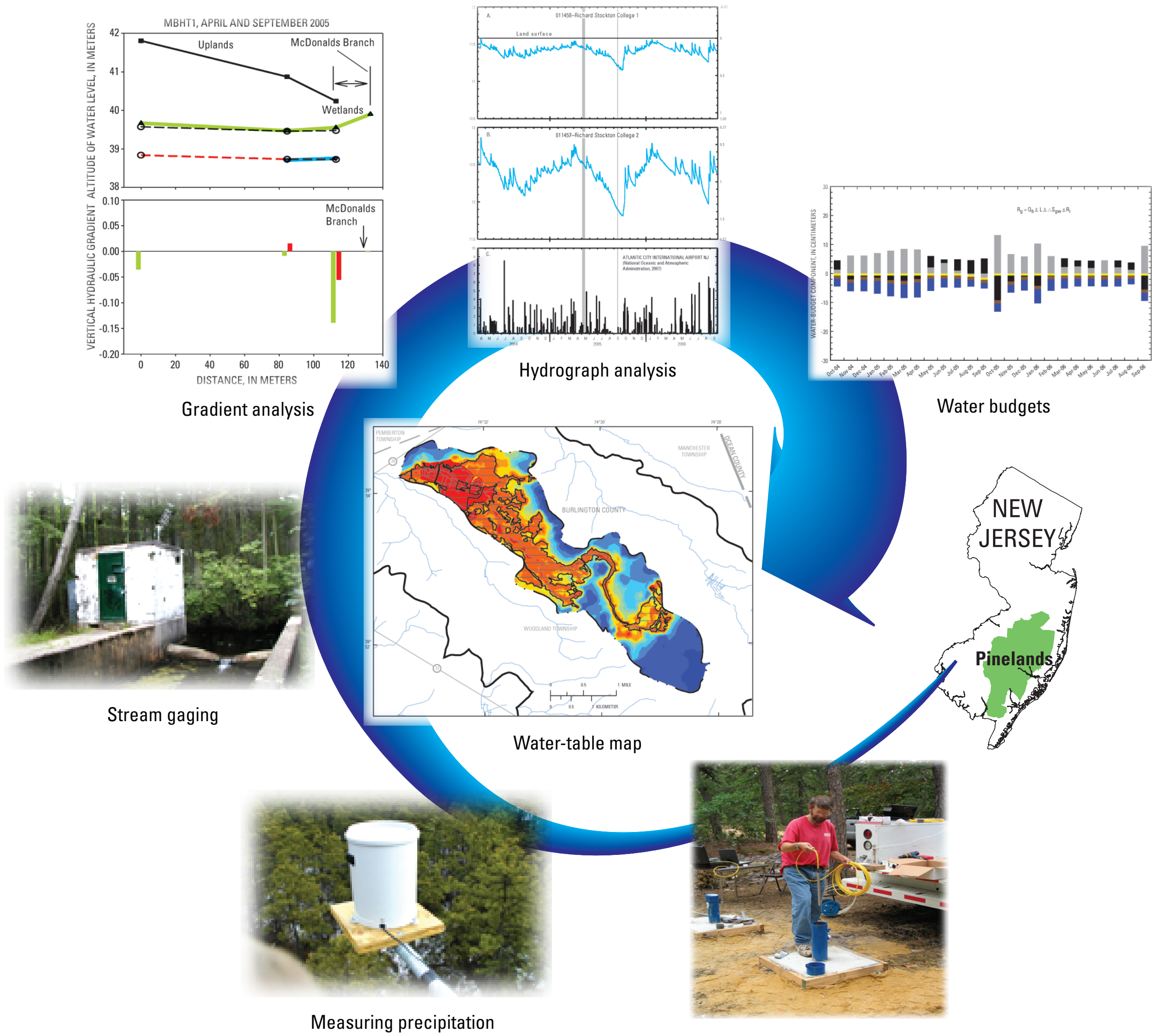
science for a changing world

**Prepared in cooperation with the New Jersey Pinelands Commission**

# Hydrologic Assessment of Three Drainage Basins in the Pinelands of Southern New Jersey, 2004–06




Scientific Investigations Report 2011–5056

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

# Hydrologic Assessment of Three Drainage Basins in the Pinelands of Southern New Jersey, 2004–06

By Richard L. Walker, Robert S. Nicholson, and Donald A. Storck

Prepared in cooperation with the New Jersey Pinelands Commission

Scientific Investigations Report 2011–5056

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

**U.S. Department of the Interior**
KEN SALAZAR, Secretary

**U.S. Geological Survey**
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov



Suggested citation:
Walker, R.L., Nicholson, R.S., and Storck, D.A., 2011, Hydrologic assessment of three drainage basins in the Pinelands of southern New Jersey, 2004–06: U.S. Geological Survey Scientific Investigations Report 2011-5056, 145 p.

# Acknowledgments

The authors gratefully acknowledge USGS colleagues Emmanuel Charles and Ralph Haefner, and Pinelands Commission scientists Allison Brown, John Bunnell, Kim Laidig, Nicholas Procopio, and Robert Zampella for providing helpful comments that greatly improved this report.

The authors also gratefully acknowledge the local and State officials who provided assistance in identifying and accessing locations for well installation and provided information about local water use and management or surface water at various locations in Winslow Township in Camden County; Brendan T. Byrne State Forest in Burlington County; Wharton State Forest in Atlantic, Burlington, and Camden Counties; and Richard Stockton College in Atlantic County, and also for their cooperation in providing access to wells and streams for collection of hydrologic data during this study. We also wish to acknowledge the gracious technical assistance of Allison Brown, Kim Laidig, and Robert Zampella in providing water-level measurements at many sites in wetland areas and for their guidance in refining the depth-to-water mapping methods in wetland areas. The cooperation of the many private well owners who kindly provided access to their wells for water-level measurements is greatly appreciated. The authors thank their USGS colleagues Robert Atkinson, Guerino Centinaro, Lawrence Feinson, Kenneth Hayes, Walter Jones, Thomas Moffett, Timothy Reilly, Robert Rosman, Jason Shvanda, Andrew Watson, and Blaine White for technical advice, field assistance, well installation, and establishing surface-water sites; and Emmanuel Charles, William Ellis, Pamela Reilly, Kara Watson, Christine Wieben, Gregory Simpson, and Denis Sun for technical guidance and assistance with report preparation and illustrations, database construction, and data validation.

# Contents

## Figures

## Tables

# Conversion Factors

SI to Inch/Pound

| Multiply | By | To obtain |
|---|---|---|
| | **Length** | |
| centimeter (cm) | 0.3937 | inch (in.) |
| millimeter (mm) | 0.03937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| meter (m) | 1.094 | yard (yd) |
| | **Area** | |
| square meter ($m^2$) | 0.0002471 | acre |
| hectare (ha) | 2.471 | acre |
| square hectometer ($hm^2$) | 2.471 | acre |
| square kilometer ($km^2$) | 247.1 | acre |
| square meter ($m^2$) | 10.76 | square foot ($ft^2$) |
| hectare (ha) | 0.003861 | square mile ($mi^2$) |
| square kilometer ($km^2$) | 0.3861 | square mile ($mi^2$) |
| | **Volume** | |
| liter (L) | 0.2642 | gallon (gal) |
| cubic meter ($m^3$) | 264.2 | gallon (gal) |
| cubic meter ($m^3$) | 0.0002642 | million gallons (Mgal) |
| cubic meter ($m^3$) | 35.31 | cubic foot ($ft^3$) |
| cubic meter ($m^3$) | 1.308 | cubic yard ($yd^3$) |
| | **Flow rate** | |
| meter per second (m/s) | 3.281 | foot per second (ft/s) |
| cubic meter per second ($m^3/s$) | 35.31 | cubic foot per second ($ft^3/s$) |
| cubic meter per second per square kilometer [($m^3/s$)/$km^2$] | 91.49 | cubic foot per second per square mile [($ft^3/s$)/$mi^2$] |
| cubic meter per day ($m^3/d$) | 35.31 | cubic foot per day ($f^{t3}/d$) |
| cubic meter per day ($m^3/d$) | 264.2 | gallon per day (gal/d) |
| cubic meter per day per square kilometer [($m^3/d$)/$km^2$] | 684.28 | gallon per day per square mile [(gal/d)/$m^{i2}$] |
| cubic meter per second ($m^3/s$) | 22.83 | million gallons per day (Mgal/d) |
| cubic meter per day per square kilometer [($m^3/d$)/$km^2$] | 0.0006844 | million gallons per day per square mile [(Mgal/d)/$mi^2$] |
| | **Hydraulic conductivity** | |
| meter per day (m/d) | 3.281 | foot per day (ft/d) |
| Hydraulic gradient | | |
| meter per kilometer (m/km) | 5.27983 | foot per mile (ft/mi) |

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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.

Water year refers to the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 2005, is called the "2005 water year."

Water-level and other data included in this report that were collected and are maintained by the New Jersey Pinelands Commission as part of the study known as the Kirkwood-Cohansey Project are available in electronic format upon request to the New Jersey Pinelands Commission, P.O. Box 359, New Lisbon, NJ, 08064.

# Hydrologic Assessment of Three Drainage Basins in the Pinelands of Southern New Jersey, 2004–06

By Richard L. Walker, Robert S. Nicholson, and Donald A. Storck

## Abstract

The New Jersey Pinelands is an ecologically diverse area in the southern New Jersey Coastal Plain, most of which overlies the Kirkwood-Cohansey aquifer system. The demand for groundwater from this aquifer system is increasing as local development increases. Because any increase in groundwater withdrawals has the potential to affect streamflows and wetland water levels, and ultimately threaten the ecological health and diversity of the Pinelands ecosystem, the U.S. Geological Survey, in cooperation with the New Jersey Pinelands Commission, began a multi-phase hydrologic investigation in 2004 to characterize the hydrologic system supporting the aquatic and wetland communities of the New Jersey Pinelands area (Pinelands). The current investigation of the hydrology of three representative drainage basins in the Pinelands (Albertson Brook, McDonalds Branch, and Morses Mill Stream basins) included a compilation of existing data; collection of water-level and streamflow data; mapping of the water-table altitude and depth to the water table; and analyses of water-level and streamflow variability, subsurface gradients and flow patterns, and water budgets.

During 2004–06, a hydrologic database of existing and new data from wells and stream sites was compiled. Methods of data collection and analysis were defined, and data networks consisting of 471 wells and 106 surface-water sites were established. Hydrographs from 26 water-level-monitoring wells and four streamflow-gaging stations were analyzed to show the response of water levels and streamflow to precipitation and recharge with respect to the locations of these wells and streams within each basin. Water-level hydrographs show varying hydraulic gradients and flow potentials, and indicate that responses to recharge events vary with well depth and proximity to recharge and discharge areas.

Results of the investigation provide a detailed characterization of hydrologic conditions, processes, and relations among the components of the hydrologic cycle in the Pinelands. In the Pinelands, recharge replenishes the aquifer system and contributes to groundwater flow, most of which moves to wetlands and surface water where natural discharge occurs. Some groundwater flow is intercepted by supply wells. Recharge rates generally are highest during the non-growing season and are inversely related to evapotranspiration. Analysis of subsurface hydraulic gradients, water-table fluctuations, and streamflow variability indicates a strong linkage between groundwater and wetlands, lakes and streams. Gradient analysis indicates that most wetlands are in groundwater discharge areas, but some wetlands are in groundwater recharge areas. The depth to the water table ranges from zero at surface-water features up to about 10 meters in topographically high areas. Depth to water fluctuates seasonally, and the magnitude of these fluctuations generally increases with distance from surface water. Variations in the permeability of the soils and sediments of the aquifer system strongly affect patterns of water movement through the subsurface and the interaction of groundwater with wetlands, lakes and streams.

Mean annual streamflow during 2004–06 ranged from 83 to 106 percent of the long-term mean annual discharge, indicating that the data-collection period can be considered representative of average conditions. Measurements of groundwater levels, stream stage, and stream discharge and locations of start-of-flow are illustrated in basin-wide maps of water-table altitude, depth to the water table, and stream base flow during the period.

Water-level data collected along 15 hydrologic transects that span the range of environments from uplands through wetlands to surface water were used to determine hydraulic gradients, potential flow directions, and areas of recharge and discharge. These data provide information about the localized interactions of groundwater with wetlands and surface water. Wetlands were categorized with respect to whether they lie in groundwater recharge or groundwater discharge areas. Recharge-area wetlands and nearby surface water are supported by local precipitation and groundwater that moves along short flow paths; therefore, they are sensitive to drought conditions. Discharge-area wetlands and surface water also receive local groundwater but also benefit from more persistent regional groundwater flow, which continues to support the wetlands and surface water during dry periods when the more localized, shallow groundwater flow is reduced or has ceased.

Geologic characteristics of sediments overlying and within the unconfined aquifer can limit infiltration and recharge rates and affect the flow of groundwater that supports wetland water levels and streamflow. Low-permeability

sediments, common in the Kirkwood-Cohansey aquifer system, were identified as the cause of localized mounding of the water table and, therefore, support local wetlands and streamflow. The extent and effectiveness of the low-permeability layers varied considerably in the areas studied; this variability may directly affect interactions among the groundwater, wetlands, and surface water.

Water budgets, a means of hydrologic accounting in which system inflows are balanced by outflows and changes in storage, were developed to quantify major components of the hydrologic cycle in the three basins. Water-budget components were evaluated monthly to examine seasonal variations in, and relations among, them. Monthly recharge to the aquifer system, estimated as a residual, was as much as 20 centimeters during "wet" months when the sum of inflows (primarily precipitation) exceeded the sum of outflows plus the net change in storage. Recharge was occasionally negative (as small as -5 centimeters) during "dry" months when the sum of outflows (primarily evapotranspiration) exceeded the sum of inflows plus the net change in storage. The water-budget analysis shows that the hydrologic system supporting the Pinelands wetland and aquatic habitats is dynamic and is potentially sensitive to variations in components of the hydrologic budget.

# Introduction

The New Jersey Pinelands area (Pinelands) (fig.1) is a 3,797-km$^2$ portion of the 4,450-km$^2$ Pinelands National Reserve in southern New Jersey that overlies the Kirkwood-Cohansey aquifer system in the Atlantic Coastal Plain (New Jersey Pinelands Commission, 1981). This ecologically diverse area supports a variety of habitats and is home to many threatened and endangered species. The landscape is a patchwork of forested uplands, agricultural areas, and developed residential and commercial land, in addition to forested lowlands that encompass areas of wetlands and surface water. In the Pinelands, wetlands have been delineated by several factors including the seasonal depth to the water table (a critical determinant of viable wetland habitat), soil conditions, and the presence of plants recognized as wetland species. In this report, the term "wetlands" includes (1) those areas delineated as such by the New Jersey Department of Environmental Protection (NJDEP, 1999) and (2) areas of standing water, herein called swamps.

Demand for water from the Kirkwood-Cohansey aquifer system is increasing in response to growth within the Pinelands and nearby areas. New Jersey Public Law 2001, chapter 165, directs the Pinelands Commission and named cooperating partners to "assess and prepare a report on the key hydrologic and ecological information necessary to determine how the current and future water supply needs within the Pinelands area may be met while protecting the Kirkwood-Cohansey aquifer system and while avoiding any adverse ecological impact on the Pinelands area." The relation between key hydrologic and ecological attributes, therefore, needed to be characterized to (1) assess the effects of groundwater diversions from the Kirkwood-Cohansey aquifer system on streamflow and wetland water levels within the Pinelands and (2) determine the potential ecological effects of altered hydrology on aquatic and wetland communities. To help address this need, the U.S. Geological Survey (USGS), in cooperation with the Pinelands Commission, began a multi-phase hydrologic investigation in 2004 to characterize the hydrologic system supporting the Pinelands aquatic and wetland communities. This investigation is part of a multidisciplinary study referred to as "the Kirkwood-Cohansey Project" (New Jersey Pinelands Commission, 2003).

Three Pinelands drainage basins—the Albertson Brook, McDonalds Branch, and Morses Mill Stream basins—were selected for a detailed hydrologic assessment to provide the information needed to develop groundwater flow models that can be used to predict hydrologic responses to increased groundwater withdrawals. The first part of the hydrologic assessment was a comprehensive hydrogeologic investigation of each basin-oriented study area to characterize its hydrogeologic framework and prepare a hydrostratigraphic model of each study area (Walker and others, 2008). The second part of the assessment, which is the subject of this report, was an evaluation and quantification of the groundwater and surface-water hydrologic processes in, and characteristics of, the three basins. This evaluation included water-table mapping and gradient analyses, streamflow measurements, development of water budgets, and characterization of wetland/groundwater/surface-water interactions under unstressed conditions for each basin. The approach included (1) compiling available hydrologic data; (2) collecting additional hydrologic data needed to improve the conceptual understanding of the hydrologic system supporting aquatic and wetland habitat; (3) characterizing the functioning of the hydrologic system within the physical framework of the Kirkwood-Cohansey aquifer system, including its connection to the wetlands and surface-water bodies; and (4) estimating the values of the water-budget components required to develop groundwater-flow models that can be used to predict hydrologic responses to withdrawal stresses.

## Purpose and Scope

This report characterizes the function of the hydrologic system in supporting wetlands and streamflow within each of the three study areas, utilizing previously available and new information to identify and document hydrogeologic characteristics that control groundwater/surface-water interactions. The methods used to establish data-collection sites, collect and analyze data from these sites, prepare maps of and sections through wetlands, and prepare monthly water budgets are described.

The methods of data collection included compiling existing hydrologic information, installing 122 wells and shallow piezometers, equipping 26 wells for continuous monitoring,

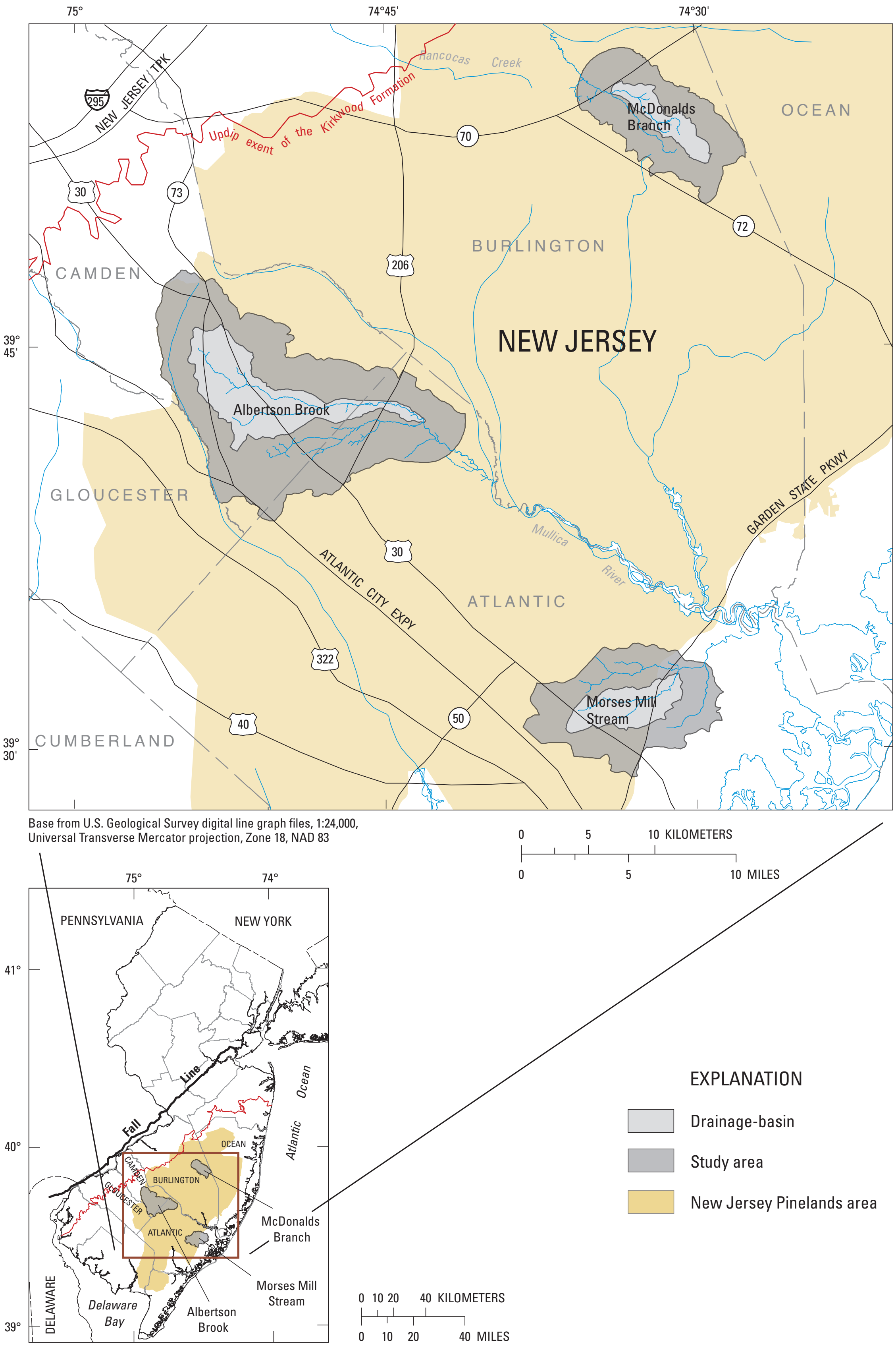



**Figure 1.** Location of the Pinelands study areas, Atlantic, Burlington, and Camden Counties, New Jersey.

installing 3 streamflow-gaging stations and installing 15 stream staff gages. Data collection also included continuous monitoring of groundwater levels, stream stage, and periodic measurements of discharge to maintain up-to-date rating curves for the streamflow-gaging stations. The report also describes the methods used to make two synoptic groundwater-level, stream-stage, and streamflow measurements at numerous sites, one in spring and one in late summer 2005, using a network of new and existing sites, including 471 wells and 106 surface-water sites.

The hydrologic characteristics that control the natural interactions of groundwater with the overlying wetlands and surface-water bodies are described for each basin. Hydrographs of groundwater levels and streamflow are used to illustrate responses to precipitation events and provide insights about recharge, potential groundwater-flow directions, and vertical and horizontal hydraulic gradients in the aquifer system in upland areas and near wetlands and streams. Maps of the water table during spring and late summer 2005 are used to illustrate potential groundwater-flow directions during these two periods. Maps showing depth to the water table, a critical determinant of a viable wetland habitat, are presented for spring 2005, a period considered to represent average wetland water-table conditions in the three basins. Site-specific water-level and hydraulic-gradient data for 15 hydrologic transects are used to examine and describe the hydrologic characteristics controlling groundwater flow and discharge to wetlands and streams. In addition, maps showing the distribution of stream-discharge measurements that illustrate the intermittent and perennial stream reaches as defined during the two synoptic measurements in 2005 are presented for each study area.

Monthly water budgets are developed for each study area from values of precipitation, evapotranspiration, groundwater and surface-water withdrawals, and stream discharge. These water budgets provide information needed to develop and calibrate groundwater-flow models for each of the study areas.

## Description of Study Areas

The study areas include three drainage basins—Albertson Brook, McDonalds Branch, and Morses Mill Stream (fig. 1)—that were selected from 39 candidate basins for the coordinated study of hydrology and ecology because they represent a range of typical hydrologic, geologic, and ecological conditions and landscape characteristics common to the Pinelands. Key hydrologic criteria for selection included aquifer thickness, drainage area, stream length, drainage density, accessibility for field work, past and current hydrologic monitoring and modeling, and current and potential future groundwater withdrawals from the Kirkwood-Cohansey aquifer system. Major landscape characteristics such as land use, soil type, and landscape cover also were considered.
For the purpose of this report, each study area consists of the drainage basin surrounded by a buffer area containing portions of the adjacent drainage basins. The study-area boundary is generally defined by the most distant basin divides of the adjacent drainage basins or some other hydrologic boundary in the adjacent drainage basin, such as a perennial stream. Using the larger area ensured that the hydrologic data set was sufficient to represent each study area such that conditions at and beyond the subject basin boundaries could be understood. In particular, the study areas may include areas where substantial groundwater withdrawals are made just outside the basin boundary, locations where groundwater and surface-water divides do not coincide, where groundwater may be leaving or entering the basin. Wetlands delineated by the NJDEP indicate areas of favorable wetland habitat as defined by soils, wetland species, and seasonal water levels. Wetlands in the Pinelands typically are in lowland areas and represent a transition between uplands and surface water. In this report, lowland environments that are temporarily or permanently inundated with shallow standing water either seasonally or historically are referred to as swamps that lie within wetlands.

The Albertson Brook study area totals 219.4 km$^2$ and consists of the Albertson Brook basin (fig. 2), which includes all of the Pump Branch and Blue Anchor Brook drainage basins and Albertson Brook; the combined area is 52.27 km$^2$, and the surrounding buffer area is 167.13 km$^2$. The Albertson Brook study area lies predominantly in Winslow Township, in Camden County, New Jersey. The easternmost part of the study area lies in the Town of Hammonton, Atlantic County, and is bordered to the south by Gloucester County and to the north by Burlington County. Portions of the Albertson Brook study area are within State Forest land in Atlantic and Camden Counties, New Jersey. The dominant forest cover in the uplands consists of mixed pine and oak forests. In the lowlands, pitch pine, hardwoods, shrubs, and white cedar are common. Agricultural land is common throughout the basin but is nearly continuous south of Albertson Brook. Residential development is most dense in the upper part of the basin in Winslow Township and along the highway corridors with only lightly developed residential areas in the lower part of the basin, which is largely agricultural or part of the State Forest.

The McDonalds Branch study area (fig. 3) occupies 72.73 km$^2$, including the buffer area surrounding the McDonalds Branch basin. The study area is located principally on State Forest land in Burlington County, New Jersey, and therefore is only minimally developed. McDonalds Branch basin (fig. 3) covers the upper 14.3 km$^2$ of the upper Rancocas Creek basin. The McDonalds Branch basin is a predominantly forested watershed, containing a mix of pine and oak forests, pitch pine lowland, and hardwood and cedar swamps (Johnsson and Barringer, 1993). In the downstream part of the basin, the McDonalds Branch flows through a small commercial cranberry bog before reaching a recreational lake and dam in a lightly developed residential area.

The Morses Mill Stream study area (including the buffer area) occupies 91.38 km$^2$ (fig. 4) surrounding the relatively small (21.63 km$^2$) segment of watershed referred to herein as the Morses Mill Stream basin, which for this study excludes the lower reaches of the Morses Mill Stream drainage area. The study area lies in Atlantic County, and most of the Morses

Mill Stream basin is in Galloway Township. Part of Egg Harbor, Hamilton, and Port Republic Townships, along with Richard Stockton College, are all within the study-area boundary. The eastern part of the study area, including both the buffer area and the basin, is outside the New Jersey Pinelands Area boundary.

Developed and agricultural land is prominent in the Albertson Brook and Morses Mill Stream study areas, whereas the McDonalds Branch study area is largely undeveloped. Information on water use in the three study areas was obtained from the USGS Site-Specific Water Use Data System (SWUDS) database. SWUDS contains water-use data from wells with capacities that exceed 378.5 $m^3/d$ that are reported to the New Jersey Bureau of Water Allocation. Excluding domestic and other low-capacity wells that may exist, the number of wells that extract water from the Kirkwood-Cohansey aquifer system within each study area are listed below by water use:

- Albertson Brook study area
    - 12 commercial and industrial wells
    - 31 public-supply and institutional wells
    - 169 irrigation wells
- Morses Mill Stream study area
    - 23 commercial and industrial wells
    - 19 public-supply and institutional wells
    - 37 irrigation wells
- McDonalds Branch study area
    - 2 public-supply wells
    - 2 irrigation wells

The three study areas are underlain by the sediments of the Kirkwood-Cohansey aquifer system in the central and southern Coastal Plain of New Jersey. The Kirkwood-Cohansey aquifer system is the uppermost hydrogeologic unit in a wedge-shaped sequence of Coastal Plain sediments that overlie pre-Cretaceous bedrock (Zapecza, 1989). The Coastal Plain sediments are composed of gravel, sand, silt, and clay layers that thicken and dip from the Coastal Plain's western limit at the Fall Line (fig. 1) to the southeast, reaching a maximum thickness of more than 1,980 m at Cape May, New Jersey (Gill and Farlekas, 1976). The sands and gravels that compose the Kirkwood-Cohansey aquifer system extend from the updip limit of the outcrop of the Kirkwood Formation (fig.1) to the Atlantic Coast. The aquifer system generally is considered to be an unconfined (water-table) aquifer, although extensive clay layers that can cause perched or semi-confined conditions do exist locally (Zapecza, 1989, p. B19).

The Kirkwood-Cohansey aquifer system is composed principally of sands, silts, and clays of the Miocene-age Kirkwood Formation and the overlying gravels, sands, and clays of the Cohansey Sand, also of Miocene age. Depending on location, the surficial sediments may include the Miocene-age Bridgeton Formation and (or) Pleistocene and Holocene sediments that may overlie the Cohansey Sand in the vicinity of the study areas. Where present, these surficial sediments are considered to be part of the Kirkwood-Cohansey aquifer system. The Cohansey Sand is typically coarser grained than the underlying Kirkwood Formation, which grades to clay near its base (Zapecza, 1989). Carter (1978) interpreted the Cohansey Sand as a sequence of regressive barrier and barrier-protected deposits ranging from surf zones to back bays and marshes, a depositional environment that contributes to the formation of discontinuous lenses of sand, silt, and clay.

In the updip part of the Kirkwood-Cohansey aquifer system, and beneath the Albertson Brook and McDonalds Branch study areas, the base of the aquifer system is a basal clay bed in the lower part of Kirkwood Formation, which is likely equivalent to the Alloway Clay Member of the Kirkwood Formation (Nemickas and Carswell, 1976) and is part of the extensive composite confining unit described by Zapecza (1989). About 13 km west of the Morses Mill Stream study area, this basal clay dips below a thick, diatomaceous clay bed, which forms an extensive confining unit in the upper part of the Kirkwood Formation (Zapecza, 1989, p. B18-B19). This clay does not crop out and locally separates the sediments of the Kirkwood Formation into upper and lower sands. From its updip extent, this diatomaceous clay dips and thickens toward the east to approximately 70 m in the vicinity of the Morses Mill Stream study area (Zapecza, 1989, pl. 22, 23), locally forming the basal clay confining layer of the Kirkwood-Cohansey aquifer system. In the vicinity of the Morses Mill Stream study area, the upper sands of the Kirkwood Formation remain hydraulically connected to the Cohansey Sand and also are considered part of the Kirkwood-Cohansey aquifer system. Sand units in the lower part of the Kirkwood Formation that lie beneath the diatomaceous clay locally are referred to as the Atlantic City 800-foot Sand (Zapezca, 1989). A detailed description of the hydrogeologic framework of each of the three study areas, including hydrogeologic sections and maps of structure tops and thicknesses of layers, can be found in Walker and others (2008).

## Previous Investigations

Rhodehamel (1970, 1973, 1979) describes the geology and hydrology of the Kirkwood and Cohansey Formations in the Pinelands in the vicinity of southern Burlington County and adjacent parts of Atlantic and Camden Counties. Rhodehamel describes the Cohansey Sand and upper part of the Kirkwood Formation as a single aquifer. Zapecza (1989) describes the Kirkwood-Cohansey aquifer system in the context of the entire New Jersey Coastal Plain as generally unconfined and locally semi-confined.

The soils of Burlington County are described by Markley (1971) and the geology and soils of the McDonalds Branch basin are summarized by Lord and others (1990) and Johnsson and Barringer (1993). Soils of the Albertson Brook study area are described by Markley (1965) in Camden County and by Johnson (1978) in Atlantic County, where both the downstream part of the Albertson Brook study area and the entire Morses Mill Stream study are located.

The hydrology and water resources of the unconfined aquifer system in and adjacent to the study areas are documented in a series of basin area reports for the Rancocas Creek (Watt and others, 2003) in Burlington County and the Mullica River (Johnson and Watt, 1996) and Great Egg Harbor River basins in Atlantic, Burlington, and Camden Counties (Watt and Johnson, 1992). The status of the landscape and selected aquatic and wetland resources in the Mullica and Rancocas River basins are described by Zampella and others (2001a and 2003, respectively).

Modica (1998) describes the head relations and hydraulic gradients in the McDonalds Branch basin and an adjacent basin, Mount Misery Brook. Modica and others (1997) simulated groundwater flow in a generic stream-aquifer system similar to those in the three study areas to characterize the relation of shallow substream flow systems and their relation to deeper groundwater flow. Sloto and Buxton (2005) developed water budgets for five tributary basins to the Delaware River Basin, including a water budget for the Greenwood Branch drainage basin of the Rancocas Creek, which includes the McDonalds Branch. Water levels at continuous-record streamflow-gaging stations and wells are published annually by the USGS and are stored in its National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nj/nwis*).

Many ecological studies have related Pinelands vegetation patterns and specific wetland, wetland-transitional, and aquatic communities to hydrologic regimes and gradients. For example, Zampella and others (1992) related water-table depth and other factors to pitch pine lowland community gradients. Recent studies that were part of the Kirkwood-Cohansey Project examined the potential effects of hydrologic change on forested wetlands (Laidig and others, 2010), intermittent-pond vegetation (Laidig, 2010), aquatic habitats (Kennen and Riskin, 2010; Procopio, 2010), and pond-breeding frogs (Bunnell and Ciraolo, 2010). Other relevant ecological studies are highlighted in reviews by McCormick (1979) and Zampella and others (2008).

## Well-Numbering System

Records of selected wells included in this study (table 1 at end of report) are in the USGS NWIS database (*http://waterdata.usgs.gov/nj/nwis*). Sites in the NWIS database are identified in this report by a site identifier (USGS well number, or UID (unique identifier)) consisting of a two-digit county code number followed by a four-digit sequence number. Some well sites listed in table 1 (at end of report) are not in NWIS and therefore do not have a UID as a site identifier. These wells are identified by their local identifier assigned by the New Jersey Pinelands Commission, which installed, maintained, and is the source of all data for those wells. The county code numbers used in this report are 01 for Atlantic County, 05 for Burlington County, and 07 for Camden County.

Records of selected surface-water sites included in this study (table 2 at end of report) are identified by site codes that use one of four different naming conventions. Most common is the stream-site station number, which consists of an 8- to 10-digit number beginning with 01. Other stream-site site codes not assigned a station number consist of 15-digit numerical codes that indicate the site's latitude and longitude expressed in degrees, minutes, and seconds. Some sites established by previous investigators (Johnson and Watt, 1996; Watt and others, 2003) are referred to in this study as "stream points," and are identified by a code beginning with "STM" followed by a sequence number (for example, STM60). The fourth type of site code listed in table 2 represents stream-point sites established during this study. This site code is composed of a two-letter study-area code followed by "STM" and a sequence number. Study-area codes used in this study are AB for Albertson Brook, MB for McDonalds Branch, and MM for Morses Mill Stream. Using these conventions, a new stream point in the Albertson Brook study area would have a site code such as ABSTM5.

# Methods of Investigation

This section describes the methods used to establish data-network sites and to obtain and analyze data to describe the hydrologic characteristics and groundwater/surface-water interactions that affect wetland and stream habitat. The data networks discussed in this section are based on the conceptual data-network model described in the Kirkwood-Cohansey Project Work Plan (New Jersey Pinelands Commission, 2003). These networks include continuous-record and periodically measured groundwater and surface-water sites.

Data-collection methods used for all groundwater-level, stream-stage, and streamflow measurements made during the study also are presented in this section. These measurements included those manual measurements required to calibrate continuous-record groundwater-level and streamflow data, in addition to the manual water-level measurements made at all sites included in the two synoptic measurements in 2005. Synoptic measurements were made at both continuously and periodically measured sites, including stream sites and the extensive network of wells described previously. Methods used to examine the results of the synoptic measurements are described, including determining the relation of water levels and hydraulic gradients as indicators of potential groundwater flow both locally, such as along 15 hydrologic transects, and sub-regionally, through study-area-wide mapping of the water table. Methods used to prepare maps showing the altitude of the water table and to draw contours representing the water table are discussed. This section also describes the approach used to prepare detailed depth-to-water maps, and documents the approach used to prepare a monthly water budget for each study area.

All altitude data presented in this report are referenced to the North American Vertical Datum of 1988 (NAVD 88). The methods of determining altitude and the accuracy of these data are listed in tables 1 and 2. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

## Data Network

The data network includes all groundwater and surface-water sites used to analyze the hydrology of the three study areas. Among the wells measured are those installed and monitored by the New Jersey Pinelands Commission.

### Wells and Well-Installation Methods

The groundwater data network included a total of 471 wells, 139 of which are considered network sites that include the following well types (figs. 2–4, table 1 at end of report):

- 18 continuous-record basin-monitoring wells
- 8 continuous-record wetland-monitoring wells
- 15 upland observation wells
- 98 hydrologic-transect wells (excludes 5 of the wetland-monitoring wells listed above)
- 332 other existing and newly installed wells also used for synoptic measurements

Eighteen basin-monitoring wells (16 newly installed and 2 existing) were instrumented for continuous monitoring of water levels in the three study areas. The basin-monitoring wells were established in each of the three study areas, in two clusters of three wells each, with one well cluster located in the upper part of a basin and the other cluster in the lower part (figs. 2–4). Wells in each cluster were screened in major water-bearing units near the top, middle, and bottom of the Kirkwood-Cohansey aquifer system (Walker and others, 2008).

A total of eight wetland-monitoring wells also were installed at selected locations (figs. 2–4) and were instrumented for continuous monitoring of the water-table altitude. Six of these wells were installed; two in each of the three basins, with one of those wells in a cedar-swamp wetland and the other near the upland limits of the wetlands. The other two wetland-monitoring wells were installed in the McDonalds Branch basin for specific purposes; one was collocated with another wetland well to compare water levels and examine vertical hydraulic gradients across a thin low-permeability zone, and the second was used in the hydrologic transect MBHT-5 (fig. 3) so that water-level fluctuations could be compared with continuous records of evapotranspiration (*ET*) collected at the same location. (The hydrologic transects are described farther on in this report.)

Fifteen upland-well sites also were used to collect water-level data in the three study areas during the two synoptic measurements. At three sites, one in the Albertson Brook basin and two in the Morses Mill Stream basin, existing wells met the criteria for water-table wells in the uplands near the basin divides. Twelve additional upland wells were installed to fill data gaps in the existing well network. The locations of the upland wells are shown in figures 2–4, associated site information is listed in table 1 (at end of report).

Fifteen hydrologic transects (5 per study area), composed of 103 wells (figs. 2–4), were established to examine potential groundwater flow and discharge resulting from groundwater hydraulic gradients and their interaction with wetlands and streams. Of the 103 wells, 12 were installed prior to this study (see Lord and others, 1990), and 91, including 5 of the 8 wetland-monitoring wells listed above, were installed during this study. Each hydrologic transect was composed of at least six wells arranged in three clusters of at least two wells each. Typically, transect wells were distributed along generalized paths of shallow groundwater flow, which are approximately normal to the streams. The well locations along the generalized paths of flow describe the hydrologic transects that extend from near the upland limit of the wetlands to the stream where the staff gages were installed. Two of the three well clusters were located at opposite ends of each transect, and the third well cluster was positioned between them, generally near the middle of each transect, where topography sloped uniformly, or near the wetland edges or at significant breaks in slope, such as where seepage may occur during seasonal high groundwater levels.

Precise vertical control was established by differential leveling methods for each hydrologic transect, such that the small differences in water levels between the well locations and the stream could be compared. The precise differential leveling survey resulted in a relative altitude accuracy for wells and staff gages in a given transect that ranged from 0.003 to 0.03 m. Because the datum, altitude accuracy, and method used to obtain the source data were used as the origin for each leveling survey, the site altitude datum, accuracy, and method for all wells in a given transect listed in table 1 (at end of report) reflect those of the origin, even though the well-to-well accuracy was more precise.

The 332-well data network (table 1 at end of report) included wells installed for this study, additional wells selected from the USGS National Water Data Information System (NWIS) database (*http://waterdata.usgs.gov/nj/nwis*), other shallow water-table wells installed and monitored by the N.J. Pinelands Commission, and additional wells that were identified prior to the synoptic measurements to fill remaining data gaps. Data for these additional wells were entered into the NWIS database. A total of 122 wells were installed in the three study areas by using one of the following three methods. Wells exceeding 3 m in depth were installed by or under the direction of a New Jersey licensed well driller, using either the standard hydraulic rotary or the Geoprobe® direct push method. Rotary-drilled wells were constructed of 50.8-mm-diameter

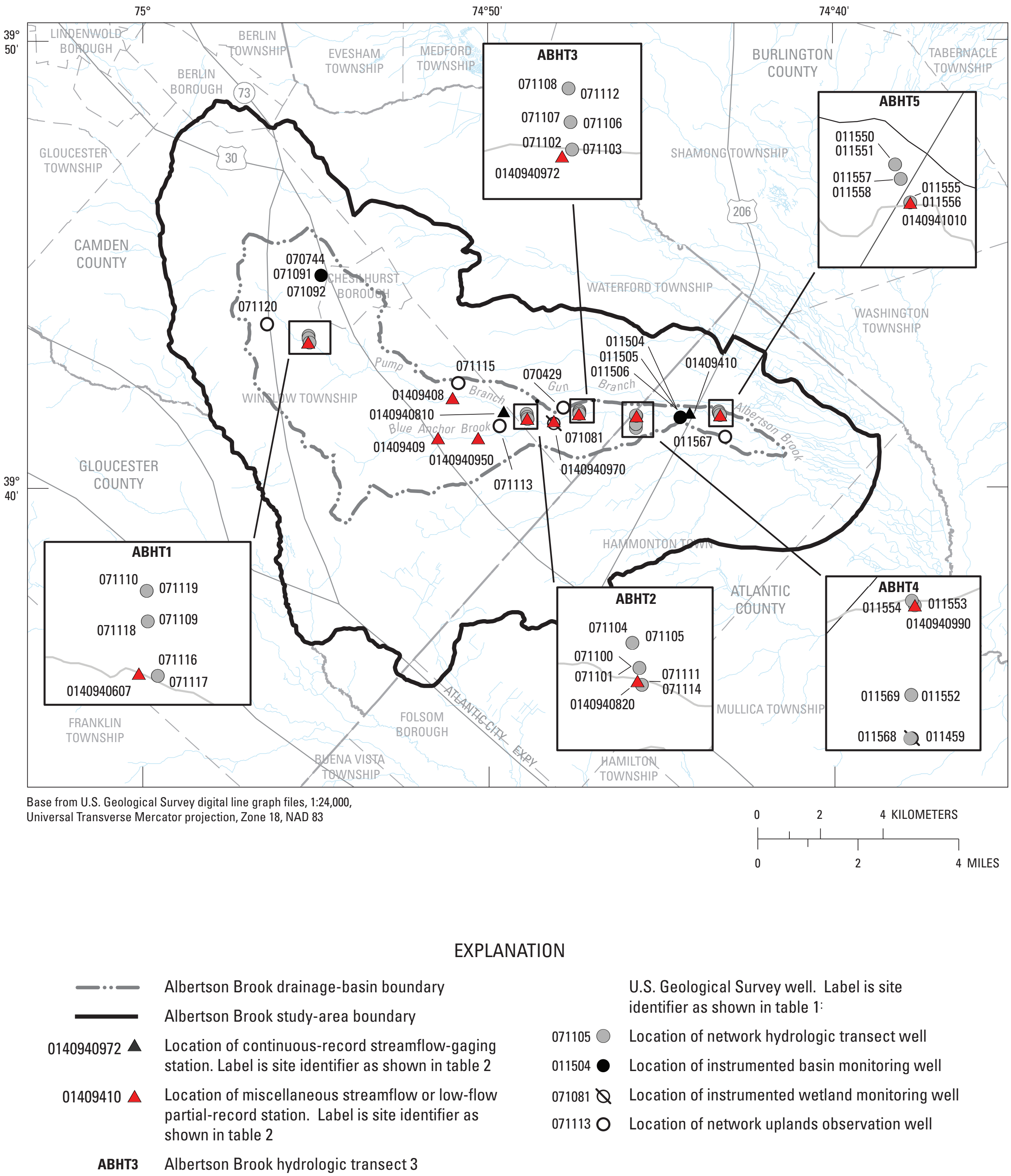



**Figure 2.** Location of selected groundwater and surface-water network sites and hydrologic transects, Albertson Brook study area, New Jersey Pinelands.

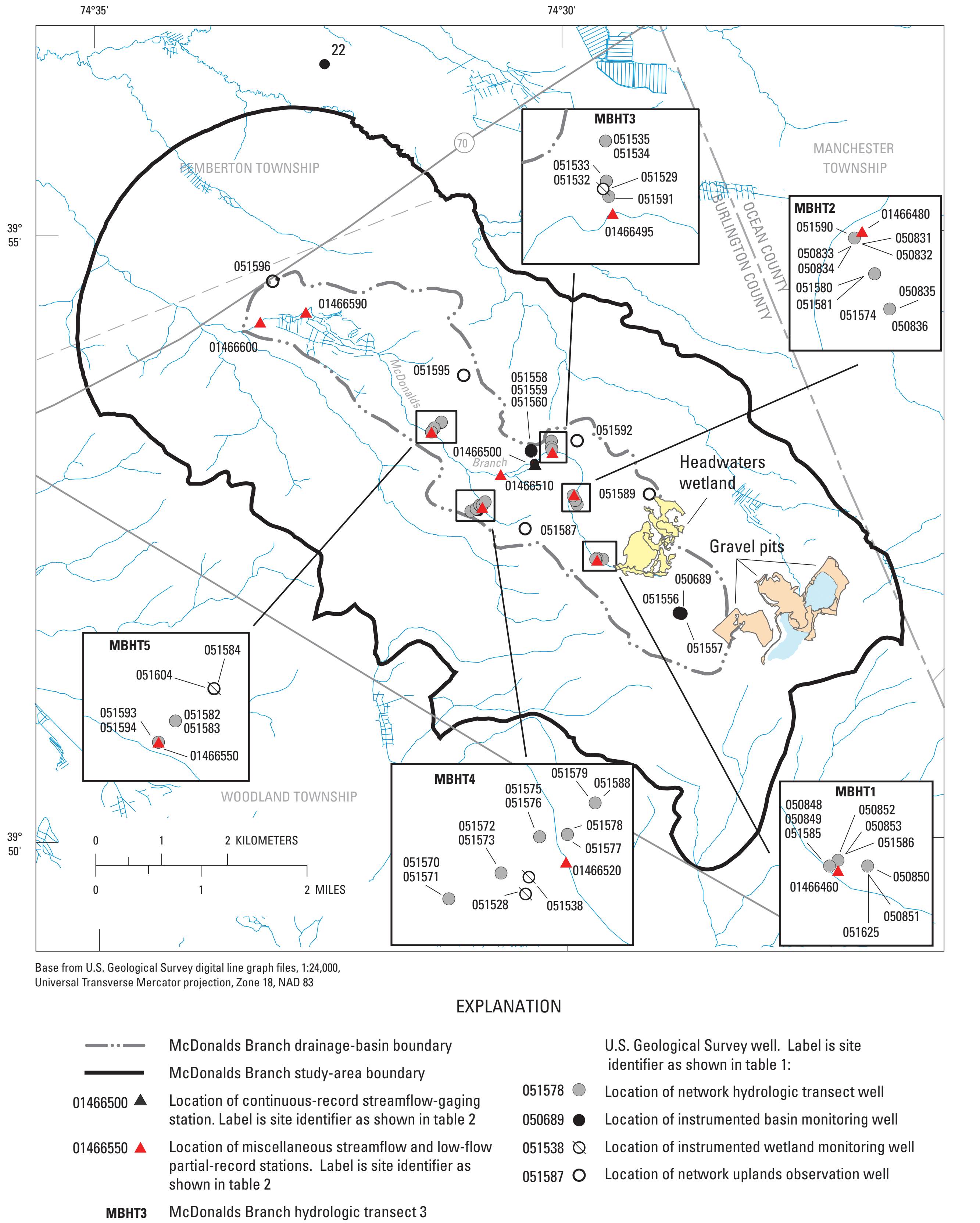



**Figure 3.** Location of selected groundwater and surface-water network sites and hydrologic transects, McDonalds Branch study area, New Jersey Pinelands.

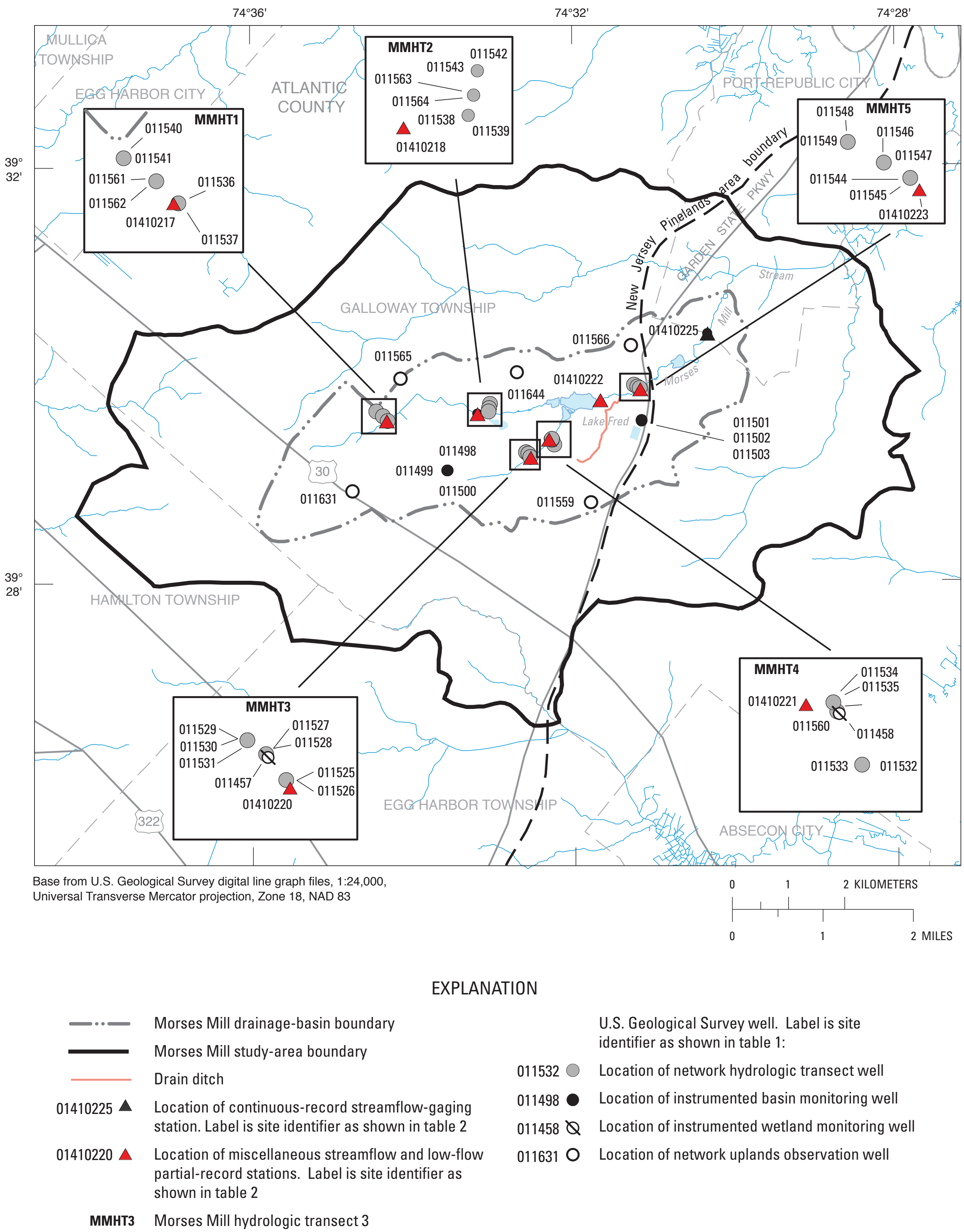



**Figure 4.** Location of selected groundwater and surface-water network sites and hydrologic transects, Morses Mill Stream study area, New Jersey Pinelands.

PVC casing with 3.048-m-long, 0.254-mm slotted well screen. Wells installed using the Geoprobe® method were constructed of 19-mm-diameter flush joint PVC casings with 3.048-m-long, 0.254-mm slotted well screen. All of these wells were finished at the surface with 101.6-mm-diameter protective casing with lockable cap.

Wells with depths of less than 3 m, including hydrologic-transect and wetland-monitoring wells, were driven by hand. Hydraulic-transect wells were constructed of 13-mm-diameter steel casing with 0.3-m-long slotted screen, driven to a depth of at least 0.3 m below the estimated annual minimum water level, and capped at the surface to deter tampering. Wetland-monitoring wells were constructed of 32-mm-diameter steel well casing with 0.3-m-long stainless steel 0.254-mm slotted well screen, driven to the required depth with a drive weight, and finished at the surface with a 76-mm-diameter steel casing with lockable cap to house the recording equipment.

Following installation, all wells were developed by using pumping and surging methods until a sustained sediment-free discharge was achieved to ensure that the well had a good hydraulic connection with the aquifer. Records of wells installed during this study are given in table 1 (at end of report).

### Surface-Water Sites

The surface-water data network includes 106 sites where stream discharge and (or) stage was measured. Data collected at these sites include one or more of the following types of data:

- 27 network surface-water sites
    - 4 continuous-record streamflow-gaging stations
    - 15 staff gages at hydrologic transects
    - 24 seepage sites where streamflow and stage measurements were made synoptically; included are 8 partial-record stations, the 4 streamflow-gaging stations, and 12 of the 15 hydrologic-transect staff gages
    - 79 miscellaneous surface-water sites, including partial-record stations where stage and discharge are measured periodically, staff-gage sites, and stream-point sites where surface-water level (stage) was measured during the synoptic measurements
    - in addition to the 106 established surface-water sites, 26 locations where start-of-flow of streams was observed during the synoptic measurements

The four continuous-record streamflow-gaging stations used in this study included an existing streamflow-gaging station in the McDonalds Branch basin, two streamflow-gaging stations installed in the Albertson Brook basin, and one streamflow-gage installed in the Morses Mill Stream basin. In the Albertson Brook basin, a streamflow-gaging station was installed on the Pump Branch near Elm, NJ (station 0140980810), about 1,200 m upstream from its confluence with Blue Anchor Brook. The combined flow of Pump Branch and Blue Anchor Brook forms Albertson Brook; however, streamflow from Blue Anchor Brook was not monitored. A second streamflow-gaging station, Albertson Brook near Hammonton, NJ (station 01409410), was installed on Albertson Brook near the downstream limit of the study area at Route 206 northeast of Hammonton. A third streamflow-gaging station was established on the lower reaches of the Morses Mill Stream at Port Republic, NJ (station 01410225). Stream-stage data were collected at these streamflow-gaging stations, and precipitation data were collected at Albertson Brook near Hammonton. Surface-water site information for the streamflow-gaging stations is given in table 2, (at end of report) and the locations are shown in figures 2 to 4.

Fifteen staff gages, 14 of which were installed for this study, were used to measure stream stage at each of the 15 hydrologic transects during the synoptic measurements. Several existing staff gages installed during previous investigations also were used to measure stream stage at selected surface-water sites. Some existing and newly established surface-water sites, referred to in this report as “stream points,” were used to measure stream stage during the synoptic measurements.

## Data Collection

Groundwater and surface-water data were collected during this study to characterize the hydrology of the Kirkwood-Cohansey aquifer system. More than 2 years of continuous groundwater-level, stream-stage, and streamflow data were collected. Continuous monitoring of groundwater levels began at six wetland-monitoring wells in April 2004. Two additional wetland-monitoring wells were added to the network in May and November 2004. By October 1, 2004, continuous groundwater-level data collection was begun in the 18 basin-monitoring wells, and data collection also was begun at the three new streamflow-gaging stations. Data collection continued through the 2-year period ending September 30, 2006. The existing streamflow gage in the McDonalds Branch basin continued to operate throughout the period of study. This station is maintained by the USGS, New Jersey Water Science Center (NJWSC), as part of the nationwide Hydrologic Benchmark Network and has been in continuous operation since October 1953.

In addition to the continuous monitoring, short-duration synoptic measurements were made in each study area during two periods, one in spring (April 13-May 13) and one in late summer (September 8–15) 2005. Each synoptic measurement involved manual measurements of groundwater levels, stream stage, and stream base-flow discharge, and a determination of start-of-flow locations in the upper reaches of each basin. All data are stored in the NWIS database (*http://waterdata.usgs.gov/nj/nwis*) and (or) at the USGS NJWSC in West Trenton, NJ.

## Groundwater Levels

Groundwater levels were measured manually using either the wetted steel-tape method or with an electric tape that sounds an alert when the probe contacts water. To ensure accuracy, water-level measurements were repeated until at least two measurements were reproducible within 6 mm. These measurements were referenced to a fixed measuring point of known altitude at a measured distance above or below land surface.

Silicon strain-gage pressure transducers with data loggers recorded water levels at hourly intervals in all basin- and wetland-monitoring wells for their respective periods of record. The pressure- transducer readings were calibrated using manual water-level measurements with a steel tape at the start of record, and the recording position was verified bi-monthly and again at the end of data collection. If these measurements revealed a drift in the recording position, corrections were applied to the record. All water levels from continuous recorders are stored in the NWIS database and are available at *http://waterdata.usgs.gov/nj/nwis*.

## Streamflow

Streamflow was measured during this study to determine discharge at the continuous-record streamflow-gaging stations and at various partial-record stations during the two synoptic measurements in 2005. Stream stage was recorded at streamflow-gaging stations every 15 minutes, and the stage values were converted to discharge on the basis of a graphical rating of stage and discharge developed for each station using manual stage and discharge measurements made at various stream stages. Throughout the station period of record, measurements of stage and discharge were made to verify the stage-discharge rating or to adjust published discharges for changes that could affect the established rating. All records for streamflow-gaging stations and partial-record-stations are stored in the NWIS database and are available at *http://waterdata.usgs.gov/nj/nwis*.

## Synoptic Measurements

In each basin, synoptic measurements of groundwater levels, stream stage, and stream discharge were made during two brief periods (several days) in spring and late summer 2005. Synoptic measurements were initiated in each study area after extended periods of little or no precipitation that resulted in stream base-flow conditions. Base flow in streams consists only of groundwater discharge and usually occurs about 5 to 7 days after precipitation events, once runoff has ceased and the normally unsaturated soils and sediments have drained. The synoptic measurement periods were planned following a thorough review of rainfall records, weather forecasts, and groundwater-level and streamflow hydrographs to determine the best time to make synoptic measurements that would coincide with surface-water base flow.

During the spring synoptic measurements, water-level and streamflow measurements were made at all network wells (figs. 2–4), including all newly selected pre-existing wells, and surface-water sites within each of the three study areas (tables 1 and 2). During the late summer synoptic measurements, water-level measurements were limited to fewer wells, including network sites and other selected sites within and near the drainage-basin boundaries. Each of the two synoptic measurements was coordinated with and included the monthly water-level measurements in shallow wells conducted by the New Jersey Pinelands Commission. The measured sites also included the wells and stream sites that make up the 15 hydrologic transects.

The altitudes of groundwater levels were used to describe the slope of the water table along the hydrologic transects. Vertical hydraulic gradients also were determined as an indicator of the potential direction and magnitude of groundwater flow supporting wetlands and streams. These assessments of groundwater flow at the hydrologic transects are based solely on the observed hydraulic gradient between measured water levels. They do not account for the limits on groundwater flow that might be caused by the hydraulic conductivity (K) of geologic sediments along a given flow path because K was not determined. Therefore, as described in this report the hydraulic gradients indicate a potential for groundwater flow. Vertical hydraulic gradients were determined by measuring differences in water levels between wells or between wells and surface water and then dividing those differences by the minimum distance separating them hydraulically, such as that between the well-screen intervals, or between a piezometer screen and the streambed. The small differences in water levels common in the water table typically were determined by a direct differential measurement using a manometer to avoid the limitations of measuring with a wetted-steel tape. At sites where a manometer differential measurement was not possible or at some locations where water-level differences were large, wetted-tape measurements were either necessary or appropriate for determining water-level differences. In this study, upward hydraulic gradients were considered positive, and downward hydraulic gradients were considered negative. The measured groundwater levels and hydraulic gradients for each of the 15 hydrologic transects are compared graphically for each study area in the “Hydrologic Assessment” section of this report.

During each synoptic measurement, surface-water stage and discharge were measured at streamflow-gaging stations and at partial-record stations, such as staff gages and stream points. At a few locations a dam or culvert maintains the stage of a lake or pond well above the stream stage downstream from a dam or culvert, creating substantial, but localized, hydraulic gradients in the local groundwater. To represent these conditions on the water-table maps, some surface-water levels were measured both in the lake or pond above the dam or culvert and in the stream below; these measurements are identified in table 3 (at end of report).

Locations of start-of-flow in each stream and (or) its tributaries also were determined by locating the point farthest upstream at which surface-water flow could be identified, which included water flowing within the channel, near-stream groundwater seeps, or, in some cases, water pooled in swamps or in flat reaches of the stream channel that did not appear to be a result of accumulated runoff. Locations of all new measuring sites were determined with a global positioning system (GPS), and the location coordinates were used to determine the altitude of the land surface from the 10-m digital elevation model (DEM). The height of points used to measure depth to water level were referenced to the altitude of the local land surface by manual measurements of their distance above or below land surface.

## Water-Table Mapping

Maps of the water-table altitude were prepared for the spring and summer 2005 synoptic measurements, and depth-to-water-table maps were prepared for spring 2005. Both manual and computational methods were used to develop the water-table maps; these methods are described farther on. Water levels in the shallowest available wells, which could best represent the water table, and surface-water levels from streamflow-gaging stations, staff gages, partial-record stations, stream points, and, in the absence of those data, stream and topographic-contour intersections were used to construct the water-table maps.

The water-table-altitude maps were prepared manually, principally using the extensive well and surface-water data set that was compiled during the synoptic measurements (table 3 at end of report). The water-table-altitude contours were drawn using linear interpolation between data points. The contours were shaped to represent the measured water levels while conforming as much as possible to the slope of the local topography and the logical direction of groundwater flow. Water-table contours that cross surface-water bodies were positioned on the basis of the topographic altitude contours where those contours intersected the surface water. The position of the water-table contours at the basin boundaries was determined by considering nearby groundwater levels, land-surface altitudes, and surface-water altitudes.

The effectiveness of the water-table contouring methods relies on the density and location of data points, the accuracy of vertical control, and how closely the slope of the water table resembles the topography. The reliability of these factors also can be affected by the precision of physical measurements, the accuracy of available altitude data, and the effect of soils, aquifer sediments, and the regional groundwater-flow system on the altitude of the water table beneath any given topographic surface. Locally, water levels can be affected by variations in soil type, or aquifer sediment texture can contribute to transient water levels and long-term mounding of the water table above low-permeability sediments such as clays. Such variations in sediment texture also can alter the effects of hydraulic stresses induced by groundwater withdrawals.

The methods described above also were used to prepare water-table-altitude maps for summer 2005. These maps were based on a data set that included water levels at most of the sites in the basin that were measured during the spring synoptic measurement period and a limited number of those sites surrounding the basin that were measured in the spring. Once the initial contouring was completed, all of the altitude maps were reviewed for accuracy and any anomalies were resolved. The maps for spring and late summer 2005 were compared with each other and with the work of previous investigators (Watt and others, 2003; Johnson and Watt, 1996). The independent analyses of the water table conducted for this study were found to compare well with those of the previous investigations. Once the water-table-altitude contours were considered final, they were digitized and a uniform grid-based data set (DEM) was created.

Water-table depth below land surface is one of the critical determinants of the suitability of an area to support wetland habitat in the Pinelands (Roman and others, 1985; Ehrenfeld and Schneider, 1991; Zampella and others, 1992; Laidig and Zampella, 1999). Consequently, the characterization of this particular hydrologic variable was a focus of this assessment and of the Kirkwood-Cohansey Project (New Jersey Pinelands Commission, 2003). Of particular concern is the determination of the variability of mean water-table depth within the range of zero to 2 m below land surface, as areas with water-table depths in this range correspond to most areas that potentially support wetland habitats in the Pinelands. To meet project objectives, the accuracy of estimates of the depth to the water table within this range needed to be on the order of tenths of meters. Water levels measured during spring 2005 approximate a mean annual water-level condition, and therefore, measurements made during this time period were selected for use in preparing maps of the depth to the water table.

Spatial variability in depth to the water table is a function of both the water-table configuration and land-surface topography. Matson and Fels (1996) describe various deterministic, statistical, and landscape classification approaches to mapping water-table depth and the complexities involved in mapping the water table on a regional basis. Such regional analyses have been conducted to estimate the water-table depth over wide ranges of conditions and settings, such as those spanning the State of North Carolina (Fels and Matson, 1996). Because the water-table-mapping accuracy requirements for the present study exceed those of regional analyses, a combination of approaches was needed to provide greater accuracy within and near wetlands areas at the scale of the present study.

Maps of the water-table depth below land surface were prepared for the three study areas using a combination of methods. The methods used in and near wetland areas were different from those used in upland areas; however, because the methods used in and near wetlands did not provide realistic results in upland areas, a different method was needed in the upland areas. To support mapping at a higher accuracy, high-resolution LiDAR (LIght Detection And Ranging) land-surface altitude data were used for some areas (where available), whereas 10-m DEM data were used where LiDAR data were unavailable. LiDAR data were available for Camden and Burlington Counties but were not available for Atlantic County (The National Map Seamless Server, 2008). In upland areas 75 m or more from mapped wetlands, depth to water was mapped as the difference between the 10-m DEM and the water-table altitude grid. The accuracy of mapped water-table depth in these areas was limited by the accuracy of the 10-m DEM, which was one-half the contour interval of the source-map topographic contours. In the McDonalds Branch and Albertson Brook basins, the source-map contour interval is 10 ft; therefore, the DEM accuracy is +/- 5 ft, or 1.5 m. In the Morses Mill basin, the source-map contour interval is 5 ft; therefore, the DEM accuracy is +/- 2.5 ft, or 0.76 m.

A variety of approaches for determining depth to water in and near wetland areas was evaluated to determine which provided the most accurate results. The methods evaluated include

1. interpolation: This method involved interpolating between boundary values at mapped hydrologic features where depth to the water table was known or could be estimated. These features included wetlands, lakes, and streams. Depth to water at streams and lakes was assumed to be zero; depth to water at the limits of wetland areas was assumed to be equal to a specified, representative value based on water levels measured near boundaries of mapped wetlands;

2. topographic deviation: Local variations in depth to water can result from local variations in topography. A topographic deviation from a local mean altitude at a point can be characterized by determining the mean altitude within some fixed radius (in geographic information system (GIS) terminology, an “n-cell neighborhood”) of a given point and comparing this mean value with the altitude at that point. This method was used to adjust the values determined using method 1 by adding the topographic deviation from the mean altitude in n-cell neighborhoods; and

3. relative altitude: In this method, measured depth to water was related statistically to the altitude of the local receiving surface-water body. This method is similar to the statistical model approach described by Matson and Fels (1996) and that used by Sepulveda (2002) to estimate water-table altitude in Florida. Values of measured depth to water in shallow observation wells were related to values of relative altitude at the well (land-surface altitude relative to that of the local receiving-water body) to determine an equation using simple linear regression. The form of the resulting predictive equation is

$$Y = \beta_0 + \beta_1 X \quad , \tag{1}$$

where

$Y$ = water-table depth, in meters;

$\beta_0$ = regression line intercept, in meters;

$\beta_1$ = regression line slope, in meters; and

$X$ = relative land-surface altitude (altitude relative to that of the local receiving-water body), in meters.

The equation was used to predict water-table depth from the value of relative altitude. This method was evaluated using altitude values determined from 3-m LiDAR data and from 10-m DEM data.

These three approaches were tested in the McDonalds Branch basin and were assessed for accuracy by comparing estimated values of water-table depth with values of water-table depth observed in monitoring wells in wetlands and within 50 m of wetlands during spring 2005. Results of this evaluation demonstrated that the relative altitude approach (method 3) using LiDAR data provided the most accurate results. The mean absolute error of 41 values estimated using this approach in the McDonalds Branch basin was 0.18 m (18 cm). This approach was applied to areas in which gridded LiDAR data were readily available. These areas included the McDonalds Branch basin and the part of the Albertson Brook basin in Camden County. In areas where gridded LiDAR data were not readily available, the same method was applied using the 10-m DEM data. These areas included the Morses Mill Stream basin and the part of the Albertson Brook basin in Atlantic County.

Regression analysis of relative land-surface altitude and observed water-table depth below land surface indicated that the relation between these two variables differed among the study areas, resulting in a different predictive equation for each area. Land-surface altitude data sources, regression coefficients, and method error for each of the three basins are summarized in the table on page 15.

Values of mean absolute error provide an indication of the method’s predictive accuracy, and reflect the relative accuracy of the altitude data used. The highest mean absolute error is associated with the 10-m DEM data, and the lowest mean absolute error is associated with the 3-m LiDAR data. In general, the water table is nearly horizontal in wetland areas; therefore, when the equations above are examined, the regression-line intercept values are expected to be near zero, and correlation coefficients are expected to be reasonably high (greater than 0.6), as is the case in the McDonalds Branch study area, the Morses Mill Stream study area, and the Camden County part of the Albertson Brook study area. The relatively large regression-line intercept value (0.33) and the relatively small correlation coefficient (0.22) for the

| Study area | Land-surface altitude data source | Regression coefficient $\beta_1$ (dimensionless) | Regression coefficient $\beta_0$ (meters) | Number of observations | Mean absolute error (meters) | Correlation coefficient |
|---|---|---|---|---|---|---|
| McDonalds Branch | 3-meter LiDAR | 0.278 | 0.03 | 41 | 0.18 | 0.72 |
| Albertson Brook (Camden County) | 3-meter LiDAR | 0.262 | 0.08 | 13 | 0.12 | 0.71 |
| Albertson Brook (Atlantic County) | 10-meter DEM | 0.276 | 0.33 | 18 | 0.27 | 0.22 |
| Morses Mill Stream | 10-m DEM | 0.552 | 0.02 | 30 | 0.21 | 0.73 |

method using the 10-m DEM in the Atlantic County part of the Albertson Brook study area indicates that, in this case, the 10-m DEM values in the vicinity of streams are not well distinguished from those of the surrounding areas. Consequently, the accuracy of the method when used with 10-m DEM data is limited, especially in the Albertson Brook study area, where the DEM accuracy is relatively poor.

The relative-altitude method described above was applied in areas within mapped wetlands and areas within 50 m of mapped wetlands, using the respective altitude data described above. Depth to the water table was estimated in areas from 50 to 75 m from mapped wetlands by interpolating between values estimated at these two boundaries.

## Water Budgets

A water budget is an equation that represents the relation among the components of the hydrologic cycle in a given area (the "budget area") and accounts for water gains to and losses from the area for a given time period. A water budget can be used to determine groundwater recharge, which is difficult to measure directly, by summing the values of the components of the equation that can be measured directly or estimated accurately. Variables in the budget represent components of the hydrologic cycle; in the equation, inflows are balanced by outflows and changes in storage. Human activities that affect the natural system, such as groundwater withdrawals and artificial discharge, also are included in the budget. Rhodehamel (1970, 1979) developed a water budget for the New Jersey Pinelands that included Brendan T. Byrne State Forest (Lebanon State Forest) and Wharton State Forest (Wharton Tract). Annual water budgets were developed as part of previous USGS studies that include all of the three basins, including the Mullica River basin (Johnson and Watt, 1996) and the Rancocas Creek and adjacent basins (Watt and others, 2003).

Monthly water budgets were developed for each of the three drainage basins (fig. 5) for the period October 2004 through September 2006. (The drainage basins should not be confused with the larger study areas.) Two equations were used to evaluate the water budget: a land-surface-based equation that describes gains and losses to and from the land surface, and a groundwater-based equation that describes gains and losses to and from the underlying Kirkwood-Cohansey aquifer system. Land-surface and groundwater equations were used to provide independent estimates of recharge and to provide a basis for comparing the relative importance of the various budget components in the overall budget. Recharge was determined as a residual in each of the equations, and monthly values were compared. In theory, the value of recharge determined by using the land-surface equation should be equal to the value of recharge determined by using the groundwater equation.

The equation used to calculate the land-surface-based water budget is

$$P + D_{as} \pm \Delta S_{sw} \pm \Delta S_{sm} = Q_{dr} + ET + W_s + R_s \ , \qquad (2)$$

where

$P$ = precipitation,
$D_{as}$ = artificial discharge to surface-water bodies,
$\Delta S_{sw}$ = change in surface-water storage,
$\Delta S_{sm}$ = change in soil-moisture storage,
$Q_{dr}$ = direct runoff,
$ET$ = evapotranspiration,
$W_s$ = surface-water withdrawals/diversions, and
$R_s$ = recharge to the aquifer system.

The equation used to calculate the groundwater-based water budget is

$$R_g + D_{ag} \pm R_i = Q_b + W_g \pm L \pm \Delta S_{gw} \ , \qquad (3)$$

where

$R_g$ = recharge to the aquifer system,
$D_{ag}$ = artificial discharge to the aquifer system,
$R_i$ = groundwater inflow to/outflow from adjacent basins,
$Q_b$ = base flow,

$W_g$ = groundwater withdrawals,
$L$ = leakage to confined aquifers, and
$\Delta S_{gw}$ = change in groundwater storage.

The budget area includes the extent of the surface-water drainage basin of each of the three basins and the thickness of the Kirkwood-Cohansey aquifer system from land surface to the underlying confining unit. Most of the water-budget terms were estimated using robust data collected in and near the study areas, or in the case of leakage to confined aquifers ($L$), a calibrated regional model (Martin, 1998; Voronin, 2004). Exceptions were changes in soil-moisture storage ($\Delta S_{sm}$), changes in groundwater storage ($\Delta S_{gw}$), and groundwater inflow to/outflow from adjacent basins ($R_i$), for which less robust indicators were used. Initial estimates of these terms were adjusted using an optimization routine to improve the agreement between the recharge estimates determined with the two equations. The optimization routine was formulated using the Microsoft Office Excel Solver® tool.

## Streamflow ($Q_{dr}$ and $Q_b$)

Streamflow data for four continuous-record streamflow-gaging stations in the basins were compiled as part of this study (fig. 5). Records of daily mean streamflow for the 2005–06 water years at three of the four stations (listed in the table below) were retrieved from the USGS NWIS database. These data were then used to estimate streamflow at the farthest downstream point in each basin, where little or no information on streamflow is available. Streamflow, base flow, and direct runoff at this point in each basin were estimated by using one or a combination of the methods described below.

Continuous-record streamflow-gaging stations used to calculate base flow and direct runoff.

| Station number used | Station name | Drainage area (square kilometers) | Method(s) used |
|---|---|---|---|
| 01409410 | Albertson Brook near Hammonton, NJ | 50.00 | MOVE1, Part |
| 01466500 | McDonalds Branch in Byrne State Forest | 6.09 | Part, MOVE1, DAR |
| 01410225 | Morses Mill Stream at Port Republic, NJ | 21.37 | Part, DAR |

Streamflow records at partial-record stations and at the basin boundaries were estimated with standard USGS techniques by using values from the nearby continuous-record streamflow-gaging stations. Daily streamflow records were estimated by using the following techniques: (1) Maintenance of Variance Extension, Type 1 (MOVE1) (Hirsch, 1982) and (2) drainage-area ratio (DAR) (Hirsch, 1979). Monthly base flow and direct runoff were estimated with the computer program PART (Rutledge, 1998, p. 33–38). For the Albertson Brook and McDonalds Branch, both MOVE1 and DAR methods were used to estimate streamflow records. For the Morses Mill Stream, only the DAR method was used. Daily streamflow values were then used to calculate monthly mean streamflow records. The partial-record stations used to calculate base flow and direct runoff are listed in the table below.

| Station number | Station name | Drainage area (square kilometers) |
|---|---|---|
| 0140941020 | Albertson Brook above Great Swamp Branch near Hammonton, NJ | 52.32 |
| 01466550 | McDonalds Branch near Presidential Lakes, NJ | 8.91 |

The MOVE1 method correlates instantaneous low-flow measurements at the partial-record stations with concurrent daily mean discharge at a nearby continuous-record gaging station to estimate streamflow at the partial-record stations. This method is a modification of linear least squares regression, in which values are set to maintain the sample mean and variance rather than to minimize squared errors (Hirsch, 1982). The best-fit line is drawn through data points that represent discharge at a partial-record station with respect to daily mean discharge at a continuous-record station. The equation of this line is then used to estimate discharge at the partial-record station on the basis of discharge measured at the continuous-record station.

In the DAR method, streamflow at partial-record stations is estimated from streamflow at an adjacent continuous-record station with similar basin characteristics. Values at the continuous-record stations were adjusted to account for differences in the drainage areas of the two stations by multiplying each value from the continuous-record station by a coefficient that represents the difference in the size of the drainage basins to determine streamflow at the partial-record station.

## Land-Surface Water-Budget Terms

Determination of the other land-surface-based water budget terms are described below.

