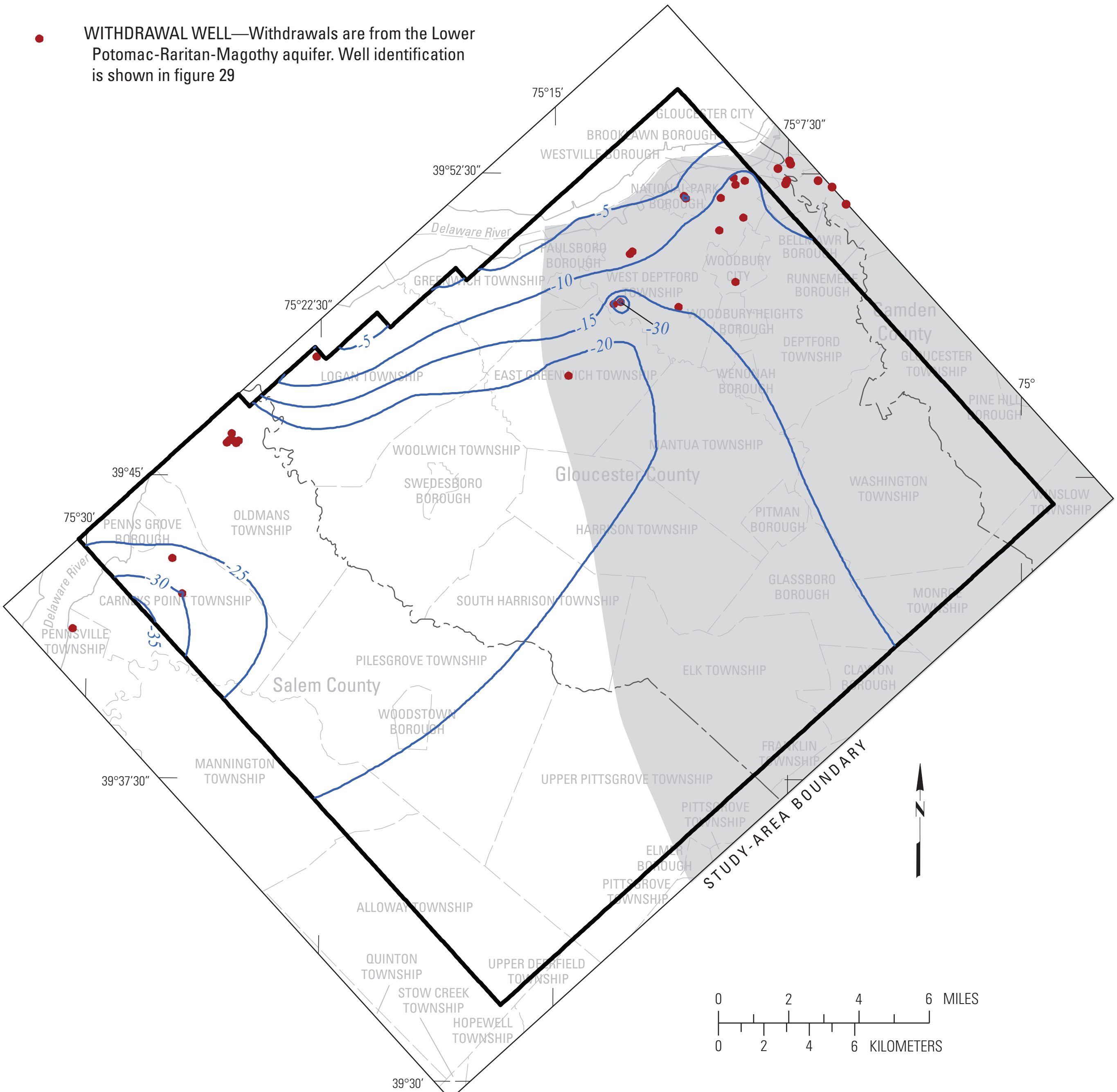
WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Lower Potomac-Raritan-Magothy aquifer

-50 LINE OF EQUAL DIFFERENCE IN SIMULATED WATER LEVELS FROM THE 2000 BASELINE SIMULATION TO THE FULL-ALLOCATION SCENARIO—Negative value indicates water-level decline. Contour interval 5 feet

WITHDRAWAL WELL—Withdrawals are from the Lower Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 29

C



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 31. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

112.9, 123.0, and 118.4 mi[2] in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively (table 12). In the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, the increase in area occurred throughout most of East Greenwich (part of which is in Critical Area 2) and Woolwich Townships and Swedesboro Borough. In the Upper and Middle Potomac-Raritan-Magothy aquifers, the increase in area also occurred in southern Oldmans and Carneys Point and Pilesgrove Townships and Woodstown Borough. In the Lower Potomac-Raritan-Magothy aquifer, the increase in area also is throughout most of Oldmans Township. Most of the increase in area is outside Critical Area 2 (fig. 30). The part of these areas that is within Critical Area 2 is 13.9, 21.2, and 22.7 mi[2] in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively, which is about 12, 17, and 19 percent, respectively, of the total area that increased in size from the 2000 baseline simulation.

The average change in simulated water levels for the model cells along the boundary of Critical Area 2 in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers for the full-allocation scenario is -18.7, -17.7, and -17.4 ft, respectively, from the 2000 baseline simulation (table 13). The largest and smallest changes in simulated water level for the model cells along the boundary of Critical Area 2 for the full-allocation scenario from the 2000 baseline simulation are summarized in table 13.

Simulated withdrawals totaled about 62 percent of outflow (16,567 Mgal/yr) which is an increase of 72 percent (6,923 Mgal/yr) from the 2000 baseline simulation. Simulated groundwater discharge to streams and wetlands

Table 13. Largest, smallest, and average change in simulated water levels along the boundary of Water Supply Critical Area 2 from the 2000 baseline simulation or the adjusted full-allocation scenario to one of the six groundwater-withdrawal scenarios, Salem-Gloucester study area, southern New Jersey.

[Negative value indicates drawdown; <, less than]

Aquifer of the Potomac-Raritan-Magothy aquifer system[1]	Change in simulated water level (feet)		
	Largest	Smallest	Average
From 2000 baseline simulation to full-allocation scenario			
Upper	-23.3	-9.5	-18.7
Middle	-23.3	-2.3	-17.7
Lower	-21.4	-2.7	-17.4
From 2000 baseline simulation to adjusted full-allocation scenario			
Upper	-6.7	-5.3	-6.0
Middle	-6.7	-1.5	-5.9
Lower	-6.7	-1.5	-5.8
From adjusted full-allocation scenario to adjusted full-allocation plus Woolwich request scenario			
Upper	-0.5	-0.1	-0.4
Middle	-0.5	<-0.1	-0.3
Lower	-0.5	<-0.1	-0.4
From adjusted full-allocation scenario to adjusted full-allocation plus all requests scenario			
Upper	-3.5	-1.0	-3.1
Middle	-3.6	-0.2	-3.0
Lower	-3.7	-0.2	-3.0
From adjusted full-allocation scenario to adjusted full-allocation plus adjusted requests scenario			
Upper	-1.7	-0.4	-1.5
Middle	-1.7	-0.1	-1.4
Lower	-1.8	-0.1	-1.4
From 2000 baseline simulation to 2025 scenario			
Upper	-1.9	-0.5	-1.5
Middle	-1.9	-0.1	-1.5
Lower	-1.9	-0.2	-1.6

[1]The number of model cells along the boundary of Critical Area 2 for the confined Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers is 151, 161, and 169, respectively.

is about 23 percent of outflow (6,018 Mgal/yr), 29 percent (2,423 Mgal/yr) less than in the 2000 baseline simulation. Specified flows at bordering hydrogeologic units (including the confined Englishtown aquifer system at the top of the model) account for about 19 percent of inflow (5,165 Mgal/yr) and about 9 percent of outflow (2,334 Mgal/yr), a 27-percent (1,088 Mgal/yr) increase in inflow and a 15-percent (413 Mgal/yr) decrease in outflow from the 2000 baseline simulation. Simulated recharge is about 68 percent of inflow (17,937 Mgal/yr) and was not changed from the 1998 calibration and the 2000 baseline simulations. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (13 percent) and outflow (6 percent) and is a net flow from the Delaware River to the Potomac-Raritan-Magothy aquifer system of about 7 percent (1,816 Mgal/yr), whereas simulated net flow in the 2000 baseline simulation was from the aquifer system to the Delaware River. Simulated flow-budget components for streams and the Delaware River in the local model for the full-allocation scenario are summarized in table 12. All flow-budget values are rounded to the nearest integer.

Adjusted Full-Allocation Scenario

In the adjusted full-allocation scenario, withdrawals from 1 industrial self-supply and 14 agricultural-irrigation wells with substantially smaller withdrawals than permitted were decreased, and withdrawals from 1 agricultural-irrigation well were increased, compared to the full-allocation scenario (table 7). Also, withdrawals from low-volume users were decreased, except withdrawals from one low-volume user remained at the amount simulated in the full-allocation scenario (table 5). Withdrawals used in the adjusted full-allocation scenario are given in tables 4 to 7. Withdrawal wells in the Potomac-Raritan-Magothy aquifer system used in the adjusted full-allocation scenario are shown in figure 32.

Simulated water levels in the confined Upper and Middle and Lower Potomac-Raritan-Magothy aquifers in the adjusted full-allocation scenario are shown in figure 33, and the change in simulated water levels from the 2000 baseline simulation is shown in figure 34. Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer in the adjusted full-allocation scenario range from about 10 ft above NGVD 29 at the northwestern outcrop area of the aquifer to more than 80 ft below NGVD 29 at a small cone of depression centered on a water-purveyor well (15-1365) in Washington Township in Critical Area 2 (fig. 33A). The largest water-level decline from the 2000 baseline simulation was 14 ft at a water-purveyor well (33-920) in Oldmans Township and at an agricultural-irrigation well (33-922) in Pilesgrove Township (fig. 34A). The average simulated water level in the Upper Potomac-Raritan-Magothy aquifer in the full-allocation scenario is 36 ft below NGVD 29, 5 ft lower than in the 2000 baseline simulation (table 12).

Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation scenario are shown in figure 33B and the change in simulated water levels from the 2000 baseline simulation is shown in figure 34B. Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation scenario range from NGVD 29 near the outcrop area of the aquifer to about 60 ft below NGVD 29 in Washington Township and Glassboro Borough in Critical Area 2 (fig. 33B). The largest water-level decline from the 2000 baseline simulation was 14 ft at four industrial self-supply wells located near each other (15-1568, 15-1569, 15-1570, and 15-1571) in Logan Township (fig. 34B). The average simulated water level in the Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation scenario is 32 ft below NGVD 29, 5 ft lower than in the 2000 baseline simulation (table 12).

Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer in the adjusted full-allocation scenario are shown in figure 33C and the change in simulated water levels from the 2000 baseline simulation is shown in figure 34C. Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer in the adjusted full-allocation scenario range from 10 ft below NGVD 29 at the northwestern updip limit of the aquifer to about 60 ft below NGVD 29 in Gloucester Township in Critical Area 2 (fig. 33C). The largest water-level decline from the 2000 baseline scenario was 24 ft at an industrial self-supply well (15-283) in West Deptford Township (fig. 34C). The average simulated water level in the Lower Potomac-Raritan-Magothy for the adjusted full-allocation scenario is 36 ft below NGVD 29, 6 ft lower than in the 2000 baseline simulation (table 12).

The areas in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in which simulated water levels are lower than 30 ft below NGVD 29 in the adjusted full-allocation scenario but above 30 ft below NGVD 29 in the 2000 baseline simulation are shown in figure 33. These areas increased in size from the area in the 2000 baseline simulation by 54.7, 54.6, and 47.8 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively (table 12). In the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, the increase in area occurred throughout southeastern East Greenwich Township in Critical Area 2; northern Harrison Township, part of which is in Critical Area 2; and northern South Harrison Township. In the Upper and Middle Potomac-Raritan-Magothy aquifers, the increase in area also is in southern West Deptford and Pilesgrove Townships and Woodstown Borough. In the Lower Potomac-Raritan-Magothy aquifer, the increase in area is in central West Deptford Township, northern Pilesgrove Township, and Carneys Point Township. Most of the increase in area is outside Critical Area 2 (fig. 33). The part of these areas that is within in Critical Area 2 is 7.0, 8.9, and 13.3 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively, which is about 13, 16, and 28 percent, respectively, of the total area that increased in size from the area in the 2000 baseline simulation.

The average change in simulated water levels for the model cells along the boundary of Critical Area 2 in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy

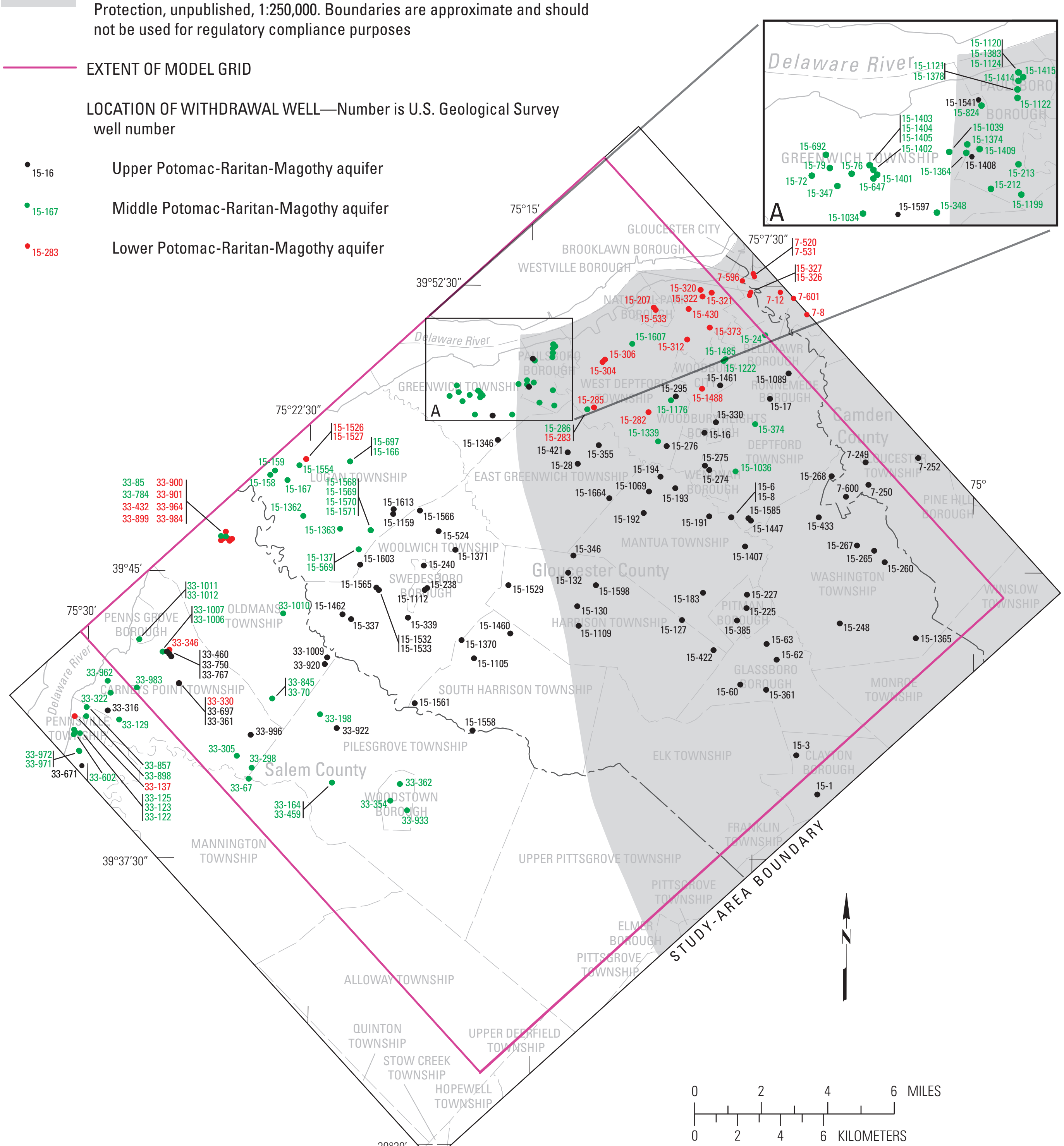
EXPLANATION

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

EXTENT OF MODEL GRID

LOCATION OF WITHDRAWAL WELL—Number is U.S. Geological Survey well number

- 15-16 Upper Potomac-Raritan-Magothy aquifer
- 15-167 Middle Potomac-Raritan-Magothy aquifer
- 15-283 Lower Potomac-Raritan-Magothy aquifer



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 32. Location of withdrawal wells and wells simulated as boundary flows in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers for the adjusted full-allocation scenario and the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.

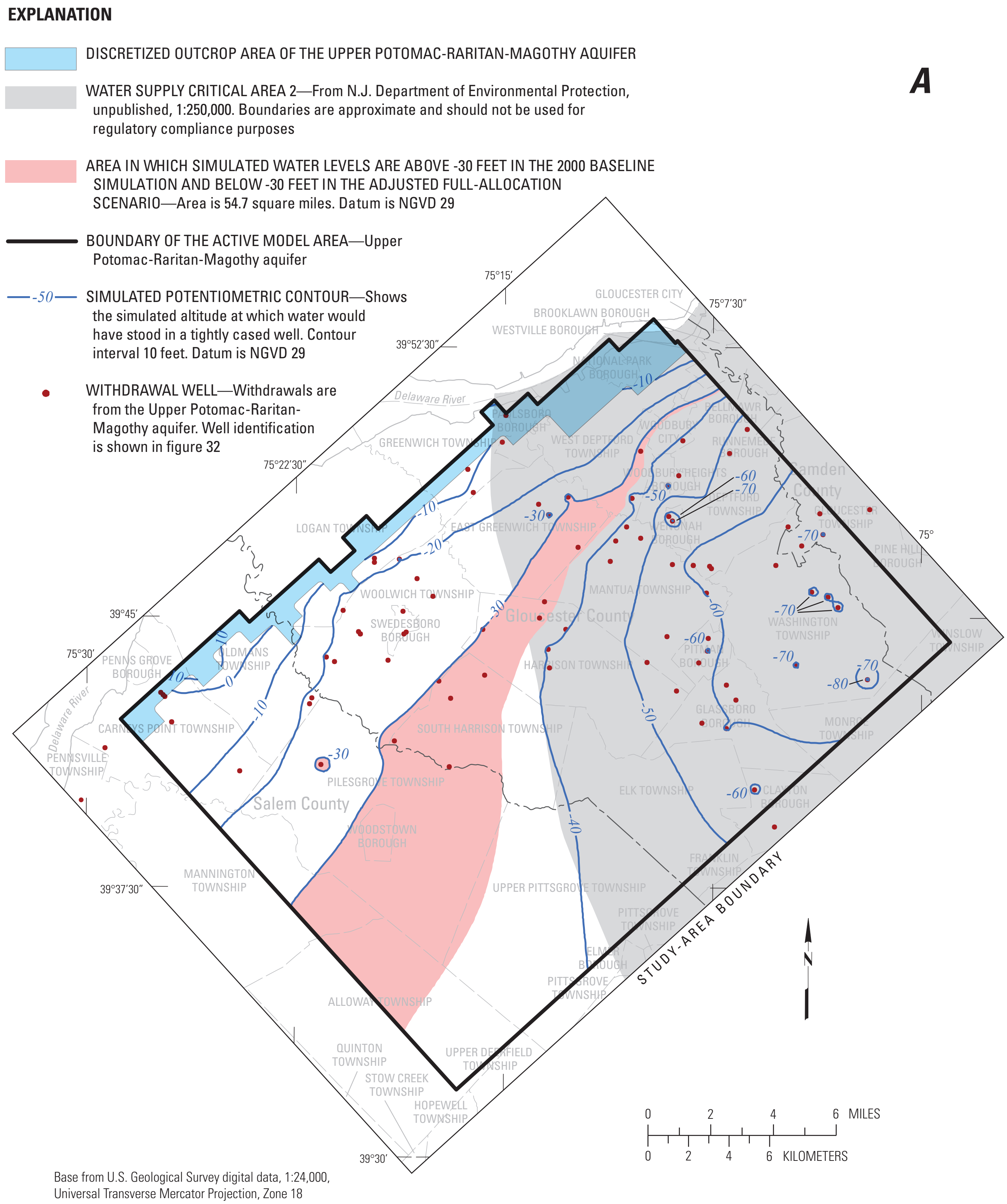


Figure 33. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.

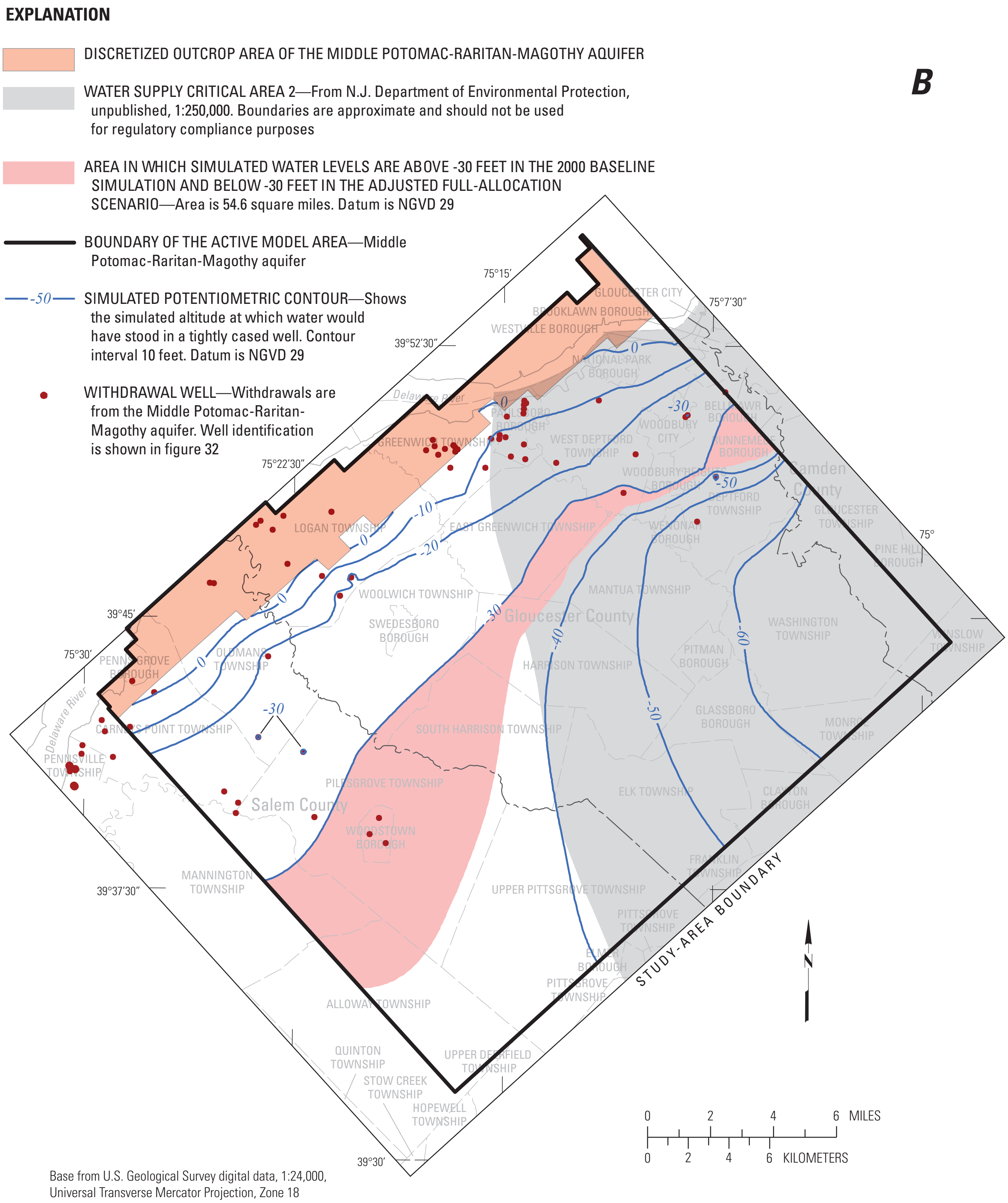


Figure 33. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

EXPLANATION

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

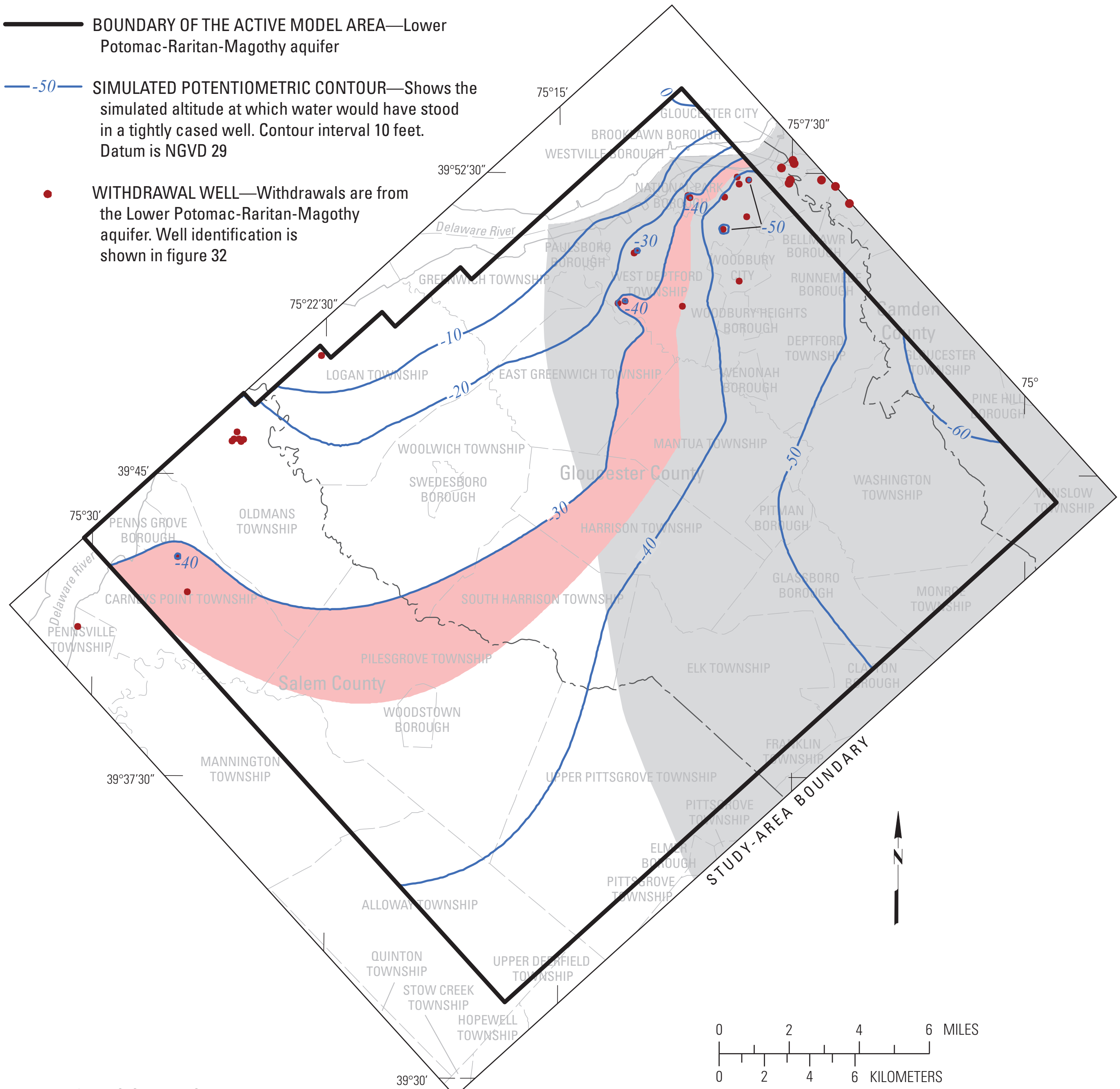
AREA IN WHICH SIMULATED WATER LEVELS ARE ABOVE -30 FEET IN THE 2000 BASELINE SIMULATION AND BELOW -30 FEET IN THE ADJUSTED FULL-ALLOCATION SCENARIO—Area is 47.8 square miles. Datum is NGVD 29

BOUNDARY OF THE ACTIVE MODEL AREA—Lower Potomac-Raritan-Magothy aquifer

-50 SIMULATED POTENTIOMETRIC CONTOUR—Shows the simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

WITHDRAWAL WELL—Withdrawals are from the Lower Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 32

C



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 33. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

EXPLANATION

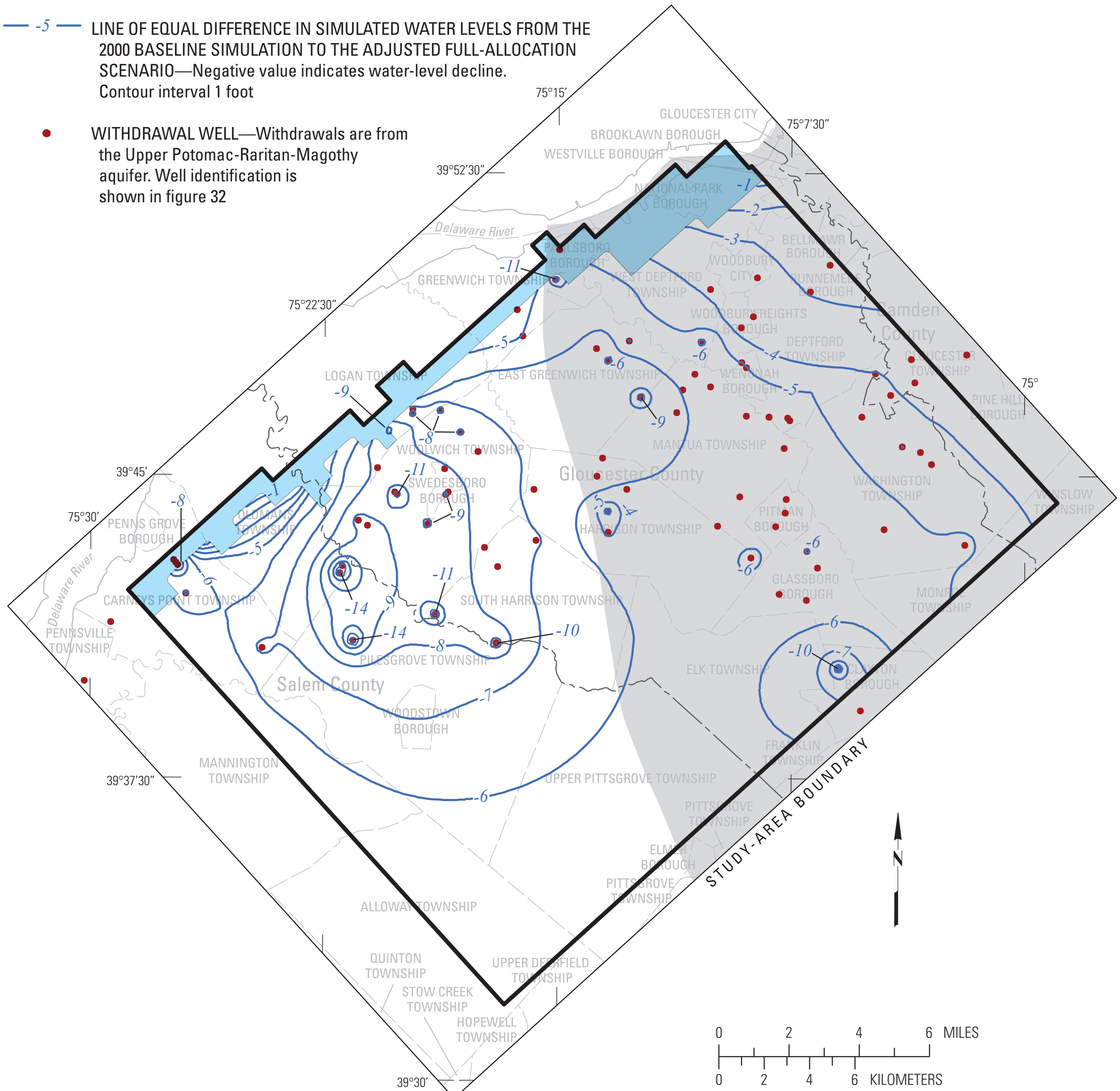
DISCRETIZED OUTCROP AREA OF THE UPPER POTOMAC-RARITAN-MAGOTHY AQUIFER

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Upper Potomac-Raritan-Magothy aquifer

-5 LINE OF EQUAL DIFFERENCE IN SIMULATED WATER LEVELS FROM THE 2000 BASELINE SIMULATION TO THE ADJUSTED FULL-ALLOCATION SCENARIO—Negative value indicates water-level decline. Contour interval 1 foot

WITHDRAWAL WELL—Withdrawals are from the Upper Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 32



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 34. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

DISCRETIZED OUTCROP AREA OF THE MIDDLE POTOMAC-RARITAN-MAGOTHY AQUIFER

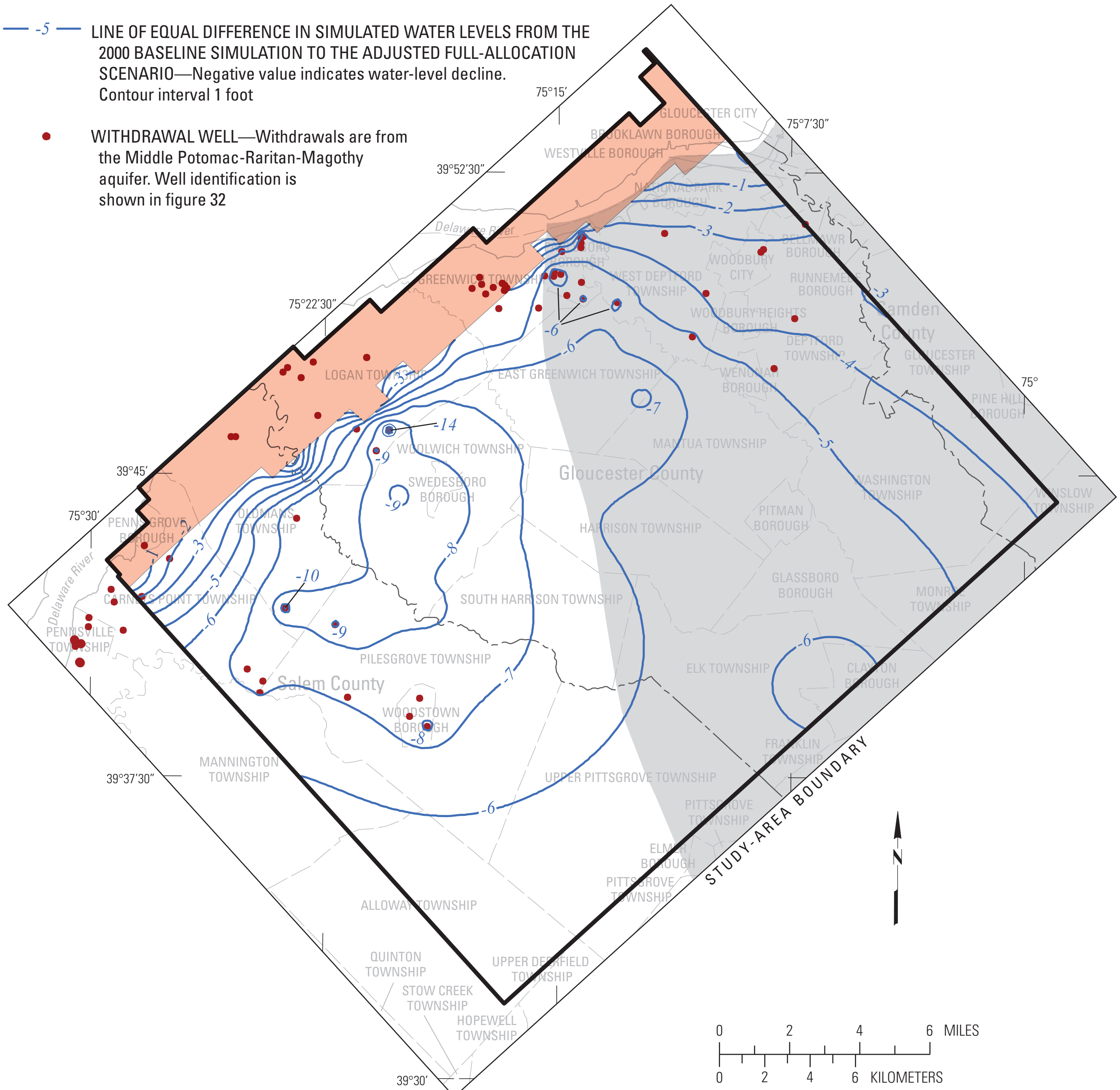
WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Middle Potomac-Raritan-Magothy aquifer

-5 LINE OF EQUAL DIFFERENCE IN SIMULATED WATER LEVELS FROM THE 2000 BASELINE SIMULATION TO THE ADJUSTED FULL-ALLOCATION SCENARIO—Negative value indicates water-level decline. Contour interval 1 foot

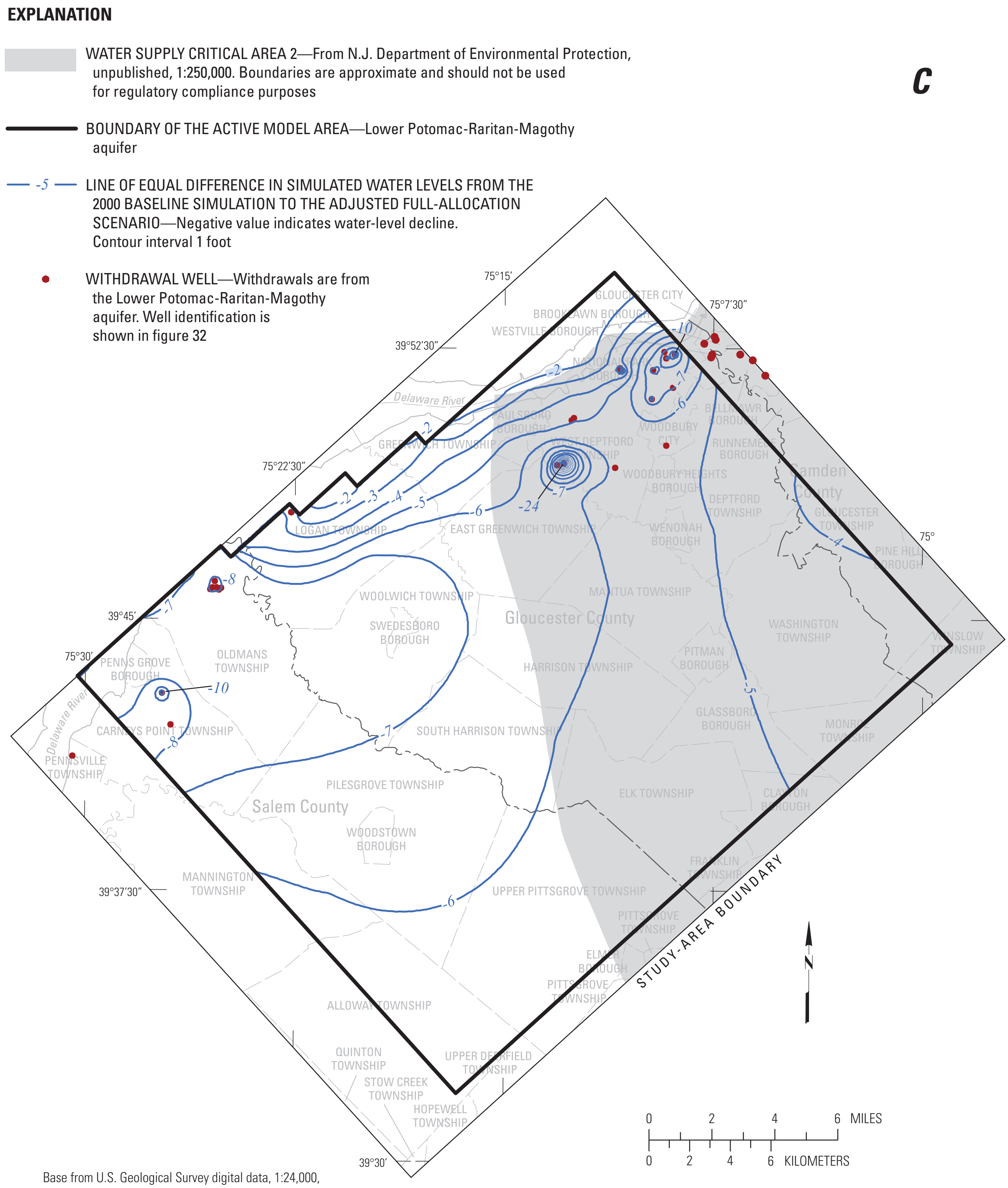
WITHDRAWAL WELL—Withdrawals are from the Middle Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 32

B



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 34. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 34. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.—Continued

aquifers for the adjusted full-allocation scenario is -6.0, -5.9, and -5.8 ft, respectively, from the 2000 baseline simulation (table 13). The largest and smallest changes in simulated water level for the model cells along the boundary of Critical Area 2 for the adjusted full-allocation scenario from the 2000 baseline simulation are summarized in table 13.

Simulated withdrawals totaled about 54 percent of outflow (13,290 Mgal/yr), 38 percent (3,646 Mgal/yr) more than in the 2000 baseline simulation. Simulated groundwater discharge to streams and wetlands is about 29 percent of outflow (7,256 Mgal/yr), 7 percent (1,185 Mgal/yr) less than in the 2000 baseline simulation. Specified flows at bordering hydrogeologic units and the upper boundary of the confined Englishtown aquifer system account for about 18 percent of inflow (4,473 Mgal/yr) and about 10 percent of outflow (2,378 Mgal/yr), which is about a 10-percent (396 Mgal/yr) increase in inflow and about a 13-percent (369 Mgal/yr) decrease in outflow from the 2000 baseline simulation. Simulated recharge is about 72 percent of inflow (17,937 Mgal/yr) and was not changed from the 1998 calibration and 2000 baseline simulations. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (10 percent) and outflow (7 percent) and is a net flow from the Delaware River to the Potomac-Raritan-Magothy aquifer system of about 3 percent (513 Mgal/yr), whereas simulated net flow in the 2000 baseline simulation was from the aquifer system to the Delaware River. Simulated flow-budget components for streams and the Delaware River in the local model for the adjusted full-allocation scenario are summarized in table 12. All flow-budget values are rounded to the nearest integer.

Adjusted Full-Allocation plus Woolwich Request Scenario

The adjusted full-allocation plus Woolwich request scenario was used to evaluate the effects of additional withdrawals in Woolwich Township on simulated water levels. The withdrawals for this scenario are the same as those used in the adjusted full-allocation scenario, except for withdrawals from one water-purveyor with two wells screened in the Upper Potomac-Raritan-Magothy aquifer in Woolwich Township: withdrawals from these wells were increased by 108.5 Mgal/yr (table 5). Withdrawal wells in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers used in the adjusted full-allocation plus Woolwich request scenario are shown in figure 32.

Simulated water levels in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers in the adjusted full-allocation plus Woolwich request scenario are shown in figure 35, and the changes in simulated water levels from the adjusted full-allocation scenario are shown in figure 36. Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer (fig. 35A) were similar to those in the adjusted full-allocation scenario, except in the Woolwich Township area. A small cone of depression developed in this aquifer around two water-purveyor wells (15-1532 and 15-1533) in Woolwich Township. When compared to the adjusted full-allocation scenario, simulated water levels in the Upper Potomac-Raritan-Magothy aquifer around these wells declined about 4 ft (fig. 36A), whereas simulated water levels in the Middle Potomac-Raritan-Magothy aquifer declined about 2 ft (fig. 36B), and simulated water levels in the Lower Potomac-Raritan-Magothy aquifers declined about 0.5 ft (fig. 36C).

Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 37, 33, and 36 ft below NGVD 29, respectively, which are 1, 1, and 0 ft lower, respectively, than in the adjusted full-allocation scenario (table 12). The areas in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in which simulated water levels are lower than 30 ft below NGVD 29 in the adjusted full-allocation plus Woolwich request scenario but above 30 ft below NGVD 29 in the adjusted full-allocation scenario are shown in figure 35. These areas increased in size from the area in the adjusted full-allocation scenario by 2.8, 3.3, and 2.9 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively (table 12). The part of these areas that increased in size that is within Critical Area 2 increased by 0.5, 0.6, and 0.7 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively, which is about 18, 18, and 24 percent, respectively, of the total area that increased in size from the area in the adjusted full-allocation scenario.

