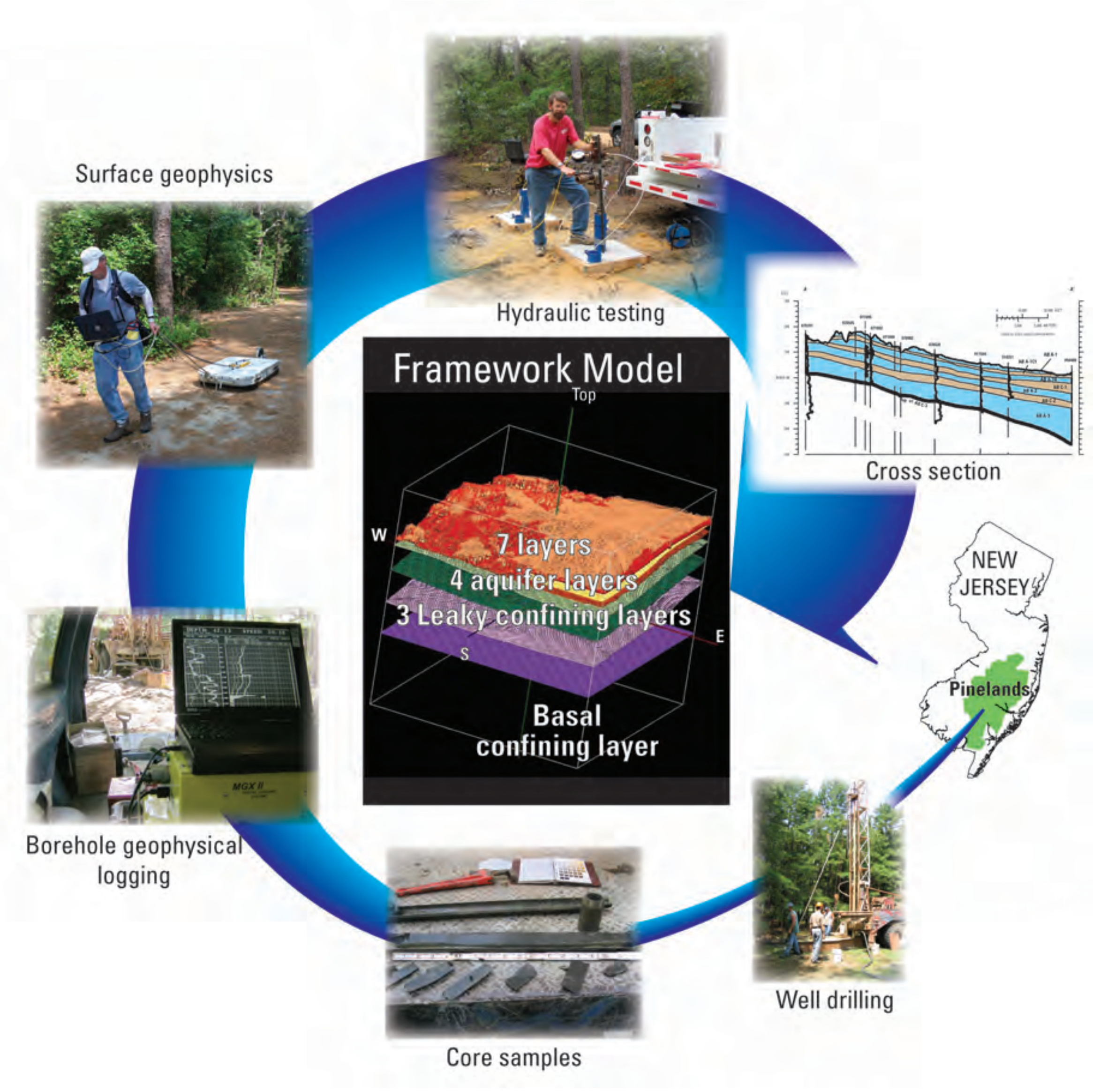
Prepared in cooperation with the
New Jersey Pinelands Commission

Hydrogeologic Framework in Three Drainage Basins in the New Jersey Pinelands, 2004-06



Scientific Investigations Report 2008-5061

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

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By Richard L. Walker, Pamela A. Reilly, and Kara M. Watson

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Conversion Factors and Datum

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
	Flow rate	
gallon per minute (gpm)	0.06309	liter per second (L/s)
gallon per day (gpd)	0.003785	cubic meter per day (m^3/d)
	Pressure	
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Velocity	
foot per microsecond (ft/µs)	0.3048	meter per microsecond (m/µs)

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.

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

Hydrogeologic Framework in Three Drainage Basins in the New Jersey Pinelands, 2004-06

By Richard L. Walker, Pamela A. Reilly, and Kara M. Watson

Abstract

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 Pinelands is an ecologically diverse area in the southern New Jersey Coastal Plain underlain by the Kirkwood-Cohansey aquifer system. The demand for ground water from this aquifer system is increasing as local development increases. To assess the effects of ground-water withdrawals on Pinelands stream and wetland water levels, three drainage basins were selected for detailed hydrologic assessments, including the Albertson Brook, McDonalds Branch and the Morses Mill Stream basins. Study areas were defined surrounding the three drainage basins to provide sub-regional hydrogeologic data for the ground-water flow modeling phase of this study.

In the first phase of the hydrologic assessments, a database of hydrogeologic information and a hydrogeologic framework model for each of the three study areas were produced. These framework models, which illustrate typical hydrogeologic variations among different geographic sub-regions of the Pinelands, are the structural foundation for predictive ground-water flow models to be used in assessing the hydrologic effects of increased ground-water withdrawals.

During 2004-05, a hydrogeologic database was compiled using existing and new geophysical and lithologic data including suites of geophysical logs collected at 7 locations during the drilling of 21 wells and one deep boring within the three study areas. In addition, 27 miles of ground-penetrating radar (GPR) surface geophysical data were collected and analyzed to determine the depth and extent of shallow clays in the general vicinity of the streams. On the basis of these data, the Kirkwood-Cohansey aquifer system was divided into 7 layers to construct a hydrogeologic framework model for each study area. These layers are defined by their predominant sediment textures as aquifers and leaky confining layers. The confining layer at the base of the Kirkwood-Cohansey aquifer system, depending on location, is defined as one of two distinct clays of the Kirkwood Formation. The framework models are described using hydrogeologic sections, maps of structure tops of layers, and thickness maps showing variations of sediment textures of the various model layers. The three framework models are similar in structure but unique to their respective study areas.

The hydraulic conductivity of the Kirkwood-Cohansey aquifer system in the vicinity of the three study areas was determined from analysis of 16 slug tests and 136 well-performance tests. The mean values for hydraulic conductivity in the three study areas ranged from about 84 feet per day to 130 feet per day.

With the exception of the basal confining layers, the variable and discontinuous nature of clay layers within the Kirkwood-Cohansey aquifer system was confirmed by the geophysical and lithologic records. Leaky confining layers and discontinuous clays are generally more common in the upper part of the aquifer system. Although the Kirkwood-Cohansey aquifer system generally has been considered a water-table aquifer in most areas, localized clays in the aquifer layers and the effectiveness of the leaky confining layers may act to impede the flow of ground water in varying amounts depending on the degree of confinement and the location, duration, and magnitude of the hydraulic stresses applied.

Considerable variability exists in the different sediment textures. The extent to which this hydrogeologic variability can be characterized is constrained by the extent of the available data. Thus, the hydraulic properties of the modeled layers were estimated on the basis of available horizontal hydraulic conductivity data and the range of sediment textures estimated from geophysical and lithologic data.

Introduction

The New Jersey Pinelands area (Pinelands) (fig.1) is a 1.1-million-acre natural reserve area in southern New Jersey that overlies the Kirkwood-Cohansey aquifer system in the Atlantic Coastal Plain (fig. 2) (New Jersey Pinelands Commission, 1981). This ecologically diverse area supports a variety of habitats and is home to many threatened and endangered species. Cedar swamps, pine and oak forests, agricultural areas, and newly developed commercial and residential areas dominate the landscape. Demand for water from the Kirkwood-Cohansey aquifer system is increasing as development within the area increases.

The Pinelands Commission has been tasked with evaluating increased water-supply demands within the Pinelands area with respect to the potential of adverse effects on the hydrologic and ecological systems in the area. The relation between key hydrologic and ecological attributes needs to be characterized to (1) assess the effects of ground-water diversions from the Kirkwood-Cohansey aquifer system on stream and wetland water levels within the Pinelands, and (2) determine the potential ecological effects of reduced water levels on aquatic and wetland communities (New Jersey Pinelands Commission, 2003). 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 Pinelands drainage basins—Albertson Brook, McDonalds Branch and Morses Mill Stream—were selected for a detailed hydrologic assessment to provide the information needed to develop a ground-water flow model that can be used to predict hydrologic responses to increased ground-water withdrawals. The first phase of this assessment consists of a comprehensive hydrogeologic investigation of each study area. The major objectives of this hydrogeologic investigation are to (1) compile available hydrogeologic data (2) conduct additional borehole and surface geophysical surveys and tests to measure aquifer hydraulic properties, (3) characterize the hydrogeologic framework, and (4) develop a hydrogeologic framework model of each study area that will be used in developing ground-water flow models for those areas.

Purpose and Scope

This report describes the methods used in, and results of, the hydrogeologic investigations conducted in and near the three study areas in the New Jersey Pinelands. The report documents the data-collection phase of the study, which included compiling historical information on surficial geology, stratigraphy, and aquifer and confining-unit characteristics; drilling 21 wells; conducting surface and borehole geophysical surveys; analyzing results of slug tests and well-performance tests to estimate hydraulic properties; and interpreting the hydrogeology of the localized Pinelands study areas. The interpretations illustrate localized differences in the hydrogeology in the vicinity of the three study areas that are typical of the Pinelands and they provide the information needed to develop and calibrate a ground-water flow model for each of the three study basins. The hydrogeologic framework is presented as structure-contour maps and maps that show the thickness of hydrogeologic layers, differences in sediment textures, and horizontal hydraulic conductivity (K) data estimated from slug tests and well-performance tests.

Description of Study Areas

The three drainage basins were selected from a pool of 39 candidate basins because they represent a range of typical hydrologic, geologic, and ecological conditions and landscape features. Key hydrologic criteria for selection include aquifer thickness, drainage area, stream length, drainage density, past and current hydrologic monitoring and modeling, and current (2004) and potential ground-water withdrawals from the Kirkwood-Cohansey aquifer system. Major landscape features such as land use, soil type, and landscape cover also were considered. The Albertson Brook, McDonalds Branch, and Morses Mill Stream drainage basins were selected for the coordinated study of hydrology and wetland ecology (fig. 1). For the purpose of this report, each study area consists of the drainage basin surrounded by a buffer zone extending beyond the drainage-basin boundary. The larger area created by the buffer assures that a comprehensive hydrogeologic data set is available for each of the study areas. The extended hydrogeologic framework buffer boundaries also encompass the planned ground-water flow model domain.

The Albertson Brook study area encompasses 84.7 mi^2 consisting of a large part of the Albertson Brook drainage basin (20.18 mi^2) and the surrounding buffer zone. The Albertson Brook study area falls predominantly within Camden County with its eastern-most part extending into Atlantic County (fig. 1). The study area is bordered to the southwest by the Gloucester County line and is situated south of the Camden-Burlington County line. The dominant forested cover in the study area consists of mixed pine and oak forests in the uplands and hardwood and cedar swamps flanking the lowlands. Agricultural land is common throughout the basin but is nearly continuous south of the Albertson Brook. Residential development is most dense in the northern part of the basin in Camden County and along the highway corridors. Lightly developed residential areas are present in the lower part of the basin, which is largely agricultural or forested.

The McDonalds Branch study area is located in a minimally developed area in Burlington County, New Jersey (fig. 1). The basin is small (5.52 mi^2) and forested, containing a mix of pine and oak forests that surround hardwood and cedar swamps (Johnsson and Barringer, 1993). A small commercial cranberry bog surrounds McDonalds Branch in the lower part of the study area. Also in the lower part of the basin are lightly developed residential areas and a small recreational lake. The McDonalds Branch study area encompasses 28.08 mi^2.

The Morses Mill Stream basin is relatively small (8.35 mi^2), and the study area totals 35.28 mi^2. The Morses Mill Stream study area is located in Atlantic County (fig. 1). In the eastern part of the study area, parts of the buffer zone and drainage basin are situated outside of the New Jersey Pinelands area boundary.

Developed and agricultural land are prominent features of the Albertson Brook and Morses Mill Stream study areas, and several production and irrigation wells, screened in the Kirkwood-Cohansey aquifer system, are within each basin.