### Precipitation ($P$)

Precipitation data were compiled for 14 sites in or near the basins for the 2005–06 water years. Precipitation sites (fig. 5) included one site operated by the National Atmospheric Deposition Program (NADP), five sites operated by the National Climatic Data Center (NCDC), two sites operated by the South Jersey Resource Conservation and Development Council (SJRCD), and six sites operated by the USGS. These sites are listed below. Missing daily values were estimated from values for several adjacent sites with complete data.

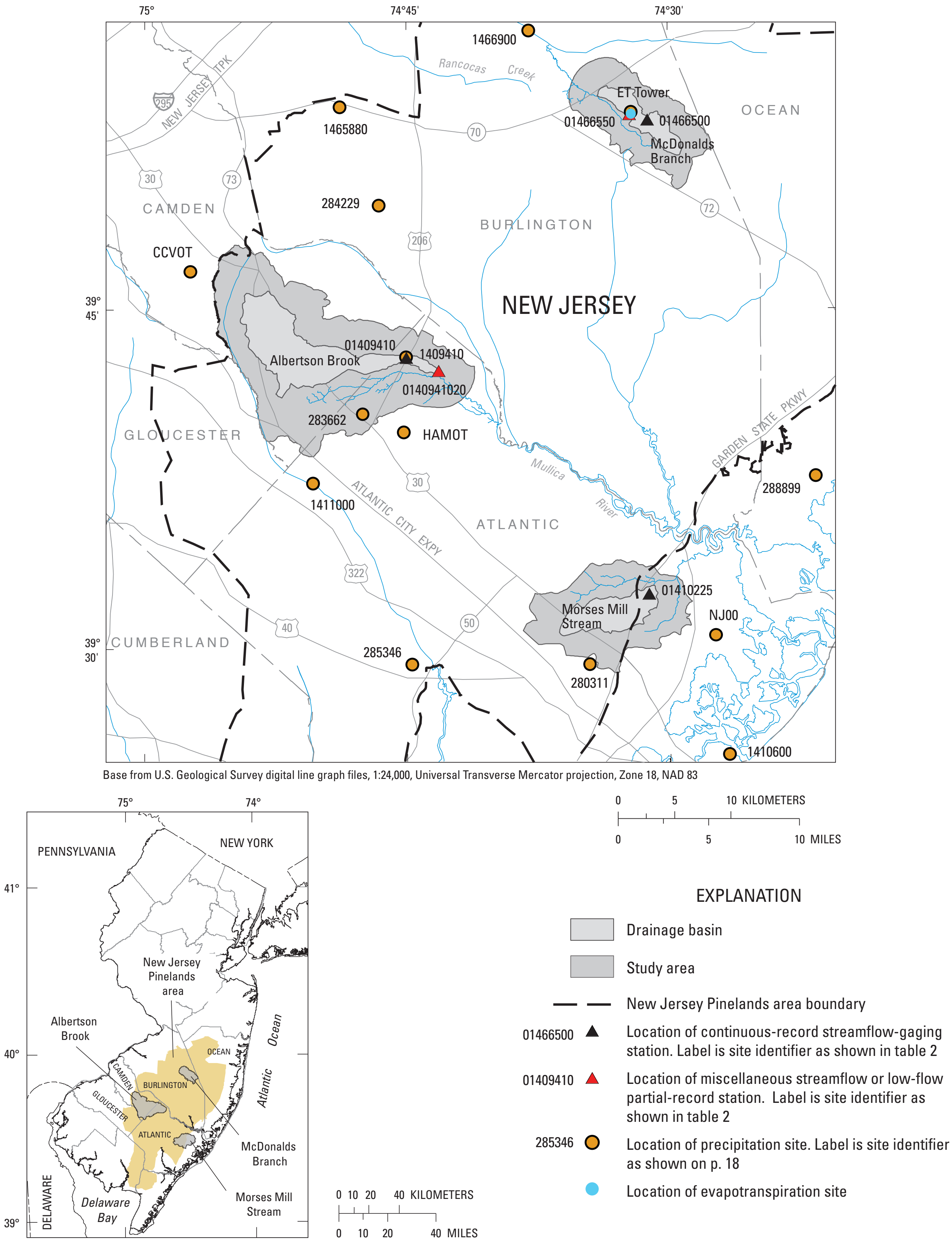



**Figure 5.** Location of evapotranspiration, precipitation, and surface-water sites used to develop water budgets for three drainage basins, New Jersey Pinelands.

Daily precipitation values and estimated values were summed to obtain the monthly values needed for the water budget. Precipitation sites used to calculate monthly precipitation within each basin are listed in the table below.

Precipitation sites.

| Site identifier | Operator | Source of data |
|---|---|---|
| NJ00 | NADP | http://nadp.sws.uiuc.edu/ |
| 280311 | NCDC | http://www7.ncdc.noaa.gov/IPS/lcd/lcd.html |
| 283662 | NCDC | http://www7.ncdc.noaa.gov/IPS/lcd/lcd.html |
| 284229 | NCDC | http://www7.ncdc.noaa.gov/IPS/lcd/lcd.html |
| 285346 | NCDC | http://www7.ncdc.noaa.gov/IPS/lcd/lcd.html |
| 288899 | NCDC | http://www7.ncdc.noaa.gov/IPS/lcd/lcd.html |
| ET Tower | USGS | http://waterdata.usgs.gov/nj/nwis/nwis |
| HAMOT | SJRDC | http://www.sjrcd.org/ |
| CCVOT | SJRDC | http://www.sjrcd.org/ |
| 01465880 | USGS | http://waterdata.usgs.gov/nj/nwis/nwis |
| 01466900 | USGS | http://waterdata.usgs.gov/nj/nwis/nwis |
| 01409410 | USGS | http://waterdata.usgs.gov/nj/nwis/nwis |
| 01410600 | USGS | http://waterdata.usgs.gov/nj/nwis/nwis |
| 01411000 | USGS | http://waterdata.usgs.gov/nj/nwis/nwis |

Monthly precipitation values for each basin were calculated using GIS. The inverse-distance weight method (IDW) was used to estimate precipitation for each cell in a grid that represented each basin based on measured precipitation at sites near the basins. The IDW method calculates values for a given cell by interpolating values between precipitation sites by weighting the values in proportion to the inverse distance between the site and the cell, with more weight being given to values from sites near the cell and less weight being given to values from sites far from the cell. The mean monthly precipitation of all cells within each basin was then determined.

### Artificial Discharge to Surface-Water Bodies ($D_{as}$)

Facilities that discharge water to a surface-water body (such as a lake, stream, or ocean) must apply for a National Pollutant Discharge Elimination System (NPDES) permit. In New Jersey, this Federal program is administered by the New Jersey Department of Environmental Protection (NJDEP). Each State agency collects data on wastewater discharges and transfers this information to the U.S. Environmental Protection Agency (USEPA) Permit Compliance System (PCS) database, which is used to track data on the quantity and quality of wastewater discharges. Available point-source discharge data for sites within each basin were obtained from the NJDEP. NPDES permits were matched with data on monthly wastewater discharges.

### Change in Storage (Surface Water, $\Delta S_{sw}$)

To accurately balance all variables used in the water-budget equations, changes in storage in surface-water bodies must be calculated if the change is substantial over time. For the most part, surface-water storage changed little from month to month. During the study period, storage in one lake in the Morses Mill Stream basin changed substantially. Lake Fred at Richard Stockton College in Pomona, NJ, was lowered during August 2005 to allow for the repair of the dam; the lake was refilled in March 2006 when repairs were complete.

### Change in Soil Moisture ($\Delta S_{sm}$)

Initial attempts to determine the monthly water balance did not take into account changes in soil-moisture storage. Results of these attempts, however, indicated that changes in soil moisture storage could not be ignored. In order to provide a basis for estimating these changes, data collected at a climatological station in the McDonalds Branch basin for the concurrent study of evapotranspiration were used. Soil moisture was monitored using a Campbell Scientific CS615 water content reflectometer probe installed to measure an averaged volumetric soil-moisture content within the upper 30 cm of the soil profile. The measured soil-moisture values at this single location are not necessarily representative of the watershed but are presumed to be correlated with generalized wetting and drying conditions across the region. Soil-moisture measurements were made and recorded on the data logger every 30 minutes. Soil-moisture values from the McDonalds Branch climatological station provided a rough indication of soil-moisture changes for all three basins.

Changes in soil moisture were calculated by using end-of-month values from the McDonalds Branch climatological station. End-of-month values were subtracted from the previous month's end-of-month value, such that a negative result represents an increase in soil moisture. This value was used as an index of the change in soil-moisture storage for the given month. For each of the three basins, the monthly soil-moisture-storage index values were adjusted using a scaling factor, such that the differences between calculated monthly land-surface recharge and calculated groundwater recharge values were minimized. Scaling factors used for the Albertson Brook, McDonalds Branch, and Morses Mill Stream basins were 25.3, 18.2, and 22.6 cm, respectively.

### Evapotranspiration (*ET*)

The rate of evapotranspiration can vary widely depending on land use, vegetation, soil moisture, wind speed, solar radiation, and other factors. *ET* from wetland areas is expected to be greater than *ET* from upland areas because wetland soils are wetter and water is more readily available for *ET* (Ballard and Buell, 1975; Ballard, 1979). Prior to this study, *ET* data from sites in or near the basins were limited. In response to this data gap, the USGS installed a climatological station at the McDonalds Branch basin ("*ET* Tower" in figure 5) at a site where the source of *ET* is primarily wetlands. Concurrent *ET* data were available from a climatological station operated by the U.S. Forest Service (USFS) at a nearby uplands site at the Silas Little Experimental Forest (SLEF) (Ameriflux, 2008).

Data from these two sites were used to determine *ET* rate indices for representative wetland and upland areas, respectively, and these indices were used to estimate total *ET* in each of the three study areas.

Evapotranspiration values at the USGS station were determined by methods described by Nicholson and Sumner (2006). *ET* measurement methods at the USFS SLEF station are documented by Ameriflux (2008). A comparison of concurrent *ET* measurements made at the two sites during 2005–06 showed that *ET* at the upland site averaged about 66 percent of *ET* at the wetland site.

To determine the total evapotranspiration from each basin, total monthly *ET* values from the USGS McDonalds Branch station were used to represent the *ET* rate from wetland areas within each basin. The same total monthly *ET* values from the McDonalds Branch station were multiplied by a factor of 66 percent and used to represent the *ET* rate in upland areas. These rates were multiplied by the area of wetlands and uplands, respectively, in each study area. Estimated values of *ET* from wetland and upland areas were then summed to estimate total *ET* for each basin.

### Water Use (Surface-Water Diversions, $W_s$)

Estimates of water use, including surface-water diversions, were compiled for each of the three basins for the 2005 and 2006 water years. A GIS with locations of intakes for surface-water diversions was used to determine which intakes were within each basin. All water-use data were obtained from the USGS's Site-Specific Water Use System (SSWUDS) database. Water use for intakes with incomplete or unreported data was estimated by using data from the most recent year for which reported values were available.

In New Jersey, high-volume water users (378.5 $m^3$/d, or 100,000 gal/d or greater) report their monthly withdrawals to NJDEP; reporting is either on an annual or a quarterly basis. New Jersey data include metered withdrawals for many categories of use (public supply, commercial, industrial, mining, and thermoelectric power), reported to NJDEP as monthly values. Low-volume water users (less than 378.5 $m^3$/d or 100,000 gal/d) must submit reports of monthly metered withdrawals. Agricultural/horticultural certification water users must submit monthly withdrawal data; however, withdrawals are rarely metered and, for the most part, are estimated by multiplying the number of hours of use by the pump capacity (Nawyn, 1998).The withdrawal data are entered in the NJDEP Bureau of Water Allocations (BWA) database and transferred electronically to the USGS as part of the USGS/NJDEP Cooperative Water-Use Program. The USGS reconfigures and tests the withdrawal and site data before they are entered into the SSWUDS database.

### Recharge ($R_s$ and $R_g$)

In both the land-surface- and groundwater-based equations, recharge is determined as a residual of the other water-budget terms; therefore, recharge estimates carry with them an accumulation of any net error associated with the estimates for the other terms. The uncertainty associated with estimates of changes in soil-moisture storage may be large, as the estimates of this term reflect a highly simplified understanding of complex processes occurring in the unsaturated zone.

Soil moisture within the unsaturated zone varies throughout the year depending on rainfall patterns, changes in evaporation and transpiration rates, temperature, and other factors. During winter and spring, when soil moisture is above field capacity, recharge typically is much higher than during summer and fall. If soil moisture is less than field capacity, which commonly occurs during summer months, a soil-moisture deficit may exist. Although some macropore flow through soils may occur following rainfall under soil-moisture deficit conditions, recharge to the groundwater system is assumed to occur only after the deficit is made up (Nicholson and Watt, 1997; Alley, 1984).

The time that elapses between a precipitation event, when water begins to infiltrate into the unsaturated zone, and the onset of recharge to the underlying aquifer system can vary greatly depending on the thickness of, and conditions in, the unsaturated zone. In areas where the water table is near the land surface, such as in and near wetlands, recharge can occur almost immediately. In areas where the water table is far below land surface, such as in upland areas near basin divides, however, recharge may take weeks or more. The presence of silt or clay layers in the unsaturated zone also can delay recharge or change the direction of flow in the unsaturated zone (Nicholson and Watt, 1997; Alley, 1984). This delay may be accentuated during winter months when some water may be stored as snow or ice on the land or frozen in the shallow part of the unsaturated zone and not immediately available for infiltration. A consequence of any delay in recharge is that some of the recharge estimated using the groundwater-based equation will tend to lag behind the recharge estimated using the land-surface-based equation. In practical application of recharge estimates, some of the recharge estimated for a given month using the land-based equation could be carried forward to the following month.

## Groundwater-Budget Terms

The determination of the other water budget terms for groundwater are described below.

### Artificial Discharge to the Aquifer System ($D_{ag}$)

Like facilities that discharge water to surface-water bodies, facilities that discharge water to groundwater through septic systems or other wastewater systems must apply for a NPDES permit. Point-source discharge data for sites within each basin were obtained from NJDEP, and NPDES permits were matched with data on monthly wastewater discharges.

### Groundwater Inflow/Outflow ($R_i$)

Horizontal groundwater inflow or outflow between the basin and adjacent basins can occur in areas where groundwater divides do not coincide with surface-water divides and where large-capacity wells are located near the basin divide. Estimation of horizontal flow to or from a basin from field data alone is difficult; these flow rates are best estimated using groundwater flow models. Pre-calibration steady-state models being developed as part of another phase of the Kirkwood-Cohansey project were used to provide a preliminary indication of the direction and magnitude of horizontal flow across basin boundaries. These initial estimates helped to improve the agreement between recharge values determined by using the land-surface water-budget equation and those determined by using the groundwater-budget equation. Values of horizontal groundwater inflow or outflow also were adjusted in the budget equation by using the optimization routine described earlier to minimize the sum of the differences between monthly land-surface recharge ($R_s$) and groundwater recharge ($R_g$).

### Water Use (Groundwater Withdrawals, $W_g$)

Estimates of water use, including groundwater withdrawals, were compiled for each of the three basins for the 2005 and 2006 water years. A GIS with well locations was used to determine which wells were within each basin. All water-use data were obtained from the SSWUDS database. Water use for wells with incomplete or unreported data was estimated by using data from the most recent year for which reported values were available.

### Leakage ($L$)

Groundwater leaks from the Kirkwood-Cohansey aquifer system to underlying confined aquifers in response to head gradients across the confining units. Mapped water-level altitudes in the underlying confined aquifers in 2003 (DePaul and others, 2009) were examined and compared with water-level altitudes presented in this report. Because water-level differences across the confining units underlying the Kirkwood-Cohansey aquifer system in the three study areas (typically greater than 20 m) are generally larger than the range of observed seasonal variations in water levels in the unconfined system (generally less than 2 m), the seasonality in both vertical gradients and vertical leakage was expected to be minor. A flow model (Martin, 1998; Voronin, 2004) developed as part of the USGS Regional Aquifer-System Analysis (RASA) program was used to determine the volume of water leaking to underlying layers (E.G. Charles, U.S. Geological Survey, written commun., 2007). The model can be used to simulate vertical flow through confining units for each grid cell of the model. Leakage values from each model cell within a basin were averaged to determine net flow out of the Kirkwood-Cohansey aquifer system. Flow rates were assumed to be constant throughout the study period; therefore, only one leakage value was used for each basin.

### Change in Storage (Groundwater, $\Delta S_{gw}$)

Changes in groundwater storage were calculated by using end-of-month depth-to-water values at basin-monitoring and wetland-monitoring wells. Basin-monitoring wells were used to represent change in water level in upland areas and wetland-monitoring wells were used to represent change in water level in wetlands. The water level in the shallowest well at each basin-monitoring well cluster was used in the calculation (table 1 at end of report). End-of-month values were subtracted from the previous month's values so that a negative value represents a decline in the water level and a negative change (net loss) in storage. An average value for each basin was determined by first summing the area-weighted changes in water level in upland and wetland areas, then multiplying the resulting value by an estimate of specific yield for each basin to determine the change in storage. Values of specific yield were initially estimated on the basis of values previously reported for similar sediments in the Kirkwood-Cohansey aquifer system (Rhodehamel, 1973; Freeze and Cherry, 1979; Fetter, 1994) and then were refined in the budget calculations using the optimization routine described earlier to minimize the sum of differences between the monthly land-surface water-budget recharge ($R_s$) and groundwater-budget recharge ($R_g$) values. The estimated specific yields used in the budget calculations were 0.17 for the Albertson Brook basin, 0.31 for the McDonalds Branch basin, and 0.11 for the Morses Mill Stream basin. These estimates are considered rough approximations and are likely influenced by differences among the basins in the degree of dependence between changes in groundwater storage and recharge determined as a residual of computations based on other budget components. For example, relatively large changes in monthly groundwater storage in the McDonalds Branch basin resulted in better agreement between estimated monthly values of $R_s$ and $R_g$ for this basin than for the other two basins, so the estimated specific yield for the McDonalds Branch basin is larger than that for the other drainage basins.

## Hydrologic Assessment

In the following sections, organized by study area, the hydrologic data collected in the three Pinelands study areas are described and interpreted. Included are descriptions of the geohydrologic, hydrologic, and climatologic conditions under which the groundwater and surface-water data were collected. Hydrographs of water levels, streamflow, and precipitation records provide a continuous record of the transient hydrologic conditions during the data-collection period. Groundwater and surface-water data collected during the two synoptic measurement periods were examined in the context of these records. Maps and graphs are used to illustrate an area-wide analysis of water-table altitude, depth to groundwater, and localized hydraulic-gradient data that characterize the hydrologic interactions among groundwater, wetlands, and streams. Spring and late summer 2005 base-flow measurements are compared, and start-of-flow locations observed during each of the synoptic measurements are reported.

## Albertson Brook Study Area

The Albertson Brook study area represents a range of hydrologic features typical of the Pinelands, with the upper and lower parts of the basin each containing different proportions of developed and undeveloped land. In the upper part of the basin, stream channels are flanked by narrow swamps, wetlands, and forests surrounded by agricultural land, some of which is unused and some that has undergone various forms of development. Several man-made lakes on the Pump Branch and Blue Anchor Brook tributaries to the Albertson Brook may affect the runoff characteristics in the basin by attenuating peak flows during periods of heavy rainfall. In contrast, the lower part of the basin is less developed, with the exception of active agriculture. In this area the Albertson Brook is flanked mostly by broad wetlands, some nearly 300 m wide that are composed largely of pine, cedar, and hardwood and abut forested uplands. In some areas on the south side of Albertson Brook, the upland forests transition to a patchwork of mostly agricultural land. The Albertson Brook basin narrows substantially in a downstream direction, an area where the basin is flanked by forest. All network wells and streamflow sites in the study area are shown in figure 2, and site information is listed in tables 1 and 2 (at end of report).

### Groundwater Levels

The hydrographs of daily mean water levels measured over the period of record (fig. 6) indicate that groundwater levels fluctuated over a maximum range of about 0.95 m at the upper-basin monitoring wells and about 0.78 m at the lower-basin monitoring wells. The three wells that make up each cluster represent three aquifer layers that lie between the water table and the base of the Kirkwood-Cohansey aquifer system (Walker and others, 2008). Seasonal water-level extremes in the upper part of the basin (recharge area) lagged behind those in the lower part of the basin (discharge area). Water levels in the upper-basin monitoring-well cluster responded only minimally to the precipitation in the latter part of 2005. These hydrographs illustrate downward hydraulic gradients indicative of a recharge area in the upper-basin wells (fig. 6A) and upward hydraulic gradients indicative of a discharge area in the lower-basin wells (fig. 6B).

The shallowest well (070744–PZ 5) in the upper-basin well cluster is screened in the unconfined (water-table) aquifer (hydrogeologic layer AB A1-B; Walker and others, 2008) and has the highest water level of the wells there. The water level in well 070744–PZ 5 fluctuated over a range of about 0.95 m during the period of record, whereas the water level in the middle well (071091–AB-OW1M) and the deep well (071092–AB-OW1D), screened in the AB A-2 and AB A-3 aquifer layers, respectively (Walker and others, 2008), fluctuated over a range of about 0.7 m during the same period. Water levels in both the middle and deep wells were as much as 1 m lower than that in the shallow well, and the hydrographs for the middle and deep wells are nearly identical (fig. 6A). The deeper wells show frequent and regular small fluctuations in daily mean water levels throughout the period of record that indicate effects of variable stresses typical of groundwater withdrawals. These fluctuations most likely are induced by pumping from one or more of the nearby public-supply wells, which are screened in the lower part of the aquifer system. These water-level fluctuations also were apparent in the shallow well, but their range was smaller than those in the deeper wells. The differences between the groundwater levels in the unconfined aquifer and those in the deeper aquifers probably can be attributed to the combined effects of local pumping and the influence of a more than 5-m-thick leaky confining layer referred to as AB C-1 (Walker and others, 2008), which separates the unconfined aquifer from the middle aquifer in this area. A thin, leaky confining layer referred to as AB C-2 (Walker and others, 2008) also separates the middle and lower aquifers but, on the basis of their nearly identical water levels (fig. 6A) and the geophysical records for this site, this leaky confining layer appears to be ineffective at isolating these aquifers hydraulically (Walker and others, 2008). These conditions indicate that man-made or natural hydraulic stresses applied to the aquifer system may affect water levels differently in the three aquifer layers depending on differences in geologic structure, hydrology, and the location of the stresses applied.

Although a downward hydraulic gradient may be expected in upper-basin areas, the observed difference in water levels of as much as 1 m between the unconfined and deeper aquifers may be attributable, in part, to local pumping from the aquifer system's lower layers. In contrast, the lower-basin wells, located more than 3 km from any possible groundwater withdrawal, show an upward hydraulic gradient, no short-term fluctuations that would indicate effects of groundwater withdrawals nearby, and a uniform difference in water levels with depth (less than 0.3 m overall), indicating a likely area of groundwater discharge where the natural vertical gradient is unaffected by local stresses.

The effects of precipitation on groundwater levels can vary with location and depth. The location and depths represented by the two basin-monitoring well clusters generally cover the range of conditions to be found in the basin and effects of precipitation on groundwater levels. Water levels in the three wells in the upper-basin recharge area vary seasonally but do not respond promptly to precipitation events, whereas water levels in wells in the lower-basin discharge area respond rapidly (fig. 6). This difference likely results, in part, from the presence of a much thicker unsaturated zone (about 8.5 m thick) at the upper-basin site than at the lower-basin site, where the unsaturated zone is less than 1 m thick. In addition, the unsaturated sediments at the lower-basin site are sandy, whereas those at the upper-basin site vary in texture

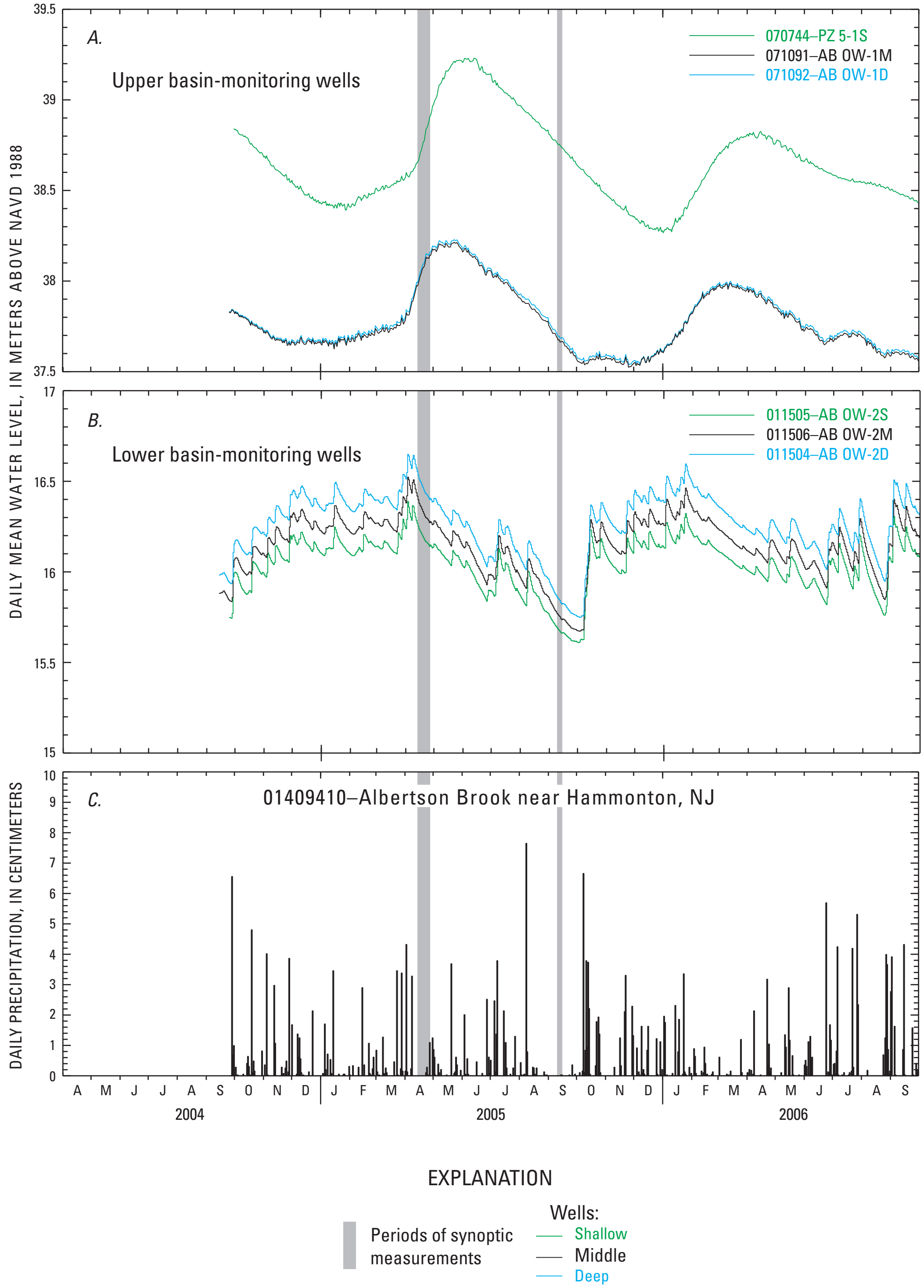



**Figure 6.** Groundwater levels in (*A*) upper and (*B*) lower basin-monitoring wells and (*C*) precipitation, Albertson Brook study area, New Jersey Pinelands, 2004–06.

from gravel to sand with some clay layers (Walker and others, 2008), and their moisture content varies with depth and time. All of these factors act to slow the rate of advance of a wetting front before it reaches the water table. Consequently, there was no definitive time during the period of record at the upper-basin site when infiltration resulted in a rapid rise of the water table (fig. 6A).

In contrast, water levels in all the wells in the lower-basin cluster responded rapidly to substantial precipitation induced recharge throughout the period of record (fig. 6B). Such a response is common in the shallow aquifer layer, but water levels in the wells screened in the middle and deep layers (011506–AB OW-2M and 011504–AB OW-2D) appear to respond simultaneously and to the same magnitude as that of the shallow well (011505—AB OW-2S) when recharge occurs. As shown in figure 6B, water levels in wells 011506–ABOW-2M and 011504–ABOW-2D also increase with depth. When the water table begins to rise in response to precipitation, this change is immediately reflected as a change in water levels in the lower aquifer layers, indicating that these deeper aquifers are hydraulically connected to the water table. This observation confirms that the aquifer layers at this location are unconfined, as described by Walker and others (2008).

Water-level data were recorded continually in two wetland-monitoring wells in the Albertson Brook study area (figs. 2, 7A, and 7B) during the study. These data indicate that the water table fluctuated over a range of 0.91 m near the upland edge of the wetlands (pitch pine uplands) at well 011459–Albertson Brook 2 (fig. 7B) and 0.51 m in the wetlands (cedar swamp) at well 071081–Albertson Brook 1 (fig.7A). Groundwater levels in the uplands were affected more by precipitation than those in the wetlands beneath the cedar swamp. During periods of high water levels, groundwater levels beneath the swamp were affected by surface-water levels in the Albertson Brook. When the swamp became dry as water levels declined, the groundwater levels were less influenced by surface-water levels, and the response to precipitation was larger and more rapid (fig. 7). Major or sustained precipitation produced rapid responses in both wells, but the response was always smaller beneath the cedar swamp as a result of its proximity to the Albertson Brook.

## Streamflow

Streamflow data recorded at the two gaging stations in the Albertson Brook study area (fig. 2) during the period of record indicate that daily mean discharge ranged from 0.06 $m^3/s$ to 1.90 $m^3/s$ at the Pump Branch station (0140940810) and from 0.26 $m^3/s$ to 2.49 $m^3/s$ at the Albertson Brook station (01409410) (fig. 8).

During the summer low-flow periods of 2005 and 2006, stream stage at the Pump Branch gaging station (0140940810) was affected by backwater from vegetation growth in the channel, which raised the apparent stream stage while discharge remained unaffected. The stage shown on the hydrograph (fig. 8) indicates the actual stage during those backwater periods. The discharge hydrograph was adjusted for the periods of backwater by applying an adjustment to the stage record for these periods before determining the daily mean discharges. These adjustments were determined on the basis of manual stage and discharge measurements made during the periods of backwater. Discharge records for station 0140940810 were considered fair (fair indicates 95 percent of the record is within 15 percent of the true value), except for discharges above 1.13 $m^3/s$, which are considered poor (less accurate than fair). With the exception of periods when stage at the Pump Branch gaging station was affected by backwater, the recorded stream stage compares well with nearby groundwater-level hydrographs, an indication of the strong hydrologic relation between groundwater and surface water in the Pinelands. The stage and discharge hydrographs for the Albertson Brook and Pump Branch gaging stations show characteristically similar responses to precipitation throughout the period of record. In the lower part of the Albertson Brook basin, a low divide separates the Albertson Brook from the adjacent Gun Branch basin to the north (fig. 2). Gun Branch joins the Albertson Brook downstream from the study area; however, on April 22, 2004, water from Gun Branch was observed flowing to the Albertson Brook through a ditch along State Route 206, indicating that inter-basin surface-water flow to the Albertson Brook upstream from the streamflow-gaging station (01409410) can occur. Given the observed inter-basin flow conditions, it is reasonable to assume that groundwater also can enter the Albertson Brook basin beneath the low divide between these two basins during periods of high water levels.

As no long-term historical streamflow records were available for the Albertson Brook basin prior to this study, a comparison with conditions observed in the adjacent Great Egg Harbor River basin helps to place the streamflow data collected during the 2-year period of this study in hydrologic context. Mean annual discharge for the streamflow-gaging station 01411000, Great Egg Harbor River at Folsom, NJ, located about 12 km southwest of the Albertson Brook study area, for 2005 and 2006 was 101 and 105 percent, respectively, of the long-term mean annual discharge determined from 82 years of record (U.S. Geological Survey, 2009).

## Synoptic Measurements

Synoptic measurements were made in the Albertson Brook study area during two low-flow periods–one in spring (April 13–25, 2005) and one in late summer (September 9–15, 2005). Water-level data collected during these periods are presented in table 3 (at end of report), and the locations of the selected sites where measurements were made are shown in figure 9. Because long-term groundwater and surface-water records for the Albertson Brook study area were unavailable, statistics calculated using data from nearby sites with similar hydrologic characteristics provided long-term daily mean groundwater-level and streamflow data with which to

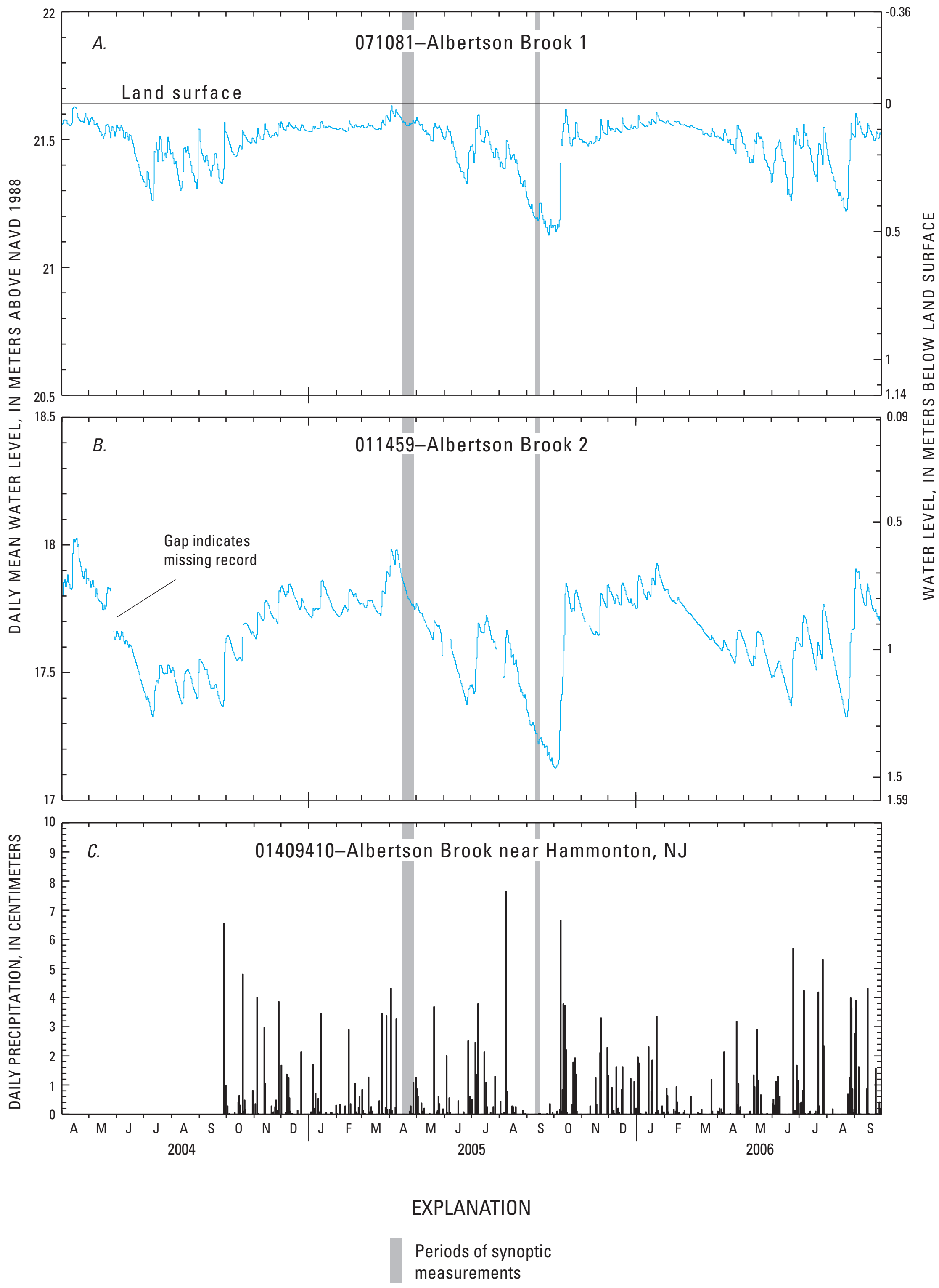



**Figure 7.** Groundwater levels in (*A*) Albertson Brook 1 (*B*) Albertson Brook 2, wetland-monitoring wells and (*C*) precipitation, Albertson Brook study area, New Jersey Pinelands, 2004–06.

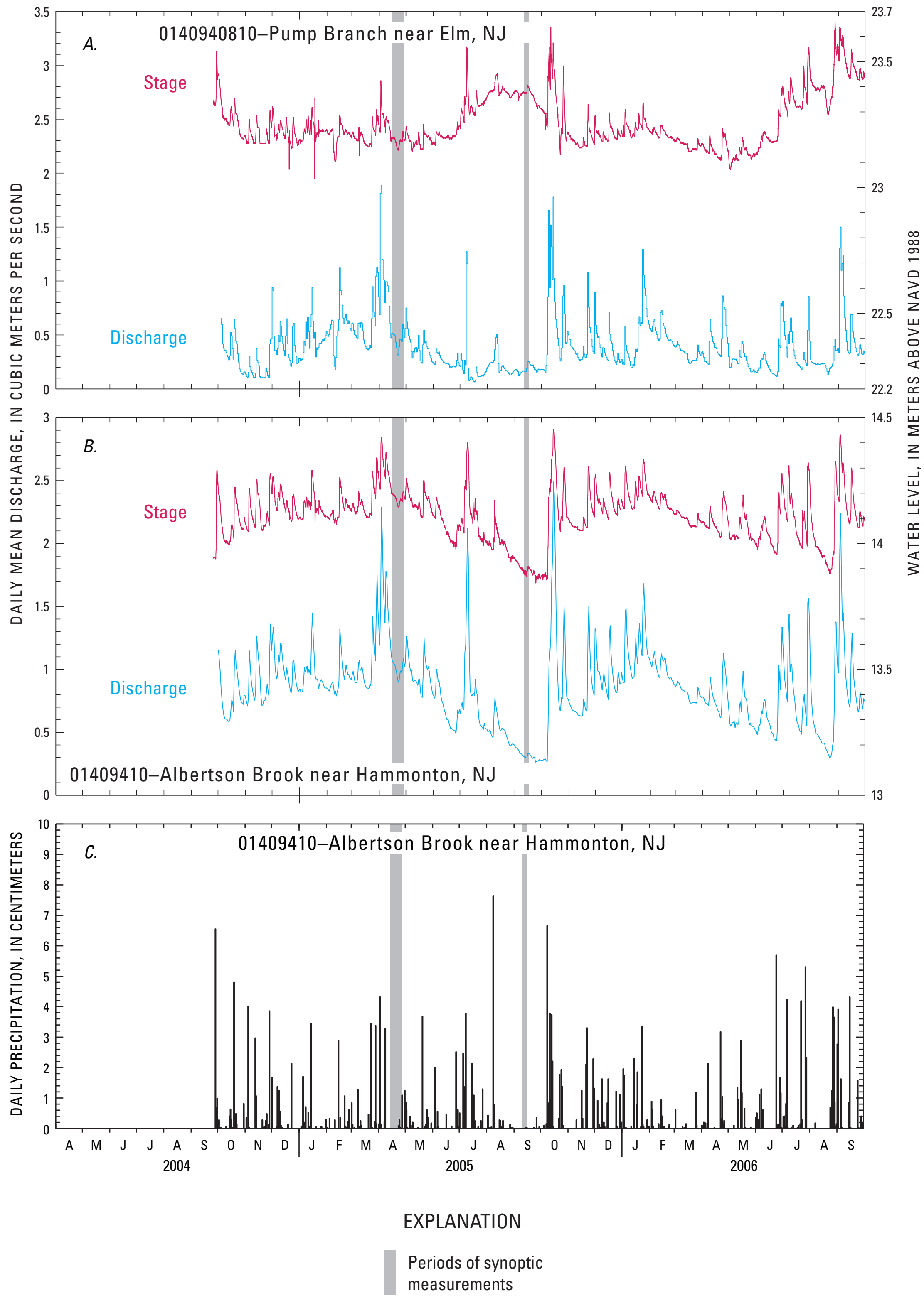
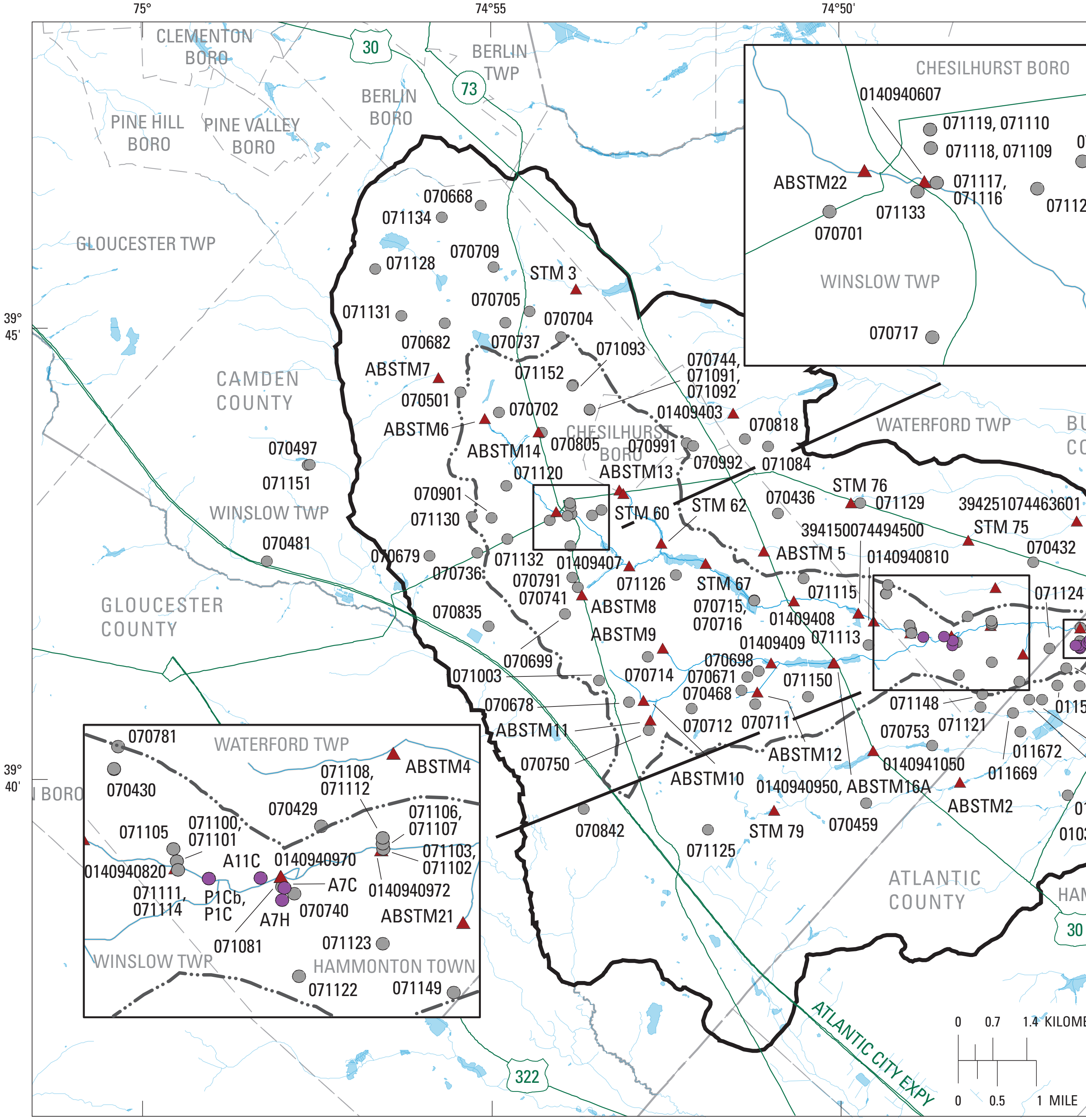
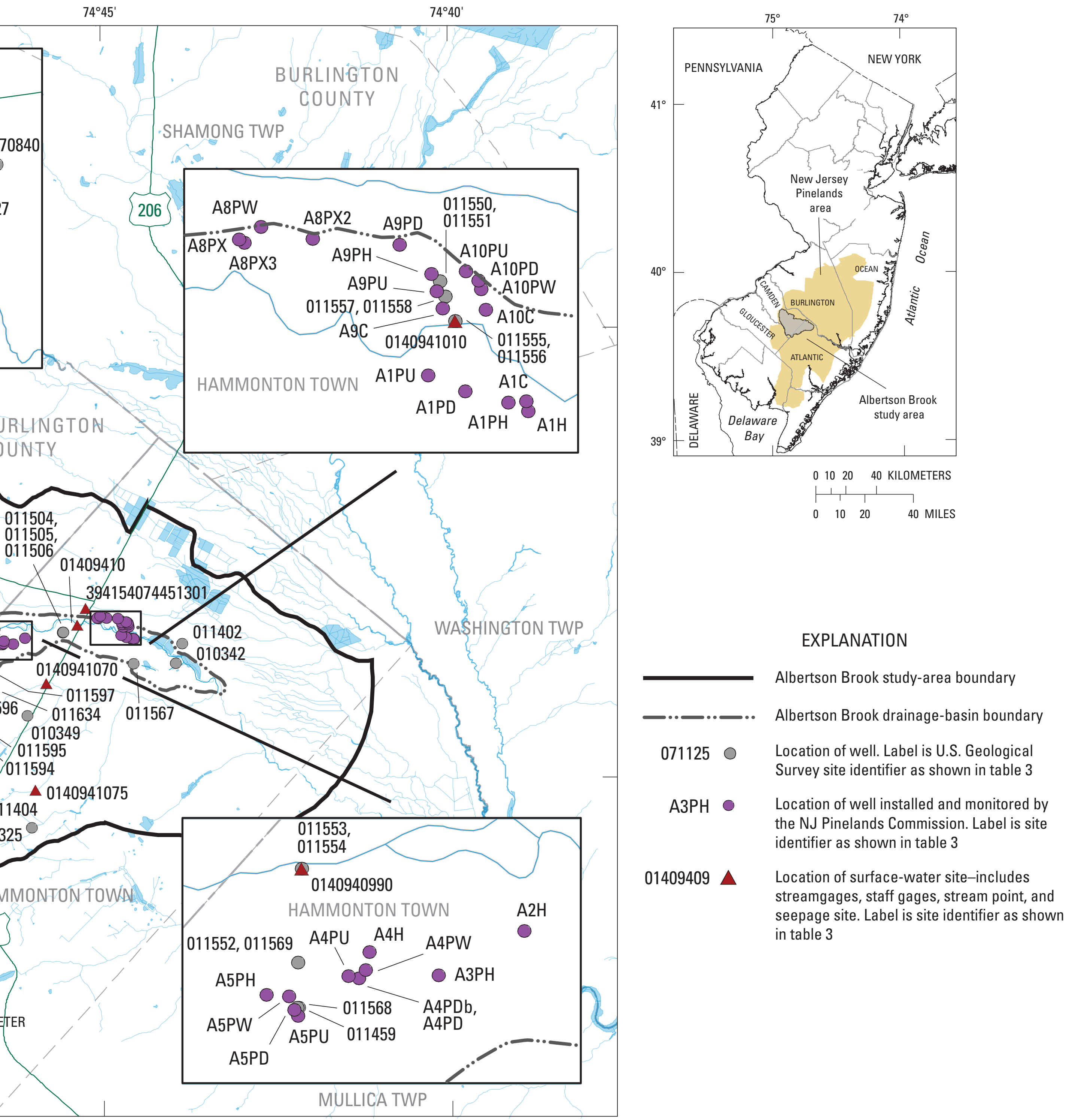



**Figure 8.** Surface-water stage and discharge at (*A*) Pump Branch near Elm and (*B*) Albertson Brook near Hammonton, NJ, gaging stations and (*C*) precipitation, Albertson Brook study area, New Jersey Pinelands, 2004–06.




Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 9.** Location of selected sites used for synoptic water-level measurements, Albertson Brook study area, New Jersey Pinelands, April and Septe


74°45'
74°40'
BURLINGTON COUNTY
SHAMONG TWP
206
A8PW
A8PX2
A9PD
011550, 011551
A8PX
A8PX3
A9PH
A10PU
A10PD
A9PU
A10PW
011557, 011558
A10C
A9C
0140941010
011555, 011556
HAMMONTON TOWN
A1PU
A1C
A1PD
A1PH
A1H
WASHINGTON TWP
011504, 011505, 011506
01409410
394154074451301
011402
010342
0140941070
011597
011634
011567
010349
011595
011594
0140941075
011553, 011554
0140940990
HAMMONTON TOWN
A2H
011552, 011569
A4PU
A4H
A4PW
A5PH
A3PH
011568
A4PDb, A4PD
A5PW
A5PU
011459
A5PD
MULLICA TWP
75°
74°
PENNSYLVANIA
NEW YORK
41°
New Jersey Pinelands area
40°
OCEAN
Ocean
Atlantic
CAMDEN
GLOUCESTER
BURLINGTON
ATLANTIC
Albertson Brook study area
DELAWARE
Delaware Bay
39°
0 10 20 40 KILOMETERS
0 10 20 40 MILES
EXPLANATION
Albertson Brook study-area boundary
Albertson Brook drainage-basin boundary
071125 Location of well. Label is U.S. Geological Survey site identifier as shown in table 3
A3PH Location of well installed and monitored by the NJ Pinelands Commission. Label is site identifier as shown in table 3
01409409 Location of surface-water site–includes streamgages, staff gages, stream point, and seepage site. Label is site identifier as shown in table 3

ember 2005.

compare the state of the hydrologic system during the synoptic measurements.

During the April 2005 synoptic measurement, groundwater levels in the vicinity of the study area were slightly above the mean daily water-level statistic for the month of April as determined from 16 years of record for the well, Washington Township 1 Obs (well 151033) located about 13 km west of the Albertson Brook study area in Gloucester County (*http://waterdata.usgs.gov/nj/nwis*). Streamflow at the gaging station in the adjacent Great Egg Harbor River basin at Folsom, NJ (01411000), during the same period was slightly lower than the long-term mean daily discharge statistic for the month of April as determined from 82 years of record (U.S. Geological Survey, 2009). Groundwater levels vary spatially at any point in time as demonstrated by the lag in the seasonal water-level extremes described previously. Streamflow integrates groundwater discharge along the length of the basin, making it a better overall indicator of the hydrologic state of the basin.

The April synoptic measurement was begun 5 days after the end of a 2-week period of frequent precipitation, with rainfall amounts typically less than 4 cm per event (figs. 6–8). Light precipitation during the last 3 days of the spring measurements totaled 0.41 cm, although the hydrographs in figures 6 through 8 show that those precipitation events did not significantly influence groundwater levels or stream stage. As a result of the time lag in seasonal extremes described previously, hydrographs for the two basin monitoring-well clusters showed different water-level trends prior to and during the synoptic measurements. Water levels in the upper-basin monitoring wells (fig. 6A) rose prior to and during the spring synoptic measurement period, whereas those at the lower-basin monitoring-well cluster declined.

During the September synoptic measurement, groundwater levels were lower than the 16-year long-term mean daily water-level statistics for the month of September, as indicated by the Washington Township 1 Obs, observation well. Streamflow in the Great Egg Harbor River at Folsom, NJ, was lower than the 82-year long-term mean daily discharge during the month of September. The September synoptic measurement was begun after an extended downward trend in both groundwater levels and streamflow, resulting from more than a month without substantial precipitation (figs. 6–8). As mentioned previously, stage at the Pump Branch gaging station prior to and during the September measurement appears higher than expected as a result of backwater caused by vegetation growth in the channel below the gage (fig. 8).

Water levels at selected wells and stream sites and at the intersections of surface-water and topographic contours were used to prepare water-table-altitude maps for April and September 2005 (figs. 10 and 11, respectively). Groundwater flows through the permeable aquifer sediments from areas where water levels are highest to areas where water levels are lowest, where it discharges to wetlands, the Albertson Brook, and its tributaries. The water-level altitude slopes along the length of the basin, decreasing more than 30 m from the upper drainage-basin boundary to the lower drainage-basin boundary for this study (figs. 10 and 11).

Fetter (1994) observes that the boundaries of surface-water basins and groundwater basins do not necessarily coincide, and this condition was observed in several parts of the Albertson Brook basin. One of these areas is in the upper part of the basin, along its southwestern boundary, where water-table contours for both spring and summer measurements indicate groundwater leaving the basin, with hydraulic gradients toward the adjacent Great Egg Harbor River basin. Water-level contours in the northernmost extent of the basin also indicate a potential for groundwater leaving the basin toward the east, northeast, and other tributaries of the Mullica River basin. Water-level contours in the lower part of the basin, along the northern basin divide between the Albertson Brook and Gun Branch, indicate potential groundwater flow into the Albertson Brook basin during both April and September. The basin narrows substantially in this area, and the topography across the divide is relatively flat. Along the southern basin divide in the lower part of the basin, water-level contours indicate another small area where groundwater probably enters the basin from an agricultural area to the south. This condition persisted during both the April and September measurements. Farther east along the southern boundary, the 18-m-altitude contour indicates that groundwater may have been flowing out of the basin in April, but no such flow potential was apparent in September.

Depth to the water table (DTW) in the Albertson Brook basin in April 2005 (fig. 12) ranged spatially from zero at points of groundwater discharge, such as ponds, streams, and wetlands, to a maximum of more than 10 m in upland areas at the northern and western limits of the basin. A histogram showing the distribution of DTW throughout the basin (fig. 13) provides a basin profile of the hydrologic setting for habitats that depend on different ranges of DTW. DTW is less than 0.5 m over 18 percent of the basin, resulting in a relatively small percentage of the basin being hydrologically suitable for wetland habitats. In comparison with the Pinelands as a whole, the basin has a smaller percentage of mapped wetlands areas; 13 percent of the basin is mapped as wetlands, whereas wetlands covered 27 percent of the entire Pinelands area in 2002 (Zampella and others, 2008). Most of the mapped wetlands are found in the downstream half of the basin. In mapped wetlands within the basin, DTW ranges from zero to 2.1 m, with a mean depth of 0.21 m. Following the relatively higher water levels in April, the water table declined throughout the basin, falling as much as 1.2 m by the time of the September measurement. These changes generally were smallest near the areas of discharge to surface water and greatest in the upland recharge areas near groundwater divides but varied locally throughout the basin as a result of local conditions.

Water level and hydraulic gradient data from five hydrologic transects in the Albertson Brook basin (fig. 2) describe the interaction of groundwater with wetlands and surface water during the two synoptic measurements in 2005. These data characterize the seasonal range in water-table altitude in and near wetlands and the changes in hydraulic gradients and potential groundwater flow leading to groundwater discharge to the wetlands and surface water between April and September 2005 (fig. 14). Site conditions and associated findings are described below.

The hydrologic transect site that is farthest upstream (ABHT1) is situated on the northeastern side of the Pump Branch tributary to the Albertson Brook near its headwaters. At this site, the land surface slopes for 230 m from the uplands into a narrow wetland (about 30 m wide) that flanks the stream channel. The slope in the water table was uniform during both synoptic measurements (fig. 14) with downward hydraulic gradients in the upland wells, representing an area of recharge, that transition to upward hydraulic gradients beneath the wetlands and the Pump Branch, indicating a hydraulic potential for groundwater discharge.

Transect ABHT2 is about 9 km downstream from transect ABHT1, on the northern side of the Pump Branch (figs. 2 and 14), where the channel broadens and is flanked by wetlands. Transect ABHT2 is about 175 m long and originates in the uplands, where the land surface slopes gently toward the Pump Branch and then steeply at the weathered bank of an ancient stream channel. This steep slope marks the transition from uplands to wetlands and the beginning of dry white cedar lowlands. From the edge of the wetlands to the stream, the topography is relatively flat for a distance of about 75 m. During both April and September, vertical hydraulic gradients in the uplands indicated potential downward groundwater flow. From the uplands, the water table slopes gently toward the middle well cluster, where hydraulic gradients were upward during both synoptic measurements. The upward gradient in the middle cluster was smaller in April than in September, probably because water levels were higher in April as a result of frequent rainfall preceding the April measurement. Small but similar upward hydraulic gradients in the near-stream well pair and substantially larger upward hydraulic gradients beneath the Pump Branch during both synoptic measurements indicate a strong potential for groundwater discharge to the Pump Branch in this area. The persistent upward hydraulic gradients beneath the wetlands and stream indicate that much of the groundwater discharge reaching the stream at this location is probably from the deeper groundwater-flow system.

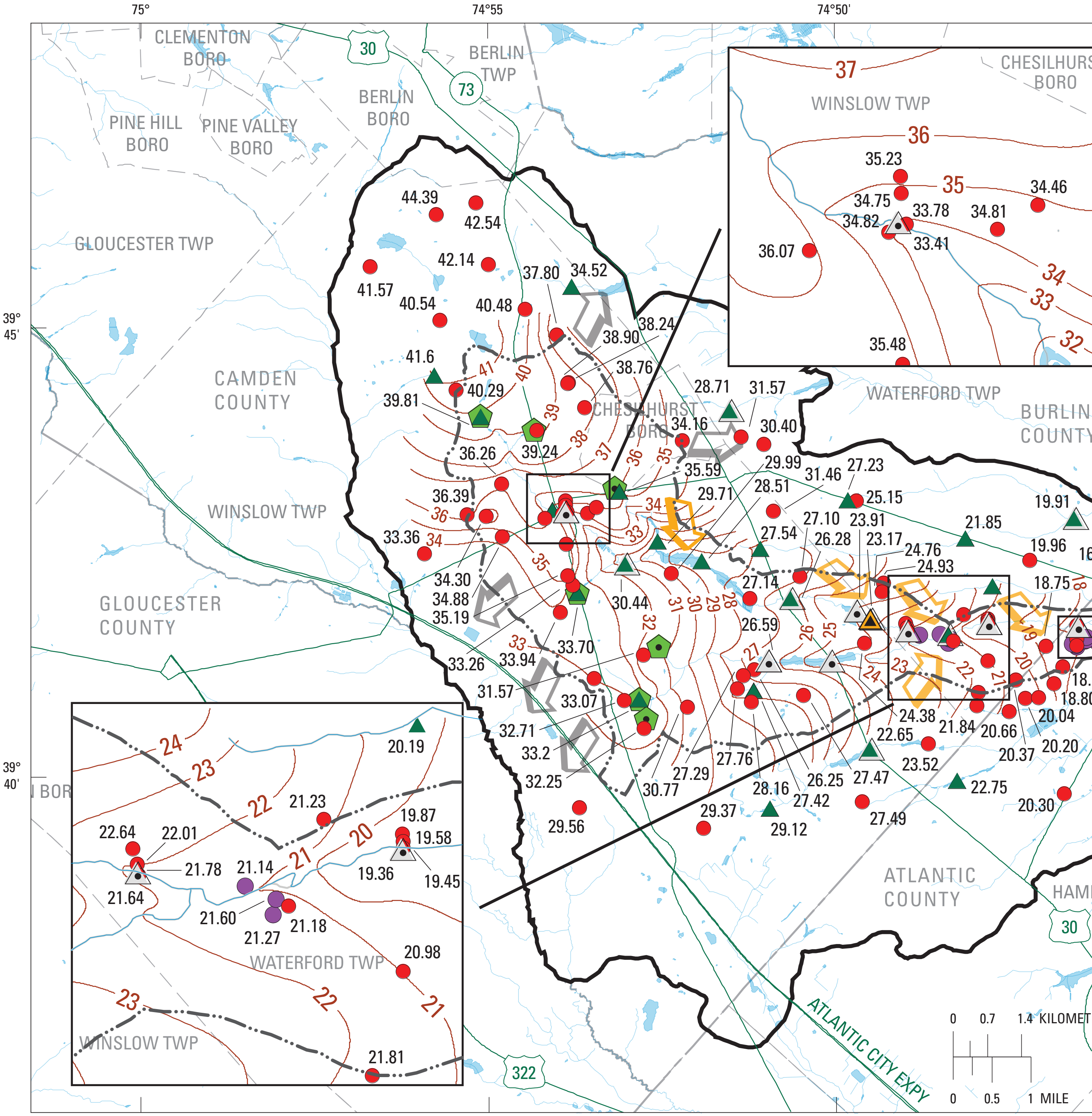
Conditions at hydrologic transect ABHT3 (fig. 14) located on the Albertson Brook about 1.6 km below the confluence of the Pump Branch with Blue Anchor Brook are similar to those described for ABHT2. This transect is about 105 m long with a moderate slope in the land surface from the uplands to the predominantly hardwood and pine wetlands that lie along the northern side of the Albertson Brook. These wetlands, about 50 m wide, are relatively flat from near the upland/wetland boundary to the stream. The water table sloped gently from the uplands to the stream in April; in September the slope was similar, but the horizontal hydraulic gradient was smaller. The upland well pair shows a slight downward hydraulic gradient in April and no vertical gradient in September, indicating that most shallow groundwater flow from the uplands in this area probably is horizontal, toward the Albertson Brook. Beneath the wetlands and the Albertson Brook, hydraulic gradients were upward during both synoptic measurements, indicating a strong potential for discharge of groundwater to the stream in this area. In September, after more than a month without rain, shallow water levels were lower, but upward gradients near and beneath the Albertson Brook were greater than in April, reflecting the influence of groundwater flow that discharges to the stream along longer and deeper flow paths.

Transect ABHT4 is located about 350 m downstream from ABHT3 on the south side of the Albertson Brook. The transect is about 400 m long, nearly 300 m of which traverses wetlands and swamp containing pine, hardwoods, and cedars that flank Albertson Brook in this area. The upland end of this transect originates at the location of Albertson Brook 2, a wetland-monitoring well described previously. The water table along the transect slopes with a uniform horizontal gradient from the uplands through the wetlands and swamp to the stream (fig. 14). In contrast to the upstream transects, hydraulic gradients at the upland end of transect ABHT4 were downward in April but upward in September. Although the reason for the upward gradient in September is not well understood, it could indicate the occurrence of sub-regional groundwater flow discharging toward the surface. This condition was documented at the lower-basin monitoring-well cluster (AB OW-2) located about 1,100 m downstream from this area, where water-level hydrographs (fig. 6 B) illustrate uniform upward hydraulic gradients from deep in the aquifer system to the water table. At the middle well cluster of the ABHT4 transect, located in the wetlands near the edge of the swamp, the hydraulic gradient was upward in April, indicating a potential for groundwater discharge to the wetlands and swamp in this area. Water levels in these wells were equal in September, indicating that local groundwater discharge likely had ceased and that shallow flow probably was horizontal toward the swamp and stream in this area. The hydraulic gradients at the near-stream well pair and beneath the stream were upward during both periods, indicating probable persistent groundwater discharge to the Albertson Brook in that area.

Transect ABHT5, on the northeasterly side of the Albertson Brook near the lower basin boundary, extends more than 120 m from the uplands through the wetlands to the stream. The well cluster that is farthest upland is near a low topographic divide separating the Albertson Brook basin from the Gun Branch basin (fig. 2). Previous descriptions of the hydrologic relation between these basins indicated that Gun Branch could be losing water to Albertson Brook in some areas.

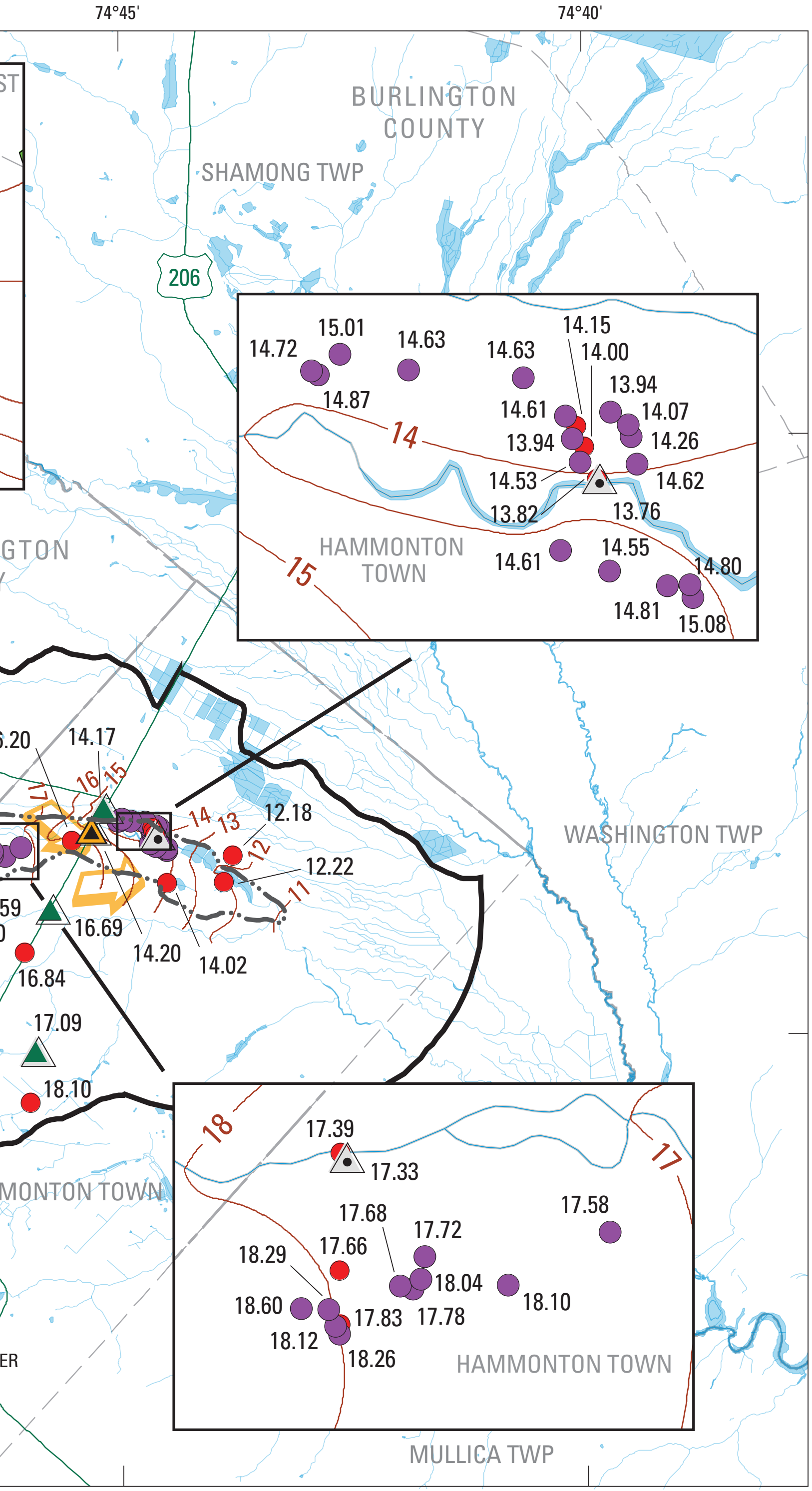
The farthest upland well cluster in this transect showed a large downward hydraulic gradient in April and a small upward gradient in September (fig. 14). The April 2005 water levels describe a water table that slopes gently toward the Albertson Brook with upward hydraulic gradients near and beneath the stream, which indicate that groundwater probably was discharging to the wetland and stream in this area.

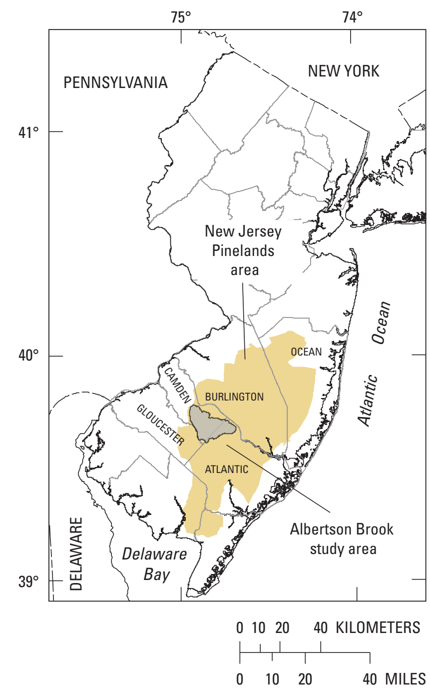
By the time of the September synoptic measurement, the Gun Branch was dry and water levels in the transect wells




Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 10.** Altitude of water table, Albertson Brook study area, New Jersey Pinelands, April 2005.




EXPLANATION

Albertson Brook study-area boundary

Albertson Brook drainage-basin boundary

30 Altitude of water table, in meters. Datum is NAVD 88

27.47 Location of well monitored by U.S. Geological Survey. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

21.27 Location of well installed and monitored by the NJ Pinelands Commission. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

Start-of-flow, April 2005

Arrow indicates area where ground-water may be leaving the basin

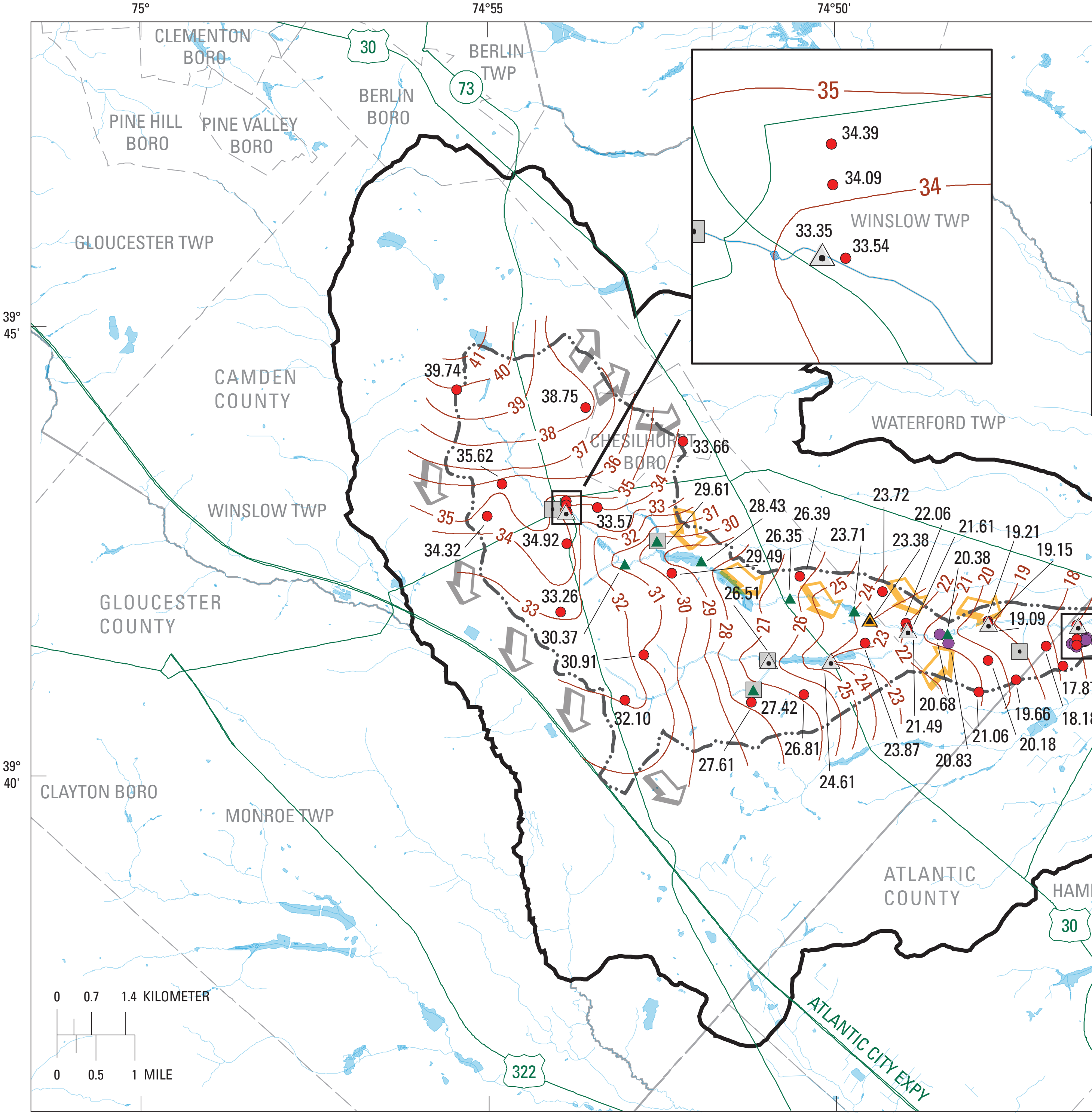
Arrow indicates area where ground-water may be entering the basin

U.S. Geological Survey surface-water site. Label is water-level altitude, in meters, as shown in table 2. Datum is NAVD 88

21.64 Partial-record station

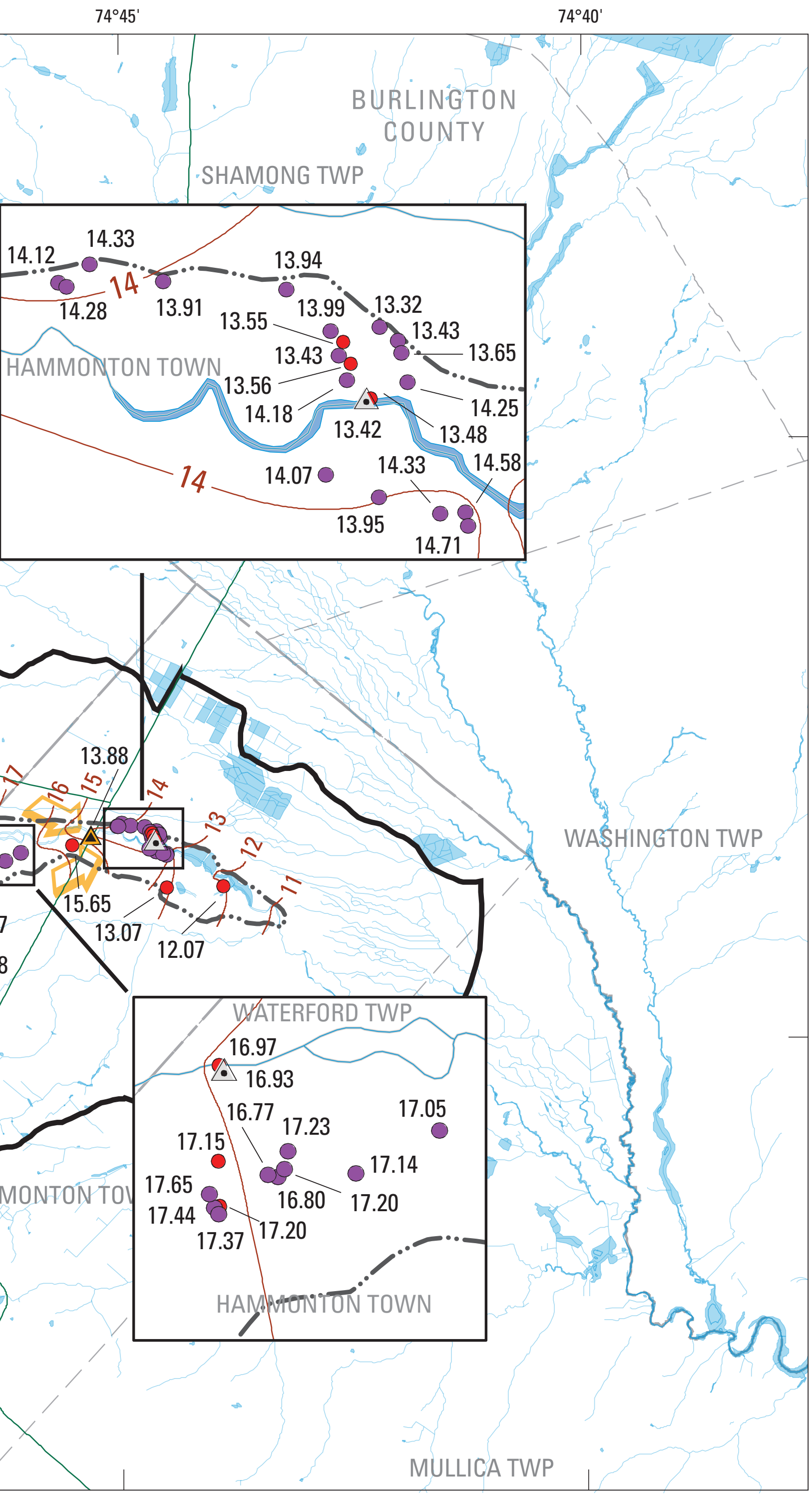
23.17 U.S. Geological Survey streamgage

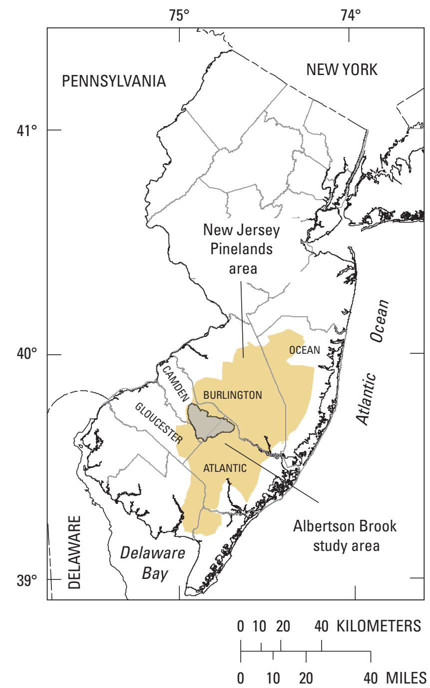
22.75 Stream point




Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 11.** Altitude of water table, Albertson Brook study area, New Jersey Pinelands, September 2005.