The average change in simulated water levels for the model cells along the boundary of Critical Area 2 in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers for the adjusted full-allocation plus Woolwich request scenario is -0.4, -0.3, and -0.4 ft, respectively, from the adjusted full-allocation scenario (table 13). The largest and smallest changes in simulated water level for the model cells along the boundary of Critical Area 2 for the adjusted full-allocation plus Woolwich request scenario from the adjusted full-allocation scenario are summarized in table 13.

Simulated withdrawals totaled about 54 percent of outflow (13,399 Mgal/yr), which is less than 1 percent (109 Mgal/yr) more than in the adjusted full-allocation scenario. Simulated groundwater discharge to streams and wetlands is about 29 percent of outflow (7,209 Mgal/yr), which is less than 1 percent (47 Mgal/yr) less than in the adjusted full-allocation scenario. Specified flows from bordering hydrogeologic units outside the model area and the upper boundary of the confined Englishtown aquifer system account for about 18 percent of inflow (4,491 Mgal/yr) and about 10 percent of outflow (2,362 Mgal/yr), which is similar to that simulated in the adjusted full-allocation scenario. Recharge is 72 percent of inflow (17,937 Mgal/yr) and was not changed from the 1998 calibration and the 2000 baseline simulations. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (10 percent), and outflow (7 percent) and is a net flow from the Delaware River to

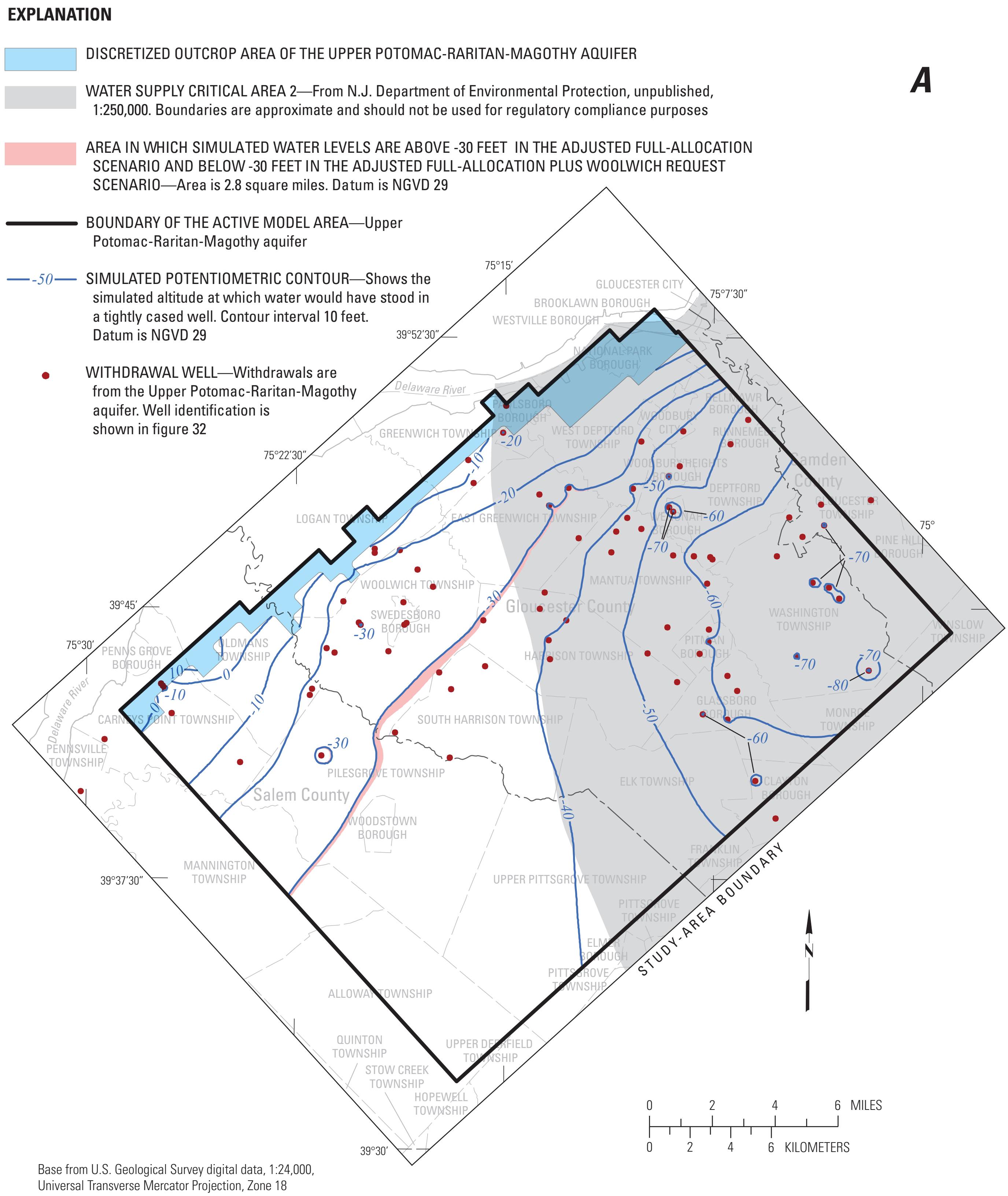


Figure 35. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.

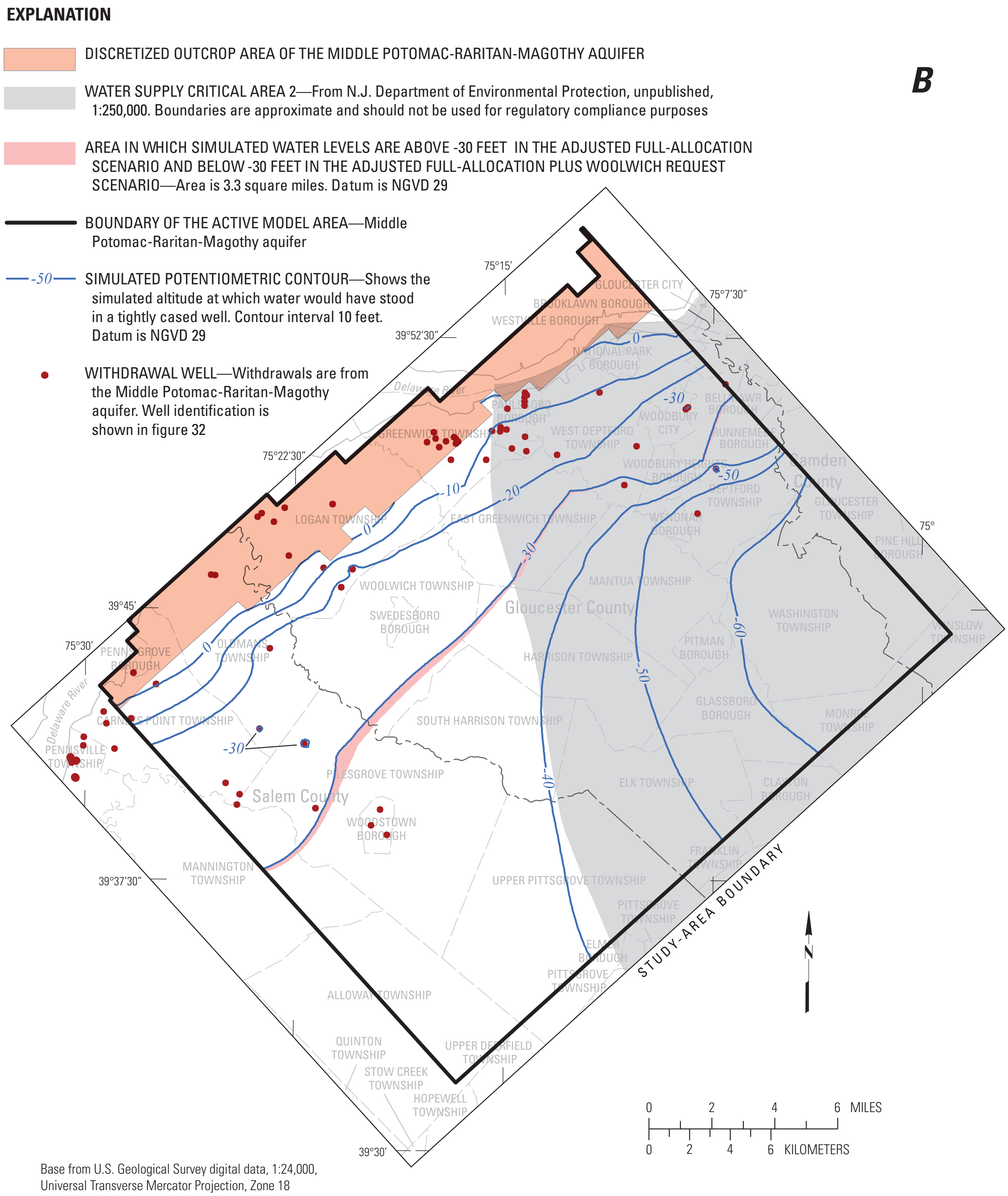


Figure 35. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.—Continued

EXPLANATION

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

AREA IN WHICH SIMULATED WATER LEVELS ARE ABOVE -30 FEET IN THE ADJUSTED FULL-ALLOCATION SCENARIO AND BELOW -30 FEET IN THE ADJUSTED FULL-ALLOCATION PLUS WOOLWICH REQUEST SCENARIO—Area is 2.9 square miles. Datum is NGVD 29

BOUNDARY OF THE ACTIVE MODEL AREA—Lower Potomac-Raritan-Magothy aquifer

-50 SIMULATED POTENTIOMETRIC CONTOUR—Shows the simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

WITHDRAWAL WELL—Withdrawals are from the Lower Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 32

C

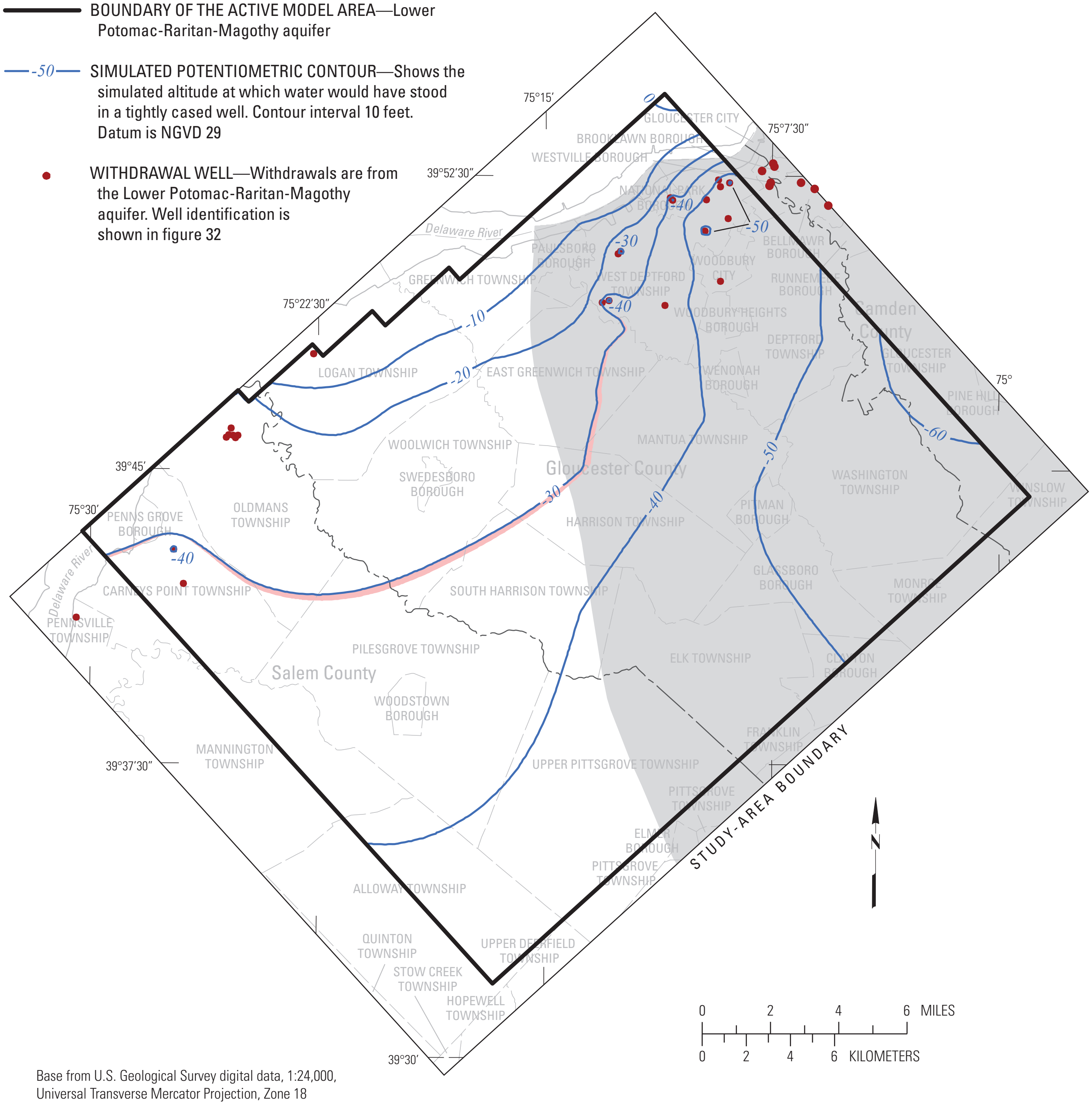


Figure 35. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.—Continued

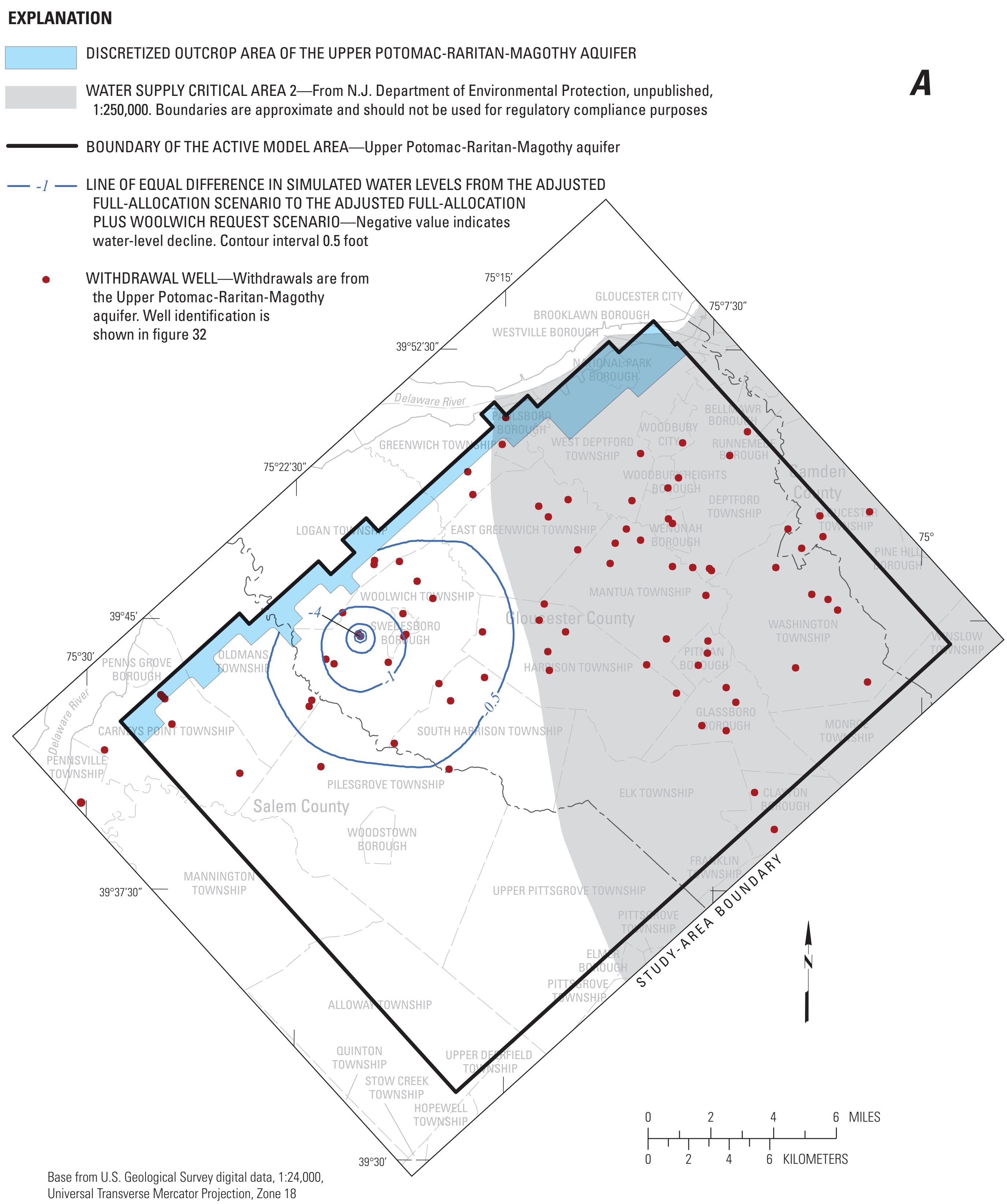


Figure 36. Change in simulated levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

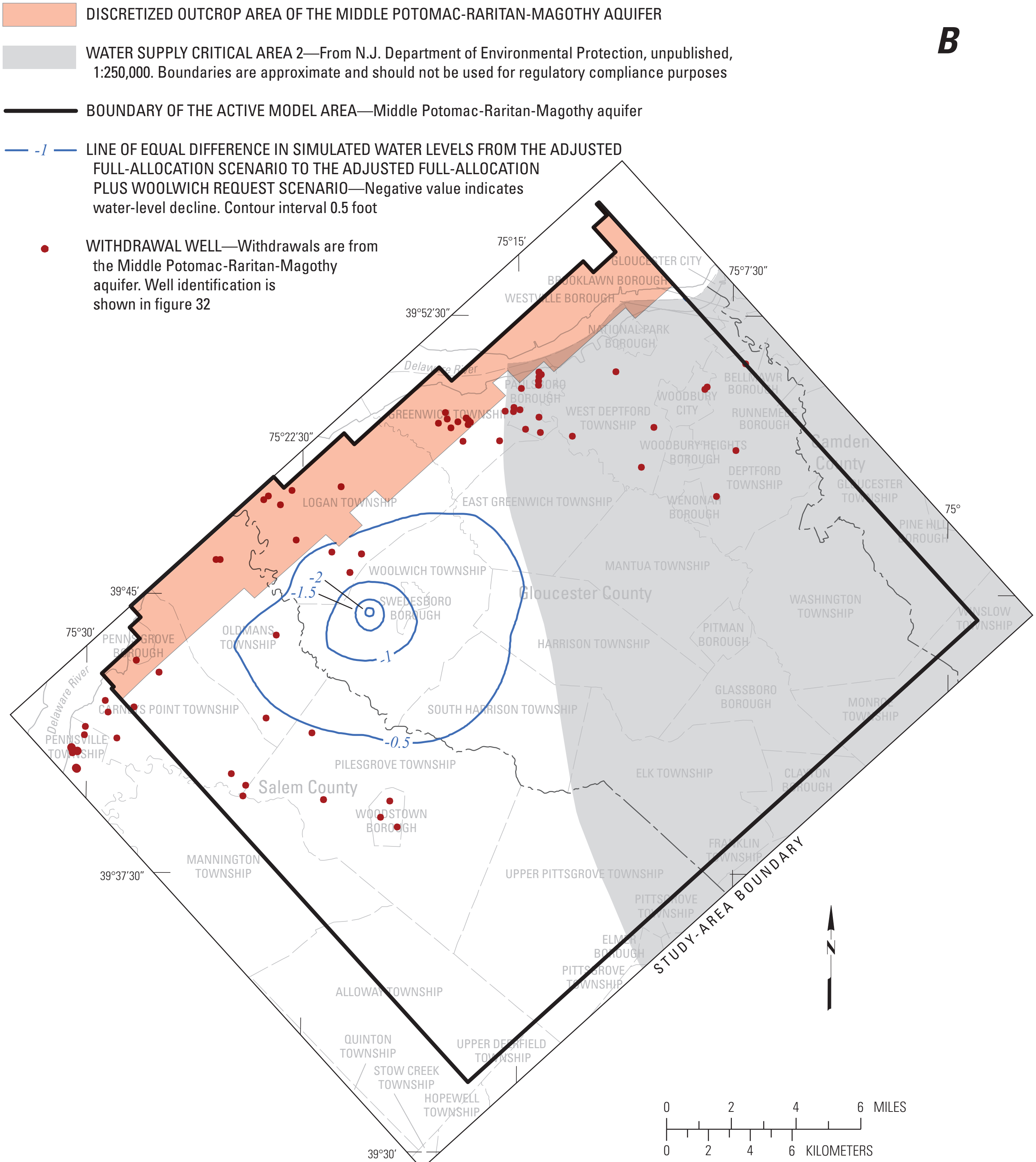
DISCRETIZED OUTCROP AREA OF THE MIDDLE POTOMAC-RARITAN-MAGOTHY AQUIFER

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Middle Potomac-Raritan-Magothy aquifer

-1 LINE OF EQUAL DIFFERENCE IN SIMULATED WATER LEVELS FROM THE ADJUSTED FULL-ALLOCATION SCENARIO TO THE ADJUSTED FULL-ALLOCATION PLUS WOOLWICH REQUEST SCENARIO—Negative value indicates water-level decline. Contour interval 0.5 foot

WITHDRAWAL WELL—Withdrawals are from the Middle Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 32



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 36. Change in simulated levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.—Continued

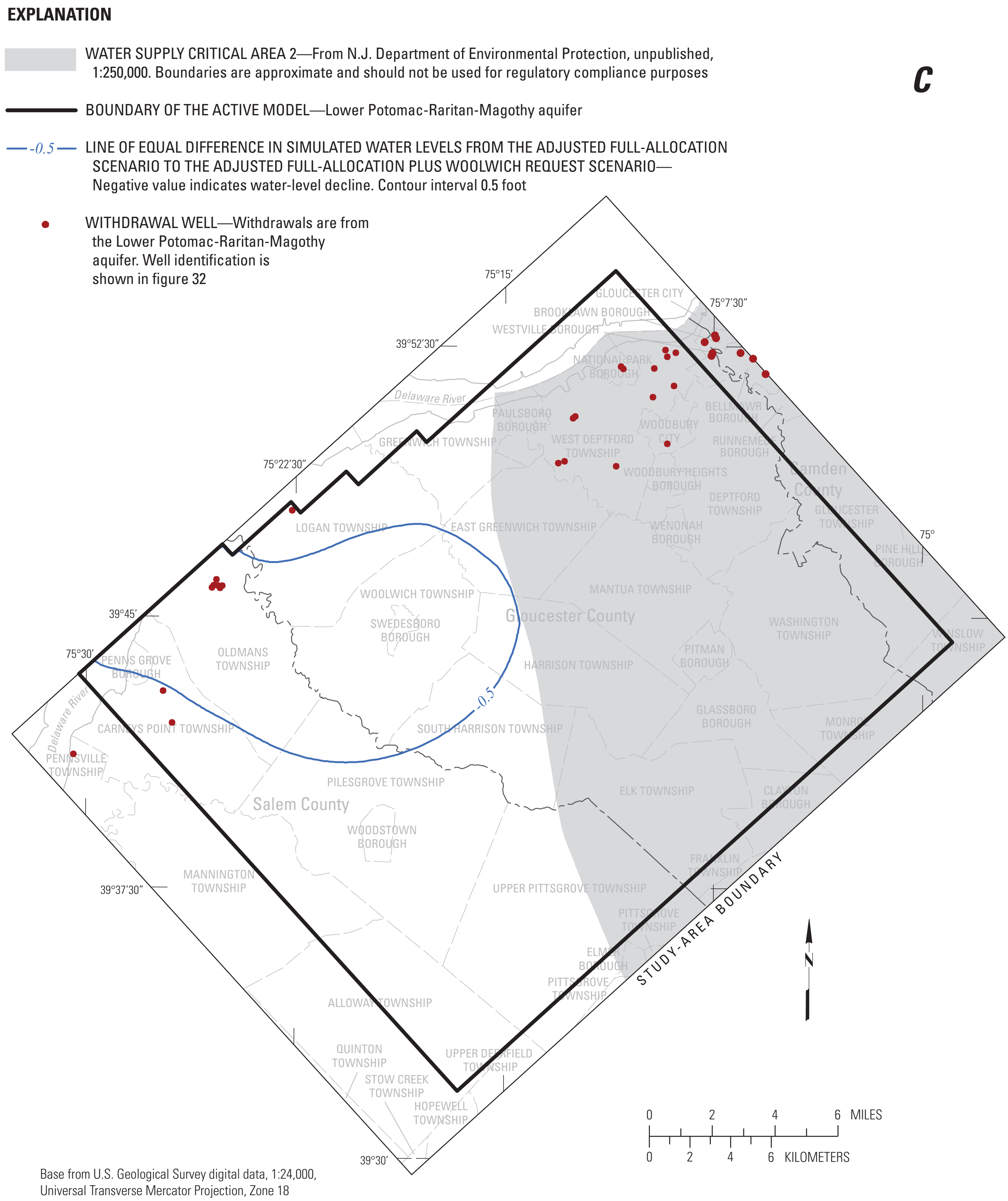


Figure 36. Change in simulated levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus Woolwich request scenario, Salem-Gloucester study area, southern New Jersey.—Continued

the Potomac-Raritan-Magothy aquifer system of more than 2 percent (541 Mgal/yr), which is similar to that simulated in the adjusted full-allocation scenario (513 Mgal/yr). Simulated flow-budget components for streams and the Delaware River in the local model for the adjusted full-allocation plus Woolwich request scenario are summarized in table 12. All flow-budget values are rounded to the nearest integer.

Adjusted Full-Allocation plus All Requests Scenario

This scenario was developed with assistance from the NJDEP BWA to evaluate the effects of withdrawals associated with pending water-allocation permit requests. Increased withdrawal rates were simulated for four municipalities—Carneys Point Township in Salem County and Greenwich, Logan, and Woolwich Townships in Gloucester County—and for six agricultural-irrigation users in East Greenwich, South Harrison, and Woolwich Townships in Gloucester County and Mannington and Pilesgrove Townships in Salem County (tables 5 and 7). The total withdrawals from wells associated with the four municipalities and six agricultural-irrigation users for this scenario, along with two other water purveyors, and two industrial self-supply users and one agricultural-irrigation user are summarized in table 14. Withdrawals for all other wells in tables 4 to 7 are the same as those in the adjusted full-allocation scenario. Withdrawal wells in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in the adjusted full-allocation plus all requests scenario are shown in figure 37.

Simulated water levels in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers in the adjusted full-allocation plus all requests scenario are shown in figure 38, and the change in simulated water levels from the adjusted full-allocation scenario is shown in figure 39. Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus all requests scenario range from about 10 ft above NGVD 29 in Oldmans Township at the outcrop area of the aquifer to 80 ft below NGVD 29 at a small cone of depression around a water-purveyor well (15-1365) in Washington Township in Critical Area 2 (fig. 38A). Three other cones of depression not observed in the adjusted full-allocation scenario are observed in Carneys Point Township, around two water-purveyor wells (33-361 and 33-697); in South Harrison Township, centered on an agricultural-irrigation well (15-1558); and in Pilesgrove Township, around two agricultural-irrigation wells (33-997 and 33-998). The largest water-level declines from the adjusted full-allocation scenario were 26 ft and 25 ft in Pilesgrove Township around two agricultural-irrigation wells (33-998 and 33-997, respectively) and 23 ft in Carneys Point Township at the updip limit of the confined aquifer near two water-purveyor wells (33-460 and 33-767) (fig. 39A). Other substantial water-level declines were 15 ft in Carneys Point Township around two water-purveyor wells (33-361 and 33-697), and 14 ft in Woolwich Township around a water-purveyor well (15-1532). The average simulated water level in the Upper Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus all requests scenario is 40 below NGVD 29, 4 ft lower than in the adjusted full-allocation scenario (table 12).

Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus all requests scenario range from NGVD 29 in Oldmans and Carney Point Townships in the northwestern outcrop area of the aquifer to about 60 ft below NGVD 29 in eastern part of the model area in Critical Area 2 (fig. 38B). A cone of depression not observed in the adjusted full-allocation scenario developed around two water-purveyor wells (33-354 and 33-933) in Woodstown Borough. Although withdrawals were not increased at these wells, withdrawals were increased at three agricultural-irrigation wells (33-922, 33-997, and 33-998) farther updip in Pilesgrove Township; this change probably altered flow patterns downdip near the wells in Woodstown Borough. Another cone of depression is observed around a water-purveyor well (15-1036) in Deptford Township. The largest simulated water-level declines from the adjusted full-allocation scenario were 9 ft in Woolwich Township, as a result of withdrawals from the overlying Upper Potomac-Raritan-Magothy aquifer, and in Pilesgrove and Mannington Townships near the model boundary, as a result of increased withdrawals from agricultural-irrigation wells (33-997, 33-998, and 33-1008) screened in the overlying Upper Potomac-Raritan-Magothy aquifer in these townships (fig. 39B). The agricultural-irrigation well located in Mannington Township (33-1008) is located outside the model; therefore, increased withdrawals from this well are accounted for in the boundary conditions. The average simulated water level in the Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus all requests scenario is 35 below NGVD 29, 3 ft lower than in the adjusted full-allocation scenario (table 12).

Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus all requests scenario range from about 10 below NGVD 29 at the northwestern updip limit of the aquifer to about 60 ft below NGVD 29 in Washington and Gloucester Townships in Critical Area 2 (fig. 38C). When compared with the simulated water levels in the adjusted full-allocation scenario (fig. 33C), a cone of depression around two industrial self-supply wells (33-900 and 33-964) is observed in Oldmans Township. The largest simulated water-level decline from the adjusted full-allocation scenario was 16 ft around a water-purveyor well (33-346) in Carneys Point Township (fig. 39C). The average simulated water in the Lower Potomac-Raritan-Magothy aquifer level in the adjusted full-allocation plus all requests scenario is 39 below NGVD 29, 3 ft lower than in the adjusted full-allocation scenario (table 12).

The areas in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in which simulated water levels are lower than 30 ft below NGVD 29 in the adjusted full-allocation plus all requests scenario but above 30 ft below

Table 14. Summary of simulated groundwater withdrawals for selected water-allocation permit numbers, Salem-Gloucester study area, southern New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	Municipality	Number of pumped wells in model	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total simulated withdrawals							
				1998 calibration simulation	2000 baseline simulation[1]	Full-allocation scenario	Adjusted full-allocation scenario	Adjusted full-allocation plus Woolwich request scenario	Adjusted full-allocation plus all requests scenario	Adjusted full-allocation plus adjusted requests scenario	2025 scenario
				Water-purveyor							
5003	Logan Twp	4	Middle	307.070	278.119	392.001	392.001	392.001	500.000	449.999	320.810
5167	Woodstown Boro	3	Middle	125.110	76.405	119.401	119.401	119.401	119.401	119.401	102.946
5183	Harrison Twp	4	Upper	236.790	[2]243.620	123.000	123.000	123.000	123.000	123.000	123.000
5253	Greenwich Twp	3	Middle	351.350	328.221	348.000	348.000	348.000	430.000	348.000	328.221
5328	Carneys Point Twp	7	Upper and Lower	478.680	491.141	629.999	629.999	629.999	1,000.000	820.000	494.113
5383	Woolwich Twp	2	Upper	0.000	[3]18.020	116.500	116.500	225.000	399.000	225.000	419.038
				Industrial self-supply							
[4]2122P	Carneys Point Twp	16	Upper, Middle, and Lower	674.750	764.728	5,078.761	1,500.000	1,500.000	1,500.000	1,500.000	764.728
2166P	Oldmans Twp	4	Middle and Lower	289.320	294.173	525.600	525.600	525.600	525.600	525.600	294.173
				Agricultural-irrigation							
GL0107	Woolwich Twp	2	Upper	16.500	[5]10.888	[6]368.000	12.000	12.000	24.000	24.000	10.888
GL0127	East Greenwich Twp	2	Upper	0.850	[7]1.240	[6]1,500.000	64.000	64.000	100.000	100.000	1.240
GL0146	South Harrison Twp	1	Upper	0.000	0.000	0.000	0.000	0.000	18.000	18.000	0.000
SA0121	Mannington Twp	1	Upper	0.000	0.000	0.000	0.000	0.000	54.000	0.000	0.000
SA0124	Pilesgrove Twp	1	Upper	[8]43.200	[9]47.820	97.800	97.800	97.800	150.000	83.333	47.820
SA0139	Pilesgrove Twp	2	Upper	[8]0.000	[9]0.000	0.000	0.000	0.000	300.000	166.666	0.000
SA0166	Carneys Point Twp	1	Upper	0.000	0.000	14.700	14.700	14.700	14.700	14.700	0.000
Total				**2,523.620**	**2,554.385**	**9,313.762**	**3,943.001**	**4,051.501**	**5,257.701**	**4,517.699**	**2,906.977**

[1]The 2000 baseline simulation withdrawals are the average annual withdrawals from 1999 to 2001, unless otherwise noted.

[2]The 2000 baseline simulation withdrawals are estimated to equal 2001 withdrawals only.

[3]The 2000 baseline simulation withdrawals are estimated to equal 2000 withdrawals only.

[4]One well is in Mannington Township and four wells are in Pennsville Township.

[5]Withdrawals are the average annual withdrawals from 2001 to 2003.

[6]Allocation is an estimated maximum withdrawal from groundwater, based on historical use and pump capacity.

[7]Withdrawals are the average annual withdrawals from 1994 to 2000.

[8]Withdrawals are estimated to equal 1997 withdrawals only.

[9]Withdrawals are the average annual withdrawals for 1997, 2001, and 2002.

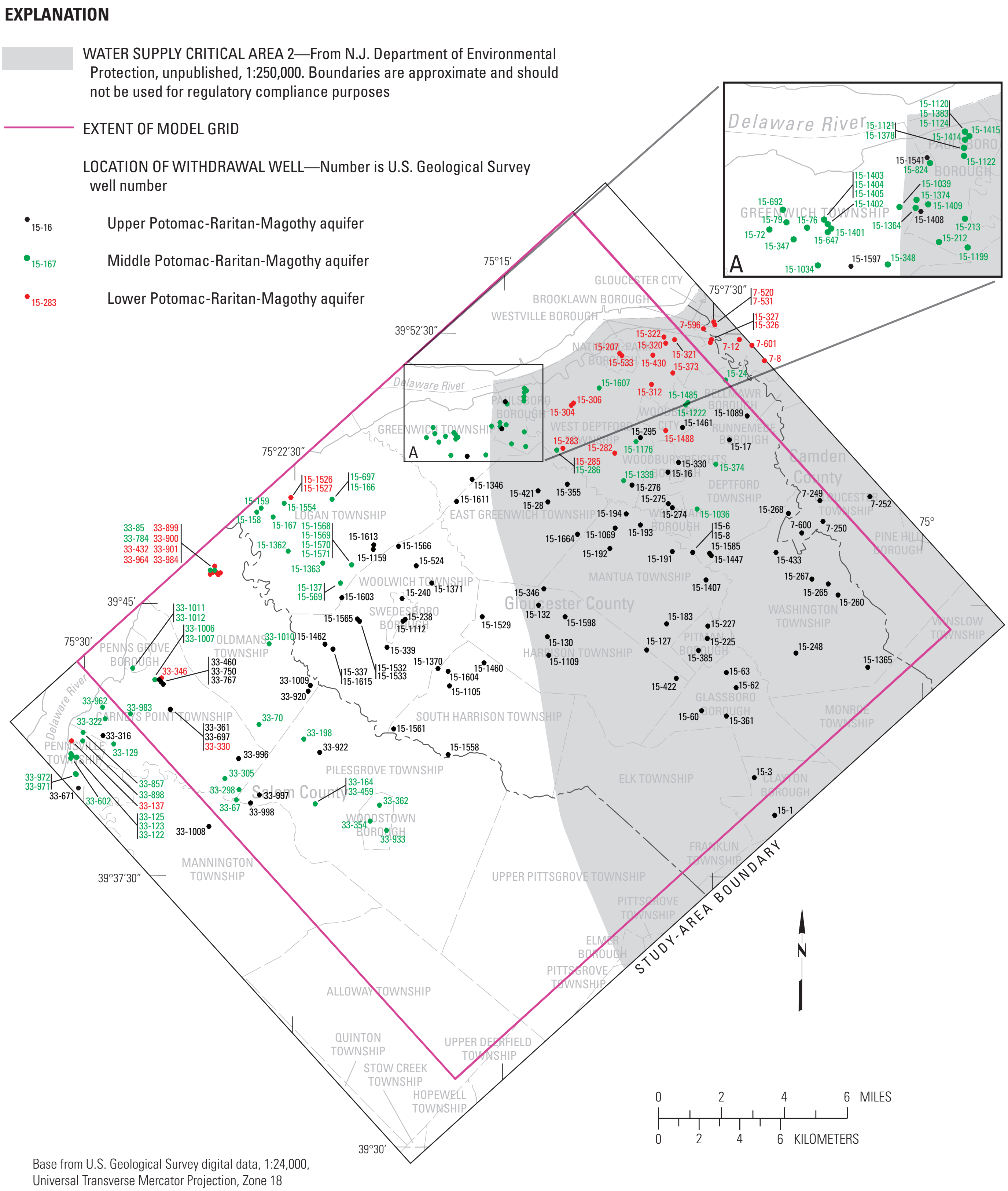


Figure 37. Location of withdrawal wells and wells simulated as boundary flows in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers for the adjusted full-allocation plus all requests scenario and the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.

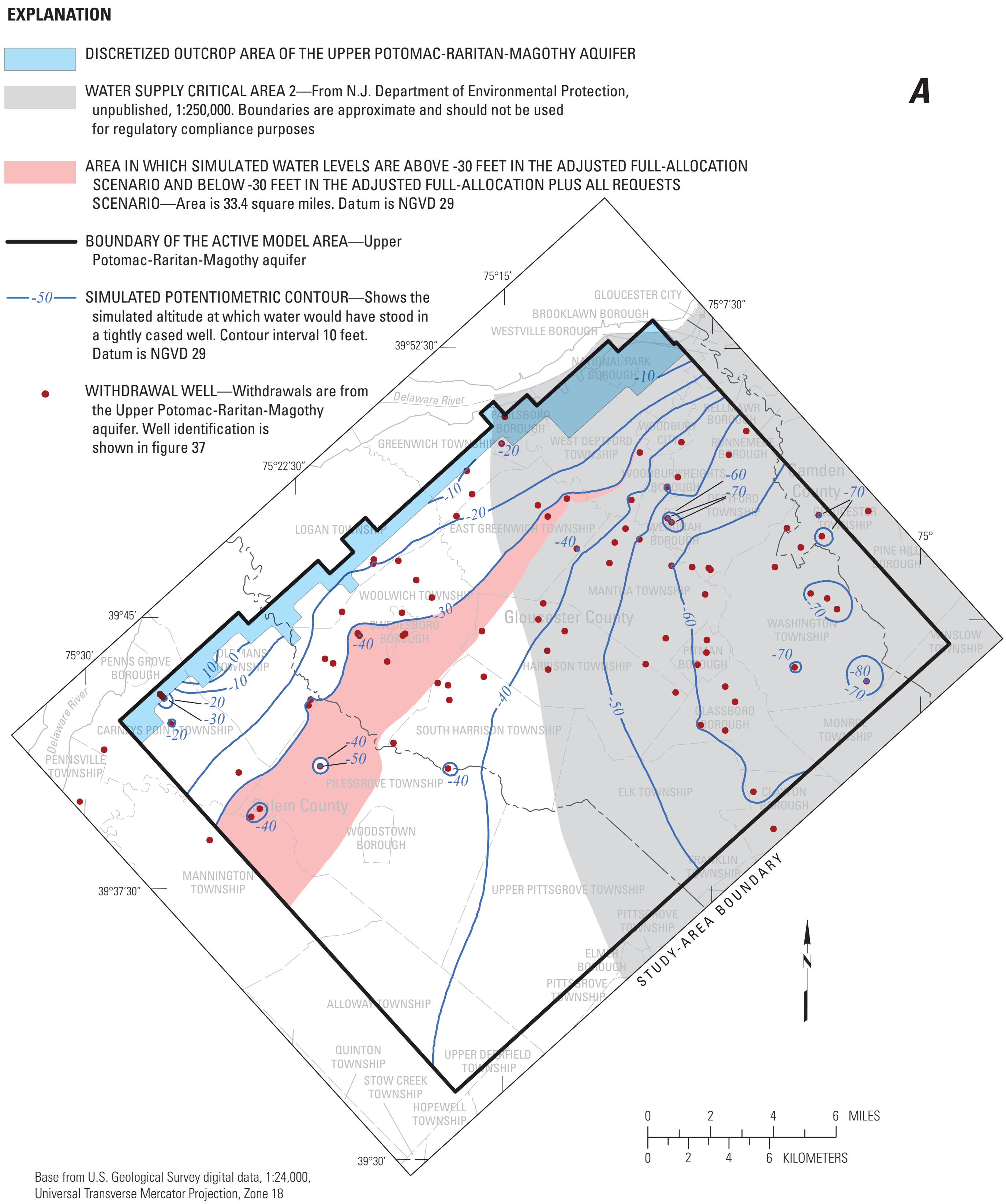


Figure 38. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus all requests scenario, Salem-Gloucester study area, southern New Jersey.