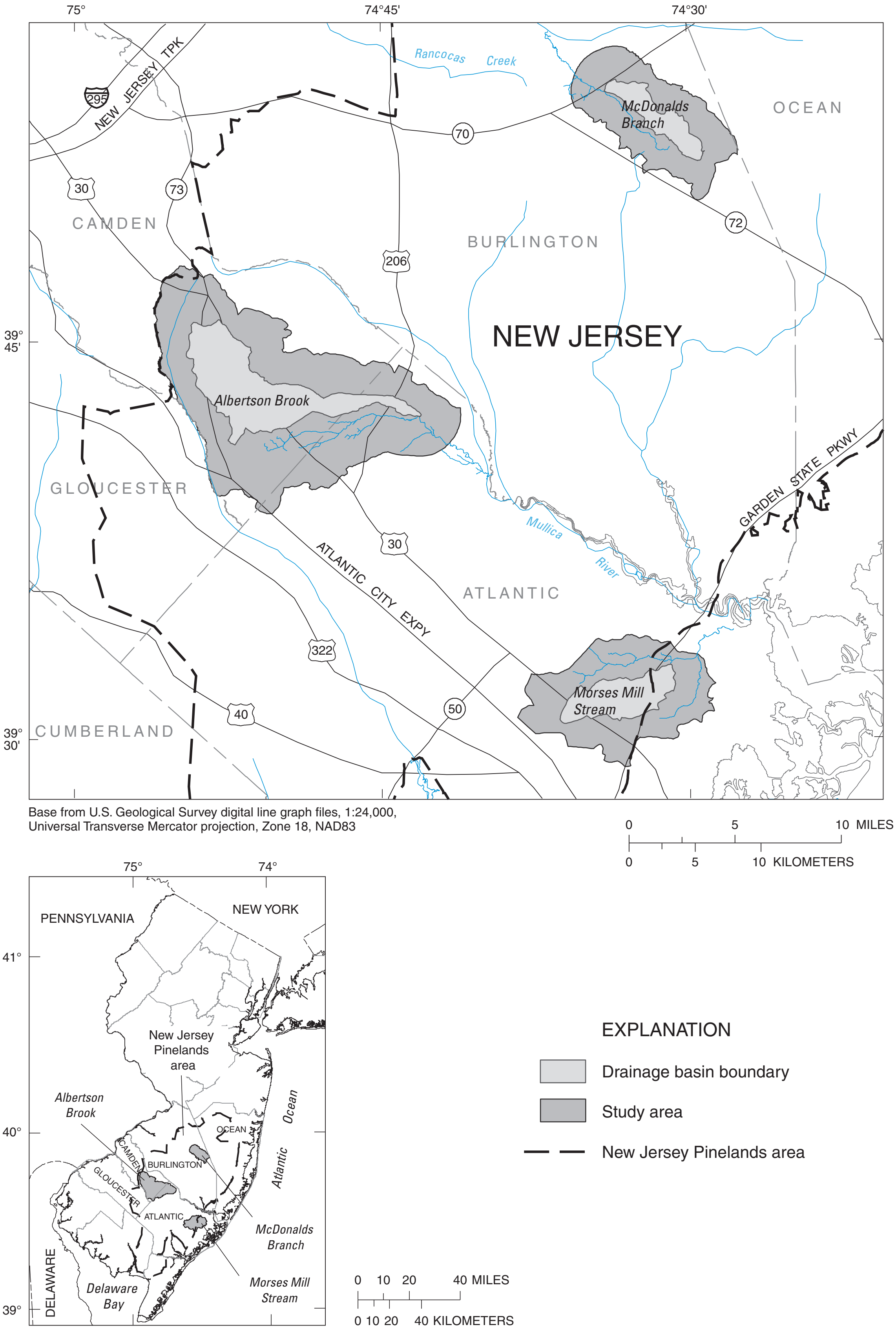


Figure 1. Location of the Pinelands study areas, Atlantic, Burlington, and Camden Counties, New Jersey.

All study areas contain wetlands, with varying vegetative cover and soil conditions that typically have ground-water levels ranging from 0 to 12 in. below land surface during the growing season (U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), 2000).

Hydrogeologic Setting

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 upper-most hydrogeologic unit of a wedge-shaped sequence of Coastal Plain sediments that lie on the pre-Cretaceous bedrock (Zapecza, 1989) (table 1). The Coastal Plain sediments are composed of sand and gravel aquifers separated by silt and clay confining layers that thicken and dip from the western limit of the Coastal Plain at the Fall Line to the southeast, reaching a thickness of more than 6,500 ft at Cape May, New Jersey (Gill and Farlekas, 1976). The Kirkwood-Cohansey aquifer system extends from the updip limit of the Kirkwood Formation to the Atlantic coast (fig. 2). The aquifer system is generally considered to be an unconfined (water-table) aquifer, although locally extensive clay layers can exist that can cause perched or semi-confined conditions (Zapecza, 1989, p. B19).

The Kirkwood-Cohansey aquifer system is principally composed of sands, silts, and clays of the Miocene age Kirkwood Formation and gravels, sands, and clays of the Cohansey Sand, also of Miocene age. Depending on location, the Miocene age Bridgeton Formation and (or) Pleistocene age and Holocene age sediments overlie the aquifer system in the vicinity of the study areas. Where present, these surficial sediments are considered to be part of the Kirkwood-Cohansey aquifer system. The material that composes the Cohansey Sand typically is coarser grained than that of the underlying Kirkwood Formation, which grades to clay near its base (Zapecza, 1989). Carter (1978) described the Miocene 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.

The generalized hydrogeologic section shown in figure 2 illustrates the position of the Kirkwood-Cohansey aquifer system in relation to other Coastal Plain sediments. The position of the two regional basal surfaces of the Kirkwood-Cohansey aquifer system, as described by Zapecza, (1989, p. B-19) are shown in figure 2. In the western part of the aquifer system, beneath the Albertson Brook and McDonalds Branch study areas, the base of the aquifer system is the basal clay bed in the lower part of Kirkwood Formation. About 8 mi west of the Morses Mill Stream study area, the basal clay described above dips below a thick diatomaceous clay, an extensive confining bed in the upper part of the Kirkwood Formation locally known as the Upper Kirkwood confining layer (Zapecza, 1989, p. B18-B19) (table 1; fig. 2). The diatomaceous clay is present locally and separates the Kirkwood Formation into upper and lower sands. From the updip extent of its subcrop, the diatomaceous clay dips and thickens toward the east to approximately 200 ft (Zapecza, 1989, pl. 22, 23) in the vicinity of Morses Mill Stream study area, locally forming the basal clay confining layer of the Kirkwood-Cohansey aquifer system. The upper sands of the Kirkwood Formation remain hydraulically connected to the Cohansey Formation and retain the name Kirkwood-Cohansey aquifer system. The lower sand of the Kirkwood Formation that dips beneath the diatomaceous clay is locally referred to as the Atlantic City 800-foot sand (fig. 2).

Previous Investigations

The geology and hydrogeology of the Miocene Kirkwood Formation, Cohansey Sand, Bridgeton Formation, and overlying Quaternary sediments that compose the Kirkwood-Cohansey aquifer system have been discussed by numerous investigators. The depositional environment of the Cohansey Sand described by Carter (1978) and the surficial geology of the central and southern Coastal Plain described and mapped by Newell and others (2000) represent some of the most recent work that interprets the origin and distribution of these sediments. The geology and ground-water resources of various counties were studied previously including Burlington County (Rush, 1968), Camden County (Farlekas and others, 1976), Gloucester County (Hardt and Hilton, 1969), and Ocean County (Anderson and Appel, 1969). Barksdale and others (1958) discuss the Kirkwood Formation and the Cohansey Sand over a four-county area in the New Jersey Coastal Plain. These early investigators describe the Kirkwood Formation and the Cohansey Sand as separate geologic units but often indicate that they are hydraulically connected. In addition, the Cohansey Sand and the overlying younger sediments were recognized as forming a single hydrologic unit. Rhodehamel (1973) discusses the geology and hydrology of the Kirkwood Formation and Cohansey Sand in the vicinity of the Mullica River basin in Atlantic and Burlington Counties (fig.1) and describes the Cohansey Sand–upper Kirkwood Formation as a single aquifer. Zapecza (1989) describes the Kirkwood-Cohansey aquifer system as it applies to a multi-layer ground-water flow model of the New Jersey Coastal Plain. The soils of Burlington County are described by Markley (1971), and the geology and soils of the McDonalds Branch basin are described and summarized by Lord and others (1990) and Johnsson and Barringer (1993), respectively.

Methods of Investigation

The methods discussed in the following sections describe the work required to acquire and interpret data in order to generate a hydrogeologic framework for each study area. The hydrogeologic framework is intended to provide a structural

Table 1. Geologic and hydrogeologic units in the New Jersey Coastal Plain in New Jersey.

SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGY	Albertson Brook and McDonalds Branch study area HYDROGEOLOGIC UNIT	Morses Mill study area HYDROGEOLOGIC UNIT	HYDROLOGIC CHARACTERISITICS
Quaternary	Holocene	Alluvial deposits	Sand, silt, and black mud	Undifferentiated	Undifferentiated	Surficial material, often hydraulically connected to underlying aquifers. Locally some units may act as confining units. Thicker sands are capable of yielding large quantities of water
		Beach sand and gravel	Sand, quartz, light-colored, medium- to coarse-grained, pebbly			
	Pleistocene	Cape May Formation	Sand, quartz, light-colored, heterogeneous, clayey, pebbly			
Tertiary	Miocene	Pensauken Formation		Kirkwood-Cohansey aquifer system	Kirkwood-Cohansey aquifer system	A major aquifer system. Ground water occurs generally under water-table conditions. In Cape May County the Cohansey Sand is a confined aquifer
		Bridgeton Formation				
		Beacon Hill Gravel	Gravel, quartz, light-colored, sandy			
		Cohansey Sand	Sand, quartz, light-colored, medium- to coarse-grained, pebbly; local clay beds			
		Kirkwood Formation	Sand, quartz, gray and tan, very fine- to medium-grained, micaceous, and dark-colored diatomaceous clay		Confining unit	Thick diatomaceous clay bed occurs along coast and for a short distance inland. A thin water-bearing sand is present in the middle of this unit
					Rio Grande water-bearing zone [1]	
					Confining unit	
					Atlantic City 800-foot sand	A major aquifer along the coast
				Composite confining unit		Alloway Clay Member or equivalent
	Eocene	Piney Point Formation [1]	Sand, quartz and glauconite, fine- to coarse-grained		Piney Point aquifer	Yields moderate quantities of water
		Shark River Formation				
		Manasquan Formation	Clay, silty and sandy, glauconitic, green, gray, and brown, contains fine-grained quartz sand			Poorly permeable sediments
	Paleocene	Vincentown Formation	Sand, quartz, gray and green, fine- to coarse-grained, glauconitic, and brown clayey, very fossiliferous, glauconite and quartz calcarenite		Vincentown aquifer	Yields small to moderate quantities of water in and near its outcrop area
		Hornerstown Sand	Sand, clayey, glauconitic, dark green, fine- to coarse-grained			Poorly permeable sediments
Cretaceous	Upper Cretaceous	Tinton Sand	Sand, quartz, and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous			
		Red Bank Sand			Red Bank Sand [1]	Yields small quantities of water in and near its outcrop area
		Navesink Formation	Sand, clayey, silty, glauconitic, green and black, medium- to coarse-grained			Poorly permeable sediments
		Mount Laurel Sand	Sand, quartz, brown and gray, fine- to coarse-grained, slightly glauconitic	Wenonah-Mount Laurel aquifer		A major aquifer
		Wenonah Formation	Sand, very fine- to fine-grained, gray and brown, silty, slightly glauconitic	Marshalltown-Wenonah confining bed		A leaky confining bed
		Marshalltown Formation	Clay, silty, dark greenish-gray, glauconitic quartz sand			
		Englishtown Formation	Sand, quartz, tan and gray, fine- to medium-grained; local clay beds	Englishtown aquifer system		A major aquifer. Two sand units in Monmouth and Ocean Counties
		Woodbury Clay	Clay, gray and black, micaceous silt	Merchantville-Woodbury confining bed		A major confining bed. Locally the Mechantville Formation may contain a thin water-bearing sand
		Merchantville Formation	Clay, glauconitic, micaceous, gray and black; locally very fine-grained quartz and glauconitic sand			
		Magothy Formation	Sand, quartz, light-gray, fine- to coarse-grained. Local beds of dark-gray lignitic clay. Includes Old Bridge Sand Member	Potomac-Raritan-Magothy aquifer system	Upper aquifer	A major aquifer system. In the northern Coastal Plain, the upper aquifer is equivalent to the Old Bridge aquifer and the middle aquifer is equivalent to the Farrington aquifer. In the Delaware River Valley, three aquifers are recognized. In the deeper subsurface, units below the upper aquifer are undifferentiated
		Raritan Formation	Sand, quartz, light-gray, fine- to coarse-grained pebbly arkosic; contains red, white, and variegated clay. Includes Farrington Sand Member		Confining bed	
					Middle aquifer	
	Lower Cretaceous	Potomac Group	Alternating clay, silt, sand, and gravel		Confining bed	
					Lower aquifer	
Pre-Cretaceous		Bedrock	Precambrian and Lower Paleozic crystalline rocks, metamorphic schist and gneiss; locally Triassic sandstone and shale and Jurassic diabase are	Bedrock confining bed		No wells obtain water from these consolidated rocks, except along Fall Line

[1]Minor aquifer not mapped in the report.

Modified from Zapecza, 1989

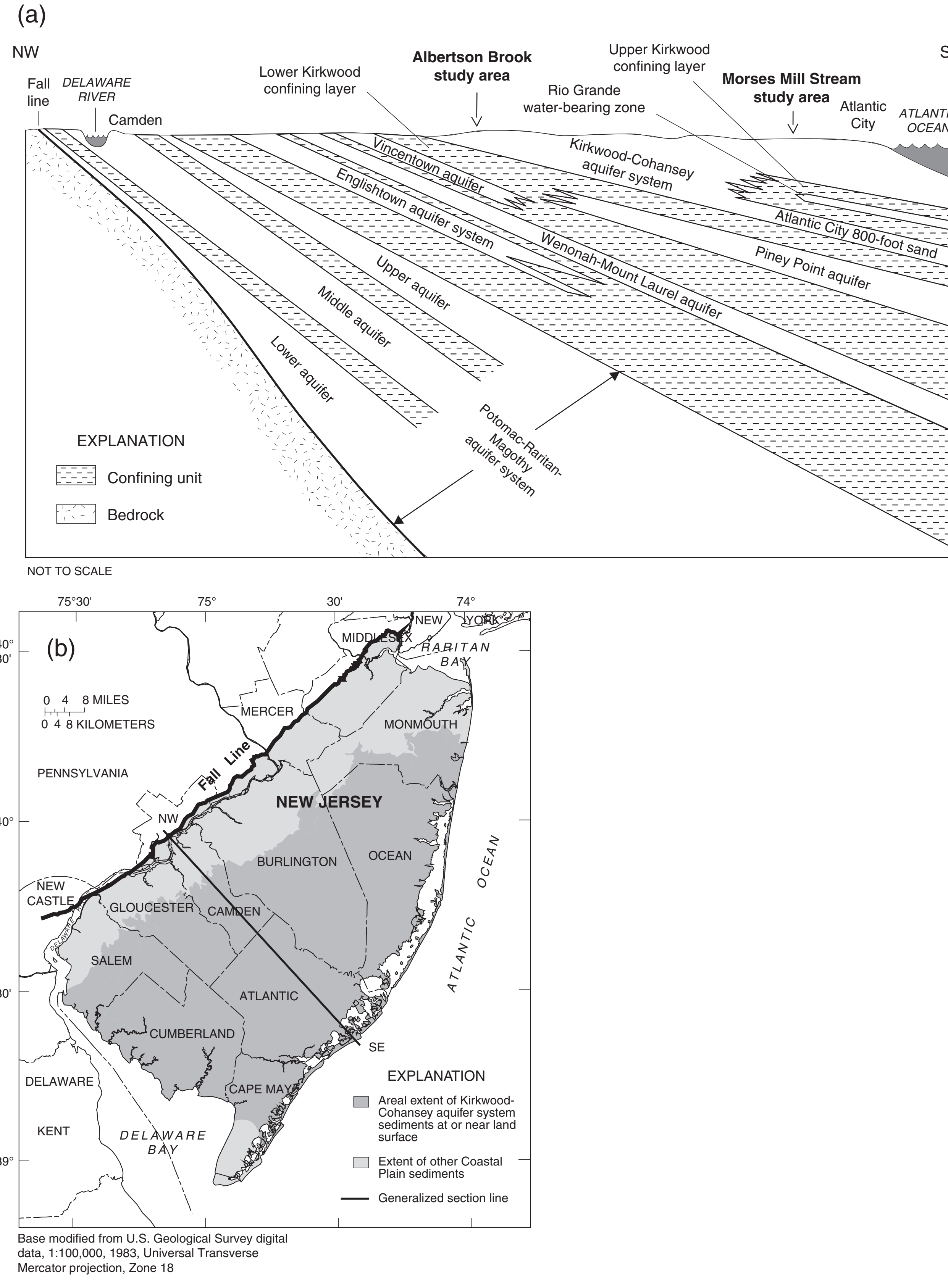


Figure 2. (a) Generalized hydrogeologic section through the New Jersey Coastal Plain (Modified from Zapecza and others, 1987) and (b) line of section.

foundation for ground-water flow modeling of the three study areas. The framework investigations were extended outside the study-area boundaries to provide additional information used to determine the sub-regional structural characteristics of the aquifer system and, thereby, improve the definition of the framework model at the limits of the study areas.