EXPLANATION

Albertson Brook study-area boundary

Albertson Brook drainage-basin boundary

30 — Altitude of water table, in meters. Datum is NAVD 88

17.15 ● Location of well monitored by U.S. Geological Survey. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

17.05 ● Location of well installed and monitored by the NJ Pinelands Commission. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

Start-of-flow, September 2005

Arrow indicates area where ground-water may be leaving the basin

Arrow indicates area where ground-water may be entering the basin

U.S. Geological Survey surface-water site. Label is water-level altitude, in meters, as shown in table 2. Datum is NAVD 88

16.93 Partial-record station

13.88 U.S. Geological Survey streamgage

20.38 Stream point

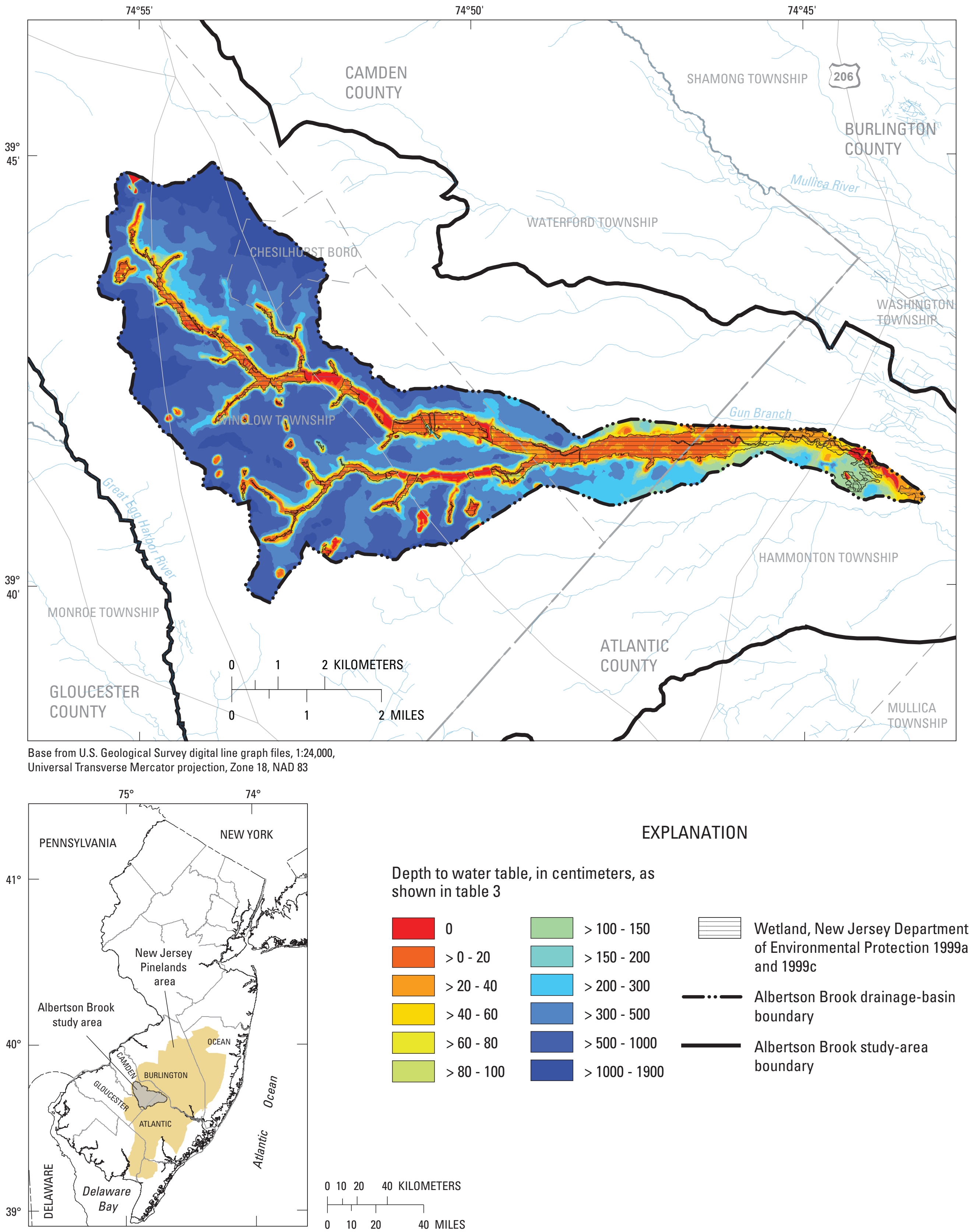



**Figure 12.** Depth to water table, Albertson Brook basin, New Jersey Pinelands, April 2005.

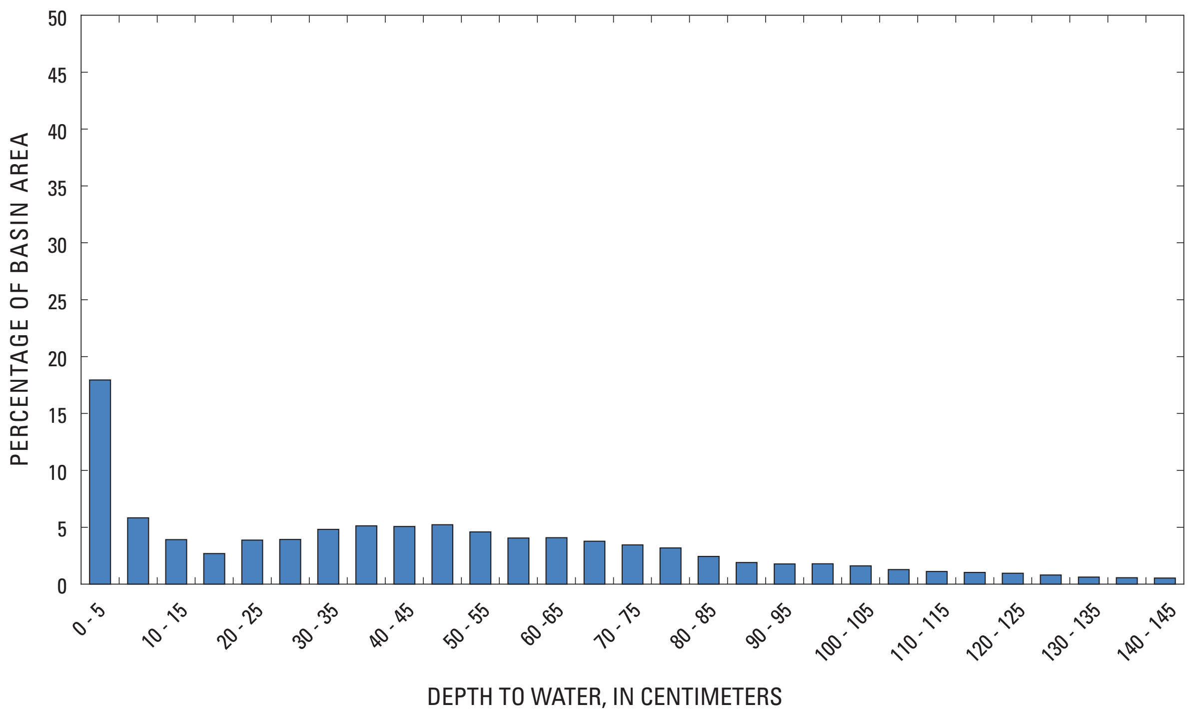



**Figure 13.** Histogram showing percentage distribution of depth to water in Albertson Brook basin, Albertson Brook study area, New Jersey Pinelands, April 2005. (Areas where 5-centimeter intervals of depth to water exceed 145 centimeters occupy less than 2 percent of the basin area and are not shown.)

had declined about 0.5 m, resulting in no apparent horizontal hydraulic gradient from the uplands to the middle well cluster (fig. 14), indicating little or no horizontal groundwater flow toward the stream in this area. The vertical hydraulic gradient at the middle well cluster also was only slightly downward in April, and there was no vertical gradient in September, indicating that groundwater flow at this location if any, probably was largely horizontal toward the stream during both periods. Between the middle well cluster and the wetlands, the apparent horizontal hydraulic gradient in September was similar to that in April. Substantial vertical hydraulic gradients were measured in the wetlands and beneath the stream during both months, indicating that deep groundwater flow that originated farther upstream in the basin probably begins to discharge to the surface in the wetlands and likely increases toward the stream. The upward hydraulic gradients near the stream were smaller in September than in April, but the upward gradient beneath the stream was slightly larger in September, indicating that the strongest hydraulic potential for groundwater discharge along this transect probably was beneath the stream. A regionally extensive but discontinuous, leaky confining layer identified by Walker and others (2008) at a depth of almost 13 m beneath transect ABHT5 could act to isolate the water table locally from the deeper groundwater. The extent to which this layer may affect groundwater discharge to the stream cannot be ascertained from the available data. During periods of high water levels, however, most groundwater discharge to the wetlands and stream at this location appears to be from the shallow part of the aquifer system and likely includes water from the Gun Branch basin. The larger upward hydraulic gradients measured beneath the stream in September probably indicate the influence of water levels in the deeper part of aquifer system, either directly through upward vertical leakage, or indirectly at locations where the leaky confining layer may be absent locally or hydraulically more conductive.

Stream base-flow measurements and the observed start-of-flow locations for both the April and September 2005 synoptic measurements show that base flow ranged from 0.003 to 0.031 $m^3/s$ at the uppermost measuring site on the Pump Branch and from 0.275 to 1.10 $m^3/s$ at the lowermost measuring site on the Albertson Brook in September and April 2005. During September, the base-flow measurements indicated that discharge increased downstream, except at station 0140940990, the third site above the lower drainage-basin boundary (figs. 2 and 15). A comparison of this discharge with that at the site immediately upstream (0140940972) reveals a possible losing reach, as discharge declined 0.026 $m^3/s$ (from 0.261 to 0.235 $m^3/s$) between the two sites (fig. 15, table 4). This apparent loss in streamflow, although not well understood, may be attributable to a local groundwater withdrawal in the area or to a discharge-measurement error, or a combination of factors. Groundwater withdrawal for agricultural irrigation, however, is known to occur during the spring and summer growing season at locations upstream from station

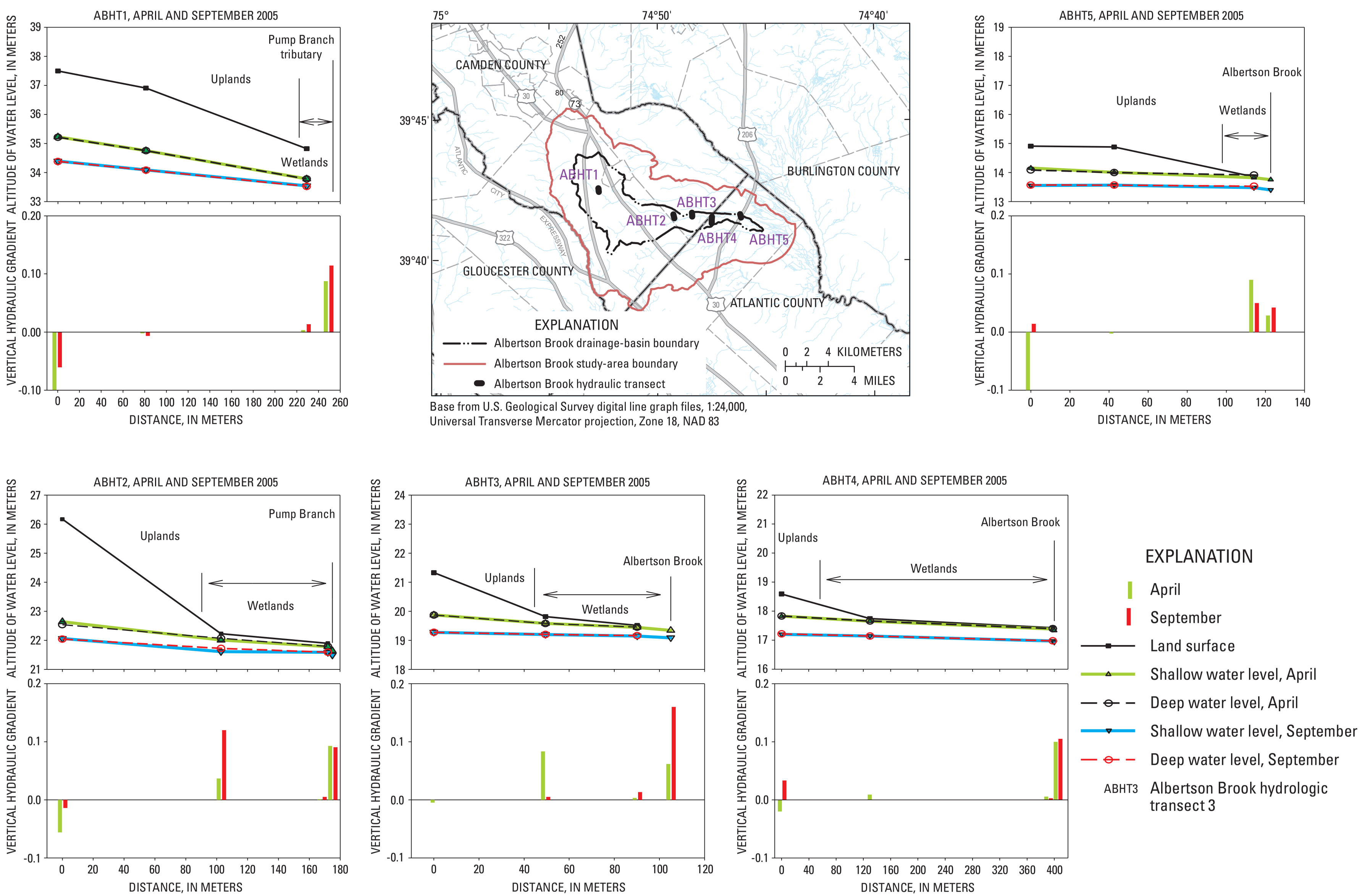



**Figure 14.** Location of five wetlands hydrologic transects and graphs showing water levels and hydraulic gradients along the transects during high (April) and low (September) flow, Albertson Brook basin, New Jersey Pinelands, 2005. (Vertical datum is NAVD 88)

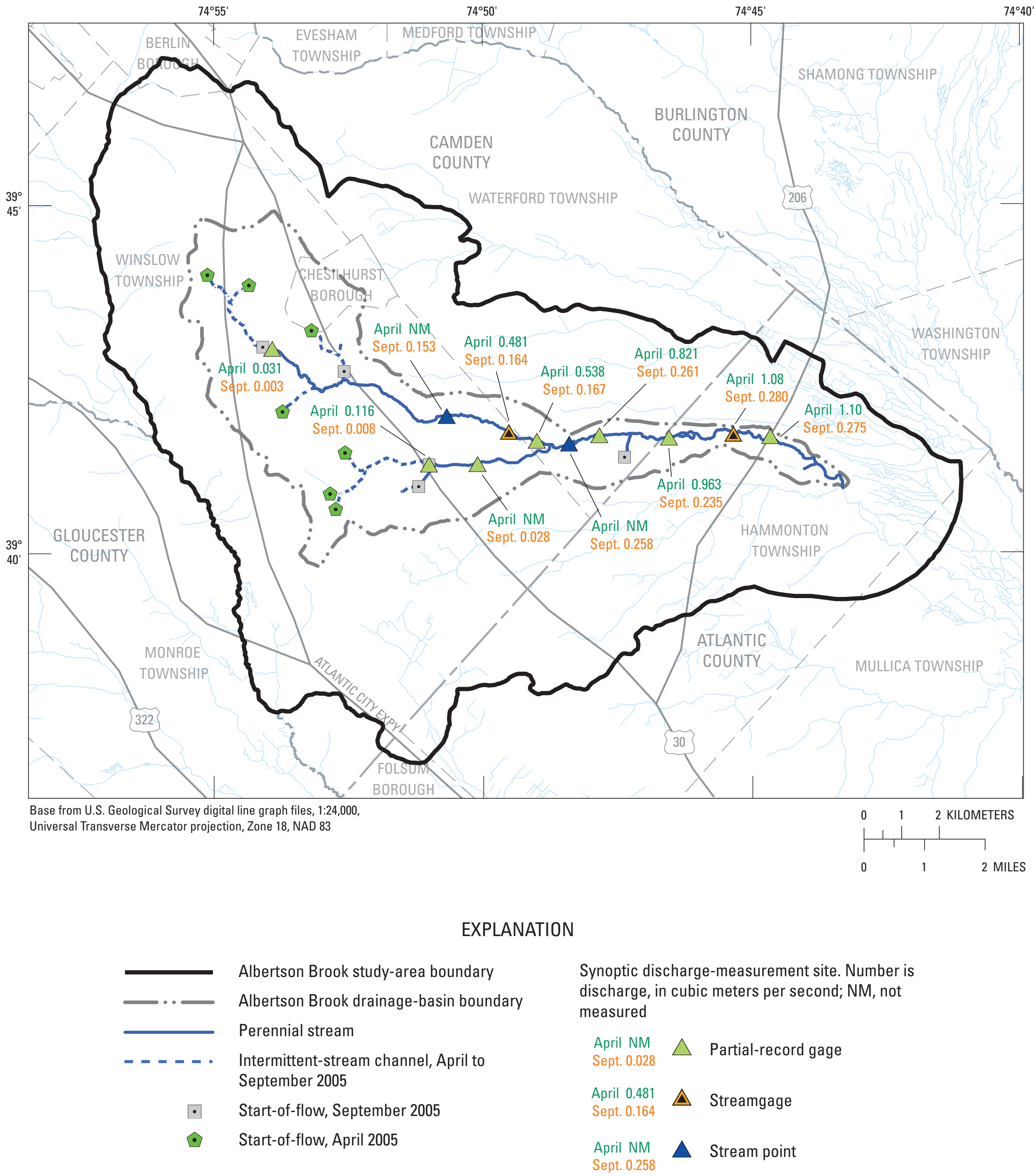



**Figure 15.** Surface-water discharge at selected locations, Albertson Brook basin, New Jersey Pinelands, April and September 2005.

**Table 4.** Base-flow measurements for selected streams in three drainage basins, New Jersey Pinelands, spring and summer, 2005.

[--, data unavailable. Site identifier: number is U.S. Geological Survey station identification number. Site type: CRGS, continuous-record streamflow-gaging station; HT, hydrologic transect; PRS, low-flow partial-record station; seep, seepage site used to measure water level; $m^3/s$, cubic meter per second]

| Site identifier | Site name | Site type | Base flow, spring 2005 ($m^3/s$) | Base flow, summer 2005 ($m^3/s$) | Ratio: spring base flow divided by summer[1] base flow |
|---|---|---|---|---|---|
| | | Albertson Brook basin | | | |
| 0140940607 | Pump Branch at Cedar Brook, NJ | PRS, seep, staff gage, HT | 0.031 | 0.003 | 10.3 |
| 01409408 | Pump Branch near Waterford Works, NJ | PRS, seep | -- | 0.153 | -- |
| 0140940810 | Pump Branch near Elm, NJ | CRGS, seep, staff gage | 0.481 | 0.164 | 2.9 |
| 0140940820 | Pump Branch above Blue Anchor Brook near Elm, NJ | PRS, seep, staff gage, HT | 0.538 | 0.167 | 3.2 |
| 01409409 | Blue Anchor Brook near Blue Anchor, NJ | PRS, seep, staff gage | 0.116 | 0.008 | 14.5 |
| 0140940950 | Blue Anchor Brook at Elm, NJ | PRS, seep | -- | 0.028 | -- |
| 0140940970 | Albertson Brook near Elm, NJ | PRS | -- | 0.258 | -- |
| 0140940972 | Albertson Brook below Railroad Bridge near Elm, NJ | PRS, seep, staff gage, HT | 0.821 | 0.261 | 3.1 |
| 0140940990 | Albertson Brook 1.3 miles above U.S. Route 206 near Atsion, NJ | PRS, seep, staff gage, HT | 0.963 | 0.235 | 4.1 |
| 01409410 | Albertson Brook near Hammonton, NJ | CRGS, staff gage | 1.08 | 0.280 | 3.9 |
| 0140941010 | Albertson Brook 0.8 miles below U.S. Route 206 near Atsion, NJ | PRS, seep, staff gage, HT | 1.10 | 0.275 | 4.0 |
| | | McDonalds Branch basin | | | |
| 01466460 | McDonalds Branch 650ft above Butler Place Road in Byrne State Forest, NJ | PRS, seep, staff gage, HT | 0.006 | 0.0 | U |
| 01466500 | McDonalds Branch in Byrne State Forest, NJ | CRGS, seep, staff gage | 0.085 | 0.031 | 2.7 |
| 01466510 | McDonalds Branch 2000ft downstream of gage in Byrne State Forest, NJ | PRS, seep | 0.108 | 0.037 | 2.9 |
| 01466520 | McDonalds Branch Tributary in Byrne State Forest, NJ | PRS, seep, staff gage, HT | 0.006 | 0.0 | U |
| 01466550 | McDonalds Branch near Presidential Lakes, NJ | PRS, seep, staff gage, HT | 0.176 | 0.065 | 2.7 |
| 01466590 | McDonalds Branch at McDonalds, NJ | PRS, seep | -- | 0.037 | -- |
| 01466600 | McDonalds Branch at Cooper Road at McDonalds, NJ | PRS, seep | 0.623 | -- | -- |
| | | Morses Mill Stream basin | | | |
| 01410217 | Morses Mill Stream at West Duerer Street near Pomona, NJ | PRS, seep, staff gage, HT | 0.022 | 0.0 | U |
| 01410218 | Morses Mill Stream at Zurich Avenue near Pomona, NJ | PRS, seep, staff gage, HT | 0.057 | 0.001 | 57.0 |
| 01410221 | Morses Mill Stream Tributary below Sand Road near Pomona, NJ | PRS, seep, staff gage, HT | 0.019 | -- | -- |
| 01410222 | Morses Mill Stream at College Drive near Pomona, NJ | PRS, seep | 0.183 | 0.011 | 16.6 |
| 01410223 | Morses Mill Stream at Garden State Parkway near Pomona, NJ | PRS, seep, staff gage, HT | 0.246 | 0.021 | 11.7 |
| 01410225 | Morses Mill Stream at Port Republic, NJ | CRGS, seep, staff gage | 0.283 | 0.059 | 4.8 |

[1]Ratio of spring base flow divided by summer base flow is undefined where summer base flow is zero.

0140940990 and more than 300 m south of Albertson Brook. This water use might have contributed to the apparent reduction in stream discharge, but the apparent streamflow loss also is approximately equal to the acceptable percent error for the discharge measurement.

Locations of start-of-flow observed in surface water during the April and September 2005 synoptic measurements (fig. 15) are shown with a dashed line indicating the possible range of the seasonally intermittent stream channel defined by the two field observations. Base-flow discharge ratios (spring streamflow/summer streamflow) were calculated for the April and September 2005 synoptic measurements in the Albertson Brook basin (table 4). Base-flow discharge ratios in the upper basin areas (12 and 14) of the Albertson Brook basin were three to four times greater than those in the lower basin, respectively. Base-flow discharge ratios were largest where the contributing drainage areas were small and smallest where drainage areas were the largest, providing a relative indication of the size of the drainage area contributing to streamflow via groundwater discharge at a given location. Groundwater that discharges to the surface in upper-basin areas, which are mostly recharge areas, typically flows along localized, relatively short flow paths when water levels are high. As groundwater levels decline, discharge to surface water at a given location may cease entirely, causing groundwater to follow longer flow paths to points of discharge farther downstream. Because stream reaches in the lower basin areas receive groundwater discharge that travels along both local, shorter flow paths and deeper, longer flow paths, however, base flow is more persistent, and discharge ratios are smaller than in upper-basin areas.

## Water Budget

The water budget below includes values for all applicable components of the hydrologic cycle in the Albertson Brook drainage basin and accounts for all known gains and losses to or from the system. The basin water budget was developed on a monthly basis. The period of this analysis is October 2004–September 2006.

The following equations were used to calculate the water budget for the Albertson Brook drainage basin.

Land-surface components:

$$R_s = P \pm \Delta S_{sm} - Q_{dr} - ET - W_s \;, \qquad (4)$$

where

$R_s$ = recharge to the aquifer system,
$P$ = precipitation,
$\Delta S_{sm}$ = change in soil moisture,
$Q_{dr}$ = direct runoff,
$ET$ = evapotranspiration,
$W_s$ = surface-water withdrawals/diversions, and

Groundwater components:

$$R_g = Q_b + W_g \pm L \pm \Delta S_{gw} - D_{ag} \pm R_i \;, \qquad (5)$$

where

$R_g$ = recharge to the aquifer system,
$Q_b$ = base flow,
$W_g$ = groundwater withdrawals,
$L$ = leakage to confined aquifers,
$\Delta S_{gw}$ = change in groundwater storage,
$D_{ag}$ = artificial discharge to the aquifer system,
$R_i$ = groundwater inflow to/outflow from adjacent basins. (There were no known artificial discharges to surface water ($D_{as}$) or changes in surface-water storage ($\Delta S_{sw}$) in the Albertson Brook drainage basin during the study period.)

Average annual precipitation in the Albertson Brook drainage basin during the study period was 114 cm (table 5). Monthly precipitation typically is fairly uniform through the year and is evenly distributed throughout the basin. Monthly precipitation averaged 9.5 cm and ranged from 1.04 cm in September 2005 to 25.2 cm in October 2005 (fig. 16, table 5).

Average annual *ET* in the Albertson Brook drainage basin during the study period was 56.1 cm—the smallest value among the three basins–probably because the Albertson Brook basin has the smallest percentage of wetlands. Monthly *ET* averaged 4.7 cm and ranged from 0.5 cm in December 2004 to 11.0 cm in July 2006. *ET* from the basin was equivalent to 49 percent of precipitation on an annual basis. This loss, however, varied widely throughout the year. In winter, when *ET* was minimal, it was less than one-tenth the precipitation. During some summer months, nearly all precipitation was lost to *ET*, and recharge to the underlying aquifer was minimal. *ET* exceeded precipitation during May, June, August, and September 2005 and May 2006.

Direct runoff of precipitation in the basin was relatively small, averaging 0.5 cm/mo during the study period. Monthly values ranged from zero cm in September 2005 to 3.1 cm in October 2005. Direct recharge of the aquifer system through infiltration of precipitation averaged 52.3 cm annually and typically was greatest during the winter months when *ET* was minimal.

During the study period, recharge during winter months (December-February) averaged about 6.4 cm/mo. During summer months (July-September) when *ET* was greatest recharge averaged about 1.9 cm/mo. Annual base flow in the basin during the study period represented 89 percent of annual streamflow. In September 2005, the month with the least precipitation during the study period, base flow accounted for 100 percent of streamflow. In October 2005, the wettest month during the 2-year period, base flow represented 46 percent of streamflow. Changes in storage of soil moisture during the study period had a moderate effect on the water budget.

**Table 5.** Basin water budget for Albertson Brook, Atlantic and Camden Counties, New Jersey Pinelands, 2005–06.

[All values are in centimeters; recharge values determined as a residual may be different from computed values due to rounding]

Land-surface budget

| Date | Precipitation | Discharge to surface-water | Change in surface-water storage | Change in soil-moisture storage | Direct runoff | Evapotran-spiration | Surface-water with-drawals | Recharge |
|---|---|---|---|---|---|---|---|---|
| Oct-04 | 8.2 | 0 | 0 | 0.5 | 0.3 | 3.7 | 0 | 4.7 |
| Nov-04 | 12.1 | 0 | 0 | -2.1 | 0.5 | 1.9 | 0 | 7.6 |
| Dec-04 | 7.7 | 0 | 0 | 1.2 | 0.4 | 0.5 | 0 | 8 |
| Jan-05 | 8.2 | 0 | 0 | -0.4 | 0.3 | 0.5 | 0 | 7 |
| Feb-05 | 5.4 | 0 | 0 | -0.5 | 0.2 | 1.3 | 0 | 3.5 |
| Mar-05 | 9.9 | 0 | 0 | -0.5 | 0.5 | 1.9 | 0 | 7 |
| Apr-05 | 10.8 | 0 | 0 | 1.4 | 0.5 | 4.6 | 0.01 | 7 |
| May-05 | 6.5 | 0 | 0 | 1 | 0.3 | 6.6 | 0.02 | 0.6 |
| Jun-05 | 6.4 | 0 | 0 | 1 | 0.1 | 9.3 | 0.02 | -2.1 |
| Jul-05 | 13.3 | 0 | 0 | 2.3 | 1.1 | 10.5 | 0.02 | 4 |
| Aug-05 | 8.5 | 0 | 0 | 2 | 0.1 | 9.4 | 0.02 | 1 |
| Sep-05 | 1 | 0 | 0 | 1 | 0 | 6.6 | 0.02 | -4.5 |
| Oct-05 | 25.2 | 0 | 0 | -7.2 | 3.2 | 3.5 | 0.02 | 11.4 |
| Nov-05 | 9.9 | 0 | 0 | -1.1 | 0.4 | 1.9 | 0 | 6.4 |
| Dec-05 | 8.6 | 0 | 0 | 0.4 | 0.4 | 0.6 | 0 | 8 |
| Jan-06 | 11.6 | 0 | 0 | 0.2 | 0.7 | 1.6 | 0 | 9.5 |
| Feb-06 | 3.6 | 0 | 0 | 0.1 | 0.1 | 1 | 0 | 2.6 |
| Mar-06 | 2.2 | 0 | 0 | 3.2 | 0 | 1.7 | 0.01 | 3.6 |
| Apr-06 | 7.9 | 0 | 0 | -0.4 | 0.2 | 4.1 | 0.02 | 3.1 |
| May-06 | 6.2 | 0 | 0 | 2 | 0.2 | 6.6 | 0.02 | 1.4 |
| Jun-06 | 16.1 | 0 | 0 | -3.5 | 0.4 | 8.4 | 0.02 | 3.8 |
| Jul-06 | 13.9 | 0 | 0 | 4 | 1.1 | 11 | 0.02 | 5.8 |
| Aug-06 | 8.7 | 0 | 0 | -0.7 | 0.3 | 8.7 | 0.03 | -1 |
| Sep-06 | 15.9 | 0 | 0 | -2.7 | 0.9 | 6.2 | 0.01 | 6.1 |
| Monthly average | 9.5 | 0 | 0 | 0.05 | 0.5 | 4.7 | 0.01 | 4.4 |
| Annual average | 113.8 | 0 | 0 | 0.6 | 6 | 56.1 | 0.1 | 52.3 |

Groundwater budget

| Date | Base flow | Groundwater withdrawals | Leakage | Change in groundwater storage | Artificial recharge | Ground-water inflow or outflow | Recharge |
|---|---|---|---|---|---|---|---|
| Oct-04 | 3.9 | 0.4 | 0.06 | -1 | 0.07 | -0.03 | 3.4 |
| Nov-04 | 4.3 | 0.3 | 0.06 | 0.5 | 0.07 | -0.03 | 5.2 |
| Dec-04 | 5.3 | 0.4 | 0.06 | -1.6 | 0.07 | -0.03 | 4.1 |
| Jan-05 | 5.1 | 0.4 | 0.06 | -0.2 | 0.07 | -0.03 | 5.3 |
| Feb-05 | 4.5 | 0.3 | 0.06 | 1.1 | 0.07 | -0.03 | 6 |
| Mar-05 | 5.5 | 0.4 | 0.06 | 1.4 | 0.07 | -0.03 | 7.2 |
| Apr-05 | 6.7 | 0.5 | 0.06 | 1.9 | 0.07 | -0.03 | 9.1 |
| May-05 | 5.2 | 0.5 | 0.06 | -0.3 | 0.07 | -0.03 | 5.5 |
| Jun-05 | 3.3 | 0.7 | 0.06 | -1.2 | 0.06 | -0.03 | 2.8 |
| Jul-05 | 3.5 | 0.8 | 0.06 | -1.5 | 0.07 | -0.03 | 2.8 |

**Table 5.** Basin water budget for Albertson Brook, Atlantic and Camden Counties, New Jersey Pinelands, 2005–06.—Continued

[All values are in centimeters; recharge values determined as a residual may be different from computed values due to rounding]

| Groundwater budget—Continued | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Base flow** | **Groundwater withdrawals** | **Leakage** | **Change in groundwater storage** | **Artificial recharge** | **Ground-water inflow or outflow** | **Recharge** |
| Aug-05 | 2.4 | 0.8 | 0.06 | -1.7 | 0.07 | -0.03 | 1.5 |
| Sep-05 | 1.4 | 0.6 | 0.06 | -3.3 | 0.06 | -0.03 | -1.3 |
| Oct-05 | 2.6 | 0.5 | 0.06 | 4.2 | 0.07 | -0.03 | 7.4 |
| Nov-05 | 3.7 | 0.4 | 0.06 | 0 | 0.06 | -0.03 | 4.1 |
| Dec-05 | 5 | 0.4 | 0.06 | -1.4 | 0.07 | -0.03 | 4.1 |
| Jan-06 | 6.1 | 0.4 | 0.06 | 2 | 0.07 | -0.03 | 8.5 |
| Feb-06 | 5 | 0.4 | 0.06 | 0.9 | 0.06 | -0.03 | 6.3 |
| Mar-06 | 4.3 | 0.4 | 0.06 | -0.2 | 0.07 | -0.03 | 4.5 |
| Apr-06 | 3.9 | 0.4 | 0.06 | -0.3 | 0.06 | -0.03 | 4.1 |
| May-06 | 3.1 | 0.6 | 0.06 | -2.1 | 0.07 | -0.03 | 1.6 |
| Jun-06 | 3 | 0.6 | 0.06 | 0.9 | 0.07 | -0.03 | 4.5 |
| Jul-06 | 3.7 | 0.6 | 0.06 | 0.4 | 0.07 | -0.03 | 4.8 |
| Aug-06 | 2.5 | 0.7 | 0.06 | -0.8 | 0.07 | -0.03 | 2.5 |
| Sep-06 | 4.7 | 0.6 | 0.06 | -0.2 | 0.07 | -0.03 | 5.1 |
| Monthly average | 4.1 | 0.5 | 0.06 | -0.1 | 0.07 | -0.03 | 4.5 |
| Annual average | 49.3 | 6 | 0.7 | -1.2 | 0.8 | -0.4 | 54.4 |

Monthly changes in soil-moisture storage ranged from 4.0 cm in July 2006 (a decrease in soil moisture) to -7.2 cm in October 2005 (an increase in soil moisture). Average annual change in storage during the 2-year study period was 0.6 cm, indicating a slight decrease in soil moisture over the study period. During this period, groundwater levels declined slightly, representing a net loss in storage of 1.2 cm/yr. Monthly changes in groundwater storage ranged from -3.3 cm in September 2005 (a decline in water level) to 4.2 cm in October 2005 (an increase in water level) (fig.17, table 5).

In general, groundwater withdrawals and surface-water diversions in the Albertson Brook basin are small, as are artificial discharges to groundwater and surface water. Annually, groundwater withdrawals and surface-water diversions combined account for about 5 percent of the total precipitation, and groundwater withdrawals account for about 11 percent of recharge (fig. 17). Withdrawals in the basin typically are greatest in summer, when withdrawals for irrigation are greatest. Although there are few public-supply wells in the basin, they account for most of the withdrawals.

Estimated net vertical leakage to underlying confined aquifers was 0.06 cm/mo, and estimated net horizontal groundwater outflow to adjacent basins was 0.03 cm/mo. To evaluate the agreement between the land-surface and groundwater components of the water-budget calculations, recharge values calculated using the land-surface equation were compared to those calculated using the groundwater equation (fig. 18). Estimates were generally in fairly close agreement, to within a few centimeters. Differences in monthly recharge estimates ranged from -5.0 cm in June 2005 to +4.1 cm in October 2005. The average difference was -0.2 cm.

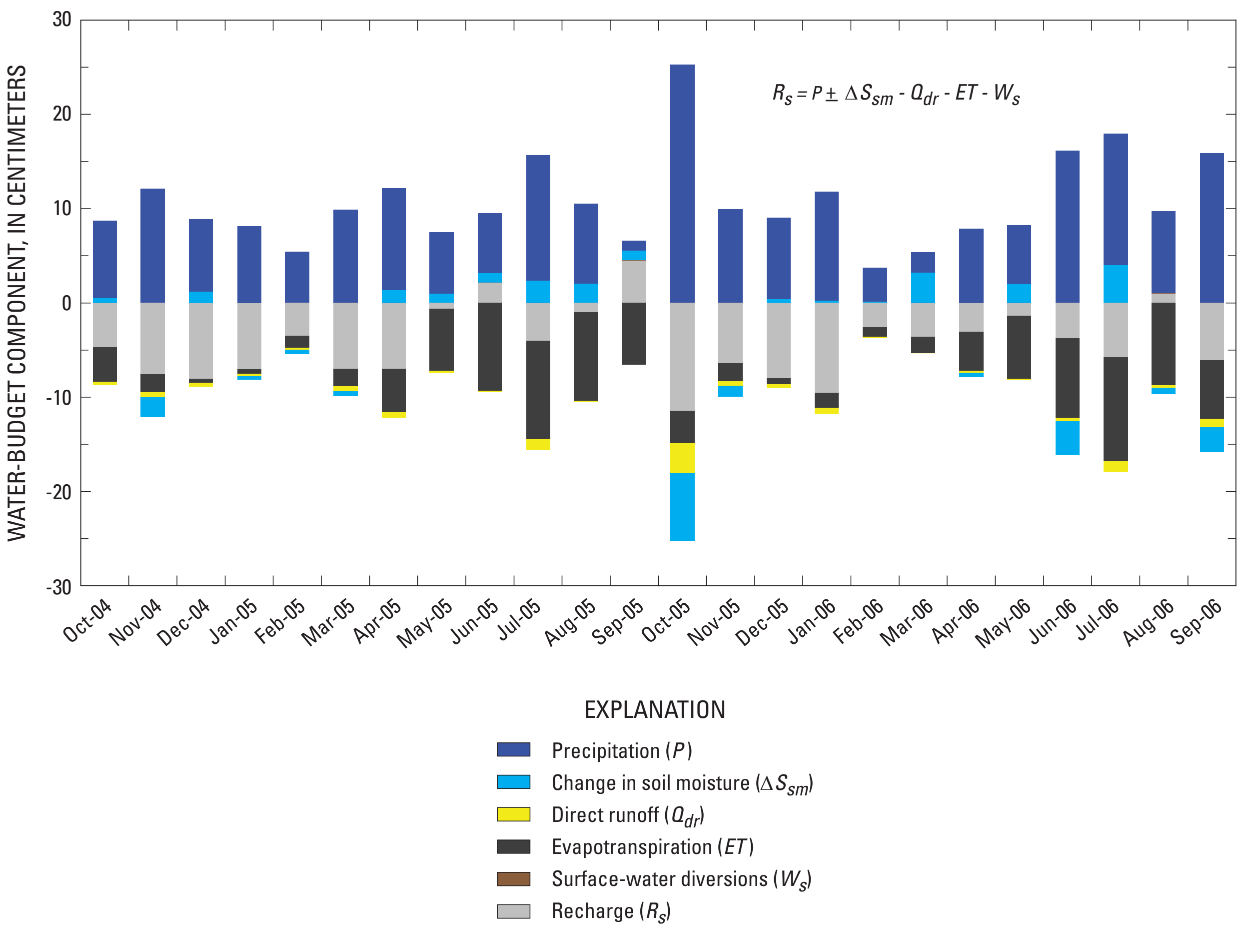



**Figure 16.** Components of the land-surface water budget by month, Albertson Brook basin, New Jersey Pinelands, water years 2005–06.

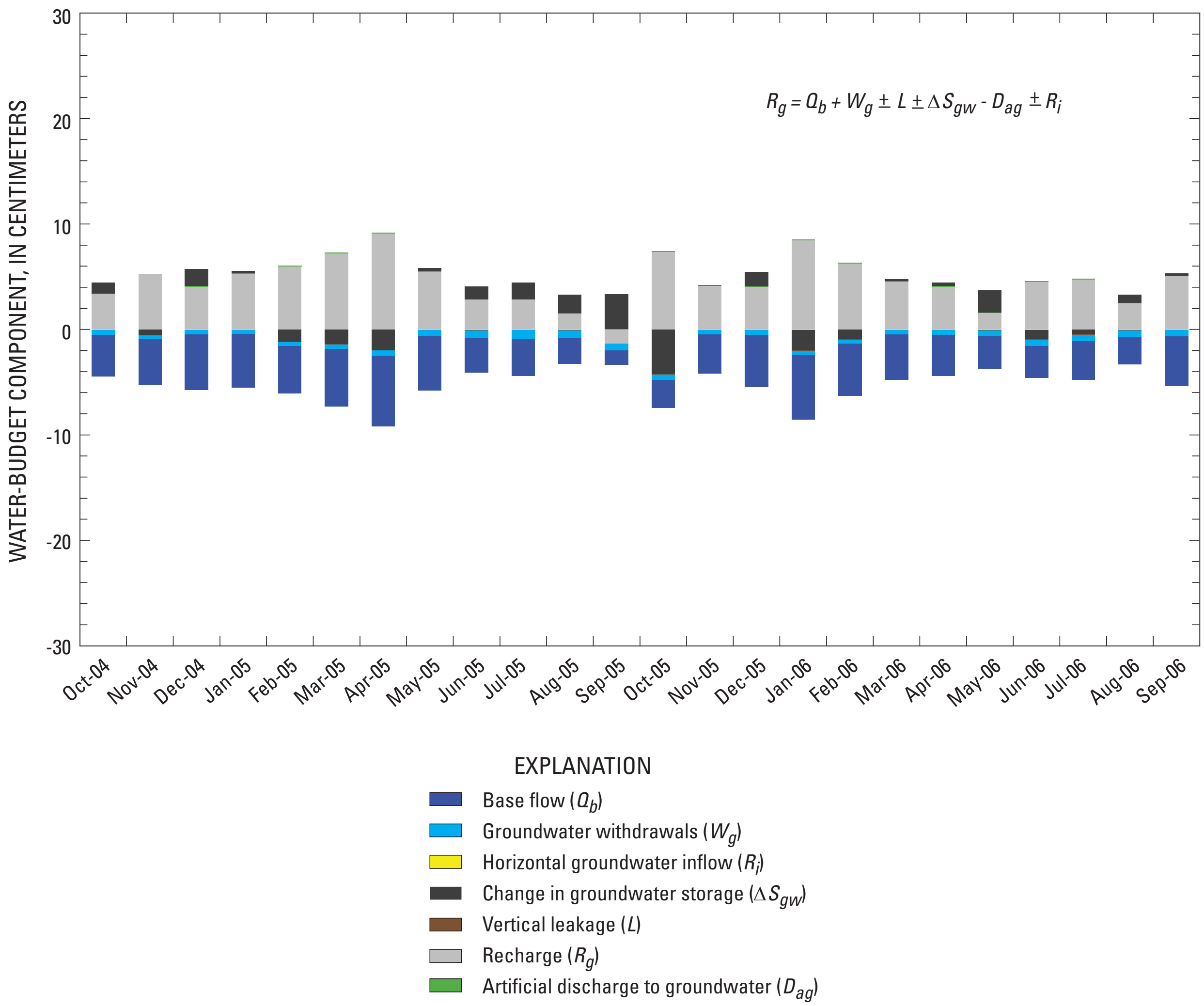



**Figure 17.** Components of the groundwater budget by month, Albertson Brook basin, New Jersey Pinelands, water years 2005–06.

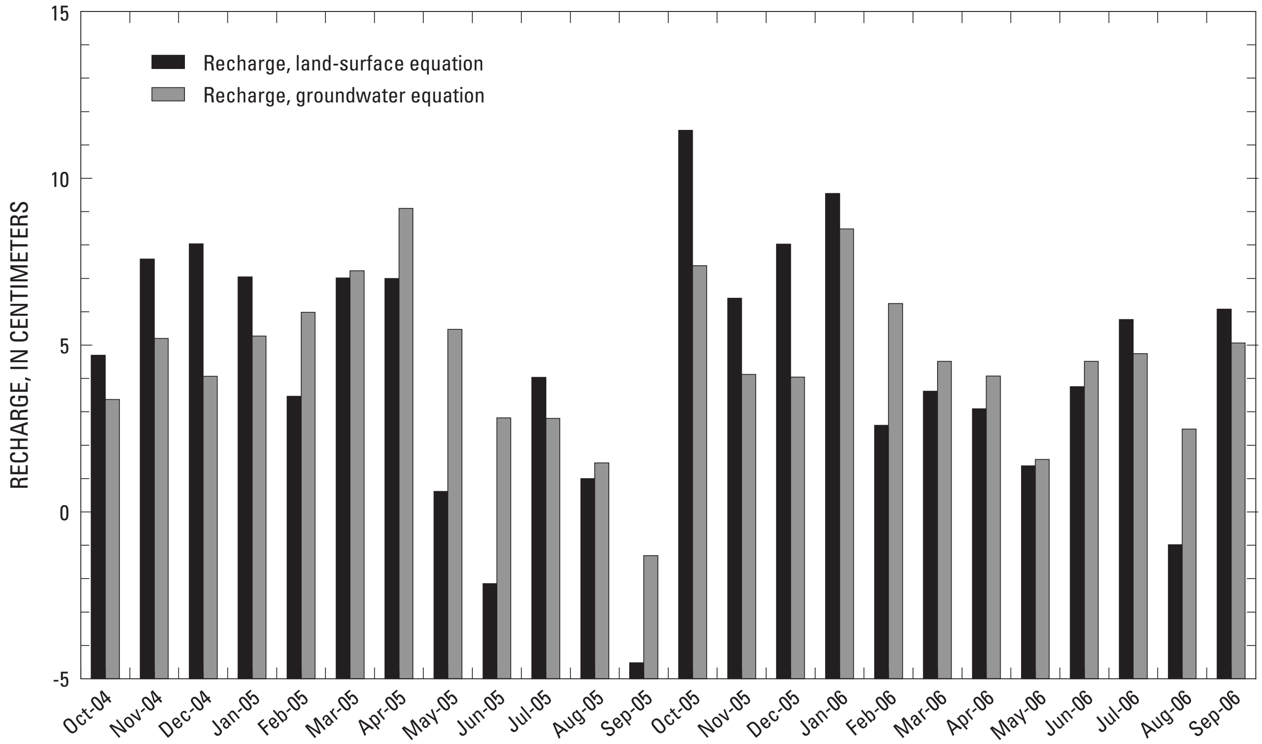



**Figure 18.** Comparison of monthly land-surface and groundwater recharge, Albertson Brook basin, New Jersey Pinelands, water years 2005–06.

## McDonalds Branch Study Area

The McDonalds Branch study area represents a range of hydrologic and geologic features that are found in other areas of the Pinelands. Most of the basin and study area is composed of Brendan Byrne State Forest land and is largely undeveloped. The headwaters of the McDonalds Branch basin lie on the western side of the topographic divide between the Delaware River and Atlantic Coastal basins. Hardwood and pine wetlands and cedar swamps surround the McDonalds Branch, and most of the drainage basin currently is largely undisturbed by human activity. In the headwaters of the drainage basin, a large wetland is supported by an extensive shallow clay layer (Walker and others, 2008). This wetland contributes both surface-water and groundwater to the streamflow in the upper part of McDonalds Branch. Farther downstream, the McDonalds Branch broadens to an open channel surrounded by mixed pine and hardwood wetlands and eventually flows into the large cedar swamp where USGS streamflow-gaging station 01466500 is located (fig. 3). A weir just upstream from a narrow paved road provides a stable control for the gaging station and maintains the water level in the cedar swamp at a relatively natural level. Below the weir, a box culvert passes beneath the road and empties into a manmade channel that was constructed prior to 1964 (R. Schopp, U.S. Geological Survey, New Jersey Water Science Center, oral communication, August 20, 2010) to a depth of about 1 m below the natural cedar-swamp altitude. The lowered stream channel probably altered the natural flow paths of groundwater that originally discharged to the stream in this area. Farther downstream, a patchwork of cedar and hardwood wetlands extends into the lower part of the McDonalds Branch basin. Still farther on, the McDonalds Branch flows through an active cranberry bog that occupies Brendan Byrne State Forest land that is leased for commercial cranberry production.

During the spring and summer months, operation of the cranberry bog involves accumulating and maintaining a reservoir of water adjacent to, and at the upstream limit of, the bog. In the fall, this upstream reservoir is released to flood the bogs for the harvest. A similar high water level was maintained during the winter to protect the cranberry plants from freezing. After the danger of frost has passed, usually sometime in April, the bog is drained and a controlled lower level is maintained during the growing season while the upstream reservoir is replenished. Below the active cranberry bogs, the McDonalds Branch flows through additional long-abandoned and unused bogs that are no longer managed to retain or alter the streamflow. The drainage basin ends just downstream from the unused bogs at the confluence of the McDonalds Branch with an adjacent tributary that drains areas southwest of McDonalds Branch.

## Groundwater Levels

During the period October 1, 2004, to September 30, 2006, water-level data were recorded continuously in six basin-monitoring wells arranged in two three-well clusters located in upland areas in the upper and lower parts of the McDonalds Branch basin (fig. 3). Each of the three wells in each cluster is screened in one of the three aquifers that lie between the water table and the base of the Kirkwood-Cohansey aquifer system (Walker and others, 2008). The hydrographs for these wells (fig. 19) show that daily mean water levels fluctuated up to 0.8 m in the upper-basin monitoring wells and about 0.5 m in the lower-basin monitoring wells. As in the Albertson Brook basin, the seasonal water-level extremes in the upper part of the McDonalds Branch basin tend to lag behind those in the lower part of the basin. Hydraulic gradients generally are downward at the upper-basin well cluster, indicating recharge conditions at this location, and upward at the lower-basin well cluster, indicating a potential for upward groundwater flow toward nearby discharge areas (fig. 19).

At the upper-basin monitoring-well cluster, the water level in well 050689–Lebanon SF 23-D OBS–screened in the unconfined aquifer layer MB A-1 was more than 0.3 m higher than that in basin-monitoring well 051557–MB OW-1M screened in the middle aquifer layer MB A-2 (Walker and others, 2008). The deepest monitoring well in the upper-basin cluster, 051556-MB OW-1D, was screened in the lower aquifer layer, MB A-3 (Walker and others, 2008). Water levels in these middle and lower aquifer wells were nearly identical (fig. 19A) even though their screened intervals are separated by a dense clay layer more than 15 m thick, referred to as layer MB C-2, that is part of an extensive, locally discontinuous leaky confining layer (Walker and others, 2008). The similarity in these water levels likely results from well screens being positioned in an area where flow is close to horizontal.

The maximum DTW values at the upper- and lower-basin monitoring-well sites during this study were 7.4 and 6.5 m, respectively. At both of these sites, the thick unsaturated zone contains sand and gravel with some thin clay layers (Walker and others, 2008). In the Kirkwood-Cohansey aquifer system, thick unsaturated zones commonly exhibit a wide range of sediment textures, which result in indirect pathways through the unsaturated zone that can retard the advance of a wetting front toward the water table. These conditions affect the rates of infiltration and recharge at both sites and are often reflected on the hydrographs as a delayed or minimal water-level rise following precipitation events (fig.19). Upper-basin monitoring-well hydrographs (fig.19A) show a delayed response to major precipitation events but also the magnitude of the change typically is larger than the lower basin monitoring wells. Comparing fluctuations from the two deeper upper basin well hydrographs with 050689–Lebanon SF 23-D Obs reveals larger and more responsive effects of precipitation in the deeper wells, suggesting a lateral hydraulic connection with other areas, perhaps less affected by a thick unsaturated zone; lower-basin monitoring-well hydrographs show a small and slightly delayed response to precipitation of a sufficient magnitude and (or) duration (fig.19B).

At the lower-basin monitoring-well cluster, water levels in the two deep wells 051558–MB OW-2M and 051560–MB OW-2D, screened in the MB A-2 and MB A-3 layers, respectively, were nearly identical during April 2005, and a slight downward hydraulic gradient between them was indicated during September 2005 (fig. 19B). The similarity in water levels in these two wells results in part from the local discontinuity of the lower leaky confining layer, MB C-2 (described above) and confirms that the middle and deep aquifer layers are well connected hydraulically in this area. The difference in water levels between well 051559–MB OW-2S, screened in the unconfined aquifer (layer MB A-1B) and either of the two deeper wells at this site was only about 0.02 m throughout the period of record. This small difference probably also can be attributed to the ineffectiveness of another leaky confining layer referred to as the middle leaky confining layer (MB C-1) (Walker and others, 2008). During both periods, however, the water level in well 051559–MB OW-2S was lowest, indicating a prevailing, but small, upward hydraulic gradient and the potential for upward groundwater flow in the vicinity of the wells. The absence of any substantial vertical hydraulic gradient between the two deeper wells indicates that local groundwater flow in the deep part of the aquifer system probably is largely horizontal and that a sub-regional zone of transition between downward and upward gradients where the vertical gradient is near zero likely exists. Groundwater flow in the deepest part of the aquifer is presumed to discharge downstream from these wells. On the basis of the recorded water levels, groundwater probably begins to move upward, toward the stream, at an unknown depth in the vertical section between the two screened intervals of wells 051559–MBOW-2S and 051558–MBOW-2M (tab. 1), in the MB A-1B and MB A-2 aquifers. These gradients and flow potentials may result from the proximity of these wells to the northeastern lateral basin boundary, limited nearby groundwater discharge, and (or) the limited effectiveness of the leaky confining layer in this area (Walker and others, 2008). Although the upward gradient at the lower-basin monitoring-well cluster is small, it nevertheless indicates a head relation that effects a simultaneous response to precipitation in water levels in all three aquifers from the water table to the base of the aquifer system. This response to precipitation, like that observed in the lower part of the Albertson Brook basin (figs. 6B, 19B), is likely caused by the absence of an effective confining layer and the resulting hydraulic connection among the aquifers at this location.

Hydrographs (fig. 20) were prepared from continuous water-level records collected during April 2, 2004, to September 30, 2006, from four wetland-monitoring wells screened in the unconfined aquifer at three locations in the McDonalds Branch basin (fig. 3). The range in water levels and their response to precipitation differed among the wells as a result of local hydrologic conditions. At well

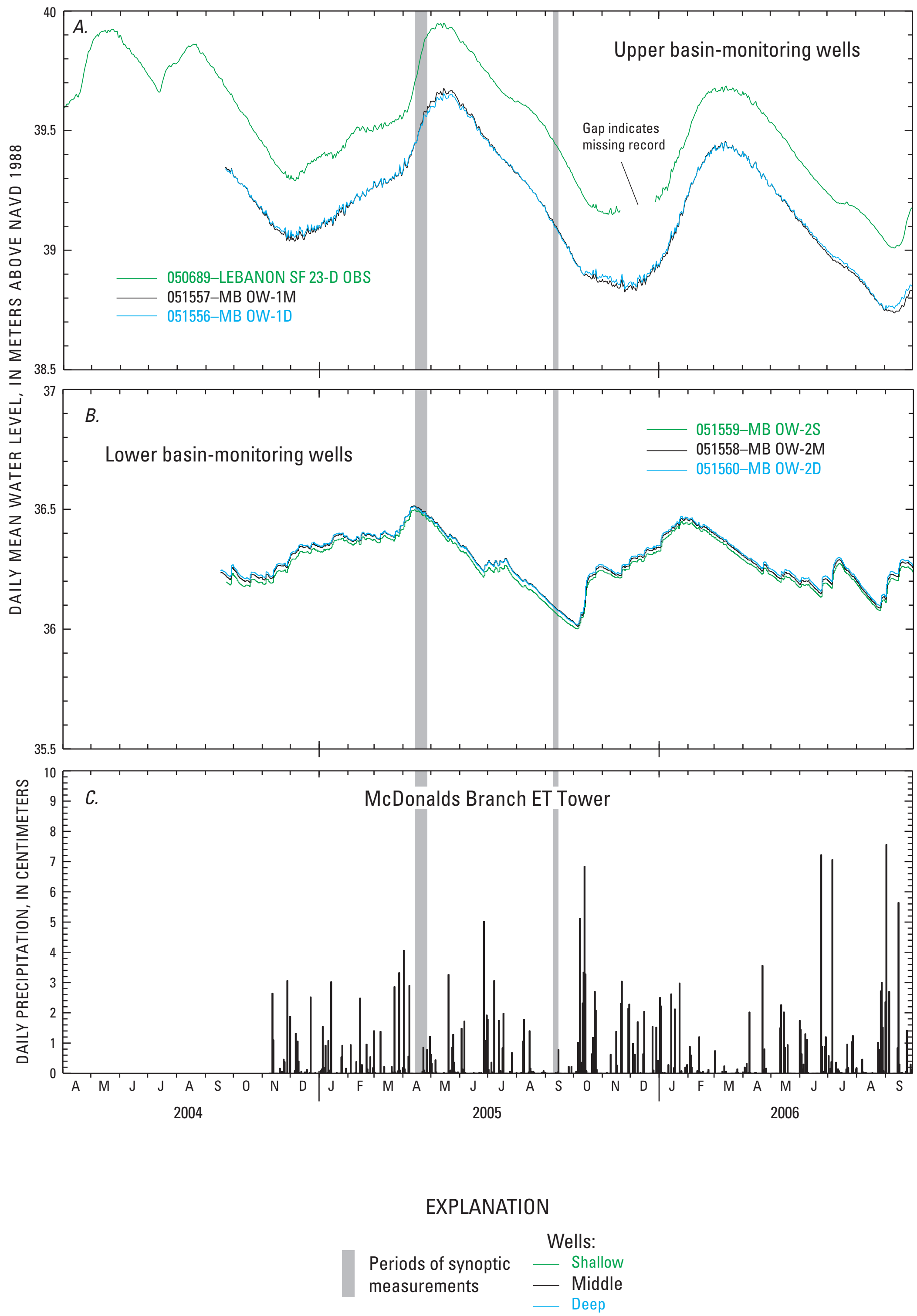



**Figure 19.** Groundwater levels in (*A*) upper and (*B*) lower basin-monitoring wells and (*C*) precipitation, McDonalds Branch study area, New Jersey Pinelands, 2004–06.

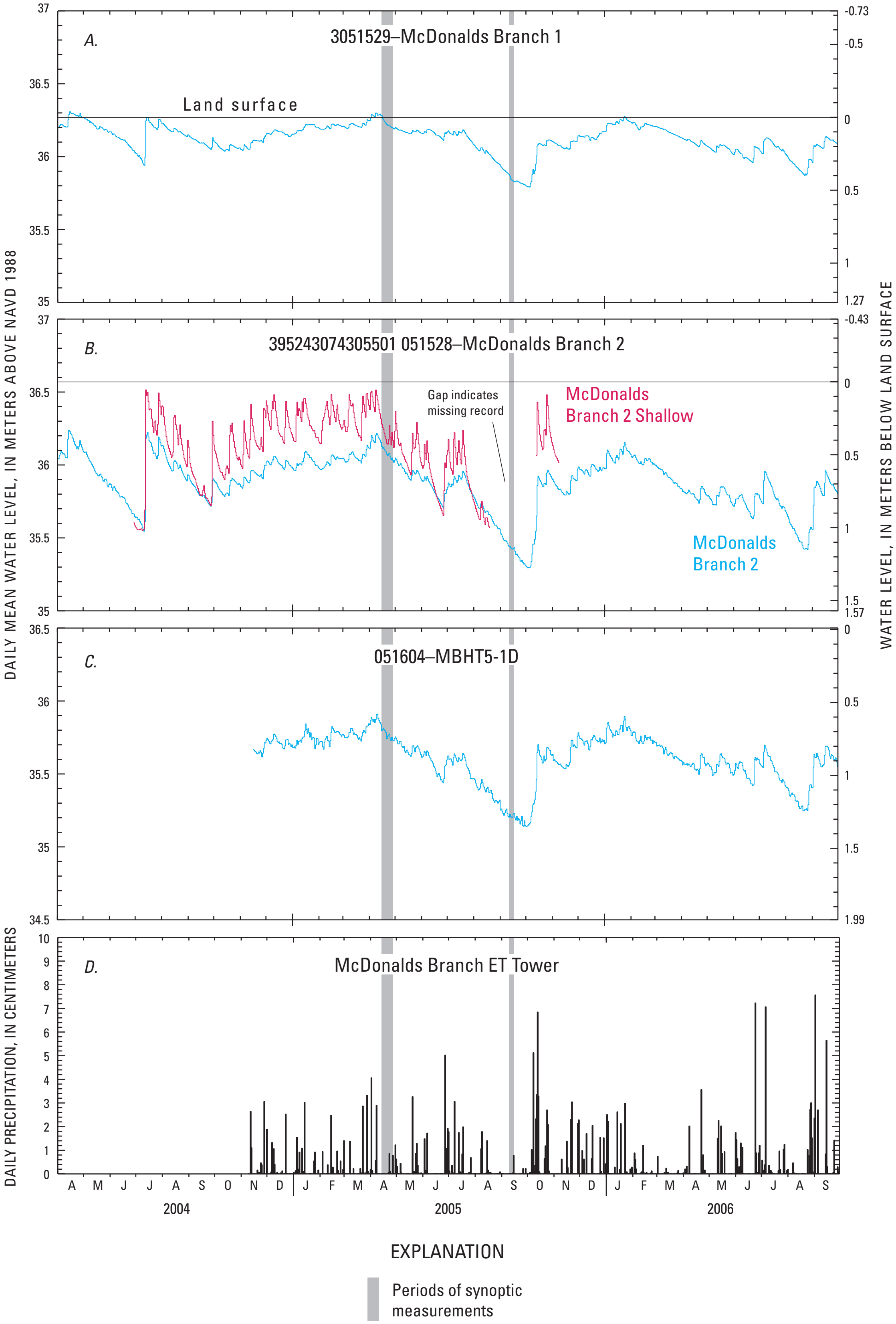



**Figure 20.** Groundwater levels in (*A*) McDonalds Branch 1, (*B*) McDonalds Branch 2, and (*C*) MBHT5-1D wetland-monitoring wells and (*D*) precipitation, McDonalds Branch study area, New Jersey Pinelands, 2004–06.

0501529–McDonalds Branch 1, located in a cedar swamp about 340 m upstream from the gaging station, groundwater levels beneath the swamp fluctuated about 0.47 m during the same period of record (fig. 20A). Groundwater levels beneath the cedar swamp are controlled to some extent by the level of surface water in the swamp and the McDonalds Branch, limiting fluctuations during periods of higher water levels and streamflow. During low-flow periods when the swamp is dry, groundwater levels fluctuate more because they are influenced less by surface-water levels. Although the other wetland-monitoring wells are not in swamps, their hydrographs also show a smaller range in water-level fluctuations during periods of high water levels and a greater range during dry periods, indicating that the nearby surface-water bodies probably also influence wetland water levels at some locations. Although hydrographs of water levels in wetland-monitoring wells are similar (figs. 20A, 20B), water levels fluctuated most in well 051528–McDonalds Branch 2, with a range of about 0.93 m during 2004–06.

Field observations in March 2004 revealed that the water level in a shallow borehole at the site of McDonalds Branch 2 was higher than the water level measured in the well. This observation prompted the installation of an additional well (051538– MCDONALDS BR 2 SHALLOW) to examine the lithology and water levels at the site. The higher water level apparently was supported by a thin, low-permeability zone of oxidized sand containing clay in its interstitial matrix (clayey sand). This zone was encountered at a depth of about 1 m and extended to a depth of about 1.4 m, the approximate depth of the seasonal low water level in this area. Rhodehamel (1973) describes the formation of similar soils in the Mullica River basin as a common occurrence during soil development, resulting from the transport of silt and clay particles from the A soil horizon to the underlying B horizon, where they accumulate as grain coatings or an interstitial matrix of silt or clay. The shallow well screen was installed in hydric soils to a depth of 0.91 m below land surface, which is just above the top of the clayey sand zone and only 0.61 m above the top of the well screen of the deeper well, 051528–McDonalds Branch 2, which is screened in sediments beneath the clayey sand (fig. 3, table 1 at end of report).

Hydrographs of water levels in these two wells (fig. 20B) for the period June 2004 to November 2005 show that water levels in the shallow well responded to precipitation events more quickly and to a greater extent than those in the deeper well. Water levels in the shallow well also remained substantially (0–0.3 m) higher than those in the deeper well during most of this period. The hydrographs also show that these conditions are transient and that water-level differences increased when the water table rose in response to infiltration and then slowly decreased until the next precipitation event or, in the absence of precipitation, until the water levels above and below the clayey sand layer had equilibrated (fig. 20B). The clayey sand layer acted to impede vertical transport of recharge until groundwater either moved laterally to a local point of discharge in the wetland or stream, moved through the layer, or was removed by *ET*. Depending on the season, all of these conditions probably contributed to the transient nature of the water levels above the clayey sand at this site.

The water-level conditions indicate that the water table can be affected locally by the variable permeability of the soils and sediments common to the Pinelands. It is likely that similar conditions affect other wetlands, but their extent and distribution is unknown. Therefore, a regionalized approach to mapping the water table may not account for those areas where wetland habitat is supported by localized mounding.

Water levels in another wetland-monitoring well (051604–MBHT5-1D), part of hydrologic transect MBHT5, were measured (figs. 3 and 20C) so that water levels beneath a wetland could be correlated with *ET* measured at the same location. (The results of the *ET* monitoring are part of a related study and are not presented here.) Water levels in well 051604–MBHT5-1D fluctuated about 0.89 m and responded to precipitation in a similar manner as did those in well 051528–McDonalds Branch 2.

## Streamflow

Streamflow data were recorded during this study at the USGS streamflow-gaging station at McDonalds Branch, a network surface-water monitoring site having 54 years of record. A concrete weir, described previously, provided a stable control for the gaging station, which is near the lower end of a large cedar swamp on the McDonalds Branch (fig. 3). Published discharge values for the McDonalds Branch include surface water that flows over the weir and any additional discharge of groundwater that enters the manmade channel between the weir and the location where manual discharge measurements are made about 240 m downstream from the gaging station. The lower than natural altitude of the manmade channel probably has altered the hydrologic relation between groundwater and the stream, locally inducing additional groundwater discharge to the McDonalds Branch below the gaging station. These and other variables that affect the quality of the record resulted in discharge records that are generally considered to be fair (95 percent of the records are within 10 percent of actual discharge (U.S. Geological Survey, 2009)).

Daily mean discharge during October 1, 2004, to September 30, 2006, ranged from 0.04 to 0.35 $m^3/s$ (fig. 21). On the basis of 54 years of record for the McDonalds Branch in Brendan T. Byrne State Forest streamflow-gaging station, values of mean annual discharge for water years 2005 and 2006 were 101 percent and 87 percent, respectively, of the mean annual discharge for the period of record (U.S. Geological Survey, 2009).

The stream-stage hydrograph for the McDonalds Branch (fig. 21) has a similar character to the water-level hydrograph for the wetland well, 0501529–McDonalds Branch 1 (fig. 20A) in the cedar swamp about 340 m upstream from the gaging station, indicating that groundwater levels and stream stage are closely linked at this site. Zampella and others

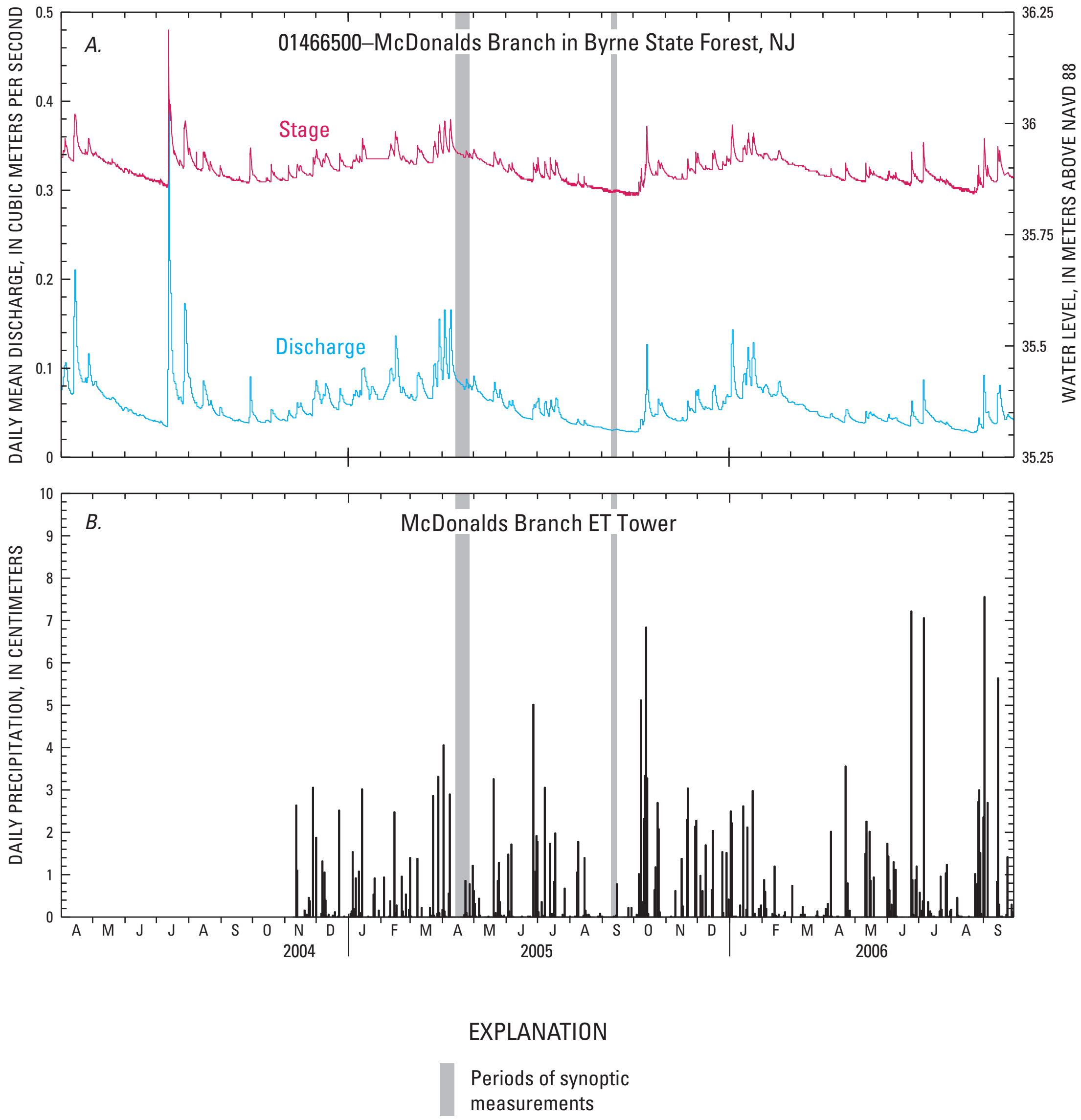



**Figure 21.** (*A*) Surface-water stage and discharge at McDonalds Branch and (*B*) precipitation, McDonalds Branch study area, New Jersey Pinelands, 2004–06.

(2001b) also report high correlations between streamflow at this gaging station and water levels in wells both in this area and more distant (up to 25 km) from the gaging station.

## Synoptic Measurements

Two synoptic measurements were made in the McDonalds Branch study area: one during base-flow conditions in spring (April 13–25) and another during late summer (September 8–15) 2005. Water-level data collected during these periods are presented in table 3 (at end of report) and the locations of the sites selected for analysis are shown in figure 22.

During the April synoptic measurement, groundwater levels were slightly higher than the period-of-record daily mean water levels determined on the basis of 25 years of record for observation well 050689–Lebanon SF 23-D Obs. (U.S. Geological Survey, 2009). Daily mean discharge determined on the basis of 54 years of record for the McDonalds Branch (01466500) indicated that streamflow during the April 2005 synoptic was slightly lower than the period-of record daily mean discharges for the duration of the April measurement (U.S. Geological Survey, 2009).

The April synoptic measurements were made at well and stream sites (figs. 3, 19–21) 5 or more days following a 2-week period of frequent precipitation. On days when

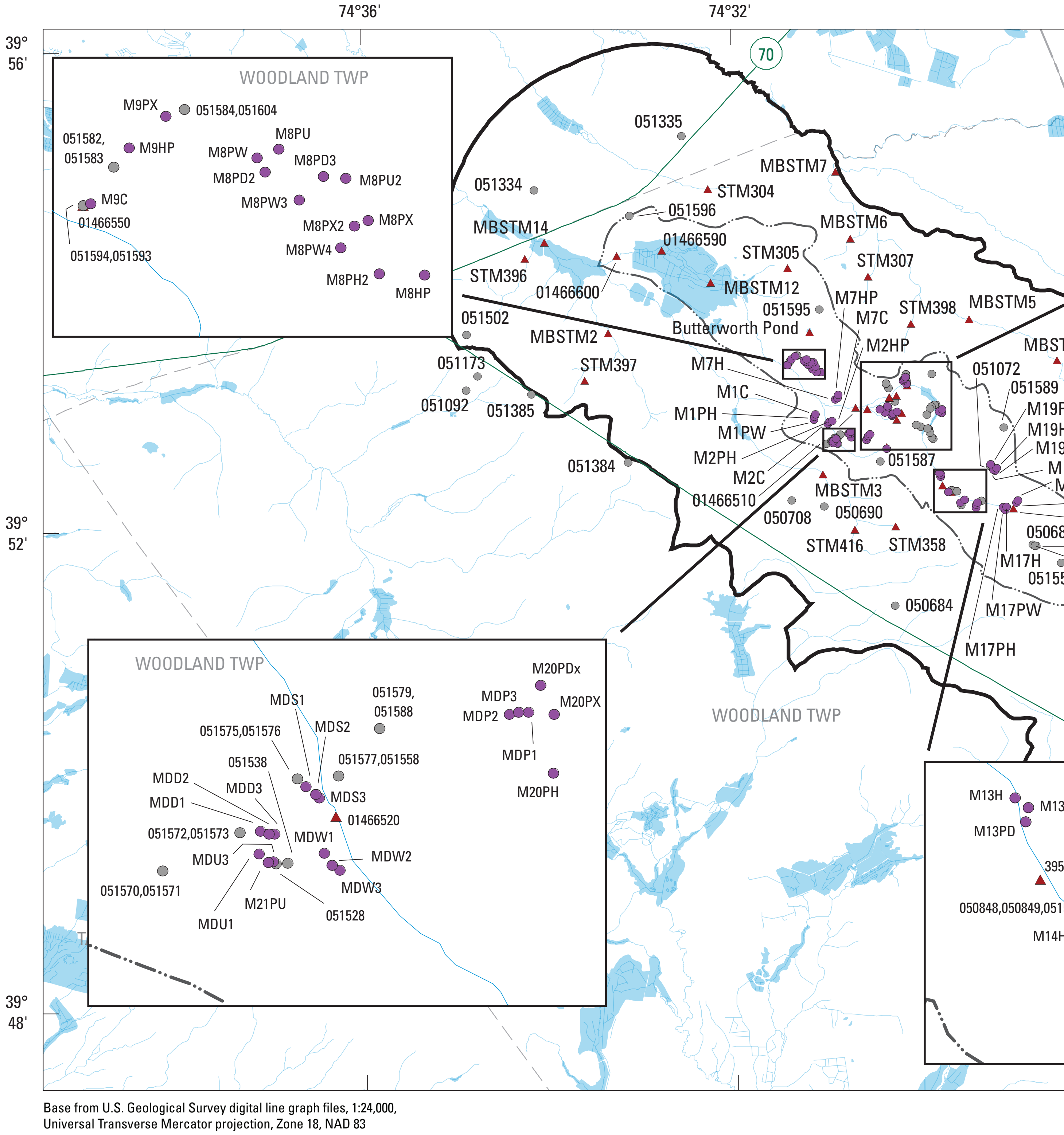
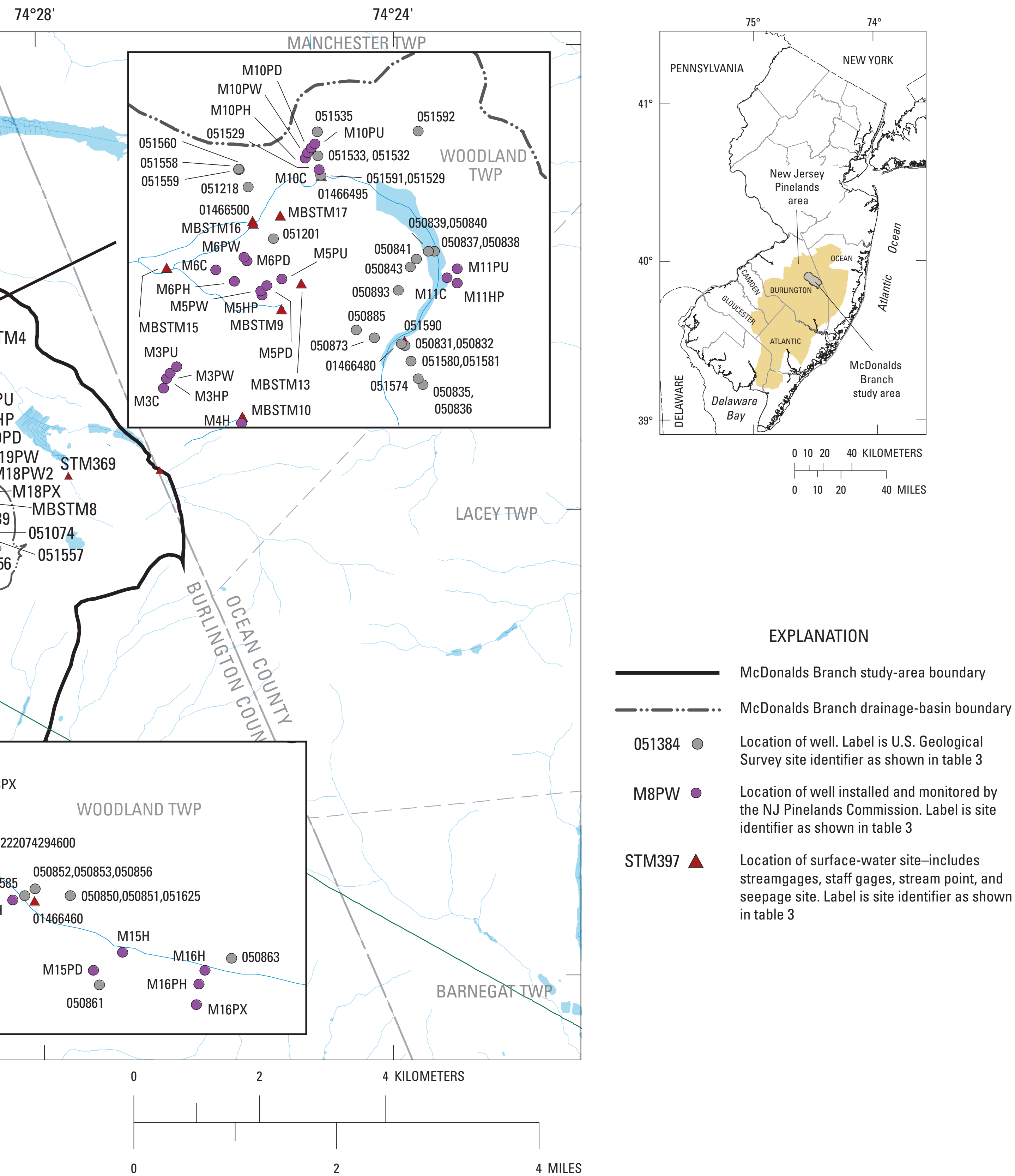



**Figure 22.** Location of selected sites used for synoptic water-level measurements, McDonalds Branch study area, New Jersey Pinelands, April and S




eptember 2005.

precipitation occurred during this 2-week period, daily totals were less than 4 cm, and daily precipitation totals on the final 2 days of the 2-week period were 0.56 cm and 2.9 cm, respectively. The last 4 days of the April measurement also were marked by light precipitation totaling 1.04 cm, although these precipitation events did not cause substantial changes in water levels or streamflow (figs. 19–21). Hydrographs from the basin-monitoring wells (fig. 19) showed an upward water-level trend in the upper basin prior to and during the synoptic measurements. In the lower-basin monitoring wells, a rainfall-induced peak in groundwater levels preceded a downward trend when the synoptic measurements were made. Wetland water levels and streamflow also were declining during the April measurement (figs. 20, 21). The commercial cranberry bogs were maintained at their winter flooded level during the April streamflow and water-level measurements in the area. The static winter water-level condition in the bog ensured that the streamflow measurement made downstream from the bog and the surrounding groundwater levels were not affected by changes in storage that would have occurred if the water stored in the bog during the winter had been released.