EXPLANATION

DISCRETIZED OUTCROP AREA OF THE MIDDLE POTOMAC-RARITAN-MAGOTHY AQUIFER

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

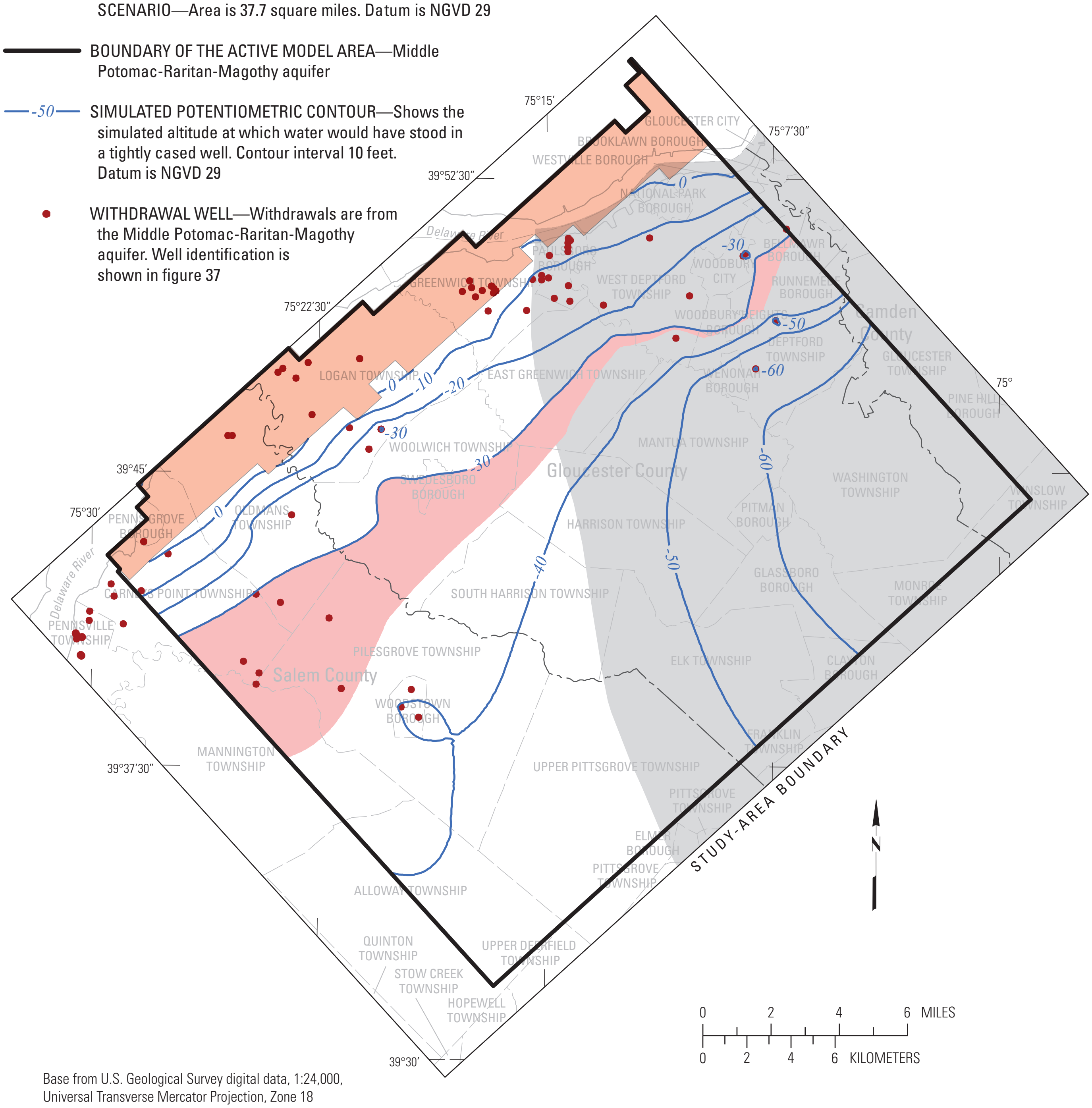
AREA IN WHICH SIMULATED WATER LEVELS ARE ABOVE -30 FEET IN THE ADJUSTED FULL-ALLOCATION SCENARIO AND BELOW -30 FEET IN THE ADJUSTED FULL-ALLOCATION PLUS ALL REQUESTS SCENARIO—Area is 37.7 square miles. Datum is NGVD 29

BOUNDARY OF THE ACTIVE MODEL AREA—Middle Potomac-Raritan-Magothy aquifer

-50 SIMULATED POTENTIOMETRIC CONTOUR—Shows the simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

WITHDRAWAL WELL—Withdrawals are from the Middle Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 37

B



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 38. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus all requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

EXPLANATION

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

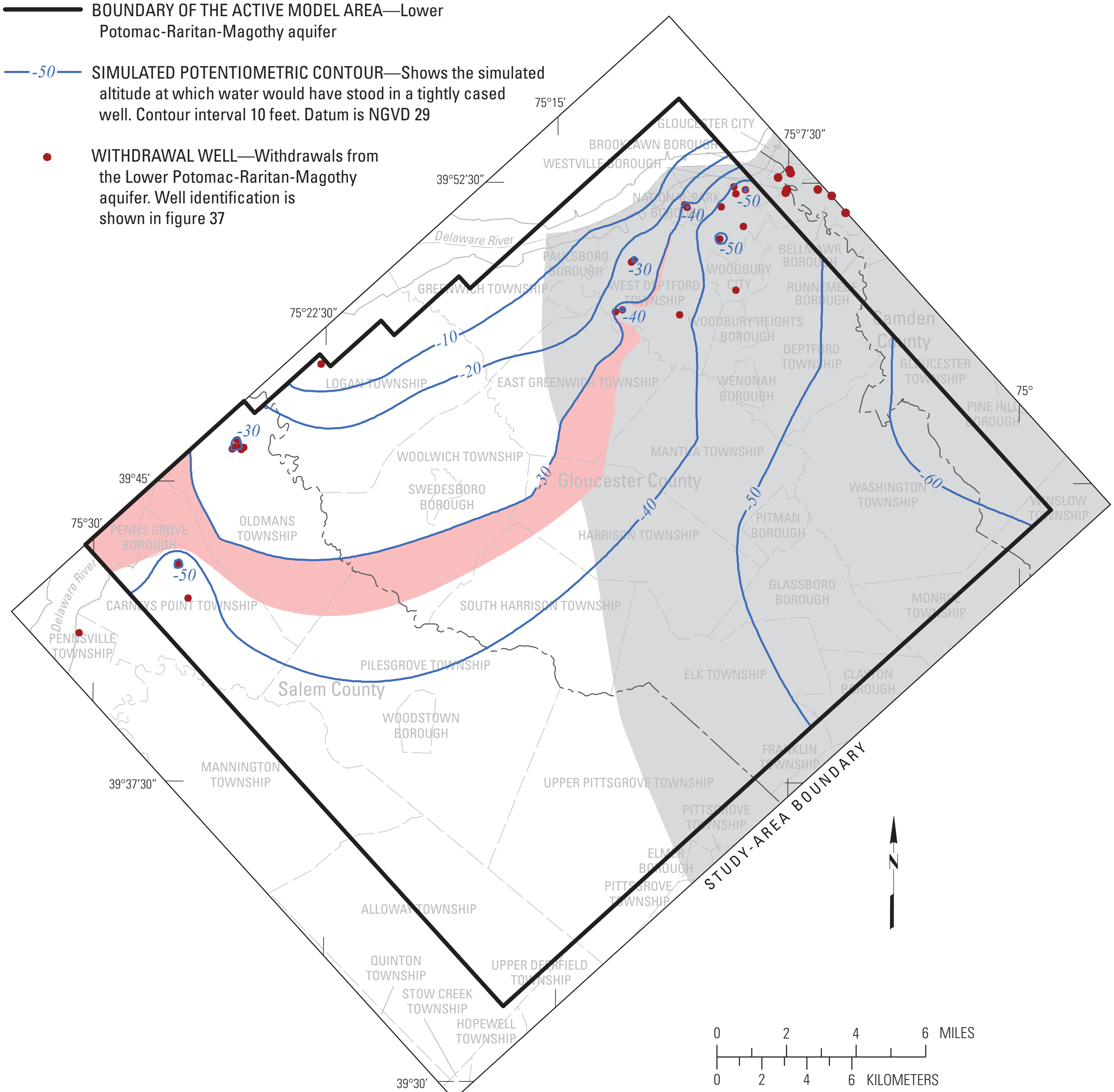
AREA IN WHICH SIMULATED WATER LEVELS ARE ABOVE -30 FEET IN THE ADJUSTED FULL-ALLOCATION SCENARIO AND BELOW -30 FEET IN THE ADJUSTED FULL-ALLOCATION PLUS ALL REQUESTS SCENARIO— Area is 27.0 square miles. Datum is NGVD 29

BOUNDARY OF THE ACTIVE MODEL AREA—Lower Potomac-Raritan-Magothy aquifer

-50 SIMULATED POTENTIOMETRIC CONTOUR—Shows the simulated altitude at which water would have stood in a tightly cased well. Contour interval 10 feet. Datum is NGVD 29

WITHDRAWAL WELL—Withdrawals from the Lower Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 37

C



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 38. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus all requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

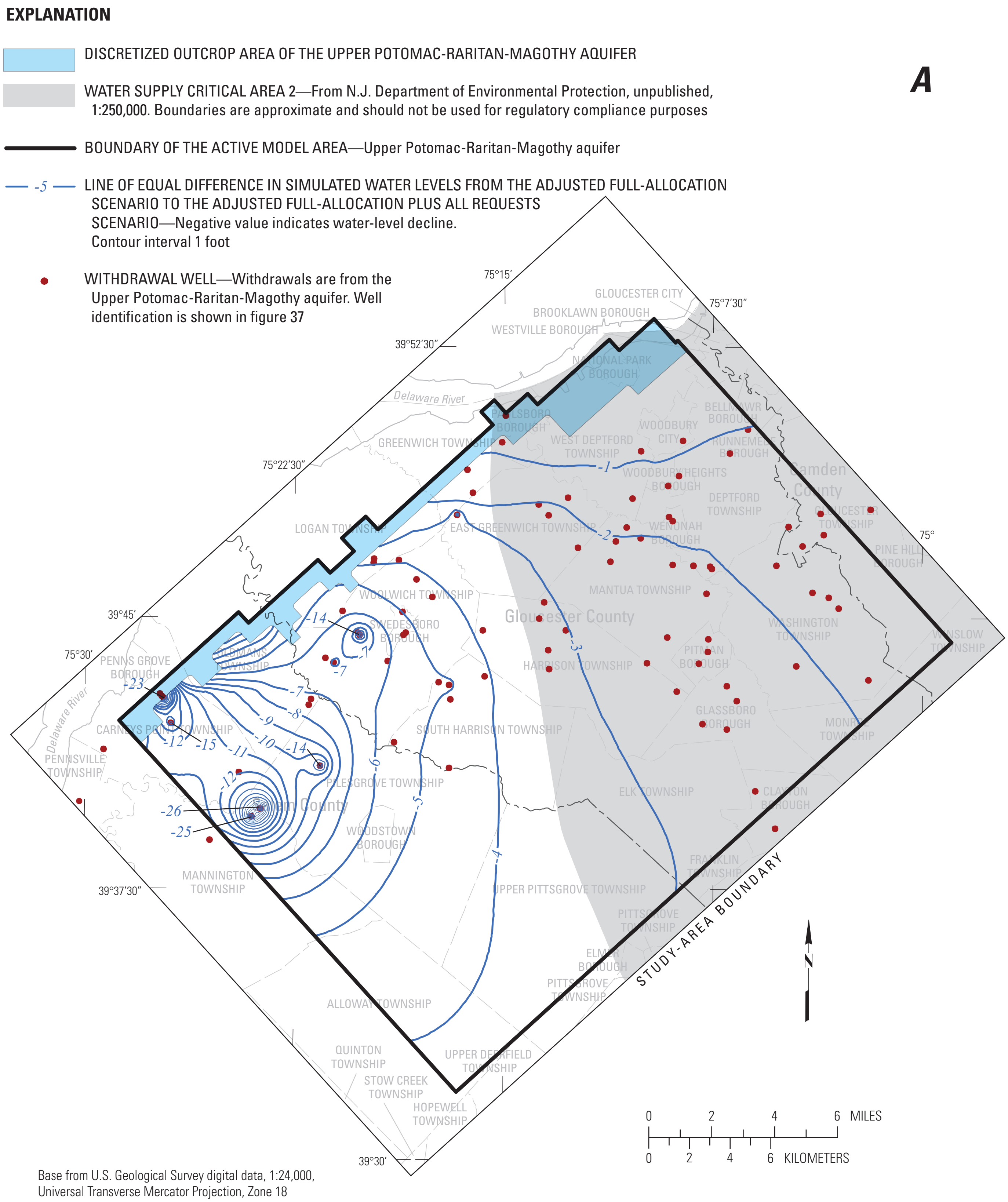


Figure 39. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus all requests scenario, Salem-Gloucester study area, southern New Jersey.

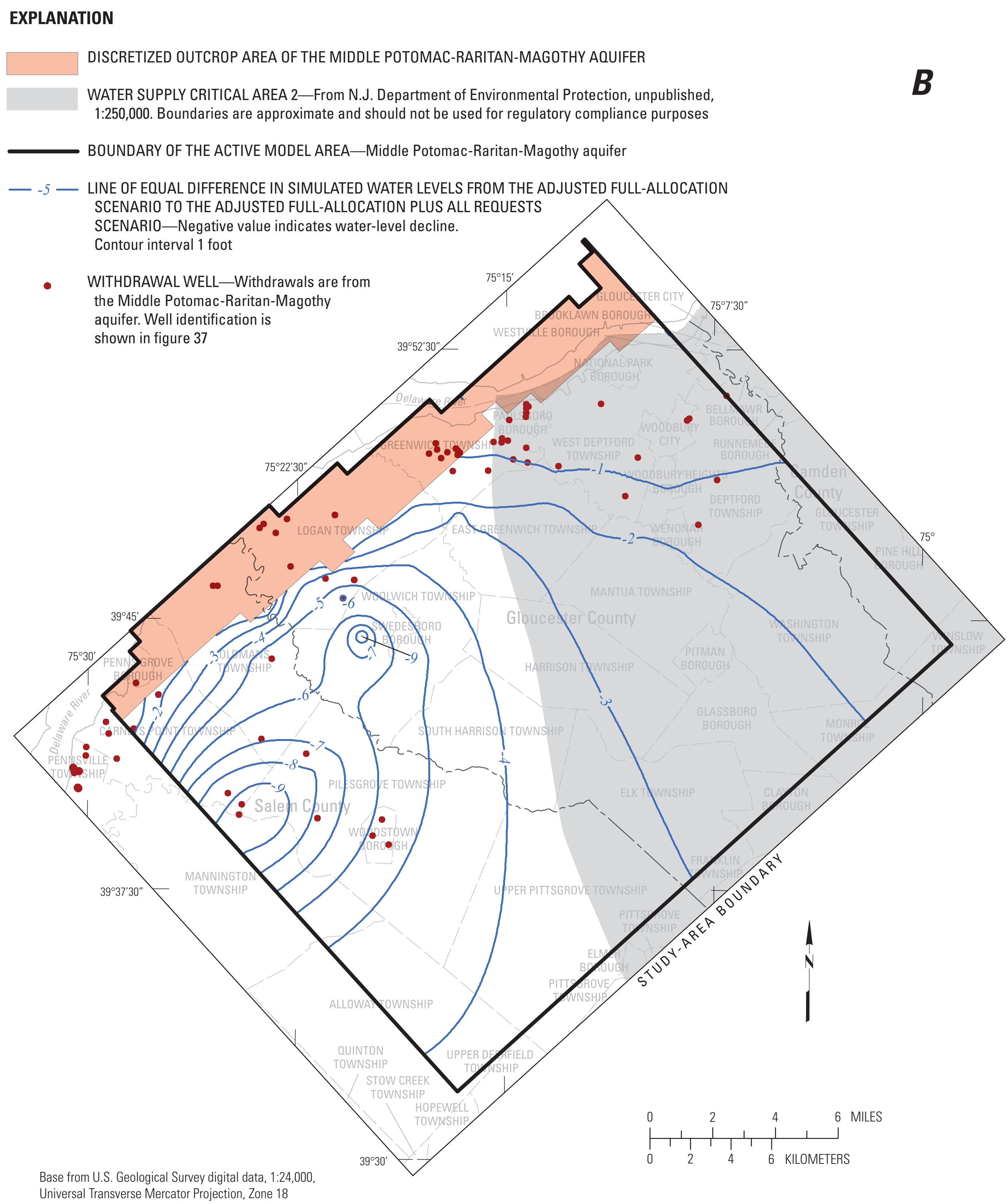


Figure 39. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus all requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

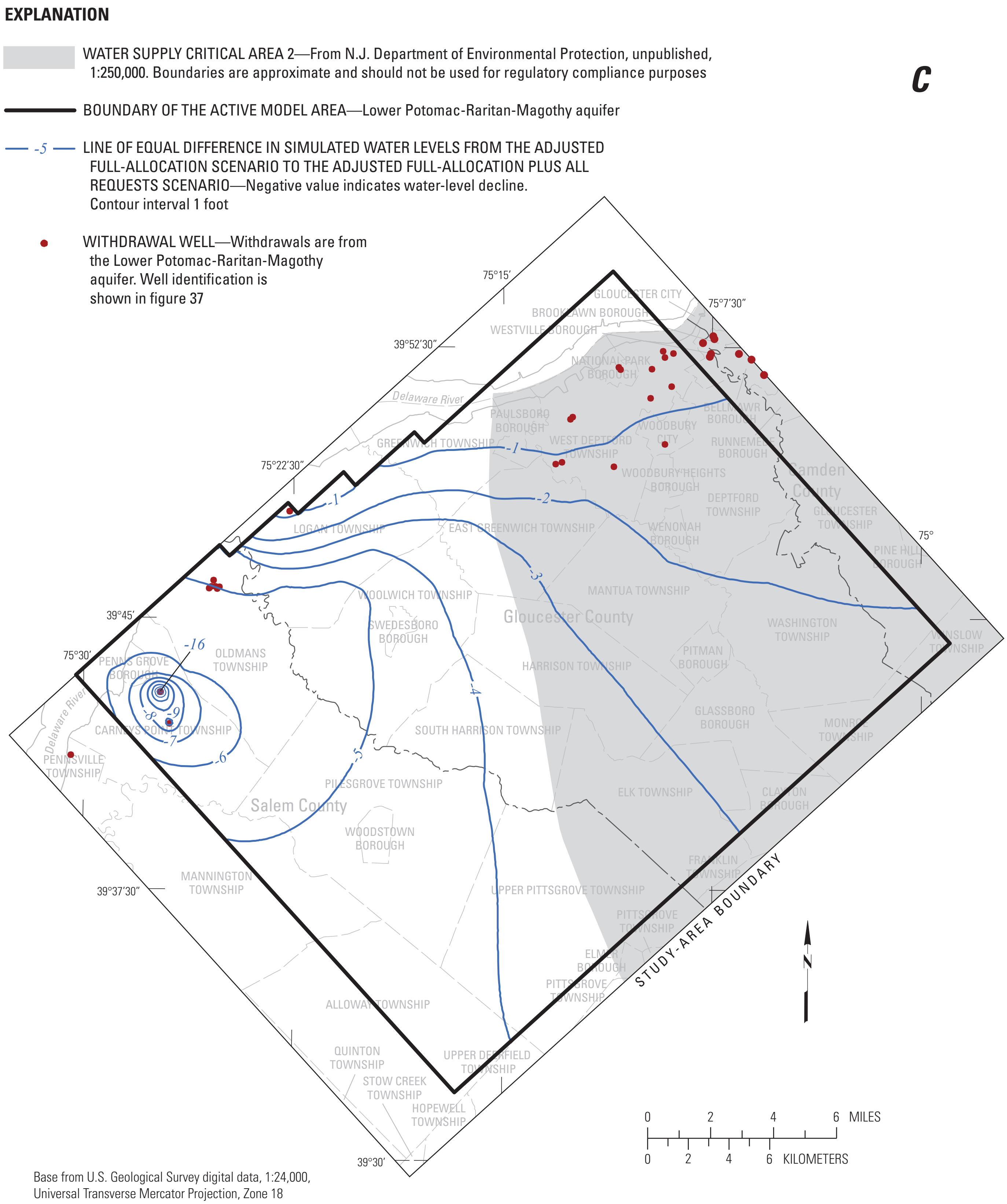


Figure 39. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus all requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

NGVD 29 in the adjusted full-allocation scenario are shown in figure 38. These areas increased in size from the area in the adjusted full-allocation scenario by 33.4, 37.7, and 27.0 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively (table 12). The increase in area occurred in the Upper and Middle Potomac-Raritan-Magothy aquifers through eastern and southwestern East Greenwich Township, part of which is located in Critical Area 2; southern Woolwich and northwestern Pilesgrove Townships; and southern Swedesboro Borough. In the Middle Potomac-Raritan-Magothy aquifer, the increase in area is also through northern Deptford and southern Oldmans and Carneys Point Townships. In the Lower Potomac-Raritan-Magothy aquifer, the increase in area is through eastern and southwestern East Greenwich and northwestern Harrison Townships, part of which is located in Critical Area 2, southern Woolwich and southern and western Oldmans Townships, and Penns Grove Borough. Most of the increase in area is outside Critical Area 2 (fig. 38). The part of these areas that is in Critical Area 2 is 2.4, 4.0, and 4.9 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively, which is about 7, 11, and 18 percent, respectively, of the total area that increased in size from the area in the adjusted full-allocation scenario.

The average change in simulated water levels for the model cells along the boundary of Critical Area 2 in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers for the adjusted full-allocation plus all requests scenario is -3.1, -3.0, and -3.0 ft, respectively, from the adjusted full-allocation scenario (table 13). The largest and smallest changes in simulated water level for the model cells along the boundary of Critical Area 2 for the adjusted full-allocation plus all requests scenario from the adjusted full-allocation scenario are summarized in table 13.

Simulated withdrawals totaled about 58 percent of outflow (14,551 Mgal/yr), 10 percent (1,261 Mgal/yr) more than in the adjusted full-allocation scenario. Simulated groundwater discharge to streams and wetlands is about 27 percent of outflow (6,706 Mgal/yr), 8 percent (550 Mgal/yr) less than in the adjusted full-allocation scenario. Specified flows at bordering hydrogeologic units (including the confined Englishtown aquifer system at the top of the model) account for about 19 percent of inflow (4,696 Mgal/yr) and about 8 percent of outflow (2,156 Mgal/yr), which is about a 5-percent increase (223 Mgal/yr) in inflow and about a 9-percent decrease (222 Mgal/yr) in outflow from the adjusted full-allocation scenario. Recharge is 71 percent of inflow (17,937 Mgal/yr) and was not changed from the 1998 calibration and 2000 baseline simulations. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (10 percent) and outflow (7 percent) and is a net flow from the Delaware River to the Potomac-Raritan-Magothy aquifer system of about 3 percent (780 Mgal/yr), which is 52 percent (267 Mgal/yr) more than in the adjusted full-allocation scenario. Simulated flow-budget components for streams and the Delaware River in the local model for the adjusted full-allocation plus all requests scenario are summarized in table 12. All flow-budget values are rounded to the nearest integer.

Adjusted Full-Allocation plus Adjusted Requests Scenario

In the adjusted full-allocation plus adjusted requests scenario, withdrawals from some of the wells in which withdrawals were increased in the adjusted full-allocation plus all requests scenario were decreased to an amount equal to or between withdrawals in the full-allocation scenario and withdrawals in the full-allocation plus all requests scenario (tables 5 and 7). For the remainder of those wells, withdrawals remained at the amount simulated in the full-allocation plus all requests scenario. Withdrawals for all other wells in tables 4 to 7 are the same as those in the adjusted full-allocation scenario. Withdrawal wells in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers used in the adjusted full-allocation plus adjusted requests scenario are shown in figure 37.

Simulated water levels in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers in the adjusted full-allocation plus adjusted requests scenario are shown in figure 40, and the change in simulated water levels from the adjusted full-allocation scenario is shown in figure 41. Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus adjusted requests scenario range from about 10 ft above NGVD 29 in Oldmans Township near the outcrop area of the aquifer to 80 ft below NGVD 29 at a cone of depression around a water-purveyor well (15-1365) in Washington Township in Critical Area 2 (fig. 40A). When compared to the adjusted full-allocation scenario (fig. 33A), several small cones of depression are observed: in Woolwich Township around two water-purveyor wells (15-1532 and 15-1533), in Swedesboro Borough centered on a water-purveyor well (15-1112), in Glassboro Borough centered on a water-purveyor well (15-60), and in Paulsboro Borough centered on an industrial self-supply well (15-1408). The largest water-level declines from the adjusted full-allocation scenario were 13 and 14 ft centered on agricultural-irrigation wells (33-997 and 33-998, respectively) in Pilesgrove Township (fig. 41A). The average simulated water level in the Upper Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus adjusted requests scenario is 38 ft below NGVD 29, 2 ft lower than in the adjusted full-allocation scenario (table 12).

Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus adjusted requests scenario range from NGVD 29 near the outcrop area of the aquifer to about 60 ft below NGVD 29 at a cone of depression around a water-purveyor well (15-1036) in Deptford Township, and also through Glassboro Borough

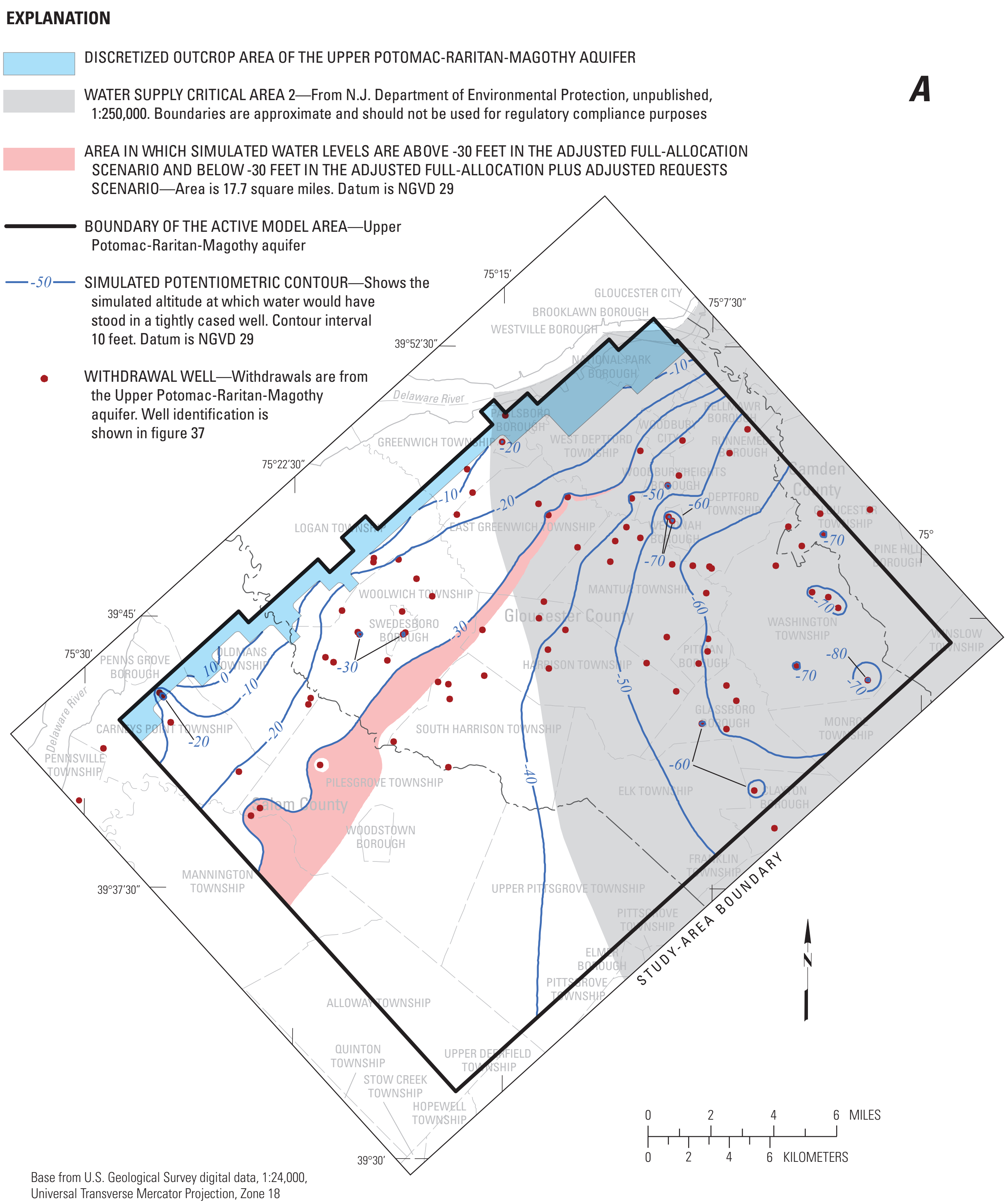


Figure 40. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.

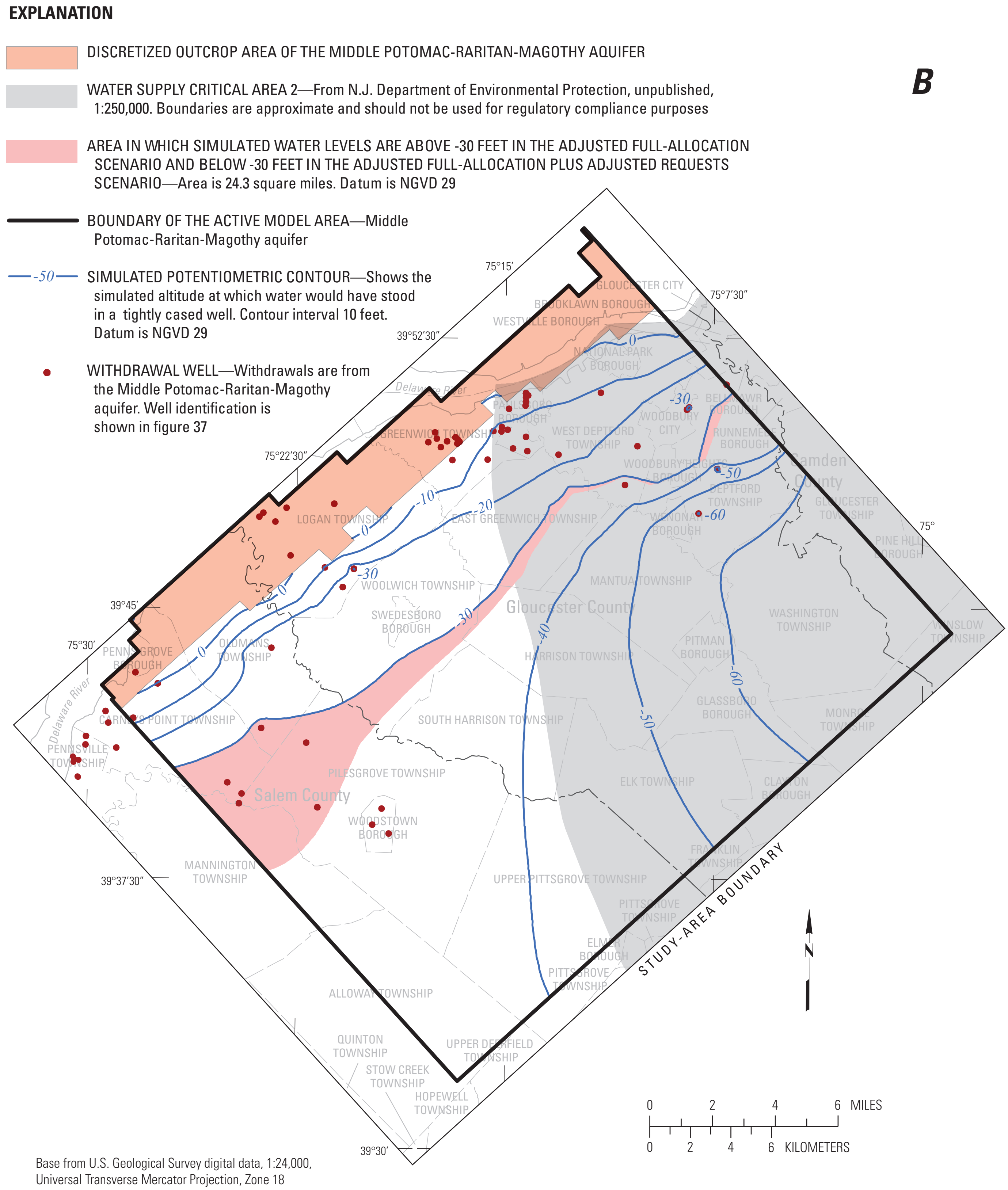


Figure 40. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

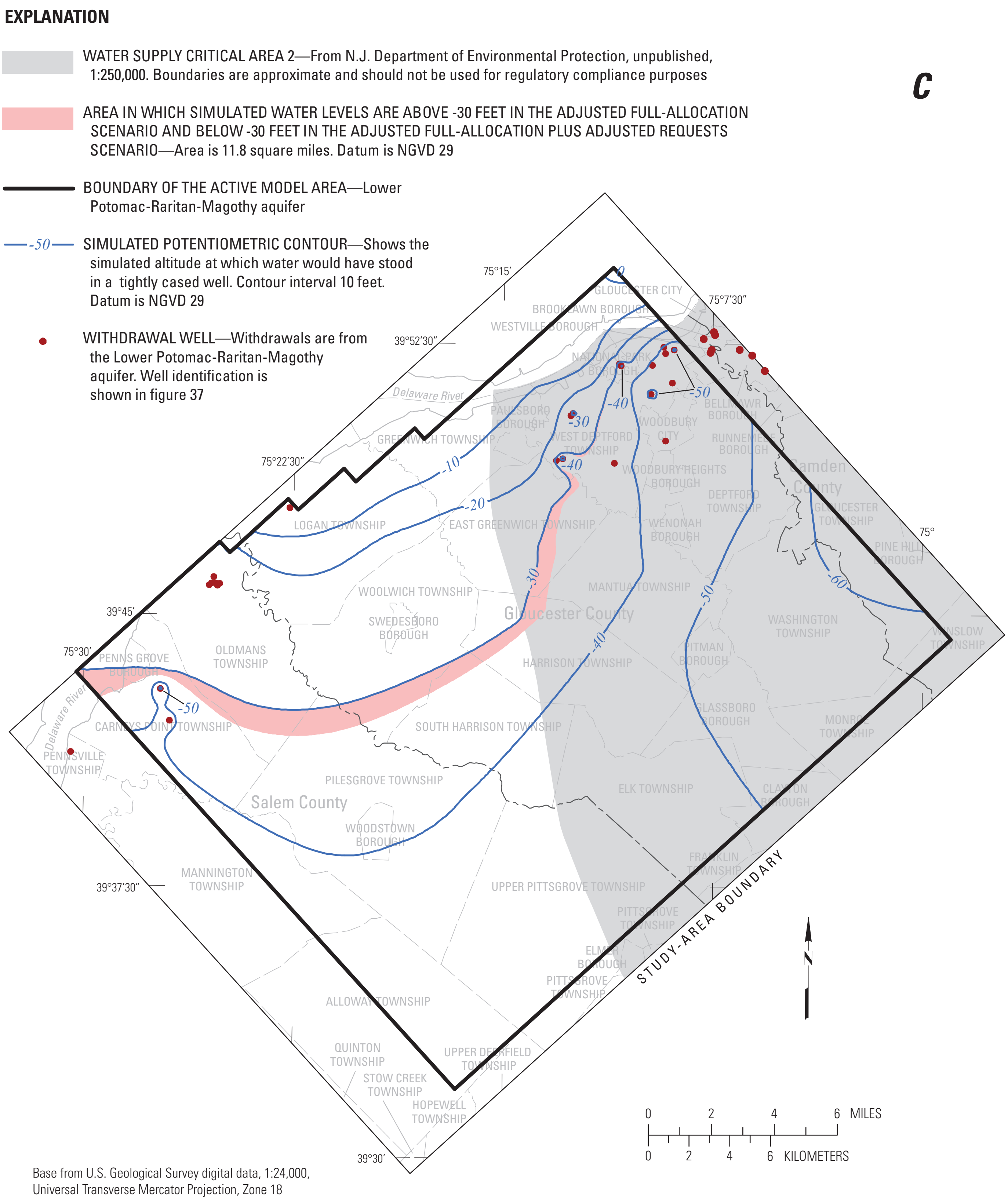


Figure 40. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

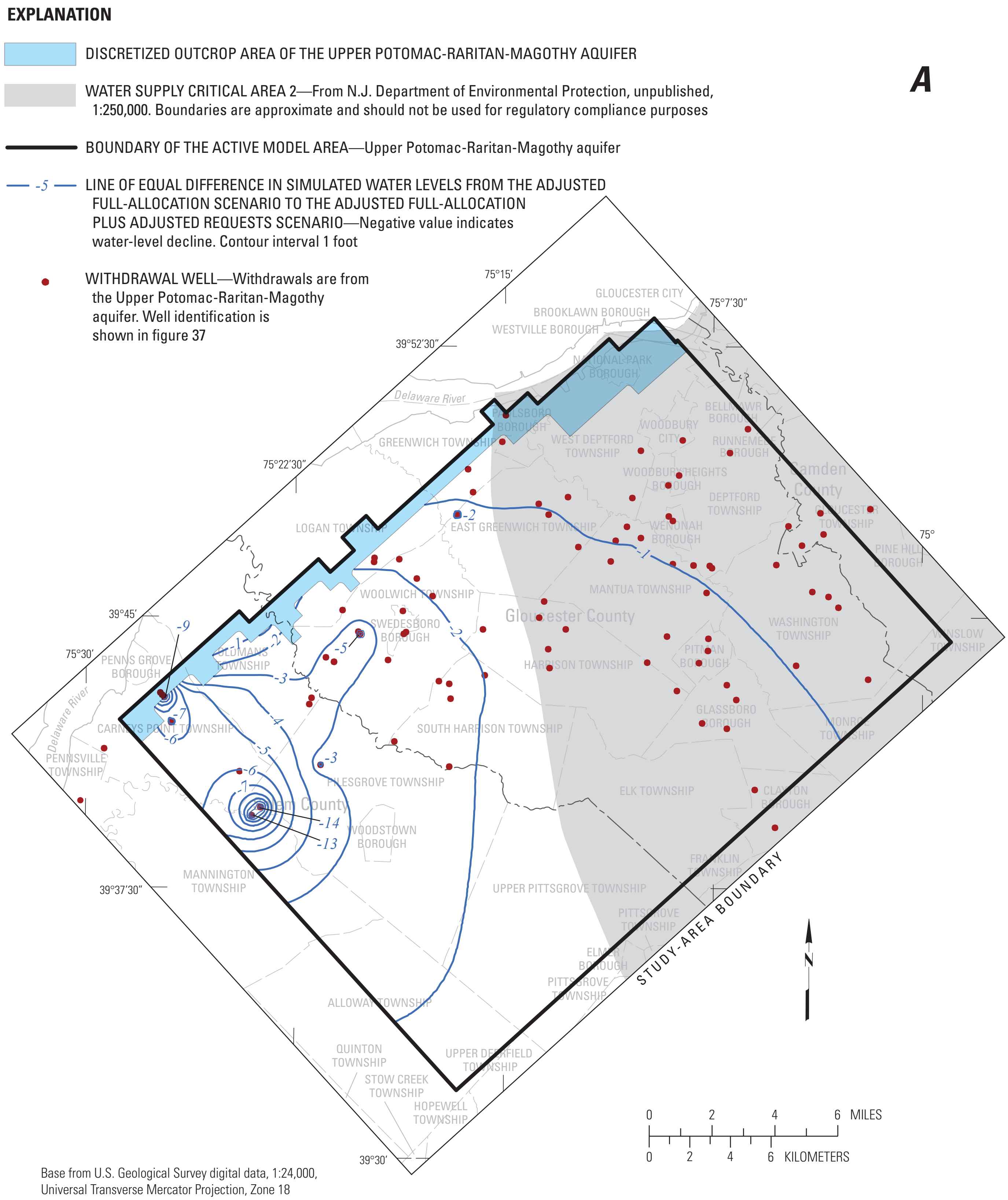
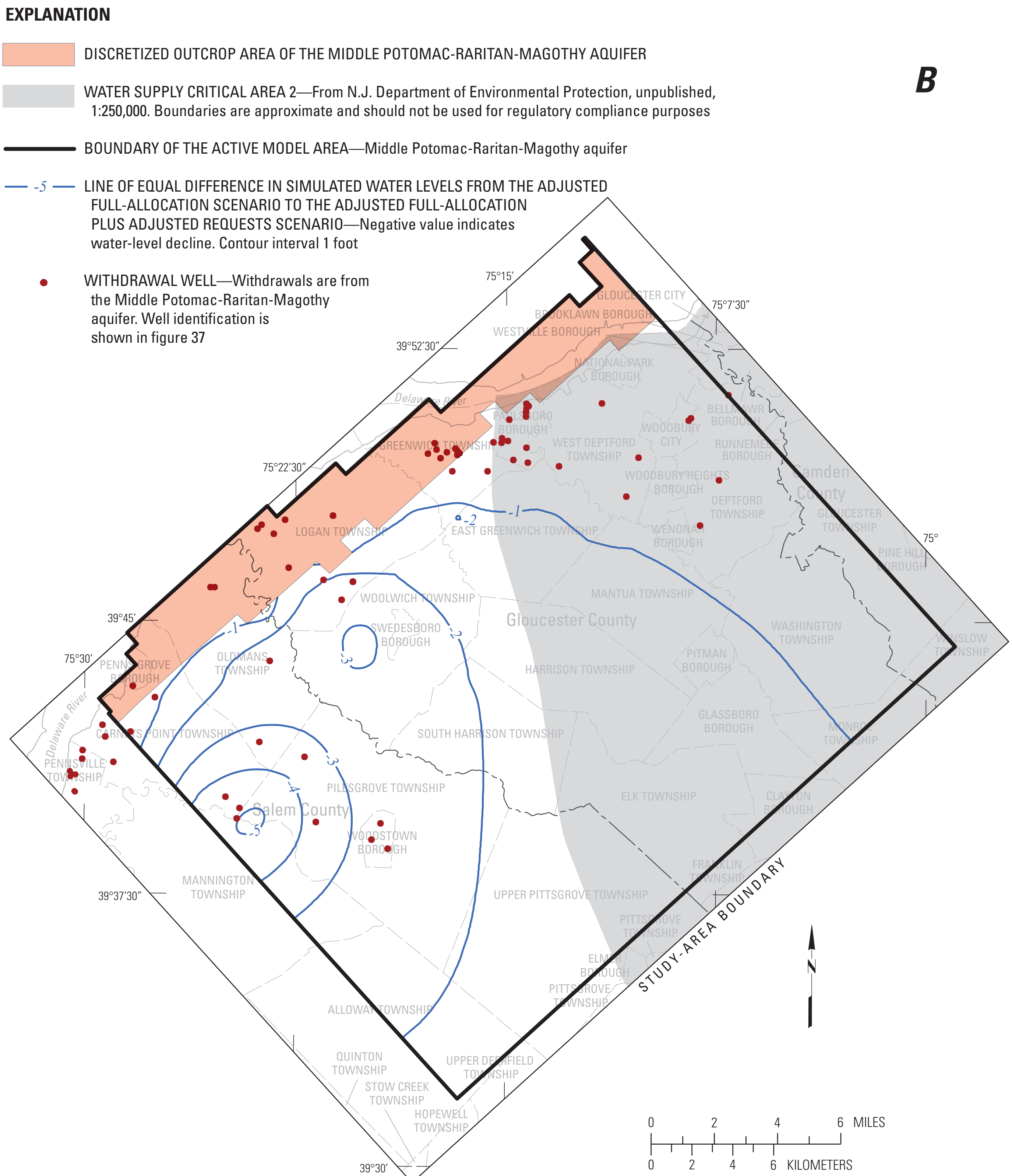


Figure 41. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.



Base from U.S. Geological Survey digital data, 1:24,000,
Universal Transverse Mercator Projection, Zone 18

Figure 41. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

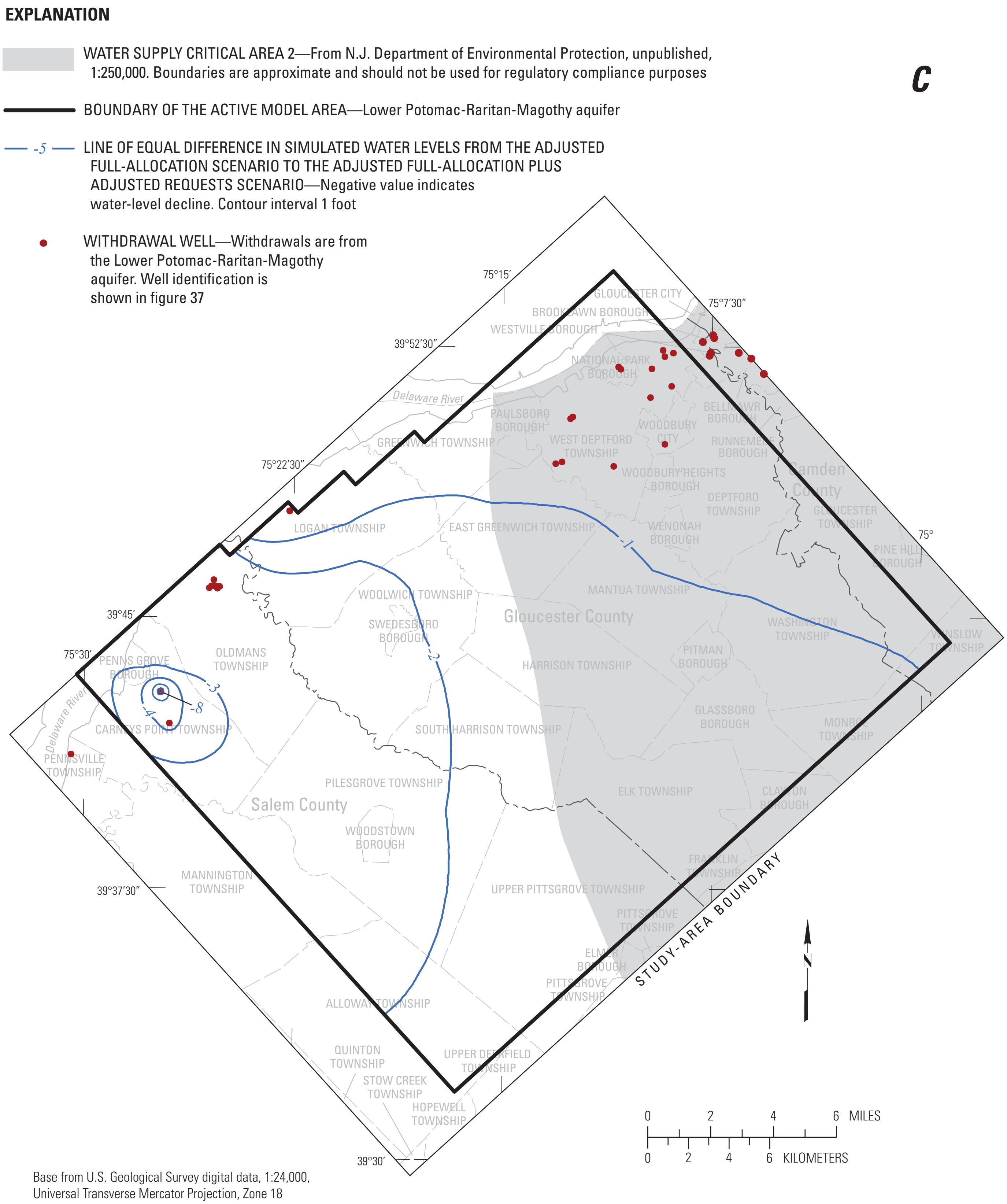


Figure 41. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the adjusted full-allocation scenario to the adjusted full-allocation plus adjusted requests scenario, Salem-Gloucester study area, southern New Jersey.—Continued

and Washington Township in Critical Area 2 (fig. 40B). The largest simulated water-level decline from the adjusted full-allocation scenario was 5 ft centered on two agricultural-irrigation wells (33-997 and 33-998) in Pilesgrove Township, which are screened in the overlying aquifer (fig. 41B). The average simulated water level in the Middle Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus adjusted requests scenario is 34 ft below NGVD 29, 2 ft lower than in the adjusted full-allocation scenario (table 12).

Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer in the adjusted full-allocation plus adjusted requests scenario range from about 10 below NGVD 29 near the updip limit of the aquifer to about 60 ft below NGVD 29 in Gloucester Township in Critical Area 2 (fig. 40C). The largest simulated water-level decline from the adjusted full-allocation scenario was 8 ft centered on a water-purveyor well (33-346) in Carneys Point Township (fig. 41C).

The areas in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in which simulated water levels are lower than 30 ft below NGVD 29 in the adjusted full-allocation plus adjusted requests scenario but above 30 ft below NGVD 29 in the adjusted full-allocation scenario are shown in figure 40. These areas increased in size from the area in the adjusted full-allocation scenario by 17.7, 24.3, and 11.8 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively (table 12). The largest increase in area in the Upper and Middle Potomac-Raritan-Magothy aquifers are in northern Pilesgrove and southern Woolwich Townships. In the Middle Potomac-Raritan-Magothy aquifer, the increase in area also is through southern Carneys Point and Oldmans Townships. Most of the increase in area is outside Critical Area 2 (fig. 40). The part of these areas that is in Critical Area 2 is 1.3, 2.0, and 2.4 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively, which is about 7, 8, and 20 percent, respectively, of the total area that increased in size from the area in the adjusted full-allocation scenario.

The average change in simulated water levels for the model cells along the boundary of Critical Area 2 in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers for the adjusted full-allocation plus adjusted requests scenario is -1.5, -1.4, and -1.4 ft, respectively, from the adjusted full-allocation scenario (table 13). The largest and smallest changes in simulated water level for the model cells along the boundary of Critical Area 2 for the adjusted full-allocation plus adjusted requests scenario from the adjusted full-allocation scenario are summarized in table 13.

Simulated withdrawals totaled about 56 percent of outflow (13,865 Mgal/yr), 4 percent (575 Mgal/yr) more than in the adjusted full-allocation scenario. Simulated groundwater discharge to streams and wetlands is about 28 percent of outflow (6,983 Mgal/yr), 4 percent (273 Mgal/yr) less than in the adjusted full-allocation scenario. Specified flows at bordering hydrogeologic units (including the confined Englishtown aquifer system at the top of the model) account for about 18 percent of inflow (4,565 Mgal/yr) and about 9 percent of outflow (2,273 Mgal/yr), which are about a 2-percent increase and a 4-percent decrease, respectively, from the adjusted full-allocation scenario. Simulated recharge is 72 percent of inflow (17,937 Mgal/yr) and was not changed from the 1998 calibration and 2000 baseline simulations. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (10 percent) and outflow (7 percent) and is a net flow from the Delaware River to the Potomac-Raritan-Magothy aquifer system of about 3 percent (619 Mgal/yr), 21 percent (106 Mgal/yr) more than in the adjusted full-allocation scenario. Simulated flow-budget components for streams and the Delaware River in the local model for the adjusted full-allocation scenario plus adjusted requests scenario are summarized in table 12. All flow-budget values are rounded to the nearest integer.

2025 Groundwater-Withdrawal Scenario

A groundwater-withdrawal scenario was developed to evaluate the effects of future 2025 groundwater withdrawals in the Salem-Gloucester study area on water levels in the study area. A population estimate for 2025 was made for each municipality in the study area by determining the change in population from 1990 to 2000. The percent change in population from 2000 to 2025 was used to estimate domestic self-supply withdrawals and withdrawals from water-purveyor wells outside Critical Area 2. The change in agricultural land use in Salem and Gloucester Counties from 2002 to 2025 was determined to estimate agricultural-irrigation withdrawals in the study area in 2025.

Projected 2025 population

During 1960–2000, population growth in Salem County differed from that in Gloucester County. Gloucester County experienced a continuous population increase, whereas Salem County experienced modest population increases from 1960–90, then a slight population decline from 1990 to 2000 (Delaware Valley Regional Planning Commission, 2002; U.S. Census Bureau, 2006; U.S. Censuses of Population and Housing, 2006).

Gloucester County

The population of Gloucester County has increased steadily since 1960 and had almost doubled by 2000 (fig. 42) (Delaware Valley Regional Planning Commission, 2002; U.S. Censuses of Population and Housing, 2006). Municipal population estimates for Gloucester County in 2025 used in this study were developed by the Delaware Valley Regional Planning Commission (DVRPC) (Delaware Valley Regional Planning Commission, 2002). The population of Gloucester County in 2000 is estimated by the DVRPC to have been 254,673. It is estimated that the population in Gloucester County will increase by almost 27 percent from 2000 to 2025. The DVRPC projected population increases in Woolwich

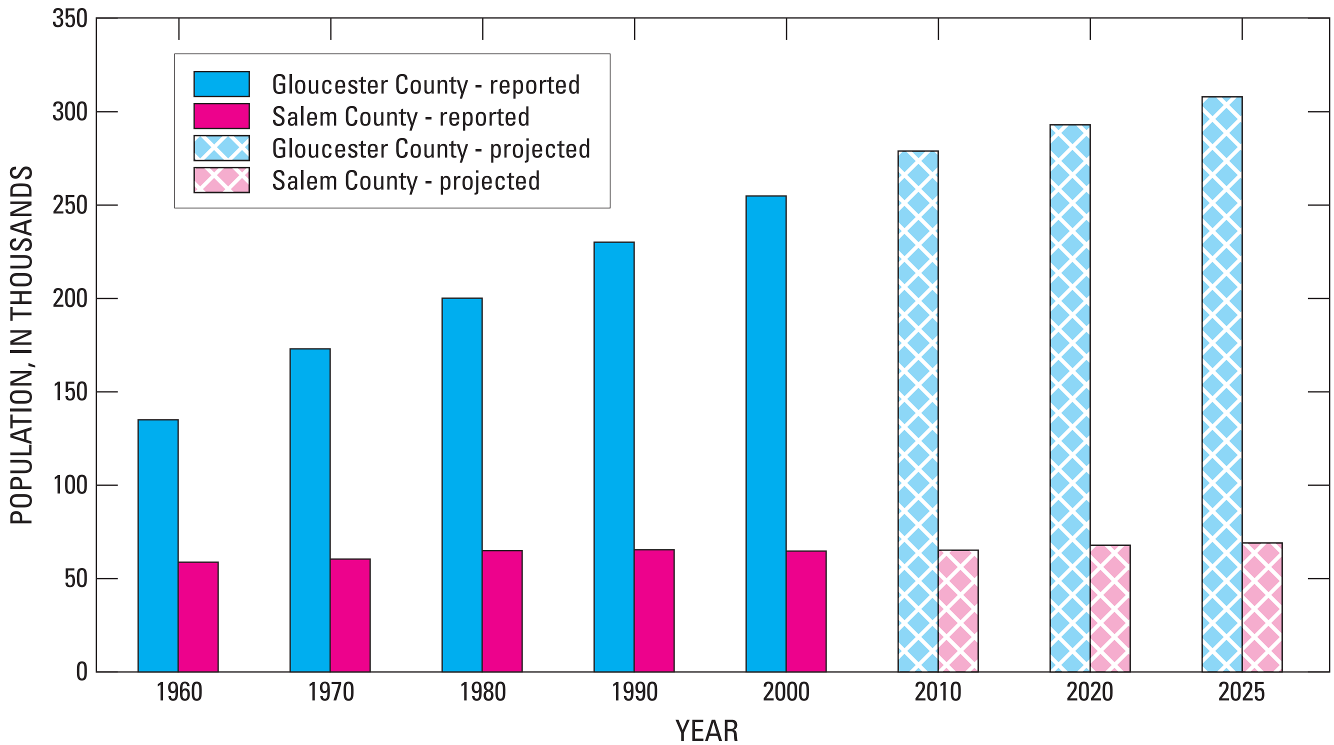


Figure 42. Reported (1960–2000) and projected (2010–25) population, Gloucester and Salem Counties, southern New Jersey. Data from Delaware Valley Regional Planning Commission, 2002 (Gloucester County, reported and projected); U.S. Census Bureau, 2006 (Salem County, reported and projected); U.S. Censuses of Population and Housing, 2006 (Gloucester and Salem Counties, reported).

(359 percent), Harrison (85 percent), Elk (79 percent), South Harrison (53 percent), Monroe (42 percent), Mantua (33 percent), East Greenwich (27 percent), West Deptford (20 percent), Logan (19 percent), Washington (18 percent), and Deptford (10 percent) Townships and Clayton (37 percent), Glassboro (28 percent), Swedesboro (8 percent), Wenonah (5 percent), and Westville (3 percent) Boroughs (Delaware Valley Regional Planning Commission, 2002). The DVRPC projected population declines of 7 percent in Paulsboro Borough, 6 percent in Woodbury City, and 5 percent or less in Greenwich Township and Woodbury Heights, Pitman, and National Park Boroughs for the same time period (Delaware Valley Regional Planning Commission, 2002).

Salem County

Salem County is the least populated county in New Jersey. Its population is concentrated in the older industrial and residential communities along the Delaware River. Tidal marshes adjacent to the Delaware River and Bay are largely uninhabited. The inland areas are populated with widely dispersed crop and dairy farms. Salem County's population increased 11 percent over the 40-year period 1960–2000 (U.S. Censuses of Population and Housing, 2006). The population of Salem County in 2000 was 64,285 (U.S. Census Bureau, 2006). From 1990 to 2000, the population of Salem County, the only county in New Jersey reporting a population loss, decreased about 2 percent (U.S. Census Bureau, 2006).

Municipal population estimates for Salem County in 2025 were not developed by the DVRPC. U.S. Census municipal-level data for 1990–2000 were used to estimate the population in 2025 for each municipality in the study area (U.S. Censuses of Population and Housing, 2006; U.S. Census Bureau, 2006). It was assumed for this study that the rate of change in population from 1990 to 2000 (as a percent) would continue to 2025 for each municipality. For each municipality, the percent change from 1990 to 2000 was halved to obtain a 5-year rate of change. A linear projection was used to calculate the change in population over every 5-year interval from 2001 to 2025 for each municipality in the study area. This percent change was used to calculate the 2025 population projection for municipalities in the study area in which the population increased from 1990 and 2000. The population of some municipalities in Salem County decreased during this period. For those municipalities, the percent change determined from 1990 to 2000 was adjusted by dividing the percent loss in population by 10, then doubling this value. This adjustment was made to account for some replacement of aged populations and the addition of new residents in the municipality. A linear projection was then used to calculate the change in population over every 5-year interval from 2001 to 2025 for each of the municipalities in Salem County in the study area in which the population decreased from 1990 to 2000. The estimation error for the 2025 population projection is considered to be relatively small because it is assumed that Salem County will continue to have the smallest population in the State and many of the municipalities in this county are only partially in the study area. Population increases in the study area from 2000 to 2025 are projected for Oldmans (18 percent), Upper Pittsgrove (29 percent), and Pilesgrove (64 percent) Townships. Over the same period, the populations of Elmer Borough, Carneys Point and Mannington Townships and Penns Grove Borough are estimated to decline by 9, 7, 6, and 5 percent, respectively, whereas the populations of Alloway Township and Woodstown Borough are estimated to remain fairly constant.

Projected 2025 Agricultural Land-Use Change

The change in agricultural land use in Gloucester and Salem Counties from 1990 to 2000 was analyzed to estimate agricultural-irrigation withdrawals in the study area in 2025.

Gloucester County

Changes in agricultural land use from 1990 to 1995 and from 1995 to 2000 in Gloucester County were analyzed using DVRPC land-use data to determine a rate of change in agricultural land use in the study area in Gloucester County (Delaware Valley Regional Planning Commission, 1998a and 1998b; Delaware Valley Regional Planning Commission, 2004). Agricultural land use was about 35 percent of the land use in northern Gloucester County in 1990, about 34 percent in 1995, and about 29 percent in 2000. During 1990–95, 1995–2000, and 1990–2000 agricultural land use decreased about 1, 5, and 6 percent, respectively. Using the percentage changes in agricultural land use from 1990 to 2000 and from 1995 to 2000, agricultural land use in the study area in Gloucester County is projected to decrease about 21 to 30 percent by 2025.

Salem County

For Salem County, Geographical Information System (GIS) data for land use in 1986, 1995, and 2002 were used to determine the change in agricultural land use, which includes cropland and pasture land (New Jersey Department of Environmental Protection, 2001 and 2007). From 1986 to 1995, agricultural land use in Salem County decreased about 13 percent (New Jersey Department of Environmental Protection, 2001). From about 1995 to 2002, agricultural land use in Salem County decreased less than 2 percent (New Jersey Department of Environmental Protection, 2007). Using the more recent (1995–2002) change in agricultural land use, agricultural land use in Salem County is projected to decrease about 8 percent from 2002 to 2025.

Projected 2025 Groundwater Withdrawals

Water-purveyor, industrial self-supply, low-volume, and agricultural-irrigation withdrawals from the Potomac-Raritan-Magothy aquifer system and domestic self-supply withdrawals from the Potomac-Raritan-Magothy and the Englishtown aquifer systems were determined for the 2025 scenario as described below and were input into the model. Agricultural withdrawals in 2025 were determined from the analysis of the change in agricultural land use in Salem and Gloucester Counties. Domestic self-supply withdrawals and water-purveyor withdrawals in 2025 in the study area but outside Critical Area 2 were estimated using the percent change in population projected for each municipality in the Salem-Gloucester study area in 2025. Withdrawals used in this scenario are shown in tables 4 to 7.

Water-Purveyor

In two municipalities in the study area, Monroe Township in Gloucester County and Winslow Township in Camden County, water purveyors withdraw groundwater from wells outside the study area and from the Kirkwood-Cohansey aquifer system, and no water-purveyor, industrial self-supply, or agricultural-irrigation withdrawals are made from the Potomac-Raritan-Magothy aquifer system in the model.

Sixteen municipalities in the study area that withdraw water from the Potomac-Raritan-Magothy aquifer system are located predominantly within Critical Area 2: Clayton, Glassboro, National Park, Paulsboro, Pitman, Wenonah, Westville, and Woodbury Heights Boroughs; Deptford, East Greenwich, Gloucester, Mantua, Harrison, West Deptford, and Washington Townships; and Woodbury City. All these municipalities are in Gloucester County except for Gloucester Township, which is in Camden County. In the 2025 scenario, it was assumed that the withdrawals from water-purveyor wells in these municipalities would be at full-allocation conditions (table 4). Any additional water supply needed for population increase within Critical Area 2 is assumed to be from sources other than groundwater pumped from wells within Critical Area 2, such as from surface water. However, withdrawals from wells in Westville Borough were not increased from the 2000 baseline simulation withdrawals.

Eight municipalities in the Salem-Gloucester study area (Carneys Point and Oldmans Townships and Penns Grove and Woodstown Boroughs in Salem County, and Greenwich, Logan, and Woolwich Townships and Swedesboro Borough in Gloucester County) are located predominantly outside Critical Area 2. These eight municipalities are served by water purveyors that withdraw groundwater from wells within the study area. The population of three of the municipalities, Carneys

Point and Greenwich Townships and Penns Grove Borough, is projected to decline by 2025, and the population of Woodstown Borough is projected to remain fairly constant from 2000 to 2025. Therefore, for these municipalities, withdrawals from the 2000 baseline simulation were used (table 5). (The water-purveyor wells for Penns Grove Borough are located in Logan Township).

In the 2025 scenario, the withdrawals from water-purveyor wells were increased for Logan, Woolwich, and Oldmans Townships and Swedesboro Borough, which are located outside Critical Area 2. It was assumed that the additional population in these four municipalities would obtain its water supply from water-purveyor wells; therefore, domestic self-supply withdrawals in these four municipalities would not increase. The withdrawals for these four municipalities were increased by first determining the proportion of the pumpage at each well in table 5 for these municipalities in 2000. The increase in population from 2000 to 2025 was determined by multiplying the 2000 population for these municipalities by 359 percent for Woolwich Township, 19 percent for Logan Township, 18 percent for Oldmans Township, and 8 percent for Swedesboro Borough, then subtracting the population in 2000 from the population in 2025 to determine the change in population from 2000 to 2025. The change in population from 2000 to 2025 for each of the four municipalities was multiplied by 101 gal/d for per capita consumptive use. These four values were multiplied by the proportion of pumpage from each well in these municipalities to obtain the change in withdrawals for each well. The value obtained for each well then was multiplied by 365 days per year and divided by 1 million gallons to convert to Mgal/yr. Finally the change in withdrawal determined for each well was added to the 2000 withdrawal for that well, yielding the estimated 2025 withdrawal for that well. These withdrawals are summarized in table 5 for these four municipalities. The withdrawals from the two wells with NJDEP BWA number 5375 in Logan Township were not increased in this scenario; however, withdrawals from one well in Woodstown Borough (33-933) were increased (table 5).

The per capita consumptive-use rate of 101 gal/d was generated from groundwater-withdrawal data on the estimated population served by water-purveyor withdrawals in Washington Township from 1980 to 2001. It is defined as the average annual withdrawals from 1980 to 2001 divided by the average population served during 1980–2001. This value accounts for future water demand resulting from lifestyle changes and activities such as lawn care, showers, and others changes in water use by the population over the decades.

Industrial Self-Supply, Low-Volume, and Agricultural-Irrigation

For the 2025 scenario, it was assumed that industrial self-supply and low-volume water use would not change substantially; therefore, the withdrawals in the 2000 baseline simulation were used (tables 5, 6, and 7). Because agricultural land in Gloucester County for the study area was estimated to decrease about 21 to 30 percent by 2025, agricultural withdrawals also are estimated to decline by 2025. Because the decrease in agricultural land in Salem County by 2025 was estimated to be about 8 percent, agricultural-irrigation withdrawals for 2025 were assumed not to substantially change from the 2000 baseline simulation withdrawals. Furthermore, the 2000 baseline simulation agricultural-irrigation withdrawals are only about 2 percent of the total withdrawals from the Potomac-Raritan-Magothy aquifer system in the study area. Therefore, the 2000 baseline simulation agricultural-irrigation withdrawals were used (table 7).

Domestic Self-Supply

There are six municipalities in the study area for which increased domestic self-supply withdrawals must be considered. Based on the previously determined Salem County population estimates for this scenario, the population of Alloway Township in 2025 is projected to be similar to the population in 2000, whereas the population of Mannington Township is projected to decline by 2025. The populations of the four remaining municipalities, Elk and South Harrison Townships in Gloucester County and Pilesgrove and Upper Pittsgrove Townships in Salem County, are projected to increase from 2000 to 2025. However, there are no domestic withdrawals in the model in Elk and Upper Pittsgrove Townships or in southeastern Pilesgrove and South Harrison Townships because in these areas water is withdrawn from either the Kirkwood-Cohansey aquifer system or the Wenonah-Mount Laurel aquifer, which are not included in the model. It is expected that the additional domestic-supply population in northwestern Pilesgrove and South Harrison Townships will withdraw water from the Englishtown aquifer system and the Upper and Middle Potomac-Raritan-Magothy aquifers. For these two areas, it was assumed that most of the additional population would be served by domestic self-supply. The populations of Pilesgrove and South Harrison Townships are projected to increase by about 64 and 53 percent, respectively, by 2025. The population served by domestic self-supply in these two municipalities in 2000 (table 8) was approximately 81 percent for Pilesgrove Township and 98 percent for South Harrison Township. The estimated population in 2025 for these two municipalities was increased by approximately this proportion (74 percent for Pilesgrove Township and 86 percent for South Harrison Township) to obtain the 2025 population served by domestic self-supply (table 15). Because domestic self-supply withdrawals are only about 2 percent of the total withdrawals from the Potomac-Raritan-Magothy aquifer system in the study area, the estimated populations in 2025 for these two municipalities are assumed not to result in a substantial error in the calculation of domestic self-supply withdrawals.

Table 15. Estimated consumptive use of groundwater from domestic self-supply wells in municipalities with a projected population increase in 2025 that are not served by water purveyors, Salem-Gloucester study area, southern New Jersey.

[- -, not applicable]

Municipality	Estimated proportion of municipality's[1] domestic self-supply wells in aquifer in 2000			Estimated population in 2000	Estimated population served by domestic self-supply in 2000	Estimated population in 2025	Simulated[2] population served by domestic self-supply in 2025	Estimated consumptive use of domestic self-supply withdrawals[3] (million gallons per year)				
								2000	2025			
	Englishtown aquifer system	Upper Potomac-Raritan-Magothy aquifer	Middle Potomac-Raritan-Magothy aquifer					Total	Englishtown aquifer system	Upper Potomac-Raritan-Magothy aquifer	Middle Potomac-Raritan-Magothy aquifer	Total
Pilesgrove Township	0.057	0.029	0.029	[4]3,923	[5]3,160	[6]6,426	4,741	10.611	7.891	4.015	4.015	15.921
South Harrison Township	- -	0.333	- -	[7]2,417	[5]2,358	[7]3,710	3,175	22.928	- -	30.880	- -	30.880

[1]Estimated from U.S. Geological Survey Ground-Water Site Inventory database. There are no domestic self-supply withdrawals from the Lower Potomac-Raritan-Magothy aquifer in these municipalities.

[2]The simulated proportion of the population served by domestic self-supply for these two municipalities was about 74 percent for Pilesgrove Township and about 86 percent for South Harrison Township in 2025.

[3]Confined-aquifer domestic self-supply withdrawals are considered 100-percent consumptive. Estimated per capita water use is 80 gallons per day (Solley and others,1998).

[4]U.S. Census Bureau (2006).

[5]Estimated from U.S. Censuses of Population and Housing (2006) and N.J. Department of Environmental Protection Bureau of Water Allocation data.

[6]Estimated from a linear projection of percent change in municipal population between 1990 and 2000 using data from U.S. Census (2006) and U.S. Censuses of Population and Housing (2006).

[7]Delaware Valley Regional Planning Commission (2002).

The populations served by domestic self-supply for the other municipalities included in table 8 were not changed.

The same procedure used to calculated the estimated consumptive use of groundwater withdrawn for domestic self-supply in 2000 (described in the section “Model Input”) was used to calculate the consumptive-use values for northwestern Pilesgrove and South Harrison Townships in 2005, except that the estimated 2025 population for these two municipalities was used. The new consumptive-use value calculated for the Upper and Middle aquifers and the Englishtown aquifer system was added uniformly across the model cells of the given aquifer in northwestern Pilesgrove and South Harrison Townships to obtain the increase in domestic self-supply withdrawals by 2025 (table 15).

2025 Scenario Results

Withdrawal wells in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers used in the 2025 population-growth scenario are shown in figure 27. Simulated water levels in the confined Upper and Middle and Lower Potomac-Raritan-Magothy aquifers for the 2025 scenario are shown in figure 43, and the changes in simulated water levels from the 2000 baseline simulation to this scenario are shown in figure 44. Withdrawals from wells used in the 2025 scenario are given in tables 4 to 7. Simulated water levels in the confined Upper Potomac-Raritan-Magothy aquifer for the 2025 scenario range from about 10 ft above NGVD 29 in Oldmans and Carneys Point Townships at the outcrop area of the aquifer to about 80 ft below NGVD 29 at a cone of depression centered on a water-purveyor wells (15-1365) in Critical Area 2 in Washington Township (fig. 43A). The largest decline in simulated water levels from the 2000 baseline simulation was 16 ft in Woolwich Township, centered on a water-purveyor well (15-1532) (fig. 44A). A simulated decline of 7 ft in Clayton Borough was centered on a water-purveyor well (15-3); however, a water-level recovery of about 1 ft was observed around a water-purveyor well (15-130) in Harrison Township. In this scenario, well 15-130 is pumping at the 2006 permitted allocation rate, which is about 80 Mgal/yr less than in the 2000 baseline simulation (table 4). The average simulated water level for the 2025 scenario in the Upper Potomac-Raritan-Magothy aquifer is 32 ft below NGVD 29, 1 ft lower than in the 2000 baseline simulation (table 12).

Simulated water levels in the confined Middle Potomac-Raritan-Magothy aquifer in the 2025 scenario range from about NGVD 29 at the outcrop area of the aquifer to about 60 ft below NGVD 29 in Critical Area 2 in Washington, Monroe, and Gloucester Townships (fig. 43B). The largest decline in simulated water levels from the 2000 baseline scenario was 8 ft in Woolwich Township, a result of withdrawals from the overlying Upper Potomac-Raritan-Magothy aquifer (fig. 44B). The average simulated water level in the Middle Potomac-Raritan-Magothy aquifer in the 2025 scenario is 29 ft below NGVD 29, 2 ft lower than in the 2000 baseline simulation (table 12).

Simulated water levels in the Lower Potomac-Raritan-Magothy aquifer for the 2025 scenario range from about NGVD 29 near the updip limit of the aquifer to 60 ft below NGVD 29 in Critical Area 2 in Gloucester Township (fig. 43C). A cone of depression is observed around a water-purveyor well (33-330) in Carneys Point Township that was not present in the 2000 baseline simulation (fig. 28C). The largest decline in simulated water levels from the 2000 baseline simulation was 3 ft in northwestern Woolwich and southwestern Logan Townships, as a result of withdrawals from the overlying aquifers, and 3 ft in West Deptford Township, as a result of withdrawals from a water-purveyor well (15-312) (fig. 44C). Simulated water levels recovered 2 ft around two water-purveyor wells (15-207 and 15-533) in National Park Borough because withdrawals from these wells were at the 2006 full-allocation permitted amount, which is about 20 Mgal/yr less than in the 2000 baseline simulation (table 4). The average simulated water level in the Lower Potomac-Raritan-Magothy in the 2025 scenario is 32 ft below NGVD 29, 2 ft lower than in the 2000 baseline simulation (table 12).

The areas in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in which simulated water levels are more than 30 ft below NGVD 29 in the 2025 scenario but above 30 ft below NGVD 29 in the 2000 baseline simulation are shown in figure 44. These areas increased in size by 17.9, 19.6, and 14.4 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, respectively, from the area in the 2000 baseline simulation (table 12). Most of the increase in area is outside Critical Area 2 (fig. 43). The part of these areas that is within Critical Area 2 is 1.3, 1.1, and 3.2 mi^2 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers respectively, which is about 7, 6, and 22 percent, respectively, of the total area that increased in size from the area in the 2000 baseline simulation.

The average change in simulated water levels for the model cells along the boundary of Critical Area 2 in the confined Upper and Middle, and Lower, Potomac-Raritan-Magothy aquifers for the 2025 scenario is -1.5, -1.5, and -1.6 ft, respectively, from the 2000 baseline simulation (table 13). The largest and smallest changes in simulated water level for the model cells along the boundary of Critical Area 2 for the 2025 scenario from the 2000 baseline simulation are summarized in table 13.

Simulated withdrawals totaled about 44 percent of outflow (10,261 Mgal/yr), which is 6 percent (617 Mgal/yr) more than in the 2000 baseline simulation. Simulated groundwater discharge to streams and wetlands is about 35 percent of outflow (8,189 Mgal/yr), which is 3 percent (252 Mgal/yr) less than in the 2000 baseline simulation. Specified flows at bordering hydrogeologic units (including the confined Englishtown aquifer system at the top of the model) account for about 18 percent of inflow (4,158 Mgal/yr) and about 12 percent of outflow (2,635 Mgal/yr), which are about a 2-percent increase in inflow and a 4-percent decrease in outflow, respectively, from the 2000 baseline simulation. Simulated recharge is 77 percent of inflow (17,937 Mgal/yr) and was not

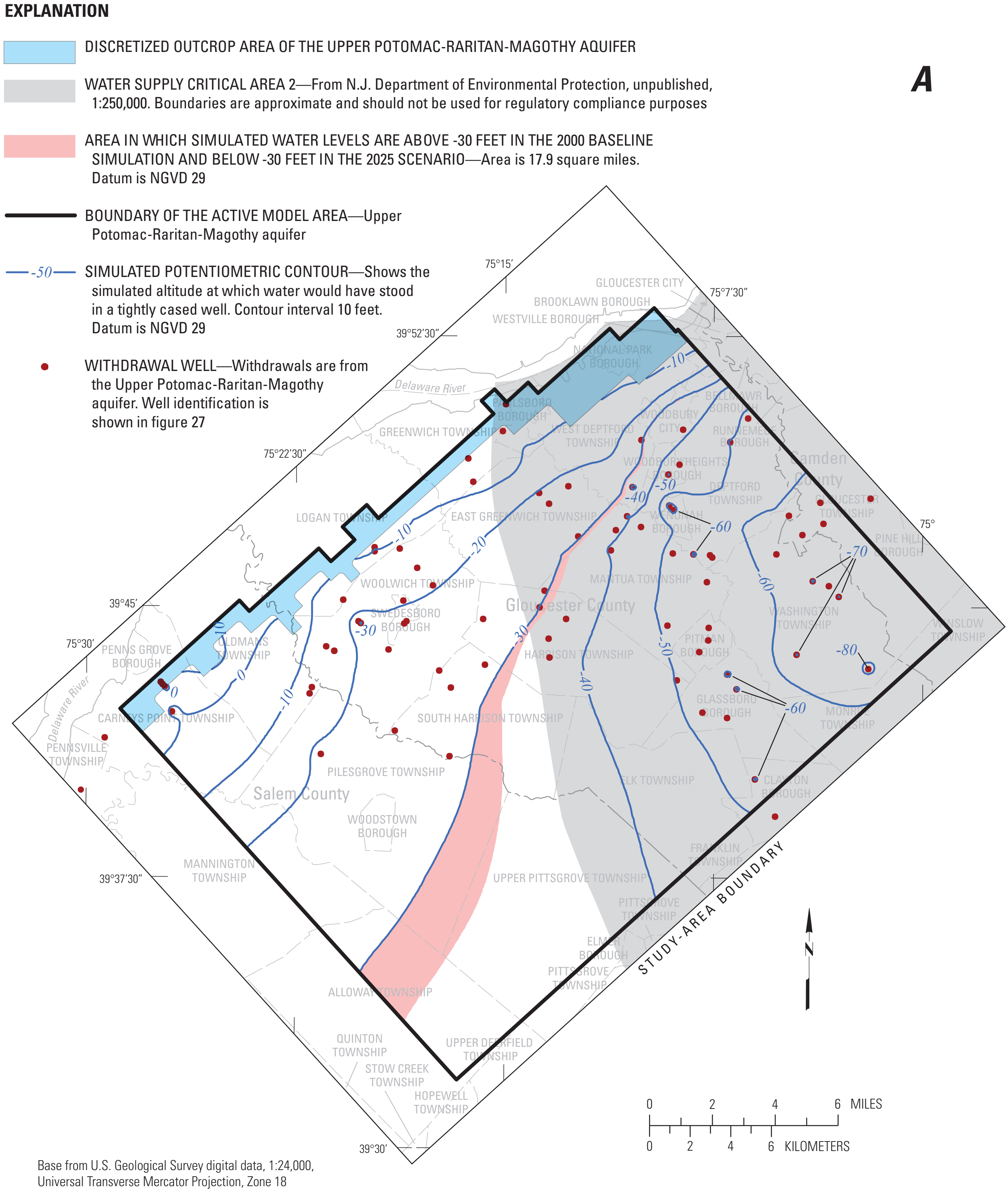


Figure 43. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the 2025 scenario, Salem-Gloucester study area, southern New Jersey.

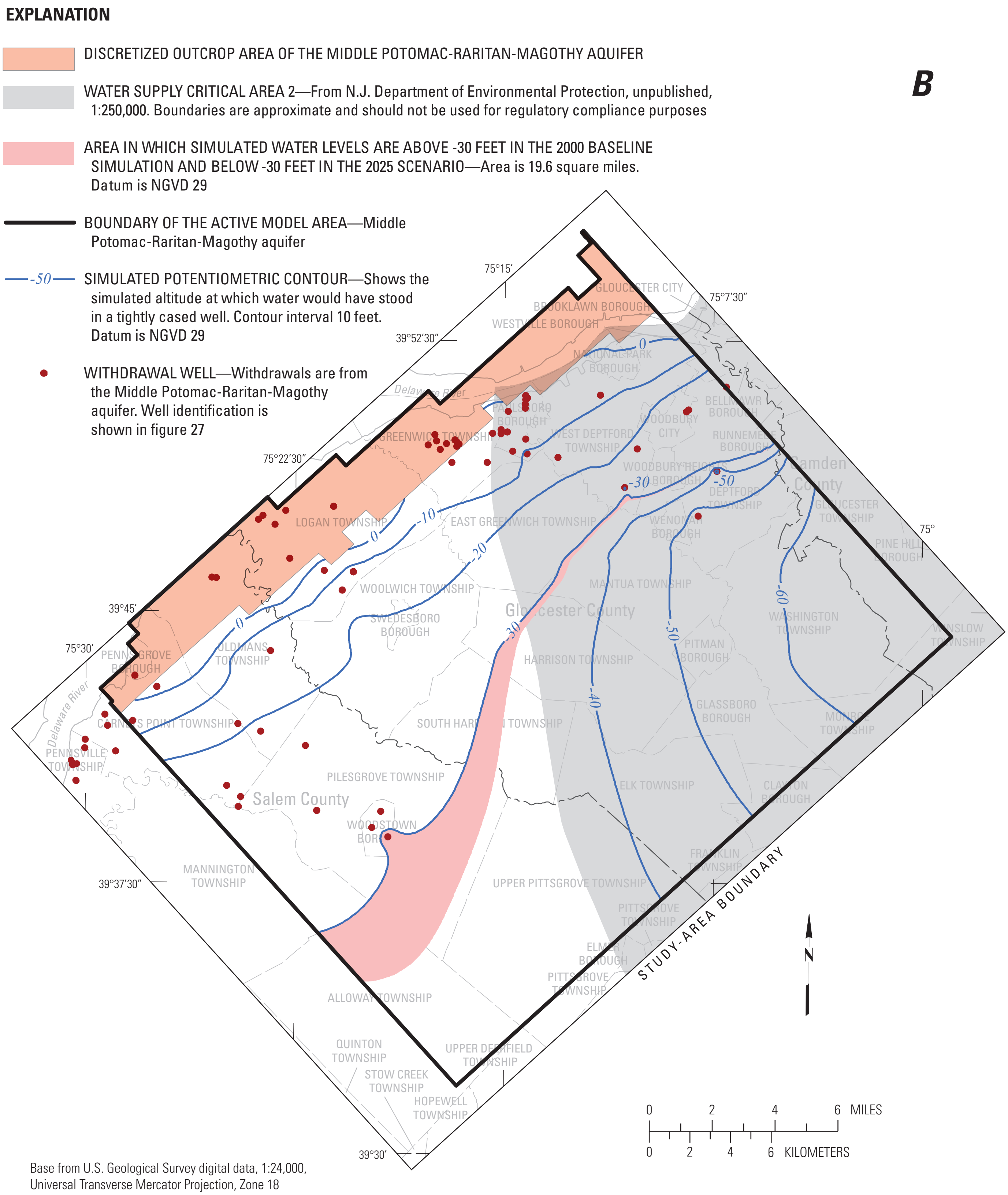


Figure 43. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the 2025 scenario, Salem-Gloucester study area, southern New Jersey.—Continued

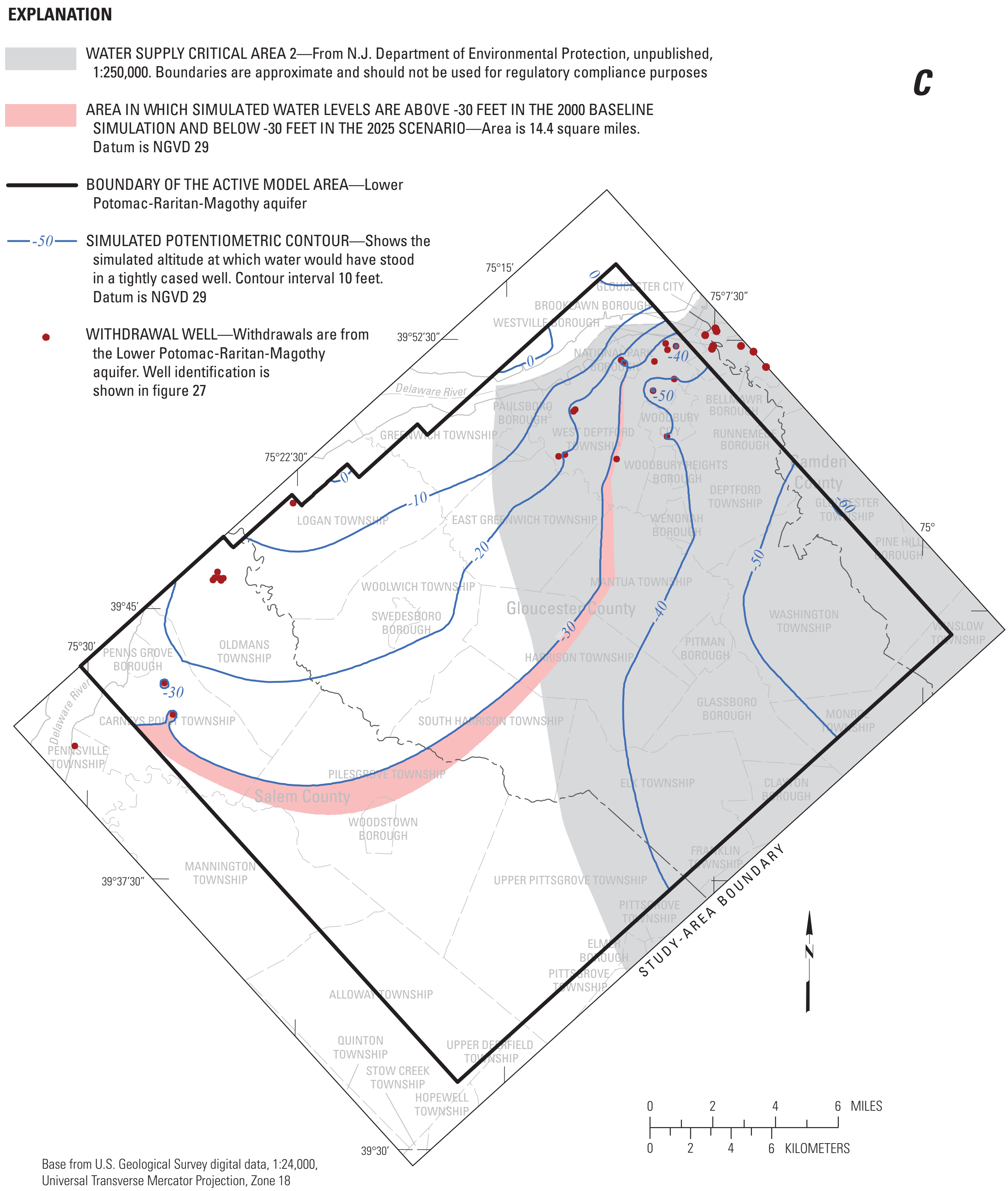


Figure 43. Simulated potentiometric surface in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer for the 2025 scenario, Salem-Gloucester study area, southern New Jersey.—Continued

EXPLANATION

DISCRETIZED OUTCROP AREA OF THE UPPER POTOMAC-RARITAN-MAGOTHY AQUIFER

WATER SUPPLY CRITICAL AREA 2—From N.J. Department of Environmental Protection, unpublished, 1:250,000. Boundaries are approximate and should not be used for regulatory compliance purposes

BOUNDARY OF THE ACTIVE MODEL AREA—Upper Potomac-Raritan-Magothy aquifer

-5 LINE OF EQUAL DIFFERENCE IN SIMULATED WATER LEVELS FROM THE 2000 BASELINE SIMULATION TO THE 2025 SCENARIO—Negative value indicates water-level decline. Contour interval 1 foot

WITHDRAWAL WELL—Withdrawals are from the Upper Potomac-Raritan-Magothy aquifer. Well identification is shown in figure 27

A

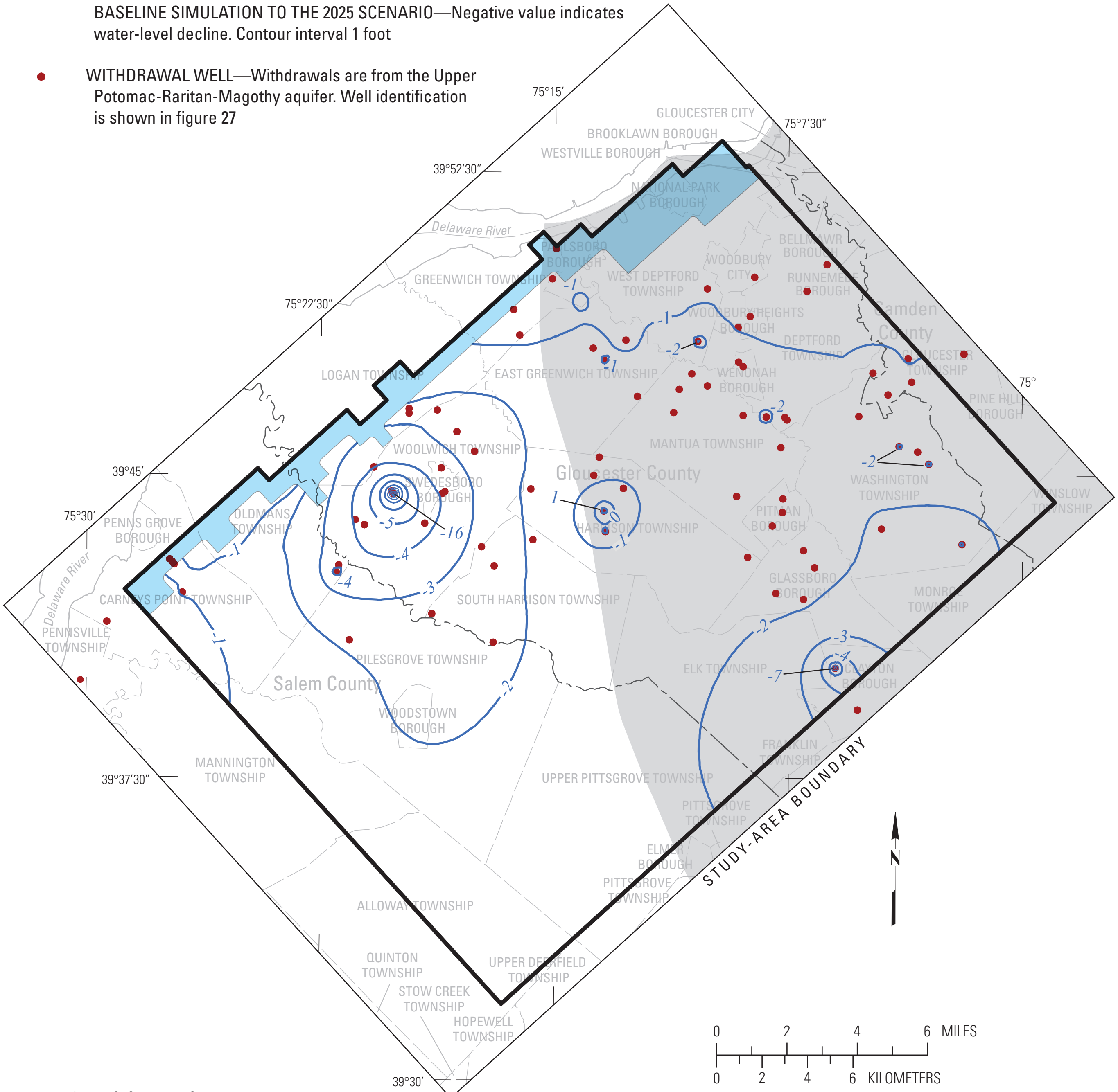


Figure 44. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the 2025 scenario, Salem-Gloucester study area, southern New Jersey.