The Kirkwood-Cohansey aquifer system has been described predominantly as a water-table aquifer, within which perched or semi-confined conditions can exist as a result of localized clays (Zapecza 1989). Thus, the framework interpretation ideally represents the structure of the aquifer system in a way that accounts for local lithologic differences, yet conforms to the sub-regional structural and depositional characteristics. The approach for developing the hydrogeologic framework model was to divide the aquifer system into aquifer layers and leaky confining layers that generally conform to the aquifer systems sub-regional structural and depositional characteristics and then describe the aquifer system hydraulic and physical properties associated with those layers.

The methods used to determine the aquifer system properties from well-performance and slug tests are described, including the details of the analytical methods used to calculate horizontal hydraulic conductivity (K). These analyses provided ranges of K values that represent the aquifer system layers at locations where suitable wells were available. In addition, methods of estimating sediment textures within the hydrogeologic framework layers using geophysical and lithologic data are discussed in the following sections.

Data Acquisition

To characterize the hydrogeology of the Kirkwood-Cohansey aquifer system in each study area and to establish the ways this aquifer system interacts with water levels that affect wetlands and surface water, a thorough understanding of the continuity and effectiveness of the individual hydrogeologic layers involved in the processes of transmitting or isolating ground water is needed. Data-collection activities used to define the extent, thickness, and character of the principal hydrogeologic layers in each of the three study areas include

- A search of hydrogeologic literature;
- Evaluation of available geophysical and lithologic data;
- Geophysical logging of boreholes during well drilling;
- Examination of aquifer sediment samples and drill cuttings;
- Collection and analysis of surface geophysical data obtained using ground-penetrating radar (GPR);
- Performing slug tests;
- Collection of well-performance test data; and
- Compilation of a database of geophysical, lithologic, and hydraulic property data.

Data were obtained from multiple sources including the files of New Jersey Department of Environmental Protection (NJDEP), Pinelands Commission, the USGS, and the U. S. Environmental Protection Agency, and records of well drillers, well owners, and previous studies.

Well-Numbering System

Water-level monitoring wells installed during this investigation have a site name composed of the following codes:
A two-letter drainage basin identifier

- MB (McDonalds Branch),
- AB (Albertson Brook),
- MM (Morses Mill Stream);

followed by a two-letter well type code

- OW (Basin cluster observation wells),
- UP (upland water-level wells);

and a well number followed by a letter suffix

- S (shallow),
- M (middle),
- D (deep).

The letter suffixes indicate the relative depth of an individual well within a cluster and are not intended to indicate that the well is screened in a specific hydrogeologic layer of the Kirkwood-Cohansey aquifer system.

Records of wells and boreholes included in this study (table 2 at end of report) were compiled and entered into the USGS Ground Water Site Inventory (GWSI) database (*http://waterdata.usgs.gov/nj/nwis/gwsi*). These sites are identified by the USGS well number (UID), a two-digit county code number followed by a four-digit sequence number, and a unique site name composed of the UID followed by the local site identifier. The county code numbers used in this report are 01 for Atlantic County, 05 for Burlington County, 07 for Camden County, 15 for Gloucester County, and 29 for Ocean County.

Altitude Data

All altitude data presented in this report are referenced to the North American Vertical Datum of 1988 (NAVD88). Altitudes below NAVD88 are preceded by a minus sign (-). Altitudes used in this study have been determined in four ways using differential leveling, from topographic maps, using a surveying altimeter, or from a digital elevation model. All land-surface altitudes were rounded to the nearest foot; the altitude values, the methods used to determine the altitudes, and the levels of accuracy are given in table 2.

Altitude data determined at new wells by level or other surveying method, with an accuracy of 1.0 ft or better, are considered highly accurate and rounded to the nearest foot. All other sites used for the hydrogeologic framework have associated altitude data that were previously manually interpolated from 10-ft interval contours on 7.5-minute topographic quadrangle maps; these are considered accurate to within 5 ft.

A digital version of the 7.5-minute quadrangle maps, referred to as the USGS 10-meter Digital Elevation Model (10-meter DEM) of New Jersey, is a digital cartographic/geographic dataset of altitudes in xyz coordinates derived from contour lines and photogrammetric methods using USGS 7.5-minute topographic quadrangle maps. The 10-meter DEM uses the same source as the historical altitude data, which are manually derived from 7.5-minute quadrangle maps, but the 10-meter DEM also contains updated point data that provide refined altitude values. The 10-meter DEM is considered to be accurate to within 5 ft.

To ensure that the 10-meter DEM was reliable, its grid was contoured and examined for anomalous data. In some localized areas, the contouring revealed altitude errors in the 10-meter DEM, indicating that during the construction of the 10-meter DEM, incorrect values were assigned to unlabeled contours on the quadrangle maps in a few areas. The errors were corrected by comparing the contours with those on the 7.5-minute quadrangle maps. Where the contours were interpreted incorrectly, corrections were applied by cutting out the affected area and patching in the corrected grid values for that area.

The altitudes of pre-existing sites that were originally determined from 7.5-minute topographic quadrangle maps were compared electronically with the corrected 10-meter DEM. Where the original site-altitude data were found to be in error, altitudes were updated in the database with values from the 10-meter DEM. The sites with more accurate altitudes, such as those determined by leveling, were not changed. Thus, the altitude used for a site is always based on the most accurate information available.

Drilling Methods

A total of 21 wells were constructed during this phase of the study in support of both the framework and water-level investigations. In addition, 1 deep boring and 10 shallow borings were completed to obtain lithologic and geophysical data. Locations of wells and borings were selected to fill gaps in the existing stratigraphic and geophysical data, aquire data on hydraulic properties of the aquifer system, and provide for collection of water-level data for another phase of this study.

All 21 wells and the 1 deep boring (051597 MBTB-1) were drilled by constructing open mud-filled boreholes using standard hydraulic rotary drilling methods. The drilling mud was composed of potable water mixed with a bentonite-clay-based drilling fluid additive. To maintain an adequate flow of cuttings from the borehole and to stabilize the borehole wall, the drilling-mud viscosity was tailored to the conditions in the borehole. During drilling, the materials penetrated by the boreholes were described by USGS field staff on the basis of drilling characteristics interpreted by the well driller, visual examination of drill cuttings washed from the hole, and visual examination of 12 aquifer sediment samples collected with a 2-in.-diameter split spoon sampler at selected locations and depth intervals.

Sixteen of the new wells were installed in the three study areas to determine aquifer hydraulic properties and to serve as water-level monitoring sites. The wells were arranged in six, 3-well nests, two nests per study area. At each of two locations, one existing shallow well was used as part of the 3-well nests. At the well nest locations, well screens were usually installed at three depth intervals representing the major water-bearing zones, which are distributed from the base of the Kirkwood-Cohansey aquifer system to the water table. Five additional wells were completed in the shallow part of the surfical aquifer in the upland areas in the McDonalds Branch basin by using the same methods and materials.

All monitoring wells were installed using hydraulic rotary drilling methods by a New Jersey Licensed well driller in accordance with New Jersey State regulations. Wells were constructed of 2-in.-diameter flush joint polyvinyl chloride (PVC) casings with 10-ft-long screens with 0.010-in. slots. All wells were finished above land surface and secured with a steel surface casing with a lockable cap. Pumping and surging methods were used to develop the wells after at least 24 hours had elapsed following well completion. Records of the wells installed are given in table 2 and the lithologic logs are provided (app. 1).

Geologic sediment samples were collected from a total of 10 shallow borings at various locations in the Albertson Brook and McDonalds Branch basins using Geoprobe® sediment-sampling equipment. Using these samples, the lithology penetrated by each boring was described and their lithologic logs are provided (app. 1). These data were used in the interpretation of the hydrogeologic framework and the GPR records presented in the following sections.

Geophysical Methods

Borehole geophysical logs collected in seven of the deep wells or boreholes drilled for this study and more than 27 mi of GPR line were used to obtain information on the subsurface lithology. Interpretations of the data on Coastal Plain sediments acquired using these methods require a working knowledge of the local geology and hydrology, and an understanding of the application and limitation of the methods used. Samples of geologic materials also were collected, examined, and compared with geophysical logs during drilling, and these data combined with historical drilling logs from locations with geophysical data provided the basis for extending the interpretation of the geophysical records. The following sections describe the methods used, technical information related to the acquisition and interpretation of the geophysical data, and the limitations of these methods.

Borehole Geophysical Methods

Borehole geophysical logs are commonly used in ground-water investigations to characterize the subsurface lithology and to correlate stratigraphy. Qualitative analysis of geophysical logs for determining lithology involves using a working knowledge of the local geology while comparing the response on logs with site-specific information, such as cores or other formation samples collected during drilling (Keys, 1987).

Geophysical logs (natural gamma, caliper, and various electric logs including spontaneous potential (VSP), single-point resistance (spr), and normal resistivity logs of 8-, 16-, 32-, and 64-in. electrode spacing), lithologic logs, and observations of drilling characteristics were made at six new wells and one new borehole within the three study basins (app.1). All of the logs were collected in open, mud-filled boreholes to depths ranging from about 182 ft to 250 ft, which is generally at or below the top of the basal clays of the Kirkwood-Cohansey aquifer system. The geophysical logs and lithologic data collected provided the information required for interpretation of the lithology at each of the three areas of study.

The geophysical logs were compared in the field with descriptions of the lithologic samples and with drilling characteristics obtained in a manner that assured, to the greatest extent possible, the collection of representative data. Geophysical log records are interpreted using knowledge of the local geology and an understanding of the responses of logs or of suites of logs to various lithologies. Natural gamma logs typically show higher radiation in clays than in sands and gravels. VSP logs tend to indicate a more negative electrical potential in sands and gravels than in clays, and spr logs usually indicate lower resistance in clays than in sands and gravels. Normal resistivity electric logs typically measure lower electrical resistivity in clays than in sands and gravels. Caliper logs simply measure the borehole diameter. Suites of geophysical logs where large variations in borehole diameter were identified were analyzed by considering the effects of variations in diameter on the response of geophysical logs collected in that suite.

The data obtained from the geophysical logs were used to develop a comprehensive interpretation of the lithology at each well or borehole to guide the selection of screened intervals during well construction and provide the basis for interpreting lithology from other geophysical logs within the geologic settings typical of each study area. These geophysical logs were used later to correlate important hydrogeologic layers throughout the study areas.

Surface Geophysical Methods

GPR is a surface geophysical method designed to investigate shallow earth materials using electromagnetic wave energy (GPR waves) to acquire information about the subsurface. GPR surveys were conducted within the McDonalds Branch, Alberston Brook, and Morses Mill Stream basins to identify the presence, depth, and extent of the first subsurface clay layer that might impede the flow of ground water to or from the streams. The GPR surveys traversed accessible areas, along sand roads and trails.

The survey was conducted using a MALÅ GeoScience RAMAC GPR system equipped with 100 MHz (megahertz) antenna. The antenna, distance measuring wheel, control unit, and the computer used for data acquisition and recording are attached to a sled pulled by the equipment operator. A total of 27 mi of GPR line were surveyed within the three study areas. The data were processed using the MALÅ Geoscience RAMAC GroundVision proprietary software. The GPR radargram, the image generated from the measured GPR data (MALÅ Geoscience, 2003), displays a nearly continuous image representing the subsurface material beneath the GPR line. The radargram is an arithmetic graph of distance over the ground and the travel time of the reflected electromagnetic waves as they are affected by spatial changes in the conductivity-associated lithologic variability as the equipment is moved along the GPR line. The depth of penetration of GPR waves in relatively low conductivity material, such as sand, is typically less than 80 ft using a 100 MHz antenna. Highly conductive materials such as clay will attenuate the GPR waves, such that no electromagnetic energy is reflected from below the top of the first clay. As such, shallow clays mask all other geologic features that may lie beneath.

The depth to the top of a conductive layer, such as clay, is determined by recording the travel time of a reflected wave at a representative velocity. The velocity of electromagnetic wave energy in aquifer sediments was estimated by dividing the known depth of a reflector (based on lithology from borings) by the actual travel time of the electromagnetic wave as measured by the GPR system. The GroundVision software was used to verify the velocity estimate, and if needed, the velocity was adjusted so that the depth of a reflector observed on the radargram matched the depth of the reflector determined from the boring. Using these methods, the GPR wave velocity of saturated aquifer sediments in the three study areas was determined to be about 225 ft per microsecond, a velocity typical of saturated sand (Peter Joesten, U.S. Geological Survey, written commun., 2004).