The September synoptic measurements were begun after almost 1 month without substantial precipitation and during an extended downward trend in both groundwater levels and streamflow (figs. 19–21). Groundwater levels during the September measurements were lower than the 25-year period-of-record daily mean water levels for the duration of the September measurement on the basis of records for the 050689—Lebanon SF 23-D observation well (U.S. Geological Survey, 2009). Streamflow records for the McDonalds Branch (01466500) indicate that the daily mean discharge for the duration of the September measurement also was lower than the period-of-record daily mean discharge for September on the basis of 54 years of record for the McDonalds Branch (U.S. Geological Survey, 2009).

The water-table-altitude maps for the two synoptic-measurement periods (figs. 23 and 24) show that the water table slopes along the length of the basin decreased about 15 m from the upper basin boundary to the lower basin boundary. By the time of the September measurement, and depending on location, the water table had declined from as little as 0.069 m to as much as 1.41 m. These changes generally were smallest near the areas of discharge to surface-water and greatest in the upland recharge areas near the groundwater divides. Local variability does exist throughout the basin, however, as affected by local conditions. Typically, areas near the topographic basin divides can be expected to show the greatest changes in seasonal water levels and those where altitudes are lower typically show smaller changes. In the McDonalds Branch basin, however, the areas near the upper basin divide between the Atlantic Coastal and Delaware River basins show uncharacteristically small water-level changes (about 0.07 m –0.20 m) during the period between the two synoptic measurements. The reason that water-level changes are smaller near the upper basin divide is not well understood but may be the timing and relatively short duration of synoptic measurements in relation to the substantial lag observed in the seasonal water-level extremes at the upper-basin monitoring wells discussed previously. Another factor that may affect the observed range of water-level extremes in this area is the large volume of water in storage in two nearby areas, one an extensive wetland in the headwaters of the McDonalds Branch and the other a large commercial gravel pit that is partly filled with groundwater and that is directly on and east of the Atlantic Coastal and Delaware River basin divide about 1,400 m east of the upper-basin monitoring-well cluster (fig. 3).

Groundwater flow in the basin generally follows the McDonalds Branch stream channel from areas of highest to areas of lowest water levels. As in the Albertson Brook basin, topographic divides (basin boundaries) do not necessarily coincide with groundwater divides; this is true in at least three areas in the McDonalds Branch basin (figs. 23 and 24). Along the southwestern basin boundary, water-table contours indicate that groundwater is probably leaving the basin beneath a low topographic divide that separates the drainage basin from a narrow adjacent basin that joins the McDonalds Branch basin at the downstream basin boundary. The water-table contours also indicate the potential for groundwater to leave the lower part of the basin along its northern boundary. In a third area, groundwater probably is leaving the basin toward the northeast from a large wetland in the headwaters of the McDonalds Branch, an important feature discussed farther on.

A locally extensive shallow clay layer supports the large wetland in the headwaters of the McDonalds Branch, where the water table is substantially (3 m) higher than water levels beneath the clay, and in the area immediately surrounding the wetland. The northeastern basin boundary crosses this wetland, indicating a potential for flow into the adjacent basin as described above. Stratigraphic and water-level information from three two-well pairs (wells 051072–QWH-5A and 051073–QWH-5B; wells 050861–QWH–7A Shallow Well and 050862–QWH– 7B; and wells 050863–QWH-8A and 050864–QWH-8B) (tables 1and 3) was used to understand how the wetland and the underlying clay affect nearby water levels and groundwater flow. In each well pair, one well was screened above the clay and the other was screened below it. Water levels above the clay were higher than those below it, confirming the downward hydraulic gradients across the clay layer at the three locations. The difference between water levels above and below the clay ranged from about 1.5 to 3 m, depending on location and seasonal water-level conditions. Water levels in wells screened below the clay rise above its top, indicating that the water table above the clay is not perched and that the clay is fully saturated. The mounded water table above the clay causes localized radial groundwater flow; some shallow groundwater likely crosses the low topographic divide to the northeast, as indicated by the water-level contours at the basin boundary. The potentiometric water levels beneath the clay are given in table 3 (at end of report). The vertical water-level differences across the clay probably decreases near its limits, and the water levels above equilibrate with those below, eventually reaching zero at the clay's edge.

The water-table contours also indicate that groundwater was bypassing the McDonalds Branch streamflow-gaging station downgradient from the headwaters wetland, where a shallow, broad, open channel develops on the McDonalds Branch during periods of high water levels. The open channel forms due to the topography and damming effects of a cedar swamp downstream from the open channel. Precise water-level-altitude data based on differential leveling for wells on both sides of the McDonalds Branch in this area confirm a horizontal hydraulic gradient supporting groundwater flow normal to and beneath the broad, open channel. These data indicate a potential for surface-water losses and groundwater flow that bypasses the open channel and probably discharges to small tributaries that join the McDonalds Branch downstream from the streamflow-gaging station (figs. 23 and 24).

Depth to the water table (DTW) in spring 2005 in the McDonalds Branch basin (fig. 25) ranges spatially from zero at points of groundwater discharge such as ponds, streams, and swamps to more than 10 m in upland areas at the southeastern limit of the basin. DTW is greatest at the major divide between the Delaware River and Atlantic Coastal basins. A histogram showing the distribution of DTW throughout the McDonalds Branch basin (fig. 26) provides a basin profile of the hydrologic settings for habitats that depend on different ranges of water-table depth. DTW is less than 0.5 m over 48 percent of the basin, resulting in a relatively large percentage of the basin being hydrologically suitable for wetland habitats. In comparison with the Pinelands as a whole, the basin has a larger percentage of mapped wetlands; 36 percent of the basin is mapped as wetlands, whereas wetlands covered 27 percent of the entire Pinelands area in 2002 (Zampella and others, 2008). A large portion of the wetlands at the northwestern (downstream) end of the basin is in active cranberry production. In mapped wetlands within the basin, DTW ranges from zero to 1.5 m, with a mean of 0.13 m.

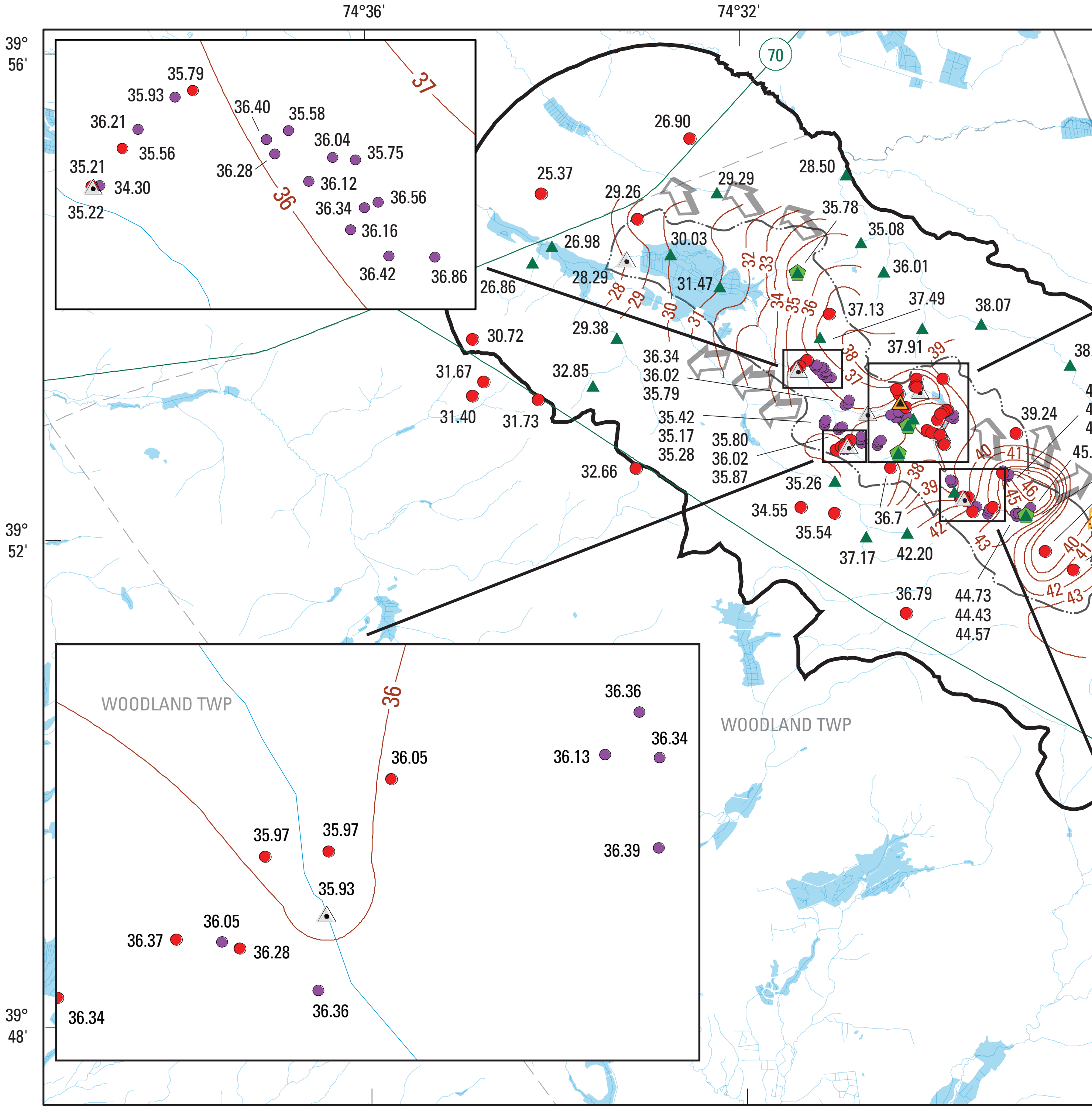
Data from five hydrologic transects (fig. 3) in the McDonalds Branch basin describe the interaction of groundwater levels with wetlands and surface water. These data characterize changes in the water table in terms of hydraulic gradients and the variability of potential groundwater flow and discharge to the wetlands and surface water during the two synoptic measurements in April and September 2005. Site conditions and findings are described below.

Graphs of water levels and hydraulic gradients along hydrologic transect MBHT1 in the headwaters of the McDonalds Branch basin (fig. 27) illustrate a substantial downward hydraulic gradient at all well locations in April and slightly higher water levels near the stream, indicating that the McDonalds Branch was losing to the shallow groundwater system in this area (fig. 27). In September, although the McDonalds Branch was dry, the near-stream vertical hydraulic gradient was smaller but still downward, indicating a continuing potential for downward groundwater flow in this area. The hydraulic gradient at the middle well cluster was slightly upward, which appears uncharacteristic when compared with the other hydraulic gradients along the transect. The cause of this upward gradient is not clear but might be related to a sharp contrast in soil or aquifer-sediment permeability and (or) the influence of the slightly higher water levels beneath the dry streambed nearby. Local contrasts in soil and sediment textures could contribute to local anomalies in hydraulic gradients and groundwater flow, particularly at locations where a stream is losing or intermittent.

Transect MBHT1 is both hydraulically downgradient and topographically downstream from the large headwaters wetland described previously. The water table declines nearly 5 m beyond the edge of the headwaters wetland before reaching the area of this transect. Beyond the edge of the wetland, the substantially higher heads above the clay equilibrate with those below, creating the sloping water table that is reflected in both shallow and deep water levels locally (MBHT1). Given that groundwater does not typically discharge to the McDonalds Branch at this location, most of the streamflow in this area probably originates from the headwaters wetland directly as surface-water flow and (or) indirectly as shallow groundwater that discharges to the McDonalds Branch upstream from MBHT1. This hypothesis does not preclude the possibility that shallow transient groundwater flow may contribute water to the wetland and stream during and after substantial precipitation events.

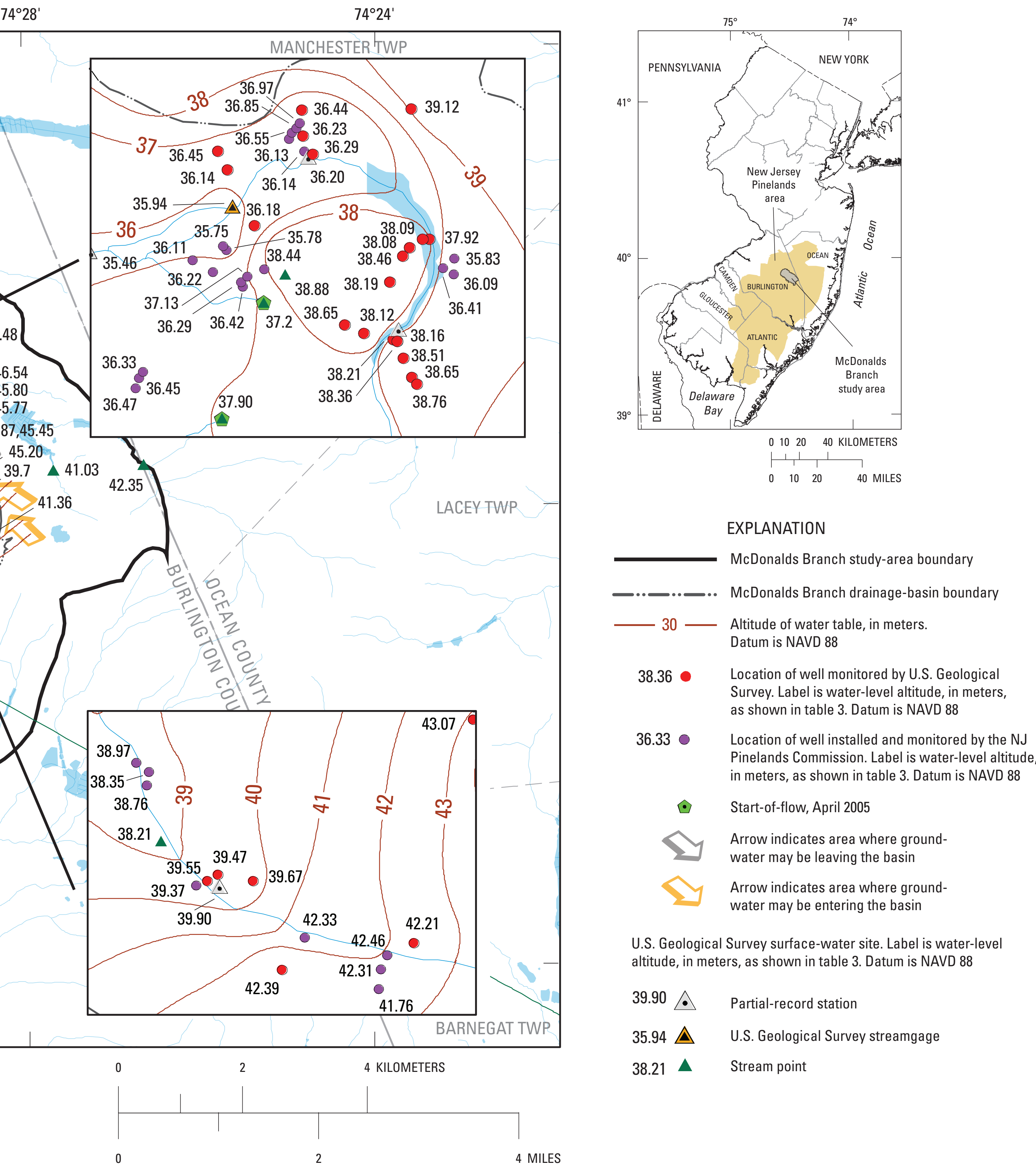
Hydrologic transect MBHT2 is on the northeast side of the McDonalds Branch at the broad, open channel. During the April and September synoptic measurements, small upward hydraulic gradients were observed at the upland end of this transect. The groundwater-level profile slopes from the uplands toward the McDonalds Branch with vertical hydraulic gradients that are slightly upward near the middle of the transect and much larger beneath the stream, indicating that the potential for discharge to the stream during the April measurement is likely. By the time of the September measurement, local water levels had declined nearly 0.7 m, and the McDonalds Branch was dry at this location. In September, deep and shallow water levels in the wetlands near the dry stream channel were nearly the same; with a slight upward hydraulic gradient similar to that observed at transect MBHT1. The water level beneath the dry stream channel, however, was higher than that of the wetlands and the hydraulic gradient was slightly downward, possibly indicating that a residual groundwater mound was created by low-permeability sediments beneath a losing stream before the channel became dry. These water-level differences below the stream channel combined with contrasts in sediment permeability also could have caused the slight upward gradient in the wetland. Water-table maps (figs. 23 and 24) show that groundwater flow can bypass the McDonalds Branch channel in this area and probably emerges in other tributaries that join the main channel downstream from the gaging station.

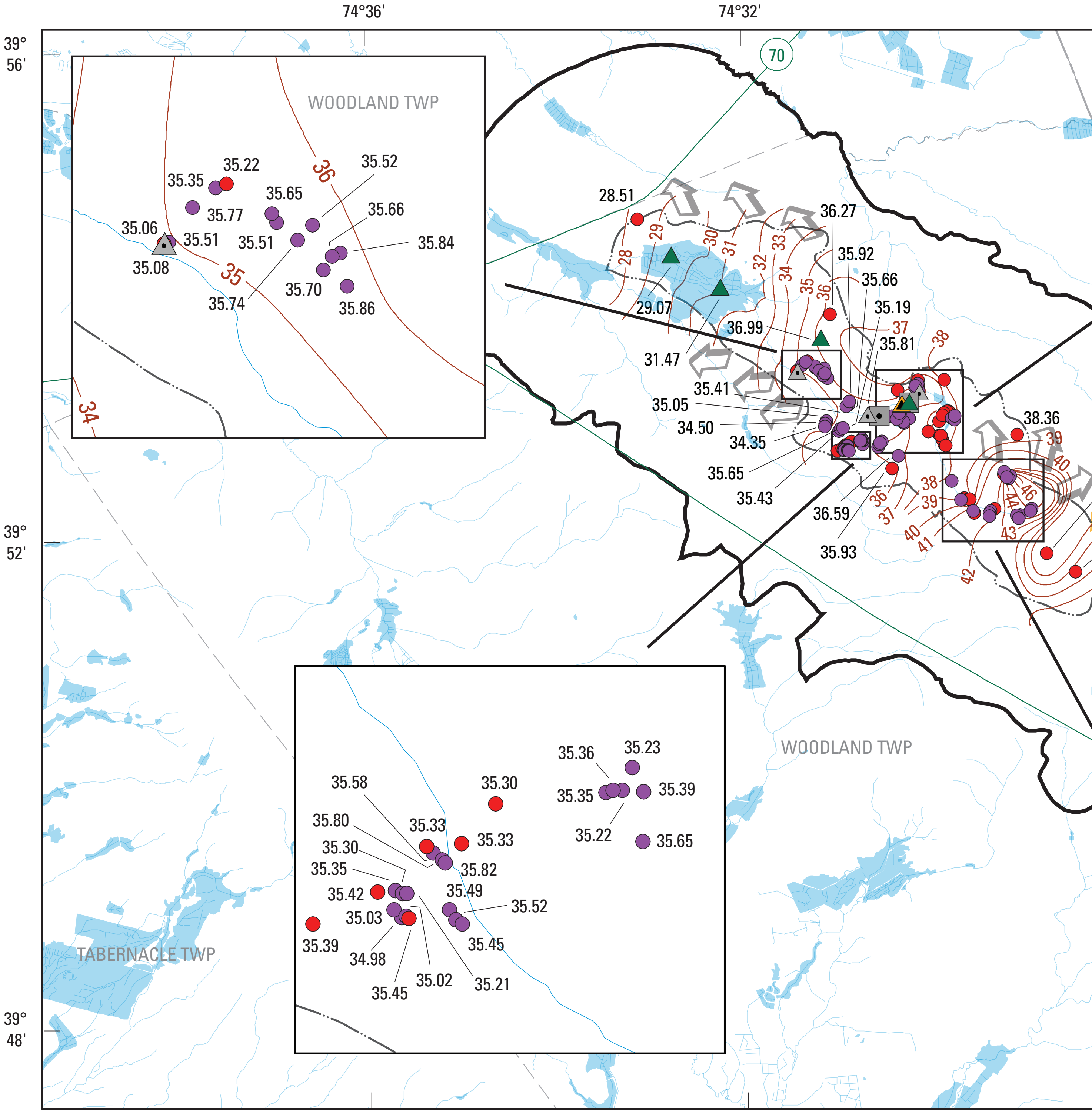
About 1,050 m downstream from transect MBHT2, transect MBHT3 (fig. 27) extends about 140 m from an upland mixed pine and hardwood forest into a large cedar swamp through which the McDonalds Branch flows. In April, the vertical hydraulic gradient at the upland end of this transect was




Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

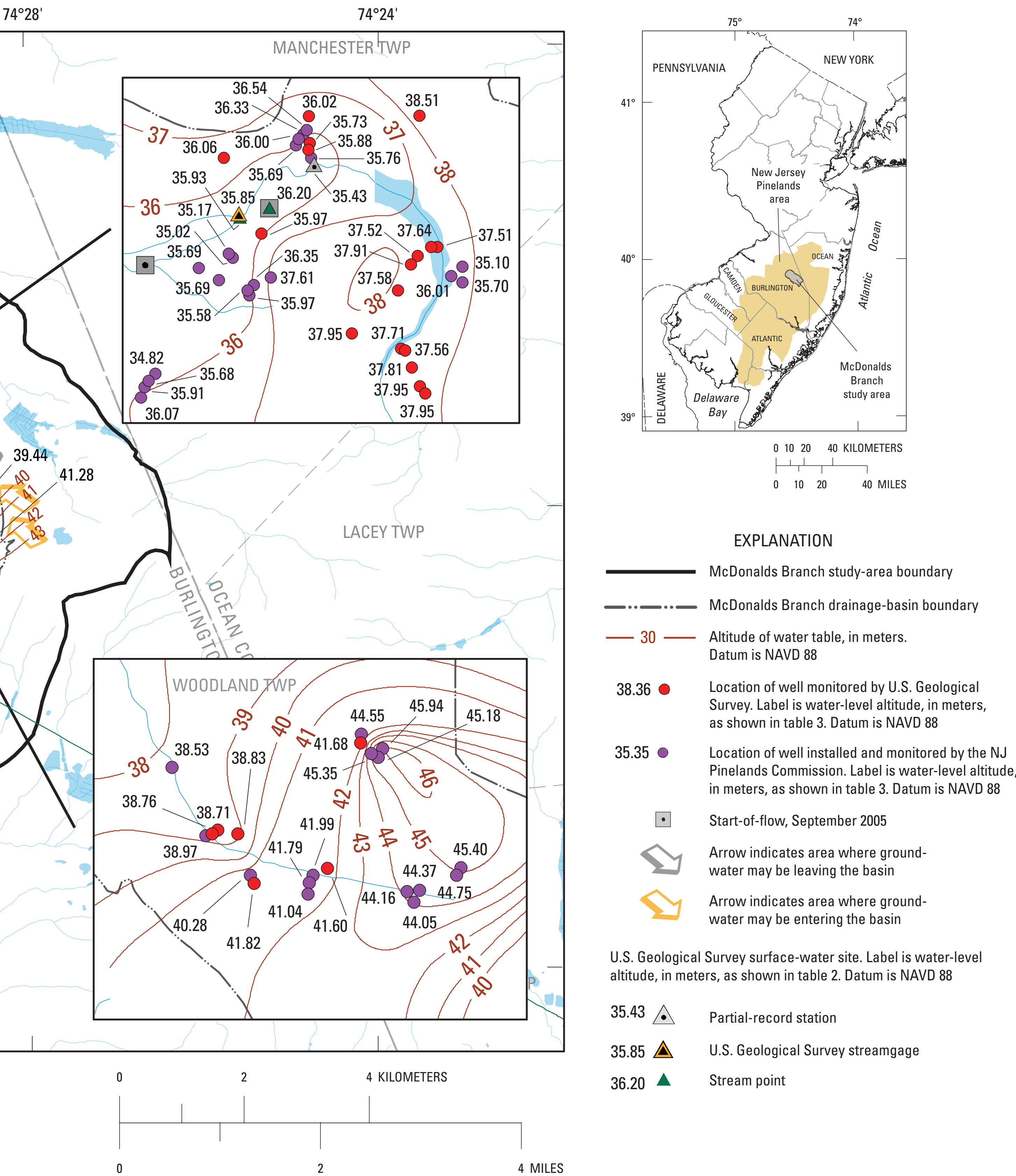
**Figure 23.** Altitude of water table, McDonalds Branch study area, New Jersey Pinelands, April 2005.


74°28'
74°24'
MANCHESTER TWP
LACEY TWP
BARNEGAT TWP
BURLINGTON COUNTY
OCEAN COUNTY
38
37
36
39
40
41
42
43
36.97
36.85
36.44
36.23
36.55
36.29
39.12
36.45
36.13
36.14
36.14
36.20
35.94
36.18
38.09
38.08
37.92
35.75
35.78
38.46
35.83
36.11
38.44
35.46
36.22
38.88
38.19
36.09
37.13
38.65
38.12
36.41
36.29
36.42
37.2
38.16
38.51
36.33
38.21
38.65
36.45
38.36
36.47
37.90
38.76
41.03
42.35
41.36
45.20
39.7
43.07
38.97
38.35
38.76
38.21
39.47
39.55
39.67
39.37
39.90
42.33
42.21
42.46
42.31
42.39
41.76
0 2 4 KILOMETERS
0 2 4 MILES
75°
74°
41°
40°
39°
PENNSYLVANIA
NEW YORK
New Jersey Pinelands area
OCEAN
BURLINGTON
CAMDEN
GLOUCESTER
ATLANTIC
Atlantic Ocean
DELAWARE
Delaware Bay
McDonalds Branch study area
0 10 20 40 KILOMETERS
0 10 20 40 MILES
EXPLANATION
McDonalds Branch study-area boundary
McDonalds Branch drainage-basin boundary
30 Altitude of water table, in meters. Datum is NAVD 88
38.36 Location of well monitored by U.S. Geological Survey. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88
36.33 Location of well installed and monitored by the NJ Pinelands Commission. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88
Start-of-flow, April 2005
Arrow indicates area where ground-water may be leaving the basin
Arrow indicates area where ground-water may be entering the basin
U.S. Geological Survey surface-water site. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88
39.90 Partial-record station
35.94 U.S. Geological Survey streamgage
38.21 Stream point



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 24.** Altitude of water table, McDonalds Branch study area, New Jersey Pinelands, September 2005.


74°28'
74°24'
MANCHESTER TWP
LACEY TWP
WOODLAND TWP
BURLINGTON
OCEAN CO
36.54
36.33
36.02
38.51
35.73
35.88
35.76
36.06
36.00
35.93
35.69
36.20
35.43
35.85
35.17
35.97
35.02
35.69
37.52
37.64
37.51
37.91
35.10
36.35
37.61
37.58
35.70
36.01
35.69
35.97
35.58
37.95
37.71
37.56
34.82
35.68
35.91
36.07
37.81
37.95
37.95
39.44
41.28
44.55
45.94
45.18
41.68
38.53
38.83
45.35
38.76
38.71
41.99
38.97
41.79
45.40
44.37
44.16
44.75
40.28
41.04
41.60
44.05
41.82
0 2 4 KILOMETERS
0 2 4 MILES
75°
74°
41°
40°
39°
PENNSYLVANIA
NEW YORK
New Jersey Pinelands area
OCEAN
CAMDEN
BURLINGTON
GLOUCESTER
ATLANTIC
Atlantic Ocean
McDonalds Branch study area
DELAWARE
Delaware Bay
0 10 20 40 KILOMETERS
0 10 20 40 MILES
EXPLANATION
McDonalds Branch study-area boundary
McDonalds Branch drainage-basin boundary
30 Altitude of water table, in meters. Datum is NAVD 88
38.36 Location of well monitored by U.S. Geological Survey. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88
35.35 Location of well installed and monitored by the NJ Pinelands Commission. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88
Start-of-flow, September 2005
Arrow indicates area where ground-water may be leaving the basin
Arrow indicates area where ground-water may be entering the basin
U.S. Geological Survey surface-water site. Label is water-level altitude, in meters, as shown in table 2. Datum is NAVD 88
35.43 Partial-record station
35.85 U.S. Geological Survey streamgage
36.20 Stream point

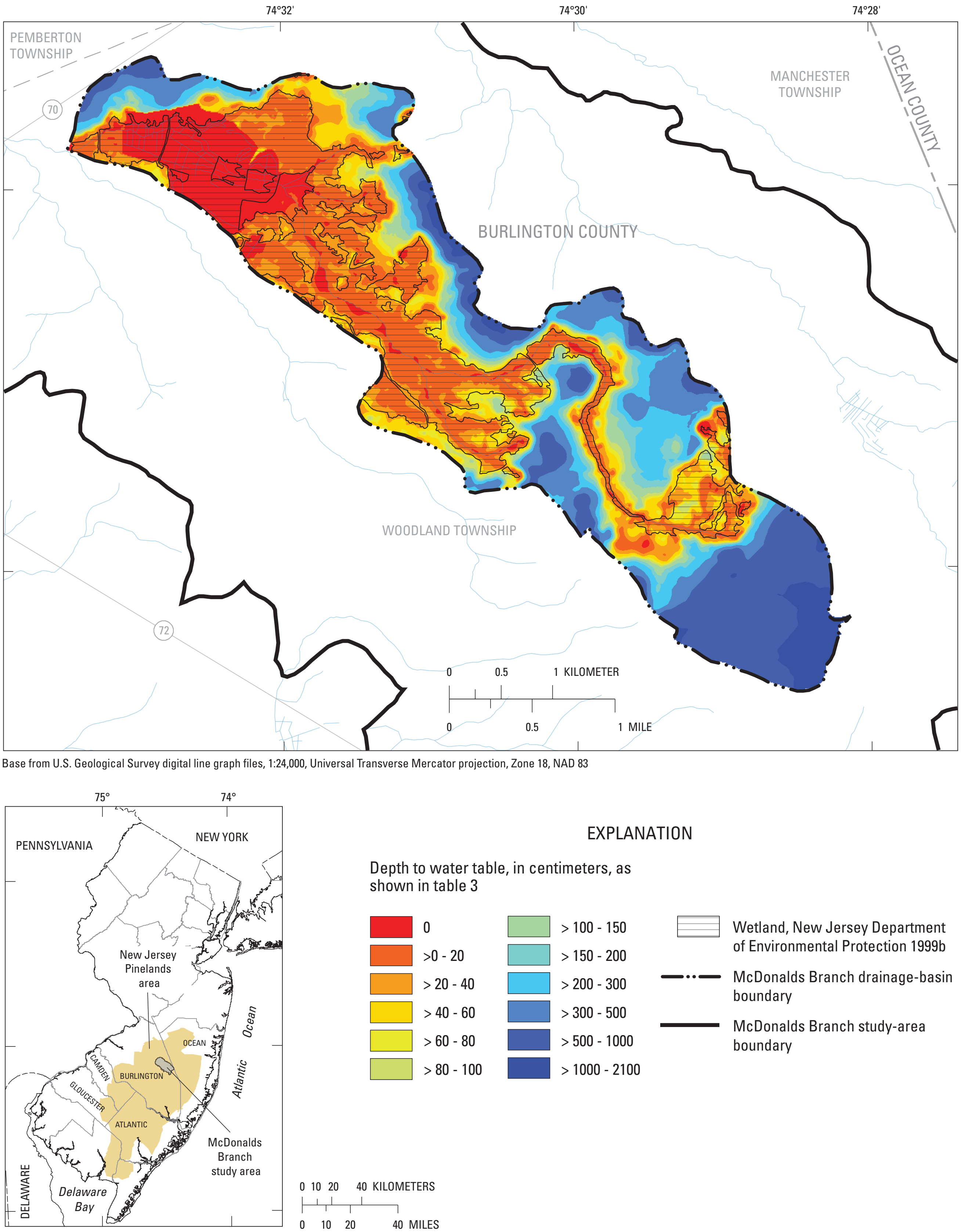



**Figure 25.** Depth to water table, McDonalds Branch basin, New Jersey Pinelands, April 2005.

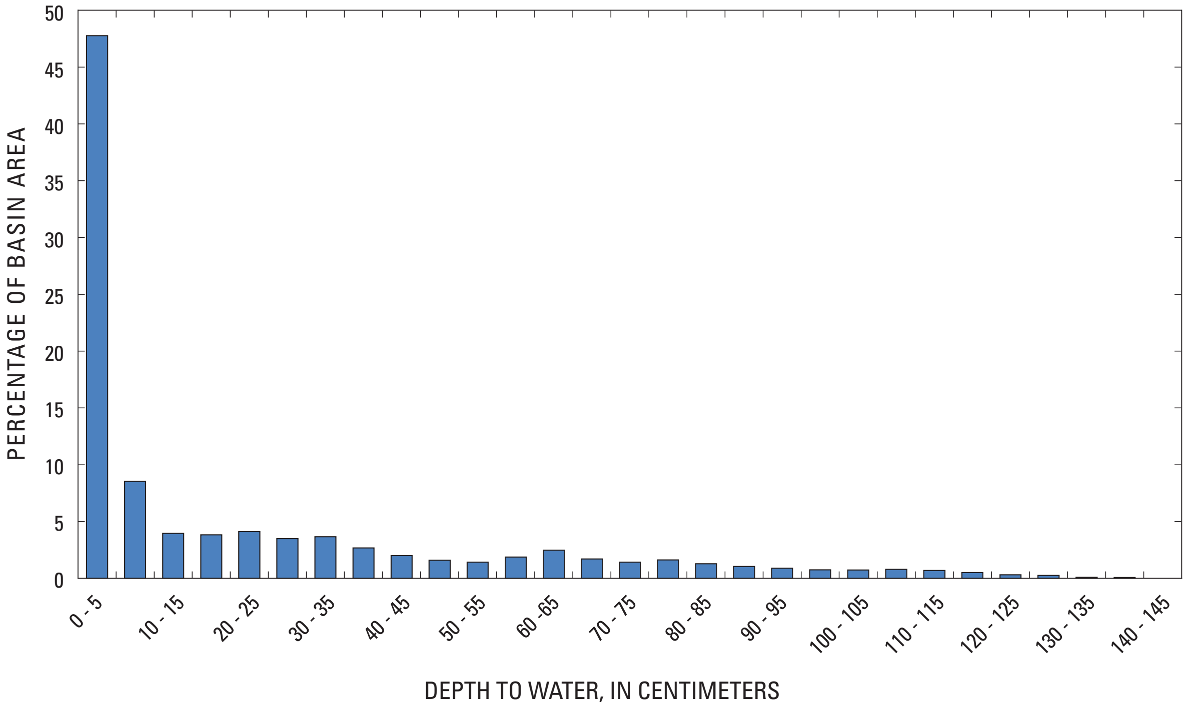



**Figure 26.** Histogram showing percentage distribution of depth to water in McDonalds Branch basin, McDonalds Branch study area, New Jersey Pinelands, April 2005. (Areas where 5-centimeter intervals of depth to water exceed 145 centimeters occupy less than 2 percent of the basin area and are not shown.)

zero, and water levels sloped toward the wetlands, indicating a potential for horizontal groundwater flow in that direction. Hydraulic gradients measured in the wetlands during April, generally indicated the potential for upward flow to the wetlands and swamp, with the strongest upward gradients near the edge of the cedar swamp. In the swamp groundwater levels were at or above land surface, which is largely represented by hummocks around either living trees or the apparent remnants of decaying root systems. Water levels showed little horizontal hydraulic gradient in the wetlands and swamp during the April and September measurements, either as a result of surface-water influence on groundwater levels or because these are principally areas of groundwater discharge. During September, the water levels in the three deep wells were equal along the length of transect MBHT3, indicating no horizontal gradient or flow, and the relation between the shallow and deep water levels indicated a downward hydraulic gradient in the uplands and a water table that sloped toward the wetlands. In the wetlands and swamp however, water levels in the shallow wells were lower than those in the deep wells at the same location indicating the persistence of upward hydraulic gradients and the continued potential for groundwater to discharge. Therefore, although lateral flow from the uplands toward the stream probably was substantially reduced by September, the hydraulic potential for groundwater to discharge to the wetlands and swamp in this area likely continued as a result of upward hydraulic gradients generated by groundwater flow along longer flow paths originating farther upstream.

Transect MBHT4 (fig. 27) is on an unnamed tributary that joins the McDonalds Branch from the south about 1,200 m downstream from the gaging station. This hydrologic transect crosses the tributary from southwest to northeast, toward a low topographic divide between the tributary and the McDonalds Branch, which is about 500 m to the north. In April, hydraulic gradients were downward in the uplands and upward beneath the wetlands (swamp) on both sides of the tributary. On the southwest side of the tributary at the 86 m location (fig. 27), the largest vertical hydraulic gradient (-0.24) in the basin was observed. This location is near the two collocated wetland-monitoring wells (McDonalds Branch 2 and McDonalds Branch 2 Shallow) discussed previously, where water levels indicated recharge-induced transient mounding of the water table. A strong downward gradient also was observed on the north side of the tributary at a transect distance of about 265 m near the wetlands margin, indicating a possible similar mounding condition. By the time of the September measurement, which followed more than a month without rain, only a small residual of the mounding could be detected in both the shallow and deeper water levels at the 86 m location, and none was detected near the wetlands margin at 265 m, where the gradient had reversed to upward. The slope of the water table also had flattened, but the gradients at the swamp remained upward

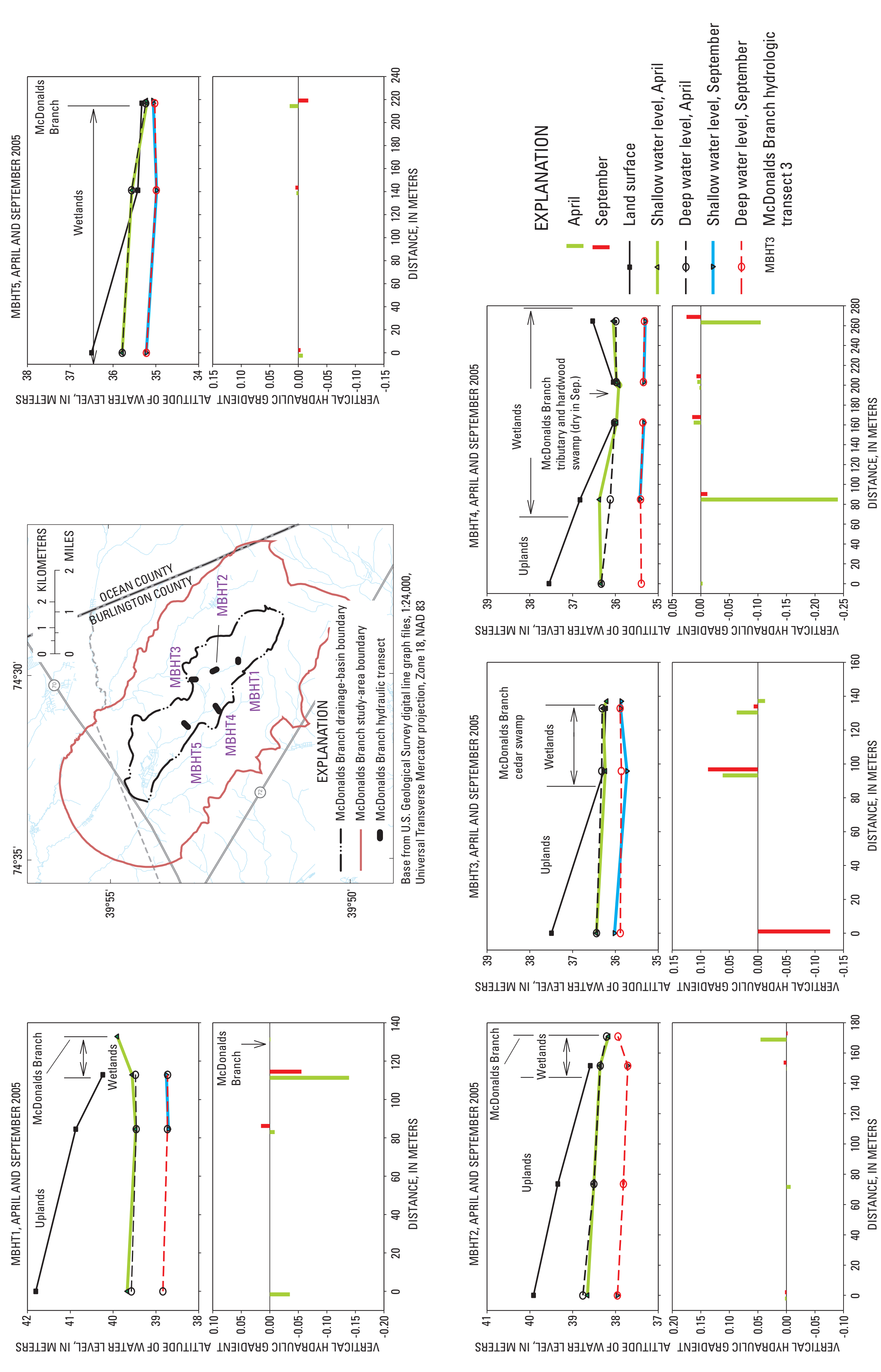



**Figure 27.** Location of five wetlands hydrologic transects and graphs showing water levels and hydraulic gradients along the transects during high (April) and low (September) flow, McDonalds Branch basin, New Jersey Pinelands, 2005. (Vertical datum is NAVD 88)

although the swamp was dry. Hydraulic gradients in the swamp and on the northeast side of the tributary were slightly upward, but the horizontal gradient indicated the potential for flow toward the northeast, and toward the McDonalds Branch.

Downstream from the tributary described above, the McDonalds Branch flows through a mature cedar swamp flanked to the northeast by a hardwood and pine lowland. Hydrologic transect MBHT5 extends about 220 m from pitch pine lowlands through the cedar swamp to the McDonalds Branch. In both April and September, the water table sloped from the uplands toward the cedar swamp and vertical hydraulic gradients were consistently downward at the upland end of this transect and upward at the margin of the cedar swamp (fig. 27). In April, upward hydraulic gradients in the cedar swamp section of the transect indicated a potential for groundwater to discharge to the cedar swamp and stream. In September, the water table generally sloped away from the stream, indicating that the stream could be losing water in this area. Dense clay, however, was identified below the streambed about 1.5 m below the water table. Although the thickness and extent of this clay is unknown, its presence indicates that the flow system that interacts with the stream may be limited, at least locally, to that depth interval above the clay.

Stream base-flow measurements and the observed start-of-flow locations for both the April and September 2005 synoptic measurements are shown in figure 28. Base flow ranged from zero (dry channel) to 0.006 $m^3/s$ at the uppermost measuring site on the McDonalds Branch and from 0.065 to 0.176 $m^3/s$ at the measuring site (01466550; fig. 3) above the active cranberry bogs in September and April 2005. Because bogs and ponds release water from storage more slowly following precipitation than natural stream channels and swamps, the streamflow of 0.583 $m^3/s$ measured in April at station 01466600 below the cranberry bogs may include some water from storage and may not represent base flow at this site for the April synoptic measurement. Stream reaches between start-of-flow locations observed in April and September 2005 are shown with a dashed line in figure 28, indicating the range of the seasonally intermittent stream channel. Base-flow data for the McDonalds Branch, including the ratio of spring base flow to summer base flow at stream sites, are provided in table 4. In the McDonalds Branch basin, the base-flow ratios ranged from 2.7 to 2.9 for three sites in the middle- and lower-basin areas, indicating that groundwater discharge to the stream is generally persistent and contributes to base flow in this area.

## Water Budget

The water budget below includes values for all applicable components of the hydrologic cycle in the McDonalds Branch drainage basin and accounts for all known gains and losses to or from the system. The basin water budget was developed on a monthly basis. The period of this analysis is October 2004–September 2006. The following equations were used to calculate the water budget for the McDonalds Branch drainage basin.

Land-surface components:

$$R_s = P \pm \Delta S_{sm} - Q_{dr} - ET \ , \qquad (6)$$

where

$R_s$ = recharge to the aquifer system,
$P$ = precipitation,
$\Delta S_{sw}$ = change in surface-water storage,
$\Delta S_{sm}$ = change in soil moisture,
$Q_{dr}$ = direct runoff, and
$ET$ = evapotranspiration; and

Groundwater components:

$$R_g = Q_b \pm L \pm \Delta S_{gw} \pm R_i \ , \qquad (7)$$

where

$R_g$ = recharge to the aquifer system,
$Q_b$ = base flow,
$L$ = leakage to confined aquifers,
$\Delta S_{gw}$ = change in groundwater storage, and
$R_i$ = groundwater inflow to/outflow from adjacent basins. In the McDonalds Branch drainage basin, there were no artificial discharges to groundwater or surface water ($D_{as}$ and $D_{ag}$, respectively), changes in surface-water storage ($\Delta S_{sw}$), or groundwater or surface-water withdrawals ($W_g$ and $W_s$, respectively).

Average annual precipitation in the McDonalds Branch drainage basin was 121 cm, slightly more than in the Albertson Brook drainage basin (114 cm), during the study period (table 6). Total monthly precipitation typically is fairly uniform through the year and is evenly distributed throughout the basin. Monthly precipitation averaged 10.1 cm and ranged from 1.3 cm in September 2005 to 29.5 cm in October 2005 (fig. 29, table 6).

Average annual *ET* in the McDonalds Branch basin during the study period was 62.0 cm, the highest of the *ET* values for the three basins. This is because the basin has a larger percentage of wetlands than the other two basins. Monthly *ET* averaged 5.2 cm and ranged from 0.5 cm in December 2004 to 12.2 cm in July 2006. *ET* from the basin was equivalent to 51 percent of precipitation on an annual basis. This loss, however, varied widely throughout the year. In winter, when *ET* was minimal, it was less than one-tenth the amount of precipitation. During some summer months, nearly all precipitation was lost to *ET*, and recharge to the underlying aquifer was minimal. *ET* exceeded precipitation in July, August, and September 2005.

Direct runoff of precipitation in the basin was small, averaging 0.1 cm/mo during the study period. Monthly values ranged from zero cm (October 2004, August and September

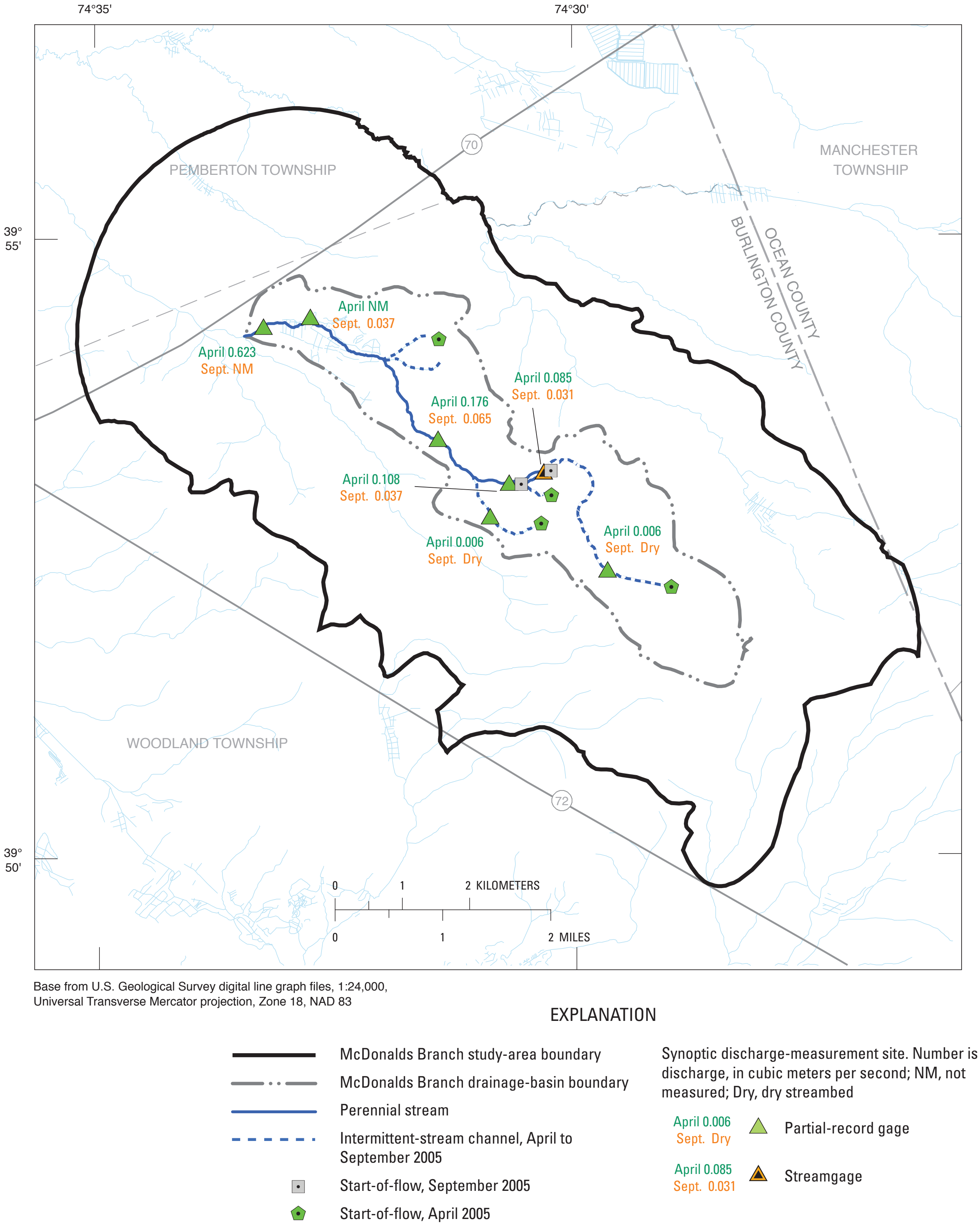



**Figure 28.** Surface-water discharge at selected locations, McDonalds Branch basin, New Jersey Pinelands, April and September 2005.

**Table 6.** Basin water budget for McDonalds Branch, Burlington County, New Jersey Pinelands, 2005–06.

[All values are in centimeters; recharge values determined as a residual may be different from computed values due to rounding]

Land-surface budget

| Date | Precipitation | Discharge to surface-water | Change in surface-water storage | Change in soil-moisture storage | Direct runoff | Evapotran-spiration | Surface-water with-drawals | Recharge |
|---|---|---|---|---|---|---|---|---|
| Oct-04 | 8.1 | 0 | 0 | 0.4 | 0 | 4.1 | 0 | 4.4 |
| Nov-04 | 10.4 | 0 | 0 | -1.5 | 0.1 | 2.1 | 0 | 6.7 |
| Dec-04 | 7.9 | 0 | 0 | 0.9 | 0.1 | 0.5 | 0 | 8.2 |
| Jan-05 | 8.8 | 0 | 0 | -0.3 | 0.1 | 0.6 | 0 | 7.9 |
| Feb-05 | 6 | 0 | 0 | -0.3 | 0.1 | 1.4 | 0 | 4.2 |
| Mar-05 | 9.7 | 0 | 0 | -0.4 | 0.2 | 2.1 | 0 | 7 |
| Apr-05 | 10.9 | 0 | 0 | 1 | 0.5 | 5.1 | 0 | 6.3 |
| May-05 | 7.5 | 0 | 0 | 0.7 | 0.1 | 7.3 | 0 | 0.8 |
| Jun-05 | 11.5 | 0 | 0 | 0.7 | 0.1 | 10.3 | 0 | 1.8 |
| Jul-05 | 10.8 | 0 | 0 | 1.7 | 0.1 | 11.6 | 0 | 0.8 |
| Aug-05 | 4.8 | 0 | 0 | 1.4 | 0 | 10 | 0 | -3.7 |
| Sep-05 | 1.3 | 0 | 0 | 0.7 | 0 | 7 | 0 | -4.9 |
| Oct-05 | 29.5 | 0 | 0 | -5.2 | 0.2 | 3.8 | 0 | 20.3 |
| Nov-05 | 12.1 | 0 | 0 | -0.8 | 0.1 | 2.1 | 0 | 9 |
| Dec-05 | 9.6 | 0 | 0 | 0.3 | 0.2 | 0.6 | 0 | 9.1 |
| Jan-06 | 13.6 | 0 | 0 | 0.2 | 0.5 | 1.7 | 0 | 11.5 |
| Feb-06 | 3.3 | 0 | 0 | 0.1 | 0 | 1.1 | 0 | 2.3 |
| Mar-06 | 1.3 | 0 | 0 | 2.3 | 0 | 1.9 | 0 | 1.8 |
| Apr-06 | 7.4 | 0 | 0 | -0.3 | 0 | 4.5 | 0 | 2.5 |
| May-06 | 7.6 | 0 | 0 | 1.4 | 0.1 | 7.3 | 0 | 1.6 |
| Jun-06 | 17.1 | 0 | 0 | -2.5 | 0.1 | 9.3 | 0 | 5.1 |
| Jul-06 | 12.5 | 0 | 0 | 2.9 | 0.1 | 12.2 | 0 | 3.1 |
| Aug-06 | 9.8 | 0 | 0 | -0.5 | 0 | 9.6 | 0 | -0.3 |
| Sep-06 | 21.3 | 0 | 0 | -1.9 | 0.2 | 6.9 | 0 | 12.3 |
| Monthly average | 10.1 | 0 | 0 | 0.04 | 0.1 | 5.1 | 0 | 4.9 |
| Annual average | 121.4 | 0 | 0 | 0.5 | 1.4 | 62 | 0 | 58.9 |

Groundwater budget

| Date | Base flow | Groundwater withdrawals | Leakage | Change in groundwater storage | Artificial recharge | Groundwater inflow or outflow | Recharge |
|---|---|---|---|---|---|---|---|
| Oct-04 | 2.7 | 0 | 1.1 | -3.2 | 0 | -0.7 | 1.3 |
| Nov-04 | 3 | 0 | 1.1 | 1.4 | 0 | -0.7 | 6.1 |
| Dec-04 | 3.9 | 0 | 1.1 | 0.4 | 0 | -0.7 | 6.1 |
| Jan-05 | 4.4 | 0 | 1.1 | 0.8 | 0 | -0.7 | 7 |
| Feb-05 | 4.4 | 0 | 1.1 | 1.7 | 0 | -0.7 | 7.9 |
| Mar-05 | 4.8 | 0 | 1.1 | 1.9 | 0 | -0.7 | 8.5 |
| Apr-05 | 5.1 | 0 | 1.1 | 1.3 | 0 | -0.7 | 8.2 |
| May-05 | 4.2 | 0 | 1.1 | -4 | 0 | -0.7 | 2.1 |

**Table 6.** Basin water budget for McDonalds Branch, Burlington County, New Jersey Pinelands, 2005–06.—Continued

[All values are in centimeters; recharge values determined as a residual may be different from computed values due to rounding]

| Groundwater budget—Continued | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Base flow** | **Groundwater withdrawals** | **Leakage** | **Change in groundwater storage** | **Artificial recharge** | **Groundwater inflow or outflow** | **Recharge** |
| Jun-05 | 3 | 0 | 1.1 | -1.2 | 0 | -0.7 | 3.6 |
| Jul-05 | 3.1 | 0 | 1.1 | -3.9 | 0 | -0.7 | 1 |
| Aug-05 | 2.3 | 0 | 1.1 | -4.6 | 0 | -0.7 | -0.5 |
| Sep-05 | 1.9 | 0 | 1.1 | -5.2 | 0 | -0.7 | -1.5 |
| Oct-05 | 2.9 | 0 | 1.1 | 8.5 | 0 | -0.7 | 13.2 |
| Nov-05 | 2.7 | 0 | 1.1 | 2.1 | 0 | -0.7 | 6.7 |
| Dec-05 | 3.6 | 0 | 1.1 | 0.4 | 0 | -0.7 | 5.9 |
| Jan-06 | 4.9 | 0 | 1.1 | 3.6 | 0 | -0.7 | 10.3 |
| Feb-06 | 3.9 | 0 | 1.1 | 0.2 | 0 | -0.7 | 6 |
| Mar-06 | 3.4 | 0 | 1.1 | -3 | 0 | -0.7 | 2.2 |
| Apr-06 | 2.7 | 0 | 1.1 | -2.1 | 0 | -0.7 | 2.4 |
| May-06 | 2.6 | 0 | 1.1 | -2.6 | 0 | -0.7 | 1.9 |
| Jun-06 | 2.4 | 0 | 1.1 | 0.3 | 0 | -0.7 | 4.5 |
| Jul-06 | 2.7 | 0 | 1.1 | -2.3 | 0 | -0.7 | 2.2 |
| Aug-06 | 1.9 | 0 | 1.1 | -2.5 | 0 | -0.7 | 1.3 |
| Sep-06 | 2.8 | 0 | 1.1 | 4.9 | 0 | -0.7 | 9.5 |
| Monthly average | 3.3 | 0 | 1.1 | -0.3 | 0 | -0.7 | 4.8 |
| Annual average | 39.5 | 0 | 13.1 | -3.5 | 0 | -8.8 | 57.9 |

2005, and March 2006) to 0.5 cm (April 2005 and January 2006). Direct recharge of the aquifer system through infiltration of precipitation typically was greatest during the winter months, when *ET* was minimal. During the study period, recharge during winter months (December-February) averaged about 7.2 cm/mo. During summer months (July-September), when *ET* was greatest, recharge averaged about 1.2 cm/mo. Annual base flow in the basin during the study period represented 96 percent of annual streamflow. In September 2005, the month with least precipitation during the study period, base flow accounted for 100 percent of streamflow. During 3 other months with less than average precipitation—October 2004, August 2005, and March 2006—base flow accounted for 100 percent of streamflow. In January 2006, one of the wettest months during the 2-year period, base flow represented 91 percent of streamflow. Changes in storage of soil moisture during the study period had a moderate effect on the water budget. Monthly changes in soil-moisture storage ranged from a decrease of 2.9 cm in July 2006 to an increase of 5.2 cm in October 2005. The average annual change in storage was 0.5 cm, representing a slight decrease in soil moisture during the 2-year study period. During the study period, groundwater levels declined slightly, representing an average loss in storage of 3.5 cm/yr. Monthly changes in groundwater storage ranged from -5.2 cm (a water-level decrease) in September 2005to 8.5 cm (a water-level increase) in October 2005 (fig. 30, table 6).

Estimated net vertical leakage to underlying confined aquifers was 1.1 cm/mo, and estimated net horizontal outflow to adjacent basins was 0.7 cm/mo. To evaluate the agreement between the land-surface and groundwater components of the water budget calculations, recharge values calculated using the land-surface equation were compared to those calculated using the groundwater equation (fig. 31). Estimates were generally in fairly close agreement, to within a few centimeters. Differences in monthly recharge estimates ranged from -3.7 cm in February 2006 and 2005 to 7.1 cm in October 2005. The average difference in monthly recharge estimates was 0.1 cm.

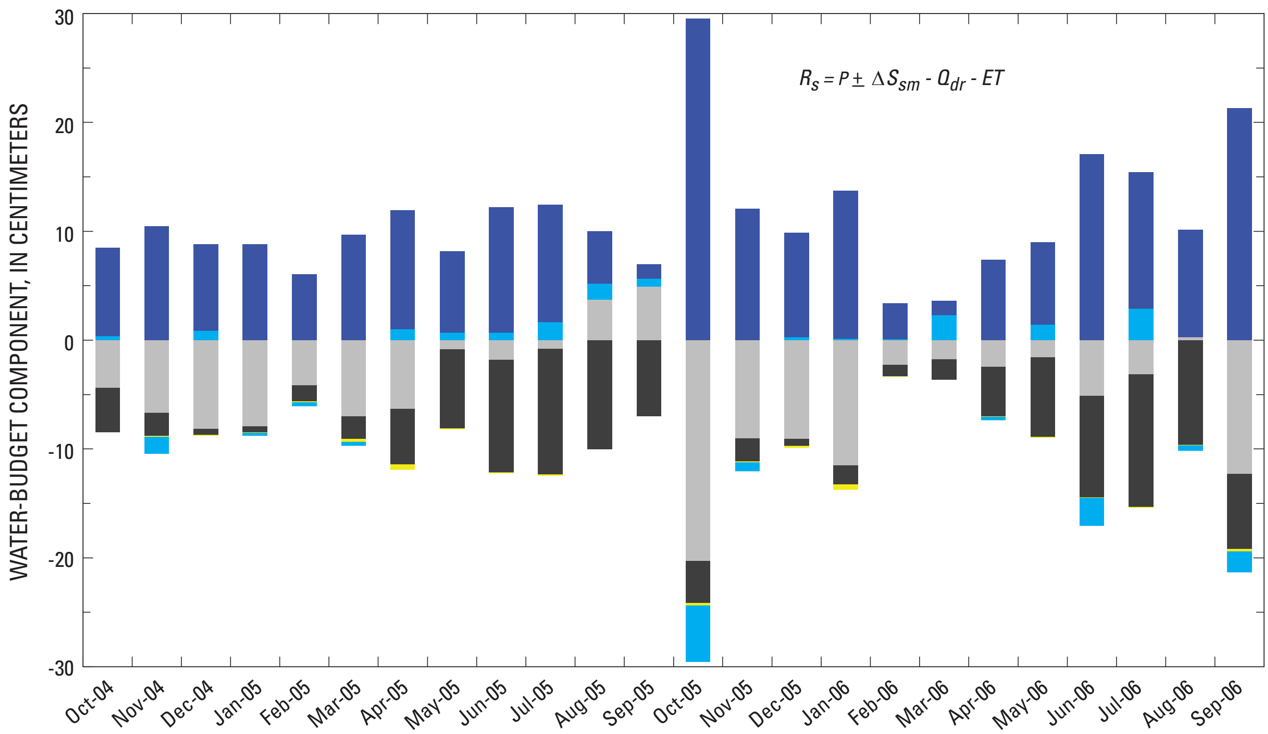



**Figure 29.** Components of the land-surface water budget by month, McDonalds Branch basin, New Jersey Pinelands, water years 2005–06.

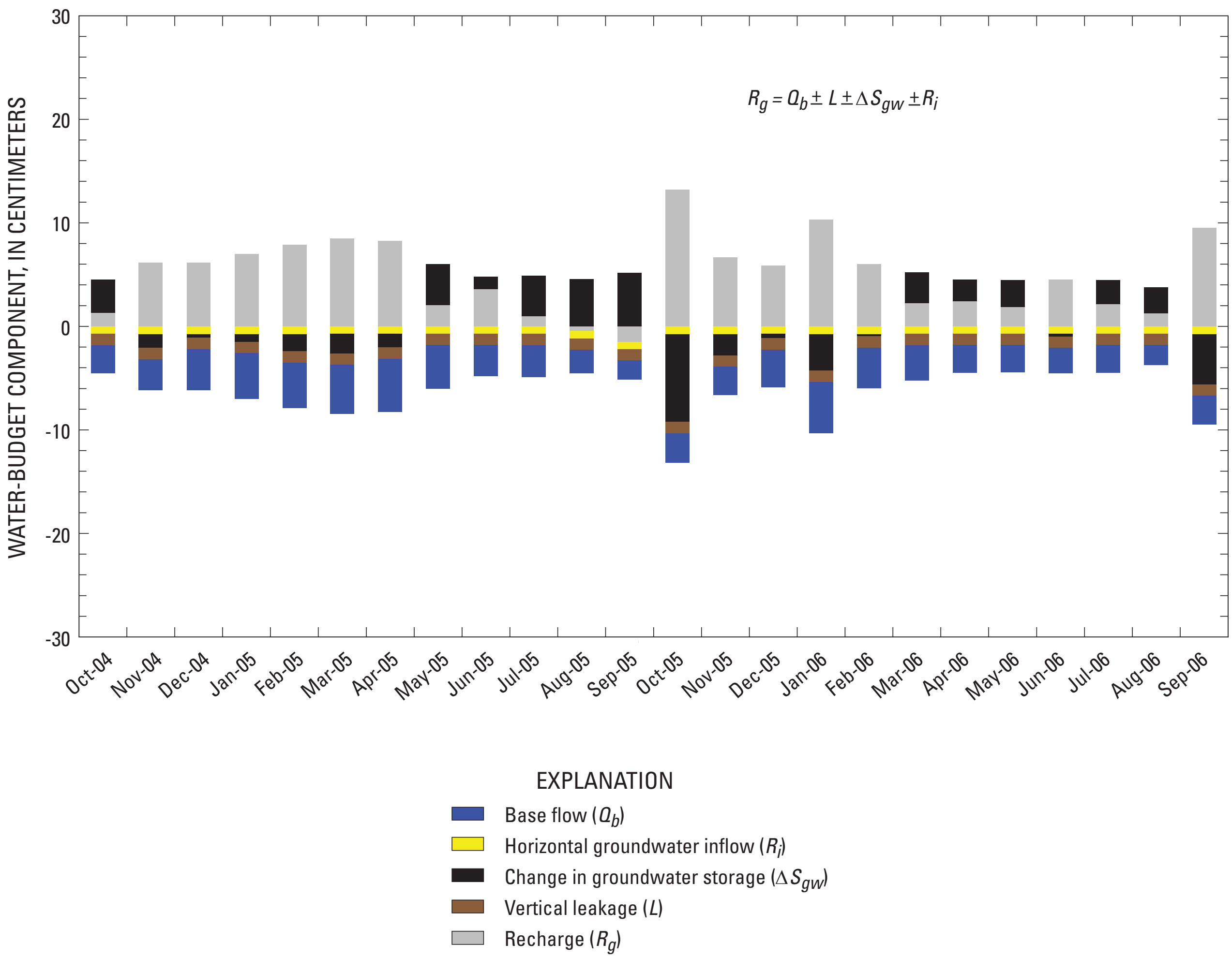



**Figure 30.** Components of the groundwater budget by month, McDonalds Branch basin, New Jersey Pinelands, water years 2005–06.

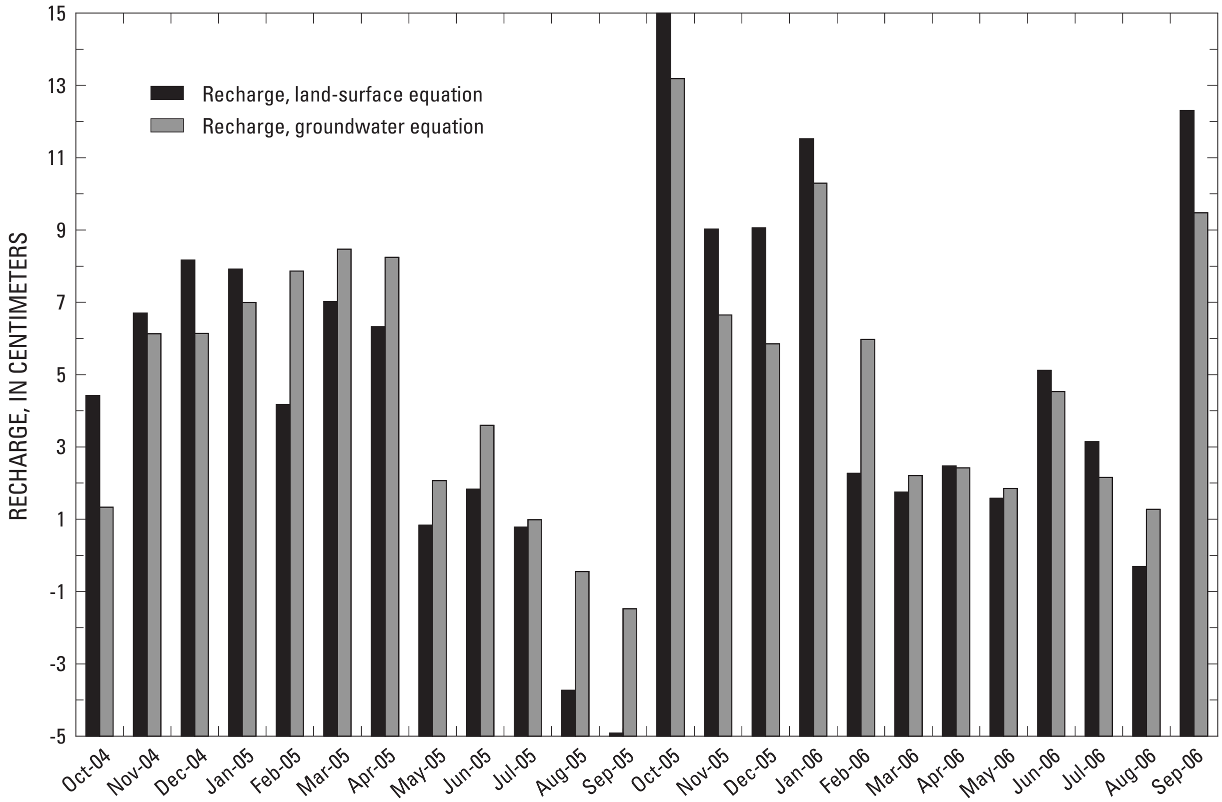



**Figure 31.** Comparison of monthly land-surface and groundwater recharge, McDonalds Branch basin, New Jersey Pinelands, water years 2005–06.

## Morses Mill Stream Study Area

The Morses Mill Stream study area is a relatively flat-lying, near-coastal area of the Pinelands with hydrologic and geologic characteristics that are similar to those of the other two study areas. The Morses Mill Stream basin is a shallow, gently sloping drainage incised in typical Coastal Plain sediments where the Cohansey Sand is commonly exposed beneath the stream channels, swamps, and wetlands. There are several large cedar swamps in the basin, and hardwood, pine, and cedar wetlands are flanked by forested uplands. In the upper part of the Morses Mill Stream basin, natural drainage patterns have been altered by various agricultural activities, such as channelizing flow around fields to drain wet areas or creating ponds for irrigation purposes. A small sand and gravel extraction operation is near, and old cranberry bogs created many years ago form ponds and small lakes on the Morses Mill Stream. By the time data collection for this study began in 2004, the remaining agricultural land in the basin was being replaced by developed land.

The agricultural areas in the upper basin transition to the property occupied by Richard Stockton College, where much of the data for this study was collected. Richard Stockton College (fig. 4) was established in 1969 on a 648-ha tract in the Pinelands that covers much of the lower part of the Morses Mill Stream basin. Since the groundbreaking in 1970, most development at the college has been in upland and near-wetland areas and does not appear to have altered the pre-development wetlands and swamps to any great extent. Exceptions include Lake Fred (fig.4); a former cranberry bog; and a deeply incised (1 to 2 m), manmade ditch (fig. 4) that appears to be designed to intercept shallow groundwater and effectively drains the wetlands that flank the campus to the east and southeast. This drainage ditch also receives stormwater from various parts of the campus. Water from the drainage ditch eventually discharges to the Morses Mill Stream at a location about 460 m downstream of the dam on Lake Fred (fig. 4).

Seasonal groundwater use in and around the study area may be affecting the groundwater levels. Groundwater also is extracted from the lower part of the Kirkwood-Cohansey aquifer system through wells at Richard Stockton College. Groundwater use on campus is primarily for institutional purposes, including landscape irrigation, and wastewater is discharged to a regional sanitary sewer. Stormwater runoff from impervious cover is routed through surface drains and pipes and either recharges the groundwater or, in some areas, discharges to nearby surface-water bodies.

During this study, management of the pond level at the dam on Lake Fred probably influenced local water-table altitudes around the pond and (or) the discharge in the Morses Mill Stream below the dam. The dam on Lake Fred sustained storm damage in August 1997, as determined from field observations and information obtained from officials at Richard Stockton College (D. Roesch, Richard Stockton College, oral communication, June 2006). Afterwards, the lake level was maintained at a relatively constant altitude about 0.3 m lower than the pre-August, 1997 pond altitude, until August 17, 2005, when it was lowered slowly an additional 0.6 m to accommodate repairs to the dam. This lower level was maintained until the repairs were complete, and the lake level was restored to the approximate pre-1997 altitude in March 2006.

Downstream from Lake Fred, the Morses Mill Stream flows though hardwood lowlands, cedar swamps, wetlands, and a privately owned recreational lake east of the Garden State Parkway before it reaches the streamflow-gaging station (01410225, fig. 4) at Port Republic, NJ.

## Groundwater Levels

During the period October 1, 2004, to September 30, 2006, water-level data were recorded continually in six basin-monitoring wells arranged in two three-well clusters in the Morses Mill Stream study area (fig. 4). The three wells at each of the basin-monitoring well clusters are screened in three of the aquifer layers that lie between the water table and the base of the Kirkwood-Cohansey aquifer system (Walker and others, 2008). Hydrographs of daily mean water levels prepared from these records (fig. 32) indicate that, during the period of record, water levels fluctuated about 1.78 m in the upper-basin monitoring wells and about 1.13 m in the lower-basin monitoring wells. These ranges are substantially greater than those recorded in either of the other two basins, indicating that the water-level fluctuations may be caused, in part, by differences between basins, such as variations in aquifer characteristics, stresses caused by groundwater withdrawals, differences in climatic conditions, or a combination of these factors.