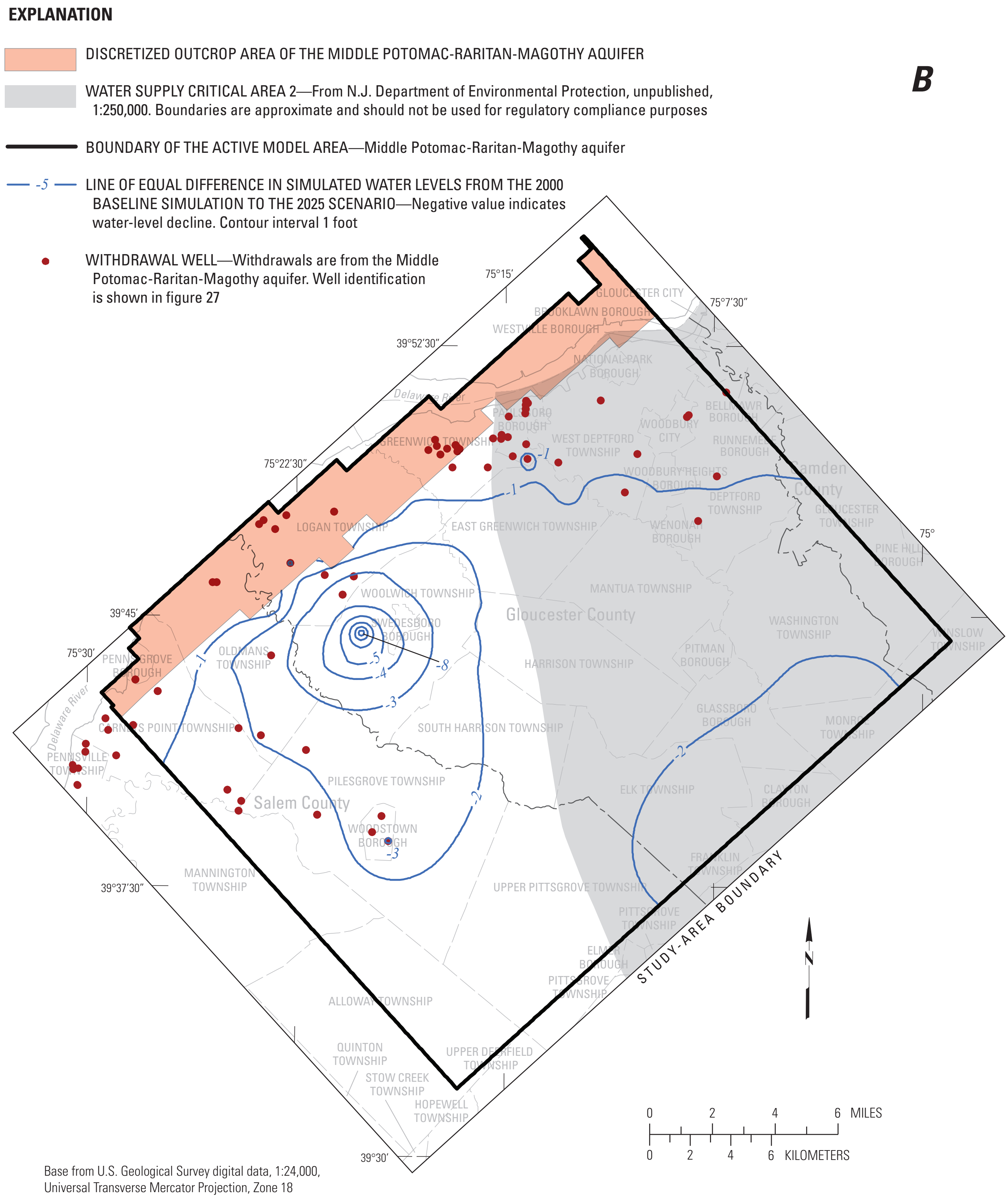


Figure 44. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the 2025 scenario, Salem-Gloucester study area, southern New Jersey.—Continued

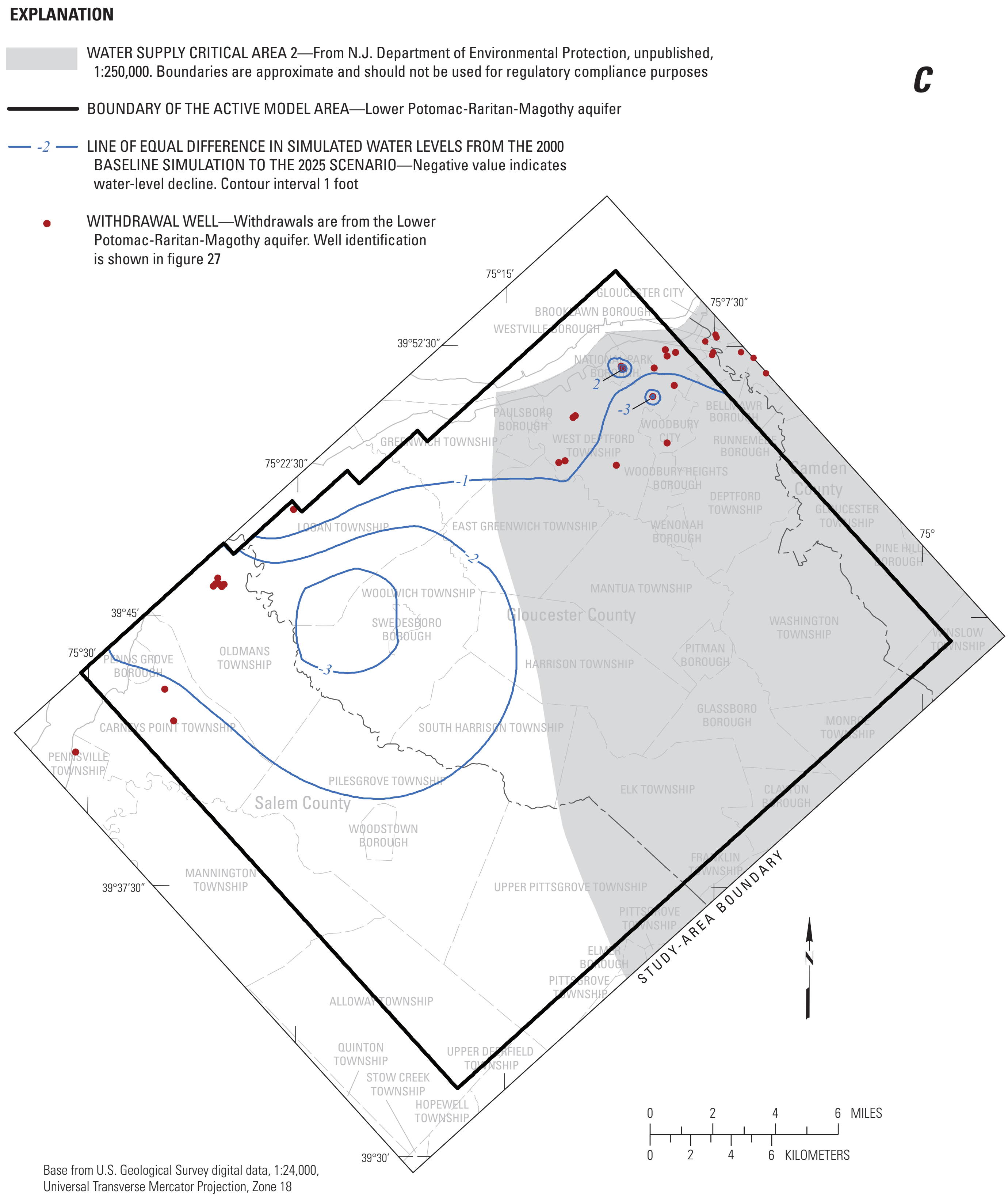


Figure 44. Change in simulated water levels in the, *A*, confined Upper Potomac-Raritan-Magothy aquifer, *B*, confined Middle Potomac-Raritan-Magothy aquifer, and, *C*, Lower Potomac-Raritan-Magothy aquifer from the 2000 baseline simulation to the 2025 scenario, Salem-Gloucester study area, southern New Jersey.—Continued

changed from the 1998 calibration and 2000 baseline simulations. Simulated groundwater discharge to the Delaware River accounts for the remaining percentage of inflow (5 percent) and outflow (9 percent) to the Potomac-Raritan-Magothy aquifer system and is a net flow from the aquifer system to the Delaware River of about 4 percent (1,010 Mgal/yr), about 15 percent (173 Mgal/yr) less than in the 2000 baseline simulation. Simulated flow-budget components for streams and the Delaware River in the local model for the 2025 scenario are summarized in table 12. All flow-budget values are rounded to the nearest integer.

Sensitivity of Water Levels at Key Boundaries to Additional Withdrawals

The effect of possible future additional withdrawals on water levels at key boundaries in the study area is an important consideration for water management. Spatial variations in hydrologic parameters such as transmissivity and recharge can cause the groundwater-level response to withdrawals to vary with the location of the well. Data from the scenarios outlined in the earlier sections of this report illustrate the effects for some specific instances. The sensitivity to water-level change at the key boundaries from withdrawals can be evaluated in a more general manner. There are four important (key) boundaries in the Upper and Middle Potomac-Raritan-Magothy aquifers within the study area. They are (1) the 250-mg/L isochlor, which delineates the boundary between potable and nonpotable water (a different location in each aquifer); (2) the western edge of Critical Area 2, where water-management decisions have required reductions in withdrawals; (3) the outcrop of each of the two aquifers; and (4) the southwestern boundary of the study area (and model), where the aquifers continue into Salem County and Delaware. The area within these boundaries represents the part of the aquifers in the study area that contains potable water that is not within Critical Area 2.

This analysis was undertaken by means of a series of simulations in which a hypothetical well screened in the Upper Potomac-Raritan-Magothy aquifer was placed in 12 different locations in a roughly gridded pattern within the area of the key boundaries (figs. 45A). The background condition for this analysis was the baseline simulation (average annual 1999–2001 withdrawals). The hypothetical well was simulated with a withdrawal of 1 Mgal/d (million gallons per day) added to the baseline simulation. The water-level results of each simulation were compared to those of the baseline simulation and inspected to determine the maximum water-level change along each of the key boundaries. This approach was repeated for a hypothetical well screened in the Middle Potomac-Raritan-Magothy aquifer (fig. 45B). The analysis was not undertaken for the Lower Potomac-Raritan-Magothy aquifer, however, because the extensive area in this aquifer in which chloride concentrations exceed 250 mg/L substantially limits the size of the area in that aquifer where future withdrawals could plausibly be located.

The results of the analysis for each of the four boundaries in the two aquifers are shown in table 16. The maximum change in simulated water level at the four boundaries resulting from the effect of the withdrawal from the hypothetical well ranged from 0.3 to 7.7 ft. The average of the maximum water-level changes for the 24 hypothetical well locations ranged from 0.6 to 4.5 ft (see figure 45A for the Upper Potomac-Raritan-Magothy aquifer and figure 45B for the Middle Potomac-Raritan-Magothy aquifer). The distinct spatial trend in water-level changes indicates that withdrawals from the northern part of the study area generally affect water levels at the key boundaries less than withdrawals from the southern part.

Simulated Movement of Saline Water

Saline water has threatened the potability of groundwater supplies derived from the Potomac-Raritan-Magothy aquifer system in the Salem-Gloucester study area (Cauller and others, 1999). The primary chemical constituents in saline water are sodium and chloride. The U.S. Environmental Protection Agency secondary maximum contaminant level (SMCL) for chloride is 250 mg/L (U.S. Environmental Protection Agency, 1992). The New Jersey secondary drinking-water standards for chloride and sodium are 250 mg/L and 50 mg/L, respectively (New Jersey Administrative Code, 2004). Within the study area, the concentrations of chloride and sodium in water from the Potomac-Raritan-Magothy aquifer system generally increase in the downdip (southeast) direction and eventually exceed the respective drinking-water standards. A regional portrayal of the 250-mg/L chloride-concentration isochlor, derived from historical and recent analyses of water from each aquifer, can be found in dePaul and others (2009, pls. 7, 8, and 9).

Four areas in the study area have experienced acute problems with saline water: (1) Glassboro Borough and adjacent municipalities, where wells are screened in the Upper Potomac-Raritan-Magothy aquifer; (2) Harrison Township in Gloucester County, where wells are screened in the Upper Potomac-Raritan-Magothy aquifer; (3) Woodstown Borough in Salem County, where wells are screened in the Middle Potomac-Raritan-Magothy aquifer; and (4) Oldmans Township, where wells are screened in the Lower Potomac-Raritan-Magothy aquifer. Sodium and chloride concentrations in groundwater in wells in these areas are near or above the secondary drinking-water standard. Historical concentrations of these constituents in water from selected wells in these areas are listed in table 17 (at end of report) and shown in figures 46 and 47. The sodium- and chloride-concentration data were retrieved from the NJDEP BWA Safe Drinking Water Systems database and the NWIS database and are on file at the USGS New Jersey Water Science Center in West Trenton, NJ. Data from the NJDEP BWA Safe Drinking Water Systems database are derived from many sources with varying quality-control procedures.

Table 16. Maximum change in simulated water level at key boundaries resulting from a hypothetical well withdrawing 1 million gallons per day, Salem-Gloucester study area, southern New Jersey.

[Well locations are shown in fig. 45; mg/L, milligrams per liter]

Simulation (designated by well number)	Location of pumped well		Maximum change in simulated water level between baseline simulation (1999–2001 average withdrawals) and simulation in which a hypothetical well is pumped (feet)				
	Row	Column	Critical Area 2 boundary	Outcrop boundary	250-mg/L isochlor boundary	Southwest boundary	Average
Upper Potomac-Raritan-Magothy aquifer							
1	40	12	0.5	7.1	0.7	7.7	4.0
2	40	46	0.5	3.7	0.6	1.7	1.6
3	46	96	0.8	1.7	0.8	0.7	1.0
4	46	130	0.9	1.2	0.6	0.5	0.8
5	91	12	1.8	1.0	2.7	6.8	3.1
6	91	46	1.7	0.7	2.2	2.5	1.8
7	83	96	1.5	0.9	1.4	1.2	1.2
8	83	120	2.3	0.8	1.4	1.0	1.4
9	141	12	3.1	0.7	7.3	7.0	4.5
10	141	46	3.2	0.7	4.2	3.8	3.0
11	141	72	3.5	0.7	5.1	3.0	3.1
12	119	96	2.5	0.7	3.7	1.5	2.1
Middle Potomac-Raritan-Magothy aquifer							
1	31	12	0.4	2.9	0.6	7.0	2.7
2	31	46	0.5	2.2	0.6	0.9	1.1
3	41	101	0.7	1.1	0.8	0.6	0.8
4	41	135	0.7	0.9	0.4	0.3	0.6
5	69	12	1.4	0.5	2.6	6.9	2.9
6	69	46	1.3	0.5	1.8	2.1	1.4
7	64	90	1.0	0.6	1.2	0.9	0.9
8	57	125	1.1	0.4	1.0	0.7	0.8
9	104	12	2.1	0.4	5.5	6.2	3.5
10	104	46	2.0	0.4	3.6	2.7	2.2
11	89	80	1.7	0.5	4.2	1.6	2.0
12	71	116	1.4	0.5	1.6	0.8	1.1

In order to assess the movement of saline water and the likelihood for continued saltwater intrusion, withdrawals from example wells in each area were simulated, and advective particle tracking was used to define groundwater flow paths; a budget analysis of the withdrawal zones was conducted. The MODPATH particle-tracking program (Pollock, 1994) was used for this assessment. MODPATH is an advective particle tracking scheme that accounts for the average linear flow velocity of a hypothetical particle of water. Groundwater flow paths beginning or ending at any location in the groundwater-flow model can be simulated with MODPATH (Pollock, 1994), which uses output from MODFLOW-2000 (Harbaugh and others, 2000) to simulate the advective path of a particle of water through model layers. Advective travel times along the flow paths are computed by using the magnitude of the flows from the model flow budget, the porosity of the aquifer, and the model cell dimensions. A porosity value of 0.25 was used for all aquifers, and a porosity value of 0.35 was used for all confining units in the particle-tracking analysis. The porosities are within the range of values for sand and silt cited in Freeze and Cherry (1979). Flow paths that originate in or pass through parts of the aquifer system that are known to contain chloride concentrations greater than the drinking-water standard (dePaul and others, 2009, pls. 7, 8, and 9) are

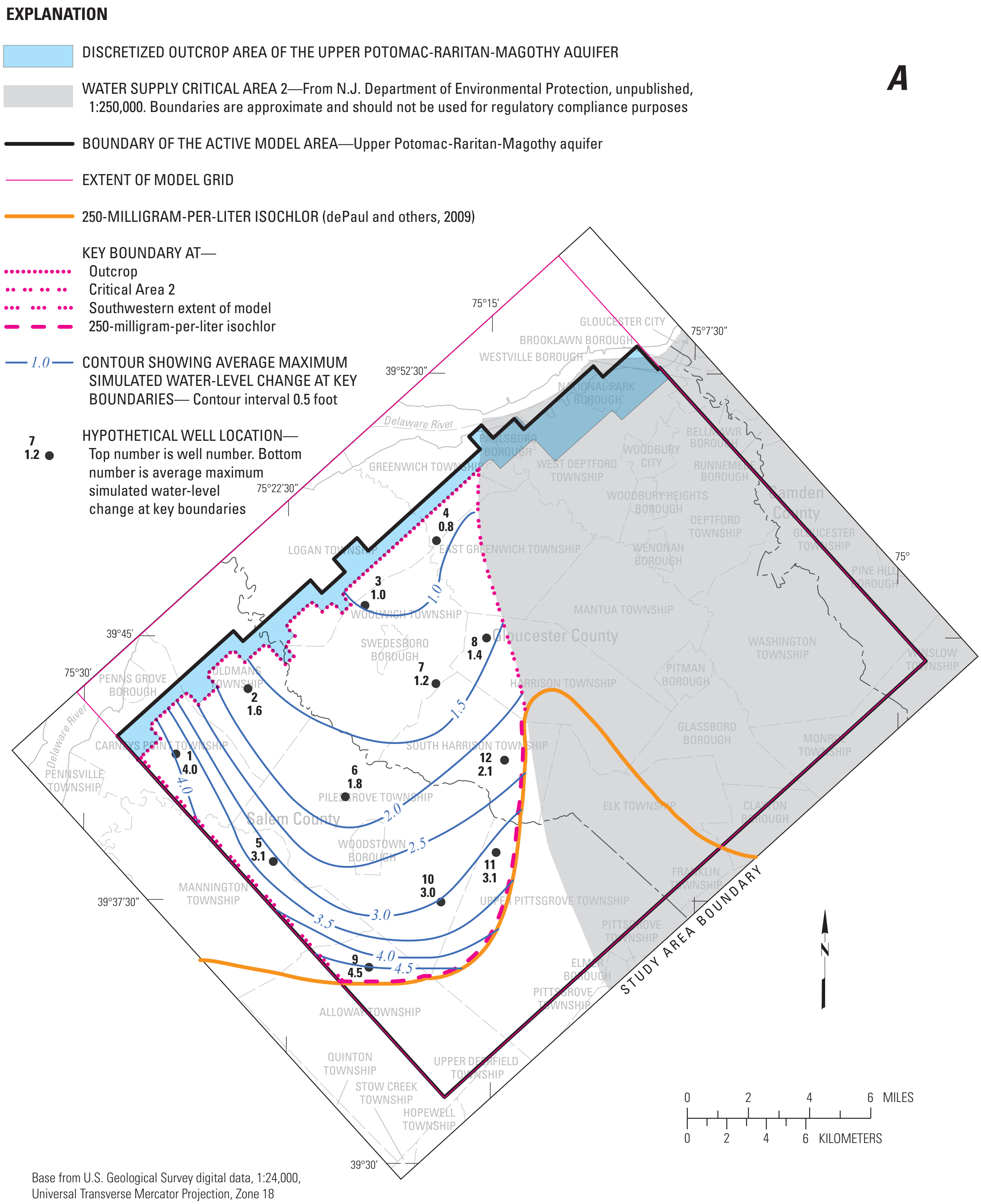


Figure 45. Distribution of average maximum simulated water-level change at key boundaries in the, *A*, Upper Potomac-Raritan-Magothy aquifer and, *B*, Middle Potomac-Raritan-Magothy aquifer, resulting from a hypothetical well withdrawing 1 million gallons per day, Salem-Gloucester study area, southern New Jersey.

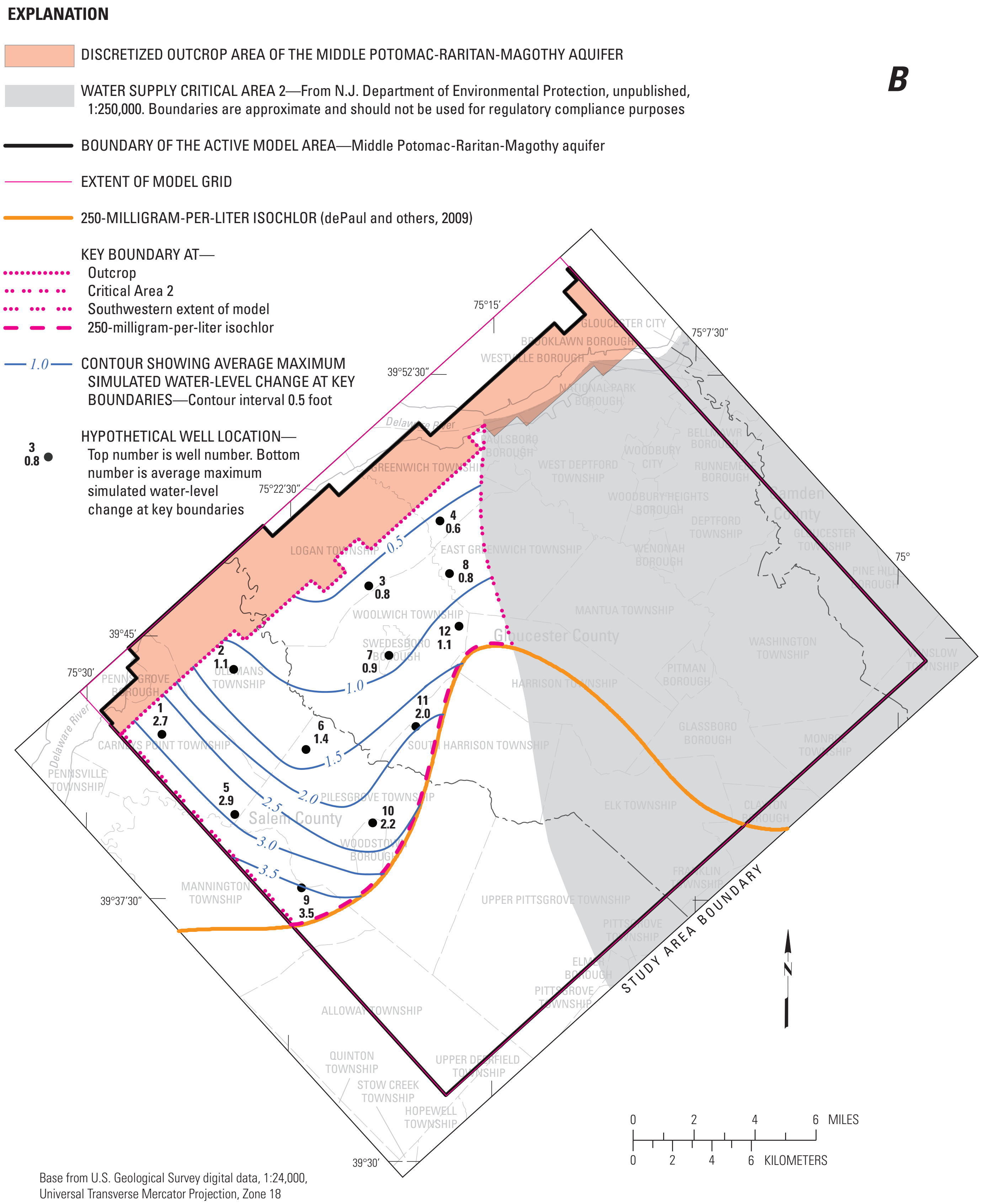


Figure 45. Distribution of average maximum simulated water-level change at key boundaries in the, *A*, Upper Potomac-Raritan-Magothy aquifer and, *B*, Middle Potomac-Raritan-Magothy aquifer, resulting from a hypothetical well withdrawing 1 million gallons per day, Salem-Gloucester study area, southern New Jersey.—Continued

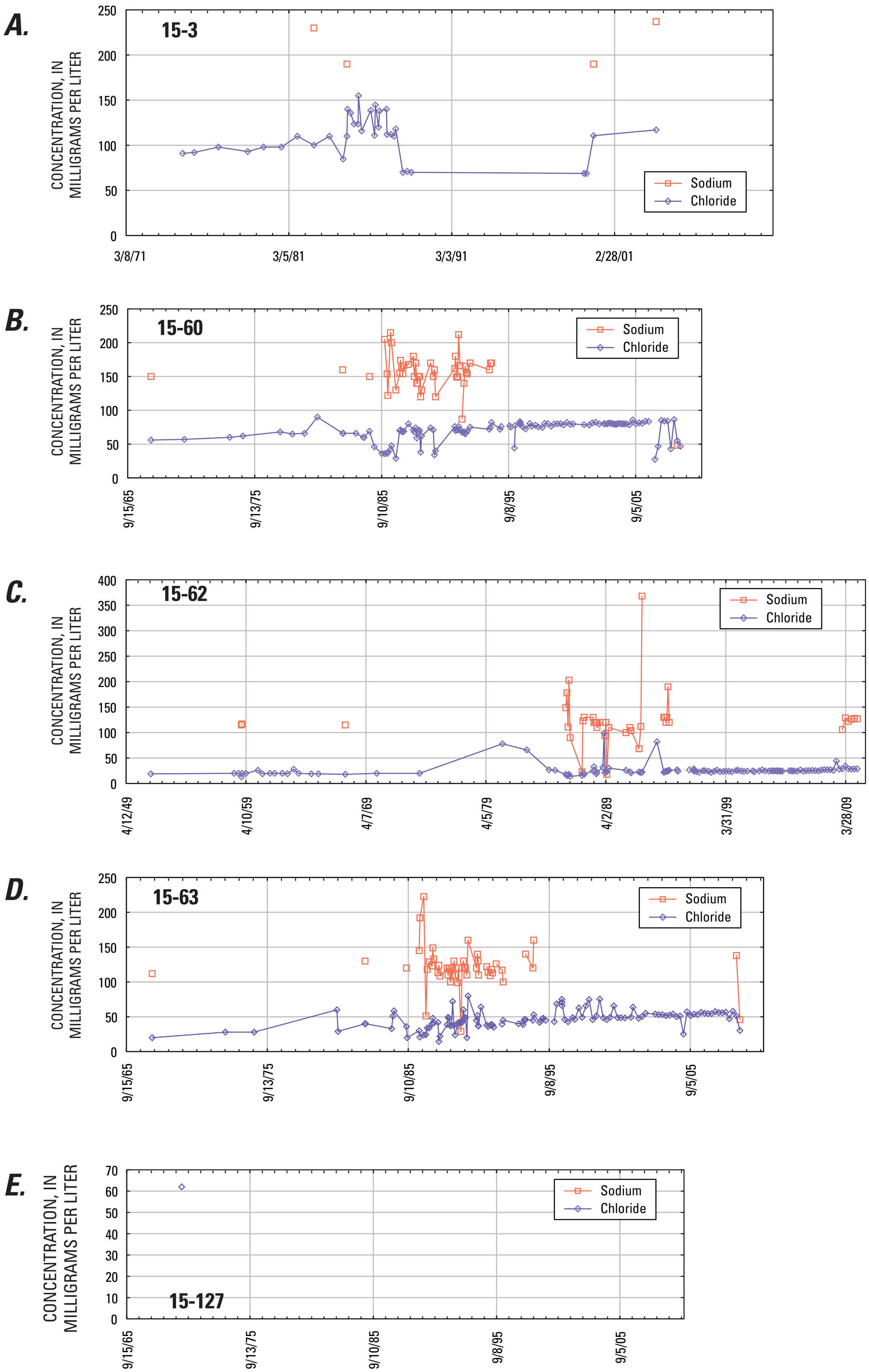


Figure 46. Measured sodium and chloride concentrations in water from selected wells screened in the Upper Potomac-Raritan-Magothy aquifer in Glassboro Borough and adjacent municipalities, Salem-Gloucester study area, southern New Jersey, 1929 to 2010.

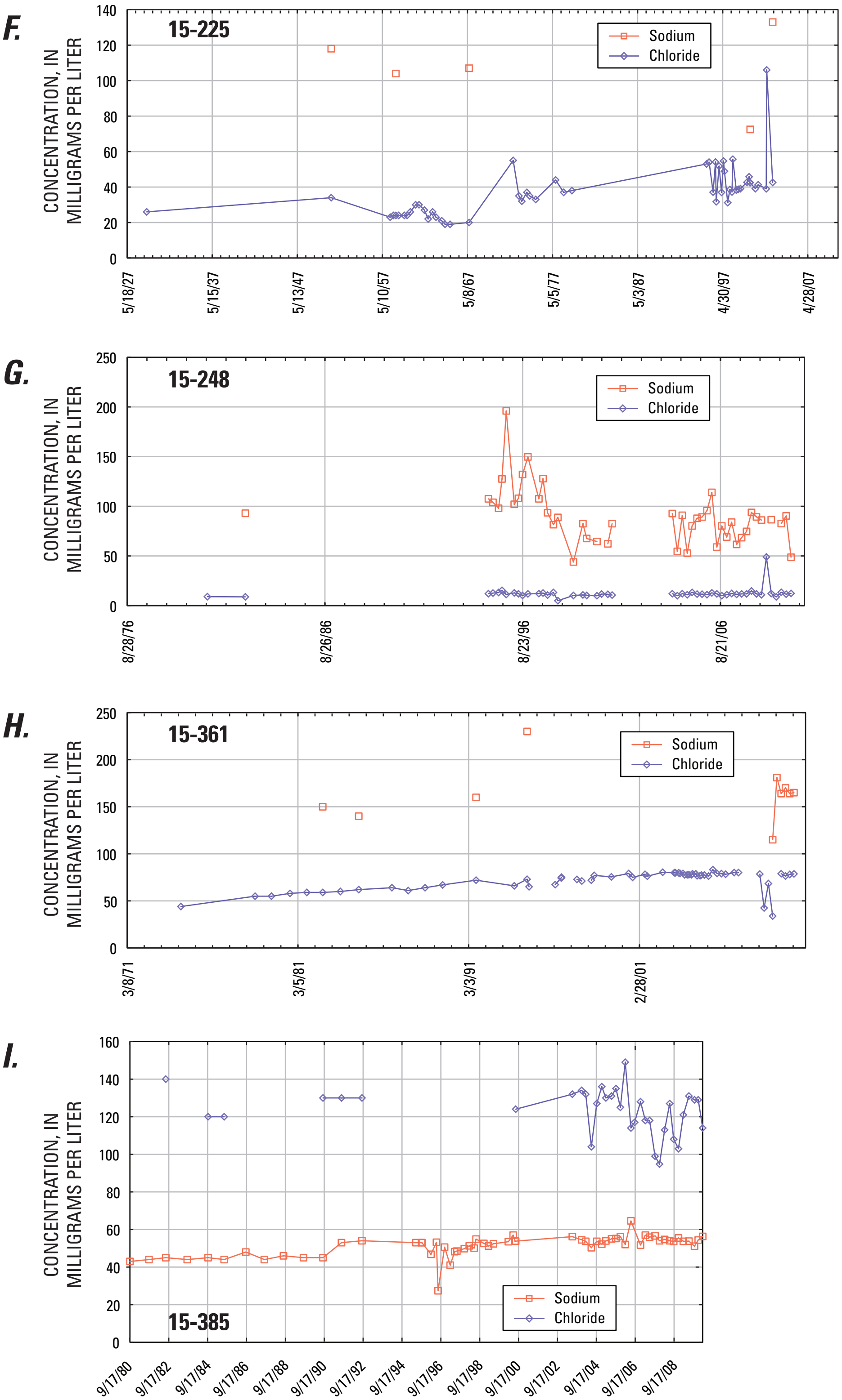


Figure 46. Measured sodium and chloride concentrations in water from selected wells screened in the Upper Potomac-Raritan-Magothy aquifer in Glassboro Borough and adjacent municipalities, Salem-Gloucester study area, southern New Jersey, 1929 to 2010.—Continued

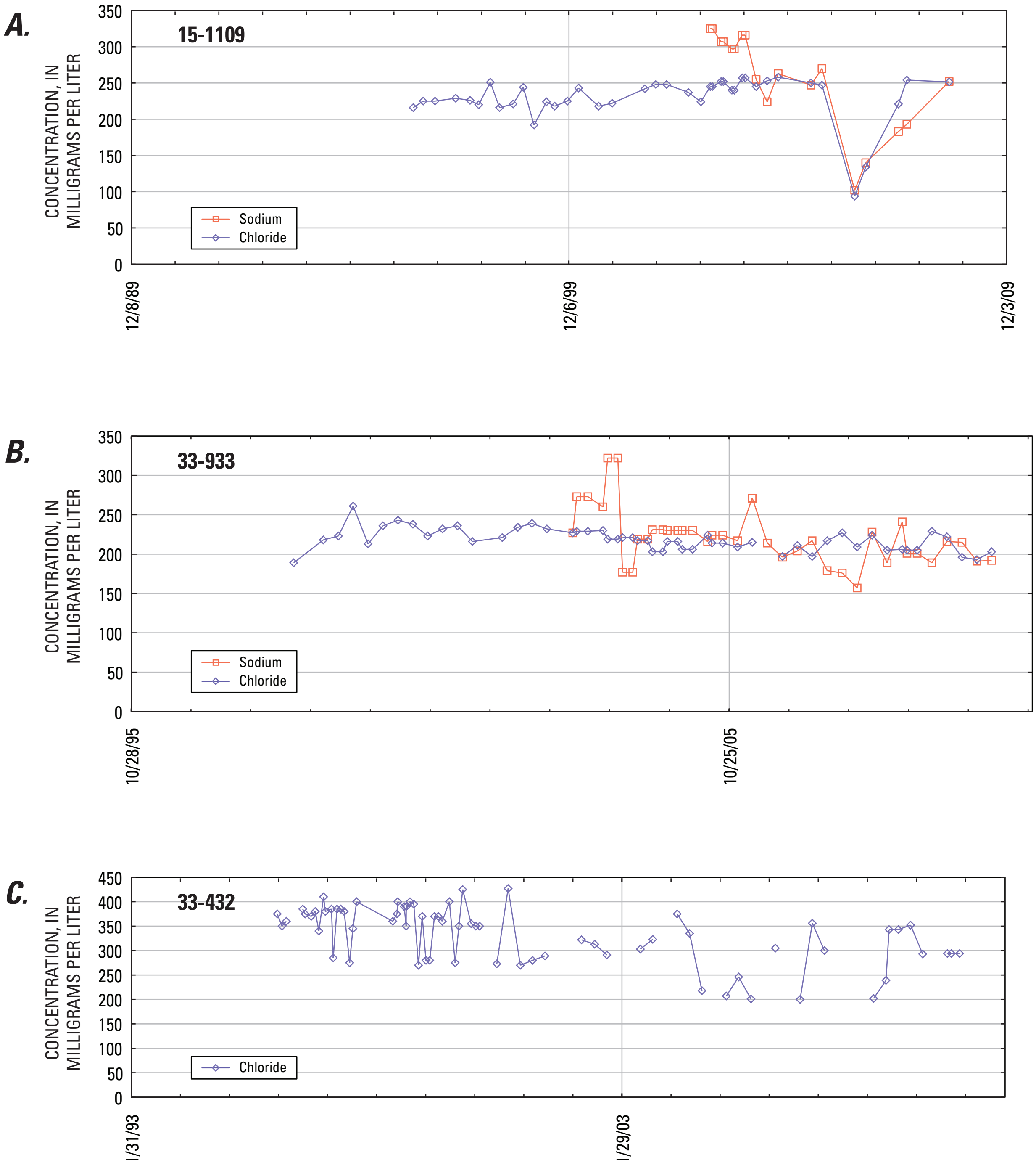


Figure 47. Measured sodium and chloride concentrations in water from selected wells in Woodstown Borough and Harrison and Oldmans Townships, Salem-Gloucester study area, southern New Jersey, 1996–2010.

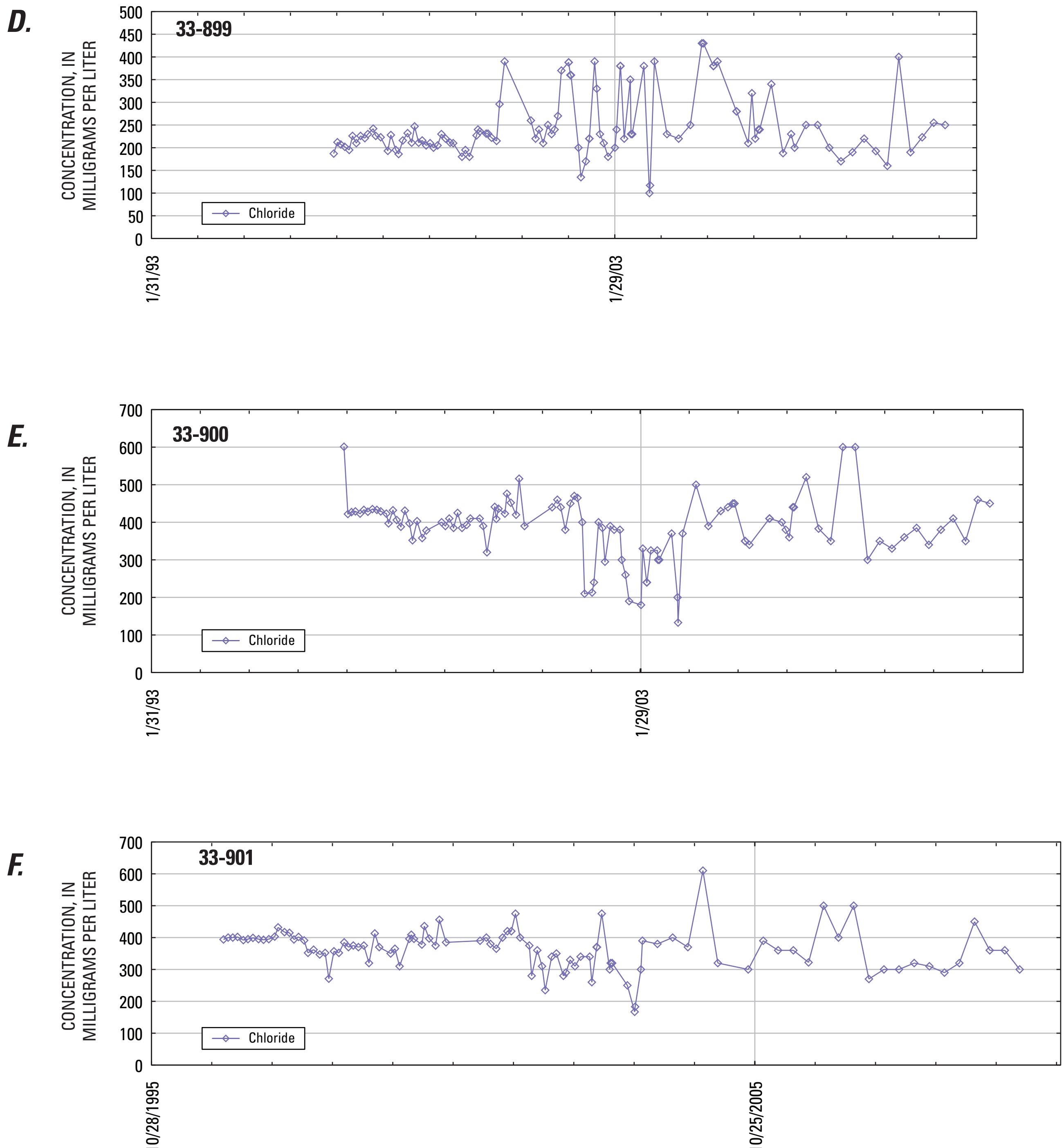


Figure 47. Measured sodium and chloride concentrations in water from selected wells in Woodstown Borough and Harrison and Oldmans Townships areas, Salem-Gloucester study area, southern New Jersey, 1996–2010.—Continued

considered a possible source of chloride to wells farther along these flow paths. Water particles were allowed to pass through weak sinks, thereby allowing them, in some instances, to be captured by a larger pumped well. Weak sinks are cells that contain withdrawals that do not capture all the water entering a cell; water flows out from at least one of the faces of the cell.

Glassboro Borough and Adjacent Municipalities

The simulated water levels in the Upper Potomac-Raritan-Magothy aquifer in Glassboro Borough and adjacent municipalities for the 2000 baseline simulation and the adjusted full-allocation scenario (figs. 28A and 33A) indicate that regional groundwater flow is from the west and northwest. Eight water-purveyor wells and two agricultural-irrigation wells were simulated in this area (fig. 48). Withdrawals from these wells simulated in the model are given in tables 4 and 7. The wells are located between 1 and 5 mi from the estimated location of the 250-mg/L isochlor. Chloride and sodium concentrations for nine of the wells in figure 48 are given in table 17. Chloride and sodium concentrations in water from agricultural-irrigation well 15-422 were not measured. Chloride concentrations in water from six of the water-purveyor wells (15-3, 15-60, 15-63, 15-225, 15-361, and 15-385) have increased slowly but are still less than the secondary drinking-water standard. Sodium concentrations in these wells typically exceed the secondary drinking-water standard (table 17). Water-purveyor wells 15-3, 15-60, and 15-361 are the closest to the 250-mg/L isochlor with no other pumped wells intervening. Chloride concentrations in water from these three wells were less than or equal to 155 mg/L for the periods of measurement (table 17). Water-purveyor wells 15-62, 15-63, 15-225, 15-248, 15-385 are located such that several of the other pumped wells are between them and the 250-mg/L isochlor. Chloride concentrations in water from these five wells were less than or equal to 106 mg/L for the period of measurement (table 17).

A forward particle-tracking analysis was conducted in Glassboro Borough, the adjoining boroughs of Clayton and Pitman, and the townships of Washington and Harrison (fig. 48) to assess the movement of groundwater from the 250-mg/L isochlor to 10 wells screened in the Upper Potomac-Raritan-Magothy aquifer in both the 2000 baseline simulation and the adjusted full-allocation scenario. The withdrawal conditions of the 2000 baseline simulation represent the smallest total withdrawals of all withdrawal simulations or scenarios in this study. The withdrawals simulated in the adjusted full-allocation scenario equaled the withdrawals simulated in the full-allocation scenario for 9 of the 10 wells. However, withdrawals from four of the water-purveyor wells in Glassboro Borough were less in the adjusted full-allocation scenario and the full-allocation scenario than in the 2000 baseline simulation because reported withdrawals from these wells exceeded the permitted allocation. For the forward tracking method, hypothetical particles were placed in model cells along the estimated location of the 250-mg/L isochlor nearest the 10 wells. The particles were tracked forward from the 250-mg/L isochlor along flow paths determined from the flow-model results.