Based on available lithologic data in the vicinity of the GPR lines and the erosional and depositional features interpreted from the GPR records, the extensive conductive layers identified beneath the GPR lines were interpreted as clay. The tops of the clays were interpreted on the radargram at a depth and (or) travel time where electromagnetic wave reflections cease. Where continuous clays were identified on the GPR record, the location of the clay along the line of the survey was identified by its two endpoints and its approximate mid-point. At these GPR points, the depth to the top of the clay was determined from the GPR record, and the altitude of the GPR point locations was determined from the 10-meter DEM.

Each GPR point was assigned an identifier that consisted of a four-digit line number followed by a letter suffix. Interpretations of previous GPR surveys in the McDonalds Branch basin (Pierre Lacombe, U.S. Geological Survey, written commun., 1990) also identified the extent and depth of clays, and these interpretations were added to the recent GPR data set. Those points are identified by either a BR (Butterworth Road) or BP (Butler Place Road) suffix followed by a two-digit line identifier and a line sequence letter suffix. Sites used in the development of the hydrogeologic framework model are listed in table 2.

A total of 273 GPR data points were interpreted in the three study areas, including 98 in the Albertson Brook, 96 in McDonalds Branch, and 79 in the Morses Mill study areas. These data were used to define the altitude and extent of the tops of the clays and to determine in which hydrogeologic model layer the individual clays were identified. In addition these data were used to describe the distribution and range of textures associated with the near-surface framework model layers.

The variability and density of the localized shallow clays revealed by the continuous GPR data, greatly exceeds the resolution needed for the sub-regional framework models, which are intended for use in ground-water flow models. Sixteen representative GPR data points were selected for use in developing the structure contour maps for the framework model layers; five in the Albertson Brook study area, seven in the McDonalds Branch study area, and four in the Morses Mill Stream study area.

Interpretive Methods

The following sections describe the methods used to compile a representative hydrogeologic data set, methods used to interpret and summarize the hydrogeologic and geophysical data, and the methods used to summarize the interpretations derived from these data. The interpreted data provided critical information about the hydrogeologic framework and the hydraulic and physical parameters needed for the ground-water flow models. All data derived by these methods are stored in the hydrogeologic database, available at the USGS New Jersey Water Science Center.

Database Compilation

Site information extracted from the Ground-Water Site Inventory (GWSI) database was used to populate a hydrogeologic framework database. The hydrogeologic database was prepared in MS Access. The hydrogeologic database is the repository for lithologic and geophysical data used for framework interpretation and includes the interpreted values that represent the tops of aquifers and leaky confining layers and characteristics of the hydrogeologic framework layers. The results of the slug test and well performance analysis are stored in a similar file.

Available well site information—geophysical, lithologic, and geologic data—were evaluated and compiled from multiple sources, including the NJDEP, Pinelands Commission, USGS, U.S. Environmental Protection Agency, well drillers, well owners, and previous studies. Data of acceptable quality were processed for analysis and entered into the hydrogeologic database.

The quality of the lithologic and geophysical data was evaluated to assure the data were acceptable and representative. The assessment of data quality is, in part, subjective, but knowledge and experience of the methods must be employed to assess data acceptability. For example, a lithologic log might be considered questionable when descriptions of sediments do not confirm the data from one or more good quality geophysical log(s) collected from the same location; an obviously poor resolution geophysical log might show no response in a zone where aquifer sediments described in the lithologic log transition abruptly from sand to a thick clay. Determining whether logs that contradict widely recognized geologic units, such as thick regional clay, are representative of the geology may require considerable scientific judgment.

Geophysical logs were preferred over lithologic logs because they generally provide reliable and unbiased information for interpreting and correlating lithology in Coastal Plain sediments. Although the descriptive logs of sediments from borings are useful in understanding lithology, the quality of available lithologic logs is highly variable, largely because descriptions of geologic sediments are often prepared by individuals representing a wide range of experience and interests, sometimes resulting in confusing descriptions that use vague or inconsistent terms to describe the observed sediment cuttings. Further complications include the difficulties in collecting representative samples of cuttings from hydraulic rotary drilled boreholes in unconsolidated sediments. Collection of samples from cuttings requires a thorough knowledge of the hydraulic rotary drilling process, but the ability to collect representative samples demands additional considerations for the travel time and stratification of cuttings in the mud-filled hole and the observed drilling characteristics.

New data collected during 2004-05 include geophysical and lithologic logs obtained from seven deep borings drilled in the study areas and lithologic logs of borings for five shallow wells in the McDonalds Branch study area. These data and the altitudes of the tops of clays interpreted from surface geophysical surveys were included in the hydrogeologic database.

Development of the Hydrogeologic Framework

A geologic data visualization software package called Rockworks ™ was used to process and analyze hydrogeologic data and to provide mapping and interpretative tools for the construction of the hydrogeologic framework models. The data set includes a site identifier (UID), site location, altitude of land surface, lithologic descriptions from drilled boreholes, digital geophysical log data, and interpretations of depths to tops of shallow clays determined from GPR data.

Geophysical log suites, including natural gamma logs, electric, and caliper logs (predominantly natural-gamma logs), were examined with other subsurface lithologic and geologic information to develop a conceptual model of the hydrogeologic framework for each Pinelands study area. The framework models are designed to support the three future study-area ground-water flow models. The approach used for preparing the framework models, discussed previously, divides the Kirkwood-Cohansey aquifer system into aquifer layers and leaky confining layers that reflect the aquifer systems sub-regional, structural and depositional characteristics and defines the range of variability of hydraulic and physical properties in those layers. The erosional and depositional environments of the Cohansey Sand, characterized by Carter (1978) and the Pleistocene age and younger surfical geologic sediments described by Newell and others (2000) provide valuable information that corroborates the apparent discontinuous nature of the lithology within the Cohansey Sand and the character and extent of the younger surficial geologic units. The framework models are intentionally based on the lithologic character of the sediments to a greater extent than the distribution of geologic formations because the framework model layers must support the ground-water flow models, which will represent the hydrogeologic system. The geologic environments leading to the deposition and erosion of the surficial sediments that has been described by previous investigators proved helpful in understanding and describing the variable lithologic character of the aquifer system.

Using the conceptual framework models, Rockworks™ was used to view and correlate geophysical and lithologic data in two-dimensional (2D) vertical sections for multiple sites with all geologic data presented in relation to a common datum. Initially, these sections were oriented along and normal to the recognized formation strike so that the regional dip of the formation could be considered in the interpretation of the framework layers. Using various sectional views, additional correlations were made between adjacent boreholes, the applicability of the conceptual framework model was confirmed, the structure tops of major hydrogeologic layers were finalized, and their depths were recorded in the hydrogeologic database. The altitudes of the tops of the hydrogeologic layers were calculated on the basis of land-surface altitude, rounded to the nearest foot.

Mapping Hydrogeologic Framework Layers

Structure contour maps of the tops of hydrogeologic layers, and thickness maps of these layers were prepared for each of the three study areas using the altitudes determined from geophysical and lithologic data. The Rockworks ™ surface modeling software tool was used to create grid models of each hydrogeologic framework layer. The process involved preparing structure contour maps of the tops of the hydrogeologic layers using the Kriging surface modeling algorithm, which also generated a comparable grid-based data set. For each study area, the boundary coordinates assigned to the modeled hydrogeologic grid layers were located outside the buffer zone (beyond the study area boundary), which allowed the use of all available hydrogeologic data in the immediate area surrounding the study area. These data, although sparse, improved the position of the structure contours at the study area boundary by forcing the edge effects that are commonly associated with limited, sparsely spaced data, to the fringes of the area of investigation. The farther outside the study area boundary the contours are, the more they tend to be of lower accuracy and, thus for illustrative purposes, all contours were clipped to the study area boundaries.

Given that the hydrogeologic layers lay one upon another, the bottom of a layer is the same as the top of the underlying layer. Thus, the thickness of each hydrogeologic layer was determined by calculating the difference in altitude between the modeled top of a layer and the top of the subjacent layer. The results of these calculations generated a thickness grid for each layer, and those grids were used to prepare structure thickness contours using Environmental Systems Research Institute, Inc., (ESRI) ArcGIS Spatial Analyst.

The extent of a layer is defined by the zero thickness contour generated from the grids. Areas where a layer crops out were identified as that area between its zero thickness contour and the position of the zero thickness contour of the overlying layer. All data used to prepare the structure contours are shown on the maps presented in appendixes 2 through 4.

In some areas, the results of the contouring process indicated either considerable stratigraphic variability and (or) possible questionable geophysical and lithological data or interpretations. In these cases, data were re-examined with Rockworks™ using the previously described interpretative process, hydrogeologic section views were examined to identify the cause of the observed variations, and interpretations were adjusted where needed. In a few cases, data determined to be of poor quality were removed from the data set. Because of the known stratigraphic variability of the Kirkwood-Cohansey aquifer system and the scarcity of data in some areas where the data showed consistency with the depositional environments described by Carter (1978) and (or) the surfical sediments described by Newell and others (2000), variability in the data was accepted as indicative of the degree of geologic variability within the aquifer system.

Hydrogeologic Sections

Hydrogeologic sections were prepared for each study area from the final three-dimensional hydrogeologic framework model of each study area, which was created in Rockworks ™ by stacking all of the layer grids. The sections illustrate four cross-sectional views for each study area, tracing point to point through interpreted data points that are located on the sections by a dashed vertical line. The 10-meter DEM was used to depict variations in the altitude of the land surface along the line of section. Gamma logs are shown on the sections where digital logs were available.

Determination of Aquifer System Properties

The process of constructing the hydrogeologic framework revealed considerable spatial variability in the lithologic character and, therefore, the hydraulic properties of aquifers and leaky confining layers within the Kirkwood-Cohansey aquifer system. The observed local variability of sediment textures that makeup the prominent hydrogeologic layers, although consistent with the depositional history of the aquifer system leaves uncertainty as to the distribution and ranges of the hydraulic properties within the aquifer system.

Developing an understanding of the spatial variability of hydraulic properties in the hydrogeologic layers provides a means of estimating their ability to transmit ground water. To examine the variability of hydraulic properties in the aquifer system, estimates of horizontal hydraulic conductivity (K) were made by analyzing results from well-performance tests. Hydraulic conductivity describes the rate at which ground water will move through porous media in a unit time at a unit hydraulic gradient through a cross-sectional area measured at right angles to the direction of ground-water flow (Lohman, 1972). Slug tests were performed to determine K at the location of 16 monitoring wells. In addition, short-term well-performance test data from 136 wells in the three study areas were analyzed to estimate K. These methods are described in the following sections.

In addition to the K values estimated from the two types of well tests, sediment textures reported on lithologic logs and interpreted from geophysical data for each hydrogeologic layer represent the distribution and range of textures in these layers and, therefore, the variability of aquifer system properties. The approach used to interpret these data is described in “Estimation of Spatial Variability of Aquifer System Properties”.

Slug-Test Methods

Slug tests were performed on 16 new wells by using either the air slug (Greene and Shapiro, 1995) or solid slug displacement methods. Air slugs were used for 14 wells where the screen was sufficiently submerged to allow air pressure to displace enough water to produce a reliable test without the risk of the air escaping through the screened interval. The air pressure was used to displace a proportional column of water from the well. Typically, the headspace in the well above the water was pressurized to about 5 to 7 lb/in^2 (11.5-16.2 ft of water). The pressure head was allowed to stabilize to assure there were no air leaks in the slug testing apparatus or well casing. Once the pressure had stabilized, the test was started by instantly releasing the pressure in the well to the atmosphere and simultaneously starting to record the water-level changes. Water-levels were recorded until they had stabilized at or near the initial level prior to pressurization, at which time the test was complete. At least two tests were run on each well.

The air slug method could not be used to create displacement in 4 of the 16 wells because the water table was too close to the screened interval. For these wells, a solid slug was used to displace an equivalent column of water from the well. At least two tests were run on each of these wells. The first of these, a falling head test, was run by quickly inserting the slug to a fixed depth and, at that instant, the test and the water-level recording was begun. Once the water level had fallen and stabilized at the initial level, the test was complete. Next, a rising head test was started by instantly removing the slug and starting the water-level recording. The rising water level was recorded until it had recovered to the initial level.

Water levels before/during/after the slug tests were recorded using a submersible data logger equipped with a pressure transducer. The data loggers were set to record water levels in log time, beginning with a time interval of three-tenths of a second. The water-level records were examined in the field for quality assurance and to determine whether the test was suitable for analysis.

Slug-Test Analysis

Water-level responses from slug tests were plotted in relation to time to determine characteristics needed to calculate K. The start time of the test and the initial static water level were identified from these plots. Typically, the start of the test was considered to be the time of the maximum displacement from the static water level. Time series data prior to initial displacement were removed from the record, and the time data were adjusted by subtracting the new start time from the remaining time data. In some cases the fully recovered water level at the end of the slug test deviated from the initial static water-level measurement by $\pm$ 0.02 ft. In these cases, the final water level was selected as the initial static water level when carrying out the slug test analysis.

The initial water displacement for air slug tests was defined as the maximum displacement from the static water level. In the case of solid slug displacement tests, early-time noise or oscillations were assumed to be caused by surging induced by rapid insertion or removal of the solid slug and not by the aquifer properties. The maximum displacement, in this case, was not considered to be the initial displacement from the static water level, but instead the initial displacement was defined as the onset of a smooth recovery.

Saturated aquifer thickness is a required parameter for each of the methods used for analysis. The total thickness of a layer was determined from the final interpreted framework thickness at each slug test well location. For the deep wells in a confined or semi-confined aquifer layer, where the layer is fully saturated, saturated thickness is equal to the total thickness of the aquifer layer. For shallow unconfined wells, the framework layer may be only partially saturated. In these cases, the thickness of the saturated part of the aquifer layer was used in the analysis.

Hydraulic conductivity for each well tested was determined by analyzing the water-level responses from slug tests. Data from tests at the 16 new wells were analyzed using two analytical methods in the AQTESOLV™ analytical software package, which contains several analytical solutions for slug-test analysis. Both methods involve the graphical matching of theoretical type curves to plots of the water-level response in relation to time. The method of Springer and Gelhar (1991), which is well suited for unconfined formations with highly transmissive zones prone to inertial oscillations, was effective in analyzing the slug test data from four wells screened in unconfined aquifer layers. The method of Butler (1998), which is also effective for analyzing test results for wells in highly transmissive zones, was used to analyze data from 12 wells screened in confined or semi-confined aquifers. Both test methods are appropriate for fully or partially penetrating wells.