Seasonal water-level extremes in the Morses Mill Stream study area occurred at nearly the same time in both the upper- and lower-basin monitoring wells (figs. 32A, 32B). In the other two drainage basins, in contrast, water levels in the upper basin lagged well behind those in the lower basin. Although the reason for this difference is not well understood, possible causes include the lower topographic relief of the Morses Mill Stream basin, the proximity of the lower-basin well cluster to a lateral basin divide, the local influence of recharge, and the stresses resulting from groundwater withdrawals in this study area. Hydraulic gradients were downward at both the upper- and lower-basin well clusters during the entire period of record (figs. 32A, 32B). Thus, water levels decreased as depth increased, indicating that both basin-monitoring well clusters are in aquifer recharge areas. Nearby, at a location closer to a cedar swamp that lies along the Morses Mill Stream, the USGS conducted an aquifer test in 2007 as part of another phase of this study to examine the effects of pumping stresses on wetlands hydrology. Before the aquifer test, water-level data from wells at the test site under unstressed conditions revealed upward hydraulic gradients from the base of the Kirkwood-Cohansey aquifer system to the water table, indicating that groundwater that follows longer flow paths probably discharges to the cedar swamp and the stream in that area, and that the water levels in the lower-basin monitoring wells reflect the effects of nearby recharge in the lower part of the basin.

At the upper-basin monitoring-well cluster, the shallow well (011500–MM OW-1S) is screened in the MM A-1 aquifer layer, which contains the water table at this location. In this aquifer, near the water table and the top of the screened interval in the shallow well, clay is found at depths ranging from about 2.5 to 4.5 m. Daily mean water levels in well 011500–MM OW-1S showed little if any response to isolated precipitation events less than 0.2 cm and somewhat attenuated responses of varying amounts when precipitation exceeded 3 cm over a period of a few days. The middle and deep basin-monitoring wells at this location, 011498–MM OW-1M and 011499–MM OW-1D, are screened in aquifer layers MM A-1B and MM A-3, respectively (Walker and others, 2008). Boring logs and geophysical logs recorded at the upper-basin well cluster indicate that clay layers up to 5 m thick separate the screened intervals of each of the upper-basin monitoring wells. These clays are part of the more extensive, locally discontinuous leaky confining layers (Walker and others, 2008). The water table is higher than water levels in the middle well (011498–MM OW-1M) with water-level differences ranging seasonally from about 0.2 to about 0.7 m. Water levels in well 011498–MM OW-1M also are consistently higher (about 0.2 m) than those in well 011499–MM OW-1D. Water-level fluctuations in the two deeper wells are smaller than, but similar to, that of the water table; they also show a smaller response to precipitation. Frequent short-duration fluctuations in water levels in the deeper wells probably are attributable to pumping effects from a nearby production well screened in aquifer layer MM A-3 about 1,200 m to the west. The distribution of water levels in the upper-basin monitoring wells indicate that (1) the water table is probably less well connected hydraulically with the deeper aquifer layers than the deeper aquifer layers are connected to one another, at least locally; (2) the leaky confining layer separating the middle and deep wells does not isolate the two wells from the influence of pumping; and (3) the deeper aquifers are probably hydraulically connected to the water table nearby, even if they are effectively isolated locally.

Geophysical logs and boring logs at the site of the lower-basin monitoring well cluster (Walker and others, 2008) show lithology similar to that at the upper-basin monitoring-well site, except that little or no clay is present in either the unsaturated or saturated sediments overlying the screened interval of the shallow well (011501–MM OW-2S). The shallow well is screened in aquifer layer MM A-1B, which contains the water table and is unconfined at this location; the

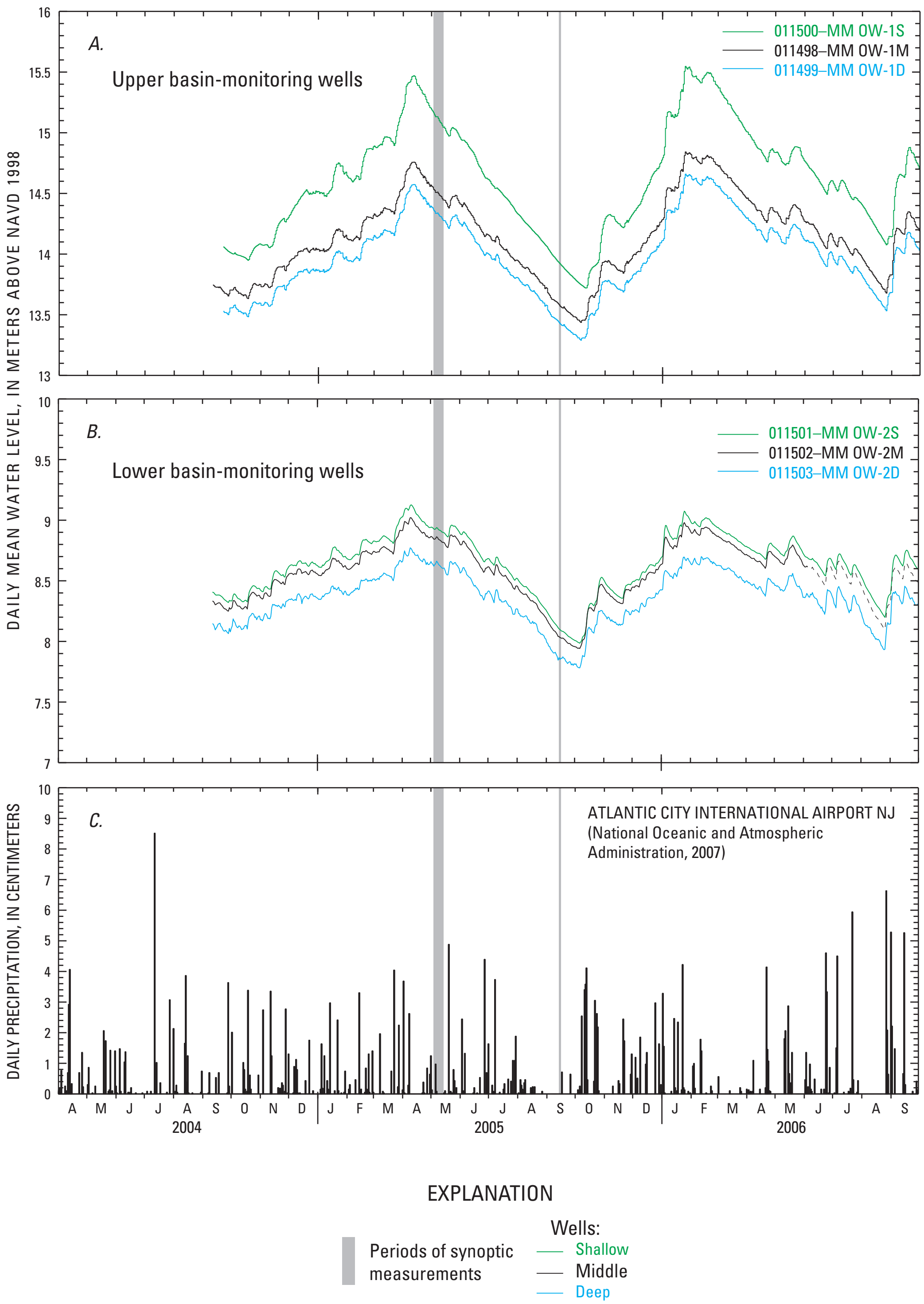



**Figure 32.** Groundwater levels in (*A*) upper and (*B*) lower basin-monitoring wells and (*C*) precipitation, Morses Mill Stream study area, New Jersey Pinelands, 2004–06.

overlying MM A-1C1 leaky confining layer consists mostly of sand and gravel and probably is ineffective as a confining layer at this location (Walker and others, 2008). The middle well, 011502–MM OW-2M, is screened in aquifer layer MM A-2, but the overlying leaky confining layer MM C-1 that separates the middle well from aquifer layer MM A-1B layer at this location is thin and probably very leaky. The water-level hydrographs for these two wells (fig. 32B), are similar and illustrate the results of this condition. The small difference between these water levels contrasts noticeably with the difference between water levels in the middle and deep wells (011502–MM OW-2M and 011503–MM OW-2D) screened in aquifer layer MM A-3, the principal source of local water-supply in the Kirkwood-Cohansey aquifer system. Three production wells are located at distances ranging from 300 to 1,200 m from the lower-basin monitoring-well cluster. Small, generally regular short-term water-level fluctuations are evident in the hydrographs of daily mean water levels for well 011503–MM OW-2D, and similar but less pronounced fluctuations are shown in the hydrograph for well 011502–MM OW-2M (fig. 32B). These fluctuations are probably a response to local pumping. The substantially lower water level in the deep well at this location also is a likely indicator of the influence of local groundwater withdrawals. The effects of precipitation on daily mean water levels are less pronounced in the lower-basin well cluster than in the upper-basin well cluster, although the pattern is similar, with the thick unsaturated sediments at the lower basin well cluster appearing to dampen the effects of infiltration and recharge.

Hydrographs for the period April 1, 2004, to September 30, 2006 (figs. 4, 33), prepared from continuous records of water levels in two wetland-monitoring wells screened in the unconfined aquifer, reveal differences in the range of water levels and their response to precipitation in wetlands along a small tributary that joins the Morses Mill Stream from the southwest at Lake Fred (fig. 4). Well 011457–Richard Stockton College 2 was used to monitor the water table in a pine and hardwood wetland in the headwaters of this tributary. Groundwater levels fluctuated 1.0 m during the period of record (fig. 33B). Water levels responded immediately to nearly all precipitation events, except those that followed sustained dry periods. Along the same tributary to Morses Mill Stream, a second shallow well (011458–Richard Stockton College 1) is screened in the sand and gravel directly beneath a cedar swamp. Water-level fluctuations were limited to 0.4 m during the period of record, probably as a result of the influence of the swamp and nearby stream (fig. 33A). Water levels generally responded immediately but minimally to even the smallest precipitation events throughout the period of record (fig. 33C). Nearby, a small engineered subsurface-stormwater-infiltration system receives rainfall from nearby parking lots and roofs, directing it to a small area where the groundwater is recharged. Although the extent to which this localized induced groundwater recharge may affect the water levels beneath the swamp is unknown, the hydrograph for 011458–Richard Stockton College 1, compares well with that of 011457–Richard Stockton College 2, which is located in an area that receives only natural recharge. This comparison suggests that the infiltration system does not substantially alter the natural water table response to precipitation in the area of 011458–Richard Stockton College 1.

## Streamflow

A streamflow-gaging station was established on the Morses Mill Stream at Port Republic, NJ, (01410225) near the lower basin boundary of this study area (fig. 3). Streamflow records collected from October 1, 2004, to September 30, 2006, indicate a range of daily mean discharge from 0.040 to 0.93 $m^3/s$ (fig. 34). A wooden box culvert forms the control downstream from the streamflow-gaging station. Streamflow may have been controlled for short periods at Lake Fred on the Richard Stockton College campus or at a private recreational lake upstream from the gaging station. The documented regulation of Lake Fred, described previously, resulted in a short-term increase in discharge during mid August 2005 (fig. 34A), when the altitude of Lake Fred was lowered by releasing water from storage to repair the dam. Streamflow also showed the effects of raising the pond altitude in March 2006, which resulted in a brief period when daily discharge at the gaging station fell to about 0.04 $m^3/s$, indicating that the period-of-record low daily mean discharge recorded for March 17, 2006, was abnormal for that time of year and was caused by regulation of Lake Fred. The lowest daily mean discharge that was unaffected by regulation during this study (0.042 $m^3/s$) occurred in both October 2004 and August 2005 and was slightly higher than that reported for March 17, 2006. Stream stage fluctuated about 0.5 m during the period of record, showing responsiveness to precipitation that could result from storm-runoff characteristics in the basin; however, stream stage also is consistent with shallow water levels in the wetlands (figs. 33A, 33B). Although groundwater beneath the wetlands is a substantial, near-surface source of discharge to surface water, the surface runoff routing and the engineered stormwater-infiltration system on the Richard Stockton College campus makes it more difficult to assess the relation of precipitation to the observed groundwater level and streamflow response.

Although no long-term historical streamflow records are available for the Morses Mill Stream basin, the understanding of data collected during this 2-year study can be improved by relating them to records from the East Branch Bass River, a tributary to the Mullica River, where hydrologic conditions are similar. Mean annual discharge at streamflow-gaging station 01410150, East Branch Bass River near New Gretna, NJ, about 14 km northeast of the Morses Mill Stream study area, for 2005 and 2006 was 88 and 95 percent, respectively, of the long-term mean annual discharge determined from 29 years of record (U.S. Geological Survey, 2009).

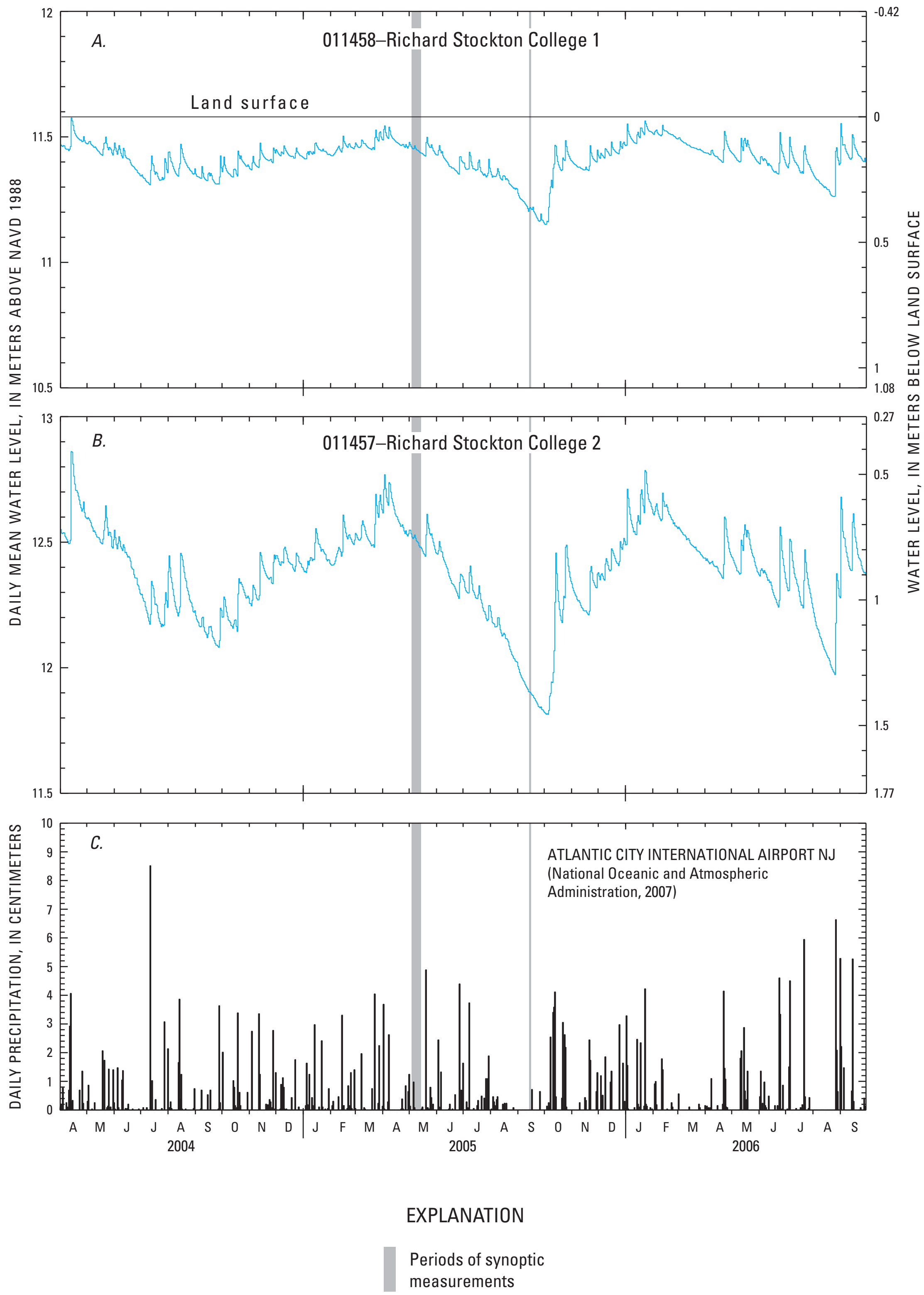



**Figure 33.** Groundwater levels in (*A*) Richard Stockton College 1 and (*B*) Richard Stockton College 2 wetland-monitoring wells and (*C*) precipitation, Morses Mill Stream study area, New Jersey Pinelands, 2004–06.

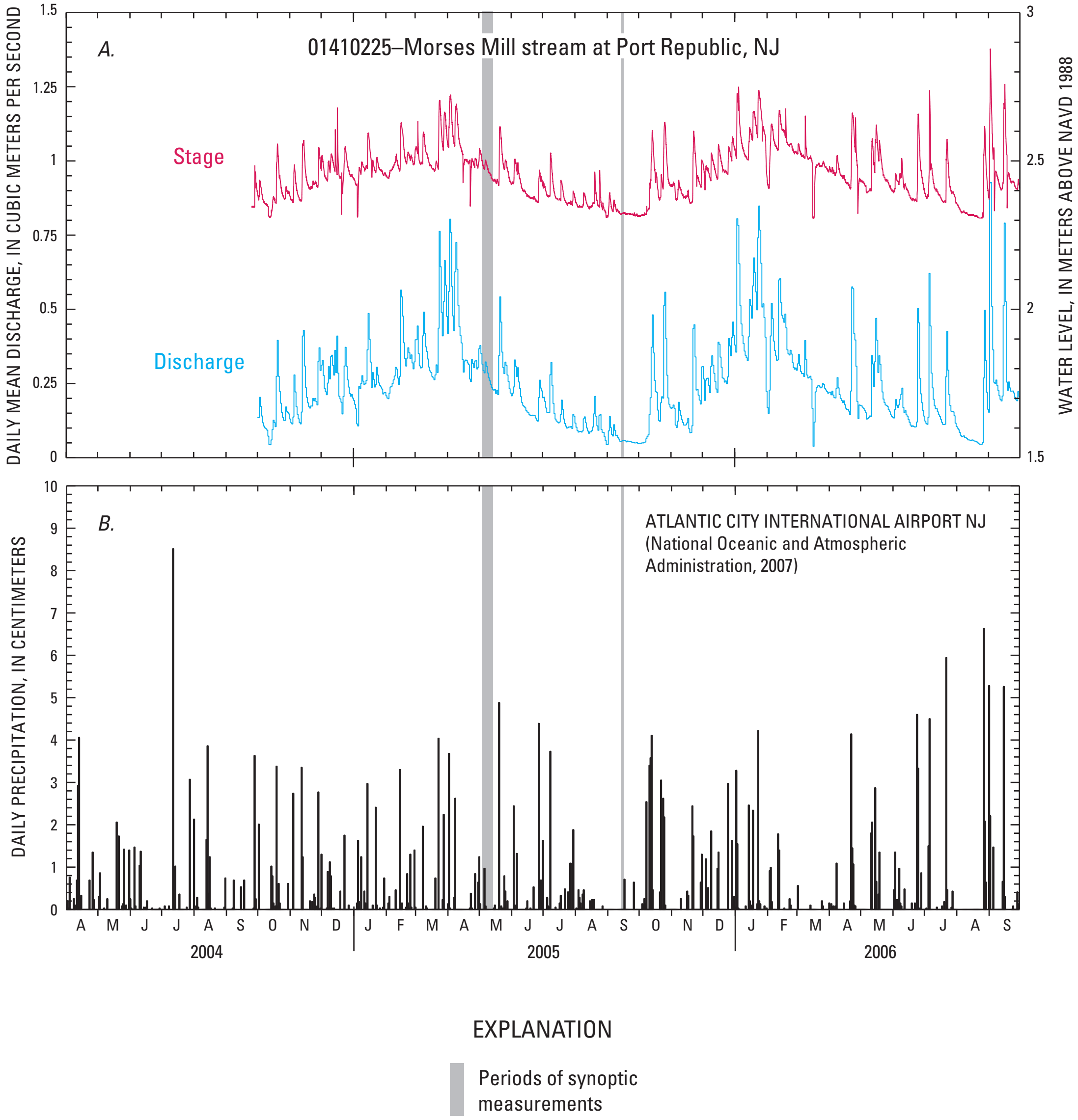



**Figure 34.** Surface-water stage and discharge at (*A*) Morses Mill Stream at Port Republic, NJ, gaging station and (*B*) precipitation, Morses Mill Stream study area, New Jersey Pinelands, 2004–06.

## Synoptic Measurements

Two synoptic measurements were made in the Morses Mill Stream study area during two low-flow periods, one in spring (May 3–13, 2005) and another during late summer (September 13–15, 2005). Water-level data collected during these periods are presented in table 3 (at end of report), and the location of the data-collection sites selected for analysis are shown in figure 35.

During the May 2005 synoptic measurement, groundwater levels in well 010256 (Scholler 1 Obs.) were about equal to the 24-year period-of-record daily mean water level for May (U.S. Geological Survey, 2009). This well is screened in the lower part of the Kirkwood-Cohansey aquifer system about 17 km west of the Morses Mill Stream study area. During the same period, daily mean discharge at streamflow-gaging station 01410150, East Branch Bass River near New Gretna, NJ, was slightly lower than the 29-year period-of-record daily mean discharge for May (U.S. Geological Survey, 2009).

The May synoptic measurements were begun following about 1 month with limited precipitation and during a downward trend in water levels following the seasonal high of 2005 (figs. 32, 33). Light precipitation totaling 1.88 cm occurred on 2 consecutive days, ending 3 days prior to the beginning of the synoptic measurements, resulting in a minor diversion from the downward water-level trend leading up to the time of the measurements. Another small event (0.97 cm) occurred during the measurements on May 6, but water levels and streamflow showed little response to that precipitation. Streamflow also remained close to the pre-precipitation trend during the measurements (fig. 34). Stream base flow was relatively high during the May measurements (fig. 34) and showed a general downward trend. The altitude of Lake Fred was not adjusted during the May measurements.

On the basis of records for well 010256 (Scholler 1 Obs), groundwater levels in the vicinity of the study area during the September synoptic measurement probably were lower than the 24-year period-of-record daily mean water levels for September. The daily mean discharge for the East Branch Bass River near New Gretna, NJ, during September also was lower than the 29-year period-of record daily mean discharge (U.S. Geological Survey, 2009). In mid August 2005, the altitude of Lake Fred was lowered for maintenance and then was maintained at a constant level throughout the period of the September synoptic measurement. The streamflow hydrograph shows the increased flow associated with the lowering of Lake Fred and indicates that the effects of the release had dissipated well before the September synoptic measurement was begun (fig. 34).

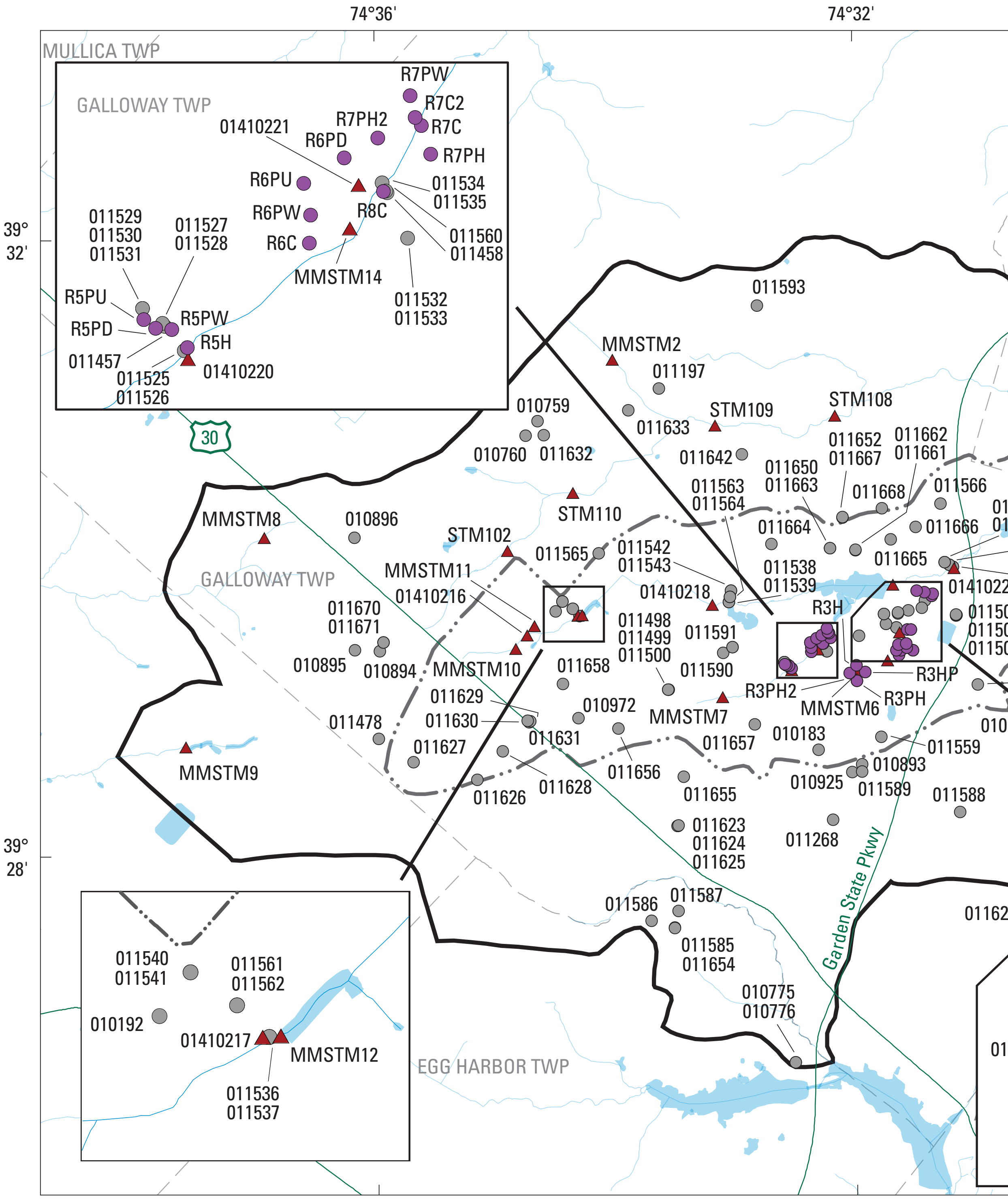
The water-table contour maps prepared from the May and September 2005 synoptic measurements (figs. 36 and 37) show that the water-level altitude slopes along the length of the basin, decreasing about 17 m between the upper and lower basin boundaries. The water-table altitude declined throughout the basin from May to September, with the decline ranging from 0.04 to 1.78 m. Water levels generally were smallest near discharge areas such as swamps, streams, and ponds and greatest in the uplands. The differences in the slope and direction of groundwater flow between the two synoptic measurements in the upper part of the basin vary locally, indicating that apparent groundwater flow paths and gradients were affected by local hydrologic conditions; specifically, upper basin streams ceased to flow because water levels had declined and localized shallow groundwater discharge to surface water ceased at locations upstream from the start-of-flow**.** As the streams became dry, they no longer influenced the near-stream groundwater flow paths associated with gaining and losing stream reaches. Consequently, the water-level contours cross the dry streambeds normal to the stream channels rather than reflecting local flow toward the stream. Groundwater flow paths in these areas describe longer, sub-regional groundwater flow paths along the slope and orientation of the basin as groundwater moves toward points of discharge farther downstream. Low-permeability sediments, typically clays, underlie much of the area surrounding the Morses Mill Stream, especially near the wetlands and swamps, which formed in ancient channels. In the lower parts of the basin, these clays appear to have been eroded and replaced with coarser sediments beneath the present-day streams and swamps. In the uplands, these low-permeability sediments commonly are capped with coarse sediments, permitting rapid infiltration to the top of the clays, which impede further vertical movement and may cause lateral flow, creating shallow flow systems that discharge directly to wetlands, swamps, and streams. In other upland areas, coarse-grained channel bars were formed, and the shallow clays may be absent (Walker and others, 2008).

Groundwater flow follows the general path of Morses Mill Stream, from areas of highest water level to those of lowest water level. The topographic divides (basin boundaries), however, do not appear to coincide with the position of the groundwater divides in localized areas along the northern and southern basin boundaries where water-table contours indicate groundwater is either leaving or, in a few locations, entering the basin in both May and September (figs. 36, 37). For example, the relatively high water table in a localized area along the basin's southern boundary indicates that groundwater may be entering the basin from the south during both synoptic measurements.

Depth to the water table in the Morses Mill Stream basin (fig. 38) ranges spatially from zero at points of groundwater discharge such as ponds, streams, and swamps to a maximum of more than 10 m in upland areas along the northern and southern basin boundaries. The distribution of the DTW in the basin is shown in figure 39, which provides a profile of the hydrologic settings in this basin for habitats dependent on various ranges of water-table depth. DTW is less than 0.5 m over 17 percent of the basin, resulting in a relatively small percentage of the basin being hydrologically suitable for wetland habitats. In comparison with the Pinelands area as a whole, mapped wetlands constitute a slightly smaller percentage of the basin; 23 percent of the basin is mapped as wetlands, whereas wetlands covered 27 percent of the entire Pinelands area in 2002 (Zampella and others, 2008). DTW in the mapped wetlands areas ranges from zero to 4.5 m, with a mean of 0.73 m. Areas where DTW ranges from 0.5 to 2.0 m occupy a greater percentage of the Morses Mill Stream basin than of the McDonalds Branch and Albertsons Brook basins, meaning that the Morses Mill Stream basin contains the greatest percentage of marginally suitable and transitional wetlands habitats of the three basins.

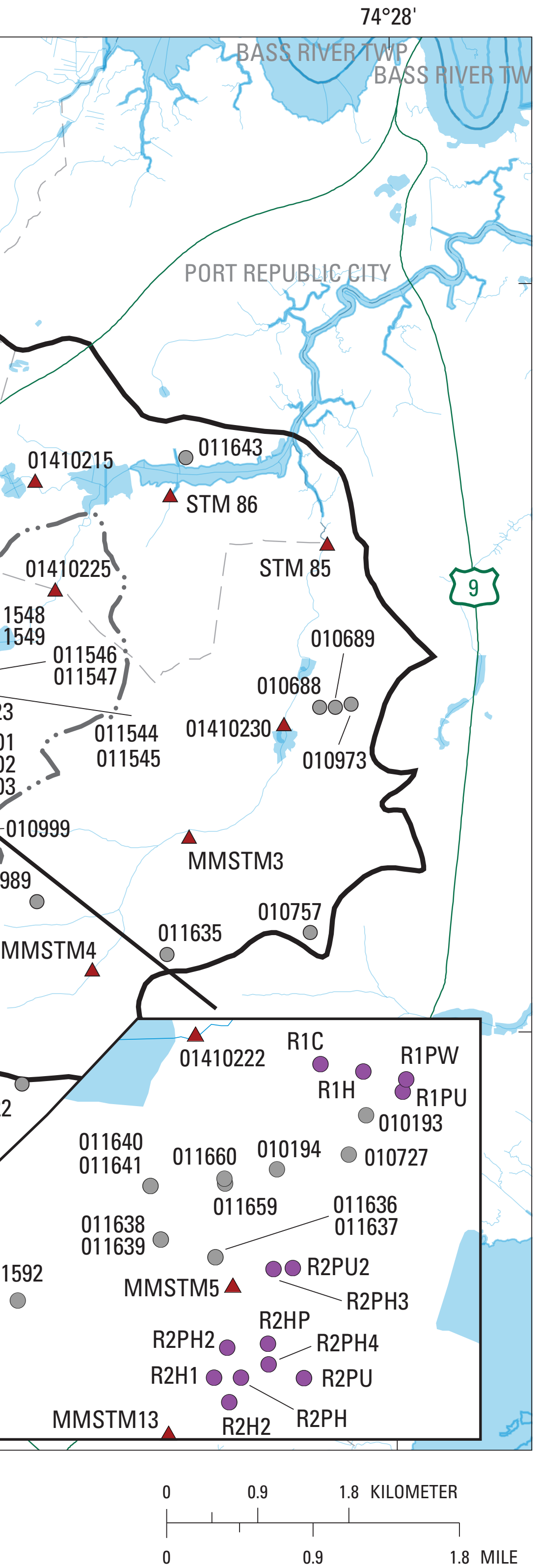
Data collected along five hydrologic transects (fig. 4) in the Morses Mill Stream basin during the synoptic measurements in May and September 2005 describe the interaction of groundwater levels with wetlands and surface water. These data characterize changes in the water table with respect to hydraulic gradients and the variability of potential groundwater flow and discharge to wetlands and surface water during periods of seasonal high and low water levels. These data are shown in figure 40 and the site conditions and other findings are described below.

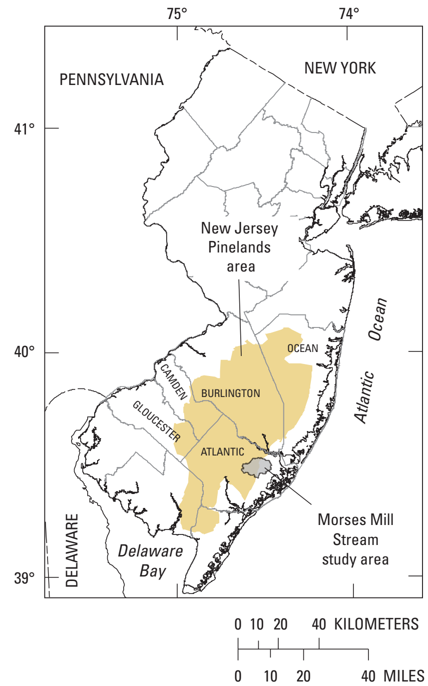
The uppermost hydrologic transect, MMHT1, is located on an intermittent stream reach near the headwaters of the Morses Mill Stream. A staff gage is located at the upstream side of the roadway culvert about 15 m downstream from the transect. During the May synoptic measurement, the stream stage was at the same altitude between the nearest transect well pair and the staff gage. The vertical hydraulic gradients in May were downward at the two well clusters farthest from




Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 35.** Location of selected sites used for synoptic water-level measurements, Morses Mill Stream study area, New Jersey Pinelands, May and S




EXPLANATION

Morses Mill Stream study-area boundary

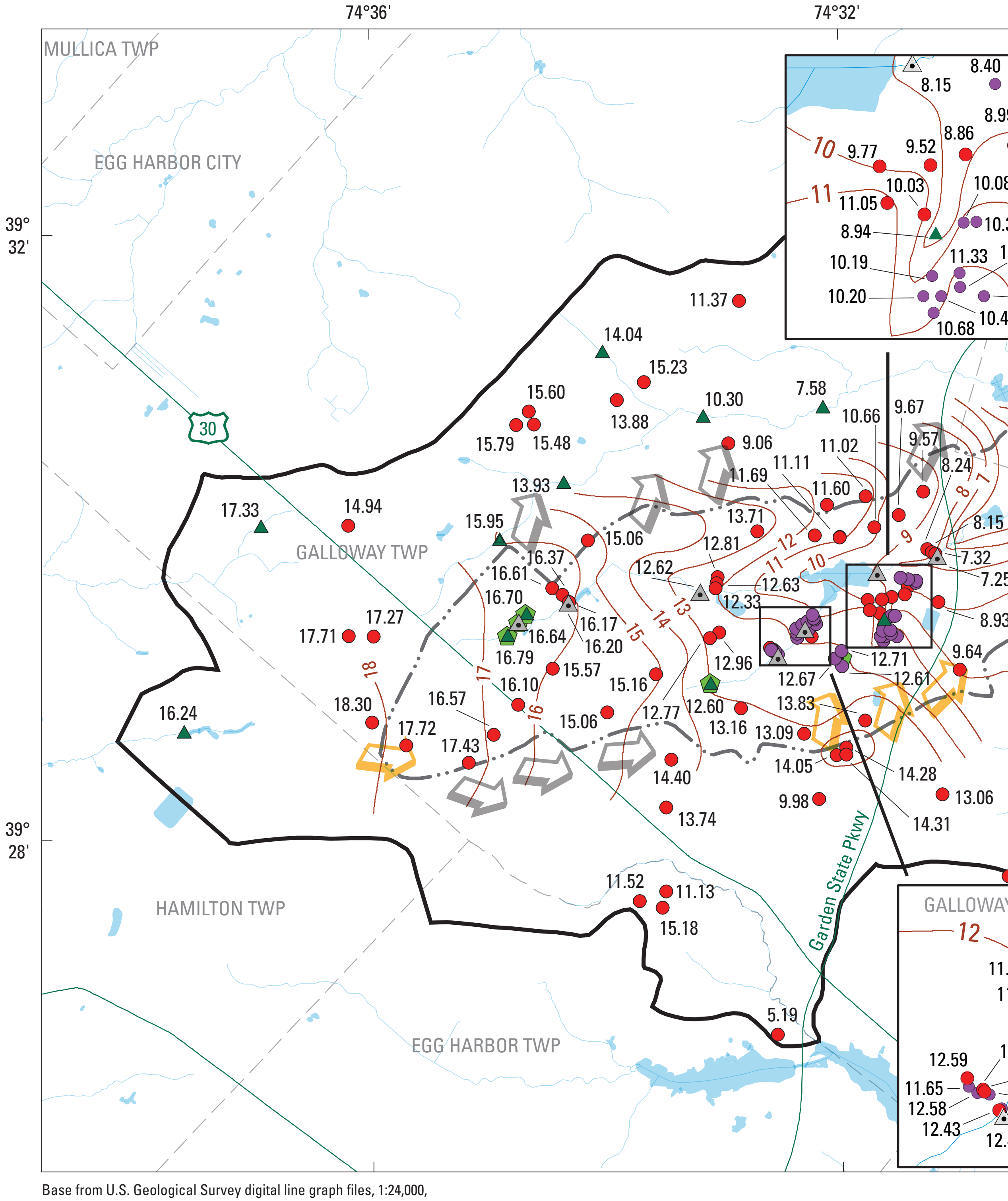
Morses Mill Stream drainage-basin boundary

011629 — Location of well. Label is U.S. Geological Survey site identifier as shown in table 3

R3PH — Location of well installed and monitored by the NJ Pinelands Commission. Label is site identifier as shown in table 3

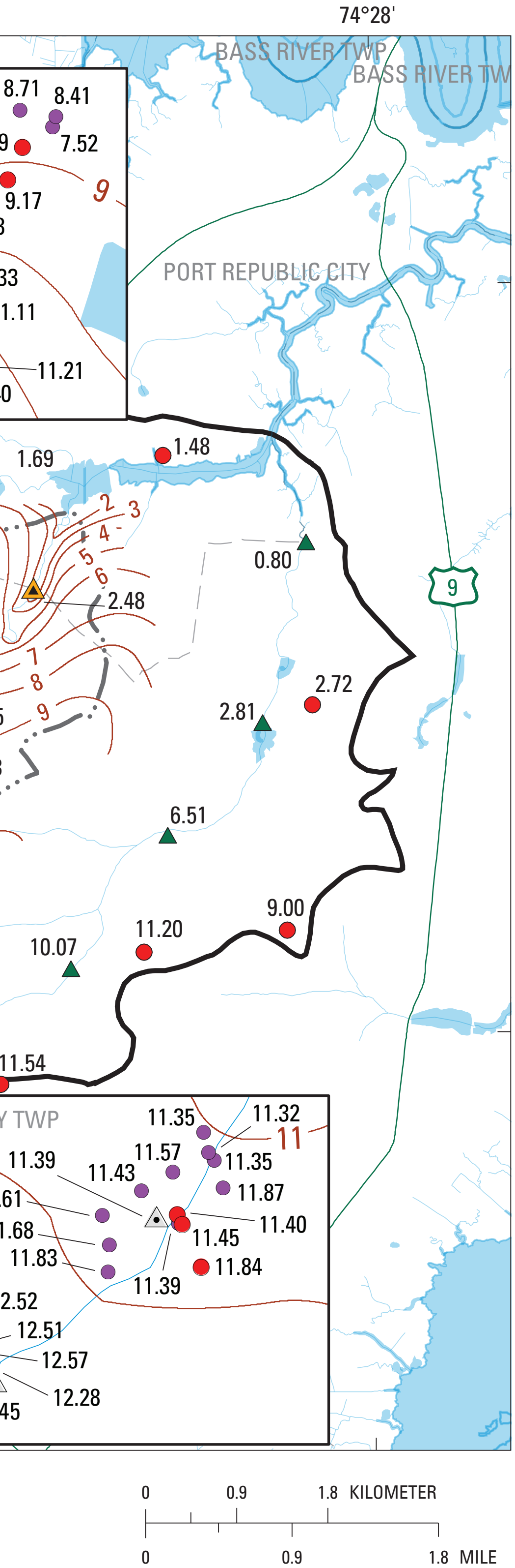
MMSTM4 — Location of surface-water site–includes streamgages, staff gages, stream point, and seepage site. Label is site identifier as shown in table 3

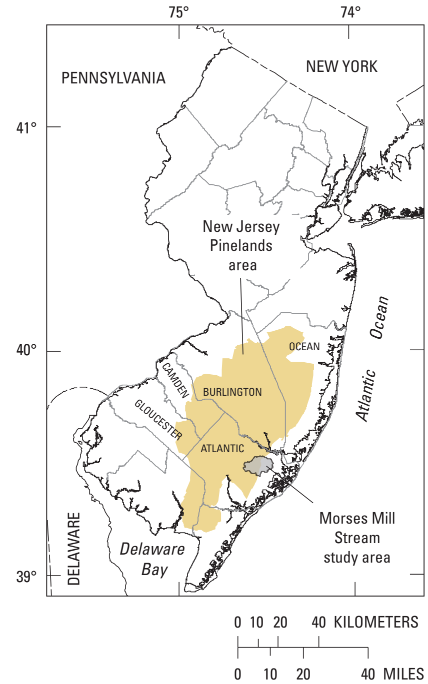
eptember 2005.




Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 36.** Altitude of water table, Morses Mill Stream study area, New Jersey Pinelands, May 2005.




EXPLANATION

Morses Mill Stream study-area boundary

Morses Mill Stream drainage-basin boundary

30 — Altitude of water table, in meters. Datum is NAVD 88

17.71 — Location of well monitored by U.S. Geological Survey. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

11.83 — Location of well installed and monitored by the NJ Pinelands Commission. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

Start-of-flow, May 2005

Arrow indicates area where ground-water may be leaving the basin

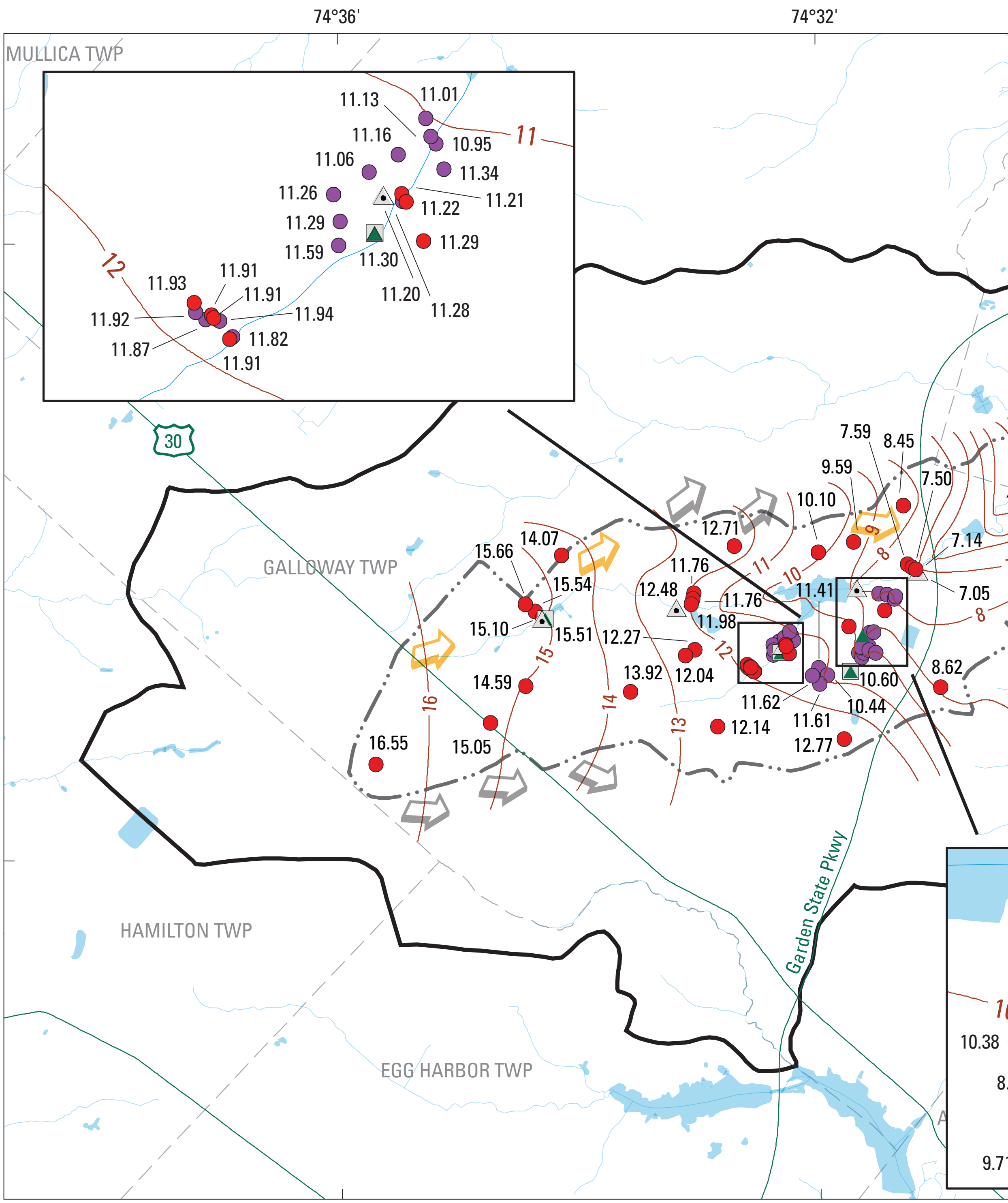
Arrow indicates area where ground-water may be entering the basin

U.S. Geological Survey surface-water site. Label is water-level altitude, in meters, as shown in table 2. Datum is NAVD 88

8.15 — Partial-record station

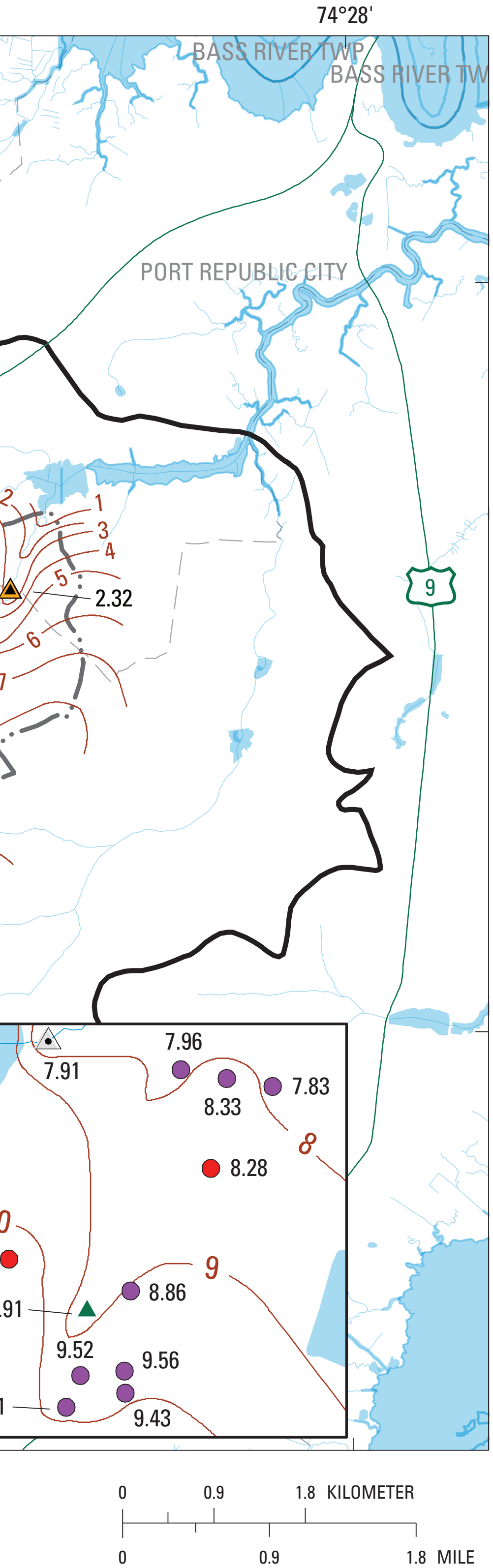
2.48 — U.S. Geological Survey streamgage

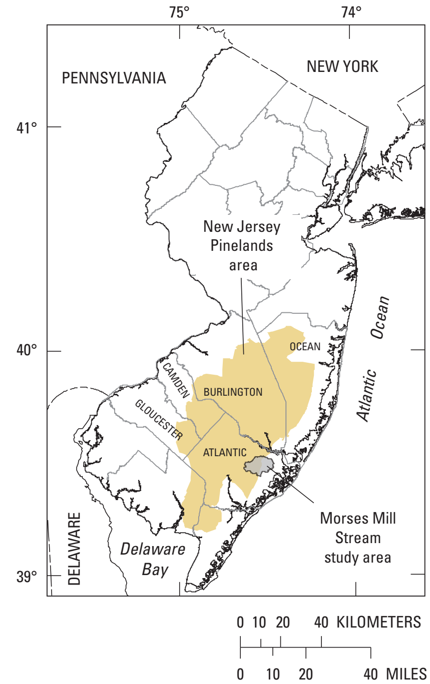
2.81 — Stream point




Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

**Figure 37.** Altitude of water table, Morses Mill Stream study area, New Jersey Pinelands, September 2005.




EXPLANATION

Morses Mill Stream study-area boundary

Morses Mill Stream drainage-basin boundary

30 — Altitude of water table, in meters. Datum is NAVD 88

12.77 — Location of well monitored by U.S. Geological Survey. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

11.16 — Location of well installed and monitored by the NJ Pinelands Commission. Label is water-level altitude, in meters, as shown in table 3. Datum is NAVD 88

Start-of-flow, September 2005

Arrow indicates area where ground-water may be leaving the basin

Arrow indicates area where ground-water may be entering the basin

U.S. Geological Survey surface-water site. Label is water-level altitude, in meters, as shown in table 2. Datum is NAVD 88

7.91 — Partial-record station

2.32 — U.S. Geological Survey streamgage

10.6 — Stream point

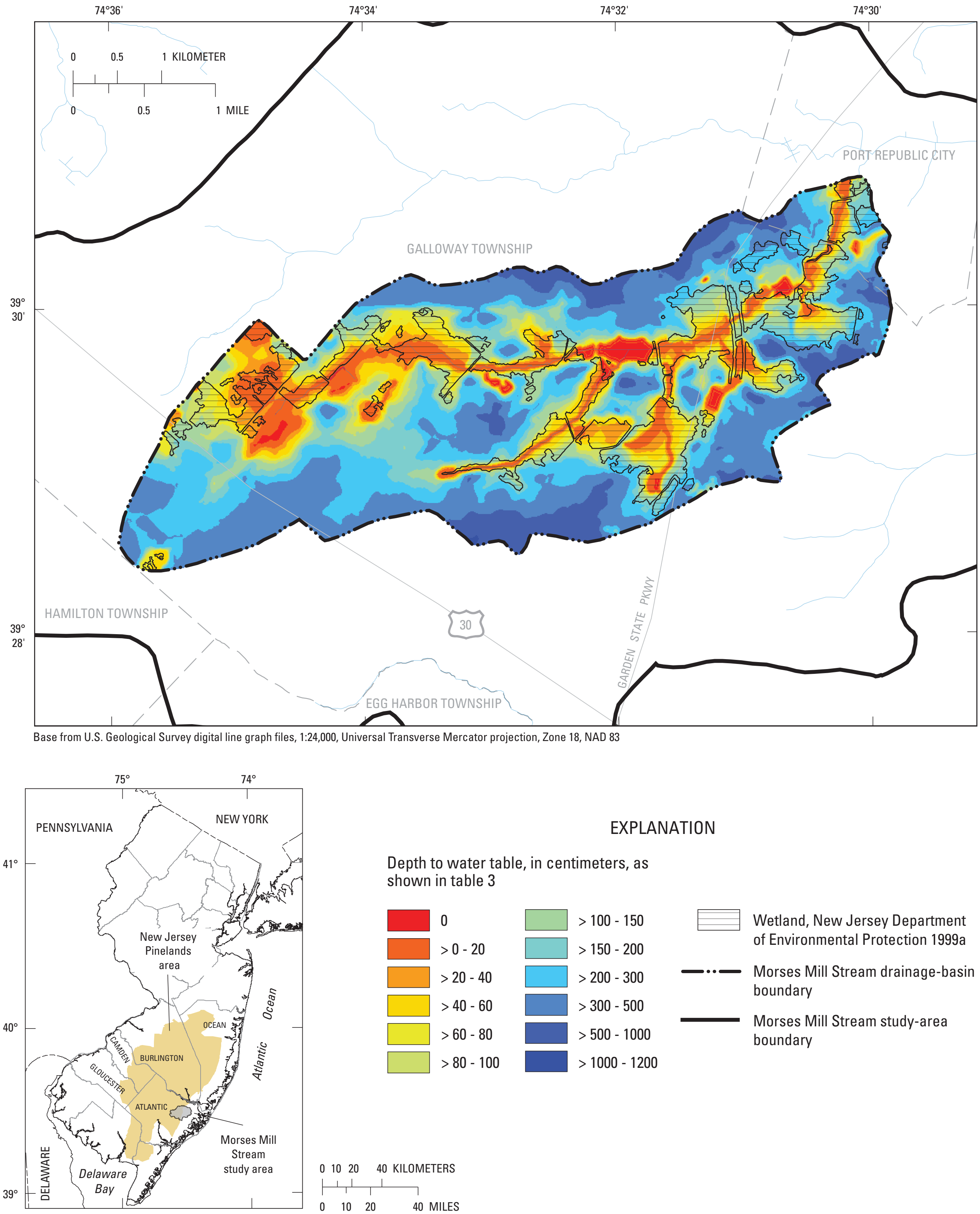



**Figure 38.** Depth to water table, Morses Mill Stream basin, New Jersey Pinelands, May 2005.

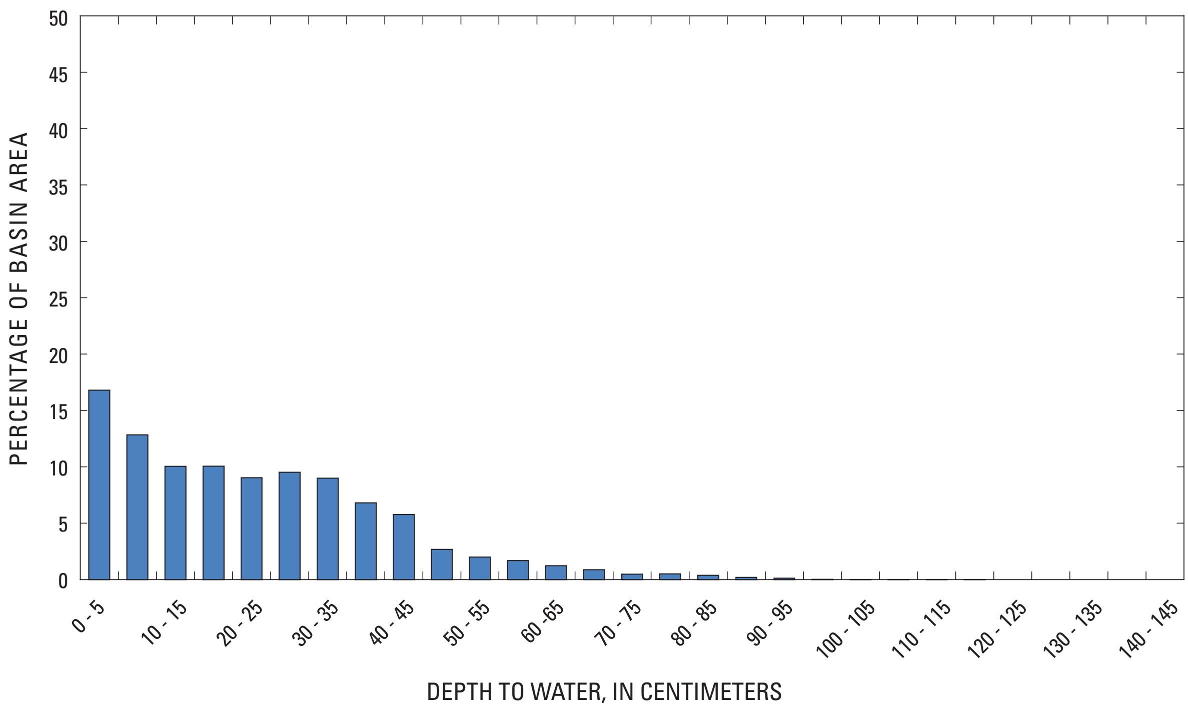



**Figure 39.** Histogram showing percentage distribution of depth to water in Morses Mill Stream basin, Morses Mill Stream study area, New Jersey Pinelands, May 2005. (Areas where 5-centimeter intervals of depth to water exceed 145 centimeters occupy less than 2 percent of the basin area and are not shown.)

the stream, whereas the near-stream well cluster indicated an upward hydraulic gradient toward the stream (fig. 40). In September, the shallowest wells in the upgradient and middle well clusters were dry and a small upward gradient was measured in the well cluster nearest the stream, which also was dry at the time of the measurement. During both synoptic measurements, water levels indicated groundwater gradients toward the stream, but the deep wells showed a decidedly smaller horizontal gradient toward the stream in September. Below the roadway, the Morses Mill Stream normally falls through a culvert into a small irrigation pond, creating a head differential between the pond and the stream above the road. Although the stream above the road was dry in September, the horizontal gradient toward the stream and the slight upward gradient measured at the near-stream well cluster indicate that groundwater discharge also may have been occurring in September. If so, groundwater likely would have been moving toward the pond (lower altitude) at that time (fig. 37).

Downstream from the irrigation pond, which is used for the surrounding blueberry fields, the Morses Mill Stream flows into a hardwood lowland and swamp flanked by forested wetlands and uplands. Transect MMHT2 is situated along the north side of the stream in this natural setting (fig. 37). Transect MMHT2 is about 150 m long; the hardwood swamp is about 30 m wide and extends to the stream. The May synoptic measurements indicated upward hydraulic gradients at all well clusters and beneath the streambed, and the water table sloped toward the stream along the length of the transect; both conditions indicate potential discharge to the stream. In September, water levels indicated no horizontal gradient from the uplands to the wetlands with slight upward gradients measured at the two well clusters nearest the stream. Also, a large downward hydraulic gradient was observed beneath the stream, indicating that the stream probably was losing water to the aquifer, at least locally.

About 1,500 m downstream from MMHT2, a small tributary joins the Morses Mill Stream from the southwest at Lake Fred. In the headwaters of this tributary, hydrologic transect MMHT3 originates in a hardwood upland area that transitions to wetlands and eventually a swamp. There is no well-defined stream channel here, and surface water flows as the groundwater discharge and recent swamp drainage allow. In May, the water table sloped with a small horizontal gradient toward the wetlands and stream. Vertical gradients were downward in the uplands and upward near the edge of both the wetlands and the swamp. A small upward hydraulic gradient was measured with a temporary piezometer beneath the swamp in the vicinity of the transect, indicating a potential for groundwater discharge in this area.

In September a very small horizontal gradient from the uplands to the wetlands is observed, but no vertical gradient could be determined at the upland end of the transect because

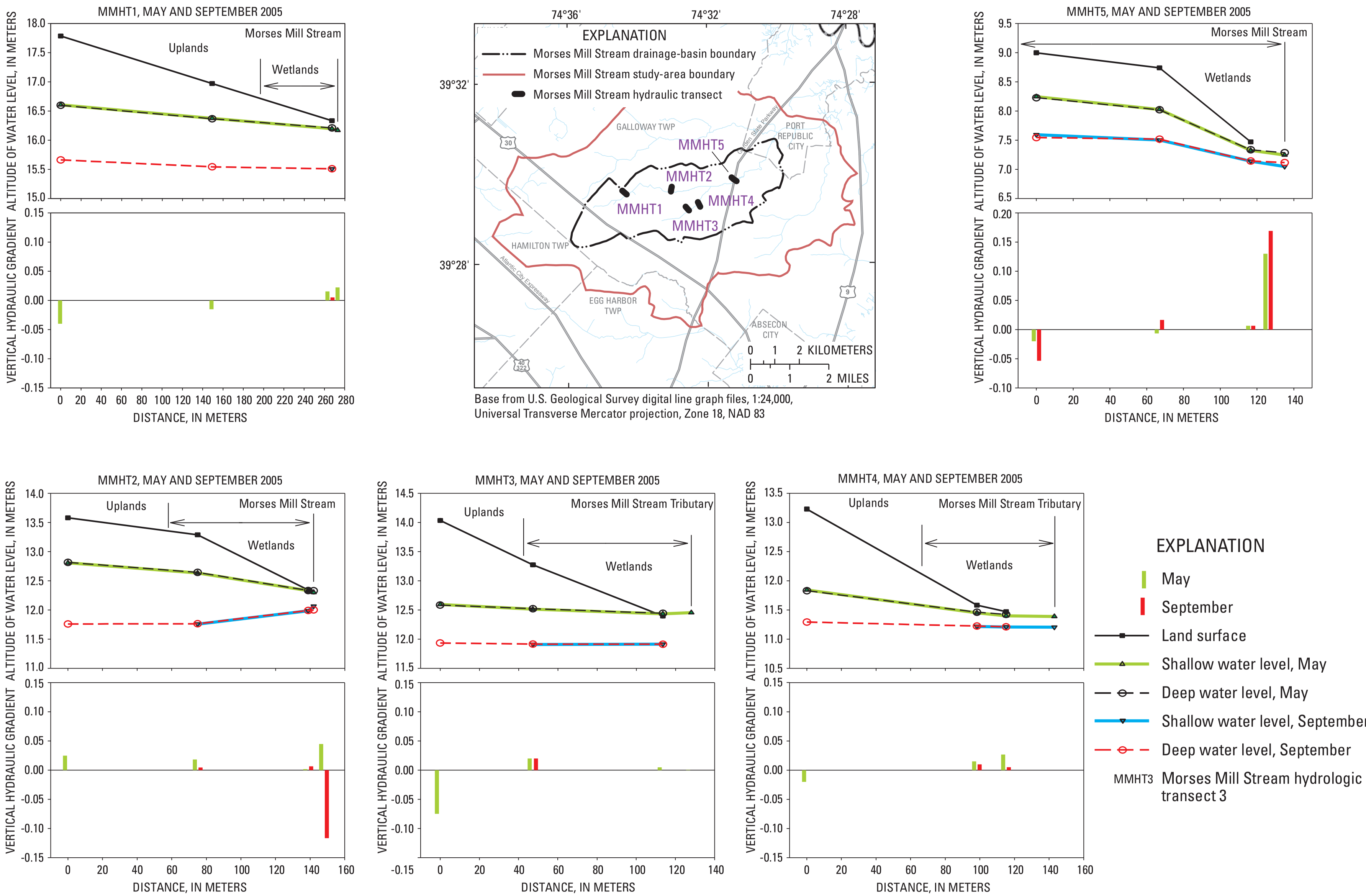



**Figure 40.** Location of five wetlands hydrologic transects and graphs showing water levels and hydraulic gradients along the transects during high (May) and low (September) flow, Morses Mill Stream basin, New Jersey Pinelands, 2005. (Vertical datum is NAVD 88)

the shallow wells there were dry. From the margin of the wetlands to the swamp, the horizontal gradients were too small to measure; the vertical gradient was upward near the wetlands but there was no vertical gradient evident near the swamp. The distribution of vertical gradient and groundwater flow at this location in September is not well understood but may have been affected by variations in sediment texture in the shallow aquifer beneath in the wetlands and the swamp.

Hydrologic transect MMHT4 is on the southern side of the same tributary about 400 m downstream from MMHT3 (figs. 4, 40). In May, water levels sloped uniformly from the pine and hardwood uplands to the cedar swamp. Hydraulic gradients were downward in the uplands, upward at the cedar swamp wells, and upward near the tributary, indicating possible discharge to the swamp and stream. In September, the shallow well in the upland cluster was dry, but the water table defined by deep wells indicated a smaller slope in the water table toward the cedar swamp than in May. Small upward gradients were measured in the middle well cluster in the cedar swamp and near the stream in September. Minimal flow also was observed in the stream, indicating that the upward hydraulic gradients between the nearby wells probably represent discharge of groundwater to the stream in this area in September.

Hydraulic transect MMHT5 is more than 800 m downstream from Lake Fred in a natural, predominantly hardwood forested area (figs. 4, 40). Groundwater levels slope with the topography toward the stream, with downward hydraulic gradients in the uplands in both May and September 2005. Downward gradients also were observed in the middle well cluster in May, but vertical gradients were upward at this location in September, probably indicating a greater contribution of deep groundwater at this location than in May. Also in September, water levels in the two deep wells in the upland and middle well clusters were the same, indicating a greater decline in groundwater levels in the uplands than at the middle well cluster and likely little shallow horizontal groundwater flow toward the stream between these well clusters. In both May and September, however, horizontal hydraulic gradients were greater between the middle well cluster and the stream; the largest upward gradients also were measured at the stream. Water-level altitudes and the distribution of the hydraulic gradient between the middle well cluster and the wells near the stream indicate that a considerable groundwater contribution from deeper in the aquifer probably discharges to the Morses Mill Stream in this area.

Stream base-flow measurements and the observed start-of-flow locations for both May and September 2005 synoptic measurements (fig. 41) show that base flow measured at streamflow sites ranged from zero (dry stream bed) to 0.022 $m^3/s$ at an upper basin stream site, and from 0.059 to 0.283 $m^3/s$ at the streamflow-gaging station in September and May 2005. Locations of start-of-flow observed during the May and September 2005 synoptic measurements are shown in figure 41 with a dashed line indicating the range of the seasonally intermittent stream channel defined by the start-of-flow observations. Base-flow discharge data for the Morses Mill Stream, including the ratio of spring base-flow discharge to summer base-flow discharge, at stream sites are provided in table 4. The base-flow discharge ratios were 17 and 48 at two sites in the upper-basin areas and 5 and 11 at two sites in the lower-basin areas.

## Water Budget

The water budget detailed below lists values for applicable components of the hydrologic cycle in the Morses Mill Stream basin and accounts for all known gains and losses to or from the system. The basin water budget was developed on a monthly basis. The time period covered by this analysis is October 2004 through September 2006. The Morses Mill Stream basin budget area encompasses 21.63 $km^2$ in Atlantic County, NJ (fig. 5).

The following equations were used to calculate the water budget for the Morses Mill Stream basin.

Land-surface components:

$$R_s = P \pm \Delta S_{sw} \pm \Delta S_{sm} - Q_{dr} - ET - W_s \quad , \qquad (8)$$

where

- $R_s$ = recharge to the aquifer system,
- $P$ = precipitation,
- $\Delta S_{sw}$ = change in surface-water storage,
- $\Delta S_{sm}$ = change in soil moisture,
- $Q_{dr}$ = direct runoff,
- $ET$ = evapotranspiration, and
- $W_s$ = surface-water withdrawals/diversions; and

Groundwater components:

$$R_g = Q_b + W_g \pm L \pm \Delta S_{gw} \pm R_i \quad , \qquad (9)$$

where

- $R_g$ = recharge to the aquifer system,
- $Q_b$ = base flow,
- $W_g$ = groundwater withdrawals,
- $L$ = leakage to confined aquifers,
- $\Delta S_{gw}$ = change in groundwater storage, and
- $R_i$ = groundwater inflow to/outflow from adjacent basins. In the Morses Mill Stream basin, there were no artificial discharges to groundwater or surface water ($D_{as}$ and $D_{ag}$, respectively).

Average annual precipitation in the Morses Mill Stream basin was 114 cm during the 2-year study period (table 7), the same as in the Albertson Brook basin. Monthly precipitation typically is fairly uniform throughout the year and evenly distributed throughout the basin. Monthly precipitation averaged

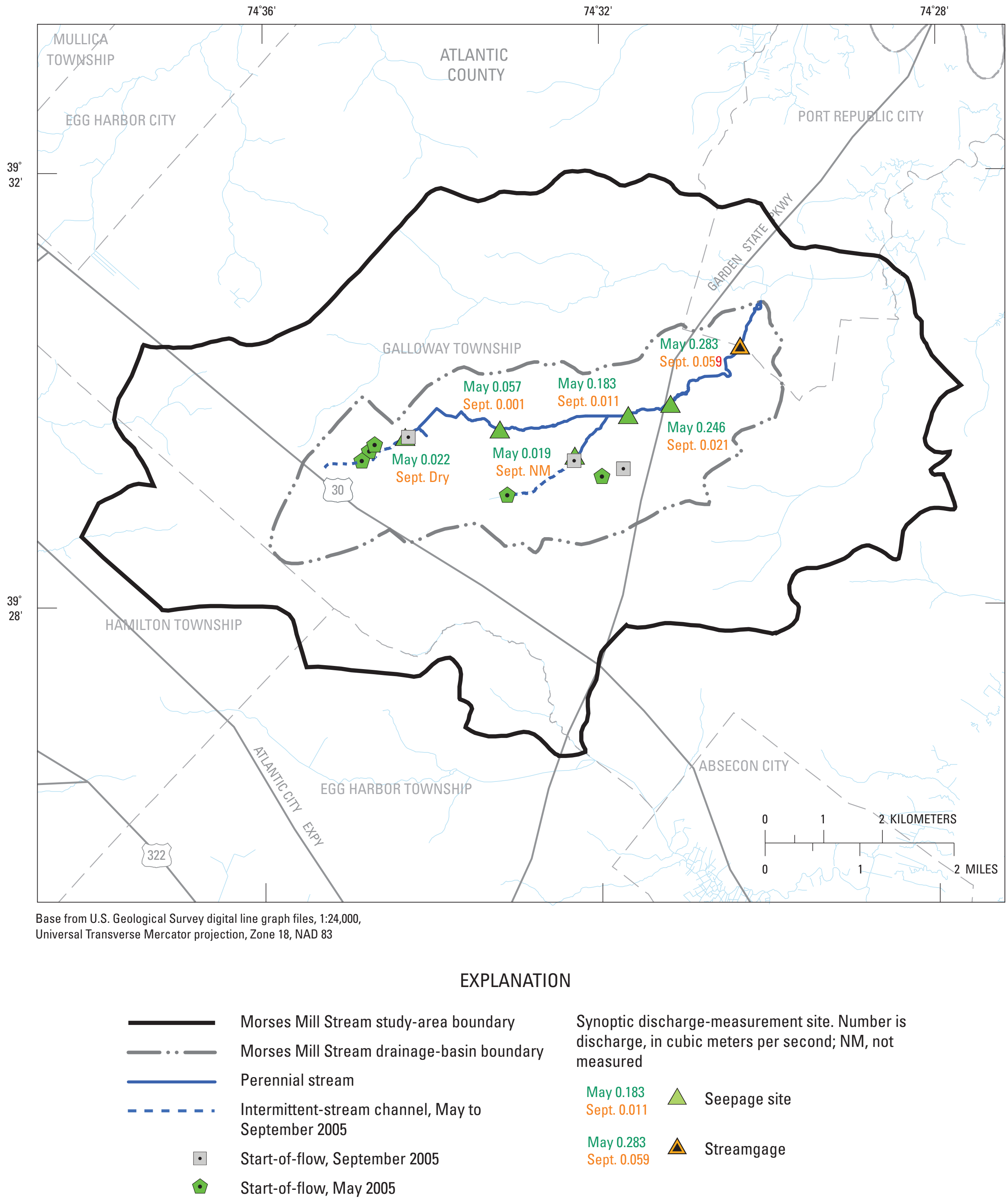



**Figure 41.** Surface-water discharge at selected locations, Morses Mill Stream basin, May and September 2005.

9.5 cm and ranged from a low of 1.0 cm in March 2006 to 23.1 cm in October 2005 (fig. 42, table 7).

Average annual *ET* in the Morses Mill Stream basin was 58.6 cm during the study period. Monthly *ET* averaged 4.9 cm and ranged from 0.4 cm in December 2004 to 11.5 cm in July 2006. *ET* from the basin was equivalent to 52 percent of precipitation on an annual basis. This loss, however, varies widely throughout the year. In winter, when *ET* is minimal (December and January of both water years), *ET* was less than one-tenth the amount of precipitation. During some summer months, nearly all precipitation was lost to *ET*, and recharge to the underlying aquifer was minimal. *ET* exceeded precipitation during June, July, August, and September 2005 and March 2006.

Direct runoff of precipitation in the basin was relatively small, averaging 0.4 cm/mo during the study period. Monthly values ranged from 0.1 cm in September 2005 to 1.3 cm in September 2006. Direct recharge of the aquifer system from precipitation typically was greatest during the winter months, when *ET* was minimal. During the study period, recharge during winter months (December-February) averaged 8.0 cm/mo. During summer months (July-September), when *ET* was greatest, recharge averaged about 0.5 cm/mo. Annual base flow in the basin during the study period represented 86 percent of the annual streamflow. In September 2005, the month with least precipitation during the study period, base flow accounted for 88 percent of streamflow. In May 2005, base flow represented 95 percent of streamflow, even though precipitation was nearly average. In September 2006, the second wettest month during the 2-year period, base flow represented 67 percent of streamflow. Changes in storage of soil moisture during the study period had a moderate effect on the water budget. Monthly changes in soil-moisture storage ranged from a decrease of 3.6 cm in July 2006 to an increase of 6.4 cm in October 2005. The average annual change in soil-moisture storage during the 2-year study period was a decrease of 0.6 cm. During the study period, groundwater levels declined slightly, representing a loss in storage of 2.1 cm/yr. Monthly changes in groundwater storage ranged from a decline of 2.7 cm in August 2005 to an increase of 5.2 cm in October 2005 (fig. 43, table 7).

In general, groundwater withdrawals and surface-water diversions from the Morses Mill Stream basin are small. On an annual basis, groundwater withdrawals and surface-water diversions account for about 4 percent of the total precipitation, and groundwater withdrawals account for about 8 percent of recharge (fig. 43). Withdrawals from the basin typically are greater in summer, when withdrawals for irrigation are greatest. A few public-supply wells, which account for most of the total withdrawals, are situated within the basin.

Estimated net leakage to underlying confined aquifers was 0.02 cm/mo, the smallest value among the three basins. Estimated net outflow to adjacent basins was 1.0 cm/mo. To evaluate the agreement between the water-budget calculations, recharge values calculated using the land-surface equation were compared to those calculated using the groundwater equation (fig. 44). Estimates were generally in close agreement, to within a few centimeters. Differences in monthly recharge estimates ranged from -4.0 cm in September 2005 to 4.2 cm in October 2006. The average difference in monthly recharge estimates was 0.1 cm.