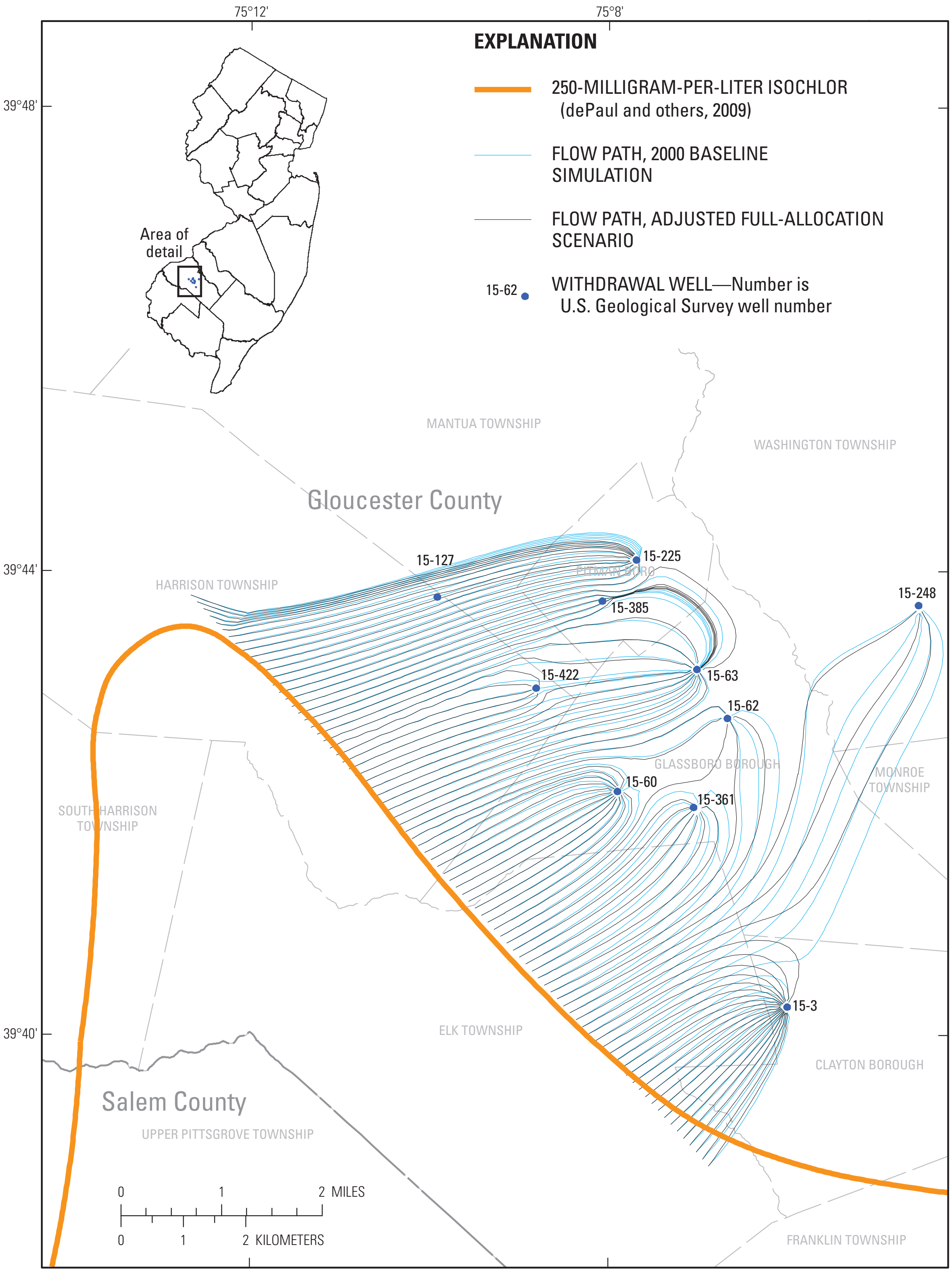
Figure 48 shows the advective flow paths from the 250-mg/L isochlor for both the 2000 baseline simulation and the adjusted full-allocation scenario. The simulated flow paths in the 2000 baseline simulation do not differ substantially from those in the adjusted full-allocation scenario. The flow paths indicate that particles that moved from the 250-mg/L isochlor toward the eight water-purveyor wells were captured by those wells. Additionally, the analysis indicates advective flow toward two agricultural-irrigation wells, 15-127 and 15-422, which were pumped at smaller rates than the water-purveyor wells (table 7). Agricultural-irrigation well 15-127 was pumped only in the adjusted full-allocation scenario. Only flow paths between the 250-mg/L isochlor and the wells are shown in this forward-tracking analysis. A considerable quantity of the water that flows to the wells does not originate from the 250-mg/L isochlor and is assumed to contain chloride at concentrations less than 250 mg/L.

Under 2000 baseline simulation withdrawal conditions, advective travel times from the 250-mg/L isochlor to 8 of the 10 pumped wells range from a minimum of 75 to 698 years, to a maximum of 116 to 862 years (table 18). Under adjusted full-allocation-scenario withdrawal conditions, advective travel times range from a minimum of 50 to 718 years to a maximum of 99 to 1,008 years (table 18). Particle travel times are similar for the 2000 baseline simulation and adjusted full-allocation scenario in most areas.

The relatively long flow paths with travel times on the order of hundreds of years through an area of the aquifer known to contain water in which chloride concentrations exceed the drinking-water standard indicate that the observed trend of slowly rising chloride concentrations in water from wells in the Glassboro Borough area is likely to continue. Adjusted full-allocation withdrawals do not change these conditions substantially. Variations in the observed chloride values likely result in part from variations in the rate of withdrawals from wells in the area. Given that the average travel time from the 250-mg/L isochlor is several hundred years and that a portion of the flow to the wells is from freshwater sources, water from wells in the Glassboro Borough area likely will remain potable with respect to chloride for at least several hundred years.

Harrison Township

Wells screened in the Upper Potomac-Raritan-Magothy aquifer in Harrison Township—purveyor well 15-1109, for example—have produced water with chloride concentrations at the 250-mg/L secondary drinking-water standard. Measured chloride concentrations in water from this well ranged from about 94 to 258 mg/L during the period 1996–2008 (table 17). During the period 2003–08, sodium concentrations ranged from 102 mg/L to 325 mg/L, which exceed the sodium drinking-water standard (fig. 47). Advective particle tracking



Base from U.S. Geological Survey digital data, 1:24,000, Universal Transverse Mercator Projection, Zone 18

Figure 48. Simulated lateral flow paths from the estimated location of the 250-milligram-per-liter isochlor to wells in the Upper Potomac-Raritan-Magothy aquifer in Glassboro Borough and adjacent municipalities, for the 2000 baseline simulation and adjusted full-allocation scenario, Salem-Gloucester study area, southern New Jersey.

Table 18. Simulated travel time of water particles from the estimated 250-milligram-per-liter isochlor in the Upper Potomac-Raritan-Magothy aquifer to eight withdrawal wells in Glassboro Borough and adjacent areas, Salem-Gloucester study area, southern New Jersey.

[Well locations are shown in fig. 48; --, no data; all travel times in years]

U.S. Geological Survey well number	Minimum travel time		Maximum travel time		Average travel time	
	Adjusted full-allocation scenario	2000 baseline simulation	Adjusted full-allocation scenario	2000 baseline simulation	Adjusted full-allocation scenario	2000 baseline simulation
15-3	111	145	605	367	145	168
15-60	108	100	196	212	143	140
15-62	152	150	692	655	328	339
15-63	105	102	252	817	147	148
15-225	75	75	106	116	85	87
15-248	718	698	1,008	862	784	740
15-361	185	182	309	358	209	214
15-422	50	--	99	--	82	--

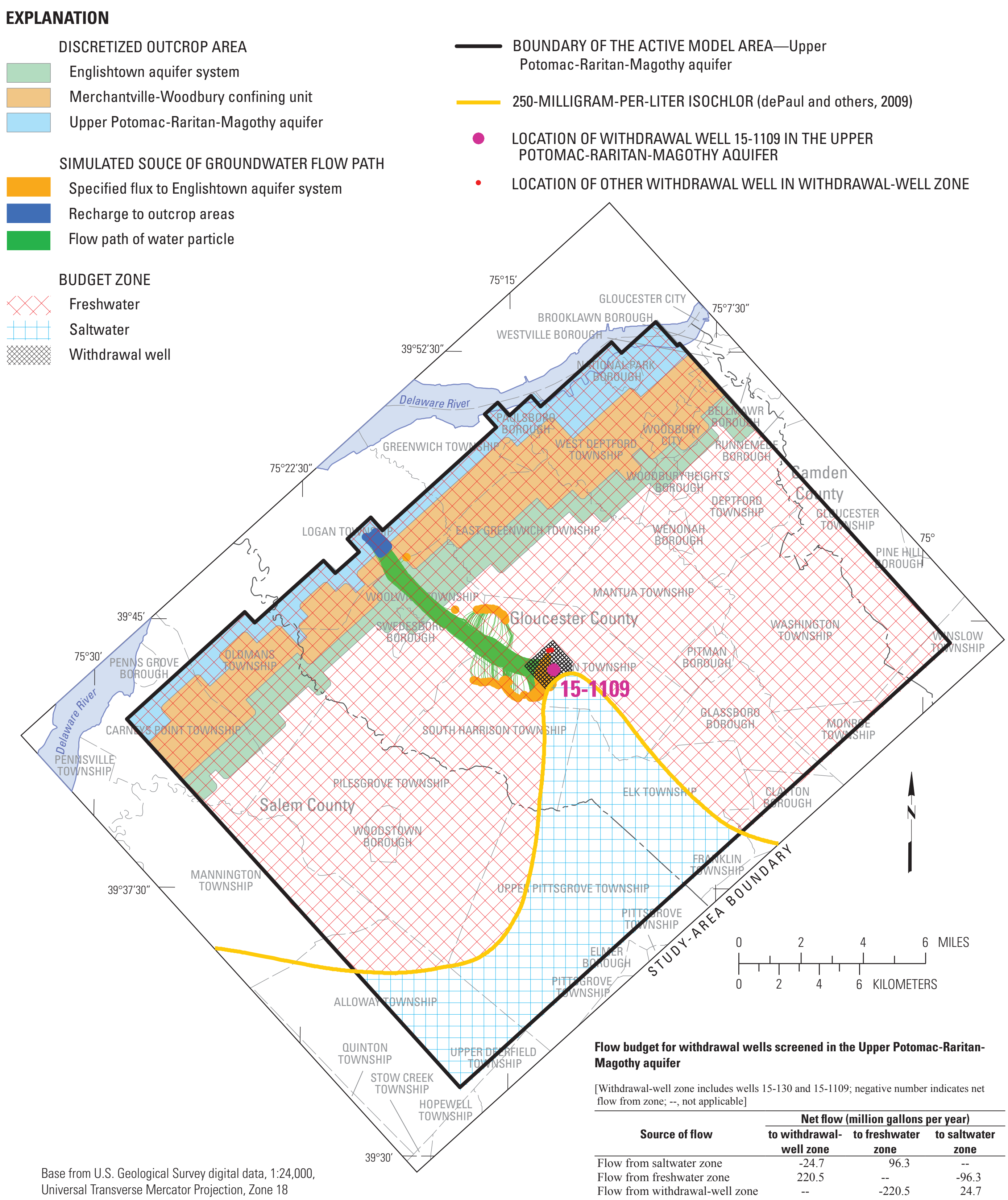
was conducted for this well to determine the contributing area to the well and to predict the possibility of movement of saline water (fig. 49) toward the well. This well is about 0.75 mi updip from the estimated location of the 250-mg/L isochlor. Withdrawals from this well in the 2000 baseline simulation are shown in table 4. Hypothetical particles were tracked backward from the well to their recharge locations. The simulated flow paths to this well indicate that flow to the well originates as recharge from the outcrop area of the Upper Potomac-Raritan-Magothy aquifer and from the Englishtown aquifer system (fig. 49). Advective travel times from the Upper Potomac-Raritan-Magothy outcrop area and the Englishtown aquifer system to well 15-1109 range from 300 to 6,000 years.

A flow-budget analysis of the groundwater simulation results in the Harrison Township area was undertaken. The analysis, using ZONEBUDGET (Harbaugh, 1990), delineated the freshwater and saltwater zones of the Upper Potomac-Raritan-Magothy aquifer, relative to the 250-mg/L isochlor, and in the vicinity of well 15-1109 and nearby well 15-130 but not beyond the 250-mg/L isochlor (fig. 49). Additional budget zones were included for the overlying and underlying aquifers. The intent of this budget analysis was to determine the proportions of flow to those wells from freshwater and saltwater sources. The budget analysis indicates that the zone containing the wells receives flow predominantly from the freshwater part of the aquifer (220.5 Mgal/yr); flow from the overlying and underlying aquifers—9.2 and 11.1 Mgal/yr, respectively—is minor (fig. 49). Additionally, the budget analysis indicates that some flow, 24.7 Mgal/yr (fig. 49), leaves the well zone, enters the saltwater zone, and continues toward the pumped wells in Glassboro Borough and adjacent areas (fig. 48). The analysis indicates that the elevated chloride concentrations observed in Harrison Township wells likely result from the proximity of the 250-mg/L isochlor, rather than from substantial movement of saline water from the direction of the isochlor.

The fluctuations of the chloride and sodium concentrations observed in well 15-1109 (table 17) may have resulted from variations in the withdrawal rate at this well, at nearby wells, and (or) at updip wells (fig. 27). Large variations in rates of withdrawal from these wells and in surrounding wells could alter flow paths to the wells. Large increases in withdrawals from wells located updip from well 15-1109 could divert freshwater originating in the outcrop area of the aquifer, potentially causing water containing higher concentrations of chloride in the downdip part of the aquifer to flow toward the well.

Woodstown Borough

Wells in Woodstown Borough screened in the Middle Potomac-Raritan-Magothy aquifer—for example, well 33-933—have produced water with chloride concentrations near the 250-mg/L secondary drinking-water standard. Measured chloride concentrations in water from this well ranged from 189 to 261 mg/L during the period 1998–2010 (table 17). During the period 2003–10, sodium concentrations ranged from 157 mg/L to 322 mg/L, which exceed the sodium drinking-water standard. Advective particle tracking was conducted for water-purveyor well 33-933, screened in the Middle Potomac-Raritan-Magothy aquifer, to determine flow paths to this well. This well is about 0.75 mi updip from the estimated location of the 250-mg/L isochlor (fig. 50). The withdrawal rate from this well in the 2000 baseline simulation is given in table 5. Hypothetical particles were tracked backward from the well to the starting location of the particles in the model. Flow paths to this well (fig. 50) indicate that simulated flow to well

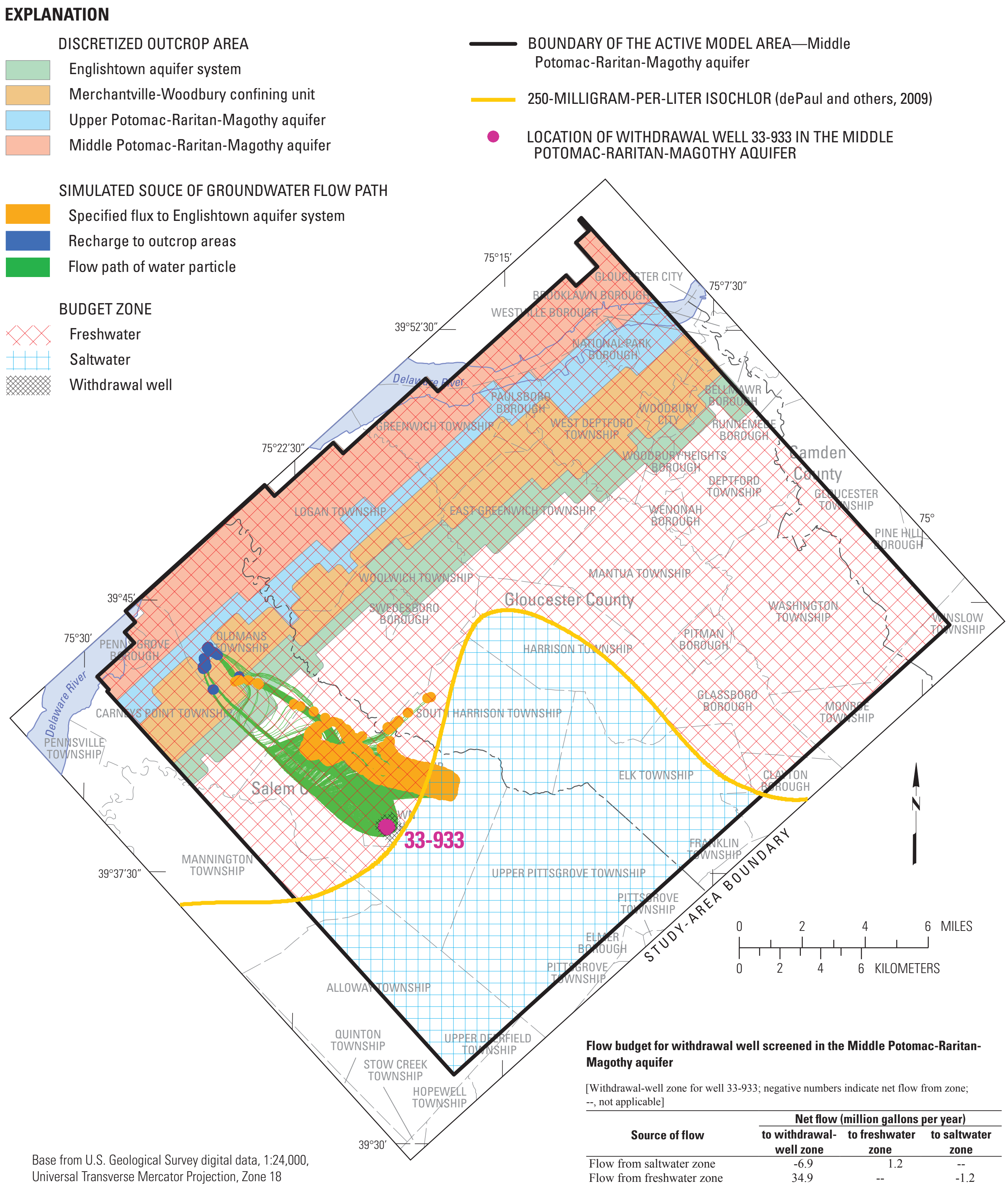


Flow budget for withdrawal wells screened in the Upper Potomac-Raritan-Magothy aquifer

[Withdrawal-well zone includes wells 15-130 and 15-1109; negative number indicates net flow from zone; --, not applicable]

Source of flow	Net flow (million gallons per year) to withdrawal-well zone	to freshwater zone	to saltwater zone
Flow from saltwater zone	-24.7	96.3	--
Flow from freshwater zone	220.5	--	-96.3
Flow from withdrawal-well zone	--	-220.5	24.7
Flow from overlying aquifer	9.2	1,139.8	177.8
Flow from underlying aquifer	11.1	-1,315.5	-50.4
Withdrawals	-216.0	-4,356.3	-6.2

Figure 49. Simulated lateral flow paths to withdrawal well 15-1109 screened in the Upper Potomac-Raritan-Magothy aquifer in Harrison Township and flow budget, 2000 baseline simulation, Salem-Gloucester study area, southern New Jersey.



Flow budget for withdrawal well screened in the Middle Potomac-Raritan-Magothy aquifer

[Withdrawal-well zone for well 33-933; negative numbers indicate net flow from zone; --, not applicable]

Source of flow	Net flow (million gallons per year) to withdrawal-well zone	to freshwater zone	to saltwater zone
Flow from saltwater zone	-6.9	1.2	--
Flow from freshwater zone	34.9	--	-1.2
Flow from withdrawal-well zone	--	-34.9	6.9
Flow from overlying aquifer	5.4	1,181.7	167.9
Flow from underlying aquifer	-1.7	-2,416.0	-85.0
Withdrawals	-31.7	-3,283.4	-1.3

Figure 50. Simulated lateral flow paths to withdrawal well 33-933 screened in the Middle Potomac-Raritan-Magothy aquifer in Woodstown Borough and flow budget, 2000 baseline simulation, Salem-Gloucester study area, southern New Jersey.

33-933 originates in the outcrop areas of the Upper Potomac-Raritan-Magothy aquifer and the Englishtown aquifer system; some flow is from the confined Englishtown aquifer system. The outcrop areas in the model receive recharge, and the flow from the confined Englishtown aquifer system is freshwater. Advective travel times from the outcrop area of the Upper Potomac-Raritan-Magothy aquifer and the Englishtown aquifer system to well 33-933 range from a minimum of 1,400 to a maximum of 6,000 years.

The analysis, using ZONEBUDGET (Harbaugh, 1990), delineated the freshwater and saltwater zones of the Middle Potomac-Raritan-Magothy aquifer relative to the 250-mg/L isochlor, and in the vicinity of well 33-933, but not beyond the 250-mg/L isochlor. Additional budget zones were included for the overlying and underlying aquifers (fig. 50). The intent of this budget analysis was to determine the proportions of flow to the well from freshwater and saltwater sources. The budget analysis indicates that the zone containing the well receives flow predominantly from the freshwater part of the aquifer, about 34.9 Mgal/yr (fig. 50); flow from the overlying aquifers (5.4 Mgal/yr) to the underlying aquifer (1.7 Mgal/yr) and into the saltwater zone (6.9 Mgal/yr) is relatively minor (fig. 50). This analysis indicates that the elevated chloride concentrations observed in the Middle Potomac-Raritan-Magothy aquifer wells in Woodstown Borough, like those in the Upper Potomac-Raritan-Magothy aquifer in the Harrison Township area, likely result from the proximity of the 250-mg/L isochlor, rather than from substantial movement of saline water from the direction of the isochlor.

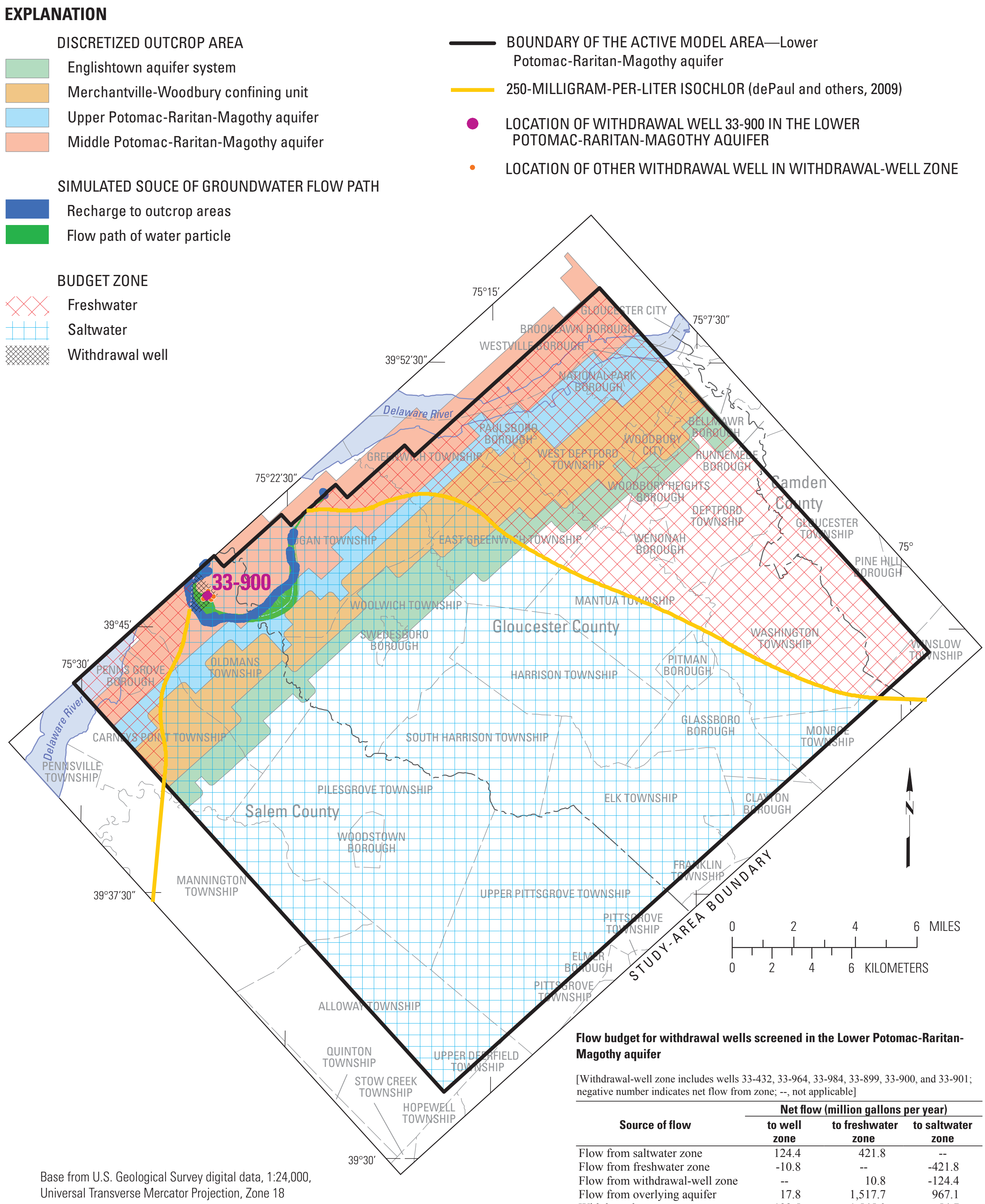
The fluctuations of the chloride and sodium concentrations observed in well 33-933 (table 17) may have resulted from variations in the withdrawal rate at this well, at nearby wells, and (or) at updip wells (fig. 27). Large variations in the rates of withdrawal from these wells and surrounding wells could alter flow paths to the wells. Large increases in withdrawals from wells located updip from well 33-933 could divert freshwater originating in the outcrop area of the aquifer, potentially causing water containing higher concentrations of chloride in the downdip part of the aquifer to flow toward the well.

Oldmans Township

Wells in Oldmans Township screened in the Lower Potomac-Raritan-Magothy aquifer—for example, wells 33-432, 33-964, 33-984, 33-899, 33-900, and 33-901—have produced water with chloride concentrations at and above the 250-mg/L secondary drinking-water standard. Measured chloride concentrations in water from these wells ranged from 100 to 610 mg/L during the period 1996–2010 (table 17). Sodium concentrations were not measured during that time period. Advective particle tracking was conducted for industrial self-supply well 33-900 to determine the contributing area to the well and to predict the possibility of movement of saline water (fig. 51) toward the well. This well is located more than 1 mi from the Delaware River (fig. 27). The withdrawal from this well in the 2000 baseline simulation is given in table 6. Hypothetical particles were tracked backward from the well to the starting location of the particles in the model.

Flow paths to this well (fig. 51) indicate that simulated flow to the well originates in the outcrop area of the Middle Potomac-Raritan-Magothy aquifer where the aquifer receives recharge in the model. The likely source of chloride to well 33-900 and the other wells is lateral flow from the Lower Potomac-Raritan-Magothy aquifer. Water in the Lower Potomac-Raritan-Magothy aquifer may mix with freshwater from the overlying Middle Potomac-Raritan-Magothy aquifer, diluting the chloride concentrations in these wells. The chloride concentrations in the water from these wells indicate that concentrations can fluctuate as much as 179 mg/L over the period of about 1 month in one well (table 17).

The analysis, using ZONEBUDGET (Harbaugh, 1990), delineated the freshwater and saltwater zones of the Lower Potomac-Raritan-Magothy aquifer and in the vicinity of well 33-900. Additional budget zones were included for the overlying aquifer (fig. 51). The intent of this budget analysis was to determine the proportions of flow to the well from outcrop areas and saline sources. The budget analysis indicates that the zone containing the well receives flow predominantly from water that has passed through the saltwater zone, about 124.4 Mgal/yr (fig. 51). The particle tracking for well 33-900 indicates that the origin of the flow path is the outcrop of the Middle Potomac-Raritan-Magothy aquifer. At the start of pumping, water from the saltwater zone would be drawn to the well. When a steady flow field is achieved, the recharge water would be drawn through overlying hydrogeologic units to the well. The flow path through the saline water allows the recharge water to mix with the ambient saline water. A minor amount of water (17.8 Mgal/yr) flows to the well zone directly from the overlying aquifers. Additionally, a minor amount of water (10.8 Mgal/yr) flows from the well zone to the freshwater zone of the Lower Potomac-Raritan-Magothy aquifer (fig. 51), possibly discharging to tidal creeks and the Delaware River. The elevated chloride concentrations found in the Lower Potomac-Raritan-Magothy aquifer in Oldmans Township are likely to persist because of the proximity of saltwater and the flow path that directs recharge water through the saline parts of the aquifer, providing an opportunity for mixing.



Flow budget for withdrawal wells screened in the Lower Potomac-Raritan-Magothy aquifer

[Withdrawal-well zone includes wells 33-432, 33-964, 33-984, 33-899, 33-900, and 33-901; negative number indicates net flow from zone; --, not applicable]

Source of flow	Net flow (million gallons per year) to well zone	to freshwater zone	to saltwater zone
Flow from saltwater zone	124.4	421.8	--
Flow from freshwater zone	-10.8	--	-421.8
Flow from withdrawal-well zone	--	10.8	-124.4
Flow from overlying aquifer	17.8	1,517.7	967.1
Withdrawals	-132.5	-1,545.0	-54.7

Figure 51. Simulated lateral flow paths to withdrawal well 33-900 screened in the Lower Potomac-Raritan-Magothy aquifer in Oldmans Township and flow budget, 2000 baseline simulation, Salem-Gloucester study area, southern New Jersey.

Summary and Conclusions

Groundwater withdrawals from the Potomac-Raritan-Magothy aquifer system, which includes the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, are the principal source of groundwater supply in northern Gloucester and northeastern Salem Counties in southern New Jersey. These withdrawals have resulted in water-level declines and can cause the lateral and vertical movement of groundwater from source areas with chloride concentrations greater than or equal to 250 mg/L in parts of the study area. The population in parts of Salem and in Gloucester Counties is expected to increase over the next 2 decades (2005–2025), which likely will result in increased groundwater withdrawals. The eastern part of Gloucester County is located in Critical Area 2, where permitted withdrawals from the Potomac-Raritan-Magothy aquifer system were restricted in 1993 in an effort to prevent the continued decline in water levels. This groundwater flow simulation study was undertaken by the U.S. Geological Survey, in cooperation with the N.J. Department of Environmental Protection, to examine the effects of increased withdrawals on water levels in the Potomac-Raritan-Magothy aquifer system in northern Gloucester and northeastern Salem Counties and on the movement of groundwater from source areas with chloride concentrations greater than or equal to 250 mg/L to withdrawal wells in these aquifers in the study area.

A steady-state groundwater-flow model was developed and calibrated to 1998 withdrawal conditions. In 1998, groundwater withdrawals in the model area were more than 10,100 Mgal/yr from the Potomac-Raritan-Magothy aquifer system and more than 22 Mgal/yr from the overlying Englishtown aquifer system for domestic self-supply. Withdrawals from water-purveyor wells accounted for 63 percent of withdrawals in the study area; industrial self-supply wells, agricultural-irrigation wells, and domestic self-supply wells (including wells screened in the Englishtown aquifer system) accounted for 32 percent, more than 2 percent, and about 2 percent of withdrawals, respectively. Low-volume users (water-purveyor, industrial self-supply, nonagricultural-irrigation, or commercial self-supply users with permitted withdrawal allocations of less than 100,000 gal/d) accounted for less than 1 percent of the total withdrawals from these aquifers in 1998.

A 2000 baseline simulation was conducted using average annual 1991–2001 groundwater withdrawals from wells in the Potomac-Raritan-Magothy aquifer system in the model area. Withdrawals in the 2000 baseline simulation were the smallest in this study. The results of this simulation were used as a baseline with which to compare the results of simulating several withdrawal scenarios representing full-allocation conditions or variations of full-allocation conditions. Withdrawals in the baseline simulation totaled 9,644 Mgal/yr, about 5 percent less than those in the 1998 calibration simulation. Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in the 2000 baseline simulation are 31, 27, and 30 ft below the National Geodetic Vertical Datum of 1929 (NGVD 29), respectively, and the lowest simulated water levels are 77, 65, and 59 ft below NGVD 29, respectively. Simulated water levels were lowest in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in Critical Area 2 in Washington Township. Simulated groundwater discharge from the Potomac-Raritan-Magothy aquifer system to streams in the 2000 baseline simulation is 8,441 Mgal/yr. Simulated net groundwater discharge from the Potomac-Raritan-Magothy aquifer system to the Delaware River is 1,183 Mgal/yr.

Of all the scenarios considered in this study, withdrawals were largest in the full-allocation scenario, although withdrawals by six water purveyors in Critical Area 2 were greater than their permitted allocation limits in the 2000 baseline simulation. In the full-allocation scenario, groundwater withdrawals from the Potomac-Raritan-Magothy aquifer system were the maximum permitted (allocated) by the State in the study area in 2006. Simulated withdrawals were 16,567 Mgal/yr, an increase of 72 percent from the 2000 baseline simulation. In the full-allocation scenario, average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 49, 43, and 48 ft below NGVD 29, respectively, and are 18, 16, and 18 ft lower, respectively, than in the 2000 baseline simulation. The lowest water levels simulated for the full-allocation scenario in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 156, 95, and 69 ft below NGVD 29, respectively, and are 79, 30, and 10 ft lower, respectively, than in the 2000 baseline simulation. The lowest simulated water levels in the Upper and Middle Potomac-Raritan-Magothy aquifers were centered on an agricultural-irrigation well in East Greenwich Township. The water-level decline at this agricultural-irrigation well was substantial because the full allocation for its water-allocation permit, which could also include surface-water diversions, was assigned to this one well in the simulation. The lowest simulated water levels in the Lower Potomac-Raritan-Magothy aquifer were observed in Carneys Point Township and near the eastern boundary of the model area in Critical Area 2. The increase in the size of the area in which simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are lower than 30 ft below NGVD 29 compared to the area in the 2000 baseline simulation is 112.9, 123.0, and 118.3 mi^2, respectively. In the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers, these areas are through most of East Greenwich and Woolwich Townships and Swedesboro Borough. Simulated net flow from the Potomac-Raritan-Magothy aquifer system to streams is 6,018 Mgal/yr in the full-allocation scenario, a decrease of 29 percent from the 2000 baseline simulation. Simulated net flow is 1,816 Mgal/yr from the Delaware River to the aquifer system, whereas in the 2000 baseline simulation net flow was from the aquifer system to the Delaware River.

In the adjusted full-allocation scenario, some of the permitted withdrawals in the full-allocation scenario were adjusted because withdrawals by some industrial self-supply, low-volume, and agricultural-irrigation users were substantially different from those allocated. Withdrawals in the adjusted full-allocation scenario were 13,290 Mgal/yr, an increase of 38 percent from the 2000 baseline simulation. Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 36, 32, and 36 ft below NGVD 29, respectively, and are 5, 5, and 6 ft lower, respectively, than in the 2000 baseline simulation. The lowest water levels simulated in the adjusted full-allocation scenario in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 83, 68, and 63 ft below NGVD 29, respectively, and are 6, 3, and 4 ft lower, respectively, than in the 2000 baseline simulation. The increase in the size of the area in which simulated water levels are lower than 30 ft below NGVD 29 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers compared to the size of the area in the 2000 baseline simulation is 54.7, 54.6, and 47.8 mi^2, respectively. Simulated flow from the Potomac-Raritan-Magothy aquifer system to streams is 7,256 Mgal/yr, 14 percent less than in the 2000 baseline simulation. Simulated net flow from the Delaware River to the aquifer system is 513 Mgal/yr, whereas in the 2000 baseline simulation net flow was from the aquifer system to the Delaware River.

The adjusted full-allocation plus Woolwich request scenario duplicated adjusted full-allocation conditions but incorporated additional withdrawals for two water-purveyor wells in Woolwich Township. Withdrawals were 13,399 Mgal/yr in this scenario, an increase of less than 1 percent from the adjusted full-allocation scenario; consequently, results are similar to those for the adjusted full-allocation simulation. Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 37, 33, and 36 ft below NGVD 29, respectively, and are 1, 1, and 0 ft lower, respectively, than in the adjusted full-allocation scenario. The lowest water levels simulated in the adjusted full-allocation plus Woolwich request scenario in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 83, 68, and 63 ft below NGVD 29, respectively, the same as in the adjusted full-allocation scenario. The increase in the size of the area in which simulated water levels are lower than 30 ft below NGVD 29 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers compared to the size of the area in the adjusted full-allocation scenario is 2.8, 3.3, and 2.9 mi^2, respectively. Simulated flow from the Potomac-Raritan-Magothy aquifer system to streams is 7,209 Mgal/yr, less than 1 percent less than in the adjusted full-allocation scenario. Simulated net flow from the Delaware River to the aquifer system is 541 Mgal/yr, 5 percent more than in the adjusted full-allocation scenario.

In the adjusted full-allocation plus all requests scenario, adjusted full-allocation conditions were modified by incorporating potential new withdrawals by four water purveyors and six agricultural-irrigation users in the study area. Simulated withdrawals in this scenario were 14,551 Mgal/yr, an increase of 9 percent from the adjusted full-allocation scenario. Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 40, 35, and 39 ft below NGVD 29, respectively, and are 4, 3, and 3 ft lower, respectively, than in the adjusted full-allocation scenario. The lowest water levels simulated in the adjusted full-allocation plus all requests scenario in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 85, 69, and 64 ft below NGVD 29, respectively, and are 2, 1, and 1 ft lower, respectively, in this scenario than in the adjusted full-allocation scenario. The increase in the size of the area in which simulated water levels are lower than 30 ft below NGVD 29 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers compared to the size of the area in the adjusted full-allocation scenario is 33.4, 37.7, and 27.0 mi^2, respectively. Simulated flow from the Potomac-Raritan-Magothy aquifer system to streams is 6,706 Mgal/yr, 8 percent less than in the adjusted full-allocation scenario. In the full-allocation plus all requests scenario, simulated net flow from the Delaware River to the aquifer system is 780 Mgal/yr, 52 percent more than in the adjusted full-allocation scenario.

In the adjusted full-allocation plus adjusted requests scenario, adjusted full-allocation conditions were modified by incorporating additional withdrawals that are smaller than those used in the adjusted full-allocation plus all requests scenario. Withdrawals in this scenario were 13,865 Mgal/yr, an increase of 4 percent from the adjusted full-allocation scenario. Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 38, 34, and 37 ft below NGVD 29, respectively, and are 2, 2, and 1 ft lower, respectively, than in the adjusted full-allocation scenario. The lowest water levels simulated in the adjusted full-allocation plus adjusted requests scenario in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers are 84, 69, and 64 ft below NGVD 29, respectively, and are 1, 1, and 1 ft lower, respectively, than in the adjusted full-allocation scenario. The increase in the size of the area in which simulated water levels are lower than 30 ft below NGVD 29 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers compared to the size of the area in the adjusted full-allocation scenario is 17.7, 24.3, and 11.8 mi^2, respectively. Simulated flow from the Potomac-Raritan-Magothy aquifer system to streams is 6,983 Mgal/yr, 4 percent less than in the adjusted full-allocation scenario. In the full-allocation plus adjusted requests scenario, simulated net flow from the Delaware River to the aquifer system is 619 Mgal/yr, 21 percent more than in the adjusted full-allocation scenario.

The 2025 groundwater-withdrawal scenario is based on estimates of population growth in the study area by 2025. Simulated withdrawals in this scenario were 10,261 Mgal/yr, an increase of 6 percent from the 2000 baseline simulation. In this scenario, full-allocation withdrawals were simulated at water-purveyor wells inside Critical Area 2, and withdrawals at some water-purveyor wells outside Critical Area 2 were increased from the 2000 baseline simulation amount. Water levels recovered around one water-purveyor well in Harrison Township in the Upper Potomac-Raritan-Magothy aquifer, and around two water-purveyor wells in the Lower Potomac-Raritan-Magothy aquifer in National Park Borough because withdrawals in these municipalities were greater in the 2000 baseline simulation than in the 2025 scenario, in which full allocations (the total permitted allocations) were used. Average simulated water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 32, 29, and 32 ft below NGVD 29, respectively, and are 1, 2, and 2 ft lower, respectively, than in the 2000 baseline simulation. The lowest water levels simulated in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers in this scenario are 81, 66, and 60 ft below NGVD 29, respectively, and are 4, 1, and 1 ft lower, respectively, than in the 2000 baseline simulation. The increase in the size of the area in which simulated water levels are lower than 30 ft below NGVD 29 in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers compared to the size of the area in the 2000 baseline simulation is 17.9, 19.6, and 14.4 mi^2, respectively. Simulated flow from the Potomac-Raritan-Magothy aquifer system to streams is 8,189 Mgal/yr, 3 percent less than in the 2000 baseline simulation. In the 2025 scenario, simulated net flow from the aquifer system to the Delaware River is 1,010 Mgal/yr, 15 percent less than in the 2000 baseline simulation.

In the 1998 calibration simulation and the simulation of the 2025 scenario, net flow was from the Potomac-Raritan-Magothy aquifer system to the Delaware River. Net flow in the 2000 baseline simulation also was from the aquifer system to the Delaware River, although simulated withdrawals by six water purveyors were greater than their water-allocation permits allowed. In all scenarios involving full-allocation conditions and variations of full-allocation conditions, net flow was from the Delaware River to the Potomac-Raritan-Magothy aquifer system.

An analysis of the sensitivity of water levels at the key boundaries to a hypothetical withdrawal well in the study area was undertaken. These boundaries include the 250-mg/L isochlor, the western edge of Critical Area 2, the aquifer outcrop, and the southwestern boundary of the model area. The sensitivities of the water levels in the Upper and Middle Potomac-Raritan-Magothy aquifers at these boundaries indicate that water levels at the key boundaries are affected less by withdrawals from the northern part of the study area than by withdrawals from the southern part.

Saline water has threatened the potability of groundwater supplies derived from the Potomac-Raritan-Magothy aquifer system in the Salem-Gloucester study area. Four areas have experienced acute problems with saline water in the study area. They include (1) Glassboro Borough and adjacent municipalities, where wells are screened in the Upper Potomac-Raritan-Magothy aquifer; (2) Harrison Township in Gloucester County, where wells are screened in the Upper Potomac-Raritan-Magothy aquifer; (3) Woodstown Borough in Salem County, where wells are screened in the Middle Potomac-Raritan-Magothy aquifer; and (4) Oldmans Township, where wells are screened in the Lower Potomac-Raritan-Magothy aquifer. Flow to example wells in each of the four areas was simulated using advective particle tracking to define groundwater flow paths, and a budget analysis of the zone around the withdrawal well was conducted to assess the movement of saline water and the likelihood of continued saltwater intrusion.

The assessment of the movement of saline water in the Glassboro Borough area, under both the 2000 baseline simulation and the adjusted full-allocation-scenario withdrawal rates, indicates that the average travel time from the 250-mg/L isochlor to the wells is several hundred years and that a portion of the flow to the wells is from freshwater sources. The simulated flow paths in the 2000 baseline simulation do not differ substantially from those in the adjusted full-allocation scenario. The water produced from the wells in the Glassboro Borough area at either average annual 1999–2001 or adjusted full-allocation scenario withdrawal rates will likely remain potable with respect to chloride for at least several hundred years, although chloride concentrations in the wells closest to the saltwater probably will continue to rise slowly.

The assessment of the movement of saline water in Harrison Township indicates that the elevated chloride concentrations observed in the wells screened in the Upper Potomac-Raritan-Magothy aquifer likely result from their proximity to the 250-mg/L isochlor rather than from substantial lateral updip movement of the saline water. Advective travel times from the Upper Potomac-Raritan-Magothy aquifer outcrop area and the Englishtown aquifer system to well 15-1109 range from a minimum of 300 years to a maximum of 6,000 years. These travel times indicate that the time required for freshwater from the outcrop area to recharge these wells would be substantial.

The particle tracking and budget analysis similarly indicate that the elevated chloride concentrations observed in the water from wells screened in the Middle Potomac-Raritan-Magothy aquifer in Woodstown Borough likely result from their close proximity to the 250-mg/L isochlor rather than from substantial movement of saline water from the direction of the isochlor. The elevated chloride concentrations found in wells screened in the Lower Potomac-Raritan-Magothy aquifer in Oldmans Township are likely to persist because of the proximity of the saltwater and the flow path that directs recharge water through the areas of the aquifer that contain saline water, providing opportunity for mixing.

The model described in this report was used to analyze the effects of both large and small changes in withdrawal rates on water levels in the Upper, Middle, and Lower Potomac-Raritan-Magothy aquifers. Making management decisions about increasing groundwater withdrawals from these aquifers with an understanding of the results and limitations of the model and a careful examination of the most recent water-level and chloride-concentrations data available for the study area can help to maximize groundwater withdrawals while minimizing effects such as lowered groundwater levels, decreased flow to the Delaware River and its tributaries, and lateral updip movement of saline water.