In both the Springer-Gelhar (1991) and Butler (1998) slug-test analytical methods, the aquifer is assumed to be infinite in areal extent, homogeneous, isotropic, and of uniform thickness; the potentiometric surface of the aquifer is initially horizontal, and flow is steady. The air or solid slug equivalent column of water is injected or discharged from the well instantaneously. Horizontal hydraulic conductivities calculated using these methods can be assumed to represent the aquifer only in the vicinity of the screened interval. The Butler method is a modification of the Hvorslev method (1951). The Springer-Gelhar method is a modification of the method of Bouwer and Rice (1976); modifications include treatment for oscillatory responses. A summary of the test details and the estimated horizontal hydraulic conductivities are given in table 3.

Well-Performance Tests

Water-transmitting properties of aquifers can be estimated from well-performance tests, such as tests commonly conducted to determine the specific capacity of a well. Specific capacity is a measure of the productivity of a well and is calculated as the pumping rate divided by the resulting drawdown after the well is pumped at the same rate for some period of time (Freeze and Cherry, 1979). Reported well-performance data for 136 wells in the three study areas were retreived from the USGS GWSI database for the purpose of estimating values of hydraulic conductivity.

Values of aquifer transmissivity can be estimated from specific capacity data if the duration of the withdrawal and the well radius are known, assuming that effects of partial penetration, well loss, hydrologic boundaries, and well development are all negligible. Walton (1970, p. 315) presents the following equation to estimate aquifer transmissivity from specific capacity data:

$$\frac{Q}{s} = \frac{T}{264 \log\left[\dfrac{Tt}{2693 r_w^2 S}\right] - 65.5}, \qquad (1)$$

where

$\frac{Q}{s}$ = specific capacity [(gallon/minute)/feet],
Q = discharge (gallon/minute),
s = drawdown (feet),
T = transmissivity [(gallon/day)/feet],
S = storage coefficient (dimensionless),
rw = well radius (feet), and
t = time after pumping started (minutes).

Hydraulic conductivity can then be estimated from the transmissivity value as:

$$K = T/b, \qquad (2)$$

where

K = estimated hydraulic conductivity (feet/day),
T = aquifer transmissivity (feet^2/day), and
b = aquifer thickness (feet).

In addition to specific capacity data for the 136 wells, reported pumping duration, depths to the top and bottom of open intervals, and well radius were used in applying equations (1) and (2). The practical application of equation (1) requires an assumption regarding the storage coefficient. A storage coefficient of 0.15 was assumed. This value is consistent with the range of specific yield values for unconfined aquifers presented by Freeze and Cherry (1979) and with that for the Kirkwood-Cohansey aquifer system presented by Rhodehamel (1973). Other important assumptions used in the calculation are that the effects of partial penetration, well loss, and hydrologic boundaries, as well as the effects of well development on the effective well radius are all negligible. The effects of partial penetration are uncertain because the partial volume of the aquifer that is stressed during these reported tests is unknown. This is because the reported pumping rate and (or) duration may be insufficient to stress the full thickness of the aquifer. An implicit assumption of the method selected for the application of equation (2) is that the thickness of the aquifer strata (b) stressed during the test is equivalent to the length of the screened interval of the well. The relations between the input variables and the estimated transmissivity values also were examined, and a determination was made that the estimated transmissivity values were only slightly affected by the pumping rate, duration, or total pumped volume.
The effects of well loss and the presence of impermeable boundaries (such as production zone pinch-out) could result in a tendency to underestimate transmissivity. The effects of the presence of recharge boundaries (such as nearby streams) and well development could result in a tendency to overestimate transmissivity. The net effect of these uncertainties and assumptions could result in either an over- or underestimation of transmissivity at a particular site. Results obtained using equations (1) and (2) can provide some indication of the likely range of hydraulic conductivities of water-bearing strata and a general indication of the spatial distribution of hydraulic con-

Table 3. Estimated horizontal hydraulic conductivities and details of slug test for the 16 new wells installed in the Kirkwood-Cohansey aquifer system, Pinelands study areas, New Jersey.

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; ft/d, feet per day; Shaded K value identifies the slug test result with the best match between the theoretical curve and measured water levels. These values, along with corresponding well information, are listed in table 4]

U.S. Geological Survey well number (UID)	Local well identifier	Study area	Test number	Method	Estimated hydraulic conductivity (K) (ft/d)	Screened interval (feet)	Aquifer thickness (feet)	Confined / unconfined	Method (air slug or displacement)	Date of test
071092	ABOW1D	AB	T1	Butler	97	10	50	Confined	Air Slug	9/8/2004
071092	ABOW1D	AB	T2	Butler	95	10	50	Confined	Air Slug	9/8/2004
071091	ABOW1M	AB	T1	Butler	23	10	28	confined	Air Slug	9/8/2004
071091	ABOW1M	AB	T2	Butler	28	10	28	confined	Air Slug	9/8/2004
011504	ABOW2D	AB	T2	Butler	32	10	68	confined	Air Slug	8/30/2004
011504	ABOW2D	AB	T3	Butler	32	10	68	confined	Air Slug	8/30/2004
011506	ABOW2M	AB	T1	Butler	70	10	28	confined	Air Slug	8/31/2004
011506	ABOW2M	AB	T2	Butler	70	10	28	confined	Air Slug	8/31/2004
011505	ABOW2S	AB	T5	Springer-Gelhar	115	10	45	unconfined	Air Slug	8/31/2004
011505	ABOW2S	AB	T6	Springer-Gelhar	110	10	44	unconfined	Air Slug	8/31/2004
051556	MBOW1D	MB	T1	Butler	110	10	59	confined	Air Slug	9/20/2004
051556	MBOW1D	MB	T2	Butler	135	10	59	confined	Air Slug	9/20/2004
051557	MBOW1M	MB	T1	Butler	147	10	47	confined	Air Slug	9/20/2004
051557	MBOW1M	MB	T2	Butler	156	10	47	confined	Air Slug	9/20/2004
051560	MBOW2D	MB	T1	Butler	40	10	66	confined	Air Slug	9/16/2004
051560	MBOW2D	MB	T2	Butler	41	10	66	confined	Air Slug	9/16/2004
051558	MBOW2M	MB	T1	Butler	83	10	37	confined	Air Slug	9/20/2004
051558	MBOW2M	MB	T3	Butler	83	10	37	confined	Air Slug	9/20/2004
051559	MBOW2S	MB	T2	Springer-Gelhar	69	10	20	unconfined	Displacement	9/22/2004
051559	MBOW2S	MB	T4	Springer-Gelhar	70	10	20	unconfined	Displacement	9/22/2004
011499	MMOW1D	MM	T2	Butler	36	10	85	confined	Air Slug	9/21/2004
011498	MMOW1M	MM	T1	Butler	74	10	26	confined	Air Slug	9/2/2004
011500	MMOW1S	MM	T2	Springer-Gelhar	65	10	9	unconfined	Displacement	9/21/2004
011500	MMOW1S	MM	T4	Springer-Gelhar	66	10	12	unconfined	Displacement	9/21/2004
011503	MMOW2D	MM	T2	Butler	45	10	89	confined	Air Slug	9/3/2004

Table 3. Estimated horizontal hydraulic conductivities and details of slug test for the 16 new wells installed in the Kirkwood-Cohansey aquifer system, Pinelands study areas, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; ft/d, feet per day; Shaded K value identifies the slug test result with the best match between the theoretical curve and measured water levels. These values, along with corresponding well information, are listed in table 4]

U.S. Geological Survey well number (UID)	Local well identifier	Study area	Test number	Method	Estimated hydraulic conductivity (K) (ft/d)	Screened interval (feet)	Aquifer thickness (feet)	Confined / unconfined	Method (air slug or displacement)	Date of test
011502	MMOW2M	MM	T1	Butler	71	10	17	confined	Air Slug	9/3/2004
011502	MMOW2M	MM	T2	Butler	70	10	14	confined	Air Slug	9/3/2004
011501	MMOW2S	MM	T1	Springer-Gelhar	130	10	37	unconfined	Air Slug	9/3/2004
011501	MMOW2S	MM	T2	Springer-Gelhar	121	10	37	unconfined	Air Slug	9/3/2004
			MEAN K for all tests (ft/d)		78.67					

ductivity in the study areas. Horizontal hydraulic conductivities estimated using well-performance data are listed in table 4 (at end of report).

Estimation of Spatial Variability of Aquifer System Properties

The distribution and range of aquifer system properties within each hydrogeologic layer was estimated at a coarse scale by characterizing sediment textures on the basis of the range of grain sizes reported on lithologic logs and by estimating grain size from geophysical data. These data indicate that within the aquifers and the leaky confining layers, lithology can vary considerably. To illustrate this variability, sediment textures were categorized into five ranges of sand content using the approach described below.

A description of the spatial variability of aquifer system properties was limited to the estimation of sediment textures as a percentage of non-clay content ("sand content" or "percent sand"). Percent sand was described at locations and depth intervals that represent each of the framework layers penetrated by a borehole or well. This approach was limited because it did not allow for differentiating possible ranges of gravel or sand grain sizes and resulted in low percent sand values that simply indicate high clay content.

The percent sand values were estimated as the percentage of a framework model layer thickness that is attributable to the permeable sediment fraction, using the description from a lithologic log and (or) the interpretation of geophysical data at a specific location. Geophysical logs were interpreted using methods described previously, and lithologic logs (drillers or geologists logs) were evaluated in part by interpreting the written log and by relying on the knowledge of how lithologic logs compare with geophysical logs interpreted at other locations within the study area. Percent sand values also were estimated from GPR records, but these values are limited to representing only that thickness of permeable sediments between the top of the framework layer that overlies the interpreted clay and the top of the clay. In this case the actual clay thickness is unknown (see previous GPR discussion in "Geophysical Methods"); thus, the percent sand values may be underestimated. Where the GPR records indicate that a specific layer of the framework model layer contains no clay, percent sand values are correctly stated as mostly sand.

The estimated percent sand values of hydrogeologic layers were illustrated by preparing a data grid using the inverse distance statistical method in Rockworks™. ESRI ArcGIS Spatial Analyst was then used to classify the sand content of the hydrogeologic layers into five categories, ranging from mostly sand (80 to 100 percent sand) to mostly clay (0 to 20 percent sand).

Although it is widely recognized that grain size distribution and hydraulic conductivity are related (Freeze and Cherry, 1979), attempts to correlate K values from the results of slug-test analyses with the percent sand values were unsuccessful because textures were estimated at a coarse scale using lithologic logs and geophysical data. Grain size distribution from sieve analysis could have improved the correlation, but that approach was beyond the scope of this study. In addition the depth intervals commonly were not comparable because the textures represent the entire framework layer thickness, whereas the well-screen intervals were rarely equal to the thickness of the hydrogeologic layers at the well locations.

Hydrogeologic Framework

For each study area, the Kirkwood-Cohansey aquifer system, which Zapecza (1989) describes as a single hydrogeologic layer, was subdivided into seven layers characterized by their predominant grain size textures as aquifers or leaky confining layers. These layers were defined through spatial comparisons of the new geophysical and lithologic data (app.1) and similar available data for the vicinity of each study area. The hydrogeologic framework modeling process described in "Development of the Hydrogeologic Framework" produced three similar but distinctly separate framework models, each one unique to a particular study area. The models, one for each of the three study areas, are described and illustrated in the following sections.

Many hydrogeologic sections were used to the develop the framework models. Twelve sections (four for each study area) were generated to illustrate the framework layers. The sections trace from data point to data point along lines of section, slicing through their associated three-dimensional hydrogeologic framework model to show the relation of the modeled layers to each other and to the land surface. Where available, gamma logs were included to show the distribution of sediment textures and the extent of the sands and clays associated with the leaky confining layers.

As discussed previously, the base of the Kirkwood-Cohansey aquifer system for this study is generally represented by the two different regional basal surfaces described by Zapecza (1989). In the western part of the aquifer system, beneath the Albertson Brook and McDonalds Branch study areas, the base of the aquifer system is the extensive basal clay bed in the lower part of Kirkwood Formation. Although no attempt was made to correlate the basal clay layers between these two study areas, the similarity of altitude of the basal clays to the basal clay described by Zapecza (1989) indicates this basal layer is common to both study areas. Beneath the Morses Mill Stream study area, the base of the aquifer system described previously in the "Hydrogeologic Setting" section is the thick diatomaceous clay, a locally extensive confining bed in the upper part of the Kirkwood Formation.

On the basis of new geophysical data collected for this study, the top of the basal clays in some parts of the study areas are represented by a geologic contact that grades from coarse- to fine-grained sediments over as much as tens of ft. In these cases gamma and electric logs may represent the contact differently because of the composition of the geologic material. Electric logs were usually preferred over gamma logs because, generally, they represented the hydrologically significant top of the basal clay bed more accurately than the gamma logs. As a result of additional geophysical and lithological data collected during this study, some of these interpretations may differ from those of Zapecza (1989).

The deeper hydrogeologic framework layers tend to dip to the southeast and generally conform to the slope of the top of the basal clay in the Albertson Brook and McDonalds Branch study areas. The deeper layers appear to dip to the southeast and conform to the slope of the diatomaceous clay in the Morses Mill Stream study area. The dip of the overlying layers decreases slightly where the layers are closer to the land surface. The tops of the shallower layers generally follow the slope of the drainage basins, more than the deeper layers, reflecting a closer relation to the erosion-incised valleys forming those basins.

With the exception of the basal clay confining beds, the variable and discontinuous nature of clays within the Kirkwood-Cohansey aquifer system was apparent in the geophysical and lithologic records. Low permeability layers appear to be more closely spaced and the presence of discontinuous clays generally more common, in the upper part of the aquifer system, which is principally represented by the Cohansey Sand. The increased presence of clays in this part of the aquifer system is consistent with the depositional environment of the Cohansey Sand, a sequence of regressive barrier and barrier protected deposits that form discontinuous layers of sand, silt, and clay (Carter 1978). In many areas the Cohansey Sand is capped by the Bridgeton Formation, Pleistocene terraces, and (or) younger near-stream deposits. This study treats these surficial geologic sediments as a hydraulically connected part of the upper-most framework model layers that exist in those areas. The hydraulic properties of these surficial deposits were integrated into the framework analysis by considering their depositional environment described by Newell and others (2000) and Carter (1978) while characterizing variations in sediment textures observed in geophysical and lithologic records.