**Table 7.** Basin water budget for Morses Mill Stream, Atlantic County, New Jersey Pinelands, 2005–06.

[All values are in centimeters; recharge values determined as a residual may be different from computed values due to rounding]

Land-surface budget

| Date | Precipi-tation | Discharge to surface water | Change in surface-water storage | Change in soil-moisture storage | Direct runoff | Evapo-tran-spiration | Surface-water with-drawals | Recharge |
|---|---|---|---|---|---|---|---|---|
| Oct-04 | 8.6 | 0 | 0 | 0.5 | 0.3 | 3.8 | 0 | 5 |
| Nov-04 | 11.4 | 0 | 0 | -1.9 | 0.5 | 2 | 0 | 7 |
| Dec-04 | 6.6 | 0 | 0 | 1.1 | 0.4 | 0.5 | 0 | 6.7 |
| Jan-05 | 10 | 0 | 0 | -0.3 | 0.5 | 0.5 | 0 | 8.7 |
| Feb-05 | 7.7 | 0 | 0 | -0.4 | 0.2 | 1.4 | 0 | 5.7 |
| Mar-05 | 9.9 | 0 | 0 | -0.5 | 0.6 | 2 | 0 | 6.9 |
| Apr-05 | 8.8 | 0 | 0 | 1.2 | 0.5 | 4.8 | 0 | 4.7 |
| May-05 | 9 | 0 | 0 | 0.9 | 0.2 | 6.9 | 0.1 | 2.8 |
| Jun-05 | 9.5 | 0 | 0 | 0.9 | 0.1 | 9.8 | 0.1 | 0.4 |
| Jul-05 | 10.7 | 0 | 0 | 2.1 | 0.2 | 10.9 | 0.1 | 1.5 |
| Aug-05 | 3 | 0 | 0.7 | 1.8 | 0.2 | 9.5 | 0.1 | -4.3 |
| Sep-05 | 1.4 | 0 | 0 | 0.9 | 0.1 | 6.7 | 0.2 | -4.6 |
| Oct-05 | 23.1 | 0 | 0 | -6.4 | 0.8 | 3.6 | 0.1 | 12.2 |
| Nov-05 | 7.3 | 0 | 0 | -1 | 0.5 | 2 | 0 | 3.8 |
| Dec-05 | 11.1 | 0 | 0 | 0.4 | 0.4 | 0.6 | 0 | 10.5 |
| Jan-06 | 14.6 | 0 | 0 | 0.2 | 0.7 | 1.6 | 0 | 12.4 |
| Feb-06 | 5.5 | 0 | 0 | 0.1 | 0.3 | 1 | 0 | 4.3 |
| Mar-06 | 1 | 0 | -1 | 2.9 | 0.6 | 1.8 | 0 | 0.5 |
| Apr-06 | 8.5 | 0 | 0 | -0.4 | 0.4 | 4.3 | 0 | 3.4 |
| May-06 | 8.9 | 0 | 0 | 1.8 | 0.3 | 6.9 | 0.2 | 3.2 |
| Jun-06 | 12.2 | 0 | 0 | -3.1 | 0.3 | 8.8 | 0.1 | -0.1 |
| Jul-06 | 13.4 | 0 | 0 | 3.6 | 0.5 | 11.5 | 0.1 | 4.8 |
| Aug-06 | 9.3 | 0 | 0 | -0.6 | 0.4 | 9.1 | 0.3 | -1.1 |
| Sep-06 | 16 | 0 | 0 | -2.4 | 1.3 | 6.5 | 0 | 5.8 |
| Monthly average | 9.5 | 0 | -0.01 | 0.1 | 0.4 | 4.9 | 0.1 | 4.1 |
| Annual average | 113.6 | 0 | -0.1 | 0.6 | 5.1 | 58.6 | 0.6 | 50 |

Groundwater budget

| Date | Base flow | Groundwater withdrawals | Leakage | Change in groundwater storage | Artificial recharge | Groundwater inflow or outflow | Recharge |
|---|---|---|---|---|---|---|---|
| Oct-04 | 1.6 | 0.5 | 0.02 | 0.8 | 0 | -1 | 3.8 |
| Nov-04 | 2 | 0.5 | 0.02 | 2 | 0 | -1 | 5.5 |
| Dec-04 | 3 | 0.4 | 0.02 | 0.9 | 0 | -1 | 5.3 |
| Jan-05 | 2.7 | 0.5 | 0.02 | 0.8 | 0 | -1 | 4.9 |
| Feb-05 | 3.4 | 0.4 | 0.02 | 1.9 | 0 | -1 | 6.6 |
| Mar-05 | 4.4 | 0.5 | 0.02 | 2.4 | 0 | -1 | 8.2 |
| Apr-05 | 4.7 | 0.5 | 0.02 | -0.6 | 0 | -1 | 5.6 |
| May-05 | 3.5 | 0.4 | 0.02 | -1.4 | 0 | -1 | 3.5 |
| Jun-05 | 2.3 | 0.3 | 0.02 | -2.5 | 0 | -1 | 1 |
| Jul-05 | 1.7 | 0.4 | 0.02 | -2.1 | 0 | -1 | 1 |

**Table 7.** Basin water budget for Morses Mill Stream, Atlantic County, New Jersey Pinelands, 2005–06.—Continued

[All values are in centimeters; recharge values determined as a residual may be different from computed values due to rounding]

| Groundwater budget—Continued | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Base flow** | **Groundwater withdrawals** | **Leakage** | **Change in groundwater storage** | **Artificial recharge** | **Groundwater inflow or outflow** | **Recharge** |
| Aug-05 | 1.1 | 0.2 | 0.02 | -2.7 | 0 | -1 | -0.4 |
| Sep-05 | 0.7 | 0.3 | 0.02 | -2.6 | 0 | -1 | -0.6 |
| Oct-05 | 1.7 | 0.2 | 0.02 | 5.2 | 0 | -1 | 8 |
| Nov-05 | 1.7 | 0.1 | 0.02 | 0.2 | 0 | -1 | 3 |
| Dec-05 | 3.4 | 0.2 | 0.02 | 3 | 0 | -1 | 7.6 |
| Jan-06 | 5.8 | 0.1 | 0.02 | 4.5 | 0 | -1 | 11.4 |
| Feb-06 | 4 | 0.2 | 0.02 | -0.8 | 0 | -1 | 4.4 |
| Mar-06 | 2.6 | 0.2 | 0.02 | -2.5 | 0 | -1 | 1.3 |
| Apr-06 | 2.5 | 0.4 | 0.02 | -0.8 | 0 | -1 | 3.1 |
| May-06 | 2.4 | 0.3 | 0.02 | -0.7 | 0 | -1 | 2.9 |
| Jun-06 | 1.8 | 0.3 | 0.02 | -1 | 0 | -1 | 2.1 |
| Jul-06 | 2 | 0.5 | 0.02 | -1.5 | 0 | -1 | 1.9 |
| Aug-06 | 0.9 | 0.5 | 0.02 | -1.7 | 0 | -1 | 0.7 |
| Sep-06 | 2.6 | 0.5 | 0.02 | 3.4 | 0 | -1 | 7.5 |
| Monthly average | 2.6 | 0.4 | 0.02 | 0.2 | 0 | -1 | 4.1 |
| Annual average | 31.1 | 4.2 | 0.2 | 2.2 | 0 | -11.4 | 49.1 |

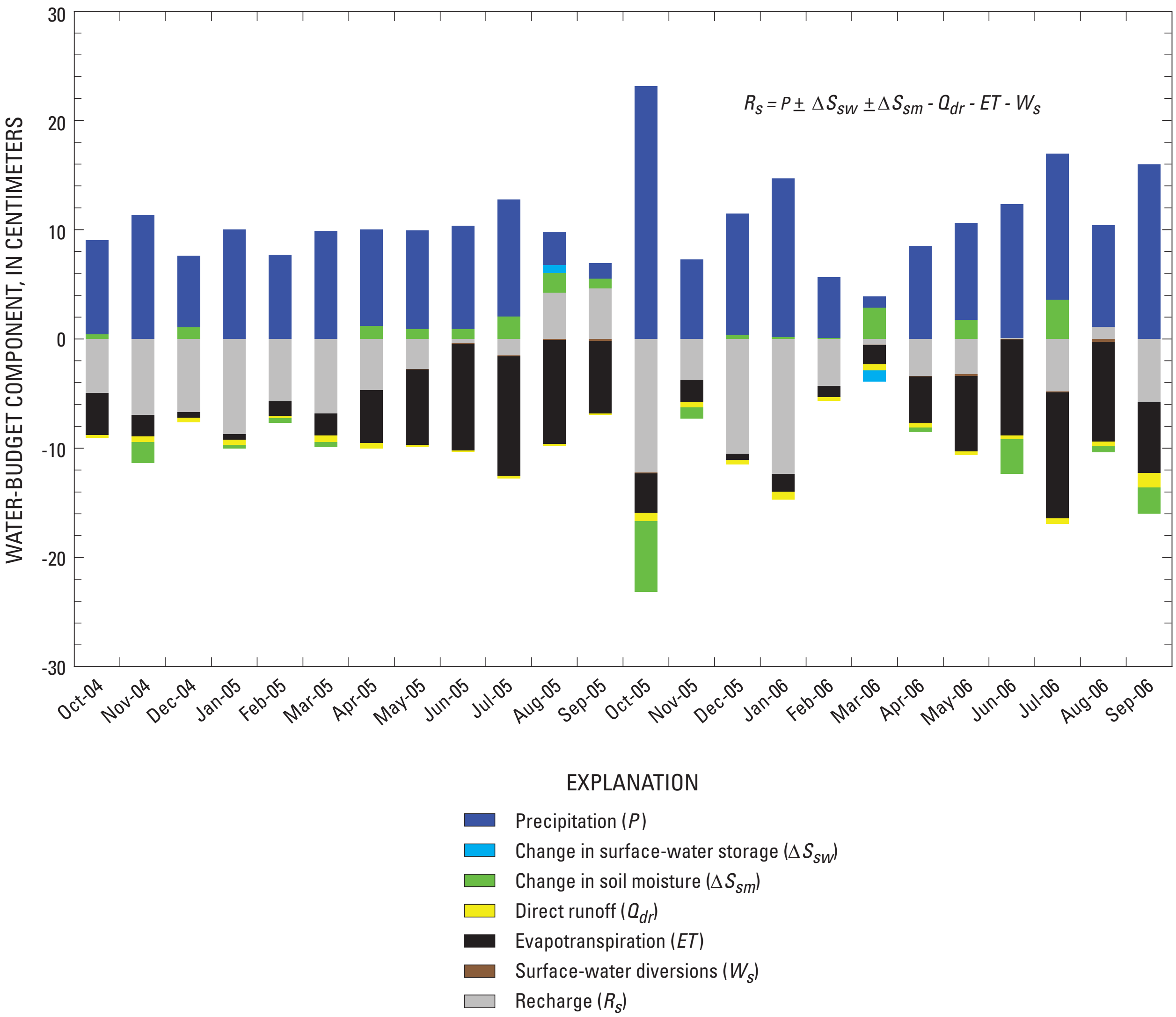



**Figure 42.** Components of the land-surface water budget by month, Morses Mill Stream basin, New Jersey Pinelands, water years 2005–06.

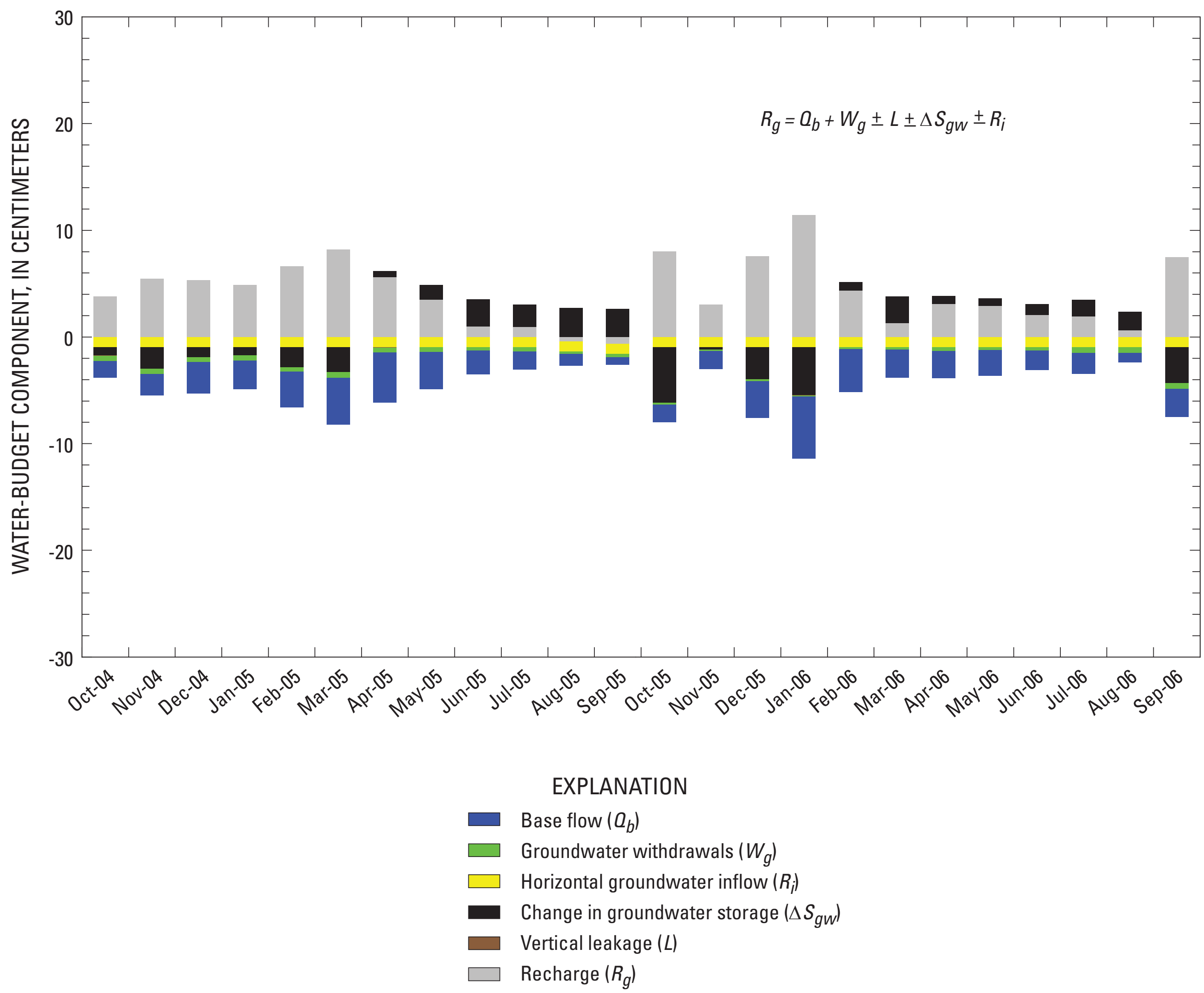



**Figure 43.** Components of the groundwater budget by month, Morses Mill Stream basin, New Jersey Pinelands, water years 2005–06.

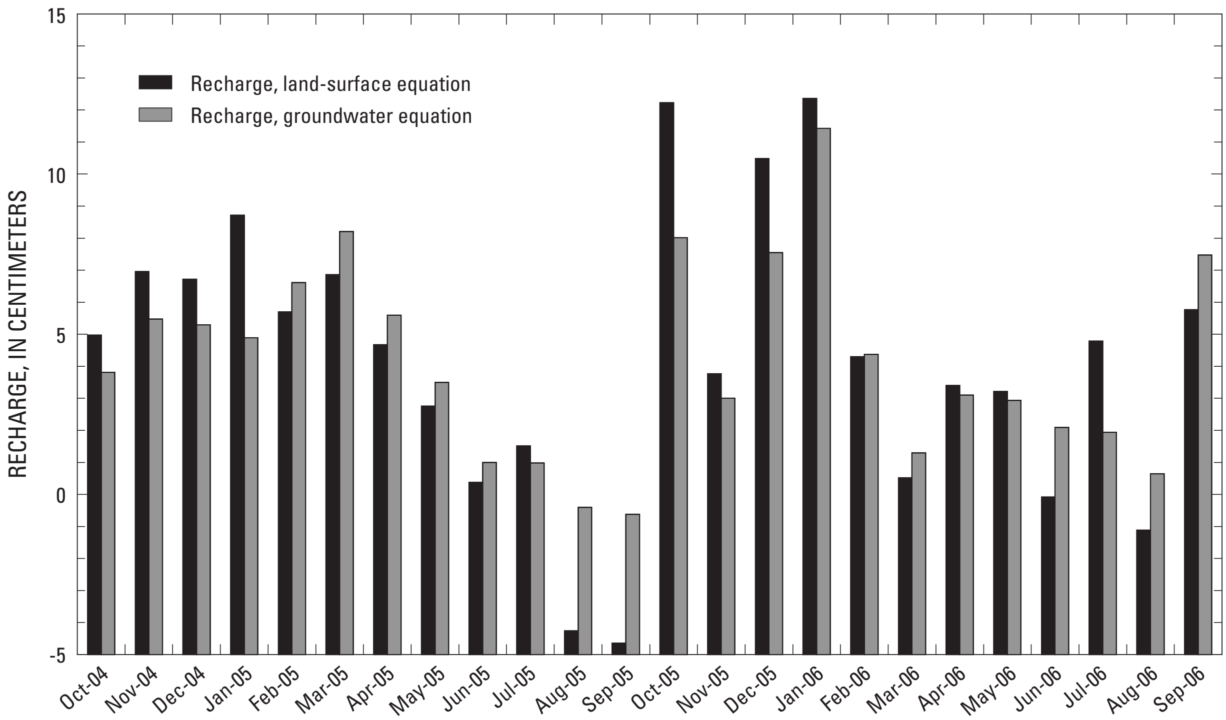



**Figure 44.** Comparison of monthly land-surface and groundwater recharge, Morses Mill Stream basin, New Jersey Pinelands, water years 2005–06.

## Characteristics of Pinelands Drainage Basins

This examination of the hydrologic conditions and the relations among groundwater, surface water, and wetlands in three Pinelands drainage basins provides an indication of the range of characteristic conditions and relations throughout the region. Results can provide a basis for identifying those hydrologic characteristics that are common to, or representative of, the Pinelands area. An understanding of both the range and commonality of these characteristics strengthens the conceptual basis for quantitative analysis of the hydrologic system and is critical to the development of predictive hydrologic models used in water-resource planning and management.

The physical site characteristics, hydrogeology, stream geomorphology, vegetation, and the type and percentage of developed land in the three basins represent a range of conditions typical of the New Jersey Pinelands. Precipitation is the primary source of all water reaching the Kirkwood-Cohansey aquifer system, and precipitation generally infiltrates the Pinelands soils readily (Rhodehamel, 1973). Excluding runoff due to impervious cover and (or) low-permeability soils or, in undeveloped areas, runoff during heavy rainfall, about 50 percent of the precipitation reaching the surface is available to recharge the aquifer system with the balance consumed by *ET* (Rhodehamel, 1970).

Recharge to the groundwater system occurs by infiltration of precipitation through the soil column and percolation through the unsaturated zone to the water table. This process may be rapid, delayed, or diverted laterally in the subsurface depending on the thickness and character of the variably permeable soils and unsaturated geologic sediments, their moisture content, and the intensity and duration of precipitation. Precipitation that reaches the water table recharges the groundwater, which flows through the complex assemblage of sediments making up the Kirkwood-Cohansey aquifer system. Groundwater flow is driven by hydraulic gradients to discharge eventually to wetlands, swamps, streams, deep confined aquifers, water-supply wells, and coastal waters.

Pinelands wetland vegetation has established itself in type settings having favorable exposure, soil conditions, precipitation, and depth to water table. The seasonal range in depth to the water table below land surface is one of the critical determinants of areas suitable as wetland habitat. Spatial variations in depth to the water table are, in part, a function of the variability of the water-table altitude and land-surface topography. In general, as local land-surface altitude increases with distance from streams, depth to the water table also increases, although not always proportionately.

Water budgets are useful for understanding the relations among the major components of hydrologic systems and system responses to changes, and for evaluating water-supply availability and sustainability (Alley and others, 1999; Healy and others, 2007; table 8). Monthly water budgets provide an indication of seasonal changes in rates of water flux, which are reflected in changes in water levels and streamflows. Monthly rates of water flux across the land surface vary with monthly precipitation, which modulates the water available for increases in soil moisture, *ET*, and aquifer recharge. Recharge rates generally are highest during the non-growing season and are inversely related to *ET*. Average non-growing-season (November-February) recharge for the three study areas ranged from 6.6 to 7.4 cm/mo. Recharge to the aquifer system generally is lowest during the growing season, when monthly *ET* is high; monthly *ET* can sometimes exceed monthly precipitation during these months. Average growing-season (March-October) recharge for the three study areas ranged from 2.6 to 3.7 cm/mo. If precipitation is relatively constant through a seasonal cycle, as occurred during water year 2005, monthly recharge will approximate a sinusoidal function peaking during late winter/early spring. If precipitation fluctuates more through a seasonal cycle, as occurred during water year 2006, monthly recharge may be more episodic; recharge rates may be low during some colder months, as occurred during March 2006, and higher during some warmer months, as occurred during September 2006.

Monthly rates of water flux into and out of the aquifer system vary primarily with rates of recharge. In basins without large withdrawals or lateral export of water, monthly recharge is balanced for the most part by stream base flow and changes in groundwater storage. Stream base flow accounted for 86 to 96 percent of the mean annual streamflow in the three study areas. Average annual groundwater withdrawals in the three study areas were small relative to average recharge (0–11 percent) and, therefore, withdrawals had a small to negligible effect on the annual water budget at the scale of this analysis. The effect of withdrawals on the water budget can be more substantial locally or when evaluated on a seasonal basis.

To understand how the Pinelands groundwater system receives recharge and functions to support wetland water levels and streamflow in specific areas, it is important to consider all the existing site conditions, physical controls, and hydraulic stresses in the aquifer system that may affect the various flow paths between recharge and discharge areas. In the Pinelands, the extent to which the groundwater system can be recharged, and is hydraulically connected to the wetlands, swamps, and streams, is in part controlled by the natural conditions that have allowed wetlands and the various surface-water environs to become established. Those conditions include physical and hydraulic controls such as topography, the thickness and character of materials through which recharge and groundwater flow take place, and the extent and thickness of fine-grained geologic sediments, iron-cemented layers, and organic material that may form barriers to flow. Knowledge of the presence and functional relation of these controls on groundwater flow and the water table is essential to understanding the potential effects of future development on local wetland, swamp, and stream ecosystems. The structure and distribution of hydrogeologic units of varying permeabilities in the three study areas described in the hydrogeologic framework developed by Walker and others (2008) form the foundation for the groundwater flow models being developed for the three study areas.

**Table 8.** Summary of average annual water budget for Albertson Brook, McDonalds Branch, and Morses Mill Stream basins, New Jersey Pinelands, 2005–06.

[All values are in centimeters]

| | Albertson Brook | McDonalds Branch | Morses Mill Stream |
|---|---|---|---|
| Land-surface budget | | | |
| Precipitation | 113.8 | 121.4 | 113.6 |
| Discharge to surface-water | 0 | 0 | 0 |
| Change in surface-water storage | 0 | 0 | -0.1 |
| Change in soil-moisture storage | 0.7 | 0.5 | 0.6 |
| Direct runoff | 6.1 | 1.4 | 5.1 |
| Evapotranspiration | 56.1 | 62 | 58.6 |
| Surface-water withdrawals | 0.1 | 0 | 0.6 |
| Recharge | 52.3 | 58.9 | 50 |
| Groundwater budget | | | |
| Base flow | 49.3 | 39.5 | 31.1 |
| Groundwater withdrawals | 6 | 0 | 4.2 |
| Leakage | 0.7 | 13.1 | 0.2 |
| Change in groundwater storage | -1.2 | -3.5 | 2.2 |
| Artificial recharge | 0.8 | 0 | 0 |
| Groundwater inflow or outflow | -0.4 | -8.8 | -11.4 |
| Recharge | 54.4 | 57.9 | 49.1 |

The water table describes the top of the complex three-dimensional flow system. Overall, the groundwater flow system has spatially varying water levels, hydraulic gradients, and flow paths connecting recharge and discharge areas. The direction of horizontal groundwater flow that can be approximated from the spring and summer 2005 water-table-altitude maps generally follows the slope of the basin topography, eventually flowing toward points of discharge at wetlands, swamps, and surface-water bodies.

Water levels measured in the basin-monitoring wells in each study area help to describe the head relations among shallow, intermediate, and deep aquifer layers in and between the upper- and lower-basin areas. These head relations reflect hydraulic gradients that control the flow of groundwater through the aquifer system. These gradients provide insight into subsurface flow patterns, which can be categorized as local or regional, as demonstrated by using numerical models (Modica, 1996; Rice and Szabo, 1997).

Water levels in the basin-monitoring wells generally indicated downward hydraulic gradients in upland-recharge areas, horizontal hydraulic gradients toward the lower parts of each basin, and upward gradients approaching points of discharge such as wetlands, swamps, and streams, as shown in the hydrographs for these well sites and the water-table maps. Although deep, more regional groundwater flow normally discharges to the surface in the lower parts of the drainage basins, hydraulic stresses in the aquifer system induced by the withdrawal of groundwater alters natural hydraulic gradients and affects groundwater flow by diverting to wells some of the flow that would otherwise reach the wetlands and streams.

Topographically high areas near lateral basin divides in the lower parts of a drainage basin also act as groundwater recharge areas and display downward hydraulic gradients. Groundwater flow paths become increasingly short and shallow as the recharge areas become closer to the discharge areas. As a result, flow paths that originate in areas near lateral basin divides contribute more flow to wetlands and streams downstream than those that originate closer to the points of discharge. Discharge to larger streams in lower-basin areas are largely supported by regional groundwater flow paths that are deeper and longer than the shallow, localized flow systems; therefore, these areas probably are less affected by seasonal drought conditions than those areas supported by localized flow systems.

Hydrologically, wetlands in the three Pinelands study areas generally fall in one of two categories: (1) those located in groundwater recharge areas and (2) those flanking streams in groundwater discharge areas.

A recharge-area wetland was identified in the headwaters of the McDonalds Branch basin. This wetland straddles a lateral basin divide and is underlain by an extensive shallow clay layer of finite areal extent. The hydraulic head of the groundwater above this clay was as much as 3 m higher than that of the underlying aquifer and also exceeded the altitude of the water table immediately surrounding the clay, creating a substantial downward gradient and a large potential for recharge to the underlying aquifer in and around the wetlands. Horizontal hydraulic gradients across these wetlands also were large, causing radial flow in the groundwater and surface water, part of which discharges to the headwaters of the McDonalds Branch. Farther downstream from the headwaters wetlands where the clay is absent, the McDonalds Branch loses water to the unconfined aquifer.

Wetlands that have established in groundwater recharge areas are normally underlain by confining layers of clay and (or) other low-permeability sediments capable of retarding the vertical movement of water, which usually results in localized groundwater mounding following recharge events. Groundwater mounding above the confining bed causes downward hydraulic gradients to develop between the water table and the aquifer below, which can promote both vertical leakage and lateral flow above the clay. Wetlands and streams that may exist in groundwater recharge areas rely on runoff and (or) recharge from precipitation, and shallow, local flow subsystems that may develop above the confining beds. The extent to which these wetlands are hydraulically connected to or isolated from the underlying aquifers is site specific and variable. During extended dry periods, the water table in recharge-area wetlands may drop sufficiently to cause locally supported stream discharge to cease. If the low-permeability sediments are sufficiently leaky, or if they are of limited extent, the water table may drain naturally and equilibrate with water levels in the underlying aquifer. Regardless of the site- specific conditions, wetlands in recharge areas are likely to be most sensitive to extended drought conditions and less sensitive to stresses of groundwater withdrawals from beneath the confining layers.

The most common wetland settings in the three study areas are those that form in lowland areas where groundwater discharges to the surface. These discharge-area wetlands generally develop in the lower parts of the Pinelands drainage basins. Observed gradients and evidence of local and regional flow subsystems in these areas indicated that flow patterns were similar to those of the generic stream-aquifer flow systems described by Toth (1963) and Modica (1997). This type of wetland is represented at 12 of the 15 hydrologic-transect locations.

Many of the hydrologic characteristics common to the discharge-area wetlands are revealed in the data analysis of hydrologic transect ABHT4 in the Albertson Brook basin. During wet periods at this location, groundwater discharges to the surface along short, shallow flow paths originating near the local, lateral basin divide in addition to deeper, longer path groundwater flow originating in recharge areas farther upstream in the basin. The vertical hydraulic gradient at the upland well cluster of ABHT4 reversed from downward in April to upward in September, whereas that in the middle well cluster in the wetlands was upward in April and zero in September. The horizontal gradient from the uplands toward the stream at this site, however, was similar in April and September, indicating continued horizontal groundwater flow from the uplands toward the stream. These conditions may indicate that groundwater traveling along long, deep flow paths was supporting the shallow groundwater in this area and helping to maintain the horizontal hydraulic gradient toward the wetlands and stream. At other hydrologic-transect sites, such as ABHT5, the April horizontal gradient between the uplands and wetland was not maintained, but the same vertical-gradient relation was present at the two well locations in the uplands and at the edge of the wetlands. Wetlands that lie in groundwater discharge areas generally flank streams in the lower parts of the drainage basins where the water table is shallow. They may be underlain by a broad range of sediments from coarse sand and gravel to clay or other low-permeability sediments, peat, and (or) muck soils. These wetlands receive water directly through infiltration of precipitation and indirectly from groundwater flow as it discharges to the surface. This groundwater discharge includes localized, relatively shallow groundwater flow that follows short flow paths and has comparably short travel times and is, therefore, more likely to be affected by seasonal drought conditions. The most persistent groundwater flow that reaches these discharge-area wetlands originates in the upper parts of the drainage basins and follows longer paths of flow to points of discharge. Hydraulic gradients from the various recharge areas to points of discharge control the relative contribution of groundwater that travels along long and short flow paths. As the local groundwater reservoir near a discharge-area wetland declines during dry periods, it is likely that a smaller proportion of groundwater discharge comes from local recharge and a larger proportion is derived from upland recharge through the longer, more regional groundwater flow paths.

During extended dry periods, near-stream wetlands in upper-basin areas may shift from a condition of groundwater discharge to one of groundwater recharge, as water levels decline and start-of-flow locations move farther downstream. Potential areas of such alternating recharge and discharge conditions probably are best described by the intermittent range of groundwater discharge to streams in the Albertson Brook, McDonalds Branch, and Morses Mill Stream study areas that is shown by the dashed lines in figures 15, 28, and 41, respectively.

The hydrologic-transect data from the three drainage basins indicate considerable similarity in the way wetlands and streams in the Pinelands were supported by groundwater during the spring 2005 measurements. The hydraulic gradients observed near wetlands and streams in the lower parts of the basins reflected the convergence of shallow, localized groundwater flow from nearby uplands with the deeper, more regional groundwater flow originating in recharge areas farther upstream in the basins. These local flow conditions generally were indicated by downward hydraulic gradients at the upland end of the hydrologic transects; horizontal gradients toward the swamps and streams; and upward gradients near points of discharge at the wetlands, swamps, and streams.

In the summer of 2005, following a month with no substantial recharge, synoptic water-level measurements along the same transects indicated changes in water levels, hydraulic gradients, and flow paths compared to those in the spring. These changes included a decline in upland and wetland water levels, reduced downward hydraulic gradients near the upland ends of transects or reversals in those gradients, and a decline in the groundwater levels resulting in reduced horizontal gradients and flow from local uplands to the wetlands. At the same time, although water levels had declined, horizontal gradients from the wetlands toward the stream often showed little change from the spring conditions, indicating continued flow toward the discharge points closest to the surface water. When this occurred, downward gradients at the upland ends of the transects were generally reduced or had reversed to upward, reflecting a transition from shallow, localized groundwater flow to deeper groundwater flow traveling along longer flow paths contributing to the wetlands, swamps, and streams. During the drought conditions of summer 2005, the horizontal gradients from the wetlands toward the stream apparently were sustained by upward flow due to increases in vertical gradients beneath these lower-basin discharge areas. Although the contribution of discharge to the surface from shallow groundwater flow may be substantially reduced or cease during seasonal drought, discharge from deeper groundwater flow traveling along longer flow paths probably continues, albeit at lower discharge rates, while supporting the water table at lower levels. Those basins or parts of basins with small drainage areas, those parts of drainage basins located in recharge areas, and (or) those discharge-area wetlands that are transitional in the intermittent stream reaches described previously, however, are least likely to receive discharge from deep groundwater flow traveling along longer flow paths.

The results of the study confirm that stream start-of-flow locations vary seasonally and with changing climatic conditions, as conceptualized by Modica (1998). In the Pinelands, start-of-flow locations occur at the most upstream point where groundwater begins discharging to the surface—a location where the altitude of the water table first exceeds that of the streambed. On the basis of long-term daily mean discharge statistics at streamflow-gaging stations near or within each of the three study areas, the hydrologic conditions in September 2005 in these areas represent an extreme low in water levels and streamflow. Therefore, start-of-flow probably occurred farther downstream in September 2005 than it would have during a normal September. Start-of-flow locations identified on the basis of field observations in the spring and summer of 2005 defined the intermittent stream sections between the measurements made in the spring and summer of 2005 (figs. 15, 28, and 41). Downstream from the intermittent stream segments, base-flow discharge ratios (table 4) are lower and appear to indicate more persistent groundwater discharge than the higher discharge ratios farther upstream.

Water levels normally fluctuate with the seasons, but if an extended period of drought should coincide with increased stresses caused by groundwater withdrawals, the depth to the water table, start-of-flow location, and stream discharge all will be affected. The stream base-flow and water-level measurements made during the spring and summer of 2005 indicate that some stream reaches may lose flow to the groundwater. Surface water can be lost by moving directly to the underlying aquifer when the hydraulic gradients are downward from the surface water (Winter and others, 1998). This also can occur when the stage in the stream is supported above the local water table by low-permeability sediments or when groundwater withdrawals reverse hydraulic gradients, inducing vertical leakage through the streambed to the aquifer below. Loss of streamflow also can occur indirectly when pumping far from the stream captures groundwater flow that might otherwise discharge to the stream (Jenkins, 1968). In this case, vertical hydraulic gradients in the groundwater could continue to indicate upward flow to the stream and (or) wetlands, but the hydraulic gradients and discharge to the surface would be reduced, but not reversed. Base-flow discharge measurements identified only one potential losing stream reach in the three study areas; the losing reach was in the lower part of the Albertson Brook basin where agricultural irrigation is known to be active within 300 m of the stream during the growing season. This water use might have contributed to the apparent loss of streamflow, but the loss was approximately equal to the acceptable error for the discharge measurement. Limited data and the inherent difficulties of measuring stream discharge at some Pinelands stream locations made the results inconclusive.

Other areas of potential losses from surface water were identified by water-level differences that indicate downward hydraulic gradients that are indicative of potential losses from surface water to groundwater. Some examples include the locations of hydrologic transects MBHT1 and MBHT5 (fig. 27) in the McDonalds Branch basin and MMHT2 in the Morses Mill Stream basin (fig. 40). Other possible stream losses are indicated by water-table contours showing that the general direction of groundwater flow crosses a stream. An example is along the upper reaches of the McDonalds Branch where groundwater contours indicate that groundwater flow probably bypasses the McDonalds Branch and emerges as groundwater discharge farther downstream (fig. 23). A similar area in the lower part of the McDonalds Branch is illustrated by water-table contours near hydrologic transect MBHT5. Upstream from this area, groundwater flow that crosses beneath the stream channel probably induces vertical leakage from the stream, causing losses in streamflow, and this water follows the path of groundwater flow into the adjacent basin as illustrated with arrows indicating flow leaving the basin in a westerly direction (fig. 23). Although it was possible to identify potential areas of losses from streamflow using water-level data, these losses could not be confirmed or quantified because either no discharge measurements could be made in those areas, or the losses were too small to be discernable given the limited ability to make accurate discharge measurements as a result of the site conditions.

The Albertson Brook and Morses Mill Stream basins have the greatest reported groundwater use of the three study areas. The use of groundwater in the vicinity of the

McDonalds Branch study area is limited to isolated domestic wells, two public-supply wells, and two irrigation wells, and because development there is minimal and the study area is composed predominantly of State-owned land, the associated hydraulic stresses appear to have been comparatively small during this study.

Considering the range of hydrologic complexities identified in the three study areas, general hydrologic characteristics of the Pinelands that are important in evaluating the relations between surface water (including wetlands) and groundwater include the following:

- Precipitation is the primary source of recharge to all parts of the Kirkwood-Cohansey aquifer system.
- Generally, aquifer-system recharge areas are topographically high (upland) areas and discharge areas (except groundwater-withdrawal areas) are topographically low areas such as at wetlands, swamps, and streams.
- Soil and geologic sediment layers of contrasting permeability are present in some areas and affect infiltration, groundwater-flow patterns, interactions between groundwater and surface water, and the degree to which stressed aquifer layers are hydraulically connected with the water table near the wetlands and surface water.
- Shallow groundwater flow supports water levels in local wetlands and surface water during wetter periods. Deeper, more regional groundwater flow supplements the shallow discharge to lower-basin areas and continues to support water levels, providing the principal groundwater discharge to wetlands and streams in those areas as local water levels decline during extended dry periods.
- Wetlands can generally be characterized as those in upland groundwater recharge areas where downward hydraulic gradients persist and, more commonly, those wetlands flanking streams in groundwater discharge areas where upward hydraulic gradients persist. During extended dry periods, near-stream wetlands in upper-basin areas may transition from areas of discharge to areas of recharge, as water levels decline and start-of-flow locations move progressively farther downstream.

# Summary and Conclusions

The New Jersey Pinelands area is a 4,450-$km^2$ National Reserve in southern New Jersey that overlies the Kirkwood-Cohansey aquifer system in the Atlantic Coastal Plain. This ecologically diverse area supports a variety of habitats and is home to many threatened and endangered species. The landscape is covered with a patchwork of cedar swamps; other wetlands; coniferous, hardwood, and mixed forests; agricultural areas; and developed residential and commercial areas. Demand for water from the Kirkwood-Cohansey aquifer system is increasing as development in the area increases.

The Pinelands Commission has been tasked with evaluating increasing water-supply demands in the Pinelands and the potential for adverse effects on the hydrologic and ecological systems of the area. An investigation of the relations among key hydrologic and ecological attributes was needed in order to (1) assess the effects of groundwater diversions from the Kirkwood-Cohansey aquifer system on streams and wetland water levels within the Pinelands and (2) determine the potential ecological effects of reduced streamflows and water levels on aquatic and wetland communities, respectively. Therefore, the U.S. Geological Survey (USGS), in cooperation with the Pinelands Commission, began a multi-phase hydrologic investigation in 2004 to characterize the hydrologic system supporting the Pinelands aquatic and wetland communities.

Three drainage basins, the Albertson Brook, McDonalds Branch, and Morses Mill Stream basins, were selected for detailed hydrologic assessment to provide the information needed to develop groundwater flow models that can be used to predict hydrologic responses to increased groundwater withdrawals. The first phase of the hydrologic assessment was a comprehensive hydrogeologic framework investigation of each study area. The second phase of the assessment, and the subject of this report, was an evaluation of the groundwater and surface-water hydrology of each of the three selected drainage basins studied. The major objectives included:

1. compiling available hydrologic data;
2. collecting additional hydrologic data;
3. characterizing the function of the hydrologic system, including the interaction of the Kirkwood-Cohansey aquifer system with wetlands and surface water;
4. quantifying the water budget for each drainage basin; and
5. providing the hydrologic data and interpretations needed to construct predictive groundwater models.

The report describes the methods used to establish new data-network sites and to collect and analyze the hydrologic data. In the data-collection phase of the study, previously available and newly acquired hydrologic and climatologic information was compiled. The data network included 471 wells, 26 of which were continuous water-level monitoring sites, and 106 surface-water sites, including 4 recording streamflow-gaging stations; the continuous records were collected during 2004–06. During this period, area groundwater levels fluctuated from about 0.8 to 1.8 m in upland recharge areas and from about 0.4 to 1.1 m in lowland discharge areas. Stream levels at base flow fluctuated over a smaller range during the same period, generally from almost no change where levels are controlled by channel conditions to as much as 0.4 m elsewhere. Annual mean streamflow in and near the study areas for water years 2005 and 2006, respectively, ranged from 88 to 101 percent and 83 to 106 percent of the long-term mean annual discharge. These values are well within the range of annual mean flows of streams in and near the study areas.

In addition to the continuous-record data collection, network sites were used to make synoptic measurements of groundwater levels, stream stage and stream discharge, and start-of-flow locations during spring and late summer 2005. These data were analyzed in the context of the previously published hydrogeologic framework of the Kirkwood-Cohansey aquifer system and in consideration of other physical and hydrologic characteristics that could affect water levels and groundwater flow and the interactions of groundwater with wetlands and surface water. The geology, geomorphology, and land-surface characteristics of each basin control how and to what extent recharge enters and flows through the groundwater system, ultimately discharging to surface water. The water-level altitudes and hydraulic gradients that develop in the aquifer system control the rate and direction of groundwater flow and its discharge. The hydrologic characteristics of and water use in and near each basin affected the groundwater system and are reflected in the hydrographs of daily mean groundwater levels and streamflow as they responded to variations in precipitation and recharge during the study period (2004–06). Excluding water lost to evapotranspiration and the storm runoff that contributes directly to streamflow, the portion of precipitation that recharges the aquifer system (about 50 percent) supports groundwater flow along various flow paths toward discharge areas and eventually contributes to stream base-flow. During wet periods, higher water levels resulted in base flow that likely included a larger proportion of groundwater discharge flowing along shorter, more localized flow paths and typically higher streamflows than during dry periods. During base-flow conditions following extended dry periods, streams and wetlands were supported principally by groundwater flowing along longer flow paths and less by shallow local groundwater flow, resulting in lower water levels in wetlands and streams and reduced streamflow.

Two contrasting hydrologic extremes representing base-flow conditions were documented with synoptic water-level and streamflow measurements and observations of start-of-flow locations in streams during spring and late summer 2005. Maps developed for each study area show water-level altitudes for these two periods, depth to the water table during the spring measurement, and distribution of base-flow discharge during the spring and summer synoptic measurements. Within mapped wetland areas, the depth to the water table ranged from zero to 4.5 m. These ranges likely are representative of average conditions throughout most of the Pinelands. The percentage of basin area characterized by the depth to the water table of less than 0.5 m ranged from 17 to 48 percent and varied with the percentage of the basin area mapped as wetlands.

The synoptic measurements made during spring and late summer 2005 also included water levels and hydraulic gradients measured in wells situated along 15 hydrologic transects, each one extending from in or near the uplands through the wetlands to the streams. A comparative analysis of hydrologic conditions during the contrasting periods of the synoptic measurements revealed the dynamic nature of water-table depth, groundwater flow patterns, sources of flow to wetlands and streams, and streamflow characteristics.

Hydrologically, wetlands in the three Pinelands study areas can be generally characterized as being either (1) those located in groundwater recharge areas or (2) those flanking streams in groundwater discharge areas. Seasonally, the source of water reaching wetlands depends on whether the wetlands are in groundwater recharge or groundwater discharge areas. Recharge-area wetlands and surface-water bodies are supported by local precipitation and local groundwater that moves along short flow paths and may cease to discharge to the surface locally during dry periods. Conversely, discharge-area wetlands and streams continue to be supported by deeper groundwater that moves through longer, regional flow paths after shallow groundwater levels have declined and discharge from the shallow, local groundwater system is reduced or has ceased altogether.

Basin-wide water budgets, in which inflows are balanced by corresponding outflows and changes in storage, were developed for each study area to quantify the major components of the hydrologic cycle. Human activities that can affect the natural system, such as groundwater withdrawals and artificial discharge, also are included in the budget. Both a land-surface-based equation that describes gains from and losses to the land surface and a groundwater-based equation that describes gains from and losses to the underlying Kirkwood-Cohansey aquifer system provided independent estimates of recharge and a basis for comparing the relative importance of the various water-budget components. Monthly rates of water flux across the land surface vary with monthly precipitation, which modulates the water available for increases in soil moisture, *ET*, and aquifer recharge. Average annual precipitation in the three study areas during water years 2005–06 ranged from 114 to 121 cm. Average annual *ET* was about 50 percent of annual precipitation, and ranged from 56 to 62 cm. Average annual recharge ranged from 50 to 59 cm and was generally highest during the non-growing season, when *ET* was low. Groundwater withdrawals in the three study areas were small on average (0–11 percent of recharge), and therefore, withdrawals had a small to negligible effect on the average water budgets of these basins at the scale of this analysis. The effect of withdrawals on water budgets can be more substantial locally or when evaluated on a seasonal basis.

Collectively, these interpretations describe the hydrologic variability in the three Pinelands study areas and provide the information needed to calibrate groundwater flow models for those areas. The following conclusions highlight other important hydrologic conditions identified during this study:

- The soils and sediments in the unsaturated zone and the sediments in the aquifer system underlying the Pinelands have varying textures and permeability that affect patterns of infiltration, recharge, groundwater flow, and discharge to wetlands, streams, and supply wells.
- Recharge replenishes the aquifer system and contributes to groundwater flow, most of which moves to wetlands and surface water where natural discharge occurs. Recharge rates are generally highest during the non-growing season and are inversely related to evapotranspiration rates.
- Groundwater-level fluctuations increase with distance from surface water.
- Stream-stage hydrographs compared closely with those of groundwater levels in nearby wells as a result of the close relation of groundwater discharge and stream base flow.
- Depth to the water table ranges from zero at points of groundwater discharge, such as ponds, streams, and swamps, to several meters in topographically high areas.
- The depth to the water table in the wetlands changes seasonally in response to variable evapotranspiration, precipitation, infiltration, and groundwater recharge.
- Wetlands in groundwater recharge areas are typically characterized by downward hydraulic gradients causing local water levels and streamflow to be entirely dependent on local precipitation and shallow groundwater flow, probably making recharge-area wetlands sensitive to drought conditions.
- Recharge-area wetlands and streams may lose water to deeper aquifer layers as a result of persistent downward hydraulic gradients that occur naturally or can be induced by pumping stresses, lowering the water table and reducing or eliminating potential streamflow.
- Wetlands that lie near surface-water bodies in the lower part of a drainage basin typically are in groundwater discharge areas that generally display persistent upward hydraulic gradients beneath wetlands and surface water.
- Although groundwater withdrawals can stress the groundwater flow system and affect water levels, the distribution of low-permeability sediments in the subsurface controls the degree to which stressed aquifer layers are hydraulically connected with the water table.
- Hydraulic gradients near wetlands are dynamic, and changes in these gradients (and consequently potential groundwater-flow directions) were observed under differing hydrologic conditions.
- In general, horizontal gradients along the hydrologic transects indicated lateral flow toward wetlands, and vertical gradients indicated upward flow toward points of discharge, such as wetlands and streams (with some exceptions observed during the summer 2005 measurement).
- Low-permeability zones can support a transient, mounded local water table in some areas.

The results of this study indicate that the precision of water-table maps in and near wetlands could be improved by knowing the location, extent, and characteristics of areas where mounding of the water table occurs. Some Pinelands wetlands have been shown to be supported by localized mounding of the water table above relatively low-permeability sediment layers, which can act to isolate the water-table hydraulically from the deeper groundwater system. Because the location, extent, hydrologic characteristics, and relation of these commonly localized wetlands to the water table are not well understood, their vulnerability to stresses placed on the hydrologic system is difficult to assess. Additional work could identify the location, extent, and characteristics of the low-permeability layers that create and maintain these wetlands and their relation to the larger groundwater system. Indicators could be developed and used to identify those types of wetlands that rely on mounded water tables in other areas.

The results of this study also show that quantifying possible losses of streamflow resulting from either natural hydrogeologic conditions or groundwater withdrawals using conventional streamflow measuring methods is difficult because Pinelands stream channels are commonly irregular, may be obstructed locally, or may have low or irregular velocity profiles. These conditions not only affect the accuracy of the streamflow measurements but also can cause localized gains and losses in flow; therefore, the locations of streamflow measurements are critical when evaluating differences in base flow along a stream reach. Additional work to determine potential areas of streamflow loss using measurements of hydraulic gradients, fluxes, and streambed permeability along losing stream reaches would substantially improve measuring-site selection and the quantification and evaluation of losses of streamflow in Pinelands streams.

# References Cited


Alley, W.M., 1984, On the treatment of evapotranspiration, soil moisture accounting, and aquifer recharge in monthly water balance models: Water Resources Research, v. 20, no. 8, p. 1137–1149.

Alley, W.M., Reilly, T.E., and Franke, O.L., 1999, Sustainability of ground-water resources: U.S. Geological Survey Circular 1186, 79 p.

Ameriflux, 2008, Flux data for Silas Little Experimental Forest US-Slt, accessed May 1, 2008, at *http://public.ornl.gov/ameriflux*.

Ballard, J.T., 1979, Fluxes of water and energy through the pine barrens ecosystems, *in* Forman, R.T.T., ed., Pine Barrens: ecosystem and landscape: New Brunswick, NJ, Rutgers University Press, p. 133–146.

Ballard, J.T., and Buell, M, 1975, The role of lowland vegetation communities in the evapotranspiration budget of the New Jersey Pine Barrens: Bulletin, New Jersey Academy of science, v. 20, no. 1, p. 26–28.

Bunnell, J.F., and Ciraolo, J.L., 2010, The potential impact of simulated groundwater withdrawals on the oviposition, larval development, and metamorphosis of pond-breeding frogs: Pinelands Commission, New Lisbon, New Jersey, 15 p.

Carter, C.H., 1978, A regressive barrier and barrier-protected deposit: Depositional environments and geographic setting of the late Tertiary Cohansey Sand: Journal of Sedimentary Petrology, v. 48, no. 3, p. 933–950.

Ehrenfeld, J.G., and Schneider, J.P., 1991, Chamaecyparis thyoides wetlands and suburbanization: Effects on hydrology, water quality and plant community composition: Journal of Applied Ecology, v. 28, p. 467–490.

Fels, J.E., and Matson, K.C., 1996, A cognitively-based approach for hydrogeomorphic land classification using Digital Terrain Models: Proceedings, Third International Conference on Integrating GIS and Environmental Modeling., National Center for Geographic Information and Analysis, Santa Fe, New Mexico, January 21–25, 1996. unpaginated, accessed September 29, 2009, at *http://www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/program.html*.

Fetter, C.W., 1994, Applied hydrogeology (3d ed.): New York, Macmillan College Publishing Company, 692 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, NJ, Prentice-Hall, 604 p.

Gill, H.E., and Farlekas, G.M., 1976, Geohydrologic maps of the Potomac-Raritan-Magothy aquifer system in the New Jersey Coastal Plain: U.S. Geological Survey Hydrologic Investigations Atlas HA-557, scale 1:500,000, 2 sheets.

Healy, R.W., Winter, T.C., LaBaugh, J.W., and Franke, O.L., 2007, Water budgets: Foundations for effective water-resources and environmental management: U.S. Geological Survey Circular 1308, 90 p.

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1081–1088.

Hirsch, R.M., 1979, An evaluation of some record reconstruction techniques: Water Resources Research, v. 15, no. 6, p. 1781–1790.

Jenkins, C.T., 1968, Computation of rate and volume of stream depletion by wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. D1, 17 p., also available at *http://pubs.usgs.gov/twri/twri4d1/pdf/twri_4-D1_a.pdf*.

Johnson, J.H., 1978, Soil survey of Atlantic County, New Jersey: U.S. Soil Conservation Service, 60 p., 51 maps.

Johnson, M.L., and Watt, M.K., 1996, Hydrology of the unconfined aquifer system, Mullica River basin, New Jersey, 1991-92: U.S. Geological Survey Water-Resources Investigations Report 94–4234, 6 sheets.

Johnsson, P.A., and Barringer, J.L., 1993, Water quality and hydrogeochemical processes in McDonalds Branch basin, New Jersey Pinelands, 1984–88: U.S. Geological Survey Water-Resources Investigations Report 91–4081, 111 p.

Kennen, J.G., and Riskin, M.L., 2010, Evaluating effects of potential changes in streamflow regime on fish and aquatic-invertebrate assemblages in the New Jersey Pinelands: U.S. Geological Survey Scientific Investigations Report 2010–5079, 34 p.

Laidig, K.J., 2010, The potential impact of simulated water-level reductions on intermittent-pond vegetation: New Lisbon, New Jersey, Pinelands Commission, 19 p.

Laidig, K.J., and Zampella, R.A., 1999, Community attributes of Atlantic white cedar (*Chamaecyparis thyoides*) swamps in disturbed and undisturbed Pinelands watersheds: Wetlands, v. 19, p. 35–49.

Laidig, K.J., Zampella, R.A., Brown, A.M., and Procopio, N.A., 2010, Development of vegetation models to predict the potential effect of groundwater withdrawals on forested wetlands: New Lisbon, New Jersey, Pinelands Commission, 30 p.

Lord, D.G., Barringer, J.L., Johnsson, P.A., Schuster, P.F., Walker, R.L., Fairchild, J.E., Sroka, B.N., and Jacobsen, Eric, 1990, Hydrogeochemical data from an acidic deposition study at McDonalds Branch basin in the New Jersey Pinelands, 1983–86: U.S. Geological Survey Open-File Report 88–500, 132 p.

Markley, M.L., 1965, Soil survey of Camden County, New Jersey: U.S. Soil Conservation Service, 94 p., 33 maps.

Markley, M.L., 1971, Soil survey of Burlington County, New Jersey: Washington, D.C., U.S. Department of Agriculture, Cartographic Division, Soil Conservation Service, 103 p.

Martin, Mary, 1998, Groundwater flow in the New Jersey Coastal Plain: U.S. Geological Survey Professional Paper 1404-H, 146 p.

Matson, K.C., and Fels, J.E., 1996. Approaches to automated water table mapping: Proceedings, Third International Conference on Integrating GIS and Environmental Modeling, National Center for Geographic Information and Analysis, Santa Fe, New Mexico, January 21–26, 1996, unpaginated, accessed September 29, 2009, at *http://www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/program.html*.

McCormick, J., 1979, The vegetation of the New Jersey Pine Barrens , *in* Forman, R.T.T., ed., Pine Barrens: Ecosystem and landscape: New York, Academic Press, p. 229–243.

Modica, E., 1996, Simulated effects of alternate withdrawal strategies on ground-water-flow patterns, New Jersey Pinelands: U.S. Geological Survey Water-Resources Investigations Report 95–4133, 46 p.

Modica, E., 1998, Analytical methods, numerical modeling, and monitoring strategies for evaluating the effects of ground-water withdrawals on unconfined aquifers in the New Jersey Coastal Plain: U.S. Geological Survey Water-Resources Investigations Report 98–4003, 66 p.

Modica, E., Reilly, T.E., and Pollock, D.W., 1997, Patterns and age distribution of ground-water flow to streams: Ground Water, v. 35, no. 3, p. 523–537.

National Oceanic and Atmospheric Administration (NOAA), 2007, National Climatic Data Center, Precipitation Data for New Jersey, accessed on March 7, 2007, at *http://www.ncdc.noaa.gov/oa/mpp/.*

Nawyn, J.P., 1998, Withdrawals of ground water and surface water in New Jersey, 1991–92: U.S. Geological Survey Open-File Report 98–282, 57 p.

Nemickas, Bronius, and Carswell, L.D., 1976, Stratigraphic and hydrologic relationship of the Piney Point aquifer and the Alloway Clay Member of the Kirkwood Formation in New Jersey: U.S. Geological Survey Journal of Research, v. 4, no. 1, p. 1–7.

New Jersey Department of Environmental Protection, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), 1999a, NJDEP wetlands of Atlantic County, New Jersey, 1986: Trenton, New Jersey, New Jersey Department of Environmental Protection, available at *http://www.state.nj.us/dep/gis/digidownload/zips/wet/atlwet.zip*.

New Jersey Department of Environmental Protection, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), 1999b, NJDEP wetlands of Burlington County, New Jersey, 1986: Trenton, New Jersey, New Jersey Department of Environmental Protection, available at *http://www.state.nj.us/dep/gis/digidownload/zips/wet/burwet.zip*.

New Jersey Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), 1999c, NJDEP wetlands of Camden County, New Jersey, 1986: Trenton, New Jersey, New Jersey Department of Environmental Protection, available at *http://www.state.nj.us/dep/gis/digidownload/zips/wet/camwet.zip*.

New Jersey Pinelands Commission, 1981, the comprehensive management plan : The CMP summary (updated periodically), accessed May 15, 2006, at *http://www.state.nj.us/pinelands/cmp/summary/*.

New Jersey Pinelands Commission, 2003, the Kirkwood-Cohansey project work plan, accessed January 15, 2010, at *http://www.state.nj.us/pinelands/infor/broch/Kirkwood-Cohansey%20Project%20Work%20Plan.pdf*.

Nicholson, R.S., and Sumner, D.M., 2006, Evapotranspiration at a wetland site in the New Jersey Pinelands (abstract): New Jersey Monitoring and Assessment Technical Workshop, New Jersey Water Monitoring Coordinating Council, Columbus, New Jersey, April 20, 2006, unpaginated.

Nicholson, R.S., and Watt, M.K., 1997, Simulation of ground-water flow in the unconfined aquifer system of the Toms River, Metedeconk River, and Kettle Creek basins, New Jersey: U.S. Geological Survey Water-Resources Investigations Report 97–4066,100 p.

Procopio, N.A., 2010, The effect of streamflow reductions on aquatic habitat availability and fish and macroinvertebrate assemblages in coastal plain streams: New Lisbon, New Jersey, Pinelands Commission, 13 p.

Rhodehamel, E.C., 1970. A hydrologic analysis of the New Jersey Pine Barrens region: New Jersey Department of Environmental Protection, Water Resources Circular Number 22, 35 p.

Rhodehamel, E.C., 1973, Geology and water resources of the Wharton Tract and the Mullica River Basin in southern New Jersey: New Jersey Department of Environmental Protection, Special Report Number 36, 58 p.

Rhodehamel, E.C., 1979, Hydrology of the New Jersey Pine Barrens, *in* Forman R.T.T., ed., Pine Barrens: Ecosystem and landscape: New York, Academic Press, p. 147–167.

Rice, D.E., and Szabo, Z., 1997, Relation of flowpaths and travel time to the distribution of radium and nitrate in current and former agricultural areas of the Kirkwood-Cohansey aquifer system, New Jersey Coastal Plain: U.S. Geological Survey Water-Resources Investigations Report 96–4165B, 41 p.

Roman, C.T., Zampella, R.A., and Jaworski A.Z., 1985, Wetland boundaries in the New Jersey Pinelands: Ecological relationships and delineation: Water Resources Bulletin, v. 21, p. 1005–1012.

Rutledge, A.T., 1998, Computer programs for describing the recession of ground-water discharge and for estimating mean ground-water recharge and discharge from streamflow records—Update: U.S. Geological Survey Water-Resources Investigations Report 98–4148, 43 p.

Sepulveda, Nicasio, 2002, Simulation of ground-water flow in the intermediate and Floridan aquifer systems in peninsular Florida: U.S. Geological Survey Water-Resources Investigations Report 02–4009, 130 p.

Sloto, R.A., and Buxton, D.E., 2005, Water budgets for selected watersheds in the Delaware River basin, eastern Pennsysvania and western New Jersey: U.S. Geological Survey Scientific Investigations Report 2005–5113, 37 p.

The National Map Seamless Server, 2008, LiDAR elevation data for Burlington and Camden Counties, New Jersey, accessed April 21, 2008, at *http://seamless.usgs.gov/website/seamless.*

Toth, J., 1963, A theoretical analysis of groundwater flow in small drainage basins: Journal of Geophysical Research, v. 68, no. 16, p. 4795–4812.

U.S. Department of Agriculture, Natural Resources Conservation Service, 2000, Hydric soils criteria, accessed June 20, 2006, at *http://soils.usda.gov/use/hydric/criteria.html*.

U.S. Geological Survey, 2005, Water resources data for New Jersey, water year 2005, volume 1– Surface-water data: U.S. Geological Survey Water Data Report NJ-05-1, 381 p., available at *http://pubs.usgs.gov/wdr/2005/wdr-nj-05-1/.*

U.S. Geological Survey, 2005, Water resources data for New Jersey, water year 2005, volume 2—Ground-water data: U.S. Geological Survey Water Data Report NJ-05-2, 259 p., available at *http://pubs.usgs.gov/wdr/2005/wdr-nj-05-2.*

U.S. Geological Survey, 2006, Water resources data for New Jersey, water year 2006, volume 1 — Surface-water data: U.S. Geological Survey Water Data Report NJ-06-1: available at *http://nj.usgs.gov/publications/Pubs_lists/pubsgw.html#2006.*

U.S. Geological Survey, 2006, Water resources data for New Jersey, water year 2006, volume 2— Ground-water data: U.S. Geological Survey Water Data Report NJ-06-2, available at *http://nj.usgs.gov/publications/Pubs_lists/pubsgw.html#2006.*

U.S. Geological Survey, 2009, National Water Information System: Web interface—USGS water data for New Jersey, accessed December 8, 2009, at *http://waterdata.usgs.gov/nj/nwis.*

Voronin, L.M., 2004, Documentation of revisions to the Regional Aquifer System Analysis model for the New Jersey Coastal Plain: U.S. Geological Survey Water-Resources Investigations Report 03–4268, 58 p., 1 pl.

Walker, R.L., Reilly, P.A., and Watson, K.M., 2008, Hydrogeologic framework in three study areas in the New Jersey Pinelands, 2004–2006: U.S. Geological Survey Scientific Investigations Report 2008–5061, 147 p.

Watt, M.K., and Johnson, M.L., 1992, Hydrology of the unconfined aquifer system of the Great Egg Harbor River basin, New Jersey, 1989–90: U. S. Geological Survey Water-Resources Investigations Report 91–4126, 5 sheets.

Watt, M.K., Kane, A.C., Charles, E.G., and Storck, D.A., 2003, Hydrology of the unconfined aquifer system, Rancocas Creek area: Rancocas, Crosswicks, Assunpink, Blacks, and Crafts Creek Basins, New Jersey, 1996: U.S. Geological Survey Water-Resources Investigations Report 02–4280, 5 sheets.

Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M., 1998, Ground water and surface water: A single resource: U.S. Geological Survey Circular 1139, 79 p.

Zampella, R.A., Moore, G.A., and Good, R.E., 1992, Gradient analysis of pitch pine (Pinus rigida Mill.) lowland communities in the New Jersey Pinelands: Bulletin of the Torrey Botanical Club, v. 119, p. 253–261.

Zampella, R.A., Bunnell, J.F., Laidig, K.J., and Dow, C.L., 2001, a. The Mullica River Basin: A report to the Pinelands Commission on the status of the landscape and selected aquatic and wetland resources: New Lisbon, NJ, Pinelands Commission, 371 p.

Zampella, R.A., Dow, C.L., and Bunnell, J.F., 2001b, Using reference sites and simple linear regression to estimate long-term water levels in coastal plain forests: Journal of the American Water Resources Association, v. 37, no. 5, p. 1189–1201.

Zampella, R.A., Bunnell, J.F., Laidig, K.J., and Procopio, N.A., 2003. The Rancocas Creek Basin: A report to the Pinelands Commission on the status of selected aquatic and wetland resources: New Lisbon, NJ, Pinelands Commission, 130 p.

Zampella, R.A., Procopio, N.A., DuBrul, M.U., and Bunnell, J.F., 2008, An ecological-integrity assessment of the New Jersey Pinelands: A comprehensive assessment of the landscape and aquatic and wetlands systems of the region: New Lisbon, NJ, Pinelands Commission, 168 p.

Zapecza, O.S., 1989, Hydrogeologic framework of the New Jersey Coastal Plain: U.S. Geological Survey Professional Paper 1404-B, 49 p., 24 pl.