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Tables 4, 5, 6, 7, 9, 12, and 17

Table 4. Allocated and simulated groundwater withdrawals by water purveyors in municipalities located predominantly in Water Supply Critical Area 2, Salem-Gloucester study area, southern New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[1]	Simulated withdrawals: Full-allocation scenario
5007	7-249	31-02703	BLACKWOD DIV 3	Gloucester Twp	Upper	652.430	184.560	142.157	134.838
	7-250	31-08176	BLACKWOD DIV 7	Gloucester Twp	Upper		108.590	190.013	180.230
	[2]7-252	31-05581	BLACKWOD DIV 6	Gloucester Twp	Upper		248.910	251.733	238.773
	7-600	31-08539	H 4	Gloucester Twp	Upper		96.980	103.940	98.589
5030	[2]7-520	31-04325	PW 3	Brooklawn Boro	Lower	105.017	34.027	34.227	34.227
	[2]7-531	31-14471	5(OW 3)	Brooklawn Boro	Lower		26.622	21.905	21.905
	[2]7-596	31-19765	PW 4	Brooklawn Boro	Lower		29.320	22.734	22.734
5130	15-212	30-00069	PW 4	Paulsboro Boro	Middle	359.680	4.740	3.877	5.094
	15-213	30-00602	PAULSBORO PW 5	Paulsboro Boro	Middle		12.460	12.817	16.839
	15-1199	30-11403	REPLACEMENT 7	Paulsboro Boro	Middle		265.870	257.073	337.747
5135	15-60	31-02358	GLASSBORO PW 3	Glassboro Boro	Upper	421.181	156.860	89.500	81.805
	15-62	51-00042	PW 2	Glassboro Boro	Upper		150.050	84.653	77.375
	15-63	31-04176	GLASSBORO PW 4	Glassboro Boro	Upper		135.120	220.703	201.728
	15-361	31-07709	PW 5	Glassboro Boro	Upper		94.290	65.943	60.274
5137	15-225	51-00017	DISCONTINUED P1	Pitman Boro	Upper	241.032	155.420	159.977	172.959
	15-227	31-04061	PITMAN PW P3	Pitman Boro	Upper		65.410	9.440	10.206
	15-385	51-00018	PW P4	Pitman Boro	Upper		93.250	53.523	57.867
5142	15-28	30-00432	EAST GREENWICH PW 2	East Greenwich Twp	Upper	178.038	80.870	80.817	66.273
	15-355	30-01426	EAST GREENWICH PW 3	East Greenwich Twp	Upper		108.310	136.293	111.765
5153	15-207	31-02555	NPWD 2/NPWD 5	National Park Boro	Lower	80.456	4.630	3.647	2.914
	15-533	31-17938	PW 6	National Park Boro	Lower		105.080	97.030	77.542
5159	15-330	31-06356	1 HELEN AVE	Woodbury Heights Boro	Upper	83.606	79.200	80.830	83.606

Table 4. Allocated and simulated groundwater withdrawals by water purveyors in municipalities located predominantly in Water Supply Critical Area 2, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[1]	Simulated withdrawals: Full-allocation scenario
5183	15-130	30-17838	PW 3	Harrison Twp	Upper	[3]123.000	160.600	162.070	81.827
	15-1088	50-00050	PW 2	Harrison Twp	Upper		0.000	0.000	0.000
	15-1109	30-08859	PW 6	Harrison Twp	Upper		76.190	53.030	26.774
	15-1529	30-14503	PW5	Harrison Twp	Upper		0.000	28.520	14.399
	15-1580	30-16075	PW7	Harrison Twp	Upper		0.000	0.000	0.000
5192	15-274	51-00065	PW 1	Wenonah Boro	Upper	72.070	34.810	33.183	33.479
	15-275	31-00170	WENONAH PW 2	Wenonah Boro	Upper		44.800	38.250	38.591
5194	15-248	51-00029	WASHINGTON TWP PW 5	Washington Twp	Upper	1,052.58	133.620	165.333	177.158
	15-260	31-05206	8(BELS LK WC2)	Washington Twp	Upper		66.210	90.717	97.205
	15-265	31-04849	PW 2	Washington Twp	Upper		55.580	60.353	64.670
	15-267	31-06050	PW 3	Washington Twp	Upper		158.200	129.163	138.401
	15-268	31-06133	PW 4	Washington Twp	Upper		76.960	65.180	69.842
	15-433	31-17801	WASHINGTON TWP PW 9	Washington Twp	Upper		211.220	173.137	185.520
	15-1365	31-45998	WASHINGTON TWP PW 15	Washington Twp	Upper		340.420	298.437	319.782
	15-1543	31-62302	WASHINGTON TWP TW20	Washington Twp	Upper		0.000	0.000	0.000
[4]5223	[2]7-8	31-04969	PW 4	Bellmawr Boro	Lower	353.102	92.507	106.927	106.927
	[2]7-12	31-02687	BELLMAWR PW 3	Bellmawr Boro	Lower		39.673	46.898	46.898
	[2]7-601	31-19218	PW 6	Bellmawr Boro	Lower		44.829	48.197	48.197
5244	[2]15-1	31-02889	CLAYTON P-3	Clayton Boro	Upper	165.166	89.007	30.330	60.100
	15-3	31-06676	4-1973	Clayton Boro	Upper		0.000	53.023	105.066
5304	15-276	31-04567	WEST DEPTFORD PW 4	West Deptford Twp	Upper	678.076	124.940	145.173	166.999
	15-282	31-07056	5 KINGS HIWAY	West Deptford Twp	Lower		132.500	8.023	9.229
	15-312	51-00063	6 RED BANK AVE	West Deptford Twp	Lower		226.320	293.427	337.541
	15-373	31-17452	PW 7	West Deptford Twp	Lower		155.470	27.420	31.542
	15-1339	31-17811	8-1981 PKVLLE RD	West Deptford Twp	Middle		2.180	115.413	132.765

Table 4. Allocated and simulated groundwater withdrawals by water purveyors in municipalities located predominantly in Water Supply Critical Area 2, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[1]	Simulated withdrawals: Full-allocation scenario
5314	15-191	31-04791	PW 2	Mantua Twp	Upper	203.288	38.320	64.120	68.655
	15-192	31-02987	PW 5	Mantua Twp	Upper		54.620	71.377	76.425
	15-193	31-01140	PW 3	Mantua Twp	Upper		11.210	15.370	16.457
	15-194	31-05309	MANTUA PW 4	Mantua Twp	Upper		81.020	38.993	41.751
5319	[2]15-326	31-05689	PW 5	Westville Boro	Lower	250.000	189.480	186.842	186.842
	[2]15-327	31-03418	PW 4	Westville Boro	Lower		13.091	7.285	7.285
5336	15-16	31-02416	PW 1	Deptford Twp	Upper	602.644	77.010	39.447	38.574
	15-17	31-02118	DISCONTINUED 3	Deptford Twp	Upper		71.660	95.243	93.134
	[2]15-24	31-05513	DEPTFORD PW 4	Deptford Twp	Middle		0.000	15.320	14.981
	15-374	31-13385	DEPTFORD PW 6	Deptford Twp	Middle		89.800	159.120	155.597
	15-1036	31-22504	DEPTFORD PW 7	Deptford Twp	Middle		155.970	133.840	130.876
	15-1089	31-37705	BOOSTER STA 8	Deptford Twp	Upper		168.430	173.320	169.482
	15-1577	31-61731	WELL 9R	Deptford Twp	Upper		0.000	0.000	0.000
5347X	[5]15-6	31-05174	SEWELL 1A	Deptford Twp	Upper	289.693	206.910	174.413	190.997
	[5]15-8	51-00101	SEWELL 2A	Deptford Twp	Upper		11.810	90.127	98.696
	[6]15-1222	31-64855	RED BANK 7	Woodbury City	Middle	212.877	0.000	61.137	61.850
	[6,7]15-1340	31-04059	1960 RR & BRBR AVE	Woodbury City	Lower		54.180	0.000	0.000
	[6]15-1485	31-48720	REDBANK 8	Woodbury City	Middle		0.000	97.173	98.306
	[6]15-1488	31-48755	5A-R	Woodbury City	Lower		78.610	52.113	52.721

[1]The 2000 baseline simulation withdrawals are the average annual withdrawals from 1999 to 2001.

[2]Well is outside the model area. Simulated withdrawals are input into the model as boundary flows.

[3]Allocation was 325 million gallons per year through December 2006 and 123 million gallons per year thereafter. The 2000 baseline simulation withdrawals are estimated to equal 2001 withdrawals.

[4]Total withdrawals in the study area are much less than the total allocation for the permit number because some wells under this permit number are outside the study area.

[5]The water-allocation permit number for wells 15-6 and 15-8 was previously 5349.

[6]The water-allocation permit number for wells 15-1222, 15-1340, 15-1485, and 15-1488 was previously 5347.

[7]Well not in use after 1998.

Table 5. Allocated and simulated groundwater withdrawals by water purveyors in municipalities located predominantly outside Water Supply Critical Area 2 and low-volume users, Salem-Gloucester study area, southern New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	2000 baseline simulation[1]	Full-allocation scenario	Adjusted full-allocation scenario	Adjusted full-allocation plus Woolwich request scenario	Adjusted full-allocation plus all requests scenario	Adjusted full-allocation plus adjusted requests scenario	2025 scenario
Water purveyors														
5003	15-137	30-01371	PURE 2(3-1973)	Logan Twp	Middle	392.000	34.450	49.523	69.801	69.801	69.801	89.000	80.129	57.125
	15-569	30-02405	PW 3	Logan Twp	Middle		115.930	92.973	131.043	131.043	131.043	167.000	150.431	107.244
	15-1362	30-09444	LWWC BIRCH CK RD 4	Logan Twp	Middle		151.230	124.573	175.582	175.582	175.582	224.000	201.560	143.695
	15-1363	30-05212	LWWC PURELAND WTP 1A	Logan Twp	Middle		5.460	11.050	15.575	15.575	15.575	20.000	17.879	12.746
	15-1555	30-13073	TEST WELL 6	Logan Twp	Middle		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
[2]5047	[3]33-671	30-05148	PENNSVILLE PW 3	Pennsville Twp	Upper	580.000	48.953	45.639	45.639	45.639	45.639	45.639	45.639	45.639
	[3]33-971	30-12164	TEST WELL 8	Pennsville Twp	Middle		0.000	139.464	139.464	139.464	139.464	139.464	139.464	139.464
	[3]33-972	30-12165	TW 7	Pennsville Twp	Middle		0.000	13.223	13.223	13.223	13.223	13.223	13.223	13.223
5105	15-236	30-01177	SWEDESBORO PW 3	Swedesboro Boro	Middle	140.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	15-238	50-00036	PW 2	Swedesboro Boro	Upper		0.000	0.593	0.894	0.894	0.894	0.894	0.894	0.632
	15-1112	30-08730	PW 4	Swedesboro Boro	Upper		92.830	92.323	139.106	139.106	139.106	139.106	139.106	98.367
5167	33-354	50-00038	PW 2	Woodstown Boro	Middle	119.400	64.470	26.023	30.183	30.183	30.183	30.183	30.183	26.023
	33-362	30-01441	PW 3	Woodstown Boro	Middle		25.570	18.680	21.666	21.666	21.666	21.666	21.666	18.680
	33-933	30-13120	WOODSTOWN PW 5	Woodstown Boro	Middle		35.070	31.702	67.552	67.552	67.552	67.552	67.552	58.243
5253	15-347	30-01545	5 (2-A)	Greenwich Twp	Middle	348.000	172.340	159.607	169.225	169.225	169.225	209.100	169.225	159.607
	15-348	30-01776	PW 6	Greenwich Twp	Middle		87.040	72.287	76.643	76.643	76.643	94.703	76.643	72.287
	15-1364	30-09345	MEMORIAL AVE 4R	Greenwich Twp	Middle		91.970	96.327	102.132	102.132	102.132	126.197	102.132	96.327
5328	33-330	50-00098	LAYTON 11	Carneys Point Twp	Lower	630.000	34.160	52.370	66.772	66.772	66.772	105.988	86.910	52.370
	33-346	30-00563	PW 1	Carneys Point Twp	Lower		180.180	175.027	223.161	223.161	223.161	354.224	290.464	175.027
	33-361	30-01815	PW 4	Carneys Point Twp	Upper		48.950	10.973	13.991	13.991	13.991	22.208	18.211	10.973
	33-460	30-03310	1A/RF2A	Carneys Point Twp	Upper		59.700	70.180	89.480	89.480	89.480	142.032	116.466	70.180
	33-697	30-01113	LAYTON 2	Carneys Point Twp	Upper		74.300	105.271	138.011	138.011	138.011	219.065	179.634	108.243
	33-750	30-03535	RF 3A	Carneys Point Twp	Upper		0.000	0.023	0.029	0.029	0.029	0.047	0.038	0.023
	33-767	30-08511	RF2B	Carneys Point Twp	Upper		81.390	77.297	98.555	98.555	98.555	156.436	128.277	77.297
[4]5375	15-166	30-00410	BRIDGEPORT 2	Logan Twp	Middle	52.000	7.520	22.400	29.523	29.523	29.523	29.523	29.523	22.400
	15-697	30-03332	BRIDGEPORT BACKUP-2	Logan Twp	Middle		30.420	17.053	22.477	22.477	22.477	22.477	22.477	17.053
5381	33-70	30-00229	SERVICE 1N-2	Oldmans Twp	Middle	32.000	24.570	13.654	31.799	31.799	31.799	31.799	31.799	15.283
	33-845	30-09813	FENWICK SRVC AREA	Carneys Point Twp	Middle		0.110	0.097	0.201	0.201	0.201	0.201	0.201	0.097
5383	15-1532	30-12611	PW 1	Woolwich Twp	Upper	116.500	0.000	[5]8.750	56.569	56.569	109.254	193.743	109.254	203.473
	15-1533	30-13044	PW 2	Woolwich Twp	Upper		0.000	[5]9.270	59.931	59.931	115.746	205.257	115.746	215.565

Table 5. Allocated and simulated groundwater withdrawals by water purveyors in municipalities located predominantly outside Water Supply Critical Area 2 and low-volume users, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	2000 baseline simulation[1]	Full-allocation scenario	Adjusted full-allocation scenario	Adjusted full-allocation plus Woolwich request scenario	Adjusted full-allocation plus all requests scenario	Adjusted full-allocation plus adjusted requests scenario	2025 scenario
Low-volume users														
11036W	33-984	30-12821	IW	Oldmans Twp	Lower	37.200	0.000	1.577	37.200	1.577	1.577	1.577	1.577	1.577
[6]10219W	15-1600	30-01158	2-MIDDLE S	Harrison Twp	Upper	37.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	15-1601	30-08182	5-NEW FIELD	Harrison Twp	Upper		0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	15-1612	30-00788	1 SR HIGH	Harrison Twp	Upper		0.698	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10231W	15-1461	31-03393	IRR 1	Woodbury City	Upper	37.200	[7]9.404	[8]10.070	37.200	10.070	10.070	10.070	10.070	10.070
10298W	15-1069	31-10357	MHP	Mantua Twp	Upper	37.200	[9]2.435	[8]2.840	37.200	2.840	2.840	2.840	2.840	2.840
10441W	15-1371	30-03041	ATH FIELD IRR	Woolwich Twp	Upper	37.200	1.970	[10]2.293	37.200	2.293	2.293	2.293	2.293	2.293
	15-1534	30-15596	HS 3	Woolwich Twp	Upper		0.000	[10]0.000	0.000	0.000	0.000	0.000	0.000	0.000
	15-1690	30-13609	WELL 2	Woolwich Twp	Upper		0.000	[10]0.000	0.000	0.000	0.000	0.000	0.000	0.000
10469W	15-240	30-00973	SWEDESBORO IND 9	Swedesboro Boro	Upper	37.200	0.000	[8]0.030	37.200	0.030	0.030	0.030	0.030	0.030
10472W	15-1346	30-03764	IRR-1985	Greenwich Twp	Upper	37.200	1.960	[8]1.420	37.200	1.420	1.420	1.420	1.420	1.420
10506W	15-1105	30-04335	COM 1	South Harrison Twp	Upper	37.200	0.000	[8]3.840	35.891	3.840	3.840	3.840	3.840	3.840
	15-1370	30-04336	2 FIRE PROTECT	South Harrison Twp	Upper		0.000	[8]0.140	1.309	0.140	0.140	0.140	0.140	0.140
10673W	33-164	50-00104	IND 2	Pilesgrove Twp	Middle	37.200	0.000	[11]0.910	18.600	0.910	0.910	0.910	0.910	0.910
	33-459	30-03336	IND 1A	Pilesgrove Twp	Middle		0.910	[11]0.910	18.600	0.910	0.910	0.910	0.910	0.910
10687W	33-983	30-08190	IRR	Carneys Point Twp	Middle	37.200	9.086	6.982	37.200	6.982	6.982	6.982	6.982	6.982
10762W	15-399	30-01616	NO-1 1977	Logan Twp	Middle	37.200	0.000	0.000	37.200	0.000	0.000	0.000	0.000	0.000
10792W	33-74	30-01151	PW 1	Oldmans Twp	Upper	37.200	0.000	[8]0.000	0.000	0.000	0.000	0.000	0.000	0.000
	33-920	30-11400	AUBURN 2	Oldmans Twp	Upper		0.000	[8]5.690	37.200	37.200	37.200	37.200	37.200	[12]17.782
11018W	33-1006	30-12665	IRR 1	Carneys Point Twp	Middle	37.200	0.000	0.278	18.600	0.278	0.278	0.278	0.278	0.278
	33-1007	30-12668	IRR 2	Carneys Point Twp	Middle		0.000	0.278	18.600	0.278	0.278	0.278	0.278	0.278
[13]11019W	33-1011	30-12667	IRR 2	Penns Grove Boro	Middle	37.200	0.000	0.030	31.886	0.030	0.030	0.030	0.030	0.030
	33-1012	30-12666	IRR 1	Penns Grove Boro	Middle		0.000	[14]0.005	5.314	0.005	0.005	0.005	0.005	0.005
11028W	15-1597	30-12748	IRR 1	Greenwich Twp	Middle	37.200	0.980	[15]0.390	37.200	0.390	0.390	0.390	0.390	0.390
11088W	15-1598	30-13781	IRR 1	Harrison Twp	Upper	37.200	0.000	[8]2.900	37.200	2.900	2.900	2.900	2.900	2.900
11100W	15-1607	31-59257	IRR 1	West Deptford	Middle	37.200	0.000	[8]0.860	37.200	0.860	0.860	0.860	0.860	0.860
	15-1608	31-59256	IRR 2	West Deptford	Middle		0.000	[8]0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5. Allocated and simulated groundwater withdrawals by water purveyors in municipalities located predominantly outside Water Supply Critical Area 2 and low-volume users, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	2000 baseline simulation[1]	Full-allocation scenario	Adjusted full-allocation scenario	Adjusted full-allocation plus Woolwich request scenario	Adjusted full-allocation plus all requests scenario	Adjusted full-allocation plus adjusted requests scenario	2025 scenario
11230W	15-1691	30-16779	WELL IND 2	East Greenwich Twp	Lower	37.200	0.000	0.000	37.200	0.000	0.000	0.000	0.000	0.000
11233W	15-1609	30-12350	PW	Woolwich Twp	Upper	37.200	0.000	0.000	18.600	0.000	0.000	0.000	0.000	0.000
	15-1610	30-13711	IRR 1	Woolwich Twp	Upper		0.000	0.000	18.600	0.000	0.000	0.000	0.000	0.000

[1]The 2000 baseline simulation withdrawals are the average annual withdrawals from 1999 to 2001, unless otherwise noted.

[2]Total withdrawals in the study area are much less than total allocation for this permit number because some wells under this permit number are outside the study area.

[3]Well is outside model area. Simulated withdrawals are input into the model as boundary flows.

[4]Withdrawals are located in Logan Township but are for Penns Grove Borough.

[5]The 2000 baseline simulation withdrawals are estimated to equal 2000 withdrawals only.

[6]Withdrawals are estimated to equal zero in the 2000 baseline simulation and all six scenarios; withdrawals in 2000 and after are for fire suppression only.

[7]Estimated 1998 calibration simulation withdrawals are the average annual withdrawals from 1992 to 1996.

[8]Estimated 2000 baseline simulation withdrawals are estimated to equal 2001 withdrawals.

[9]Estimated 1998 calibration simulation withdrawals are the average annual withdrawals from 1992 to 1995.

[10]Estimated 2000 baseline simulation withdrawals are the average annual withdrawals from 1992 to 1998.

[11]Estimated 2000 baseline simulation withdrawals are the average annual withdrawals from two wells from 1999 to 2001.

[12]Although permit number 10792W is for a low-volume user, withdrawals were increased in 2025 from 2000 baseline simulation withdrawals.

[13]At the time of the study, the water-allocation permit number for wells 33-1011 and 33-1012 was 11019W; subsequently, these wells were combined with water-allocation permit number 11018W.

[14]Estimated 2000 baseline simulation withdrawals are the average annual withdrawals from 2000 and 2001.

[15]Estimated 2000 baseline simulation withdrawals are the average annual withdrawals from 1999 and 2000.

Table 6. Allocated and simulated groundwater withdrawals by industrial self-supply users, Salem-Gloucester study area, southern New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[1]	Simulated withdrawals: Full-allocation and adjusted full-allocation scenario[2]
2099P	15-158	30-00873	BRIDGEPORT W2	Logan Twp	Middle	494.000	164.321	87.062	117.779
	15-159	30-00872	BRIDGEPORT E1	Logan Twp	Middle		102.890	83.780	113.339
	15-167	30-01170	IND 1	Logan Twp	Middle		119.515	48.272	65.303
	15-1554	30-14055	PW4	Logan Twp	Middle		0.000	146.050	197.579
2104P	[3]33-122	30-01234	DEEPWATER 3R	Pennsville Twp	Middle	360.000	7.415	1.239	1.239
	[3]33-123	50-00001	DEEPWATER 2	Pennsville Twp	Middle		0.540	0.969	0.969
	[3]33-125	30-00151	DEEPWATER 5	Pennsville Twp	Middle		1.099	0.150	0.150
2166P	33-85	30-01141	6 (PW-2)	Oldmans Twp	Middle	525.600	233.860	219.020	391.323
	33-432	50-00079	IND 3	Oldmans Twp	Lower		0.000	0.393	0.703
	33-784	30-06023	BFG SHALLOW 10	Oldmans Twp	Middle		35.090	55.433	99.043
	33-964	30-10864	IND 9A	Oldmans Twp	Lower		20.370	19.327	34.531
2204P	15-118	30-00198	IND 47	Greenwich Twp	Lower	1,202.197	0.000	0.000	0.000
	15-406	30-01966	POLLUTE 1	Greenwich Twp	Middle		0.000	0.000	0.000
	15-814	30-02336	RW-12	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-817	30-02341	RW-16	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-818	30-02339	RW-15	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-819	30-02334	RW-14	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-821	30-01908	RW-3	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-822	30-01910	RW-4	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-823	30-01909	RW-5	Greenwich Twp	Middle[4]		33.200	0.000	0.000
	15-824	30-01905	RW-6	Greenwich Twp	Middle[4]		52.060	44.457	121.176
	15-826	30-01906	RW-8	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-828	30-02337	RW-18	Greenwich Twp	Middle[4]		0.000	0.000	0.000
	15-1039	30-05060	48 DWTA	Greenwich Twp	Middle		91.440	83.747	228.268
	15-1374	30-05642	RW-19	Greenwich Twp	Middle		228.290	91.930	250.574
	15-1375	30-05645	PW-49	Greenwich Twp	Lower		0.000	0.000	0.000
	15-1376	30-05643	RW-20	Greenwich Twp	Middle		0.000	0.000	0.000
	15-1377	30-05644	RW-21	Greenwich Twp	Middle		0.000	0.000	0.000
	15-1408	30-11178	RW-22	Paulsboro Boro	Upper		99.350	69.940	190.635
	15-1409	30-11162	PW-50	Paulsboro Boro	Middle		105.310	73.243	199.639
	15-1414	30-10019	RW-61/1	Paulsboro Boro	Middle[4]		0.000	10.483	28.574
	15-1415	30-09959	RW-1	Paulsboro Boro	Middle[4]		0.000	18.637	50.798
	15-1541	30-12907	RW-5A	Greenwich Twp	Upper		0.000	48.623	132.533

Table 6. Allocated and simulated groundwater withdrawals by industrial self-supply users, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[1]	Simulated withdrawals: Full-allocation and adjusted full-allocation scenario[2]
2205P	15-320	31-00007	IND 1	West Deptford Twp	Lower	813.890	234.790	99.907	147.550
	15-321	31-00028	EAGLE POINT 5	West Deptford Twp	Lower		130.180	299.523	442.361
	15-322	31-00008	IND 3	West Deptford Twp	Lower		144.690	22.350	33.008
	15-410	31-10647	EAGLE POINT 4A	West Deptford Twp	Lower		1.390	0.000	0.000
	15-430	31-17788	EAGLE POINT 6A	West Deptford Twp	Lower		95.430	129.307	190.971
2215P	15-283	30-00900	SHELL 3	West Deptford Twp	Lower	326.163	40.930	31.227	143.565
	15-284	30-00901	SHELL 4	West Deptford Twp	Upper		0.002	0.000	0.000
	15-285	30-00898	SHELL 1	West Deptford Twp	Lower		170.130	8.887	40.857
	15-286	30-00899	SHELL IND 2	West Deptford Twp	Middle		5.320	30.830	141.741
2227P	15-76	30-01224	4 1970	Greenwich Twp	Middle	216.000	24.640	23.080	49.868
	15-632	30-03315	PW 6	Greenwich Twp	Middle		0.000	0.000	0.000
	15-647	30-03372	MW 19B	Greenwich Twp	Middle		0.000	3.687	7.966
	15-1034	30-04319	PW 11	Greenwich Twp	Middle		46.710	47.587	102.818
	15-1373	30-04426	PW-10	Greenwich Twp	Middle		6.270	0.000	0.000
	15-1400	30-03273	PW-5B	Greenwich Twp	Middle		10.850	0.000	0.000
	15-1401	30-03264	MW-6	Greenwich Twp	Middle		0.560	0.927	2.003
	15-1402	30-04317	PW-9	Greenwich Twp	Middle		9.890	11.560	24.977
	15-1403	30-03651	PW-8B	Greenwich Twp	Middle		2.770	5.213	11.264
	15-1404	30-03650	PW-7B	Greenwich Twp	Middle		4.350	5.900	12.748
	15-1405	30-03649	PW-8	Greenwich Twp	Middle		2.410	2.017	4.357
2234P	15-304	30-01173	418	West Deptford Twp	Lower	301.130	0.640	3.187	3.248
	15-306	30-01174	417	West Deptford Twp	Lower		299.770	292.260	297.882
2251P	15-72	30-00037	REPAUNO 3	Greenwich Twp	Middle	540.000	167.040	145.130	229.477
	15-79	30-01145	REPAUNO 6	Greenwich Twp	Middle		13.250	24.010	37.964
	15-692	30-03594	INTERCEPTOR 46	Greenwich Twp	Middle		154.640	172.377	272.559
	15-1696	31-16503	PW 3R	Greenwich Twp	Middle		0.000	0.000	0.000
2257P	15-295	31-06200	IRR	West Deptford Twp	Upper	13.900	13.070	11.430	13.502
	15-1176	31-43251	DEEP 1	West Deptford Twp	Middle		0.800	0.337	0.398
2280P	15-183	31-05060	IRR	Mantua Twp	Upper	3.585	1.830	11.510	3.585
2391P	15-1407	31-02558	IND 2	Mantua Twp	Upper	33.399	29.870	26.360	33.399

Table 6. Allocated and simulated groundwater withdrawals by industrial self-supply users, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; Boro, Borough; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water-allocation permit number	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Total allocation	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[1]	Simulated withdrawals: Full-allocation and adjusted full-allocation scenario[2]
2401P	15-1120	30-07032	R-6-A	Paulsboro Boro	Middle	365.000	51.160	32.403	93.096
	15-1121	30-07014	R-8-A	Paulsboro Boro	Middle		1.320	16.723	48.047
	15-1122	30-07015	R-9-A	Paulsboro Boro	Middle		11.540	20.187	57.997
	15-1123	30-07013	R-5-A	Paulsboro Boro	Middle		0.000	0.000	0.000
	15-1124	30-07012	R-7-A	Paulsboro Boro	Middle		28.500	25.793	74.105
	15-1378	30-06920	R-4A	Paulsboro Boro	Middle		20.530	23.093	66.348
	15-1382	30-05183	RECOVERY 2	Paulsboro Boro	Middle		0.000	0.000	0.000
	15-1383	30-07028	R-10A	Paulsboro Boro	Middle		9.270	8.843	25.407
	[5]15-1697	30-17621	RW011	Paulsboro Boro	Middle		0.000	0.000	0.000
	15-1698	30-17927	SUMP 3	Paulsboro Boro	Middle		0.000	0.000	0.000
2421P	33-899	30-08172	PW-3	Oldmans Twp	Lower	170.400	67.600	56.900	87.286
	33-900	30-07824	PW-2	Oldmans Twp	Lower		15.290	6.037	9.260
	33-901	30-07176	PW-1	Oldmans Twp	Lower		37.670	48.143	73.853
2423P	15-339	30-01161	IND 1	Woolwich Twp	Upper	31.000	[6]7.100	6.733	31.000
2495E	15-548	30-02504	CLDW	Logan Twp	Upper	177.000	0.000	0.000	[7]0.000
2530P	15-1568	30-09789	15D	Logan Twp	Middle	214.320	[8]25.000	[9]22.705	53.580
	15-1569	30-09788	21D	Logan Twp	Middle		[8]25.000	[9]22.705	53.580
	15-1570	30-09787	24D	Logan Twp	Middle		[8]25.000	[9]22.705	53.580
	15-1571	30-09785	35D	Logan Twp	Middle		[8]25.000	[9]22.705	53.580
4059PS	15-1526	30-08633	PW 1B	Logan Twp	Lower	1.080	0.000	[10]0.003	0.006
	15-1527	30-08635	PW 1A	Logan Twp	Lower		0.000	[10]0.525	1.074

[1]Withdrawals are the average annual withdrawals from 1999 to 2001, unless otherwise noted.

[2]Full-allocation withdrawals were also used in the adjusted full-allocation scenario for the water-allocation permit numbers in this table, except for water-allocation permit number 2495E.

[3]Well is outside model area. Simulated withdrawals are input into the model as boundary flows.

[4]Withdrawals are from wells screened in the Quarternary system or in the undifferentiated Holocene, Pleistocene, Pliocene, and Miocene aquifers but are simulated as withdrawals from the Middle Potomac-Raritan-Magothy aquifer in this study.

[5]Well is screened in the Upper Potomac-Raritan-Magothy aquifer, but withdrawals are simulated as withdrawals from the Middle Potomac-Raritan-Magothy aquifer in this study.

[6]Withdrawals are the average annual withdrawals from 1997 and 1999.

[7]Withdrawals were 0 million gallons per year in the adjusted full-allocation scenario and 177 million gallons per year in the full-allocation scenario.

[8]Withdrawals are the average annual withdrawals from 1996 to 1999.

[9]Withdrawals are the average withdrawals from October 2004 through September 2005.

[10]Withdrawals are the average annual withdrawals from 2000 to 2001.

Table 7. Allocated and simulated groundwater withdrawals by the industrial self-supply user and the agricultural-irrigation users for which full-allocation withdrawals were adjusted, Salem-Gloucester study area, southern New Jersey.

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

						Allocated withdrawals		Simulated withdrawals						
NJDEP water allocation permit number[1]	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Permitted (full) allocation	Adjusted permitted (full) allocation[2]	1998 calibration simulation	2000 baseline simulation[3]	Full-allocation scenario	Adjusted full-allocation and adjusted full-allocation plus Woolwich request scenarios	Adjusted full-allocation plus all requests scenario	Adjusted full-allocation plus adjusted requests scenario[4]	2025 scenario
Industrial self-supply user														
2122P	15-238	30-17308	PW 2	Carneys Point Twp	Lower	5,078.760	1,500.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	33-67	30-01081	IRR P1	Mannington Twp	Middle			2.520	6.823	45.316	13.384	13.384	13.384	6.823
	[5]33-129	30-01018	CHAMBERS INJ 1	Carneys Point Twp	Middle			75.800	111.260	738.907	218.234	218.234	218.234	111.260
	[5]33-137	50-00003	DRINKWATER 8	Pennsville Twp	Lower			0.010	2.549	16.929	5.000	5.000	5.000	2.549
	33-298	30-01082	COURSE LAND P2	Carneys Point Twp	Middle			2.330	7.053	46.843	13.835	13.835	13.835	7.053
	33-305	30-01083	COURSE LAND P3	Carneys Point Twp	Middle			2.660	17.187	114.141	33.711	33.711	33.711	17.187
	[5]33-316	30-02322	102	Carneys Point Twp	Upper			24.440	69.910	464.291	137.127	137.127	137.127	69.910
	[5]33-322	50-00004	CARNEY PT 2	Carneys Point Twp	Middle			27.250	74.140	492.383	145.424	145.424	145.424	74.140
	33-326	30-00423	CARNEY PT 4	Carneys Point Twp	Upper			0.000	0.000	0.000	0.000	0.000	0.000	0.000
	33-335	30-01133	CARNEY PT 7	Carneys Point Twp	Lower			0.000	0.000	0.000	0.000	0.000	0.000	0.000
	[5]33-602	30-03368	CHAMBERS 108	Pennsville Twp	Middle			167.700	87.110	578.520	170.865	170.865	170.865	87.110
	[5]33-857	30-03367	REPL 103A	Pennsville Twp	Middle			177.800	220.520	1,464.531	432.546	432.546	432.546	220.520
	[5]33-898	30-04667	CHAMBERS 5-R	Pennsville Twp	Middle			191.720	165.303	1,097.820	324.239	324.239	324.239	165.303
	[5]33-962	30-04091	MW257	Carneys Point Twp	Middle			2.520	2.873	19.080	5.635	5.635	5.635	2.873
	33-979	30-13038	Q13R01D	Carneys Point Twp	Middle			0.000	0.000	0.000	0.000	0.000	0.000	0.000
	33-980	30-13039	Q13R01C	Carneys Point Twp	Middle			0.000	0.000	0.000	0.000	0.000	0.000	0.000
Agricultural-irrigation user														
GL0007	15-346	30-01565	IRR	Harrison Twp	Upper	18.000	18.000	0.690	0.544	18.000	18.000	18.000	18.000	0.544
GL0021	15-1462	30-12217	IRR 1	Woolwich Twp	Upper	[6]442.720	40.000	11.965	[7]12.331	442.720	40.000	40.000	40.000	12.331
GL0028	15-132	30-01258	IRR 1	Harrison Twp	Upper	48.000	42.000	13.000	9.400	48.000	42.000	42.000	42.000	9.400
GL0033	15-1159	50-00097	IRR-1	Logan Twp	Upper	[6]102.400	60.000	28.675	20.610	65.253	38.234	38.234	38.234	20.610
	15-1613	30-10793	IRR 2	Logan Twp	Upper			16.325	11.733	37.147	21.766	21.766	21.766	11.733
GL0046	15-1460	30-00829	IRR	South Harrison Twp	Upper	[8]12.400	18.000	0.300	5.178	12.400	18.000	18.000	18.000	5.178
GL0092	15-1566	30-07814	IRR	Woolwich Twp	Upper	36.000	31.500	0.000	1.488	36.000	31.500	31.500	31.500	1.488
GL0097	15-524	30-01078	2-DOM	Woolwich Twp	Upper	80.280	80.280	4.100	[9]2.850	80.280	80.280	80.280	80.280	2.850
GL0101	15-1561	30-08495	IRR1	South Harrison Twp	Upper	[6]110.000	44.000	17.700	[10]4.636	111.000	44.000	44.000	44.000	4.636
GL0107	15-337	30-00431	IRR S1	Woolwich Twp	Upper	[6]368.000	12.000	16.500	[11]5.730	368.000	12.000	12.000	12.000	5.730
	15-1615	30-14768	IRR	Woolwich Twp	Upper			0.000	[11]5.158	0.000	0.000	12.000	12.000	5.158
GL0127	15-1611	30-16050	IRR	East Greenwich Twp	Upper	[6]1,500.000	64.000	0.000	[12]0.000	0.000	0.000	36.000	36.000	0.000
	15-1664	50-00101	WELL 1	East Greenwich Twp	Upper			0.850	[12]1.240	1,500.000	64.000	64.000	64.000	1.240
[13]GL0141	15-1614	50-00275	IRR 1	Washington Twp	Upper	0.000	0.000	3.160	0.000	0.000	0.000	0.000	0.000	0.000
GL0146	15-1604	30-16630	IRR	South Harrison Twp	Upper	[8]0.000	0.000	0.000	0.000	0.000	0.000	18.000	18.000	0.000
GL0151	15-422	31-17085	1980-1-PEACH	Harrison Twp	Upper	51.058	51.058	44.500	12.899	51.058	51.058	51.058	51.058	12.899
GL0190	15-1447	31-36273	IRR 3	Deptford Twp	Upper	[8]18.000	18.000	14.150	[14]12.040	17.381	17.381	17.381	17.381	12.040
	15-1585	31-46811	IRR 3	Washington Twp	Upper			0.000	[14]0.429	0.619	0.619	0.619	0.619	0.429
GL199R	15-421	30-01042	IRR	East Greenwich Twp	Upper	[8]18.000	18.000	4.100	4.547	18.000	18.000	18.000	18.000	4.547
GL0214	15-1558	30-12585	IRR1	South Harrison Twp	Upper	60.000	60.000	8.350	[15]11.150	60.000	60.000	60.000	60.000	11.150
GL0216	15-1565	30-09279	IRR1	Woolwich Twp	Upper	[6]48.000	16.000	0.000	[16]2.963	33.504	11.168	11.168	11.168	2.963
	15-1603	30-12655	IRR 3	Logan Twp	Upper			0.000	[16]1.280	14.496	4.832	4.832	4.832	1.280
GL208R	15-127	31-03280	IRR-5	Harrison Twp	Upper	12.400	10.800	0.000	0.000	12.400	10.800	10.800	10.800	0.000
SA0011	33-657	30-02862	IRRIG	Oldmans Twp	Middle	154.000	32.000	0.000	[17]0.000	0.000	0.000	0.000	0.000	0.000
	33-1010	30-14087	IRR	Oldmans Twp	Upper			0.000	[17]9.568	154.000	32.000	32.000	32.000	9.568
SA0014	33-198	30-01383	IRR 74	Pilesgrove Twp	Middle	48.000	20.000	8.250	[18]7.078	48.000	20.000	20.000	20.000	7.078

Table 7. Allocated and simulated groundwater withdrawals by the industrial self-supply user and the agricultural-irrigation users for which full-allocation withdrawals were adjusted, Salem-Gloucester study area, southern New Jersey.—Continued

[NJDEP, New Jersey Department of Environmental Protection; Twp, Township; allocations and withdrawals are from the Potomac-Raritan-Magothy aquifer system, in million gallons per year]

NJDEP water allocation permit number[1]	U.S. Geological Survey well number	NJDEP well permit number	Well name	Municipality	Aquifer of the Potomac-Raritan-Magothy aquifer system	Allocated withdrawals: Permitted (full) allocation	Allocated withdrawals: Adjusted permitted (full) allocation[2]	Simulated withdrawals: 1998 calibration simulation	Simulated withdrawals: 2000 baseline simulation[3]	Simulated withdrawals: Full-allocation scenario	Simulated withdrawals: Adjusted full-allocation and adjusted full-allocation plus Woolwich request scenarios	Simulated withdrawals: Adjusted full-allocation plus all requests scenario	Simulated withdrawals: Adjusted full-allocation plus adjusted requests scenario[4]	Simulated withdrawals: 2025 scenario
Agricultural-irrigation user—Continued														
SA0121	[5]33-1008	30-16845	IRR	Mannington Twp	Upper	0.000	0.000	0.000	0.000	0.000	0.000	54.000	0.000	0.000
SA0124	33-922	30-10178	IRR 1	Pilesgrove Twp	Upper	[19]97.800	[19]97.800	[20]43.200	[21]47.820	97.800	97.800	150.000	83.333	47.820
SA0139	33-997	30-13862	IRR1	Pilesgrove Twp	Upper	97.800	97.800	[20]0.000	[21]0.000	0.000	0.000	150.000	83.333	0.000
	33-998	30-13864	IRR2	Pilesgrove Twp	Upper			[20]0.000	[21]0.000	0.000	0.000	150.000	83.333	0.000
SA0151	33-1009	30-05648	IRR 1	Oldmans Twp	Upper	[8]60.000	18.000	0.060	[22]0.110	60.000	18.000	18.000	18.000	0.110
SA0166	33-996	30-14084	IRR	Carneys Point Twp	Upper	14.700	14.700	0.000	0.000	14.700	14.700	14.700	14.700	0.000

[1]Allocation permit includes the allocation permits and agricultural certifications.

[2]Adjusted full-allocation withdrawal was decreased because it greatly exceeds the 1998 withdrawal.

[3]Withdrawals for NJDEP allocation permit number 2122P are the average of annual withdrawals from 1999 to 2001; agricultural-irrigation withdrawals are average of annual withdrawals from 1992 to 2001, unless otherwise noted.

[4]Agricultural-irrigation withdrawals in the adjusted full-allocation and adjusted requests scenario are equal to withdrawals in the adjusted full-allocation plus all requests scenario, except for wells 33-922, 33-997, and 33-998 where withdrawals are 50 percent of those used in the adjusted full-allocation plus all requests scenario.

[5]Well is outside the model area. Simulated withdrawals from this well are input into the model as boundary flows.

[6]Allocation is an estimated maximum withdrawal from groundwater, based on historical use, and pump capacity.

[7]Withdrawals are the average annual withdrawals from 1997 to 1999, and 2001.

[8]Allocated withdrawals are equal to four times the monthly agricultural-irrigation allocation.

[9]Withdrawals are the average annual withdrawals from 1995 to 2000.

[10]Withdrawals are the average annual withdrawals from 1995 to 2001.

[11]Withdrawals are the average annual withdrawals from 2001 to 2003.

[12]Withdrawals are the average annual withdrawals from 1994 to 2000.

[13]Withdrawals equal zero for all scenarios because no withdrawals were reported after 1999 and the agricultural certification was cancelled.

[14]Withdrawals are estimated to be equal to 2001 withdrawals.

[15]Withdrawals are the average annual withdrawals from 1998 to 2001.

[16]Withdrawals are the average annual withdrawals from 2000 to 2002.

[17]Beginning in 2000 all withdrawals under water-allocation permit SA0011 were made from well 33-1010 and there were no withdrawals from well 33-657 in 1998.

[18]Withdrawals are the average annual withdrawals from 1992 to 1998 and 2000 to 2001.

[19]Total allocation is combined with water allocation permit number SA0139.

[20]Withdrawals are estimated to be equal to 1997 withdrawals.

[21]Withdrawals are the average annual withdrawals for 1997, 2001, and 2002.

[22]Withdrawals are the average annual withdrawals from 1992 to 1998.

Table 9. Difference between simulated and measured 1998 water levels, Salem-Gloucester study area, southern New Jersey.