The tops of clays interpreted from GPR data recorded at selected locations illustrate the full linear extent or absence of clays lying beneath the GPR survey lines. Estimation of the depths to the tops of clays was limited by the presence of the first clay or the practical depth investigated by the equipment used, which was generally less than 80 ft. In areas where the first clay obscured all underlying sediments, no GPR data are available to define the presence or extent of the underlying clays. Altitudes of the clay tops determined from GPR data were compared with the framework model, and the hydrogeologic framework model layer within which the clays lie was determined. Although clays were commonly identified in the leaky confining layers, in all study areas, some clay layers were found to lie within the aquifer layers.

Although the Kirkwood-Cohansey aquifer system generally has been considered a water-table aquifer in most areas, localized clays within the aquifers and the relative effectiveness of the leaky confining layers may impede the flow of ground water in varying amounts, depending on the effectiveness of confinement and the duration and magnitude of the hydraulic stresses applied. The available data indicate considerable variation in sediment textures in the hydrogeologic layers; the lack of sufficient available data limits the extent to which these variations can be interpreted. Estimates of hydraulic conductivity derived from slug tests and well-performance tests at previously installed wells (tables 3 and 4) and a general understanding of the distribution and range of textures throughout the thickness of the hydrogeologic layers provides additional information for understanding the spatial distribution of aquifer system properties within and among the modeled layers.

Site information for wells that were used to determine hydraulic conductivity are listed in table 2 by data type code: ST for wells with slug-test data, and WP for wells with well-performance data. Slug tests were conducted in relatively low-yielding, small-diameter wells with short screen intervals (figs. 3-5); for these wells, K values represent point values for specific aquifer layers. Some wells used to estimate K from well-performance tests were of high capacity, have long screened intervals that penetrate leaky confining layer boundaries, and are open to multiple layers of the framework. In these cases, the K values represent multiple hydrogeologic framework model layers of the aquifer system. The hydrogeologic layers penetrated by the well screens are identified in table 4. The mean hydraulic conductivity values determined from various well tests in the three study areas ranged from 84 to 130 ft/d. The estimated K values from well tests are consistent with those reported by Rhodehamel (1973) for the Kirkwood-Cohansey aquifer system, which ranged from 90 to 130 ft/d in the general vicinity of the study areas. K values for the study areas are discussed in the following sections.

Hydrogeology of Albertson Brook Study Area and Vicinity

The base of the Kirkwood-Cohansey aquifer system in the vicinity of the Albertson Brook study area (fig. 2) is the regionally extensive basal clay bed in the lower part of the Kirkwood Formation (Zapecza, 1989). In this area, the Kirkwood-Cohansey aquifer system is composed of sand, gravel, and clay that typically grade to fine sand, silt, and clay near the base of the aquifer system, forming a gradational contact with the basal clay confining bed.

The Albertson Brook study area lies at the approximate southern limits of the Central Uplands described by Newell and others, (2000). From this area to the south, the upper delta plain deposits of the Miocene Bridgeton Formation overlie the Cohansey Sand with an unconformable contact. The Bridgeton Formation is generally a coarse-grained fluvial deposit,

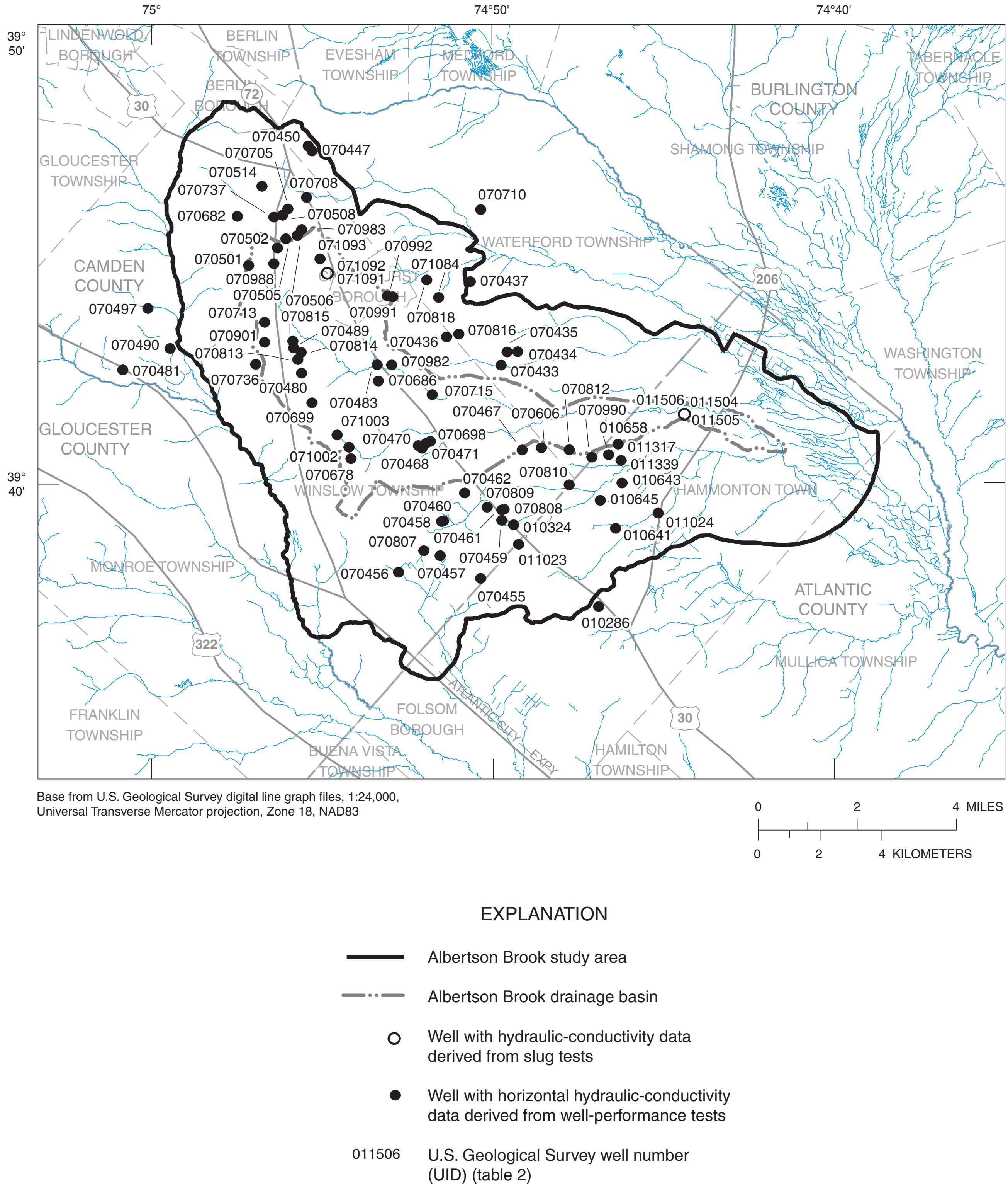
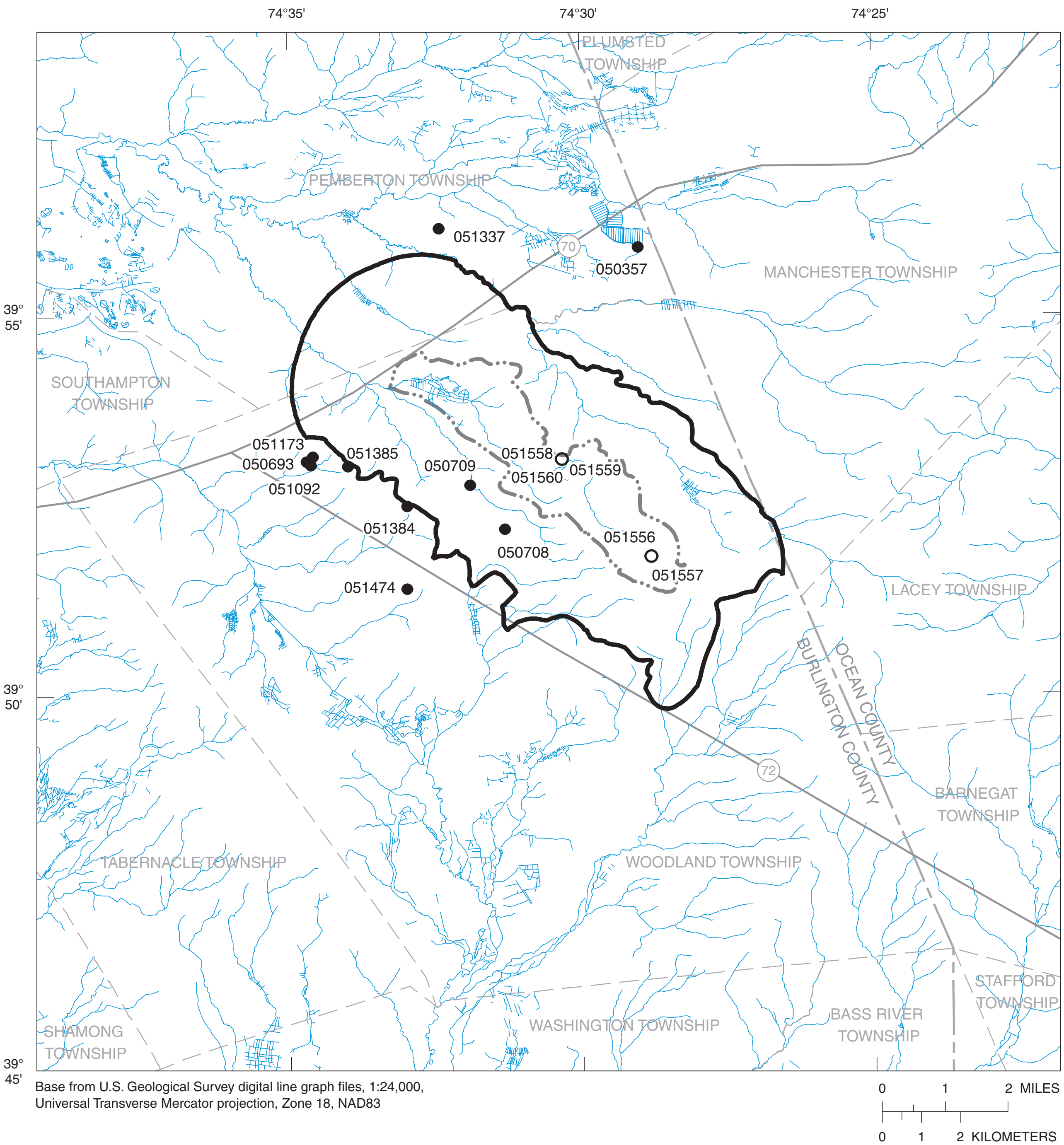


Figure 3. Location of wells with horizontal hydraulic-conductivity data, Albertson Brook study area and vicinity, New Jersey Pinelands.



EXPLANATION

McDonalds Branch study area

McDonalds Branch drainage basin

Well with hydraulic-conductivity data derived from slug tests

Well with horizontal hydraulic-conductivity data derived from well-performance tests

011506 U.S. Geological Survey well number (UID) (table 2)

Figure 4. Location of wells with horizontal hydraulic-conductivity data, McDonalds Branch study area and vicinity, New Jersey Pinelands.

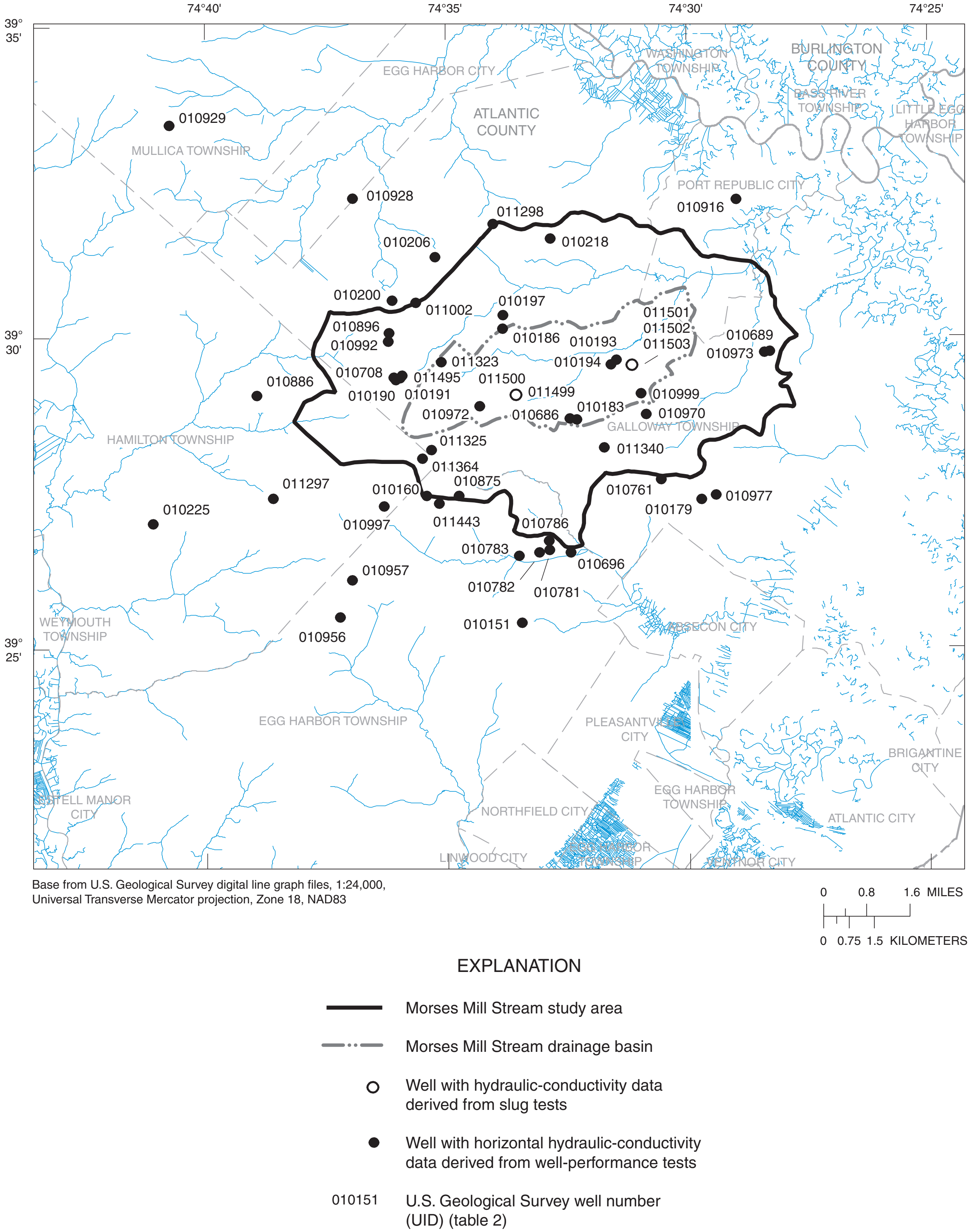


Figure 5. Location of wells with horizontal hydraulic-conductivity data, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

with numerous channel bars forming the higher topographic features within the study area. In the areas flanking the drainages, the Bridgeton Formation is absent where downcutting of stream valleys has exposed the Cohansey Sand. In these areas, Pleistocene to Holocene age deposits commonly are present near the streams and swamps. The shallowest framework layers consist of the surficial geologic sediments described by Newell and others (2000). Depending on location, the uppermost hydrogeologic layers may consist of highly permeable sediments of the Bridgeton Formation and (or) the sediments of the Cohansey Sand, which are capped locally with Pleistocene to Holocene age deposits.