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area | | | | | | | | | | |
| 010325 | 010325–IRR 2A | -- | W | 18.80 | DEM | 1.524 | 07/00/1957 | 19.81 | -- | -- |
| 010342 | 010342–IW40 | -- | W | 12.80 | DEM | 1.524 | 00/00/1900 | 27.43 | 26.21 | 27.43 |
| 010349 | 010349–MULLICA 2D | -- | W | 17.53 | Level | 0.003 | 06/27/1975 | 45.72 | 44.20 | 45.72 |
| 011402 | 011402–ATSION MW51 | 3225196 | W | 12.80 | DEM | 1.524 | 09/06/2000 | 3.51 | 1.98 | 3.51 |
| 011404 | 011404–MW54 | 3160862 | W | 21.20 | DEM | 1.524 | 06/22/2001 | 4.27 | 2.74 | 4.27 |
| 011459 | 011459–ALBERTSON BROOK 2 | -- | INS, W, WM | 18.59 | DEM | 1.524 | 03/26/2004 | 2.16 | 1.86 | 2.16 |
| 011504 | 011504–AB OW-2D | 3227988 | BM,INS, W | 16.97 | DEM | 1.524 | 08/10/2004 | 48.77 | 45.72 | 48.77 |
| 011505 | 011505–AB OW-2S | 3227990 | BM,INS, W | 16.93 | DEM | 1.524 | 08/11/2004 | 15.24 | 12.19 | 15.24 |
| 011506 | 011506–AB OW-2M | 3227989 | BM,INS, W | 16.93 | DEM | 1.524 | 08/12/2004 | 28.04 | 24.99 | 28.04 |
| 011550 | 011550–ABHT5-1D | -- | HT, W | 14.87 | DEM | 1.524 | 02/02/2005 | 2.90 | 2.59 | 2.90 |
| 011551 | 011551–ABHT5-1S | -- | HT, W | 14.90 | DEM | 1.524 | 02/02/2005 | 1.52 | 1.22 | 1.52 |
| 011552 | 011552–ABHT4-2S | -- | HT, W | 17.75 | DEM | 1.524 | 02/03/2005 | 1.52 | 1.22 | 1.52 |
| 011553 | 011553–ABHT4-3D | -- | HT, W | 17.40 | DEM | 1.524 | 02/03/2005 | 2.90 | 2.59 | 2.90 |
| 011554 | 011554–ABHT4-3S | -- | HT, W | 17.43 | DEM | 1.524 | 02/03/2005 | 1.52 | 1.22 | 1.52 |
| 011555 | 011555–ABHT5-3D | -- | HT, W | 13.85 | DEM | 1.524 | 01/20/2005 | 2.74 | 2.44 | 2.74 |
| 011556 | 011556–ABHT5-3S | -- | HT, W | 13.80 | DEM | 1.524 | 01/20/2005 | 1.52 | 1.22 | 1.52 |
| 011557 | 011557–ABHT5-2D | -- | HT, W | 14.90 | DEM | 1.524 | 01/20/2005 | 2.74 | 2.44 | 2.74 |
| 011558 | 011558–ABHT5-2S | -- | HT, W | 14.88 | DEM | 1.524 | 01/20/2005 | 1.83 | 1.52 | 1.83 |
| 011567 | 011567–AB UP-5 | 3228343 | HT, W | 15.50 | DEM | 1.524 | 03/03/2005 | 6.10 | 4.57 | 6.10 |
| 011568 | 011568–ABHT4-1D | -- | HT, W | 18.66 | DEM | 1.524 | 02/03/2005 | 2.90 | 2.59 | 2.90 |
| 011569 | 011569–ABHT4-2D | -- | HT, W | 17.77 | DEM | 1.524 | 02/03/2005 | 2.50 | 2.20 | 2.50 |
| 011594 | 011594–MW-1 | 3220603 | W | 22.77 | Level | 1.524 | 04/17/1995 | 7.01 | 2.44 | 7.01 |
| 011595 | 011595–MW-7 | 3220604 | W | 21.31 | Level | 1.524 | 04/17/1995 | 6.40 | 1.83 | 6.40 |
| 011596 | 011596–IRR 10 | 3158336 | W | 20.60 | DEM | 1.524 | 06/04/2001 | 43.28 | 18.90 | 43.28 |
| 011597 | 011597–MW-5 | 3220599 | W | 20.45 | Level | 1.524 | 04/17/1995 | 6.40 | 2.13 | 6.40 |
| 011634 | 011634–MW-6 | 3220600 | W | 19.17 | Level | 1.524 | 04/17/1995 | 6.40 | 2.13 | 6.40 |
| 011669 | 011669–MW-8 | -- | W | 21.19 | Level | 1.524 | -- | 3.81 | -- | -- |
| 011672 | 011672–MW | -- | W | 22.20 | DEM | 1.524 | -- | 5.49 | -- | -- |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Albertson Brook Study Area—Continued | | | | | | |
| 050408 | 050408–ATSION 2 OBS | -- | W | 14.11 | Level | 0.003 | 00/00/1963 | 19.81 | 19.20 | 19.81 |
| 050409 | 050409–ATSION 3 OBS | -- | W | 13.99 | Level | 0.003 | 00/00/1963 | 5.18 | 4.27 | 5.18 |
| 070429 | 070429–MULLICA 17S | -- | UP,W | 23.15 | Level | 0.003 | 06/25/1975 | 5.79 | 4.27 | 5.79 |
| 070430 | 070430–MULLICA 7D | -- | W | 28.20 | Level | 0.003 | 09/23/1975 | 36.58 | 35.05 | 36.58 |
| 070431 | 070431–MULLICA 16S | -- | W | 28.17 | Level | 0.003 | 06/24/1975 | 8.84 | 7.32 | 8.84 |
| 070432 | 070432–MULLICA 18S | -- | W | 20.91 | Level | 0.003 | 06/25/1975 | 7.62 | 6.10 | 7.62 |
| 070436 | 070436–IRR | 3104953 | W | 36.00 | DEM | 1.524 | 04/29/1966 | 39.62 | 33.53 | 39.62 |
| 070459 | 070459–IRR | 3104937 | W | 29.20 | DEM | 1.524 | 05/20/1966 | 54.86 | 12.19 | 54.86 |
| 070468 | 070468–DOM-6 | 3105716 | W | 31.10 | DEM | 1.524 | 07/12/1971 | 50.29 | 44.20 | 50.29 |
| 070481 | 070481–3-1973 | 3106874 | W | 37.49 | DEM | 1.524 | 03/23/1973 | 33.83 | 22.56 | 32.61 |
| 070497 | 070497–PROD 2 | 3105543 | W | 37.19 | DEM | 1.524 | 01/00/1971 | 30.78 | 19.51 | 27.43 |
| 070501 | 070501–IND 2 | 3105295 | W | 50.70 | DEM | 1.524 | 08/05/1969 | 42.98 | 35.36 | 42.98 |
| 070668 | 070668–IRR 1 | 3116649 | W | 52.70 | DEM | 1.524 | 02/03/1981 | 36.58 | 18.29 | 36.58 |
| 070671 | 070671–INSTITUTIONAL 7 | 3108079 | W | 31.70 | DEM | 1.524 | 07/03/1974 | 43.89 | 35.36 | 42.98 |
| 070678 | 070678–IRR | 3124091 | W | 38.70 | DEM | 1.524 | 12/11/1985 | 30.48 | 24.38 | 30.48 |
| 070679 | 070679–DOM 705 | 3120472 | W | 40.20 | DEM | 1.524 | 12/28/1984 | 24.38 | 21.34 | 24.38 |
| 070682 | 070682–DOM | 3108663 | W | 48.70 | DEM | 1.524 | 06/06/1975 | 22.56 | 19.51 | 22.56 |
| 070698 | 070698–8/REPLACEMENT 4 | 3126123 | W | 30.80 | DEM | 1.524 | 03/25/1987 | 50.90 | 40.72 | 49.99 |
| 070699 | 070699–DOM | 3126654 | W | 39.00 | DEM | 1.524 | 09/10/1988 | 33.53 | 30.48 | 33.53 |
| 070701 | 070701–DOM | 3119213 | W | 42.00 | DEM | 1.524 | 06/11/1982 | 31.70 | 28.65 | 31.70 |
| 070702 | 070702–DOM | 3117576 | W | 43.40 | DEM | 1.524 | 05/13/1981 | 27.43 | 24.38 | 27.43 |
| 070704 | 070704–SCH | 3120150 | W | 54.50 | DEM | 1.524 | 04/13/1984 | 43.89 | 40.84 | 43.89 |
| 070705 | 070705–DOM | 3122181 | W | 45.50 | DEM | 1.524 | 03/14/1985 | 27.43 | 23.16 | 26.21 |
| 070709 | 070709–DOM | 3129794 | W | 46.40 | DEM | 1.524 | 11/08/1988 | 24.38 | 21.34 | 24.38 |
| 070711 | 070711–1-L OBS | 3119136 | W | 33.24 | Level | 0.003 | 00/00/1982 | 15.24 | -- | -- |
| 070712 | 070712–6 OBS | 3119134 | W | 39.23 | Level | 0.030 | 00/00/1982 | 15.24 | -- | -- |
| 070714 | 070714–ADMIN BLDG | 3120841 | W | 40.40 | DEM | 1.524 | 10/29/1983 | 34.75 | 31.70 | 34.75 |
| 070715 | 070715–DOM 1 | 3129999 | W | 29.87 | M | 1.524 | 12/15/1988 | 31.70 | 28.65 | 31.70 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| 070716 | 070716–IRR 1 | -- | W | 29.87 | M | 1.524 | -- | 4.88 | -- | -- |
| 070717 | 070717–NURSERY | 3125408 | W | 39.70 | DEM | 1.524 | 03/17/1987 | 45.72 | 42.67 | 45.72 |
| 070736 | 070736–PW 3 | 3105578 | W | 43.28 | DEM | 1.524 | 01/25/1971 | 29.54 | 24.66 | 29.24 |
| 070737 | 070737–BERLIN-BLUE ANCHOR RD 2 | 3136453 | W | 49.00 | DEM | 1.524 | 05/03/1991 | 36.27 | 27.74 | 33.83 |
| 070740 | 070740–PZ 3 | 3139312 | W | 21.14 | DEM | 1.524 | 06/12/1992 | 3.96 | 2.44 | 3.96 |
| 070741 | 070741–PZ 4 | 3137739 | W | 37.50 | DEM | 1.524 | 06/08/1992 | 9.75 | 8.23 | 9.75 |
| 070744 | 070744–PZ 5 | 3139311 | BM, INS, W | 47.36 | DEM | 1.524 | 06/09/1992 | 14.33 | 12.80 | 14.33 |
| 070750 | 070750–IRR 3 | 5100109 | W | 36.70 | DEM | 1.524 | 00/00/1944 | 33.53 | -- | -- |
| 070753 | 070753–IRR 3 | 5100114 | W | 24.30 | DEM | 1.524 | -- | 30.48 | -- | -- |
| 070781 | 070781–IRR 2 | 5100191 | W | 27.30 | DEM | 1.524 | 00/00/1958 | 36.58 | -- | -- |
| 070791 | 070791–IRR 1 | 5100201 | W | 39.20 | DEM | 1.524 | 00/00/1950 | 42.67 | -- | -- |
| 070805 | 070805–IRR 1 | 5100389 | W | 42.20 | DEM | 1.524 | 00/00/1950 | 30.48 | -- | -- |
| 070818 | 070818–N OF POND IRR | 3104949 | W | 36.50 | DEM | 1.524 | 04/29/1966 | 39.62 | 33.53 | 39.62 |
| 070835 | 070835–UND01 | 3149659 | W | 42.37 | M | 1.524 | 07/30/1996 | 9.63 | 9.02 | 9.63 |
| 070840 | 070840–NU15 | 3149746 | W | 39.62 | M | 1.524 | 09/05/1996 | 8.84 | 8.23 | 8.84 |
| 070842 | 070842–UND09 | 3149664 | W | 30.18 | M | 1.524 | 09/26/1996 | 4.27 | 3.66 | 4.27 |
| 070901 | 070901–PW 8 | 3151329 | W | 46.63 | DEM | 1.524 | 07/08/1994 | 45.60 | 31.49 | 44.07 |
| 070991 | 070991–PW 2 | 3105617 | W | 47.00 | DEM | 1.524 | 04/14/1971 | 32.00 | 25.91 | 32.00 |
| 070992 | 070992–PW 1 | 3114167 | W | 46.00 | DEM | 1.524 | 08/16/1979 | 37.80 | 31.70 | 37.80 |
| 071003 | 071003–IRR 2 | 3130945 | W | 39.50 | DEM | 1.524 | 06/01/1989 | 42.67 | 21.34 | 42.67 |
| 071081 | 071081–Albertson Brook 1 | -- | INS, W, WM | 21.64 | DEM | 1.524 | 03/24/2004 | 2.52 | 1.61 | 1.91 |
| 071084 | 071084–ELEMENTARY SCH | 3124130 | W | 36.20 | DEM | 1.524 | 01/02/1986 | 28.35 | 25.30 | 28.35 |
| 071091 | 071091–AB OW-1M | 3168275 | BM,INS, W | 47.33 | DEM | 1.524 | 08/31/2004 | 28.96 | 25.91 | 28.96 |
| 071092 | 071092–AB OW-1D | 3168274 | BM, INS, W | 47.31 | DEM | 1.524 | 08/27/2004 | 48.77 | 45.72 | 48.77 |
| 071093 | 071093–TW1 | 3159328 | W | 47.90 | DEM | 1.524 | 12/21/2000 | 47.24 | 33.53 | 45.72 |
| 071100 | 071100–ABHT2-2D | -- | HT, W | 22.17 | M | 1.524 | 02/17/2005 | 2.74 | 2.44 | 2.74 |
| 071101 | 071101–ABHT2-2S | -- | HT, W | 22.23 | M | 1.524 | 02/17/2005 | 1.52 | 1.22 | 1.52 |
| 071102 | 071102–ABHT3-3D | -- | HT, W | 19.50 | DEM | 1.524 | 02/15/2005 | 2.74 | 2.44 | 2.74 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| 071103 | 071103–ABHT3-3S | -- | HT, W | 19.51 | DEM | 1.524 | 02/15/2005 | 1.52 | 1.22 | 1.52 |
| 071104 | 071104–ABHT2-1D | 3169539 | HT, W | 26.12 | M | 1.524 | 03/04/2005 | 9.14 | 7.62 | 9.14 |
| 071105 | 071105–ABHT2-1S | 3169540 | HT, W | 26.17 | M | 1.524 | 03/04/2005 | 6.10 | 5.18 | 6.10 |
| 071106 | 071106–ABHT3-2D | -- | HT, W | 19.81 | DEM | 1.524 | 02/09/2005 | 2.74 | 2.44 | 2.74 |
| 071107 | 071107–ABHT3-2S | -- | HT, W | 19.81 | DEM | 1.524 | 02/09/2005 | 1.52 | 1.22 | 1.52 |
| 071108 | 071108–ABHT3-1D | -- | HT, W | 21.33 | DEM | 1.524 | 02/09/2005 | 2.74 | 2.44 | 2.74 |
| 071109 | 071109–ABHT1-2D | 3169669 | HT, W | 36.90 | DEM | 1.524 | 03/31/2005 | 6.10 | 5.18 | 6.10 |
| 071110 | 071110–ABHT1-1S | 3169672 | HT, W | 37.49 | DEM | 1.524 | 03/31/2005 | 4.42 | 3.51 | 4.42 |
| 071111 | 071111–ABHT2-3D | -- | HT, W | 21.89 | M | 1.524 | 02/17/2005 | 2.74 | 2.44 | 2.74 |
| 071112 | 071112–ABHT3-1S | -- | HT, W | 21.33 | DEM | 1.524 | 02/09/2005 | 1.83 | 1.52 | 1.83 |
| 071113 | 071113–AB UP-3 | 3169538 | UP, W | 29.20 | DEM | 1.524 | 03/03/2005 | 9.14 | 7.62 | 9.14 |
| 071114 | 071114–ABHT2-3S | -- | HT, W | 21.90 | M | 1.524 | 02/17/2005 | 1.83 | 1.52 | 1.83 |
| 071115 | 071115–AB UP-2 | 3169541 | UP, W | 33.00 | DEM | 1.524 | 03/04/2005 | 10.67 | 9.14 | 10.67 |
| 071116 | 071116–ABHT1-3D | -- | HT, W | 34.83 | DEM | 1.524 | 04/01/2005 | 3.05 | 2.74 | 3.05 |
| 071117 | 071117–ABHT1-3S | -- | HT, W | 34.82 | DEM | 1.524 | 04/01/2005 | 1.83 | 1.52 | 1.83 |
| 071118 | 071118–ABHT1-2S | 3169670 | HT, W | 36.91 | DEM | 1.524 | 03/31/2005 | 4.27 | 3.35 | 4.27 |
| 071119 | 071119–ABHT1-1D | 3169671 | HT, W | 37.51 | DEM | 1.524 | 03/31/2005 | 6.10 | 5.18 | 6.10 |
| 071120 | 071120–AB UP-1 | 3169542 | UP, W | 41.40 | DEM | 1.524 | 03/02/2005 | 10.67 | 9.14 | 10.67 |
| 071121 | 071121–MW-2 | 3220598 | W | 23.16 | Level | 1.524 | 04/17/1995 | 6.10 | 1.52 | 6.10 |
| 071122 | 071122–IRR 11 | 3163161 | W | 24.41 | DEM | 1.524 | 04/24/2002 | 48.77 | 24.38 | 48.77 |
| 071123 | 071123–MW-3 | 3220601 | W | 24.51 | Level | 1.524 | 04/17/1995 | 8.23 | 3.66 | 8.23 |
| 071124 | 071124–MW-4 | 3220602 | W | 20.60 | Level | 1.524 | 04/17/1995 | 6.71 | 2.13 | 6.71 |
| 071125 | 071125–DOM | 3148501 | W | 35.40 | DEM | 1.524 | 01/08/1996 | 24.38 | 21.34 | 24.38 |
| 071126 | 071126–DOM | 3167844 | W | 36.41 | DEM | 1.524 | 05/17/2004 | 32.00 | 28.96 | 32.00 |
| 071127 | 071127–DOM | 3144113 | W | 37.70 | DEM | 1.524 | 06/06/1994 | 29.57 | 24.99 | 26.52 |
| 071128 | 071128–DOM | 3155453 | W | 48.90 | DEM | 1.524 | 03/08/1999 | 30.48 | 27.43 | 30.48 |
| 071129 | 071129–DOM | 3161981 | W | 27.70 | DEM | 1.524 | 10/04/2001 | 33.53 | 30.48 | 33.53 |
| 071130 | 071130–DOM | 3158850 | W | 48.20 | DEM | 1.524 | 08/15/2000 | 24.38 | 21.34 | 24.38 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in “Site-Numbering System” section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| 071131 | 071131–DOM | 3143163 | W | 47.20 | DEM | 1.524 | 12/31/1993 | 27.43 | 24.38 | 27.43 |
| 071132 | 071132–DOM | 3106686 | W | 45.50 | DEM | 1.524 | 04/16/1973 | 22.56 | 19.51 | 22.56 |
| 071133 | 071133–DOM | 3142607 | W | 36.00 | DEM | 1.524 | 10/01/1993 | 25.30 | 22.25 | 25.30 |
| 071134 | 071134–DOM | 3165871 | W | 49.00 | DEM | 1.524 | 05/15/2003 | 28.65 | 25.60 | 28.65 |
| 071148 | 071148–MW 10 | -- | W | 24.13 | Level | 1.524 | -- | 5.49 | -- | -- |
| 071149 | 071149–MW-9 | -- | W | 22.13 | Level | 1.524 | -- | 5.33 | -- | -- |
| 071150 | 071150–DOM | 3153467 | W | 34.00 | DEM | 1.524 | 05/18/1998 | 27.43 | 24.38 | 27.43 |
| 071151 | 071151–MW 12D | 3168282 | W | 37.00 | DEM | 1.524 | 08/23/2004 | 7.92 | 3.35 | 7.92 |
| 071152 | 071152–MW | -- | W | 47.70 | DEM | 1.524 | -- | 43.28 | -- | -- |
| A10C | A10C | -- | W | 14.60 | DEM | 1.524 | -- | -- | -- | -- |
| A10PD | A10PD | -- | W | 14.65 | DEM | 1.524 | -- | -- | -- | -- |
| A10PU | A10PU | -- | W | 14.80 | DEM | 1.524 | -- | -- | -- | -- |
| A10PW | A10PW | -- | W | 14.60 | DEM | 1.524 | -- | -- | -- | -- |
| A11C | A11C | -- | W | 21.17 | DEM | 1.524 | -- | -- | -- | -- |
| A1C | A1C | -- | W | 14.80 | DEM | 1.524 | -- | -- | -- | -- |
| A1H | A1H | -- | W | 15.10 | DEM | 1.524 | -- | -- | -- | -- |
| A1PD | A1PD | -- | W | 15.10 | DEM | 1.524 | -- | -- | -- | -- |
| A1PH | A1PH | -- | W | 14.94 | DEM | 1.524 | -- | -- | -- | -- |
| A1PU | A1PU | -- | W | 15.10 | DEM | 1.524 | -- | -- | -- | -- |
| A2H | A2H | -- | W | 17.57 | DEM | 1.524 | -- | -- | -- | -- |
| A3PH | A3PH | -- | W | 18.20 | DEM | 1.524 | -- | -- | -- | -- |
| A4H | A4H | -- | W | 17.80 | DEM | 1.524 | -- | -- | -- | -- |
| A4PD | A4PD | -- | W | 18.20 | DEM | 1.524 | -- | -- | -- | -- |
| A4PDb | A4PDb | -- | W | 18.20 | DEM | 1.524 | -- | -- | -- | -- |
| A4PU | A4PU | -- | W | 18.20 | DEM | 1.524 | -- | -- | -- | -- |
| A4PW | A4PW | -- | W | 18.20 | DEM | 1.524 | -- | -- | -- | -- |
| A5PD | A5PD | -- | W | 18.70 | DEM | 1.524 | -- | -- | -- | -- |
| A5PH | A5PH | -- | W | 18.50 | DEM | 1.524 | -- | -- | -- | -- |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| A5PU | A5PU | -- | W | 18.80 | DEM | 1.524 | -- | -- | -- | -- |
| A5PW | A5PW | -- | W | 18.56 | DEM | 1.524 | -- | -- | -- | -- |
| A7C | A7C | -- | W | 21.67 | DEM | 1.524 | -- | -- | -- | -- |
| A7H | A7H | -- | W | 21.34 | DEM | 1.524 | -- | -- | -- | -- |
| A8PW | A8PW | -- | W | 15.24 | DEM | 1.524 | -- | -- | -- | -- |
| A8PX | A8PX | -- | W | 15.23 | DEM | 1.524 | -- | -- | -- | -- |
| A8PX2 | A8PX2 | -- | W | 15.10 | DEM | 1.524 | -- | -- | -- | -- |
| A8PX3 | A8PX3 | -- | W | 15.23 | DEM | 1.524 | -- | -- | -- | -- |
| A9C | A9C | -- | W | 14.60 | DEM | 1.524 | -- | -- | -- | -- |
| A9PD | A9PD | -- | W | 15.10 | DEM | 1.524 | -- | -- | -- | -- |
| A9PH | A9PH | -- | W | 15.00 | DEM | 1.524 | -- | -- | -- | -- |
| A9PU | A9PU | -- | W | 14.80 | DEM | 1.524 | -- | -- | -- | -- |
| P1C | P1C | -- | W | 24.15 | DEM | 1.524 | -- | -- | -- | -- |
| P1Cb | P1Cb | -- | W | 24.15 | DEM | 1.524 | -- | -- | -- | -- |
| McDonalds Branch Study Area | | | | | | | | | | |
| 050684 | 050684–BUTLER PLACE 2 OBS | -- | W | 42.54 | Level | 0.030 | 00/00/1965 | 51.82 | 48.77 | 51.82 |
| 050689 | 050689–LEBANON SF 23-D OBS | -- | BM, INS, W | 45.95 | Level | 0.030 | 00/00/1955 | 10.06 | -- | -- |
| 050690 | 050690–LEBANON SF 2 | -- | W | 38.12 | Level | 0.030 | 00/00/1964 | 24.69 | 23.16 | 24.69 |
| 050708 | 050708–GLASSWORKS | 3200727 | W | 37.40 | DEM | 1.524 | 07/14/1971 | 28.04 | 23.47 | 28.04 |
| 050831 | 050831–QWO-1A | 3210453 | HT, W | 37.84 | Level | 0.030 | 08/17/1984 | 1.92 | 1.01 | 1.92 |
| 050832 | 050832–QWO-1B | 3210454 | HT, W | 37.93 | Level | 0.030 | 08/17/1984 | 7.07 | 6.16 | 7.07 |
| 050833 | 050833–QWO-2A | 3210455 | HT, W | 38.54 | Level | 0.030 | 08/09/1984 | 2.10 | 1.19 | 2.10 |
| 050834 | 050834–QWO-2B | 3210456 | HT, W | 38.54 | Level | 0.030 | 08/09/1984 | 6.58 | 5.67 | 6.58 |
| 050835 | 050835–QWO-3A | 3210457 | HT, W | 39.91 | Level | 0.030 | 08/15/1984 | 5.00 | 4.08 | 5.00 |
| 050836 | 050836–QWO-3B | 3210458 | HT, W | 39.94 | Level | 0.030 | 08/15/1984 | 9.60 | 8.69 | 9.60 |
| 050837 | 050837–QWC-1A | 3210459 | W | 37.69 | Level | 0.030 | 09/26/1984 | 2.41 | 1.49 | 2.41 |
| 050838 | 050838–QWC-1B | 3210460 | W | 37.72 | Level | 0.030 | 09/26/1984 | 8.75 | 7.83 | 8.75 |
| 050839 | 050839–QWC-2A | 3210461 | W | 38.30 | Level | 0.030 | 09/06/1984 | 1.86 | 0.95 | 1.86 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 050840 | 050840–QWC-2B | 3210462 | W | 38.33 | Level | 0.305 | 09/06/1984 | 8.05 | 7.13 | 8.05 |
| 050841 | 050841–QWC-3A | 3210463 | W | 41.96 | Level | 0.030 | 09/06/1984 | 6.65 | 5.73 | 6.65 |
| 050842 | 050842–QWC-3B | 3210464 | W | 41.96 | Level | 0.030 | 09/06/1984 | 11.16 | 10.24 | 11.16 |
| 050843 | 050843–QWC-4 | 3210465 | W | 43.57 | Level | 0.030 | 09/25/1984 | 7.83 | 6.92 | 7.83 |
| 050848 | 050848–QWH-2A | 3210470 | HT, W | 40.16 | Level | 0.305 | 08/30/1984 | 3.60 | 2.68 | 3.60 |
| 050849 | 050849–QWH-2B | 3210471 | HT, W | 40.19 | Level | 0.030 | 08/10/1984 | 9.54 | 8.63 | 9.54 |
| 050850 | 050850–QWH-3A | 3210472 | HT, W | 41.83 | Level | 0.003 | 08/31/1984 | 5.09 | 4.18 | 5.09 |
| 050851 | 050851–QWH-3B | 3210473 | HT, W | 41.86 | Level | 0.003 | 08/14/1984 | 9.11 | 8.20 | 9.11 |
| 050852 | 050852–QWH-4A | 3210474 | HT, W | 40.95 | Level | 0.030 | 08/30/1984 | 4.91 | 3.99 | 4.91 |
| 050853 | 050853–QWH-4B | 3210475 | HT, W | 40.95 | Level | 0.030 | 08/30/1984 | 10.85 | 9.94 | 10.85 |
| 050861 | 050861–QWH-7A SHALLOW WELL | 3213412 | W | 42.92 | Level | 0.305 | 04/16/1987 | 3.05 | 2.13 | 3.05 |
| 050862 | 050862–QWH-7B | 3213413 | W | 42.23 | Level | 0.305 | 04/16/1987 | 7.92 | 7.01 | 7.92 |
| 050863 | 050863–QWH-8A | 3213414 | W | 42.73 | Level | 0.305 | 04/16/1987 | 3.76 | 2.85 | 3.76 |
| 050864 | 050864–QWH-8B | 3213415 | W | 42.89 | Level | 0.305 | 04/16/1987 | 9.66 | 8.75 | 9.66 |
| 050873 | 050873–O-1A | -- | W | 40.68 | Level | 0.305 | 05/22/1984 | 5.64 | 4.72 | 5.64 |
| 050874 | 050874–O-1B | -- | W | 40.67 | Level | 0.305 | 06/21/1984 | 8.84 | 7.92 | 8.84 |
| 050885 | 050885–O-11A | -- | W | 42.07 | Level | 0.305 | 08/06/1984 | 5.40 | 4.48 | 5.40 |
| 050886 | 050886–O-11B | -- | W | 42.10 | Level | 0.305 | 08/22/1984 | 9.14 | 8.23 | 9.14 |
| 050893 | 050893–CQ-6 | -- | W | 47.11 | Level | 0.305 | 08/08/1984 | 11.84 | 10.93 | 11.84 |
| 051072 | 051072–QWH-5A | -- | W | 44.91 | Level | 0.305 | 09/19/1985 | 4.66 | 3.75 | 4.66 |
| 051073 | 051073–QWH-5B | -- | W | 44.91 | Level | 0.305 | 09/19/1985 | 12.47 | 11.55 | 12.47 |
| 051074 | 051074–LEAD WELL | -- | W | 52.26 | Level | 0.030 | 09/18/1985 | 13.59 | 12.68 | 13.59 |
| 051092 | 051092–INSTITUTIONAL 2 | 3208688 | W | 36.90 | DEM | 1.524 | 12/15/1982 | 25.91 | 16.76 | 25.91 |
| 051173 | 051173–DEV CENTER | 3206083 | W | 39.20 | DEM | 1.524 | 05/27/1980 | 29.57 | 23.47 | 29.57 |
| 051201 | 051201–LSF PZ-MW-2 | 3218908 | W | 36.94 | Level | 0.030 | 06/01/1993 | 1.34 | 1.03 | 1.34 |
| 051218 | 051218–LSF PZ-MW-19 | 3218929 | W | 37.31 | Level | 0.030 | 06/01/1993 | 2.04 | 1.89 | 2.04 |
| 051334 | 051334–DOM | 3213114 | W | 33.00 | DEM | 1.524 | 12/18/1986 | 32.92 | 28.96 | 30.48 |
| 051335 | 051335–IRR | 3214492 | W | 36.20 | DEM | 1.524 | 03/30/1988 | 27.43 | 22.86 | 27.43 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 051384 | 051384–DOM | 3219191 | W | 42.40 | DEM | 1.524 | 04/16/1993 | 24.38 | 21.34 | 24.38 |
| 051385 | 051385–DOM | 3219550 | W | 43.50 | DEM | 1.524 | 10/20/1994 | 32.00 | 28.96 | 32.00 |
| 051502 | 051502–LEBANON ST F MW15 | 3224681 | W | 41.00 | DEM | 1.524 | 06/13/2000 | 11.89 | 10.36 | 11.89 |
| 051528 | 051528–MCDONALDS BRANCH 2 | -- | INS, W, WM | 36.53 | DEM | 1.524 | 03/23/2004 | 1.83 | 1.52 | 1.83 |
| 051529 | 051529–MCDONALDS BRANCH 1 | -- | HT, INS, W, WM | 36.27 | DEM | 1.524 | 03/23/2004 | 2.18 | 1.27 | 1.57 |
| 051532 | 051532–MBHT3-2D | -- | HT, W | 36.25 | DEM | 1.524 | 04/16/2004 | 3.05 | 2.80 | 3.05 |
| 051533 | 051533–MBHT3-2S | -- | HT, W | 36.27 | DEM | 1.524 | 04/16/2004 | 1.37 | 1.13 | 1.37 |
| 051534 | 051534–MBHT3-1D | -- | HT, W | 37.49 | DEM | 1.524 | 04/16/2004 | 2.74 | 2.44 | 2.74 |
| 051535 | 051535–MBHT3-1S | -- | HT, W | 37.49 | DEM | 1.524 | 04/16/2004 | 1.52 | 1.22 | 1.52 |
| 051538 | 051538–MCDONALDS BR 2 SHALLOW | -- | INS, W, WM | 36.57 | DEM | 1.524 | 05/13/2004 | 1.62 | 0.40 | 1.01 |
| 051556 | 051556–MB OW-1D | 3227994 | BM, INS, W | 45.96 | DEM | 1.524 | 09/14/2004 | 57.91 | 54.86 | 57.91 |
| 051557 | 051557–MB OW-1M | 3227995 | BM, INS, W | 45.91 | DEM | 1.524 | 09/15/2004 | 27.43 | 24.38 | 27.43 |
| 051558 | 051558–MB OW-2M | 3227992 | BM, INS, W | 42.63 | DEM | 1.524 | 09/09/2004 | 30.48 | 27.43 | 30.48 |
| 051559 | 051559–MB OW-2S | 3227993 | BM, INS, W | 42.58 | DEM | 1.524 | 09/08/2004 | 10.67 | 7.62 | 10.67 |
| 051560 | 051560–MB OW-2D | 3227991 | BM, INS, W | 42.58 | DEM | 1.524 | 09/03/2004 | 56.39 | 53.34 | 56.39 |
| 051570 | 051570–MBHT4-1S | -- | HT, W | 37.55 | DEM | 1.524 | 01/10/2005 | 2.13 | 1.83 | 2.13 |
| 051571 | 051571–MBHT4-1D | -- | HT, W | 37.57 | DEM | 1.524 | 01/10/2005 | 2.90 | 2.59 | 2.90 |
| 051572 | 051572–MBHT4-2D | -- | HT, W | 36.85 | DEM | 1.524 | 01/18/2005 | 2.90 | 2.59 | 2.90 |
| 051573 | 051573–MBHT4-2S | -- | HT, W | 36.83 | DEM | 1.524 | 01/19/2005 | 1.52 | 1.22 | 1.52 |
| 051574 | 051574–MBHT2-1 | -- | HT, W | 39.91 | Level | 1.524 | 01/04/2005 | 2.90 | 2.59 | 2.90 |
| 051575 | 051575–MBHT4-3D | -- | HT, W | 36.02 | DEM | 1.524 | 01/19/2005 | 2.74 | 2.44 | 2.74 |
| 051576 | 051576–MBHT4-3S | -- | HT, W | 36.04 | DEM | 1.524 | 01/19/2005 | 1.22 | 0.91 | 1.22 |
| 051577 | 051577–MBHT4-RB1D | -- | HT, W | 36.07 | DEM | 1.524 | 01/19/2005 | 2.74 | 2.44 | 2.74 |
| 051578 | 051578–MBHT4-RB1S | -- | HT, W | 36.05 | DEM | 1.524 | 01/19/2005 | 1.22 | 0.91 | 1.22 |
| 051579 | 051579–MBHT4-RB2S | -- | HT, W | 36.53 | DEM | 1.524 | 11/18/2004 | 1.83 | 1.52 | 1.83 |
| 051580 | 051580–MBHT2-2S | -- | HT, W | 39.35 | Level | 1.524 | 01/04/2005 | 1.98 | 1.68 | 1.98 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 051581 | 051581–MBHT2-2D | -- | HT, W | 39.36 | Level | 1.524 | 01/04/2005 | 2.90 | 2.59 | 2.90 |
| 051582 | 051582–MBHT5-2D | -- | HT, W | 35.42 | DEM | 1.524 | 02/15/2005 | 2.74 | 2.44 | 2.74 |
| 051583 | 051583–MBHT5-2S | -- | HT, W | 35.42 | DEM | 1.524 | 02/15/2005 | 1.52 | 1.22 | 1.52 |
| 051584 | 051584–MBHT5-1S | -- | HT, W | 36.50 | DEM | 1.524 | 02/16/2005 | 1.83 | 1.52 | 1.83 |
| 051585 | 051585–MBHT1-3 | -- | HT, W | 40.24 | DEM | 1.524 | 12/15/2004 | 2.13 | 1.83 | 2.13 |
| 051586 | 051586–MBHT1-2 | -- | HT, W | 40.87 | DEM | 1.524 | 12/15/2004 | 2.59 | 2.29 | 2.59 |
| 051587 | 051587–MB UP-2 | 3228096 | UP, W | 39.01 | DEM | 1.524 | 09/16/2004 | 6.71 | 3.66 | 6.71 |
| 051589 | 051589–MB UP-1 | 3228097 | UP, W | 42.37 | DEM | 1.524 | 09/23/2004 | 8.84 | 5.79 | 8.84 |
| 051590 | 051590–MBHT2-3 | -- | HT, W | 38.59 | DEM | 1.524 | 12/16/2004 | 3.05 | 2.74 | 3.05 |
| 051591 | 051591–MBHT3-3D | -- | HT, W | 36.23 | DEM | 1.524 | 01/18/2005 | 2.74 | 2.44 | 2.74 |
| 051592 | 051592–MB UP-3 | 3228095 | UP, W | 42.04 | DEM | 1.524 | 09/17/2004 | 9.75 | 6.71 | 9.75 |
| 051593 | 051593–MBHT5-3D | -- | HT, W | 35.34 | DEM | 1.524 | 02/15/2005 | 2.44 | 2.13 | 2.44 |
| 051594 | 051594–MBHT5-3S | -- | HT, W | 35.33 | DEM | 1.524 | 02/15/2005 | 0.91 | 0.61 | 0.91 |
| 051595 | 051595–MB UP-4 | 3228094 | UP, W | 41.21 | DEM | 1.524 | 09/17/2004 | 7.62 | 4.57 | 7.62 |
| 051596 | 051596–MB UP-5 | 3228093 | UP, W | 34.44 | DEM | 1.524 | 09/22/2004 | 12.04 | 8.99 | 12.04 |
| 051604 | 051604–MBHT5-1D | -- | HT, INS, W | 36.48 | DEM | 1.524 | 11/10/2004 | 3.05 | 2.59 | 3.05 |
| 051625 | 051625–MBHT1-1 | -- | HT, W | 41.81 | Level | 1.524 | 12/16/2004 | 3.05 | 2.74 | 3.05 |
| M10C | M10C | -- | W | 36.20 | DEM | 1.524 | -- | -- | -- | -- |
| M10PD | M10PD | -- | W | 37.17 | DEM | 1.524 | -- | -- | -- | -- |
| M10PH | M10PH | -- | W | 36.20 | DEM | 1.524 | -- | -- | -- | -- |
| M10PU | M10PU | -- | W | 37.50 | DEM | 1.524 | -- | -- | -- | -- |
| M10PW | M10PW | -- | W | 36.74 | DEM | 1.524 | -- | -- | -- | -- |
| M11C | M11C | -- | W | 36.30 | DEM | 1.524 | -- | -- | -- | -- |
| M11HP | M11HP | -- | W | 36.21 | DEM | 1.524 | -- | -- | -- | -- |
| M11PU | M11PU | -- | W | 36.65 | DEM | 1.524 | -- | -- | -- | -- |
| M13H | M13H | -- | W | 38.86 | DEM | 1.524 | -- | -- | -- | -- |
| M13PD | M13PD | -- | W | 39.20 | DEM | 1.524 | -- | -- | -- | -- |
| M13PX | M13PX | -- | W | 39.20 | DEM | 1.524 | -- | -- | -- | -- |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in “Site-Numbering System” section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| M14H | M14H | -- | W | 39.40 | DEM | 1.524 | -- | -- | -- | -- |
| M15H | M15H | -- | W | 42.30 | DEM | 1.524 | -- | -- | -- | -- |
| M15PD | M15PD | -- | W | 41.15 | DEM | 1.524 | -- | -- | -- | -- |
| M16H | M16H | -- | W | 42.42 | DEM | 1.524 | -- | -- | -- | -- |
| M16PH | M16PH | -- | W | 42.40 | DEM | 1.524 | -- | -- | -- | -- |
| M16PX | M16PX | -- | W | 42.20 | DEM | 1.524 | -- | -- | -- | -- |
| M17H | M17H | -- | W | 44.70 | DEM | 1.524 | -- | -- | -- | -- |
| M17PH | M17PH | -- | W | 44.50 | DEM | 1.524 | -- | -- | -- | -- |
| M17PW | M17PW | -- | W | 45.00 | DEM | 1.524 | -- | -- | -- | -- |
| M18PW2 | M18PW2 | -- | W | 45.87 | DEM | 1.524 | -- | -- | -- | -- |
| M18PX | M18PX | -- | W | 45.70 | DEM | 1.524 | -- | -- | -- | -- |
| M19HP | M19HP | -- | W | 46.50 | DEM | 1.524 | -- | -- | -- | -- |
| M19HPb | M19HPb | -- | W | 46.50 | DEM | 1.524 | -- | -- | -- | -- |
| M19PD | M19PD | -- | W | 46.13 | DEM | 1.524 | -- | -- | -- | -- |
| M19PU | M19PU | -- | W | 45.50 | DEM | 1.524 | -- | -- | -- | -- |
| M19PUb | M19PUb | -- | W | 45.50 | DEM | 1.524 | -- | -- | -- | -- |
| M1C | M1C | -- | W | 35.48 | DEM | 1.524 | -- | -- | -- | -- |
| M1PH | M1PH | -- | W | 35.34 | DEM | 1.524 | -- | -- | -- | -- |
| M1PW | M1PW | -- | W | 35.50 | DEM | 1.524 | -- | -- | -- | -- |
| M20PDx | M20PDx | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M20PH | M20PH | -- | W | 36.40 | DEM | 1.524 | -- | -- | -- | -- |
| M20PX | M20PX | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M21PU | M21PU | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M2C | M2C | -- | W | 36.00 | DEM | 1.524 | -- | -- | -- | -- |
| M2HP | M2HP | -- | W | 36.09 | DEM | 1.524 | -- | -- | -- | -- |
| M2PH | M2PH | -- | W | 36.03 | DEM | 1.524 | -- | -- | -- | -- |
| M3C | M3C | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M3HP | M3HP | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| M3PU | M3PU | -- | W | 36.80 | DEM | 1.524 | -- | -- | -- | -- |
| M3PW | M3PW | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M4H | M4H | -- | W | 36.90 | DEM | 1.524 | -- | -- | -- | -- |
| M5HP | M5HP | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M5PD | M5PD | -- | W | 37.56 | DEM | 1.524 | -- | -- | -- | -- |
| M5PU | M5PU | -- | W | 40.00 | DEM | 1.524 | -- | -- | -- | -- |
| M5PW | M5PW | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M6C | M6C | -- | W | 36.20 | DEM | 1.524 | -- | -- | -- | -- |
| M6PD | M6PD | -- | W | 36.40 | DEM | 1.524 | -- | -- | -- | -- |
| M6PH | M6PH | -- | W | 36.28 | DEM | 1.524 | -- | -- | -- | -- |
| M6PW | M6PW | -- | W | 36.20 | DEM | 1.524 | -- | -- | -- | -- |
| M7C | M7C | -- | W | 36.20 | DEM | 1.524 | -- | -- | -- | -- |
| M7H | M7H | -- | W | 36.00 | DEM | 1.524 | -- | -- | -- | -- |
| M7HP | M7HP | -- | W | 36.40 | DEM | 1.524 | -- | -- | -- | -- |
| M8HP | M8HP | -- | W | 36.89 | DEM | 1.524 | -- | -- | -- | -- |
| M8PD2 | M8PD2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M8PD3 | M8PD3 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M8PH2 | M8PH2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M8PU | M8PU | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M8PU2 | M8PU2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M8PW | M8PW | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M8PW4 | M8PW4 | -- | W | 36.47 | DEM | 1.524 | -- | -- | -- | -- |
| M8PX | M8PX | -- | W | 36.70 | DEM | 1.524 | -- | -- | -- | -- |
| M8PX2 | M8PX2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| M9HP | M9HP | -- | W | 36.18 | DEM | 1.524 | -- | -- | -- | -- |
| M9PX | M9PX | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDD1 | MDD1 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDD2 | MDD2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| MDD2b | MDD2b | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDD3 | MDD3 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDP1 | MDP1 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDP2 | MDP2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDP3 | MDP3 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDS1 | MDS1 | -- | W | 36.25 | DEM | 1.524 | -- | -- | -- | -- |
| MDS2 | MDS2 | -- | W | 36.36 | DEM | 1.524 | -- | -- | -- | -- |
| MDS2b | MDS2b | -- | W | 36.36 | DEM | 1.524 | -- | -- | -- | -- |
| MDS3 | MDS3 | -- | W | 36.40 | DEM | 1.524 | -- | -- | -- | -- |
| MDU1 | MDU1 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDU2 | MDU2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDU3 | MDU3 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDW1 | MDW1 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDW2 | MDW2 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDW2b | MDW2b | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| MDW3 | MDW3 | -- | W | 36.50 | DEM | 1.524 | -- | -- | -- | -- |
| Morses Mill Study Area | | | | | | | | | | |
| 010183 | 010183–PW 1 | 3600443 | W | 20.80 | DEM | 1.524 | 6/19/1974 | 58.52 | 52.43 | 58.52 |
| 010192 | 010192–WELL 1 | -- | W | 16.70 | DEM | 1.524 | -- | 30.48 | -- | -- |
| 010193 | 010193–INSTITUTIONAL 1 | 3600425 | W | 11.00 | DEM | 1.524 | 06/07/1971 | 45.72 | 39.62 | 45.72 |
| 010194 | 010194–INSTITUTIONAL 2 | 3600424 | W | 10.00 | DEM | 1.524 | 05/24/1971 | 44.20 | 38.10 | 44.20 |
| 010688 | 010688–PW 1 | 3602432 | W | 9.50 | DEM | 1.524 | 07/19/1981 | 54.86 | 39.62 | 54.86 |
| 010689 | 010689–SWC 2 | 3602433 | W | 9.50 | DEM | 1.524 | 07/18/1981 | 54.86 | 39.62 | 54.86 |
| 010727 | 010727–AC 13 OBS | 3606135 | W | 12.60 | DEM | 1.524 | 11/12/1985 | 6.98 | 6.07 | 6.98 |
| 010757 | 010757–SLF MW-2-1980 | 3601216 | W | 12.48 | Level | 0.030 | 03/00/1980 | 9.75 | 6.71 | 9.75 |
| 010759 | 010759–SLF MW-1-1984 | 3604538 | W | 17.76 | Level | 0.003 | 08/09/1984 | 5.79 | 1.22 | 5.79 |
| 010760 | 010760–SLF MW-2-1984 | 3604539 | W | 17.07 | Level | 0.305 | 08/09/1984 | 5.18 | 0.61 | 5.18 |
| 010775 | 010775–FAA INTERMEDIATE OBS | -- | W | 11.22 | Level | 0.030 | 01/24/1984 | 55.47 | 40.23 | 55.47 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Study Area—Continued | | | | | | | | | | |
| 010776 | 010776–FAA SHALLOW OBS | -- | W | 11.22 | Level | 0.030 | 02/03/1984 | 28.35 | 22.25 | 28.35 |
| 010893 | 010893–MW-3 | 36-08523-5 | W | 16.10 | Level | 0.003 | 06/10/1987 | 8.53 | 2.44 | 8.53 |
| 010894 | 010894–10 MW | 36-07161-7 | W | 18.52 | Level | 1.524 | 07/09/1986 | 9.57 | 5.00 | 9.57 |
| 010895 | 010895–8 MW | 3603875 | W | 19.74 | Level | 1.524 | 12/12/1983 | 8.53 | 2.44 | 8.53 |
| 010896 | 010896–DOM | 3214365 | W | 18.20 | DEM | 1.524 | 12/30/1988 | 33.53 | 30.48 | 33.53 |
| 010925 | 010925–MW-1 | 36-08521-9 | W | 18.33 | Level | 0.003 | 06/09/1987 | 9.75 | 3.66 | 9.75 |
| 010972 | 010972–PW 1 | 3608845 | W | 19.20 | DEM | 1.524 | 09/10/1987 | 47.70 | 36.42 | 46.33 |
| 010973 | 010973–3/17 MOSSMILL | 3614415 | W | 9.80 | DEM | 1.524 | 05/06/1991 | 56.39 | 40.84 | 56.39 |
| 010989 | 010989–WRANGLEBORO 3 | 5600061 | W | 12.80 | DEM | 1.524 | 00/00/1981 | 57.91 | -- | -- |
| 010999 | 010999–IRR | 3612213 | W | 13.60 | DEM | 1.524 | 08/23/1989 | 59.44 | 51.82 | 57.91 |
| 011197 | 011197–IRR 1 | 5600119 | W | 15.10 | DEM | 1.524 | 00/00/1956 | 30.48 | -- | -- |
| 011268 | 011268–SUSCP15 | 3617164 | W | 18.90 | M | 1.524 | 11/30/1994 | 30.48 | 27.43 | 30.48 |
| 011457 | 011457–STOCKTON 2 | -- | INS, W, WM | 13.27 | DEM | 1.524 | 03/25/2004 | 2.09 | 1.78 | 2.09 |
| 011458 | 011458–STOCKTON 1 | -- | INS, W, WM | 11.58 | DEM | 1.524 | 03/25/2004 | 1.83 | 1.52 | 1.83 |
| 011478 | 011478–E-1 | 3622753 | W | 20.70 | DEM | 1.524 | 02/19/1999 | 49.99 | 34.14 | 49.38 |
| 011498 | 011498–MM OW-1M | 3628385 | BM, INS, W | 17.02 | DEM | 1.524 | 08/19/2004 | 19.81 | 16.76 | 19.81 |
| 011499 | 011499–MM OW-1D | 3628384 | BM, INS, W | 16.80 | DEM | 1.524 | 08/17/2004 | 50.29 | 47.24 | 50.29 |
| 011500 | 011500–MM OW-1S | 3628386 | BM, INS, W | 16.96 | DEM | 1.524 | 08/19/2004 | 6.71 | 3.66 | 6.71 |
| 011501 | 011501–MM OW-2S | 3628383 | BM, INS, W | 12.16 | DEM | 1.524 | 08/25/2004 | 12.19 | 9.14 | 12.19 |
| 011502 | 011502–MM OW-2M | 3628382 | BM, INS, W | 12.15 | DEM | 1.524 | 08/25/2004 | 22.25 | 19.20 | 22.25 |
| 011503 | 011503–MM OW-2D | 3628381 | BM, INS, W | 12.33 | DEM | 1.524 | 08/25/2004 | 51.82 | 48.77 | 51.82 |
| 011525 | 011525–MMHT3-3D | -- | HT, W | 12.43 | DEM | 1.524 | 02/11/2005 | 2.74 | 2.44 | 2.74 |
| 011526 | 011526–MMHT3-3S | -- | HT, W | 12.40 | DEM | 1.524 | 02/11/2005 | 1.83 | 1.52 | 1.83 |
| 011527 | 011527–MMHT3-2D | -- | HT, W | 13.29 | DEM | 1.524 | 03/17/2005 | 2.74 | 2.44 | 2.74 |
| 011528 | 011528–MMHT3-2S | -- | HT, W | 13.29 | DEM | 1.524 | 03/09/2005 | 1.22 | 0.91 | 1.22 |
| 011529 | 011529–MMHT3-1D | -- | HT, W | 14.04 | DEM | 1.524 | 03/09/2005 | 2.13 | 1.83 | 2.13 |
| 011531 | 011531–MMHT3-1S | -- | HT, W | 14.03 | DEM | 1.524 | 03/09/2005 | 1.71 | 1.40 | 1.71 |
| 011532 | 011532–MMHT4-1D | -- | HT, W | 13.23 | DEM | 1.524 | 03/04/2005 | 2.74 | 2.44 | 2.74 |
| 011533 | 011533–MMHT4-1S | -- | HT, W | 13.23 | DEM | 1.524 | 03/04/2005 | 1.83 | 1.52 | 1.83 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Study Area—Continued | | | | | | | | | | |
| 011534 | 011534–MMHT4-3D | -- | HT, W | 11.47 | DEM | 1.524 | 03/03/2005 | 2.74 | 2.44 | 2.74 |
| 011535 | 011535–MMHT4-3S | -- | HT, W | 11.47 | DEM | 1.524 | 03/03/2005 | 1.52 | 1.22 | 1.52 |
| 011536 | 011536–MMHT1-3D | -- | HT, W | 16.28 | DEM | 1.524 | 03/02/2005 | 2.68 | 2.38 | 2.68 |
| 011537 | 011537–MMHT1-3S | -- | HT, W | 16.33 | DEM | 1.524 | 03/02/2005 | 1.52 | 1.22 | 1.52 |
| 011538 | 011538–MMHT2-3D | -- | HT, W | 12.33 | DEM | 1.524 | 03/14/2005 | 2.74 | 2.44 | 2.74 |
| 011539 | 011539–MMHT2-3S | -- | HT, W | 12.34 | DEM | 1.524 | 03/14/2005 | 1.52 | 1.22 | 1.52 |
| 011540 | 011540–MMHT1-1D | -- | HT, W | 17.80 | DEM | 1.524 | 03/03/2005 | 2.44 | 2.13 | 2.44 |
| 011541 | 011541–MMHT1-1S | -- | HT, W | 17.78 | DEM | 1.524 | 03/03/2005 | 1.52 | 1.22 | 1.52 |
| 011542 | 011542–MMHT2-1D | -- | HT, W | 13.59 | DEM | 1.524 | 03/16/2005 | 2.74 | 2.44 | 2.74 |
| 011543 | 011543–MMHT2-1S | -- | HT, W | 13.58 | DEM | 1.524 | 03/16/2005 | 1.83 | 1.52 | 1.83 |
| 011544 | 011544–MMHT5-3D | -- | HT, W | 7.50 | DEM | 1.524 | 03/07/2005 | 2.74 | 2.44 | 2.74 |
| 011545 | 011545–MMHT5-3S | -- | HT, W | 7.47 | DEM | 1.524 | 03/07/2005 | 1.52 | 1.22 | 1.52 |
| 011546 | 011546–MMHT5-2D | -- | HT, W | 8.73 | DEM | 1.524 | 03/07/2005 | 2.74 | 2.44 | 2.74 |
| 011547 | 011547–MMHT5-2S | -- | HT, W | 8.74 | DEM | 1.524 | 03/07/2005 | 1.52 | 1.22 | 1.52 |
| 011548 | 011548–MMHT5-1S | -- | HT, W | 9.00 | DEM | 1.524 | 03/07/2005 | 1.52 | 1.22 | 1.52 |
| 011549 | 011549–MMHT5-1D | -- | HT, W | 9.01 | DEM | 1.524 | 03/07/2005 | 2.74 | 2.44 | 2.74 |
| 011559 | 011559–MM UP-4 | 3628860 | UP, W | 15.10 | DEM | 1.524 | 03/07/2005 | 6.10 | 4.57 | 6.10 |
| 011560 | 011560–MMHT4-2D | -- | HT, W | 11.57 | DEM | 1.524 | 03/03/2005 | 2.74 | 2.44 | 2.74 |
| 011561 | 011561–MMHT1-2D | -- | HT, W | 16.95 | DEM | 1.524 | 03/02/2005 | 2.44 | 2.13 | 2.44 |
| 011562 | 011562–MMHT1-2S | -- | HT, W | 16.97 | DEM | 1.524 | 03/02/2005 | 1.52 | 1.22 | 1.52 |
| 011563 | 011563–MMHT2-2S | -- | HT, W | 13.29 | DEM | 1.524 | 03/16/2005 | 1.77 | 1.46 | 1.77 |
| 011564 | 011564–MMHT2-2D | -- | HT, W | 13.30 | DEM | 1.524 | 03/17/2005 | 2.74 | 2.44 | 2.74 |
| 011565 | 011565–MM UP-2 | 3628859 | UP, W | 16.70 | DEM | 1.524 | 03/08/2005 | 6.10 | 4.57 | 6.10 |
| 011566 | 011566–MM UP-5 | 3628858 | UP, W | 12.10 | DEM | 1.524 | 03/07/2005 | 7.62 | 6.10 | 7.62 |
| 011585 | 011585–F-MW2S | 36-08761-1 | W | 18.17 | Level | 1.524 | 04/27/1987 | 3.81 | 0.76 | 3.81 |
| 011586 | 011586–29-PW1 | 3623954 | W | 17.75 | Level | 1.524 | 08/10/2000 | 31.39 | 25.30 | 31.39 |
| 011587 | 011587–29-MW6S | 3619118 | W | 14.30 | Level | 1.524 | 06/22/1995 | 7.62 | 4.57 | 7.62 |
| 011588 | 011588–DOM | 3603031 | W | 18.20 | DEM | 1.524 | 10/08/1982 | 44.81 | 43.28 | 44.81 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Study Area—Continued | | | | | | | | | | |
| 011589 | 011589–MW-2 | 36-08522-7 | W | 19.70 | DEM | 1.524 | 06/10/1987 | 10.67 | 4.57 | 10.67 |
| 011590 | 011590–BLDG 6 | 3616530 | W | 17.20 | DEM | 1.524 | 01/12/1993 | 25.30 | 23.77 | 25.30 |
| 011591 | 011591–ATH FLD | 3621583 | W | 17.60 | DEM | 1.524 | 10/01/1997 | 54.86 | 51.82 | 54.86 |
| 011592 | 011592–BIG BLUE | 3621377 | W | 13.10 | DEM | 1.524 | 07/09/1997 | 51.82 | 47.24 | 50.29 |
| 011593 | 011593–DOM | 3622654 | W | 17.20 | DEM | 1.524 | 12/15/1998 | 32.31 | 29.26 | 32.31 |
| 011622 | 011622–MW-2 | 36-07181-1 | W | 17.88 | Level | 1.524 | 10/02/1986 | 9.14 | 3.05 | 9.14 |
| 011624 | 011624–POMONA OAKS MW-7I | 36-10894-4 | W | 15.34 | Level | 1.524 | 01/05/1989 | 26.52 | 23.47 | 26.52 |
| 011625 | 011625–POMONA OAKS MW-7S | 3610893 | W | 15.44 | Level | 1.524 | 11/10/1988 | 5.18 | 2.13 | 5.18 |
| 011626 | 011626–MW-5 | 3620936 | W | 21.50 | DEM | 1.524 | 12/30/1996 | 7.62 | 3.05 | 7.62 |
| 011627 | 011627–MW-3 | 3620934 | W | 20.80 | DEM | 1.524 | 12/30/1996 | 7.62 | 3.05 | 7.62 |
| 011628 | 011628–MW-4 | 3620935 | W | 20.70 | DEM | 1.524 | 12/30/1996 | 7.62 | 3.05 | 7.62 |
| 011629 | 011629–POMONA OAKS MW-8D | 36-10848-1 | W | 20.71 | Level | 1.524 | 01/18/1989 | 62.64 | 59.59 | 62.64 |
| 011630 | 011630–POMONA OAKS MW-8I | 3610906 | W | 20.68 | Level | 1.524 | 01/17/1989 | 27.43 | 24.38 | 27.43 |
| 011631 | 011631–POMONA OAKS MW-8S | 36-10903-7 | W | 20.39 | Level | 1.524 | 11/28/1988 | 7.77 | 4.72 | 7.77 |
| 011632 | 011632–HERSCHEL MW-4 | 3604541 | W | 18.11 | Level | 1.524 | 08/09/1984 | 5.79 | 1.22 | 5.79 |
| 011633 | 011633–IRR | 3622184 | W | 15.10 | DEM | 1.524 | 06/30/1998 | 24.38 | 18.29 | 24.38 |
| 011635 | 011635–DOM | 3609754 | W | 16.30 | DEM | 0.762 | 04/27/1989 | 31.70 | 28.65 | 31.70 |
| 011636 | 011636–SO CLUSTER-F46 RED | -- | W | 11.50 | DEM | 1.524 | -- | 18.29 | -- | -- |
| 011637 | 011637–SO CLUSTER-F46 BLUE | -- | W | 11.50 | DEM | 1.524 | -- | 48.77 | -- | -- |
| 011638 | 011638–WEST CLUSTER-L23 BLUE | -- | W | 15.10 | DEM | 1.524 | -- | 47.85 | -- | -- |
| 011639 | 011639–WEST CLUSTER-L23 RED | -- | W | 15.10 | DEM | 1.524 | -- | 20.73 | -- | -- |
| 011640 | 011640–NO CLUSTER-B1 RED | -- | W | 13.60 | DEM | 1.524 | -- | 24.08 | -- | -- |
| 011641 | 011641–NO CLUSTER-B1 BLUE | -- | W | 13.60 | DEM | 1.524 | -- | 53.95 | -- | -- |
| 011642 | 011642–DOM | 3619490 | W | 12.80 | DEM | 1.524 | 01/05/1996 | 34.14 | 31.09 | 34.14 |
| 011643 | 011643–DOM | 3626823 | W | 3.20 | DEM | 1.524 | 04/01/2003 | 26.52 | 24.99 | 26.52 |
| 011650 | 011650–MW104-D | 3625547 | W | 17.11 | Level | 0.030 | 10/23/2001 | 32.16 | 29.11 | 32.16 |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Study Area—Continued | | | | | | | | | | |
| 011652 | 011652–MW106-D | 3625387 | W | 17.31 | Level | 0.030 | 10/02/2001 | 36.79 | 33.74 | 36.79 |
| 011654 | 011654–F-MW4S | -- | W | 18.43 | R | 0.030 | 11/09/1988 | 12.95 | 6.86 | 12.95 |
| 011655 | 011655–P-5 | 3610843 | W | 17.51 | Level | 1.524 | 10/26/1988 | 7.47 | 5.03 | 7.47 |
| 011656 | 011656–P-7 | 3610845 | W | 17.66 | Level | 1.524 | 10/25/1988 | 7.01 | 3.96 | 7.01 |
| 011657 | 011657–KF IRR-1 | -- | W | 15.80 | DEM | 1.524 | -- | 22.86 | -- | -- |
| 011658 | 011658–P-1 | -- | W | 17.94 | Level | 1.524 | 10/31/1988 | 7.01 | 3.96 | 7.01 |
| 011659 | 011659–LIFT ST 1-2 | 3618535 | W | 10.60 | DEM | 1.524 | -- | 16.76 | -- | -- |
| 011660 | 011660–LIFT STA 1-1 | 3618536 | W | 10.60 | DEM | 1.524 | -- | 48.77 | -- | -- |
| 011661 | 011661–MW102 | 3624547 | W | 14.69 | R | 0.030 | 11/16/2000 | 21.34 | 18.29 | 21.34 |
| 011662 | 011662–MW101 | 3624546 | W | 14.75 | R | 0.030 | 11/17/2000 | 32.61 | 29.57 | 32.61 |
| 011663 | 011663–MW104-S | -- | W | 17.15 | Level | 0.030 | -- | 25.66 | 22.62 | 25.66 |
| 011664 | 011664–MW-4 | 3620012 | W | 17.00 | DEM | 1.524 | 03/21/1996 | 16.76 | 13.72 | 16.76 |
| 011665 | 011665–MW109-S | 3625389 | W | 13.22 | Level | 0.030 | 10/25/2001 | 18.29 | 15.24 | 18.29 |
| 011666 | 011666–MW108-S | 3625388 | W | 11.98 | Level | 0.030 | 10/29/2001 | 18.23 | 15.18 | 18.23 |
| 011667 | 011667–MW106-S | -- | W | 17.28 | Level | 0.030 | -- | 25.73 | 22.68 | 25.73 |
| 011668 | 011668–MW110-S | 3625513 | W | 15.77 | Level | 0.030 | 10/23/2001 | 21.31 | 18.26 | 21.31 |
| 011670 | 011670–MW 14D | 36-10219-6 | W | 18.52 | Level | 1.524 | 07/14/1988 | 25.91 | 22.86 | 25.91 |
| R1C | R1C | -- | W | 8.46 | DEM | 1.524 | -- | -- | -- | -- |
| R1H | R1H | -- | W | 8.80 | DEM | 1.524 | -- | -- | -- | -- |
| R1PU | R1PU | -- | W | 9.01 | DEM | 1.524 | -- | -- | -- | -- |
| R1PW | R1PW | -- | W | 9.03 | DEM | 1.524 | -- | -- | -- | -- |
| R2H1 | R2H1 | -- | W | 10.60 | DEM | 1.524 | -- | -- | -- | -- |
| R2H2 | R2H2 | -- | W | 10.96 | DEM | 1.524 | -- | -- | -- | -- |
| R2HP | R2HP | -- | W | 11.30 | DEM | 1.524 | -- | -- | -- | -- |
| R2PH | R2PH | -- | W | 11.10 | DEM | 1.524 | -- | -- | -- | -- |
| R2PH2 | R2PH2 | -- | W | 10.70 | DEM | 1.524 | -- | -- | -- | -- |
| R2PH3 | R2PH3 | -- | W | 10.27 | DEM | 1.524 | -- | -- | -- | -- |
| R2PH4 | R2PH4 | -- | W | 11.30 | DEM | 1.524 | -- | -- | -- | -- |

**Table 1.** Descriptions of selected wells used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of text; Shaded site information was provided by the N.J. Pinelands Commission, New Lisbon, NJ. Site type: BM, Basin-monitoring well; HT, Hydrologic-transect well; INS, Instrumented with data logger; UP, Upland well; W, Well; WM, Wetland-monitoring well. Method of altitude measurement; DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; M, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Altitude of land surface, NAVD 88 (meters)[1] | Altitude method | Altitude accuracy (meters)[2] | Date of construction | Well depth below land surface (meters)[1] | Screen top below land surface (meters)[1] | Screen bottom below land surface (meters)[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Study Area—Continued | | | | | | | | | | |
| R2PU | R2PU | -- | W | 11.91 | DEM | 1.524 | -- | -- | -- | -- |
| R2PU2 | R2PU3 | -- | W | 11.53 | DEM | 1.524 | -- | -- | -- | -- |
| R2PUb | R2PUb | -- | W | 11.91 | DEM | 1.524 | | | | |
| R3H | R3H | -- | W | 12.80 | DEM | 1.524 | -- | -- | -- | -- |
| R3HP | R3HP | -- | W | 11.93 | DEM | 1.524 | -- | -- | -- | -- |
| R3PH | R3PH | -- | W | 12.81 | DEM | 1.524 | -- | -- | -- | -- |
| R3PH2 | R3PH3 | -- | W | 12.80 | DEM | 1.524 | -- | -- | -- | -- |
| R5H | R5H | -- | W | 11.33 | DEM | 1.524 | -- | -- | -- | -- |
| R5PD | R5PD | -- | W | 12.41 | DEM | 1.524 | -- | -- | -- | -- |
| R5PU | R5PU | -- | W | 12.68 | DEM | 1.524 | -- | -- | -- | -- |
| R5PW | R5PW | -- | W | 12.14 | DEM | 1.524 | -- | -- | -- | -- |
| R6C | R6C | -- | W | 11.94 | DEM | 1.524 | -- | -- | -- | -- |
| R6PD | R6PD | -- | W | 12.10 | DEM | 1.524 | -- | -- | -- | -- |
| R6PU | R6PU | -- | W | 12.30 | DEM | 1.524 | -- | -- | -- | -- |
| R6PW | R6PW | -- | W | 12.10 | DEM | 1.524 | -- | -- | -- | -- |
| R7C | R7C | -- | W | 11.46 | DEM | 1.524 | -- | -- | -- | -- |
| R7C2 | R7C3 | -- | W | 11.38 | DEM | 1.524 | -- | -- | -- | -- |
| R7PH | R7PH | -- | W | 12.18 | DEM | 1.524 | -- | -- | -- | -- |
| R7PH2 | R7PH3 | -- | W | 11.80 | DEM | 1.524 | -- | -- | -- | -- |
| R7PW | R7PW | -- | W | 11.60 | DEM | 1.524 | -- | -- | -- | -- |
| R8C | R8C | -- | W | 11.48 | DEM | 1.524 | -- | -- | -- | -- |

[1] The source of the data is the U.S. Geological Survey Groundwater Site Inventory (GWSI) database. The data are in English units, and were converted to metric units for this study (feet x 0.3048 = meters). Because of the variable accuracy of the source data and the implied accuracy resulting from the precision of the conversion, unless noted, the data are presented uniformly in this table to hundredths of a meter.

[2] Altitude accuracy (meters) is a conversion of the accuracy of the source data (feet). For example, accuracies shown here of 1.524 and 0.003 meters are based on accuracies of 5 and 0.01 feet, respectively, in the source data.

**Table 2.** Descriptions of selected surface-water sites used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of the text. Site type: CRGS, continuous-record streamflow-gaging station; HT, hydraulic transect; PRS, low-flow partial-record station; seep, seepage site used to measure streamflow or water-level; stream point and staff gage, stream site used to measure water-level. Data type: FF, start-of-flow; GH, gage height; Q, discharge; WL, water level. Method of altitude measurement: DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; Map, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | Site type | Altitude of land surface, NAVD 88 (meters) | Altitude method | Altitude accuracy (meters) | Data type |
|---|---|---|---|---|---|---|
| Albertson Brook Study Area | | | | | | |
| 01409403 | Wildcat Branch at Chesilhurst, NJ | PRS | 29.79 | Level | 0.003 | WL |
| 01409407 | Pump Branch near Blue Anchor, NJ | PRS | 31.70 | DEM | 1.524 | WL |
| 01409408 | Pump Branch near Waterford Works, NJ | PRS, seep | 27.10 | DEM | 1.524 | WL, Q |
| 01409409 | Blue Anchor Brook near Blue Anchor, NJ | PRS, seep, staff gage | 25.51 | Level | 0.003 | GH, FF, Q |
| 01409410 | Albertson Brook near Hammonton, NJ | CRGS, seep, staff gage | 12.63 | DEM | 1.524 | GH, Q |
| 0140941010 | Albertson Brook above Great Swamp Branch near Hammonton, NJ | PRS | 12.19 | DEM | 1.524 | Q |
| 0140940607 | Pump Branch at Cedar Brook, NJ | PRS, seep, staff gage, HT | 32.86 | DEM | 1.524 | GH, Q |
| 0140940810 | Pump Branch near Elm, NJ | CRGS, seep, staff gage | 22.48 | Map | 1.524 | GH, Q |
| 0140940820 | Pump Branch above Blue Anchor Brook near Elm, NJ | PRS, seep, staff gage, HT | 21.17 | Map | 1.524 | GH, Q |
| 0140940950 | Blue Anchor Brook at Elm, NJ | PRS, seep | 26.82 | DEM | 1.524 | WL, Q |
| 0140940970 | Albertson Brook near Elm, NJ | PRS, seep | 22.60 | DEM | 1.524 | WL |
| 0140940972 | Albertson Brook below Railroad Bridge near Elm, NJ | PRS, seep, staff gage, HT | 18.20 | DEM | 1.524 | GH, Q |
| 0140940990 | Albertson Brook 1.3 miles above U.S. Route 206 near Atsion, NJ | PRS, seep, staff gage, HT | 16.78 | DEM | 1.524 | GH, Q |
| 0140941010 | Albertson Brook 0.8 miles below U.S. Route 206 near Atsion, NJ | PRS, seep, staff gage, HT | 12.60 | DEM | 1.524 | GH, Q |
| 0140941050 | Great Swamp Branch at Elm, NJ | PRS | 24.50 | DEM | 1.524 | WL |
| 0140941070 | Great Swamp Branch below U.S. Route 206 near Hammonton, NJ | PRS | 17.70 | DEM | 1.524 | WL |
| 0140941075 | Cedar Brook at Columbia Road at Hammonton, NJ | PRS | 18.20 | DEM | 1.524 | WL |
| 394150074494500 | Pump Branch at Ancora, NJ | Stream point | 25.12 | Map | 1.524 | WL |
| 394154074451301 | Gun Branch at US Route 206 near Atsion, NJ | Stream point | 15.30 | DEM | 1.524 | WL |
| 394251074463601 | Clark Branch at Burnt House Road near Atsion, NJ | Stream point | 20.70 | DEM | 1.524 | WL |
| ABSTM 5 | ABSTM 5 | Stream point | 30.50 | DEM | 1.524 | WL |
| ABSTM10 | ABSTM10 | Stream point | 33.20 | DEM | 1.524 | WL, FF |
| ABSTM11 | ABSTM11 | Stream point | 34.70 | DEM | 1.524 | WL, FF |
| ABSTM12 | ABSTM12 | Stream point | 29.87 | Map | 1.524 | WL, FF |
| ABSTM13 | ABSTM13 | Stream point | 37.00 | DEM | 1.524 | WL, FF |
| ABSTM14 | ABSTM14 | Stream point | 42.00 | DEM | 1.524 | WL, FF |
| ABSTM16A | Blue Anchor Brook at Rt 30 | Stream point | 25.10 | DEM | 1.524 | WL |
| ABSTM2 | ABSTM2 | Stream point | 24.20 | DEM | 1.524 | WL |
| ABSTM21 | ABSTM21 | Stream point | 21.20 | DEM | 1.524 | WL, FF |

**Table 2.** Descriptions of selected surface-water sites used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in “Site-Numbering System” section of the text. Site type: CRGS, continuous-record streamflow-gaging station; HT, hydraulic transect; PRS, low-flow partial-record station; seep, seepage site used to measure streamflow or water-level; stream point and staff gage, stream site used to measure water-level. Data type: FF, start-of-flow; GH, gage height; Q, discharge; WL, water level. Method of altitude measurement: DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; Map, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | Site type | Altitude of land surface, NAVD 88 (meters) | Altitude method | Altitude accuracy (meters) | Data type |
|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | |
| ABSTM22 | ABSTM22 | Stream point | 35.70 | DEM | 1.524 | WL, FF |
| ABSTM4 | Gun Branch at Flemming Pike | Stream point | 21.20 | DEM | 1.524 | WL |
| ABSTM6 | ABSTM6 | Stream point | 42.20 | DEM | 1.524 | WL, FF |
| ABSTM7 | ABSTM7 | Stream point | 42.50 | DEM | 1.524 | WL |
| ABSTM8 | ABSTM8 | Stream point | 33.70 | DEM | 1.524 | WL, FF |
| ABSTM9 | ABSTM9 | Stream point | 33.50 | DEM | 1.524 | WL, FF |
| STM 3 | STM 3 | Stream point | 36.50 | DEM | 1.524 | WL |
| STM 60 | STM 60 | Stream point | 37.20 | DEM | 1.524 | WL |
| STM 62 | STM 62 | Stream point | 31.20 | DEM | 1.524 | WL, FF |
| STM 67 | STM 67 | Stream point | 30.32 | DEM | 1.524 | WL |
| STM 75 | STM 75 | Stream point | 22.70 | DEM | 1.524 | WL |
| STM 76 | STM 76 | Stream point | 27.70 | DEM | 1.524 | WL |
| STM 79 | STM 79 | Stream point | 30.20 | DEM | 1.524 | WL |
| McDonalds Branch Study Area | | | | | | |
| 01466460 | McDonalds Branch 650ft above Butler Place Road in Byrne State Forest, NJ | PRS, seep, staff gage, HT | 39.43 | DEM | 1.524 | GH, Q |
| 01466480 | McDonalds Branch 4900ft above gage in Byrne State Forest, NJ | Staff gage, HT | 37.83 | DEM | 1.524 | GH |
| 01466495 | McDonalds Branch 0.3 miles above gage in Byrne State Forest, NJ | Staff gage, HT | 35.65 | DEM | 1.524 | GH |
| 01466500 | McDonalds Branch in Byrne State Forest, NJ | CRGS, seep, staff gage | 35.50 | Level | 0.006 | GH, Q |
| 01466510 | McDonalds Branch 2000ft downstream of gage in Byrne State Forest, NJ | PRS, seep | 36.20 | DEM | 1.524 | WL, Q |
| 01466520 | McDonalds Branch Tributary in Byrne State Forest, NJ | PRS, seep, staff gage, HT | 35.40 | DEM | 1.524 | GH, Q |
| 01466550 | McDonalds Branch near Presidential Lakes, NJ | PRS, seep, staff gage, HT | 34.28 | DEM | 1.524 | GH, Q |
| 01466590 | McDonalds Branch at McDonalds, NJ | PRS, seep | 30.51 | DEM | 1.524 | WL,Q |
| 01466600 | McDonalds Branch at Cooper Road at McDonalds, NJ | PRS, seep | 29.20 | Map | 1.524 | WL,Q |
| 395222074294600 | McDonalds Branch 50ft downstream of gage in Lebanon State Forest, NJ | Stream point | 39.20 | DEM | 1.524 | WL |
| MBSTM10 | MBSTM10 | Stream point | 37.90 | DEM | 1.524 | WL, FF |
| MBSTM12 | MBSTM 12 Upper cranberry bog | Stream point | 31.96 | DEM | 1.524 | WL |
| MBSTM13 | MBSTM 13 | Stream point | 40.50 | DEM | 1.524 | WL |
| MBSTM14 | McDonalds Branch at Lebanon Lake | Stream point | 28.11 | DEM | 1.524 | WL |
| MBSTM15 | MBSTM15 | Stream point | 36.20 | DEM | 1.524 | WL, FF |

**Table 2.** Descriptions of selected surface-water sites used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in "Site-Numbering System" section of the text. Site type: CRGS, continuous-record streamflow-gaging station; HT, hydraulic transect; PRS, low-flow partial-record station; seep, seepage site used to measure streamflow or water-level; stream point and staff gage, stream site used to measure water-level. Data type: FF, start-of-flow; GH, gage height; Q, discharge; WL, water level. Method of altitude measurement: DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; Map, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | Site type | Altitude of land surface, NAVD 88 (meters) | Altitude method | Altitude accuracy (meters) | Data type |
|---|---|---|---|---|---|---|
| | | McDonalds Branch Study Area—Continued | | | | |
| MBSTM16 | MBSTM16 | Stream point | 35.97 | DEM | 1.524 | WL |
| MBSTM17 | MBSTM17 | Stream point | 36.20 | DEM | 1.524 | WL, FF |
| MBSTM2 | Shinns Branch | Stream point | 30.20 | DEM | 1.524 | WL |
| MBSTM3 | Cooper Branch | Stream point | 35.70 | DEM | 1.524 | WL |
| MBSTM4 | MBSTM4 | Stream point | 39.40 | DEM | 1.524 | WL |
| MBSTM5 | MBSTM5 | Stream point | 38.90 | DEM | 1.524 | WL |
| MBSTM6 | MBSTM6 | Stream point | 36.00 | DEM | 1.524 | WL |
| MBSTM7 | MBSTM7 | Stream point | 29.30 | DEM | 1.524 | WL |
| MBSTM8 | MBSTM8 | Stream point | 45.20 | DEM | 1.524 | WL, FF |
| MBSTM9 | MBSTM9 | Stream point | 37.20 | DEM | 1.524 | WL, FF |
| STM304 | STM304 | Stream point | 29.70 | DEM | 1.524 | WL |
| STM305 | STM305 | Stream point | 36.50 | DEM | 1.524 | WL, FF |
| STM307 | STM307 | Stream point | 36.70 | DEM | 1.524 | WL |
| STM358 | STM358 | Stream point | 42.20 | DEM | 1.524 | WL |
| STM368 | STM368 | Stream point | 42.20 | DEM | 1.524 | WL |
| STM369 | STM369 | Stream point | 41.90 | DEM | 1.524 | WL |
| STM396 | STM396 | Stream point | 27.30 | DEM | 1.524 | WL |
| STM397 | STM397 | Stream point | 33.50 | DEM | 1.524 | WL |
| STM398 | STM398 | Stream point | 38.50 | DEM | 1.524 | WL |
| STM416 | STM416 | Stream point | 37.70 | DEM | 1.524 | WL |
| -- | Butterworth Pond | Staff gage | -- | DEM | 1.524 | WL |
| | | Morses Mill Stream Study Area | | | | |
| 01410215 | Clarks Mill Stream at Port Republic, NJ | Stream point | 3.00 | DEM | 1.524 | WL |
| 01410216 | Morses Mill Stream at Odessa Avenue near Pomona, NJ | PRS | 17.61 | DEM | 1.524 | WL, FF, Q |
| 01410217 | Morses Mill Stream at West Duerer Street near Pomona, NJ | PRS, seep, staff gage, HT | 15.33 | DEM | 1.524 | GH, Q |
| 01410218 | Morses Mill Stream at Zurich Avenue near Pomona, NJ | PRS, seep, staff gage, HT | 10.29 | DEM | 1.524 | GH, Q |
| 01410220 | Morses Mill Stream Tributary above Sand Road near Pomona, NJ | Staff gage, HT | 12.36 | DEM | 1.524 | GH |
| 01410221 | Morses Mill Stream Tributary below Sand Road near Pomona, NJ | PRS, seep, staff gage, HT | 10.89 | DEM | 1.524 | GH, Q |
| 01410222 | Morses Mill Stream at College Drive near Pomona, NJ | PRS, seep | 9.00 | Map | 1.524 | WL, Q |

**Table 2.** Descriptions of selected surface-water sites used in the hydrologic assessment of three drainage basins, New Jersey Pinelands, 2004–06.—Continued

[--, data unavailable. Site identifier: site identifiers described in “Site-Numbering System” section of the text. Site type: CRGS, continuous-record streamflow-gaging station; HT, hydraulic transect; PRS, low-flow partial-record station; seep, seepage site used to measure streamflow or water-level; stream point and staff gage, stream site used to measure water-level. Data type: FF, start-of-flow; GH, gage height; Q, discharge; WL, water level. Method of altitude measurement: DEM, interpolated from 10-meter Digital Elevation Model; Level, level or other surveying method; Map, interpolated from topographic map. NAVD 88, North American Vertical Datum of 1988.]