[Well locations shown in figures 23–26; NGVD 29, National Geodetic Vertical Datum of 1929]

U.S. Geological Survey well number	Measured altitude of water level (feet above NGVD 29)[1]	Simulated altitude of water level (feet above NGVD 29)	Difference between simulated and measured water level (feet)	Accuracy of water-level altitude (+/- feet)
Englishtown aquifer system				
15-188	30.69	36.82	6.13	2.5
15-344	67.05	62.71	-4.34	5.0
15-676	29.65	32.42	2.77	0.1
33-168	16.61	18.92	2.31	2.5
Upper Potomac-Raritan-Magothy aquifer				
7-249	-62.65	-69.33	-6.68	5
15-3	-61.75	-53.97	7.78	5
15-8	-52.02	-60.27	-8.25	5
15-28	-23.50	-25.71	-2.21	5
15-60	-62.70	-61.92	0.78	5
15-63	-56.57	-62.87	-6.30	5
15-127	-44.80	-49.62	-4.82	5
15-194	-40.55	-42.22	-1.67	5
15-227	-62.30	-57.73	4.57	5
15-240	-19.40	-17.74	1.66	3
15-253	-66.54	-66.84	-0.30	5
15-261	-68.00	-67.52	0.48	5
15-275	-65.90	-64.04	1.86	5
15-276	-39.78	-38.65	1.13	5
15-281	-30.07	-26.89	3.18	5
15-303	-7.25	-8.74	-1.49	5
15-330	-37.78	-44.16	-6.38	5
15-339	-19.75	-19.25	0.50	5
15-346	-27.05	-30.12	-3.07	5
15-355	-28.90	-27.93	0.97	5
15-378	-18.68	-21.93	-3.25	5
15-433	-67.19	-65.39	1.80	5
15-617	-7.84	-10.02	-2.18	0.1
15-728	-7.65	-6.56	1.09	0.01
15-741	-37.57	-45.94	-8.37	5
15-779	-1.12	0.72	1.84	5
15-1000	-56.41	-61.26	-4.85	5
15-1031	-9.17	-15.23	-6.06	5
15-1089	-45.43	-52.31	-6.88	5
15-1105	-22.38	-26.51	-4.13	5
15-1106	-14.10	-3.96	10.14	5
15-1346	-10.72	-7.36	3.36	5
15-1482	-14.82	-15.86	-1.04	5
15-1483	-19.57	-15.88	3.69	5
15-1513	-33.24	-30.16	3.08	5
33-74	-12.96	-11.53	1.43	5
33-76	1.00	5.30	4.30	2.5
33-342	3.05	4.17	1.12	0.01
33-355	-24.22	-27.66	-3.44	5
33-361	0.61	-1.53	-2.14	2.5

Table 9. Difference between simulated and measured 1998 water levels, Salem-Gloucester study area, southern New Jersey.—Continued

[Well locations shown in figures 23–26; NGVD 29, National Geodetic Vertical Datum of 1929]

U.S. Geological Survey well number	Measured altitude of water level (feet above NGVD 29)[1]	Simulated altitude of water level (feet above NGVD 29)	Difference between simulated and measured water level (feet)	Accuracy of water-level altitude (+/- feet)
Middle Potomac-Raritan-Magothy aquifer				
15-135	-2.84	-0.75	2.09	0.1
15-140	-1.93	-2.06	-0.13	0.1
15-213	-10.13	-9.22	0.91	5
15-236	-19.72	-18.98	0.74	5
15-279	-25.27	-17.31	7.96	0.01
15-348	-10.12	-7.80	2.32	5
15-359	-0.90	0.64	1.54	5
15-374	-50.16	-41.90	8.26	5
15-415	-34.45	-25.74	8.71	5
15-444	-8.43	-7.07	1.36	5
15-569	-7.72	-14.06	-6.34	2
15-585	-0.99	2.96	3.95	0.1
15-616	-8.36	-10.04	-1.68	0.1
15-620	1.04	4.17	3.13	1
15-679	-4.72	-3.66	1.06	0.1
15-713	-7.70	-6.55	1.15	0.01
15-727	-8.37	-6.55	1.82	0.01
15-771	-3.22	-1.48	1.74	5
15-780	-3.70	0.48	4.18	5
15-998	-55.55	-54.03	1.52	5
15-1036	-51.38	-54.30	-2.92	5
15-1122	-3.10	-3.77	-0.67	5
15-1176	-11.20	-21.00	-9.80	5
15-1484	-14.44	-15.86	-1.42	5
15-1485	-33.20	-23.60	9.60	5
33-65	-17.72	-22.44	-4.72	1
33-71	-24.44	-20.05	4.39	2.5
33-158	-25.18	-29.24	-4.06	5
33-166	-17.59	-22.88	-5.29	1
33-198	-25.13	-22.90	2.23	5
33-305	-16.39	-22.37	-5.98	2.5
33-933	-33.40	-31.70	1.70	5
P10105	-3.81	2.09	5.90	0.1

Table 9. Difference between simulated and measured 1998 water levels, Salem-Gloucester study area, southern New Jersey.—Continued

[Well locations shown in figures 23–26; NGVD 29, National Geodetic Vertical Datum of 1929]

U.S. Geological Survey well number	Measured altitude of water level (feet above NGVD 29)[1]	Simulated altitude of water level (feet above NGVD 29)	Difference between simulated and measured water level (feet)	Accuracy of water-level altitude (+/- feet)
		Lower Potomac-Raritan-Magothy aquifer		
15-133	-4.19	-14.15	-9.96	5
15-139	-11.24	-12.14	-0.90	1
15-282	-50.98	-51.26	-0.28	5
15-308	-25.70	-21.35	4.35	5
15-312	-52.05	-51.94	0.11	5
15-316	-42.45	-41.71	0.74	0.1
15-323	-27.73	-28.18	-0.45	0.1
15-331	-42.09	-45.89	-3.80	5
15-349	-5.83	-8.48	-2.65	3
15-615	-15.41	-14.38	1.03	0.1
15-618	-7.74	-6.00	1.74	1
15-678	-7.94	-5.57	2.37	0.1
15-680	-5.16	-2.69	2.47	0.01
15-712	-11.11	-11.15	-0.04	0.1
15-738	-9.14	-7.88	1.26	0.1
15-742	-31.73	-37.04	-5.31	5
15-770	-17.23	-19.83	-2.60	5
15-778	-17.08	-13.61	3.47	5
15-1004	-55.47	-52.60	2.87	5
15-1125	-4.10	-3.25	0.85	1
15-1487	-14.82	-15.54	-0.72	5
33-86	-13.96	-18.18	-4.22	1
33-187	-27.92	-30.20	-2.28	0.01
33-330	-33.98	-28.94	5.04	2.5
P10103	-16.01	-12.96	3.05	0.1
P10110	-8.87	-6.18	2.69	0.1
P10113	-2.76	-0.44	2.32	0.1
Maximum residual			10.14	
Minimum residual			-9.96	
Average residual			0.12	
Root mean square error			4.14	

[1]Water-level measurements made October to December 1998 (Lacombe and Rosman, 2001).

Table 12. Summary of simulation and scenario results and differences in water levels and flow to streams between simulation and scenario results, Salem-Gloucester study area, southern New Jersey.

[--, not applicable; <, less than; Mgal/yr, million gallons per year]

Aquifer of the Potomac-Raritan-Magothy aquifer system	Withdrawals (Mgal/yr)	Average simulated water level (feet below NGVD 29)[1]	Lowest simulated water level (feet below NGVD 29)	Simulated net flow to Delaware River (Mgal/yr)	Simulated flow to streams (Mgal/yr)	Change in average simulated water level (feet)	Largest change in simulated water level (feet)	Change in simulated flow to Delaware River (Mgal/yr)	Change in simulated flow to streams (Mgal/yr)	Increase in area of[1] water levels lower than 30 feet below NGVD 29 (square miles)
1998 calibration simulation										
Upper	4,621	-33	-84	--	--	--	--	--	--	--
Middle	3,268	-29	-69	--	--	--	--	--	--	--
Lower	2,233	-33	-63	--	--	--	--	--	--	--
Total for all aquifers[2]	10,144	--	--	833	8,242	--	--	--	--	--
2000 baseline simulation										
Upper	4,576	-31	-77	--	--	--	--	--	--	--
Middle	3,315	-27	-65	--	--	--	--	--	--	--
Lower	1,731	-30	-59	--	--	--	--	--	--	--
Total for all aquifers[2]	9,644	--	--	1,183	8,441	--	--	--	--	--
Full-allocation scenario						**From 2000 baseline simulation to full-allocation scenario**				
Upper	8,278	-49	-156	--	--	-18	-128	--	--	112.9
Middle	5,882	-43	-95	--	--	-16	-67	--	--	123.0
Lower	2,385	-48	-69	--	--	-18	-36	--	--	118.4
Total for all aquifers[2]	16,567	--	--	-1,816	6,018	--	--	-2,999	-2,423	--
Adjusted full-allocation scenario						**From 2000 baseline simulation to adjusted full-allocation scenario**				
Upper	5,582	-36	-83	--	--	-5	-14	--	--	54.7
Middle	5,374	-32	-68	--	--	-5	-14	--	--	54.6
Lower	2,312	-36	-63	--	--	-6	-24	--	--	47.8
Total for all aquifers[2]	13,290	--	--	-513	7,256	--	--	-1,696	-1,185	--
Adjusted full-allocation plus Woolwich request scenario						**From adjusted full-allocation scenario to adjusted full-allocation plus Woolwich request scenario**				
Upper	5,691	-37	-83	--	--	-1	-4	--	--	2.8
Middle	5,374	-33	-68	--	--	-1	-2	--	--	3.3
Lower	2,312	-36	-63	--	--	0	<-1	--	--	2.9
Total for all aquifers[2]	13,399	--	--	-541	7,209	--	--	-28	-47	--

Table 12. Summary of simulation and scenario results and differences in water levels and flow to streams between simulation and scenario results, Salem-Gloucester study area, southern New Jersey.—Continued.

[--, not applicable; <, less than; Mgal/yr, million gallons per year]

Aquifer of the Potomac-Raritan-Magothy aquifer system	Withdrawals (Mgal/yr)	Average simulated water level (feet below NGVD 29)[1]	Lowest simulated water level (feet below NGVD 29)	Simulated net flow to Delaware River (Mgal/yr)	Simulated flow to streams (Mgal/yr)	Change in average simulated water level (feet)	Largest change in simulated water level (feet)	Change in simulated flow to Delaware River (Mgal/yr)	Change in simulated flow to streams (Mgal/yr)	Increase in area of[1] water levels lower than 30 feet below NGVD 29 (square miles)
Adjusted full-allocation plus all requests scenario						**From adjusted full-allocation scenario to adjusted full-allocation plus all requests scenario**				
Upper	6,482	-40	-85	--	--	-4	-26	--	--	33.4
Middle	5,564	-35	-69	--	--	-3	-9	--	--	37.7
Lower	2,482	-39	-64	--	--	-3	-16	--	--	27.0
Total of all aquifers[2]	14,551	--	--	-780	6,706	--	--	-267	-550	--
Adjusted full-allocation plus adjusted requests scenario						**From adjusted full-allocation scenario to adjusted full-allocation plus adjusted requests scenario**				
Upper	6,011	-38	-84	--	--	-2	-14	--	--	17.7
Middle	5,432	-34	-69	--	--	-2	-5	--	--	24.3
Lower	2,399	-37	-64	--	--	-1	-8	--	--	11.8
Total for all aquifers[2]	13,865	--	--	-619	6,983	--	--	-106	-273	--
2025 scenario						**From 2000 baseline simulation to 2025 scenario**				
Upper	4,990	-32	-81	--	--	-1	-16	--	--	17.9
Middle	3,485	-29	-66	--	--	-2	-8	--	--	19.6
Lower	1,761	-32	-60	--	--	-2	-3	--	--	14.4
Total for all aquifers[2]	10,261	--	--	1,010	8,189	--	-3	-173	-252	--

[1] Datum is National Geodetic Vertical Datum (NGVD) of 1929.

[2] Total for all aquifers is the sum of all withdrawals from the Englishtown and Potomac-Raritan-Magothy aquifer systems simulated within the boundary of the model grid. This sum does not include the wells outside the model area whose withdrawals were included in the model. Withdrawals from wells outside the model area are simulated in the specified-head boundary for the layer in which the well is located. Simulated withdrawals from the Englishtown aquifer system totaled about 22.5 Mgal/yr for all simulations and scenarios, except the 2025 scenario. Simulated withdrawals from the Englishtown aquifer system in the 2025 scenario totaled about 25.15 Mgal/yr. Individual aquifer values may not add to totals as a result of rounding.

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
Upper Potomac-Raritan-Magothy aquifer			
15-3	8/28/1974	--	91
	5/13/1975	--	92
	11/5/1976	--	98
	8/24/1978	--	93
	8/17/1979	--	98
	9/17/1980	--	98
	9/10/1981	--	110
	9/17/1982	230	100
	8/30/1983	--	110
	7/2/1984	--	84.7
	9/25/1984	190	110
	10/9/1984	--	139.8
	12/19/1984	--	135.7
	3/5/1985	--	123.6
	6/1/1985	--	123.6
	6/10/1985	--	155
	8/21/1985	--	115.8
	3/13/1986	--	138.6
	6/9/1986	--	111
	6/24/1986	--	144.5
	9/4/1986	--	120
	9/26/1986	--	138
	2/28/1987	--	140
	3/13/1987	--	112
	6/18/1987	--	112
	8/18/1987	--	110
	9/24/1987	--	118
	3/3/1988	--	70
	6/6/1988	--	71
	9/8/1988	--	70
	4/19/1999	--	68.79
	4/19/1999	--	68.8
	6/11/1999	--	68.79
	11/15/1999	190	110.6
	9/17/2003	237	117
15-60	7/17/1967	150	56
	2/28/1970	--	57
	9/24/1973	--	60
	10/7/1974	--	62
	9/14/1977	--	68
	9/1/1978	--	65
	8/17/1979	--	66
	8/19/1980	--	90
	8/17/1982	160	66
	9/1/1982	--	66
	8/30/1983	--	66
	4/1/1984	--	60
15-60 (continued)	4/17/1984	--	60
	4/18/1984	--	60
	9/25/1984	150	69
	2/11/1985	--	46
	9/19/1985	--	36
	12/1/1985	205	36
	2/13/1986	154	36
	3/6/1986	122	38
	5/22/1986	215	42
	6/20/1986	200	47.5
	10/23/1986	130	29
	2/12/1987	155	70
	3/5/1987	174	71
	4/7/1987	163	69
	5/12/1987	154	68
	6/9/1987	166	69
	10/20/1987	168	80
	3/8/1988	180	71
	4/5/1988	150	68
	5/17/1988	170	74
	6/15/1988	140	59
	7/5/1988	140	71
	8/3/1988	150	68
	9/6/1988	150	70
	10/4/1988	120	38
	11/1/1988	130	62
	7/18/1989	170	74
	10/3/1989	150	71
	11/6/1989	160	34
	12/5/1989	120	40
	6/15/1991	162	76
	7/2/1991	180	70
	8/6/1991	149	71
	9/3/1991	150	71
	10/1/1991	212	76
	11/12/1991	166.2	71.5
	12/3/1991	--	70.4
	1/7/1992	87	67.5
	3/3/1992	140	68
	4/7/1992	165	65.1
	5/5/1992	156	66.5
	6/2/1992	154	69.2
	8/26/1992	170	75
	3/1/1994	160	72
	4/5/1994	170	75
	5/3/1994	170	82
	1/3/1995	--	72
	2/7/1995	--	76
15-60 (continued)	10/6/1995	--	77
	11/15/1995	--	75.3
	2/22/1996	--	44.2
	3/18/1996	--	77.7
	7/30/1996	--	83.2
	8/5/1996	--	78.9
	8/6/1996	--	81.1
	10/15/1996	--	75.7
	1/7/1997	--	72.4
	5/6/1997	--	80.4
	7/2/1997	--	76.4
	10/15/1997	--	77.9
	1/7/1998	--	75.5
	5/5/1998	--	74.6
	7/7/1998	--	80.5
	10/6/1998	--	80.2
	1/13/1999	--	76.4
	4/7/1999	--	79.7
	7/8/1999	--	80
	10/7/1999	--	80.2
	1/5/2000	--	78.5
	4/5/2000	--	82
	7/12/2000	--	79.2
	10/4/2000	--	79.8
	8/15/2001	--	78.7
	1/9/2002	--	78.2
	4/10/2002	--	81.3
	7/17/2002	--	82.2
	10/30/2002	--	79.8
	3/15/2003	--	80.2
	4/8/2003	--	79.9
	6/15/2003	--	79.9
	7/15/2003	--	81.1
	9/15/2003	--	81.1
	10/21/2003	--	80.1
	12/15/2003	--	80.1
	1/20/2004	--	79.2
	3/15/2004	--	79.2
	4/7/2004	--	80.5
	6/15/2004	--	80.5
	7/13/2004	--	80
	9/15/2004	--	80
	10/12/2004	--	80
	12/15/2004	--	80
	3/15/2005	--	78.5
	6/15/2005	--	85.7
	9/15/2005	--	80.2
	12/15/2005	--	81.5

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
15-60 (continued)	3/15/2006	--	80.8
	6/15/2006	--	83.7
	9/15/2006	--	83.5
	3/15/2007	--	27.4
	6/15/2007	--	46.6
	9/15/2007	--	85.1
	12/15/2007	--	84
	3/15/2008	--	84.1
	6/15/2008	--	43.1
	9/15/2008	--	86.3
	12/15/2008	48.3	55
	3/15/2009	--	46.8
15-62	5/7/1951	--	19
	4/11/1958	--	20
	8/26/1958	--	20
	11/19/1958	115	13
	12/9/1958	117	20
	4/8/1959	--	20
	4/6/1960	--	26
	8/23/1960	--	19
	4/5/1961	--	20
	8/29/1961	--	20
	4/18/1962	--	20
	9/24/1962	--	19
	4/3/1963	--	28
	8/27/1963	--	20
	9/18/1964	--	19
	4/22/1965	--	19
	7/17/1967	115	18
	2/28/1970	--	20
	9/24/1973	--	20
	8/19/1980	--	78
	9/1/1982	--	66
	7/6/1984	--	27
	1/10/1985	--	26
	12/1/1985	149	18
	1/2/1986	178	16
	2/6/1986	111	16
	3/6/1986	203	18
	4/11/1986	90	14
	4/9/1987	23	16
	5/5/1987	123	21
	6/11/1987	130	18
	3/8/1988	130	25
	4/5/1988	120	33
	5/17/1988	120	25
	6/15/1988	120	19
	7/5/1988	110	22
15-62 (continued)	1/3/1989	120	32
	2/7/1989	--	99
	3/7/1989	94	21
	4/4/1989	120	24
	5/2/1989	18	23
	7/3/1989	110	30
	12/4/1990	100	26
	4/2/1991	110	23
	5/7/1991	104	21
	1/7/1992	68.5	22.7
	3/3/1992	112	21.7
	4/7/1992	368	22.3
	7/6/1993	--	82
	2/1/1994	130	22
	3/1/1994	130	23
	4/5/1994	120	24
	5/3/1994	130	24
	6/7/1994	190	25
	7/12/1994	120	26
	3/14/1995	--	27
	4/4/1995	--	24
	3/18/1996	--	26.6
	7/30/1996	--	28.6
	8/5/1996	--	24.6
	8/6/1996	--	25.5
	10/15/1996	--	23.5
	1/7/1997	--	22.3
	5/6/1997	--	25.3
	7/2/1997	--	25.3
	10/15/1997	--	24.2
	1/7/1998	--	21.8
	4/14/1998	--	24.1
	7/7/1998	--	26.3
	10/6/1998	--	23.2
	1/13/1999	--	23.6
	4/7/1999	--	24.5
	7/8/1999	--	24
	10/7/1999	--	23.2
	2/9/2000	--	25.6
	4/5/2000	--	25.9
	7/12/2000	--	24.6
	10/4/2000	--	24
	1/17/2001	--	24.4
	6/27/2001	--	24.8
	8/15/2001	--	23.3
	1/9/2002	--	24.8
	4/10/2002	--	26.7
	7/10/2002	--	24.9
15-62 (continued)	10/30/2002	--	24.4
	1/14/2003	--	25
	3/15/2003	--	25
	4/9/2003	--	24.8
	6/15/2003	--	24.8
	7/15/2003	--	24.8
	9/15/2003	--	24.8
	10/21/2003	--	24.3
	12/15/2003	--	24.3
	7/13/2004	--	25.1
	9/15/2004	--	25.1
	10/12/2004	--	24.7
	12/15/2004	--	24.7
	3/15/2005	--	24.2
	6/15/2005	--	26.7
	9/15/2005	--	24.2
	12/15/2005	--	25.3
	3/15/2006	--	25.4
	6/15/2006	--	25.9
	9/15/2006	--	25.3
	12/15/2006	--	24.8
	3/15/2007	--	26.4
	6/15/2007	--	27.4
	9/15/2007	--	27
	12/15/2007	--	27.1
	3/15/2008	--	25.8
	6/15/2008	--	44.2
	9/15/2008	--	28.3
	12/15/2008	106	28.8
	3/15/2009	129	34.2
	6/15/2009	122	29.2
	9/15/2009	126	28
	12/15/2009	128	28.5
	3/15/2010	127	28.8
15-63	7/17/1967	112	20
	9/21/1972	--	28
	10/7/1974	--	28
	8/19/1980	--	60
	9/17/1980	--	29
	8/17/1982	130	40
	9/1/1982	--	40
	7/6/1984	--	33
	8/8/1984	--	51
	9/5/1984	--	58.5
	7/24/1985	120	36
	8/12/1985	--	20
	6/20/1986	145	30
	7/8/1986	192	21

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
15-63 (continued)	10/16/1986	222.5	24
	12/11/1986	51.2	24.5
	1/13/1987	118	34
	3/5/1987	129	34
	5/19/1987	123	40
	6/9/1987	149	48
	7/1/1987	133	41
	10/20/1987	113.3	42
	11/12/1987	123.9	14.5
	12/10/1987	108.5	22
	6/15/1988	120	39
	7/5/1988	110	49
	8/3/1988	120	48
	9/6/1988	100	37
	10/4/1988	120	38
	11/1/1988	110	72
	12/6/1988	130	38
	1/3/1989	110	24
	3/7/1989	99	38
	4/4/1989	120	42
	6/6/1989	29	43
	7/3/1989	120	42
	8/8/1989	130	60
	9/6/1989	120	48
	10/3/1989	120	49
	11/6/1989	110	20
	12/5/1989	160	80
	7/10/1990	120	45
	8/7/1990	140	52
	8/24/1990	130	37
	9/4/1990	110	37
	11/5/1990	--	64
	4/2/1991	122	38
	5/7/1991	114	36
	7/2/1991	109	38
	8/6/1991	118	39
	9/3/1991	113	38
	10/1/1991	--	35
	12/3/1991	126	--
	5/5/1992	117	39.5
	6/2/1992	100	45
	7/6/1993	--	40
	10/5/1993	--	41
	11/1/1993	--	39
	12/7/1993	--	46
	1/4/1994	140	46
	7/12/1994	120	45
	8/2/1994	160	53
15-63 (continued)	1/3/1995	--	42
	2/7/1995	--	44
	3/14/1995	--	47
	4/4/1995	--	48
	6/6/1995	--	45
	1/16/1996	--	43
	3/18/1996	--	68.6
	7/30/1996	--	75.1
	8/5/1996	--	66.1
	8/6/1996	--	70.8
	10/15/1996	--	46
	1/7/1997	--	42.9
	5/6/1997	--	48.7
	7/2/1997	--	46.4
	10/15/1997	--	62.7
	1/7/1998	--	49.3
	4/14/1998	--	65.8
	7/7/1998	--	74.7
	10/6/1998	--	46
	1/13/1999	--	51.2
	4/7/1999	--	75.3
	7/8/1999	--	48.5
	10/7/1999	--	46
	1/5/2000	--	49.4
	4/5/2000	--	65.8
	7/12/2000	--	48.8
	10/4/2000	--	48.8
	1/17/2001	--	48.4
	6/27/2001	--	49.4
	8/15/2001	--	63.8
	1/9/2002	--	47.8
	4/10/2002	--	50.6
	7/10/2002	--	55
	3/15/2003	--	54
	6/15/2003	--	53
	9/15/2003	--	52.9
	12/15/2003	--	51.6
	3/15/2004	--	52.2
	6/15/2004	--	53.9
	9/15/2004	--	50.3
	12/15/2004	--	51.2
	3/15/2005	--	25.2
	6/15/2005	--	57.1
	9/15/2005	--	51.8
	12/15/2005	--	53.8
	3/15/2006	--	53.2
	6/15/2006	--	56.3
	9/15/2006	--	55
15-63 (continued)	12/15/2006	--	54.5
	3/15/2007	--	54.5
	6/15/2007	--	57.4
	9/15/2007	--	56
	12/15/2007	--	55.7
	3/15/2008	--	56.6
	6/15/2008	--	47.2
	9/15/2008	--	58
	12/15/2008	138	51.1
	3/15/2009	45.9	30.4
15-127	2/28/1970	--	62
15-225	9/2/1929	--	26
	5/7/1951	118	34
	4/11/1958	--	23
	8/26/1958	--	24
	12/9/1958	104	24
	4/8/1959	--	24
	12/9/1959	--	24
	4/6/1960	--	24
	8/23/1960	--	26
	4/5/1961	--	30
	8/29/1961	--	30
	4/18/1962	--	27
	9/24/1962	--	22
	4/3/1963	--	26
	8/27/1963	--	23
	4/29/1964	--	21
	9/18/1964	--	19
	4/22/1965	--	19
	7/17/1967	107	20
	9/21/1972	--	55
	5/24/1973	--	35
	9/24/1973	--	32
	4/29/1974	--	37
	8/28/1974	--	35
	5/13/1975	--	33
	9/14/1977	--	44
	8/24/1978	--	37
	8/14/1979	--	38
	6/6/1995	--	53
	9/20/1995	--	54
	9/26/1995	--	54
	3/15/1996	--	37.1
	6/26/1996	--	54.1
	7/26/1996	--	31.7
	11/26/1996	--	51.8
	3/11/1997	--	37
	6/4/1997	--	54.7

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
15-225 (continued)	7/15/1997	--	48.9
	12/2/1997	--	31.2
	3/5/1998	--	38.6
	6/4/1998	--	37.2
	7/10/1998	--	55.7
	12/4/1998	--	38.3
	3/2/1999	--	38.7
	6/2/1999	--	39.1
	3/8/2000	--	42.7
	6/7/2000	--	45.8
	7/11/2000	--	42.5
	7/24/2000	72.5	42.5
	3/1/2001	--	39.1
	7/3/2001	--	41.3
	6/11/2002	--	39
	7/2/2002	--	106
	3/15/2003	133	42.6
15-248	9/17/1980	--	9
	8/18/1982	93	8.8
	11/29/1994	107.5	12
	2/21/1995	104	12.6
	6/5/1995	98	13.2
	8/7/1995	127.5	15.4
	10/24/1995	196	11.2
	3/20/1996	102	12.8
	6/6/1996	108	11.9
	8/20/1996	132	10.2
	11/27/1996	149.7	11.8
	6/17/1997	107.5	12.1
	9/2/1997	127.8	12.66
	11/25/1997	93.5	10.57
	3/13/1998	81.5	13.2
	6/3/1998	88.8	4.97
	3/17/1999	43.9	10.17
	9/8/1999	82.5	10.74
	11/17/1999	67.6	10.2
	5/24/2000	64.5	9.94
	8/18/2000	--	11.64
	12/11/2000	62.2	11.35
	2/28/2001	82.5	10.6
	3/15/2004	92.7	12
	6/15/2004	54.6	10
	9/15/2004	90.9	12
	12/15/2004	52.8	10.9
	3/15/2005	80.2	13.3
	6/15/2005	87.9	11.6
	9/15/2005	89.2	11.5
	12/15/2005	95.6	11
15-248 (continued)	3/15/2006	114	12.8
	6/15/2006	58.9	11.8
	9/15/2006	80.2	10
	12/15/2006	69	11
	3/15/2007	84	12.2
	6/15/2007	61.6	11.3
	9/15/2007	68.4	11.8
	12/15/2007	74.7	11.8
	3/15/2008	93.8	14.74
	6/15/2008	89.3	11.8
	9/15/2008	86.1	10.9
	12/15/2008	--	49
	3/15/2009	86.5	12.15
	6/15/2009	--	8.8
	9/15/2009	82.6	13.4
	12/15/2009	90.3	11.5
	3/15/2010	48.7	12.3
15-361	4/29/1974	--	44
	9/1/1978	--	55
	8/17/1979	--	55
	9/17/1980	--	58
	9/10/1981	--	59
	8/17/1982	150	59
	8/30/1983	--	60
	9/25/1984	140	62
	9/4/1986	--	64
	8/18/1987	--	61
	8/12/1988	--	64
	8/23/1989	--	67
	8/7/1991	160	72
	11/1/1993	--	66
	8/2/1994	230	73
	9/13/1994	--	65
	3/25/1996	--	67.3
	7/30/1996	--	74.4
	8/5/1996	--	74.5
	8/6/1996	--	75.2
	7/2/1997	--	72.8
	10/15/1997	--	71.1
	5/5/1998	--	72
	7/7/1998	--	77.1
	7/8/1999	--	75.5
	7/12/2000	--	79.1
	10/4/2000	--	75
	6/27/2001	--	78.3
	8/15/2001	--	76.2
	7/10/2002	--	80.4
	3/15/2003	--	79.9
15-361 (continued)	4/8/2003	--	79.9
	6/15/2003	--	79.9
	7/15/2003	--	79.2
	9/15/2003	--	79.2
	10/21/2003	--	77.7
	12/15/2003	--	77.7
	1/20/2004	--	77.8
	3/15/2004	--	77.8
	4/7/2004	--	78.8
	6/15/2004	--	78.8
	7/13/2004	--	76.7
	9/15/2004	--	76.7
	10/12/2004	--	77.5
	12/15/2004	--	77.5
	3/15/2005	--	76.3
	6/15/2005	--	83.2
	9/15/2005	--	79.1
	12/15/2005	--	79
	3/15/2006	--	78.3
	9/15/2006	--	80.1
	12/15/2006	--	80.1
	3/15/2008	--	78.5
	6/15/2008	--	42.5
	9/15/2008	--	68.4
	12/15/2008	115	33.9
	3/15/2009	181	--
	6/15/2009	164	78.9
	9/15/2009	170	76.4
	12/15/2009	164	78.1
	3/15/2010	165	78.7
15-385	9/17/1980	--	43
	9/10/1981	--	44
	7/23/1982	140	45
	8/30/1983	--	44
	9/25/1984	120	45
	7/24/1985	120	44
	9/4/1986	--	48
	8/18/1987	--	44
	8/12/1988	--	46
	8/23/1989	--	45
	8/24/1990	130	45
	8/7/1991	130	53
	8/26/1992	130	54
	6/6/1995	--	53
	9/20/1995	--	53
	9/26/1995	--	53
	3/15/1996	--	46.8
	6/26/1996	--	53.2

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
15-385 (continued)	7/26/1996	--	27.4
	11/26/1996	--	50.6
	3/11/1997	--	41
	6/4/1997	--	48.2
	7/15/1997	--	48.5
	12/2/1997	--	49.8
	3/5/1998	--	51.3
	6/4/1998	--	50.1
	7/10/1998	--	54.9
	12/4/1998	--	52.6
	3/2/1999	--	51.2
	6/2/1999	--	52.4
	3/8/2000	--	53.5
	6/7/2000	--	57
	7/11/2000	--	53.8
	7/24/2000	124	53.8
	6/24/2003	132	56.2
	12/16/2003	134	54.5
	3/2/2004	132	53.7
	6/15/2004	104	50.3
	9/25/2004	127	53.7
	12/28/2004	136	52.2
	3/15/2005	130	53.9
	6/30/2005	131	55
	9/20/2005	135	55.2
	12/13/2005	125	56.2
	3/14/2006	149	52
	6/29/2006	114	64.6
	9/6/2006	117	--
	12/26/2006	128	51.7
	3/27/2007	118	57
	6/15/2007	118	55.9
	9/25/2007	99	56.6
	12/18/2007	94.8	54
	3/24/2008	113	54.7
	6/27/2008	127	54
	9/10/2008	108	53.6
	12/9/2008	103	55.5
	3/10/2009	121	53.7
	6/23/2009	131	53.8
	10/6/2009	129	51.1
	12/15/2009	129	54.4
	3/9/2010	114	56.3
15-1109	5/16/1996	--	216
	8/7/1996	--	225
	11/14/1996	--	225
	5/5/1997	--	229
	9/2/1997	--	226
15-1109 (continued)	11/13/1997	--	220
	2/18/1998	--	251
	5/6/1998	--	216
	8/27/1998	--	221
	11/20/1998	--	244
	2/18/1999	--	192
	6/1/1999	--	224
	8/9/1999	--	218
	11/23/1999	--	225
	2/25/2000	--	243
	8/9/2000	--	218
	11/30/2000	--	222
	8/30/2001	--	242
	11/30/2001	--	248
	2/27/2002	--	248
	8/28/2002	--	237
	12/10/2002	--	224
	2/27/2003	325	245
	3/15/2003	325	245
	5/28/2003	307	252
	6/15/2003	307	252
	8/26/2003	297	240
	9/15/2003	297	240
	11/20/2003	316	257
	12/15/2003	316	257
	3/15/2004	255	245
	6/15/2004	224	253
	9/15/2004	263	258
	6/15/2005	247	250
	9/15/2005	270	247
	6/15/2006	102	93.9
	9/15/2006	140	134
	6/15/2007	183	221
	8/24/2007	193	254
	8/11/2008	252	251.4
Middle Potomac-Raritan-Magothy aquifer			
33-933	7/15/1998	--	189
	1/12/1999	--	218
	4/14/1999	--	223
	7/13/1999	--	261
	10/12/1999	--	213
	1/11/2000	--	236
	4/12/2000	--	243
	7/12/2000	--	238
	10/10/2000	--	223
	1/9/2001	--	232
	4/10/2001	--	236
	7/10/2001	--	216
33-933 (continued)	1/8/2002	--	221
	4/12/2002	--	234
	4/14/2002	--	234
	7/9/2002	--	239
	10/8/2002	--	232
	3/15/2003	227	227
	4/8/2003	273	229
	6/15/2003	273	229
	9/15/2003	260	230
	10/14/2003	322	219
	12/15/2003	322	219
	1/13/2004	177	221
	3/15/2004	177	221
	4/13/2004	219	217
	6/15/2004	219	217
	7/13/2004	231	203
	9/15/2004	231	203
	10/12/2004	230	216
	12/15/2004	230	216
	1/11/2005	230	206
	3/15/2005	230	206
	6/15/2005	216	224
	7/12/2005	224	214
	9/15/2005	224	214
	12/15/2005	217	209
	3/14/2006	271	215
	3/15/2006	271	215
	6/15/2006	214	--
	9/15/2006	196	197
	12/15/2006	204	211
	3/15/2007	217	197
	6/15/2007	179	217
	9/15/2007	176	227
	12/15/2007	157	209
	3/15/2008	228	224
	6/15/2008	189	205
	9/15/2008	241	206
	10/14/2008	201	205
	12/15/2008	201	205
	3/15/2009	189	229
	6/15/2009	216	222
	9/15/2009	215	196
	12/15/2009	191	193
	3/15/2010	192	203
Lower Potomac-Raritan-Magothy aquifer			
33-432	1/22/1996	--	375
	2/26/1996	--	350
	3/29/1996	--	360

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
33-432	7/29/1996	--	385
(continued)	8/16/1996	--	375
	9/30/1996	--	370
	10/30/1996	--	380
	11/26/1996	--	340
	12/31/1996	--	410
	1/13/1997	--	380
	2/28/1997	--	385
	3/13/1997	--	285
	4/10/1997	--	385
	5/8/1997	--	385
	6/2/1997	--	380
	7/13/1997	--	275
	8/6/1997	--	345
	9/3/1997	--	400
	5/30/1998	--	360
	6/30/1998	--	375
	7/6/1998	--	400
	8/23/1998	--	390
	9/6/1998	--	350
	9/7/1998	--	390
	10/5/1998	--	400
	11/2/1998	--	395
	12/7/1998	--	270
	1/4/1999	--	370
	2/1/1999	--	280
	3/1/1999	--	280
	4/5/1999	--	370
	5/3/1999	--	370
	6/2/1999	--	360
	7/25/1999	--	400
	9/6/1999	--	275
	10/4/1999	--	350
	11/1/1999	--	425
	1/3/2000	--	355
	2/7/2000	--	350
	3/6/2000	--	350
	7/12/2000	--	273
	10/4/2000	--	427
	1/3/2001	--	270
	4/4/2001	--	280
	7/5/2001	--	289
	4/3/2002	--	322
	7/10/2002	--	313
	10/9/2002	--	291
	6/15/2003	--	303
	9/15/2003	--	323
	3/15/2004	--	375
33-432	6/15/2004	--	335
(continued)	9/15/2004	--	218
	3/15/2005	--	207
	6/15/2005	--	246
	9/15/2005	--	201
	3/15/2006	--	305
	9/15/2006	--	200
	12/15/2006	--	356
	3/15/2007	--	300
	3/15/2008	--	202
	6/15/2008	--	239
	7/8/2008	--	343
	9/15/2008	--	343
	12/15/2008	--	352
	3/15/2009	--	293
	9/15/2009	--	294
	10/14/2009	--	294
	12/15/2009	--	294
33-899	1/6/1997	--	187
	2/4/1997	--	212
	3/3/1997	--	207
	4/3/1997	--	202
	5/8/1997	--	195
	6/3/1997	--	226
	7/3/1997	--	210
	8/5/1997	--	226
	9/8/1997	--	221
	10/2/1997	--	230
	11/13/1997	--	242
	12/3/1997	--	226
	1/11/1998	--	223
	3/8/1998	--	193
	4/1/1998	--	228
	5/10/1998	--	195
	6/1/1998	--	186
	7/4/1998	--	216
	8/11/1998	--	232
	9/12/1998	--	211
	10/5/1998	--	247
	11/6/1998	--	211
	12/4/1998	--	216
	1/4/1999	--	205
	2/4/1999	--	210
	3/3/1999	--	200
	4/4/1999	--	205
	5/4/1999	--	230
	6/6/1999	--	220
	7/12/1999	--	211
33-899	8/5/1999	--	210
(continued)	10/13/1999	--	180
	11/9/1999	--	195
	12/11/1999	--	180
	2/5/2000	--	227
	2/16/2000	--	240
	3/3/2000	--	236
	4/21/2000	--	231
	5/5/2000	--	231
	6/2/2000	--	222
	7/12/2000	--	215
	8/4/2000	--	296
	9/13/2000	--	390
	4/8/2001	--	260
	5/15/2001	--	220
	6/11/2001	--	240
	7/14/2001	--	210
	8/20/2001	--	250
	9/18/2001	--	230
	10/12/2001	--	240
	11/7/2001	--	270
	12/4/2001	--	370
	1/30/2002	--	388
	1/31/2002	--	388
	2/13/2002	--	360
	2/18/2002	--	360
	4/18/2002	--	200
	5/7/2002	--	135
	6/15/2002	--	170
	7/12/2002	--	220
	7/13/2002	--	220
	8/23/2002	--	390
	9/9/2002	--	330
	10/4/2002	--	230
	11/3/2002	--	210
	12/7/2002	--	180
	1/30/2003	--	200
	2/12/2003	--	240
	3/13/2003	--	380
	3/15/2003	--	380
	4/13/2003	--	220
	5/31/2003	--	350
	6/6/2003	--	230
	6/15/2003	--	230
	9/15/2003	--	380
	10/29/2003	--	100
	11/3/2003	--	117
	12/7/2003	--	390

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
33-899 (continued)	3/15/2004	--	230
	6/15/2004	--	220
	9/15/2004	--	250
	12/15/2004	--	430
	12/27/2004	--	430
	3/15/2005	--	380
	3/17/2005	--	380
	4/17/2005	--	390
	9/13/2005	--	280
	9/15/2005	--	280
	12/15/2005	--	210
	1/13/2006	--	320
	2/8/2006	--	220
	3/7/2006	--	240
	3/15/2006	--	240
	6/15/2006	--	340
	9/15/2006	--	188
	11/18/2006	--	230
	12/15/2006	--	200
	3/15/2007	--	250
	6/15/2007	--	250
	9/15/2007	--	200
	12/15/2007	--	170
	3/15/2008	--	190
	6/15/2008	--	220
	9/15/2008	--	192.5
	12/15/2008	--	160
	3/15/2009	--	400
	6/15/2009	--	190
	9/15/2009	--	223
	12/15/2009	--	255
	3/15/2010	--	250
33-900	1/6/1997	--	601
	2/4/1997	--	422
	3/3/1997	--	427
	4/1/1997	--	429
	5/6/1997	--	423
	6/3/1997	--	433
	7/3/1997	--	428
	8/6/1997	--	435
	9/8/1997	--	433
	10/7/1997	--	429
	11/18/1997	--	423
	12/4/1997	--	397
	1/6/1998	--	432
	2/3/1998	--	406
	3/6/1998	--	388
	4/5/1998	--	431
33-900 (continued)	5/9/1998	--	397
	6/1/1998	--	352
	7/5/1998	--	403
	8/12/1998	--	358
	9/12/1998	--	378
	1/4/1999	--	400
	2/1/1999	--	390
	3/2/1999	--	410
	4/3/1999	--	385
	5/3/1999	--	425
	6/5/1999	--	385
	7/10/1999	--	393
	8/6/1999	--	410
	10/15/1999	--	410
	11/10/1999	--	390
	12/8/1999	--	320
	2/4/2000	--	441
	2/16/2000	--	409
	3/3/2000	--	436
	4/20/2000	--	423
	5/5/2000	--	476
	6/3/2000	--	452
	7/12/2000	--	420
	8/4/2000	--	516
	9/13/2000	--	390
	4/7/2001	--	440
	5/16/2001	--	460
	6/10/2001	--	440
	7/14/2001	--	380
	8/21/2001	--	450
	9/19/2001	--	470
	10/13/2001	--	465
	11/18/2001	--	400
	12/5/2001	--	210
	1/30/2002	--	213
	2/13/2002	--	240
	3/19/2002	--	400
	4/17/2002	--	385
	5/6/2002	--	295
	6/14/2002	--	390
	7/13/2002	--	380
	8/26/2002	--	380
	9/8/2002	--	300
	10/6/2002	--	260
	11/2/2002	--	190
	1/30/2003	--	180
	2/12/2003	--	330
	3/13/2003	--	240
33-900 (continued)	3/15/2003	--	240
	4/13/2003	--	325
	5/31/2003	--	325
	6/6/2003	--	300
	6/15/2003	--	300
	9/15/2003	--	370
	10/29/2003	--	200
	11/2/2003	--	133
	12/6/2003	--	370
	3/15/2004	--	500
	6/15/2004	--	390
	9/15/2004	--	430
	11/8/2004	--	440
	12/15/2004	--	450
	12/27/2004	--	450
	3/15/2005	--	350
	3/17/2005	--	350
	4/17/2005	--	340
	9/13/2005	--	410
	9/15/2005	--	410
	12/15/2005	--	400
	1/13/2006	--	380
	2/8/2006	--	360
	3/7/2006	--	440
	3/15/2006	--	440
	6/15/2006	--	520
	9/15/2006	--	383
	12/15/2006	--	350
	3/15/2007	--	600
	6/15/2007	--	600
	9/15/2007	--	300
	12/15/2007	--	350
	3/15/2008	--	330
	6/15/2008	--	360
	9/15/2008	--	385
	12/15/2008	--	340
	3/15/2009	--	380
	6/15/2009	--	410
	9/15/2009	--	350
	12/15/2009	--	460
	3/15/2010	--	450
33-901	1/6/1997	--	394
	2/3/1997	--	400
	3/3/1997	--	400
	4/1/1997	--	402
	5/6/1997	--	392
	6/3/1997	--	395
	7/3/1997	--	399

Table 17. Measured sodium and chloride concentrations in water from selected wells in the Salem-Gloucester study area, southern New Jersey, 1929–2010.—Continued

[Well locations are shown in figs. 48–51; concentrations in milligrams per liter; --, not measured]

Well	Date	Concentration	
		Sodium	Chloride
33-901	8/6/1997	--	395
(continued)	9/5/1997	--	393
	10/7/1997	--	395
	11/12/1997	--	403
	12/2/1997	--	432
	1/10/1998	--	417
	2/9/1998	--	415
	3/8/1998	--	394
	4/5/1998	--	402
	5/9/1998	--	391
	6/1/1998	--	352
	7/5/1998	--	362
	8/11/1998	--	347
	9/13/1998	--	352
	10/5/1998	--	271
	11/5/1998	--	357
	12/5/1998	--	352
	1/6/1999	--	385
	2/1/1999	--	370
	3/2/1999	--	375
	4/2/1999	--	370
	5/5/1999	--	375
	6/5/1999	--	320
	7/10/1999	--	413
	8/6/1999	--	370
	10/14/1999	--	350
	11/9/1999	--	365
	12/7/1999	--	310
	2/4/2000	--	396
	2/16/2000	--	409
	3/3/2000	--	396
	4/20/2000	--	378
	5/5/2000	--	436
	6/3/2000	--	397
	7/12/2000	--	375
	8/4/2000	--	456
	9/13/2000	--	385
	4/7/2001	--	390
	5/15/2001	--	400
	6/9/2001	--	380
	7/14/2001	--	365
	8/21/2001	--	400
	9/19/2001	--	420
	10/13/2001	--	420
	11/7/2001	--	475
	12/5/2001	--	400
	1/30/2002	--	375
	2/13/2002	--	280

Well	Date	Concentration	
		Sodium	Chloride
33-901	3/19/2002	--	360
(continued)	4/17/2002	--	310
	5/6/2002	--	235
	6/14/2002	--	340
	7/13/2002	--	350
	8/24/2002	--	280
	9/8/2002	--	290
	10/4/2002	--	330
	11/2/2002	--	310
	12/6/2002	--	340
	1/30/2003	--	340
	2/12/2003	--	260
	3/13/2003	--	370
	3/15/2003	--	370
	4/13/2003	--	475
	5/31/2003	--	300
	6/6/2003	--	320
	6/15/2003	--	320
	9/15/2003	--	250
	10/29/2003	--	167
	11/1/2003	--	183
	12/6/2003	--	300
	12/15/2003	--	390
	3/15/2004	--	380
	6/15/2004	--	400
	9/15/2004	--	370
	12/15/2004	--	610
	3/15/2005	--	320
	9/15/2005	--	300
	12/15/2005	--	390
	3/15/2006	--	360
	6/15/2006	--	360
	9/15/2006	--	322
	12/15/2006	--	500
	3/15/2007	--	400
	6/15/2007	--	500
	9/15/2007	--	270
	12/15/2007	--	300
	3/15/2008	--	300
	6/15/2008	--	320
	9/15/2008	--	310
	12/15/2008	--	290
	3/15/2009	--	320
	6/15/2009	--	450
	9/15/2009	--	360
	12/15/2009	--	360
	3/15/2010	--	300

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