The upper tributaries of the Albertson Brook basin drain from the upper delta plain deposits of the Bridgeton Formation northeast of the Egg Harbor River basin (not shown). In the lower part of the Albertson Brook basin, Pleistocene age terraces, and slope and valley deposits of the Central Uplands border the stream channel where the Albertson Brook drains to the Mullica River and Atlantic coast (Newell and others, 2000).

Soils in the Albertson Brook study area are generally well-drained sandy loams and loamy sands with a moderate to rapid permeability; permeability is reduced in areas of shallow water table, where hydric soils are present and where muck soils are common in the areas of streams and swamps (Markley, 1965).

The hydrogeologic framework of the Albertson Brook study area is represented by four aquifer layers separated by three leaky confining layers and a basal confining layer generally represented by the basal clay bed in the lower part of the Kirkwood Formation described by Zapecza (1989). The following list describes the hydrogeologic framework layers for the Albertson Brook study area and presents their identifiers.

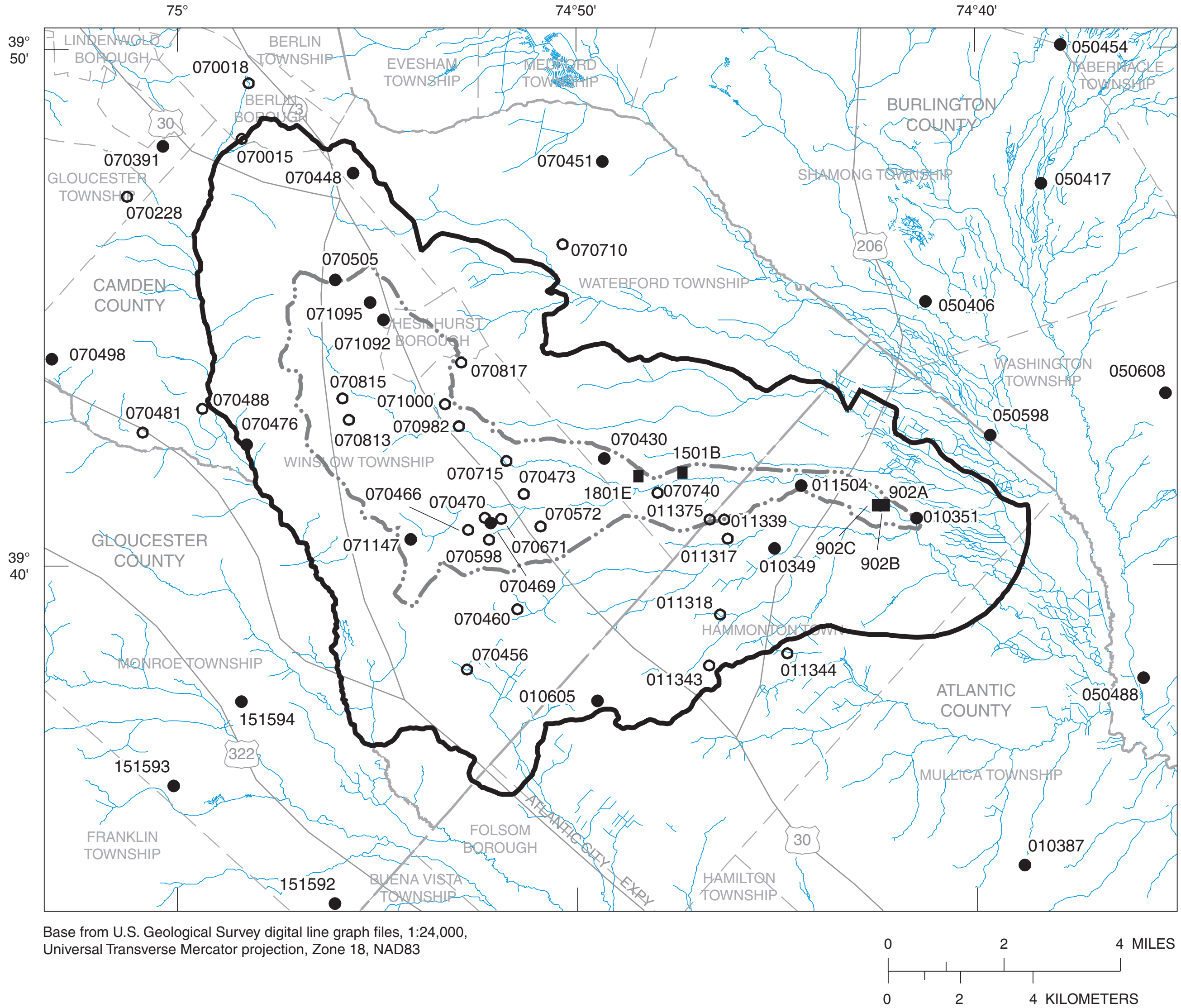
Layer identifier	Description of the hydrogeologic framework of the Albertson Brook study area
AB A-1	Upper aquifer - upper layer
AB A-1C1	Upper leaky confining layer
AB A-1B	Upper aquifer - lower layer
AB C-1	Middle leaky confining layer
AB A-2	Middle aquifer
AB C-2	Lower leaky confining layer
AB A-3	Lower aquifer
AB C-3	Lower Kirkwood basal clay

The location of the 57 sites including wells and selected GPR data points used to describe the hydrogeologic framework for the Albertson Brook study area are shown in figure 6. Detailed site information is provided in table 2. The altitudes of the tops of the hydrogeologic layers in the Albertson Brook study area and vicinity are listed in table 5.

Four hydrogeologic sections (A-A', B-B', C-C', and D-D') were generated from geophysical and lithological data for selected well and borehole sites (table 2) in the Albertson Brook study area. The location of these sections are shown in figure 7. Two sections, A-A' and B-B', (figs. 8 and 9) trace from site to site, slicing through the framework model from the southeast and following the general orientation of the drainage basin and the direction of the regional dip of Coastal Plain sediments. The two other sections, C-C' and D-D', (figs. 10 and 11) cross the basin normal to the southeast trending sections. The distribution of fine-textured sediments illustrated by the gamma logs indicates the variable nature of the sands and clays associated with the framework layers.

Structure contours were prepared from the altitudes of the tops of seven of the hydrogeologic layers listed in table 5 using methods described previously. A contour map was not prepared for the top or the AB A-1 layer because, where the layer exists, it is the same as the land surface and is best described by the 10-meter DEM. Thickness maps were prepared for seven of the hydrogeologic layers, but none was prepared for the lower Kirkwood confining layer, AB C-3, because the thickness of this layer was not investigated during this study. (See Zapecza, 1989, pl. 23.) The distribution and range of textures estimated for the hydrogeologic layers are shown on the thickness maps. In addition, K values representing individual framework layers are shown on their respective thickness maps so that the distribution of K and the textures can be compared. K values estimated from well-performance tests (table 4) in the Albertson Brook basin ranged from 11 ft/day to 608 ft/day, and the average K was 130 ft/day. The structure contour and thickness maps are presented in appendix 2-1 through 2-14.

The results of the GPR surveys in the Albertson Brook study area (fig. 12) confirm the variabilty of the altitude of the tops of clays near the Albertson Brook stream. In the areas investigated in the upper part of the basin, GPR records indicated relatively few places where coarse sediments in any one hydrogeologic layer are continuous down to the top of the AB C-1 leaky confining layer. In this area a continuous clay principally associated with the AB A-1C1 leaky confining layer was identified (fig. 12). The AB A-1 aquifer layer obscured all underlying sediments in a few areas, and the AB A-1C1 layer obscured the other layers below. GPR records also indicate the presence of erosional and depositional features in several areas where sloping bedding planes were revealed in the coarse-grained media, and (or) the tops of clays appear to be sloping, truncated, or absent. These conditions appear to be more common in the lower (eastern) part of the Albertson Brook basin where fewer clays were identified near Albertson Brook than in the upper part of the basin. Given the depositional history of the Cohansey Sand, it is also possible that some clays simply represent discontinuous lenses that are eroded to the slope of the drainage basin and may not be remnants of a single layer. For the purpose of the framework model, however, these clays are considered to represent one leaky confining layer of low permeability sediments.



EXPLANATION

	Albertson Brook drainage basin	●	Well or borehole with geophysical log
	Albertson Brook study area	■	GPR interpretation point
o	Well or borehole with lithologic log	010349	U.S. Geological Survey well number (UID) (table 2)
		902B	GPR point identifier number. The site name listed in table 2 is the GPR point identifier number preceded by the basin code and data type (ex. ABGPR902B)

Figure 6. Location of boreholes, wells, and ground-penetrating radar (GPR) data points used to describe the hydrogeologic framework of the Albertson Brook study area and vicinity, New Jersey Pinelands.

Table 5. Altitudes of tops of hydrogeologic layers of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

[UID, Unique Identification Number; *, no data; AB, Albertson Brook; NAVD88, North American Vertical Datum 1988]

U.S.Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD88)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD88)							
			AB A-1	AB A-1C1	AB A-1B	AB C-1	AB A-2	AB C-2	AB A-3	AB C-3
010349	010349-- MULLICA 2D	58	58	40	28	10	-9	-26	-53	-140
010351	010351-- 23S	38	38	26	11	-7	-24	-53	-78	*
010387	010387-- OBS 6	61	61	18	6	-14	-42	-77	*	*
010605	010605-- 30/BLOCK 1709 TW	110	110	72	58	32	-2	-24	-50	-148
011317	011317-- IRR 5	70	70	53	40	18	-3	-21	-49	*
011318	011318-- IRR 3	71	71	47	36	*	*	*	*	*
011339	011339-- IRR 4	64	64	48	36	16	-6	*	*	*
011343	011343-- IRR 6	85	85	58	41	17	-12	*	*	*
011344	011344-- IRR-7	60	60	45	31	10	-19	-42	-76	*
011375	011375-- IRR 7	72	72	56	44	22	-2	-22	-48	*
011504	011504-- AB OW-2D	56	56	37	29	4	-8	-36	-54	-122
050406	050406-- IW44 ATSN T B	45	*	45	35	15	-14	-32	-49	-133
050417	050417-- MULLICA 10D	47	47	41	32	17	0	-24	-45	-138
050454	050454-- MULLICA 3D OBS	65	65	45	35	20	7	-25	-45	-98
050488	050488-- BATSTO 2	36	36	9	-4	-24	-66	-102	-121	-268
050598	050598-- MULLICA 11D	33	33	14	5	-8	-30	-48	-79	*
050608	050608-- MULLICA 4D OBS	62	62	-4	-15	-34	-59	-72	-100	-164
070015	070015-- BERLIN PW 11	149	*	*	*	149	138	103	79	14
070018	070018-- BERLIN PW 9	146	*	*	*	146	134	100	80	33
070228	070228-- VOC&TECH 1	144	*	*	*	144	132	108	87	16
070391	070391-- OVERBROOK HS 1	167	93	83	69	160	139	102	85	15
070430	070430-- MULLICA 7D	93	93	83	69	45	22	8	-23	-90
070448	070448-- WINSLOW 6	160	121	111	154	120	98	70	49	-9
070451	070451-- MULLICA 1D	121	121	111	100	83	71	39	9	-56
070456	070456-- TEST 1	98	104	78	79	55	19	-8	-32	-119
070460	070460-- IND 1	104	104	78	71	45	18	-6	-37	-119

Table 5. Altitudes of tops of hydrogeologic layers of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.—Continued

[UID, Unique Identification Number; *, no data; AB, Albertson Brook; NAVD88, North American Vertical Datum 1988]