| Site identifier | Site name | Site type | Altitude of land surface, NAVD 88 (meters) | Altitude method | Altitude accuracy (meters) | Data type |
|---|---|---|---|---|---|---|
| | | Morses Mill Stream Study Area—Continued | | | | |
| 01410223 | Morses Mill Stream at Garden State Parkway near Pomona, NJ | PRS, seep, staff gage, HT | 6.73 | DEM | 1.524 | GH, Q |
| 01410225 | Morses Mill Stream at Port Republic, NJ | CRGS, seep, staff gage | 0.00 | DEM | 1.524 | GH, Q |
| 01410230 | Mattix Run near Smithville, NJ | Stream point | 3.70 | DEM | 1.524 | WL |
| MMSTM10 | MMSTM10 | Stream point | 17.61 | DEM | 1.524 | WL, FF |
| MMSTM11 | MMSTM11 | Stream point | 16.70 | DEM | 1.524 | WL, FF |
| MMSTM12 | MMSTM12 | Stream point | 15.10 | DEM | 1.524 | WL, FF |
| MMSTM13 | MMSTM13 | Stream point | 10.60 | DEM | 1.524 | WL, FF |
| MMSTM14 | MMSTM14 | Stream point | 11.30 | DEM | 1.524 | WL, FF |
| MMSTM2 | MMSTM2 | Stream point | 15.10 | DEM | 1.524 | WL |
| MMSTM3 | MMSTM3 | Stream point | 7.50 | DEM | 1.524 | WL |
| MMSTM4 | MMSTM4 | Stream point | 11.30 | DEM | 1.524 | WL |
| MMSTM5 | MMSTM5 | Stream point | 10.60 | DEM | 1.524 | WL |
| MMSTM6 | MMSTM6 | Stream point | 13.50 | DEM | 1.524 | WL, FF |
| MMSTM7 | MMSTM7 | Stream point | 12.60 | DEM | 1.524 | WL, FF |
| MMSTM8 | MMSTM8 | Stream point | 18.20 | DEM | 1.524 | WL |
| MMSTM9 | MMSTM9 | Stream point | 17.30 | DEM | 1.524 | WL |
| STM 85 | STM 85 | Stream point | 2.50 | DEM | 1.524 | WL |
| STM 86 | STM 86 | Stream point | 1.70 | DEM | 1.524 | WL |
| STM102 | STM102 | Stream point | 16.70 | DEM | 1.524 | WL |
| STM108 | STM108 | Stream point | 9.10 | DEM | 1.524 | WL |
| STM109 | STM109 | Stream point | 12.10 | DEM | 1.524 | WL |
| STM110 | STM110 | Stream point | 15.10 | DEM | 1.524 | WL |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Albertson Brook Study Area | | | | | | |
| 010325 | 010325–IRR 2A | -- | GW | 19.81 | 18.80 | 18.98 | 0.70 | 18.10 | -- | -- |
| 010342 | 010342–IW40 | -- | GW | 27.43 | 12.80 | 13.01 | 0.58 | 12.22 | 0.73 | 12.07 |
| 010349 | 010349–MULLICA 2D | -- | GW | 45.72 | 17.53 | 18.18 | 0.69 | 16.84 | -- | -- |
| 011402 | 011402–ATSION MW51 | 3225196 | GW | 3.51 | 12.80 | 13.43 | 0.62 | 12.18 | -- | -- |
| 011404 | 011404–MW54 | 3160862 | GW | 4.27 | 21.20 | 21.14 | 0.90 | 20.30 | -- | -- |
| 011459 | 011459–ALBERTSON BROOK 2 | -- | GW | 2.16 | 18.59 | 19.48 | 0.77 | 17.83 | 1.39 | 17.20 |
| 011504 | 011504–AB OW-2D | 3227988 | GW | 48.77 | 16.97 | 17.42 | 0.51 | 16.46 | [3]1.14 | [3]15.83 |
| 011505 | 011505–AB OW-2S | 3227990 | GW | 15.24 | 16.93 | 17.45 | 0.73 | 16.20 | [3]1.28 | [3]15.65 |
| 011506 | 011506–AB OW-2M | 3227989 | GW | 28.04 | 16.93 | 17.44 | 0.60 | 16.33 | [3]1.19 | [3]15.74 |
| 011550 | 011550–ABHT5-1D | -- | GW | 2.90 | 14.87 | 15.17 | 0.78 | 14.08 | 1.30 | 13.57 |
| 011551 | 011551–ABHT5-1S | -- | GW | 1.52 | 14.90 | 15.51 | 0.75 | 14.15 | 1.35 | 13.55 |
| 011552 | 011552–ABHT4-2S | -- | GW | 1.52 | 17.75 | 18.05 | 0.09 | 17.65 | 0.60 | 17.15 |
| 011553 | 011553–ABHT4-3D | -- | GW | 2.90 | 17.40 | 17.56 | 0.01 | 17.40 | 0.43 | 16.98 |
| 011554 | 011554–ABHT4-3S | -- | GW | 1.52 | 17.43 | 18.04 | 0.04 | 17.39 | 0.45 | 16.97 |
| 011555 | 011555–ABHT5-3D | -- | GW | 2.74 | 13.85 | 14.15 | -0.06 | 13.91 | 0.33 | 13.52 |
| 011556 | 011556–ABHT5-3S | -- | GW | 1.52 | 13.80 | 14.41 | -0.02 | 13.82 | 0.33 | 13.48 |
| 011557 | 011557–ABHT5-2D | -- | GW | 2.74 | 14.90 | 15.20 | 0.90 | 14.00 | 1.33 | 13.56 |
| 011558 | 011558–ABHT5-2S | -- | GW | 1.83 | 14.88 | 15.49 | 0.87 | 14.00 | 1.31 | 13.56 |
| 011567 | 011567–AB UP-5 | 3228343 | GW | 6.10 | 15.50 | 16.26 | 1.48 | 14.02 | 2.43 | 13.07 |
| 011568 | 011568–ABHT4-1D | -- | GW | 2.90 | 18.66 | 18.82 | 0.83 | 17.83 | 1.44 | 17.22 |
| 011569 | 011569–ABHT4-2D | -- | GW | 2.50 | 17.77 | 17.92 | 0.12 | 17.66 | 0.62 | 17.15 |
| 011594 | 011594–MW-1 | 3220603 | GW | 7.01 | 22.77 | 23.60 | 2.57 | 20.20 | -- | -- |
| 011595 | 011595–MW-7 | 3220604 | GW | 6.40 | 21.31 | 22.22 | 1.26 | 20.04 | -- | -- |
| 011596 | 011596–IRR 10 | 3158336 | GW | 43.28 | 20.60 | 20.65 | 1.80 | 18.80 | -- | -- |
| 011597 | 011597–MW-5 | 3220599 | GW | 6.40 | 20.45 | 20.96 | 1.87 | 18.59 | 2.58 | 17.87 |
| 011634 | 011634–MW-6 | 3220600 | GW | 6.40 | 19.17 | 20.08 | 2.12 | 17.05 | -- | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| 011669 | 011669–MW-8 | -- | GW | 3.81 | 21.19 | 22.28 | 0.53 | 20.66 | 1.07 | 20.12 |
| 011672 | 011672–MW | -- | GW | 5.49 | 22.20 | 22.90 | 0.42 | 21.78 | -- | -- |
| 050408 | 050408–ATSION 2 OBS | -- | GW | 19.81 | 14.11 | 14.41 | 1.14 | 12.97 | -- | -- |
| 050409 | 050409–ATSION 3 OBS | -- | GW | 5.18 | 13.99 | 14.59 | 1.78 | 12.21 | -- | -- |
| 070429 | 070429–MULLICA 17S | -- | GW | 5.79 | 23.15 | 23.15 | 1.92 | 21.23 | -- | -- |
| 070430 | 070430–MULLICA 7D | -- | GW | 36.58 | 28.20 | 28.67 | 3.64 | 24.56 | 4.51 | 23.69 |
| 070431 | 070431–MULLICA 16S | -- | GW | 8.84 | 28.17 | 28.59 | 3.41 | 24.76 | 4.45 | 23.72 |
| 070436 | 070436–IRR | 3104953 | GW | 39.62 | 36.00 | 36.34 | 4.54 | 31.46 | -- | -- |
| 070459 | 070459–IRR | 3104937 | GW | 54.86 | 29.20 | 29.47 | 1.71 | 27.49 | -- | -- |
| 070468 | 070468–DOM-6 | 3105716 | GW | 50.29 | 31.10 | 31.64 | 3.34 | 27.76 | -- | -- |
| 070481 | 070481–3-1973 | 3106874 | GW | 33.83 | 37.49 | 37.99 | 3.16 | 34.33 | -- | -- |
| 070497 | 070497–PROD 2 | 3105543 | GW | 30.78 | 37.19 | 37.67 | 2.60 | 34.58 | -- | -- |
| 070501 | 070501–IND 2 | 3105295 | GW | 42.98 | 50.70 | 51.25 | 10.41 | 40.29 | 10.96 | 39.74 |
| 070668 | 070668–IRR 1 | 3116649 | GW | 36.58 | 52.70 | 53.26 | 10.16 | 42.54 | -- | -- |
| 070671 | 070671–INSTITUTIONAL 7 | 3108079 | GW | 43.89 | 31.70 | 32.28 | 4.41 | 27.29 | -- | -- |
| 070678 | 070678–IRR | 3124091 | GW | 30.48 | 38.70 | 39.15 | 5.99 | 32.71 | 6.60 | 32.10 |
| 070679 | 070679–DOM 705 | 3120472 | GW | 24.38 | 40.20 | 40.60 | 6.84 | 33.36 | -- | -- |
| 070682 | 070682–DOM | 3108663 | GW | 22.56 | 48.70 | 48.42 | 8.16 | 40.54 | -- | -- |
| 070698 | 070698–8/REPLACEMENT 4 | 3126123 | GW | 50.90 | 30.80 | 31.24 | 4.55 | 26.25 | -- | -- |
| 070699 | 070699–DOM | 3126654 | GW | 33.53 | 39.00 | 39.35 | 5.06 | 33.94 | 5.74 | 33.26 |
| 070701 | 070701–DOM | 3119213 | GW | 31.70 | 42.00 | 42.18 | 5.93 | 36.07 | -- | -- |
| 070702 | 070702–DOM | 3117576 | GW | 27.43 | 43.40 | 43.80 | 4.61 | 38.79 | 5.47 | 37.93 |
| 070704 | 070704–SCH | 3120150 | GW | 43.89 | 54.50 | 55.17 | 16.70 | 37.80 | -- | -- |
| 070705 | 070705–DOM | 3122181 | GW | 27.43 | 45.50 | 45.32 | 5.02 | 40.48 | -- | -- |
| 070709 | 070709–DOM | 3129794 | GW | 24.38 | 46.40 | 46.83 | 4.26 | 42.14 | -- | -- |
| 070711 | 070711–1-L OBS | 3119136 | GW | 15.24 | 33.24 | 33.71 | 5.08 | 28.16 | 5.63 | 27.61 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| 070712 | 070712–6 OBS | 3119134 | GW | 15.24 | 39.23 | 39.96 | 8.46 | 30.77 | -- | -- |
| 070714 | 070714–ADMIN BLDG | 3120841 | GW | 34.75 | 40.40 | 40.22 | 8.84 | 31.57 | 9.49 | 30.91 |
| 070715 | 070715–DOM 1 | 3129999 | GW | 31.70 | 29.87 | 30.31 | 2.92 | 26.95 | -- | -- |
| 070716 | 070716–IRR 1 | -- | GW | 4.88 | 29.87 | 28.62 | 2.73 | 27.14 | -- | -- |
| 070717 | 070717–NURSERY | 3125408 | GW | 45.72 | 39.70 | 40.05 | 4.22 | 35.48 | 4.78 | 34.92 |
| 070736 | 070736–PW 3 | 3105578 | GW | 29.54 | 43.28 | 43.91 | 10.45 | 32.83 | -- | -- |
| 070737 | 070737–BERLIN-BLUE ANCHOR RD 2 | 3136453 | GW | 36.27 | 49.00 | 49.38 | 9.13 | 39.87 | 9.52 | 39.48 |
| 070740 | 070740–PZ 3 | 3139312 | GW | 3.96 | 21.14 | 21.72 | -0.04 | 21.18 | -- | -- |
| 070741 | 070741–PZ 4 | 3137739 | GW | 9.75 | 37.50 | 38.26 | 4.24 | 33.26 | -- | -- |
| 070744 | 070744–PZ 5 | 3139311 | GW | 14.33 | 47.36 | 48.06 | 8.60 | 38.76 | [3]8.61 | [3]38.75 |
| 070750 | 070750–IRR 3 | 5100109 | GW | 33.53 | 36.70 | 34.81 | 4.45 | 32.25 | -- | -- |
| 070753 | 070753–IRR 3 | 5100114 | GW | 30.48 | 24.30 | 24.45 | 0.78 | 23.52 | -- | -- |
| 070781 | 070781–IRR 2 | 5100191 | GW | 36.58 | 27.30 | 27.79 | 2.37 | 24.93 | -- | -- |
| 070791 | 070791–IRR 1 | 5100201 | GW | 42.67 | 39.20 | 40.79 | 4.01 | 35.19 | -- | -- |
| 070805 | 070805–IRR 1 | 5100389 | GW | 30.48 | 42.20 | 43.11 | 2.96 | 39.24 | -- | -- |
| 070818 | 070818–N OF POND IRR | 3104949 | GW | 39.62 | 36.50 | 37.02 | 4.93 | 31.57 | -- | -- |
| 070835 | 070835–UND01 | 3149659 | GW | 9.63 | 42.37 | 42.66 | 8.00 | 34.37 | -- | -- |
| 070840 | 070840–NU15 | 3149746 | GW | 8.84 | 39.62 | 39.46 | 5.16 | 34.46 | 6.05 | 33.57 |
| 070842 | 070842–UND09 | 3149664 | GW | 4.27 | 30.18 | 31.01 | 0.62 | 29.56 | -- | -- |
| 070901 | 070901–PW 8 | 3151329 | GW | 45.60 | 46.63 | 47.20 | 12.34 | 34.30 | 12.32 | 34.32 |
| 070991 | 070991–PW 2 | 3105617 | GW | 32.00 | 47.00 | 44.73 | 12.84 | 34.16 | 13.34 | 33.66 |
| 070992 | 070992–PW 1 | 3114167 | GW | 37.80 | 46.00 | 43.96 | 12.36 | 33.64 | -- | -- |
| 071003 | 071003–IRR 2 | 3130945 | GW | 42.67 | 39.50 | 40.11 | 6.43 | 33.07 | -- | -- |
| 071081 | 071081–Albertson Brook 1 | -- | GW | 2.52 | 21.64 | 22.47 | 0.08 | 21.56 | [3]0.45 | [3]21.20 |
| 071084 | 071084–ELEMENTARY SCH | 3124130 | GW | 28.35 | 36.20 | 36.52 | 5.80 | 30.40 | -- | -- |
| 071091 | 071091–AB OW-1M | 3168275 | GW | 28.96 | 47.33 | 47.76 | 9.25 | 38.08 | [3]9.71 | [3]37.62 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in “Site-Numbering System” section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| 071092 | 071092–AB OW-1D | 3168274 | GW | 48.77 | 47.31 | 47.83 | 9.24 | 38.08 | [3]9.67 | [3]37.65 |
| 071093 | 071093–TW1 | 3159328 | GW | 47.24 | 47.90 | 48.48 | 9.66 | 38.24 | -- | -- |
| 071100 | 071100–ABHT2-2D | -- | GW | 2.74 | 22.17 | 22.48 | 0.10 | 22.07 | 0.45 | 21.72 |
| 071101 | 071101–ABHT2-2S | -- | GW | 1.52 | 22.23 | 22.68 | 0.22 | 22.01 | 0.62 | 21.61 |
| 071102 | 071102–ABHT3-3D | -- | GW | 2.74 | 19.50 | 19.80 | 0.04 | 19.45 | 0.34 | 19.16 |
| 071103 | 071103–ABHT3-3S | -- | GW | 1.52 | 19.51 | 19.97 | 0.07 | 19.45 | 0.37 | 19.15 |
| 071104 | 071104–ABHT2-1D | 3169539 | GW | 9.14 | 26.12 | 26.89 | 3.59 | 22.54 | 4.08 | 22.04 |
| 071105 | 071105–ABHT2-1S | 3169540 | GW | 6.10 | 26.17 | 26.93 | 3.53 | 22.64 | 4.11 | 22.06 |
| 071106 | 071106–ABHT3-2D | -- | GW | 2.74 | 19.81 | 20.06 | 0.23 | 19.58 | 0.61 | 19.20 |
| 071107 | 071107–ABHT3-2S | -- | GW | 1.52 | 19.81 | 20.33 | 0.23 | 19.58 | 0.61 | 19.20 |
| 071108 | 071108–ABHT3-1D | -- | GW | 2.74 | 21.33 | 21.57 | 1.48 | 19.85 | 2.06 | 19.27 |
| 071109 | 071109–ABHT1-2D | 3169669 | GW | 6.10 | 36.90 | 36.83 | 2.15 | 34.75 | 2.82 | 34.08 |
| 071110 | 071110–ABHT1-1S | 3169672 | GW | 4.42 | 37.49 | 37.43 | 2.27 | 35.23 | 3.10 | 34.39 |
| 071111 | 071111–ABHT2-3D | -- | GW | 2.74 | 21.89 | 22.20 | 0.10 | 21.79 | 0.30 | 21.59 |
| 071112 | 071112–ABHT3-1S | -- | GW | 1.83 | 21.33 | 21.57 | 1.46 | 19.87 | -- | -- |
| 071113 | 071113–AB UP-3 | 3169538 | GW | 9.14 | 29.20 | 29.96 | 4.82 | 24.38 | 5.33 | 23.87 |
| 071114 | 071114–ABHT2-3S | -- | GW | 1.83 | 21.90 | 22.35 | 0.12 | 21.78 | 0.31 | 21.59 |
| 071115 | 071115–AB UP-2 | 3169541 | GW | 10.67 | 33.00 | 33.76 | 5.90 | 27.10 | 6.61 | 26.39 |
| 071116 | 071116–ABHT1-3D | -- | GW | 3.05 | 34.83 | 34.75 | 1.05 | 33.78 | 1.31 | 33.52 |
| 071117 | 071117–ABHT1-3S | -- | GW | 1.83 | 34.82 | 34.76 | 1.04 | 33.78 | 1.28 | 33.54 |
| 071118 | 071118–ABHT1-2S | 3169670 | GW | 4.27 | 36.91 | 36.82 | 2.15 | 34.75 | 2.82 | 34.09 |
| 071119 | 071119–ABHT1-1D | 3169671 | GW | 6.10 | 37.51 | 37.42 | 2.30 | 35.21 | 3.13 | 34.38 |
| 071120 | 071120–AB UP-1 | 3169542 | GW | 10.67 | 41.40 | 42.16 | 5.14 | 36.26 | 5.78 | 35.62 |
| 071121 | 071121–MW-2 | 3220598 | GW | 6.10 | 23.16 | 24.02 | 1.32 | 21.84 | -- | -- |
| 071122 | 071122–IRR 11 | 3163161 | GW | 48.77 | 24.41 | 24.47 | 4.70 | 19.71 | 5.12 | 19.29 |
| 071123 | 071123–MW-3 | 3220601 | GW | 8.23 | 24.51 | 25.41 | 3.53 | 20.98 | 4.32 | 20.18 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Albertson Brook Study Area—Continued | | | | | | |
| 071124 | 071124–MW-4 | 3220602 | GW | 6.71 | 20.60 | 21.52 | 1.85 | 18.75 | 2.42 | 18.18 |
| 071125 | 071125–DOM | 3148501 | GW | 24.38 | 35.40 | 35.49 | 6.03 | 29.37 | -- | -- |
| 071126 | 071126–DOM | 3167844 | GW | 32.00 | 36.41 | 36.68 | 6.42 | 29.99 | 6.92 | 29.49 |
| 071127 | 071127–DOM | 3144113 | GW | 29.57 | 37.70 | 38.07 | 2.90 | 34.81 | -- | -- |
| 071128 | 071128–DOM | 3155453 | GW | 30.48 | 48.90 | 49.13 | 7.32 | 41.57 | -- | -- |
| 071129 | 071129–DOM | 3161981 | GW | 33.53 | 27.70 | 27.97 | 2.55 | 25.15 | -- | -- |
| 071130 | 071130–DOM | 3158850 | GW | 24.38 | 48.20 | 48.57 | 11.81 | 36.39 | -- | -- |
| 071131 | 071131–DOM | 3143163 | GW | 27.43 | 47.20 | 47.55 | 7.29 | 39.91 | -- | -- |
| 071132 | 071132–DOM | 3106686 | GW | 22.56 | 45.50 | 45.68 | 10.62 | 34.88 | -- | -- |
| 071133 | 071133–DOM | 3142607 | GW | 25.30 | 36.00 | 36.41 | 1.18 | 34.82 | -- | -- |
| 071134 | 071134–DOM | 3165871 | GW | 28.65 | 49.00 | 49.43 | 4.61 | 44.39 | -- | -- |
| 071148 | 071148–MW 10 | -- | GW | 5.49 | 24.13 | 25.02 | 2.32 | 21.81 | 3.07 | 21.06 |
| 071149 | 071149–MW-9 | -- | GW | 5.33 | 22.13 | 23.12 | 1.75 | 20.37 | 2.47 | 19.66 |
| 071150 | 071150–DOM | 3153467 | GW | 27.43 | 34.00 | 34.49 | 6.53 | 27.47 | 7.19 | 26.81 |
| 071151 | 071151–MW 12D | 3168282 | GW | 7.92 | 37.00 | 36.91 | 2.54 | 34.46 | -- | -- |
| 071152 | 071152–MW | -- | GW | 43.28 | 47.70 | 48.37 | 8.80 | 38.90 | -- | -- |
| 01409403 | Wildcat Branch at Chesilhurst, NJ | = | SW | = | = | = | = | 28.71 | = | -- |
| 01409407 | Pump Branch near Blue Anchor, NJ | = | SW | = | = | = | = | 30.44 | = | 30.37 |
| 01409408 | Pump Branch near Waterford Works, NJ | = | SW | = | = | = | = | 26.28 | = | 26.35 |
| 01409409 | Blue Anchor Brook near Blue Anchor, NJ | = | SW | = | = | = | = | 26.59 | = | 26.51 |
| 01409410 | Albertson Brook near Hammonton, NJ | = | SW | = | = | = | = | 14.19 | = | 13.88 |
| 0140940607 | Pump Branch at Cedar Brook, NJ | = | SW | = | = | = | = | 33.41 | = | 33.35 |
| 0140940810 | Pump Branch near Elm, NJ | = | SW | = | = | = | = | 23.16 | = | 23.38 |
| 0140940820 | Pump Branch above Blue Anchor Brook near Elm, NJ | = | SW | = | = | = | = | 21.64 | = | 21.49 |
| 0140940950 | Blue Anchor Brook at Elm, NJ | = | SW | = | = | = | = | -- | = | 24.61 |
| 0140940970 | Albertson Brook near Elm, NJ | = | SW | = | = | = | = | -- | = | 20.62 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Albertson Brook Study Area—Continued | | | | | | | | | |
| 0140940972 | Albertson Brook below Railroad Bridge near Elm, NJ | = | SW | = | = | = | = | 19.36 | = | 19.09 |
| 0140940990 | Albertson Brook 1.3 miles above U.S. Route 206 near Atsion, NJ | = | SW | = | = | = | = | 17.33 | = | 16.93 |
| 0140941010 | Albertson Brook 0.8 miles below U.S. Route 206 near Atsion, NJ | = | SW | = | = | = | = | 13.76 | = | 13.42 |
| 0140941050 | Great Swamp Branch at Elm, NJ | = | SW | = | = | = | = | 22.65 | = | -- |
| 0140941070 | Great Swamp Branch below U.S. Route 206 near Hammonton, NJ | = | SW | = | = | = | = | 16.69 | = | -- |
| 0140941075 | Cedar Brook at Columbia Road at Hammonton, NJ | = | SW | = | = | = | = | 17.09 | = | -- |
| 394150074494500 | Pump Branch at Ancora, NJ | = | SW | = | = | = | = | [4]24.64 | = | [4]24.64 |
| 394150074494500 | Pump Branch at Ancora, NJ | = | SW | = | = | = | = | [5]23.91 | = | [5]23.71 |
| 394154074451301 | Gun Branch at U.S. Route 206 Nr Hammonton, NJ | = | SW | = | = | = | = | 14.17 | = | -- |
| 394251074463601 | Clark Branch at Burnt House Road near Atsion, NJ | = | SW | = | = | = | = | 19.91 | = | -- |
| ABSTM 5 | ABSTM 5 | = | SW | = | = | = | = | 27.54 | = | -- |
| ABSTM10 | ABSTM10 | = | SW | = | = | = | = | 33.20 | = | -- |
| ABSTM11 | ABSTM11 | = | SW | = | = | = | = | 34.70 | = | -- |
| ABSTM12 | ABSTM12 | = | SW | = | = | = | = | -- | = | 27.42 |
| ABSTM13 | ABSTM13 | = | SW | = | = | = | = | 37.00 | = | -- |
| ABSTM14 | ABSTM14 | = | SW | = | = | = | = | 42.00 | = | -- |
| ABSTM16A | Blue Anchor Brook at Rt 30 | = | SW | = | = | = | = | -- | = | 22.98 |
| ABSTM2 | ABSTM2 | = | SW | = | = | = | = | 22.75 | = | -- |
| ABSTM21 | ABSTM21 | = | SW | = | = | = | = | -- | = | 21.20 |
| ABSTM22 | ABSTM22 | = | SW | = | = | = | = | -- | = | 35.70 |
| ABSTM4 | Gun Branch at Flemming Pike | = | SW | = | = | = | = | 20.19 | = | -- |
| ABSTM6 | ABSTM6 | = | SW | = | = | = | = | 39.81 | = | -- |
| ABSTM7 | ABSTM7 | = | SW | = | = | = | = | 41.60 | = | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| ABSTM8 | ABSTM8 | = | SW | = | = | = | = | 33.70 | = | -- |
| ABSTM9 | ABSTM9 | = | SW | = | = | = | = | 33.50 | = | -- |
| STM 3 | STM 3 | = | SW | = | = | = | = | 34.52 | = | -- |
| STM 60 | STM 60 | = | SW | = | = | = | = | 35.59 | = | -- |
| STM 62 | STM 62 | = | SW | = | = | = | = | 29.71 | = | 29.61 |
| STM 67 | STM 67 | = | SW | = | = | = | = | 28.51 | = | 28.43 |
| STM 75 | STM 75 | = | SW | = | = | = | = | 21.85 | = | -- |
| STM 76 | STM 76 | = | SW | = | = | = | = | 27.23 | = | -- |
| STM 79 | STM 79 | = | SW | = | = | = | = | 29.12 | = | -- |
| A10C | A10C | -- | GW | -- | 14.60 | -- | -0.02 | 14.62 | 0.35 | 14.25 |
| A10PD | A10PD | -- | GW | -- | 14.65 | -- | 0.58 | 14.07 | 1.22 | 13.43 |
| A10PU | A10PU | -- | GW | -- | 14.80 | -- | 0.86 | 13.94 | 1.48 | 13.32 |
| A10PW | A10PW | -- | GW | -- | 14.60 | -- | 0.34 | 14.26 | 0.95 | 13.65 |
| A11C | A11C | -- | GW | -- | 21.17 | -- | 0.03 | 21.14 | 0.40 | 20.77 |
| A1C | A1C | -- | GW | -- | 14.80 | -- | 0.00 | 14.80 | 0.22 | 14.58 |
| A1H | A1H | -- | GW | -- | 15.10 | -- | 0.02 | 15.08 | 0.39 | 14.71 |
| A1PD | A1PD | -- | GW | -- | 15.10 | -- | 0.55 | 14.55 | 1.15 | 13.95 |
| A1PH | A1PH | -- | GW | -- | 14.94 | -- | 0.12 | 14.81 | 0.61 | 14.33 |
| A1PU | A1PU | -- | GW | -- | 15.10 | -- | 0.49 | 14.61 | 1.03 | 14.07 |
| A2H | A2H | -- | GW | -- | 17.57 | -- | -0.01 | 17.58 | 0.53 | 17.05 |
| A3PH | A3PH | -- | GW | -- | 18.20 | -- | 0.10 | 18.10 | 1.06 | 17.14 |
| A4H | A4H | -- | GW | -- | 17.80 | -- | 0.08 | 17.72 | 0.57 | 17.23 |
| A4PD | A4PD | -- | GW | -- | 18.20 | -- | 0.42 | 17.78 | 1.38 | 16.82 |
| A4PDb | A4PDb | -- | GW | -- | 18.20 | -- | 0.44 | 17.76 | 1.40 | 16.80 |
| A4PU | A4PU | -- | GW | -- | 18.20 | -- | 0.52 | 17.68 | 1.43 | 16.77 |
| A4PW | A4PW | -- | GW | -- | 18.20 | -- | 0.16 | 18.04 | 0.99 | 17.20 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Albertson Brook Study Area—Continued | | | | | | | | | | |
| A5PD | A5PD | -- | GW | -- | 18.70 | -- | 0.58 | 18.12 | 1.26 | 17.44 |
| A5PH | A5PH | -- | GW | -- | 18.50 | -- | -0.10 | 18.60 | 0.49 | 18.01 |
| A8PX2 | A8PX2 | -- | GW | -- | 15.10 | -- | 0.47 | 14.63 | 1.19 | 13.91 |
| A8PX3 | A8PX3 | -- | GW | -- | 15.23 | -- | 0.36 | 14.87 | 0.95 | 14.28 |
| A9C | A9C | -- | GW | -- | 14.60 | -- | 0.07 | 14.53 | 0.42 | 14.18 |
| A9PD | A9PD | -- | GW | -- | 15.10 | -- | 0.47 | 14.63 | 1.16 | 13.94 |
| A9PH | A9PH | -- | GW | -- | 15.00 | -- | 0.39 | 14.61 | 1.01 | 13.99 |
| A9PU | A9PU | -- | GW | -- | 14.80 | -- | 0.86 | 13.94 | 1.37 | 13.43 |
| P1C | P1C | -- | GW | -- | 24.15 | -- | 0.16 | 23.99 | 0.34 | 23.82 |
| P1Cb | P1Cb | -- | GW | -- | 24.15 | -- | 0.07 | 24.08 | 0.28 | 23.88 |
| McDonalds Branch Study Area | | | | | | | | | | |
| 050684 | 050684–BUTLER PLACE 2 OBS | -- | GW | 51.82 | 42.54 | 43.31 | 5.75 | 36.79 | -- | -- |
| 050689 | 050689–LEBANON SF 23-D OBS | -- | GW | 10.06 | 45.95 | 46.17 | 6.25 | 39.70 | [3]6.52 | [3]39.44 |
| 050690 | 050690–LEBANON SF 2 | -- | GW | 24.69 | 38.12 | 38.59 | 2.58 | 35.54 | -- | -- |
| 050708 | 050708–GLASSWORKS | 3200727 | GW | 28.04 | 37.40 | 35.84 | 2.85 | 34.55 | -- | -- |
| 050831 | 050831–QWO-1A | 3210453 | GW | 1.92 | 37.84 | 39.19 | -0.37 | 38.21 | 0.28 | 37.56 |
| 050832 | 050832–QWO-1B | 3210454 | GW | 7.07 | 37.93 | 39.15 | -0.28 | 38.21 | 0.36 | 37.57 |
| 050833 | 050833–QWO-2A | 3210455 | GW | 2.10 | 38.54 | 38.87 | 0.19 | 38.36 | 0.83 | 37.71 |
| 050834 | 050834–QWO-2B | 3210456 | GW | 6.58 | 38.54 | 38.83 | 0.19 | 38.35 | 0.84 | 37.71 |
| 050835 | 050835–QWO-3A | 3210457 | GW | 5.00 | 39.91 | 40.30 | 1.15 | 38.76 | 1.96 | 37.95 |
| 050836 | 050836–QWO-3B | 3210458 | GW | 9.60 | 39.94 | 40.18 | 1.43 | 38.52 | 2.00 | 37.94 |
| 050837 | 050837–QWC-1A | 3210459 | GW | 2.41 | 37.69 | 39.18 | -0.23 | 37.92 | 0.18 | 37.51 |
| 050838 | 050838–QWC-1B | 3210460 | GW | 8.75 | 37.72 | 38.81 | -0.38 | 38.10 | 0.20 | 37.52 |
| 050839 | 050839–QWC-2A | 3210461 | GW | 1.86 | 38.30 | 38.80 | 0.30 | 38.00 | 0.64 | 37.64 |
| 050840 | 050840–QWC-2B | 3210462 | GW | 8.05 | 38.33 | 38.59 | 0.24 | 38.09 | 0.82 | 37.51 |
| 050841 | 050841–QWC-3A | 3210463 | GW | 6.65 | 41.96 | 42.16 | 3.88 | 38.08 | 4.43 | 37.52 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 050842 | 050842–QWC-3B | 3210464 | GW | 11.16 | 41.96 | 42.16 | 3.91 | 38.05 | 4.47 | 37.48 |
| 050843 | 050843–QWC-4 | 3210465 | GW | 7.83 | 43.57 | 44.12 | 5.11 | 38.46 | 5.66 | 37.91 |
| 050848 | 050848–QWH-2A | 3210470 | GW | 3.60 | 40.16 | 40.53 | 0.68 | 39.47 | 1.43 | 38.72 |
| 050849 | 050849–QWH-2B | 3210471 | GW | 9.54 | 40.19 | 40.48 | 0.73 | 39.45 | 1.46 | 38.72 |
| 050850 | 050850–QWH-3A | 3210472 | GW | 5.09 | 41.83 | 42.11 | 2.26 | 39.57 | 3.00 | 38.83 |
| 050851 | 050851–QWH-3B | 3210473 | GW | 9.11 | 41.86 | 42.58 | 2.33 | 39.54 | 3.05 | 38.82 |
| 050852 | 050852–QWH-4A | 3210474 | GW | 4.91 | 40.95 | 41.36 | 1.49 | 39.46 | 2.22 | 38.73 |
| 050853 | 050853–QWH-4B | 3210475 | GW | 10.85 | 40.95 | 41.36 | 1.49 | 39.46 | 2.21 | 38.74 |
| 050861 | 050861–QWH-7A SHALLOW WELL | 3213412 | GW | 3.05 | 42.92 | 43.77 | 0.53 | 42.39 | 1.10 | 41.82 |
| 050862 | 050862–QWH-7B | 3213413 | GW | 7.92 | 42.23 | 42.48 | 2.09 | 40.15 | 2.90 | 39.34 |
| 050863 | 050863–QWH-8A | 3213414 | GW | 3.76 | 42.73 | 42.94 | 0.52 | 42.21 | 1.13 | 41.60 |
| 050864 | 050864–QWH-8B | 3213415 | GW | 9.66 | 42.89 | 43.29 | 2.50 | 40.39 | 3.15 | 39.74 |
| 050873 | 050873–O-1A | -- | GW | 5.64 | 40.68 | 40.99 | 2.57 | 38.12 | -- | -- |
| 050874 | 050874–O-1B | -- | GW | 8.84 | 40.67 | 40.98 | 2.57 | 38.11 | -- | -- |
| 050885 | 050885–O-11A | -- | GW | 5.39 | 42.07 | 42.37 | 3.42 | 38.65 | 4.11 | 37.95 |
| 050886 | 050886–O-11B | -- | GW | 9.14 | 42.10 | 42.40 | 4.15 | 37.94 | 4.69 | 37.41 |
| 050893 | 050893–CQ-6 | -- | GW | 11.84 | 47.11 | 47.46 | 8.92 | 38.19 | 9.53 | 37.58 |
| 051072 | 051072–QWH-5A | -- | GW | 4.66 | 44.91 | 45.60 | 1.84 | 43.07 | 3.23 | 41.68 |
| 051073 | 051073–QWH-5B | -- | GW | 12.47 | 44.91 | 45.25 | 4.92 | 40.00 | 5.69 | 39.22 |
| 051074 | 051074–LEAD WELL | -- | GW | 13.59 | 52.26 | 52.93 | 10.90 | 41.36 | 10.98 | 41.28 |
| 051092 | 051092–INSTITUTIONAL 2 | 3208688 | GW | 25.91 | 36.90 | 37.52 | 5.50 | 31.40 | -- | -- |
| 051173 | 051173–DEV CENTER | 3206083 | GW | 29.57 | 39.20 | 39.86 | 7.53 | 31.67 | -- | -- |
| 051201 | 051201–LSF PZ-MW-2 | 3218908 | GW | 1.34 | 36.94 | 36.99 | 0.76 | 36.18 | 0.97 | 35.97 |
| 051218 | 051218–LSF PZ-MW-19 | 3218929 | GW | 2.04 | 37.31 | 37.39 | 1.17 | 36.14 | -- | -- |
| 051334 | 051334–DOM | 3213114 | GW | 32.92 | 33.00 | 33.24 | 7.64 | 25.37 | -- | -- |
| 051335 | 051335–IRR | 3214492 | GW | 27.43 | 36.20 | 36.29 | 9.30 | 26.90 | -- | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 051384 | 051384–DOM | 3219191 | GW | 24.38 | 42.40 | 42.85 | 9.74 | 32.66 | -- | -- |
| 051385 | 051385–DOM | 3219550 | GW | 32.00 | 43.50 | 43.63 | 11.77 | 31.73 | -- | -- |
| 051502 | 051502–LEBANON ST F MW15 | 3224681 | GW | 11.89 | 41.00 | 41.41 | 10.28 | 30.72 | -- | -- |
| 051528 | 051528–MCDONALDS BRANCH 2 | -- | GW | 1.83 | 36.53 | 37.44 | 0.40 | 36.12 | [3]1.08 | [3]35.45 |
| 051529 | 051529–MCDONALDS BRANCH 1 | -- | GW | 2.18 | 36.27 | 37.14 | -0.02 | 36.29 | 0.39 | 35.88 |
| 051532 | 051532–MBHT3-2D | -- | GW | 3.05 | 36.25 | 36.64 | -0.07 | 36.32 | 0.39 | 35.86 |
| 051533 | 051533–MBHT3-2S | -- | GW | 1.37 | 36.27 | 36.42 | 0.04 | 36.23 | 0.54 | 35.73 |
| 051534 | 051534–MBHT3-1D | -- | GW | 2.74 | 37.49 | 37.87 | 1.05 | 36.44 | -- | -- |
| 051534 | 051534–MBHT3-1D | -- | GW | 2.74 | 37.49 | 37.80 | -- | -- | 1.61 | 35.88 |
| 051535 | 051535–MBHT3-1S | -- | GW | 1.52 | 37.49 | 37.66 | 1.05 | 36.44 | -- | -- |
| 051535 | 051535–MBHT3-1S | -- | GW | 1.52 | 37.49 | 37.95 | -- | -- | 1.47 | 36.02 |
| 051538 | 051538–MCDONALDS BR 2 SHALLOW | -- | GW | 1.62 | 36.57 | 37.39 | 0.28 | 36.28 | -- | -- |
| 051556 | 051556–MB OW-1D | 3227994 | GW | 57.91 | 45.96 | 46.39 | 6.56 | 39.41 | -- | -- |
| 051556 | 051556–MB OW-1D | 3227994 | GW | 57.91 | 45.96 | 46.36 | -- | -- | [3]6.87 | [3]39.09 |
| 051557 | 051557–MB OW-1M | 3227995 | GW | 27.43 | 45.91 | 46.39 | 6.50 | 39.41 | -- | -- |
| 051557 | 051557–MB OW-1M | 3227995 | GW | 27.43 | 45.91 | 46.36 | -- | -- | [3]6.81 | [3]39.10 |
| 051558 | 051558–MB OW-2M | 3227992 | GW | 30.48 | 42.63 | 43.05 | 6.16 | 36.47 | -- | -- |
| 051558 | 051558–MB OW-2M | 3227992 | GW | 30.48 | 42.63 | 43.02 | -- | -- | [3]6.54 | [3]36.09 |
| 051559 | 051559–MB OW-2S | 3227993 | GW | 10.67 | 42.58 | 42.98 | 6.13 | 36.45 | -- | -- |
| 051559 | 051559–MB OW-2S | 3227993 | GW | 10.67 | 42.58 | 42.95 | -- | -- | [3]6.52 | [3]36.06 |
| 051560 | 051560–MB OW-2D | 3227991 | GW | 56.39 | 42.58 | 42.98 | 6.11 | 36.47 | -- | -- |
| 051560 | 051560–MB OW-2D | 3227991 | GW | 56.39 | 42.58 | 42.95 | -- | -- | [3]6.50 | [3]36.08 |
| 051570 | 051570–MBHT4-1S | -- | GW | 2.13 | 37.55 | 37.86 | 1.22 | 36.34 | -- | -- |
| 051571 | 051571–MBHT4-1D | -- | GW | 2.90 | 37.57 | 37.73 | 1.24 | 36.33 | 2.18 | 35.39 |
| 051572 | 051572–MBHT4-2D | -- | GW | 2.90 | 36.85 | 37.00 | 0.73 | 36.12 | 1.44 | 35.41 |
| 051573 | 051573–MBHT4-2S | -- | GW | 1.52 | 36.83 | 37.28 | 0.45 | 36.37 | 1.40 | 35.42 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 051574 | 051574–MBHT2-1 | -- | GW | 2.90 | 39.91 | 40.07 | 1.26 | 38.65 | 1.96 | 37.95 |
| 051575 | 051575–MBHT4-3D | -- | GW | 2.74 | 36.02 | 36.32 | 0.00 | 36.02 | 0.66 | 35.36 |
| 051576 | 051576–MBHT4-3S | -- | GW | 1.22 | 36.04 | 36.50 | 0.07 | 35.97 | 0.71 | 35.33 |
| 051577 | 051577–MBHT4-RB1D | -- | GW | 2.74 | 36.07 | 36.37 | 0.09 | 35.98 | 0.73 | 35.34 |
| 051578 | 051578–MBHT4-RB1S | -- | GW | 1.22 | 36.05 | 36.51 | 0.08 | 35.97 | 0.72 | 35.33 |
| 051579 | 051579–MBHT4-RB2S | -- | GW | 1.83 | 36.53 | 37.14 | 0.48 | 36.05 | 1.23 | 35.30 |
| 051580 | 051580–MBHT2-2S | -- | GW | 1.98 | 39.35 | 39.65 | 0.84 | 38.51 | -- | -- |
| 051581 | 051581–MBHT2-2D | -- | GW | 2.90 | 39.36 | 39.51 | 0.86 | 38.50 | 1.55 | 37.81 |
| 051582 | 051582–MBHT5-2D | -- | GW | 2.74 | 35.42 | 35.73 | -0.14 | 35.56 | 0.43 | 34.99 |
| 051583 | 051583–MBHT5-2S | -- | GW | 1.52 | 35.42 | 35.97 | -0.14 | 35.56 | 0.44 | 34.98 |
| 051584 | 051584–MBHT5-1S | -- | GW | 1.83 | 36.50 | 37.11 | 0.72 | 35.79 | 1.28 | 35.22 |
| 051585 | 051585–MBHT1-3 | -- | GW | 2.13 | 40.24 | 40.70 | 0.69 | 39.55 | 1.48 | 38.76 |
| 051586 | 051586–MBHT1-2 | -- | GW | 2.59 | 40.87 | 41.27 | 1.40 | 39.47 | 2.16 | 38.71 |
| 051587 | 051587–MB UP-2 | 3228096 | GW | 6.71 | 39.01 | 39.65 | 2.31 | 36.70 | 3.08 | 35.93 |
| 051588 | 051588–MBHT4-RB2D | -- | GW | 3.05 | 36.52 | 37.06 | 0.53 | 35.99 | 1.19 | 35.32 |
| 051589 | 051589–MB UP-1 | 3228097 | GW | 8.84 | 42.37 | 42.95 | 3.13 | 39.24 | 4.01 | 38.36 |
| 051590 | 051590–MBHT2-3 | -- | GW | 3.05 | 38.59 | 38.98 | 0.23 | 38.36 | 0.87 | 37.71 |
| 051591 | 051591–MBHT3-3D | -- | GW | 2.74 | 36.23 | 36.53 | -0.08 | 36.31 | 0.34 | 35.89 |
| 051592 | 051592–MB UP-3 | 3228095 | GW | 9.75 | 42.04 | 42.68 | 2.92 | 39.12 | 3.53 | 38.51 |
| 051593 | 051593–MBHT5-3D | -- | GW | 2.44 | 35.34 | 35.95 | 0.11 | 35.23 | 0.32 | 35.02 |
| 051594 | 051594–MBHT5-3S | -- | GW | 0.91 | 35.33 | 36.21 | 0.12 | 35.21 | 0.27 | 35.06 |
| 051595 | 051595–MB UP-4 | 3228094 | GW | 7.62 | 41.21 | 41.82 | 4.08 | 37.13 | 4.94 | 36.27 |
| 051596 | 051596–MB UP-5 | 3228093 | GW | 12.04 | 34.44 | 34.80 | 5.18 | 29.26 | 5.93 | 28.51 |
| 051604 | 051604–MBHT5-1D | -- | GW | 3.05 | 36.48 | 37.16 | 0.70 | 35.78 | 1.26 | 35.22 |
| 051625 | 051625–MBHT1-1 | -- | GW | 3.05 | 41.81 | 42.20 | 2.14 | 39.67 | -- | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| 01466460 | McDonalds Branch 650ft above Butler Place Road in Byrne State Forest, NJ | = | SW | = | = | = | = | 39.90 | = | -- |
| 01466480 | McDonalds Branch 4900ft above gage in Byrne State Forest, NJ | = | SW | = | = | = | = | 38.16 | = | -- |
| 01466495 | McDonalds Branch 0.3 miles above gage in Byrne State Forest, NJ | = | SW | = | = | = | = | 36.20 | = | 35.43 |
| 01466500 | McDonalds Branch in Byrne State Forest, NJ | = | SW | = | = | = | = | 35.94 | = | 35.85 |
| 01466510 | McDonalds Branch 2000ft downstream of gage in Byrne State Forest, NJ | = | SW | = | = | = | = | 35.46 | = | 35.81 |
| 01466520 | McDonalds Branch Tributary in Byrne State Forest, NJ | = | SW | = | = | = | = | 35.93 | = | -- |
| 01466550 | McDonalds Branch near Presidential Lakes, NJ | = | SW | = | = | = | = | 35.22 | = | 35.08 |
| 01466590 | McDonalds Branch at McDonalds, NJ | = | SW | = | = | = | = | 30.03 | = | 29.07 |
| 01466600 | McDonalds Branch at Cooper Road at McDonalds, NJ | = | SW | = | = | = | = | 28.29 | = | -- |
| 395222074294600 | McDonalds Branch 50ft downstream of gage in Lebanon State Forest, NJ | = | SW | = | = | = | = | 38.21 | = | -- |
| MBSTM10 | MBSTM10 | = | SW | = | = | = | = | 37.90 | = | -- |
| MBSTM12 | MBSTM 12 Upper cranberry bog | = | SW | = | = | = | = | 31.47 | = | 31.47 |
| MBSTM13 | MBSTM 13 | = | SW | = | = | = | = | 38.88 | = | -- |
| MBSTM14 | MB at Lebanon Lake | = | SW | = | = | = | = | 26.98 | = | -- |
| MBSTM15 | MBSTM15 | = | SW | = | = | = | = | -- | = | 36.20 |
| MBSTM16 | MBSTM16 | = | SW | = | = | = | = | -- | = | 35.93 |
| MBSTM17 | MBSTM17 | = | SW | = | = | = | = | -- | = | 36.20 |
| MBSTM2 | Shinns Branch | = | SW | = | = | = | = | 29.38 | = | -- |
| MBSTM3 | Cooper Branch | = | SW | = | = | = | = | 35.26 | = | -- |
| MBSTM4 | MBSTM4 | = | SW | = | = | = | = | 38.48 | = | -- |
| MBSTM5 | MBSTM5 | = | SW | = | = | = | = | 38.07 | = | -- |
| MBSTM6 | MBSTM6 | = | SW | = | = | = | = | 35.08 | = | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| MBSTM7 | MBSTM7 | = | SW | = | = | = | = | 28.50 | = | -- |
| MBSTM8 | MBSTM8 | = | SW | = | = | = | = | 45.20 | = | -- |
| MBSTM9 | MBSTM9 | = | SW | = | = | = | = | 37.20 | = | -- |
| STM304 | STM304 | = | SW | = | = | = | = | 29.29 | = | -- |
| STM305 | STM305 | = | SW | = | = | = | = | 35.78 | = | -- |
| STM307 | STM307 | = | SW | = | = | = | = | 36.01 | = | -- |
| STM358 | STM358 | = | SW | = | = | = | = | 42.20 | = | -- |
| STM368 | STM368 | = | SW | = | = | = | = | 42.35 | = | -- |
| STM369 | STM369 | = | SW | = | = | = | = | 41.03 | = | -- |
| STM396 | STM396 | = | SW | = | = | = | = | 26.86 | = | -- |
| STM397 | STM397 | = | SW | = | = | = | = | 32.85 | = | -- |
| STM398 | STM398 | = | SW | = | = | = | = | 37.91 | = | -- |
| STM416 | STM416 | = | SW | = | = | = | = | 37.17 | = | -- |
| -- | Butterworth Pond | = | SW | = | = | = | = | [3]37.49 | = | [3]36.99 |
| M10C | M10C | -- | GW | -- | 36.20 | -- | 0.06 | 36.14 | 0.44 | 35.76 |
| M10PD | M10PD | -- | GW | -- | 37.17 | -- | 0.33 | 36.85 | 0.85 | 36.33 |
| M10PH | M10PH | -- | GW | -- | 36.20 | -- | 0.08 | 36.13 | 0.51 | 35.69 |
| M10PU | M10PU | -- | GW | -- | 37.50 | -- | 0.53 | 36.97 | 0.97 | 36.54 |
| M10PW | M10PW | -- | GW | -- | 36.74 | -- | 0.19 | 36.55 | 0.74 | 36.00 |
| M11C | M11C | -- | GW | -- | 36.30 | -- | -0.10 | 36.41 | 0.30 | 36.01 |
| M11HP | M11HP | -- | GW | -- | 36.21 | -- | 0.11 | 36.09 | 0.50 | 35.70 |
| M11PU | M11PU | -- | GW | -- | 36.65 | -- | 0.82 | 35.83 | 1.55 | 35.10 |
| M13H | M13H | -- | GW | -- | 38.86 | -- | -0.11 | 38.97 | 0.33 | 38.53 |
| M13PD | M13PD | -- | GW | -- | 39.20 | -- | 0.44 | 38.76 | 1.38 | 37.82 |
| M13PX | M13PX | -- | GW | -- | 39.20 | -- | 0.85 | 38.35 | 1.63 | 37.57 |
| M14H | M14H | -- | GW | -- | 39.40 | -- | 0.03 | 39.37 | 0.43 | 38.97 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| M15H | M15H | -- | GW | -- | 42.30 | -- | -0.03 | 42.33 | 0.30 | 42.00 |
| M15PD | M15PD | -- | GW | -- | 41.15 | -- | 0.22 | 40.94 | 0.87 | 40.28 |
| M16H | M16H | -- | GW | -- | 42.42 | -- | -0.04 | 42.46 | 0.43 | 41.99 |
| M16PH | M16PH | -- | GW | -- | 42.40 | -- | 0.09 | 42.31 | 0.61 | 41.79 |
| M16PX | M16PX | -- | GW | -- | 42.20 | -- | 0.44 | 41.76 | 1.16 | 41.04 |
| M17H | M17H | -- | GW | -- | 44.70 | -- | -0.03 | 44.73 | 0.33 | 44.37 |
| M17PH | M17PH | -- | GW | -- | 44.50 | -- | 0.07 | 44.43 | 0.34 | 44.16 |
| M17PW | M17PW | -- | GW | -- | 45.00 | -- | 0.43 | 44.57 | 0.95 | 44.05 |
| M18PW2 | M18PW2 | -- | GW | -- | 45.87 | -- | 0.00 | 45.87 | 0.47 | 45.40 |
| M18PX | M18PX | -- | GW | -- | 45.70 | -- | 0.25 | 45.45 | 0.95 | 44.75 |
| M19HP | M19HP | -- | GW | -- | 46.50 | -- | -0.03 | 46.54 | 0.35 | 46.15 |
| M19HPb | M19HPb | -- | GW | -- | 46.50 | -- | 0.05 | 46.45 | 0.57 | 45.94 |
| M19PD | M19PD | -- | GW | -- | 46.13 | -- | 0.36 | 45.77 | 0.95 | 45.18 |
| M19PU | M19PU | -- | GW | -- | 45.50 | -- | 0.16 | 45.34 | 0.94 | 44.56 |
| M19PUb | M19PUb | -- | GW | -- | 45.50 | -- | 0.14 | 45.36 | 0.95 | 44.55 |
| M19PW | M19PW | -- | GW | -- | 46.00 | -- | 0.20 | 45.80 | 0.65 | 45.35 |
| M1C | M1C | -- | GW | -- | 35.48 | -- | 0.06 | 35.42 | 0.43 | 35.05 |
| M1PH | M1PH | -- | GW | -- | 35.34 | -- | 0.17 | 35.17 | 0.84 | 34.50 |
| M1PW | M1PW | -- | GW | -- | 35.50 | -- | 0.22 | 35.28 | 1.15 | 34.35 |
| M20PDx | M20PDx | -- | GW | -- | 36.50 | -- | 0.14 | 36.36 | 1.28 | 35.23 |
| M20PH | M20PH | -- | GW | -- | 36.40 | -- | 0.01 | 36.39 | 0.74 | 35.65 |
| M20PX | M20PX | -- | GW | -- | 36.50 | -- | 0.16 | 36.34 | 1.11 | 35.39 |
| M21PU | M21PU | -- | GW | -- | 36.50 | -- | 0.60 | 35.90 | 1.52 | 34.98 |
| M2C | M2C | -- | GW | -- | 36.00 | -- | 0.13 | 35.87 | 0.57 | 35.43 |
| M2HP | M2HP | -- | GW | -- | 36.09 | -- | 0.07 | 36.02 | 0.44 | 35.65 |
| M2PH | M2PH | -- | GW | -- | 36.03 | -- | 0.23 | 35.80 | 0.84 | 35.19 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| M3C | M3C | -- | GW | -- | 36.50 | -- | 0.03 | 36.47 | 0.43 | 36.07 |
| M3HP | M3HP | -- | GW | -- | 36.50 | -- | 0.05 | 36.45 | 0.59 | 35.91 |
| M3PU | M3PU | -- | GW | -- | 36.80 | -- | 0.95 | 35.85 | 1.98 | 34.82 |
| M3PW | M3PW | -- | GW | -- | 36.50 | -- | 0.17 | 36.33 | 0.82 | 35.68 |
| M4H | M4H | -- | GW | -- | 36.90 | -- | 0.07 | 36.83 | 0.32 | 36.59 |
| M5HP | M5HP | -- | GW | -- | 36.50 | -- | 0.08 | 36.42 | 0.53 | 35.97 |
| M5PD | M5PD | -- | GW | -- | 37.56 | -- | 0.44 | 37.13 | 1.22 | 36.35 |
| M5PU | M5PU | -- | GW | -- | 40.00 | -- | 1.56 | 38.44 | 2.39 | 37.61 |
| M5PW | M5PW | -- | GW | -- | 36.50 | -- | 0.22 | 36.29 | 0.93 | 35.58 |
| M6C | M6C | -- | GW | -- | 36.20 | -- | 0.09 | 36.11 | 0.51 | 35.69 |
| M6PD | M6PD | -- | GW | -- | 36.40 | -- | 0.62 | 35.78 | 1.38 | 35.02 |
| M6PH | M6PH | -- | GW | -- | 36.28 | -- | 0.06 | 36.22 | 0.59 | 35.69 |
| M6PW | M6PW | -- | GW | -- | 36.20 | -- | 0.45 | 35.75 | 1.04 | 35.17 |
| M7C | M7C | -- | GW | -- | 36.20 | -- | 0.18 | 36.02 | 0.54 | 35.66 |
| M7H | M7H | -- | GW | -- | 36.00 | -- | 0.21 | 35.79 | 0.59 | 35.41 |
| M7HP | M7HP | -- | GW | -- | 36.40 | -- | 0.06 | 36.34 | 0.48 | 35.92 |
| M8HP | M8HP | -- | GW | -- | 36.89 | -- | 0.02 | 36.86 | 0.39 | 36.50 |
| M8PD2 | M8PD2 | -- | GW | -- | 36.50 | -- | 0.22 | 36.28 | 0.99 | 35.51 |
| M8PD3 | M8PD3 | -- | GW | -- | 36.50 | -- | 0.46 | 36.04 | 0.98 | 35.52 |
| M8PH2 | M8PH2 | -- | GW | -- | 36.50 | -- | 0.08 | 36.42 | 0.64 | 35.86 |
| M8PU | M8PU | -- | GW | -- | 36.50 | -- | 0.92 | 35.58 | 1.73 | 34.77 |
| M8PU2 | M8PU3 | -- | GW | -- | 36.50 | -- | 0.76 | 35.75 | 1.64 | 34.86 |
| M8PW | M8PW | -- | GW | -- | 36.50 | -- | 0.10 | 36.40 | 0.85 | 35.65 |
| M8PW3 | M8PW3 | -- | GW | -- | 36.20 | -- | 0.08 | 36.12 | 0.46 | 35.74 |
| M8PW4 | M8PW4 | -- | GW | -- | 36.47 | -- | 0.31 | 36.16 | 0.80 | 35.66 |
| M8PX | M8PX | -- | GW | -- | 36.70 | -- | 0.14 | 36.56 | 0.86 | 35.84 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| McDonalds Branch Study Area—Continued | | | | | | | | | | |
| M8PX2 | M8PX2 | -- | GW | -- | 36.50 | -- | 0.16 | 36.34 | 0.84 | 35.66 |
| M9C | M9C | -- | GW | -- | 34.44 | -- | 0.14 | 34.30 | 0.53 | 33.90 |
| M9HP | M9HP | -- | GW | -- | 36.18 | -- | -0.03 | 36.21 | 0.43 | 35.75 |
| M9PX | M9PX | -- | GW | -- | 36.50 | -- | 0.57 | 35.93 | 1.15 | 35.35 |
| MDD1 | MDD1 | -- | GW | -- | 36.50 | -- | 0.56 | 35.94 | 1.15 | 35.35 |
| MDD2 | MDD2 | -- | GW | -- | 36.50 | -- | 0.45 | 36.05 | 1.20 | 35.30 |
| MDD2b | MDD2b | -- | GW | -- | 36.50 | -- | -- | -- | 1.38 | 35.12 |
| MDD3 | MDD3 | -- | GW | -- | 36.50 | -- | 0.42 | 36.08 | 1.29 | 35.21 |
| MDP1 | MDP1 | -- | GW | -- | 36.50 | -- | 0.28 | 36.22 | 1.28 | 35.22 |
| MDP2 | MDP2 | -- | GW | -- | 36.50 | -- | 0.37 | 36.13 | 1.15 | 35.35 |
| MDP3 | MDP3 | -- | GW | -- | 36.50 | -- | 0.13 | 36.37 | 1.14 | 35.36 |
| MDS1 | MDS1 | -- | GW | -- | 36.25 | -- | 0.00 | 36.26 | 0.68 | 35.58 |
| MDS2 | MDS2 | -- | GW | -- | 36.36 | -- | -0.12 | 36.47 | 0.55 | 35.80 |
| MDS2b | MDS2b | -- | GW | -- | 36.36 | -- | -- | -- | 0.50 | 35.85 |
| MDS3 | MDS3 | -- | GW | -- | 36.40 | -- | -0.06 | 36.45 | 0.58 | 35.82 |
| MDU1 | MDU1 | -- | GW | -- | 36.50 | -- | 0.71 | 35.79 | 1.47 | 35.03 |
| MDU2 | MDU2 | -- | GW | -- | 36.50 | -- | 0.73 | 35.77 | 1.57 | 34.93 |
| MDU3 | MDU3 | -- | GW | -- | 36.50 | -- | 0.72 | 35.78 | 1.48 | 35.02 |
| MDW1 | MDW1 | -- | GW | -- | 36.50 | -- | 0.13 | 36.37 | 1.01 | 35.49 |
| MDW2 | MDW2 | -- | GW | -- | 36.50 | -- | 0.14 | 36.36 | 0.98 | 35.52 |
| MDW2b | MDW2b | -- | GW | -- | 36.50 | -- | -- | -- | 1.13 | 35.37 |
| MDW3 | MDW3 | -- | GW | -- | 36.50 | -- | 0.19 | 36.31 | 1.05 | 35.45 |
| Morses Mill Stream Study Area | | | | | | | | | | |
| 010183 | 010183–PW 1 | 3600443 | GW | 58.52 | 20.80 | 21.53 | 7.71 | 13.09 | -- | -- |
| 010192 | 010192–WELL 1 | -- | GW | 30.48 | 16.70 | 17.35 | 0.81 | 15.89 | -- | -- |
| 010193 | 010193–INSTITUTIONAL 1 | 3600425 | GW | 45.72 | 11.00 | 10.94 | 2.01 | 8.99 | -- | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Morses Mill Stream Study Area—Continued | | | | | | |
| 010194 | 010194–INSTITUTIONAL 2 | 3600424 | GW | 44.20 | 10.00 | 10.32 | 1.14 | 8.86 | -- | -- |
| 010688 | 010688–PW 1 | 3602432 | GW | 54.86 | 9.50 | 10.05 | 5.04 | 4.46 | -- | -- |
| 010689 | 010689–SWC 2 | 3602433 | GW | 54.86 | 9.50 | 9.99 | 6.78 | 2.72 | -- | -- |
| 010727 | 010727–AC 13 OBS | 3606135 | GW | 6.98 | 12.60 | 12.89 | 3.44 | 9.17 | 4.32 | 8.28 |
| 010757 | 010757–SLF MW-2-1980 | 3601216 | GW | 9.75 | 12.48 | 12.77 | 3.48 | 9.00 | -- | -- |
| 010759 | 010759–SLF MW-1-1984 | 3604538 | GW | 5.79 | 17.76 | 18.35 | 2.15 | 15.60 | -- | -- |
| 010760 | 010760–SLF MW-2-1984 | 3604539 | GW | 5.18 | 17.07 | 17.73 | 1.29 | 15.79 | -- | -- |
| 010775 | 010775–FAA INTERMEDIATE OBS | -- | GW | 55.47 | 11.22 | 11.60 | 9.73 | 1.49 | -- | -- |
| 010776 | 010776–FAA SHALLOW OBS | -- | GW | 28.35 | 11.22 | 11.51 | 6.03 | 5.19 | -- | -- |
| 010893 | 010893–MW-3 | 36-08523-5 | GW | 8.53 | 16.10 | 16.91 | 1.82 | 14.28 | -- | -- |
| 010894 | 010894–10 MW | 36-07161-7 | GW | 9.57 | 18.52 | 18.98 | 1.24 | 17.27 | -- | -- |
| 010895 | 010895–8 MW | 3603875 | GW | 8.53 | 19.74 | 20.09 | 2.02 | 17.71 | -- | -- |
| 010896 | 010896–DOM | 3214365 | GW | 33.53 | 18.20 | 18.47 | 3.26 | 14.94 | -- | -- |
| 010925 | 010925–MW-1 | 36-08521-9 | GW | 9.75 | 18.33 | 19.00 | 4.28 | 14.05 | -- | -- |
| 010972 | 010972–PW 1 | 3608845 | GW | 47.70 | 19.20 | 19.72 | 3.03 | 16.17 | -- | -- |
| 010973 | 010973–3/17 MOSSMILL | 3614415 | GW | 56.39 | 9.80 | 10.38 | 6.19 | 3.61 | -- | -- |
| 010989 | 010989–WRANGLEBORO 3 | 5600061 | GW | 57.91 | 12.80 | 13.68 | 3.63 | 9.17 | -- | -- |
| 010999 | 010999–IRR | 3612213 | GW | 59.44 | 13.60 | 14.00 | 3.96 | 9.64 | 4.98 | 8.62 |
| 011197 | 011197–IRR 1 | 5600119 | GW | 30.48 | 15.10 | 15.74 | -0.13 | 15.23 | -- | -- |
| 011268 | 011268–SUSCP15 | 3617164 | GW | 30.48 | 18.90 | 18.62 | 8.92 | 9.98 | -- | -- |
| 011457 | 011457–STOCKTON 2 | -- | GW | 2.09 | 13.27 | 13.93 | 0.76 | 12.51 | 1.37 | 11.91 |
| 011458 | 011458–STOCKTON 1 | -- | GW | 1.83 | 11.58 | 12.19 | 0.13 | 11.45 | 0.37 | 11.22 |
| 011478 | 011478–E-1 | 3622753 | GW | 49.99 | 20.70 | 20.88 | 2.40 | 18.30 | -- | -- |
| 011498 | 011498–MM OW-1M | 3628385 | GW | 19.81 | 17.02 | 17.57 | 2.48 | 14.54 | [3]3.44 | [3]13.58 |
| 011499 | 011499–MM OW-1D | 3628384 | GW | 50.29 | 16.80 | 17.41 | 2.42 | 14.38 | [3]3.37 | [3]13.43 |
| 011500 | 011500–MM OW-1S | 3628386 | GW | 6.71 | 16.96 | 17.48 | 1.80 | 15.16 | [3]3.04 | [3]13.92 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Stream Study Area—Continued | | | | | | | | | | |
| 011501 | 011501–MM OW-2S | 3628383 | GW | 12.19 | 12.16 | 12.67 | 3.22 | 8.93 | [3]4.06 | [3]8.10 |
| 011502 | 011502–MM OW-2M | 3628382 | GW | 22.25 | 12.15 | 12.70 | 3.30 | 8.85 | [3]4.11 | [3]8.04 |
| 011503 | 011503–MM OW-2D | 3628381 | GW | 51.82 | 12.33 | 12.84 | 3.72 | 8.61 | [3]4.47 | [3]7.86 |
| 011525 | 011525–MMHT3-3D | -- | GW | 2.74 | 12.43 | 12.59 | -0.01 | 12.44 | 0.52 | 11.91 |
| 011526 | 011526–MMHT3-3S | -- | GW | 1.83 | 12.40 | 12.70 | -0.04 | 12.43 | 0.48 | 11.91 |
| 011527 | 011527–MMHT3-2D | -- | GW | 2.74 | 13.29 | 13.74 | 0.77 | 12.52 | 1.37 | 11.91 |
| 011528 | 011528–MMHT3-2S | -- | GW | 1.22 | 13.29 | 13.74 | 0.77 | 12.52 | -- | -- |
| 011529 | 011529–MMHT3-1D | -- | GW | 2.13 | 14.04 | 14.34 | 1.45 | 12.59 | -- | -- |
| 011530 | 011530–MMHT3-1RD | -- | GW | 2.74 | 14.01 | 14.35 | 1.43 | 12.58 | 2.08 | 11.93 |
| 011531 | 011531–MMHT3-1S | -- | GW | 1.71 | 14.03 | 14.49 | 1.44 | 12.59 | -- | -- |
| 011532 | 011532–MMHT4-1D | -- | GW | 2.74 | 13.23 | 13.54 | 1.40 | 11.83 | 1.94 | 11.29 |
| 011533 | 011533–MMHT4-1S | -- | GW | 1.83 | 13.23 | 13.69 | 1.39 | 11.84 | -- | -- |
| 011534 | 011534–MMHT4-3D | -- | GW | 2.74 | 11.47 | 11.75 | 0.05 | 11.42 | 0.26 | 11.21 |
| 011535 | 011535–MMHT4-3S | -- | GW | 1.52 | 11.47 | 11.93 | 0.07 | 11.40 | 0.26 | 11.21 |
| 011536 | 011536–MMHT1-3D | -- | GW | 2.68 | 16.28 | 16.65 | 0.07 | 16.21 | 0.77 | 15.51 |
| 011537 | 011537–MMHT1-3S | -- | GW | 1.52 | 16.33 | 16.79 | 0.14 | 16.20 | 0.83 | 15.51 |
| 011538 | 011538–MMHT2-3D | -- | GW | 2.74 | 12.33 | 12.68 | 0.00 | 12.33 | 0.34 | 11.99 |
| 011539 | 011539–MMHT2-3S | -- | GW | 1.52 | 12.34 | 12.80 | 0.01 | 12.33 | 0.36 | 11.98 |
| 011540 | 011540–MMHT1-1D | -- | GW | 2.44 | 17.80 | 18.38 | 1.21 | 16.60 | 2.14 | 15.66 |
| 011541 | 011541–MMHT1-1S | -- | GW | 1.52 | 17.78 | 18.72 | 1.17 | 16.61 | -- | -- |
| 011542 | 011542–MMHT2-1D | -- | GW | 2.74 | 13.59 | 13.90 | 0.78 | 12.81 | 1.83 | 11.76 |
| 011543 | 011543–MMHT2-1S | -- | GW | 1.83 | 13.58 | 14.04 | 0.77 | 12.81 | -- | -- |
| 011544 | 011544–MMHT5-3D | -- | GW | 2.74 | 7.50 | 7.80 | 0.16 | 7.33 | 0.36 | 7.14 |
| 011545 | 011545–MMHT5-3S | -- | GW | 1.52 | 7.47 | 7.93 | 0.15 | 7.32 | 0.33 | 7.14 |
| 011546 | 011546–MMHT5-2D | -- | GW | 2.74 | 8.73 | 9.06 | 0.71 | 8.02 | 1.21 | 7.52 |
| 011547 | 011547–MMHT5-2S | -- | GW | 1.52 | 8.74 | 9.20 | 0.71 | 8.03 | 1.24 | 7.50 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Stream Study Area—Continued | | | | | | | | | | |
| 011548 | 011548–MMHT5-1S | -- | GW | 1.52 | 9.00 | 9.45 | 0.75 | 8.24 | 1.41 | 7.59 |
| 011549 | 011549–MMHT5-1D | -- | GW | 2.74 | 9.01 | 9.31 | 0.78 | 8.23 | 1.47 | 7.54 |
| 011559 | 011559–MM UP-4 | 3628860 | GW | 6.10 | 15.10 | 15.86 | 1.27 | 13.83 | 2.33 | 12.77 |
| 011560 | 011560–MMHT4-2D | -- | GW | 2.74 | 11.57 | 11.91 | 0.39 | 11.18 | 0.35 | 11.22 |
| 011561 | 011561–MMHT1-2D | -- | GW | 2.44 | 16.95 | 17.22 | 0.59 | 16.36 | 1.41 | 15.54 |
| 011562 | 011562–MMHT1-2S | -- | GW | 1.52 | 16.97 | 17.43 | 0.60 | 16.37 | -- | -- |
| 011563 | 011563–MMHT2-2S | -- | GW | 1.77 | 13.29 | 13.74 | 0.65 | 12.63 | 1.53 | 11.76 |
| 011564 | 011564–MMHT2-2D | -- | GW | 2.74 | 13.30 | 13.60 | 0.66 | 12.64 | 1.54 | 11.76 |
| 011565 | 011565–MM UP-2 | 3628859 | GW | 6.10 | 16.70 | 16.64 | 1.64 | 15.06 | 2.63 | 14.07 |
| 011566 | 011566–MM UP-5 | 3628858 | GW | 7.62 | 12.10 | 12.86 | 2.53 | 9.57 | 3.65 | 8.45 |
| 011585 | 011585–F-MW2S | 36-08761-1 | GW | 3.81 | 18.17 | 19.17 | 2.99 | 15.18 | -- | -- |
| 011586 | 011586–29-PW1 | 3623954 | GW | 31.39 | 17.75 | 18.51 | 6.23 | 11.52 | -- | -- |
| 011587 | 011587–29-MW6S | 3619118 | GW | 7.62 | 14.30 | 14.95 | 3.17 | 11.13 | -- | -- |
| 011588 | 011588–DOM | 3603031 | GW | 44.81 | 18.20 | 18.46 | 5.14 | 13.06 | -- | -- |
| 011589 | 011589–MW-2 | 36-08522-7 | GW | 10.67 | 19.70 | 20.37 | 5.39 | 14.31 | -- | -- |
| 011590 | 011590–BLDG 6 | 3616530 | GW | 25.30 | 17.20 | 17.54 | 4.43 | 12.77 | 5.16 | 12.04 |
| 011591 | 011591–ATH FLD | 3621583 | GW | 54.86 | 17.60 | 18.00 | 4.64 | 12.96 | -- | -- |
| 011591 | 011591–ATH FLD | 3621583 | GW | 54.86 | 17.60 | 18.15 | -- | -- | 5.33 | 12.27 |
| 011592 | 011592–BIG BLUE | 3621377 | GW | 51.82 | 13.10 | 13.50 | 2.29 | 10.81 | -- | -- |
| 011593 | 011593–DOM | 3622654 | GW | 32.31 | 17.20 | 17.51 | 5.83 | 11.37 | -- | -- |
| 011622 | 011622–MW-2 | 36-07181-1 | GW | 9.14 | 17.88 | 18.83 | 6.34 | 11.54 | -- | -- |
| 011623 | 011623–POMONA OAKS MW-7D | 3610847 | GW | 64.92 | 15.37 | 15.88 | 2.12 | 13.26 | -- | -- |
| 011624 | 011624–POMONA OAKS MW-7I | 36-10894-4 | GW | 26.52 | 15.34 | 15.90 | 1.59 | 13.75 | -- | -- |
| 011625 | 011625–POMONA OAKS MW-7S | 3610893 | GW | 5.18 | 15.44 | 15.96 | 1.70 | 13.74 | -- | -- |
| 011626 | 011626–MW-5 | 3620936 | GW | 7.62 | 21.50 | 22.07 | 4.07 | 17.43 | -- | -- |
| 011627 | 011627–MW-3 | 3620934 | GW | 7.62 | 20.80 | 21.54 | 3.08 | 17.72 | 4.25 | 16.55 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in “Site-Numbering System” section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Stream Study Area—Continued | | | | | | | | | | |
| 011628 | 011628–MW-4 | 3620935 | GW | 7.62 | 20.70 | 21.23 | 4.13 | 16.57 | -- | -- |
| 011629 | 011629–POMONA OAKS MW-8D | 36-10848-1 | GW | 62.64 | 20.71 | 21.41 | 4.81 | 15.90 | -- | -- |
| 011630 | 011630–POMONA OAKS MW-8I | 3610906 | GW | 27.43 | 20.68 | 21.41 | 4.62 | 16.06 | -- | -- |
| 011631 | 011631–POMONA OAKS MW-8S | 36-10903-7 | GW | 7.77 | 20.39 | 20.99 | 4.29 | 16.10 | 5.34 | 15.05 |
| 011632 | 011632–HERSCHEL MW-4 | 3604541 | GW | 5.79 | 18.11 | 18.76 | 2.63 | 15.48 | -- | -- |
| 011633 | 011633–IRR | 3622184 | GW | 24.38 | 15.10 | 15.52 | 1.22 | 13.88 | -- | -- |
| 011635 | 011635–DOM | 3609754 | GW | 31.70 | 16.30 | 16.70 | 5.11 | 11.20 | -- | -- |
| 011636 | 011636–SO CLUSTER-F46 RED | -- | GW | 18.29 | 11.50 | 11.42 | 1.47 | 10.03 | -- | -- |
| 011637 | 011637–SO CLUSTER-F46 BLUE | -- | GW | 48.77 | 11.50 | 11.42 | 1.38 | 10.12 | -- | -- |
| 011638 | 011638–WEST CLUSTER-L23 BLUE | -- | GW | 47.85 | 15.10 | 15.10 | 3.94 | 11.16 | -- | -- |
| 011639 | 011639–WEST CLUSTER-L23 RED | -- | GW | 20.73 | 15.10 | 15.10 | 4.05 | 11.05 | 4.72 | 10.38 |
| 011640 | 011640–NO CLUSTER-B1 RED | -- | GW | 24.08 | 13.60 | 13.51 | 3.83 | 9.77 | -- | -- |
| 011641 | 011641–NO CLUSTER-B1 BLUE | -- | GW | 53.95 | 13.60 | 13.51 | 3.62 | 9.98 | -- | -- |
| 011642 | 011642–DOM | 3619490 | GW | 34.14 | 12.80 | 13.16 | 3.73 | 9.06 | -- | -- |
| 011643 | 011643–DOM | 3626823 | GW | 26.52 | 3.20 | 3.03 | 1.72 | 1.48 | -- | -- |
| 011650 | 011650–MW104-D | 3625547 | GW | 32.16 | 17.11 | 17.73 | 5.46 | 11.66 | -- | -- |
| 011652 | 011652–MW106-D | 3625387 | GW | 36.79 | 17.31 | 17.91 | 6.18 | 11.13 | -- | -- |
| 011654 | 011654–F-MW4S | -- | GW | 12.95 | 18.43 | 19.27 | 7.53 | 10.89 | -- | -- |
| 011655 | 011655–P-5 | 3610843 | GW | 7.47 | 17.51 | 18.13 | 3.11 | 14.40 | -- | -- |
| 011656 | 011656–P-7 | 3610845 | GW | 7.01 | 17.66 | 18.30 | 2.61 | 15.06 | -- | -- |
| 011657 | 011657–KF IRR-1 | -- | GW | 22.86 | 15.80 | 16.23 | 2.64 | 13.16 | 3.66 | 12.14 |
| 011658 | 011658–P-1 | -- | GW | 7.01 | 17.94 | 18.53 | 2.37 | 15.57 | 3.35 | 14.59 |
| 011659 | 011659–LIFT ST 1-2 | 3618535 | GW | 16.76 | 10.60 | 10.75 | 1.08 | 9.52 | -- | -- |
| 011660 | 011660–LIFT STA 1-1 | 3618536 | GW | 48.77 | 10.60 | 10.88 | 0.79 | 9.81 | -- | -- |
| 011661 | 011661–MW102 | 3624547 | GW | 21.34 | 14.69 | 14.64 | 3.65 | 11.05 | 4.59 | 10.10 |
| 011662 | 011662–MW101 | 3624546 | GW | 32.61 | 14.75 | 14.69 | 3.64 | 11.11 | -- | -- |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Stream Study Area—Continued | | | | | | | | | | |
| 011663 | 011663–MW104-S | -- | GW | 25.66 | 17.15 | 17.80 | 5.47 | 11.69 | -- | -- |
| 011664 | 011664–MW-4 | 3620012 | GW | 16.76 | 17.00 | 17.60 | 3.29 | 13.71 | 4.29 | 12.71 |
| 011665 | 011665–MW109-S | 3625389 | GW | 18.29 | 13.22 | 13.15 | 2.56 | 10.66 | 3.62 | 9.59 |
| 011666 | 011666–MW108-S | 3625388 | GW | 18.23 | 11.98 | 11.92 | 2.30 | 9.67 | -- | -- |
| 011667 | 011667–MW106-S | -- | GW | 25.73 | 17.28 | 17.91 | 5.68 | 11.60 | -- | -- |
| 011668 | 011668–MW110-S | 3625513 | GW | 21.31 | 15.77 | 16.41 | 4.76 | 11.02 | -- | -- |
| 011670 | 011670–MW 14D | 36-10219-6 | GW | 25.91 | 18.52 | 19.01 | 1.39 | 17.13 | -- | -- |
| 011671 | 011671–MW 14S | 36-10215-6 | GW | 16.76 | 18.52 | 19.02 | 1.39 | 17.13 | -- | -- |
| 01410215 | Clarks Mill Stream at Port Republic, NJ | = | SW | = | = | = | = | 1.69 | = | -- |
| 01410216 | Morses Mill Stream at Odessa Avenue near Pomona, NJ | = | SW | = | = | = | = | 16.64 | = | -- |
| 01410217 | Morses Mill Stream at West Duerer Street near Pomona, NJ | = | SW | = | = | = | = | 16.17 | = | -- |
| 01410218 | Morses Mill Stream at Zurich Avenue near Pomona, NJ | = | SW | = | = | = | = | 12.62 | = | 12.48 |
| 01410220 | Morses Mill Stream Tributary above Sand Road near Pomona, NJ | = | SW | = | = | = | = | 12.45 | = | -- |
| 01410221 | Morses Mill Stream Tributary below Sand Road near Pomona, NJ | = | SW | = | = | = | = | 11.39 | = | 11.20 |
| 01410222 | Morses Mill Stream at College Drive near Pomona, NJ | = | SW | = | = | = | = | 8.15 | = | 7.91 |
| 01410223 | Morses Mill Stream at Garden State Parkway near Pomona, NJ | = | SW | = | = | = | = | 7.25 | = | 7.05 |
| 01410225 | Morses Mill Stream at Port Republic, NJ | = | SW | = | = | = | = | 2.48 | = | 2.32 |
| 01410230 | Mattix Run near Smithville, NJ | = | SW | = | = | = | = | 2.81 | = | -- |
| MMSTM10 | MMSTM10 | = | SW | = | = | = | = | 16.79 | = | -- |
| MMSTM11 | MMSTM11 | = | SW | = | = | = | = | 16.70 | = | -- |
| MMSTM12 | MMSTM12 | = | SW | = | = | = | = | -- | = | 15.10 |
| MMSTM13 | MMSTM13 | = | SW | = | = | = | = | -- | = | 10.60 |
| MMSTM14 | MMSTM14 | = | SW | = | = | = | = | -- | = | 11.30 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Stream Study Area—Continued | | | | | | | | | | |
| MMSTM2 | MMSTM2 | = | SW | = | = | = | = | 14.04 | = | -- |
| MMSTM3 | MMSTM3 | = | SW | = | = | = | = | 6.51 | = | -- |
| MMSTM4 | MMSTM4 | = | SW | = | = | = | = | 10.07 | = | -- |
| MMSTM5 | MMSTM5 | = | SW | = | = | = | = | 8.94 | = | 8.91 |
| MMSTM6 | MMSTM6 | = | SW | = | = | = | = | 13.50 | = | -- |
| MMSTM7 | MMSTM7 | = | SW | = | = | = | = | 12.60 | = | -- |
| MMSTM8 | MMSTM8 | = | SW | = | = | = | = | 17.33 | = | -- |
| MMSTM9 | MMSTM9 | = | SW | = | = | = | = | 16.24 | = | -- |
| STM 85 | STM 85 | = | SW | = | = | = | = | 0.80 | = | -- |
| STM 86 | STM 86 | = | SW | = | = | = | = | -0.37 | = | -- |
| STM102 | STM102 | = | SW | = | = | = | = | 15.95 | = | -- |
| STM108 | STM108 | = | SW | = | = | = | = | 7.58 | = | -- |
| STM109 | STM109 | = | SW | = | = | = | = | 10.30 | = | -- |
| STM110 | STM110 | = | SW | = | = | = | = | 13.93 | = | -- |
| R1C | R1C | -- | GW | -- | 8.46 | -- | 0.07 | 8.40 | 0.52 | 7.95 |
| R1H | R1H | -- | GW | -- | 8.80 | -- | 0.09 | 8.71 | 0.48 | 8.32 |
| R1PU | R1PU | -- | GW | -- | 9.01 | -- | 1.49 | 7.52 | 2.03 | 6.98 |
| R1PW | R1PW | -- | GW | -- | 9.03 | -- | 0.62 | 8.41 | 1.17 | 7.86 |
| R2H1 | R2H1 | -- | GW | -- | 10.60 | -- | 0.40 | 10.20 | 0.91 | 9.69 |
| R2H2 | R2H2 | -- | GW | -- | 10.96 | -- | 0.28 | 10.68 | 1.47 | 9.48 |
| R2HP | R2HP | -- | GW | -- | 11.30 | -- | -0.03 | 11.33 | 1.74 | 9.56 |
| R2PH | R2PH | -- | GW | -- | 11.10 | -- | 0.70 | 10.40 | 1.81 | 9.29 |
| R2PH2 | R2PH2 | -- | GW | -- | 10.70 | -- | 0.51 | 10.19 | 1.09 | 9.62 |
| R2PH3 | R2PH3 | -- | GW | -- | 10.27 | -- | 0.19 | 10.08 | 1.41 | 8.86 |
| R2PH4 | R2PH4 | -- | GW | -- | 11.30 | -- | 0.19 | 11.11 | 1.87 | 9.43 |
| R2PU | R2PU | -- | GW | -- | 11.91 | -- | 0.70 | 11.21 | 2.15 | 9.76 |

**Table 3.** Water levels measured in wells and at surface-water sites in three study areas, New Jersey Pinelands, 2005.—Continued

[--, data unavailable; =, data are not applicable for surface-water sites. Site identifier: site identifiers described in "Site-Numbering System" section of text. Shaded site information and water-level data were provided by the N.J. Pinelands Commission, New Lisbon NJ. Site Type: GW, Groundwater; SW, Surface water: NAVD 88, North American vertical Datum of 1988.]

| Site identifier | Site name | New Jersey permit number | Site type | Well depth (meters) | Altitude of land surface, NAVD 88 (meters) | Altitude of measuring point, NAVD 88 (meters) | Depth to water below land surface, spring 2005[1] (meters) | Altitude of water level, spring 2005[1] (meters) | Depth to water below land surface, summer 2005[2] (meters) | Altitude of water level, summer 2005[2] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Morses Mill Stream Study Area—Continued | | | | | | | | | | |
| R2PU2 | R2PU2 | -- | GW | -- | 11.53 | -- | 1.19 | 10.33 | 2.98 | 8.55 |
| R2PUb | R2PUb | -- | GW | -- | 11.91 | -- | 0.77 | 11.14 | 2.17 | 9.74 |
| R3H | R3H | -- | GW | -- | 12.80 | -- | 0.09 | 12.71 | 1.39 | 11.41 |
| R3HP | R3HP | -- | GW | -- | 11.93 | -- | 0.96 | 10.97 | 1.48 | 10.44 |
| R3PH | R3PH | -- | GW | -- | 12.81 | -- | 0.20 | 12.61 | 1.19 | 11.62 |
| R3PH2 | R3PH2 | -- | GW | -- | 12.80 | -- | 0.13 | 12.67 | 1.18 | 11.62 |
| R5H | R5H | -- | GW | -- | 11.33 | -- | 0.13 | 11.20 | 0.64 | 10.68 |
| R5PD | R5PD | -- | GW | -- | 12.41 | -- | 0.91 | 11.50 | 1.51 | 10.89 |
| R5PU | R5PU | -- | GW | -- | 12.68 | -- | 1.12 | 11.57 | 1.76 | 10.92 |
| R5PW | R5PW | -- | GW | -- | 12.14 | -- | 0.65 | 11.49 | 1.24 | 10.91 |
| R6C | R6C | -- | GW | -- | 11.94 | -- | 0.12 | 11.83 | 0.41 | 11.53 |
| R6PD | R6PD | -- | GW | -- | 12.10 | -- | 0.67 | 11.43 | 1.04 | 11.06 |
| R6PU | R6PU | -- | GW | -- | 12.30 | -- | 0.69 | 11.61 | 1.04 | 11.26 |
| R6PW | R6PW | -- | GW | -- | 12.10 | -- | 0.42 | 11.68 | 0.81 | 11.29 |
| R7C | R7C | -- | GW | -- | 11.46 | -- | 0.11 | 11.35 | 0.36 | 11.10 |
| R7C2 | R7C2 | -- | GW | -- | 11.38 | -- | 0.06 | 11.32 | 0.34 | 11.04 |
| R7PH | R7PH | -- | GW | -- | 12.18 | -- | 0.30 | 11.87 | 0.76 | 11.42 |
| R7PH2 | R7PH2 | -- | GW | -- | 11.80 | -- | 0.23 | 11.57 | 0.64 | 11.16 |
| R7PW | R7PW | -- | GW | -- | 11.60 | -- | 0.25 | 11.35 | 0.59 | 11.01 |
| R8C | R8C | -- | GW | -- | 11.48 | -- | 0.10 | 11.39 | 0.31 | 11.17 |

[1]The date range for spring water-level measurements is 4/13-5/19/05.

[2]The date range for summer water-level measurements is 9/8-9/15/05.

[3]Value represents measurement from water-level recorder.

[4]Value represents lake level above culvert.

[5]Value represents stream level below culvert.

For additional information, write to:
Director
U.S. Geological Survey
New Jersey Water Science Center
Mountain View Office Park
810 Bear Tavern Rd., Suite 206
West Trenton, NJ 08628

or visit our Web site at:
http://nj.usgs.gov/

Walker and others—**Hydrologic Assessment of Three Drainage Basins in the Pinelands of Southern New Jersey, 2004–06**—Scientific Investigations Report 2011–5056