U.S.Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD88)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD88)							
			AB A-1	AB A-1C1	AB A-1B	AB C-1	AB A-2	AB C-2	AB A-3	AB C-3
070466	070466-- DISCONTINUED 2	119	119	104	89	68	37	9	-25	-93
070469	070469-- DISCONTINUED 3	110	110	96	84	68	39	5	-25	-93
070470	070470-- TEST WELL 4	110	110	96	85	63	35	7	-25	-95
070473	070473-- FARM	104	*	92	82	61	38	11	-21	-95
070476	070476-- NEW BR. PARK 1	110	*	*	*	114	86	65	34	-37
070481	070481-- 3-1973	123	*	*	*	114	99	79	50	*
070488	070488-- 2 OBS	113	*	*	*	113	102	67	42	*
070498	070498-- 4-1971 OBS	143	174	169	150	143	135	104	86	*
070505	070505-- REGIONAL H S 1	174	174	169	150	119	98	69	44	-103
070572	070572-- ELMTOWNE VIL 1	107	110	87	74	56	31	7	-25	-103
070598	070598-- WINSLOW 1	110	110	96	85	60	31	6	-22	*
070671	070671-- INSTITUTIONAL 7	104	104	95	85	63	37	7	-25	*
070710	070710-- DOM	110	*	110	99	85	75	32	11	*
070715	070715-- DOM 1	91	69	56	91	68	41	17	*	*
070740	070740-- PZ 3	70	69	56	124	95	81	46	*	*
070813	070813-- IRR 2	138	138	134	124	95	81	46	*	*
070815	070815-- IRR 1	141	136	140	126	99	85	25	7	*
070817	070817-- IRR 1988	136	136	115	106	84	61	25	7	*
070982	070982-- ENVIRON CTR 1	106	*	*	101	74	52	24	-9	*
071000	071000-- IRR 2	125	*	35	106	78	56	*	*	*
071092	071092-- AB OW-1D	156	155	145	131	107	91	51	25	-25
071095	071095-- WELL 2	157	*	*	*	112	93	59	30	
071147	071147-- REPL	138	138	109	98	66	39	16	-19	-90
151592	151592--TEST 2	101	100	80	62	30	-9	-34	-54	-126
151593	151593-- COLES MILL TEST	117	*	104	93	70	42	17	-9	-73
151594	151594-- BLK HORSE TEST	113	*	110	93	70	47	18	-9	-66

Table 5. Altitudes of tops of hydrogeologic layers of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.—Continued

[UID, Unique Identification Number; *, no data; AB, Albertson Brook; NAVD88, North American Vertical Datum 1988]

U.S.Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD88)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD88)							
			AB A-1	AB A-1C1	AB A-1B	AB C-1	AB A-2	AB C-2	AB A-3	AB C-3
*	ABGPR-0902A	48	*	35	*	*	*	*	*	*
*	ABGPR-0902B	43	*	30	*	*	*	*	*	*
*	ABGPR-0902C	41	*	29	*	*	*	*	*	*
*	ABGPR-1501B	71	*	58	*	*	*	*	*	*
*	ABGPR-1801E	89	155	70	131	107	91	51	25	-25

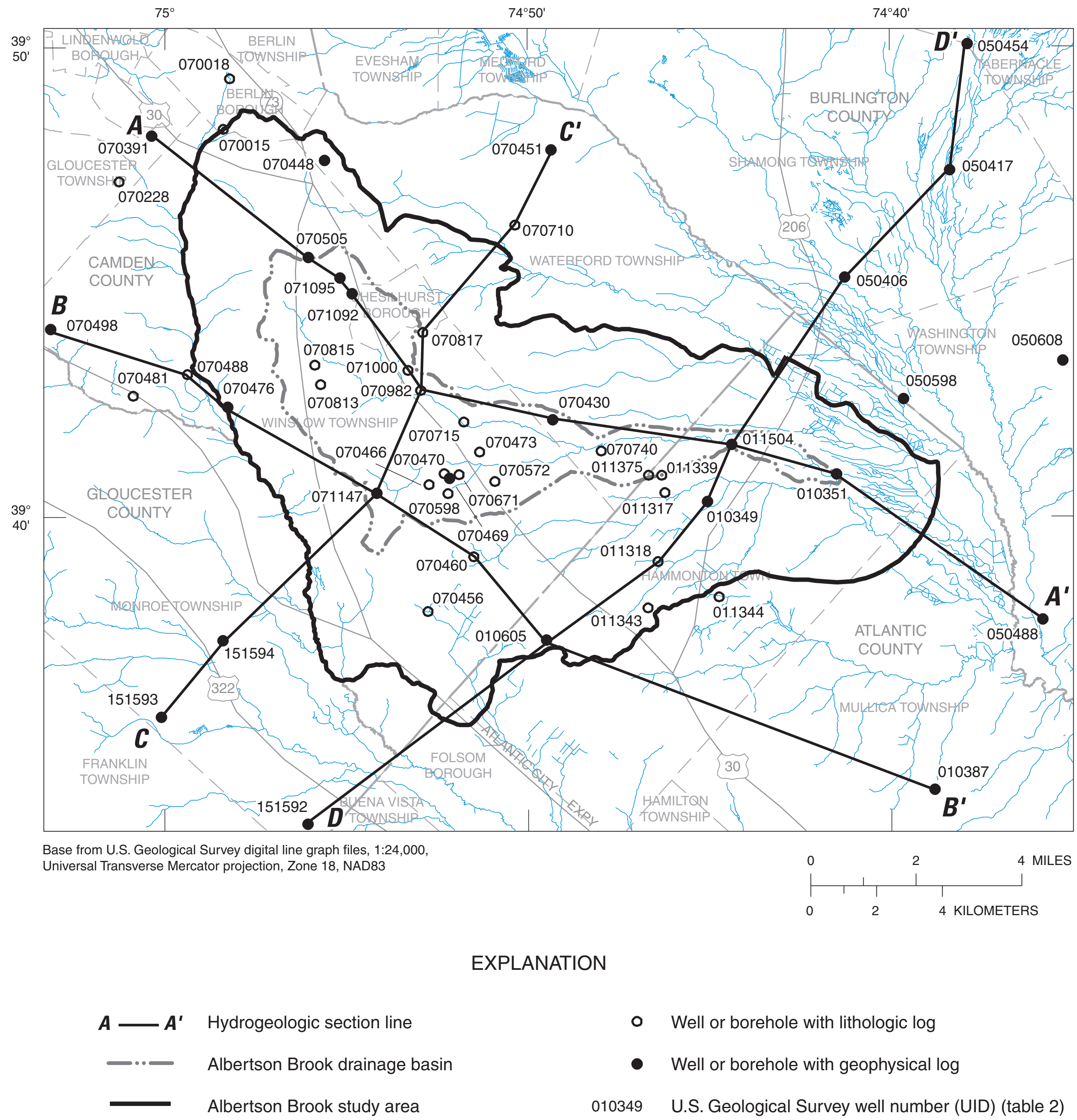
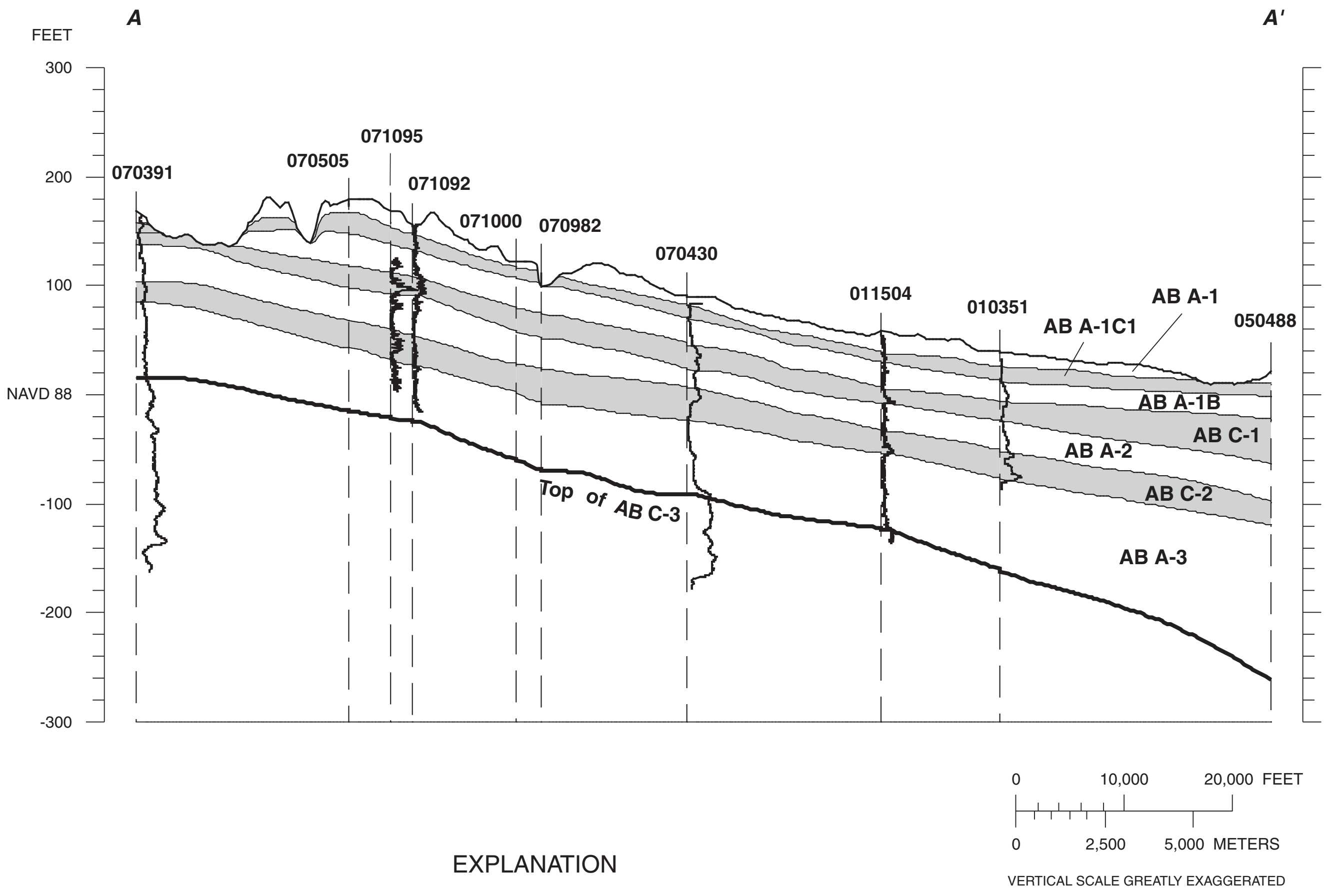


Figure 7. Location of hydrogeologic lines of section, and wells or boreholes with lithologic or geophysical data, Albertson Brook study area and vicinity, New Jersey Pinelands.



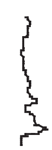
EXPLANATION

070391 — Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

AB — Albertson Brook

GAMMA LOG

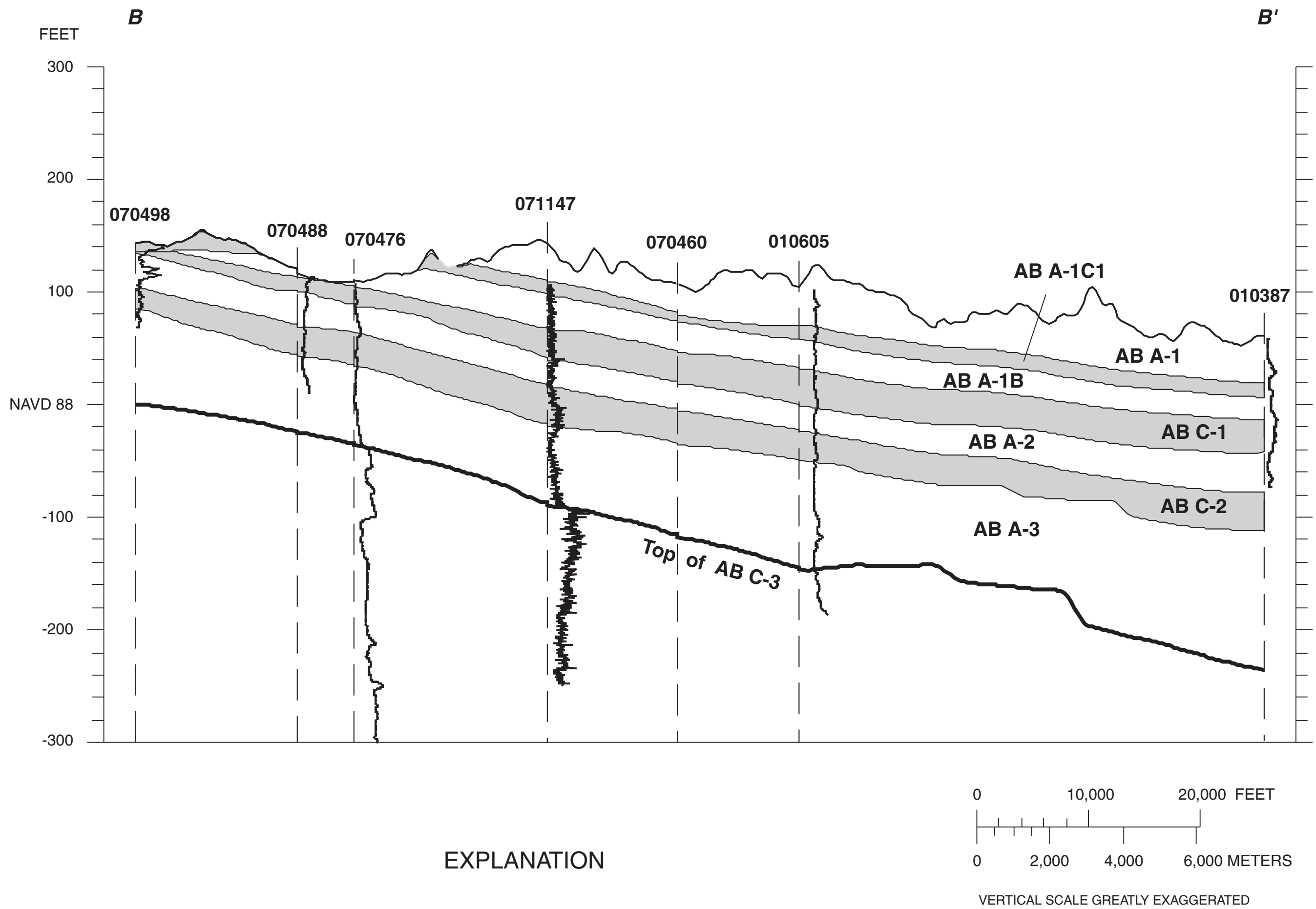
RADIATION INCREASES →



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Alberston Brook study area.

Layer	Description
AB A-1	Upper aquifer - upper layer
AB A-1C1	Upper leaky - confining layer
AB A-1B	Upper aquifer - lower layer
AB C-1	Middle leaky - confining layer
AB A-2	Middle aquifer
AB C-2	Lower leaky - confining layer
AB A-3	Lower aquifer
AB C-3	Lower Kirkwood - confining layer

Figure 8. Hydrogeologic section *A-A′*, Albertson Brook study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 7.)



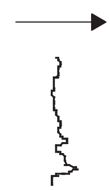
EXPLANATION

070498 Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

AB Albertson Brook

GAMMA LOG

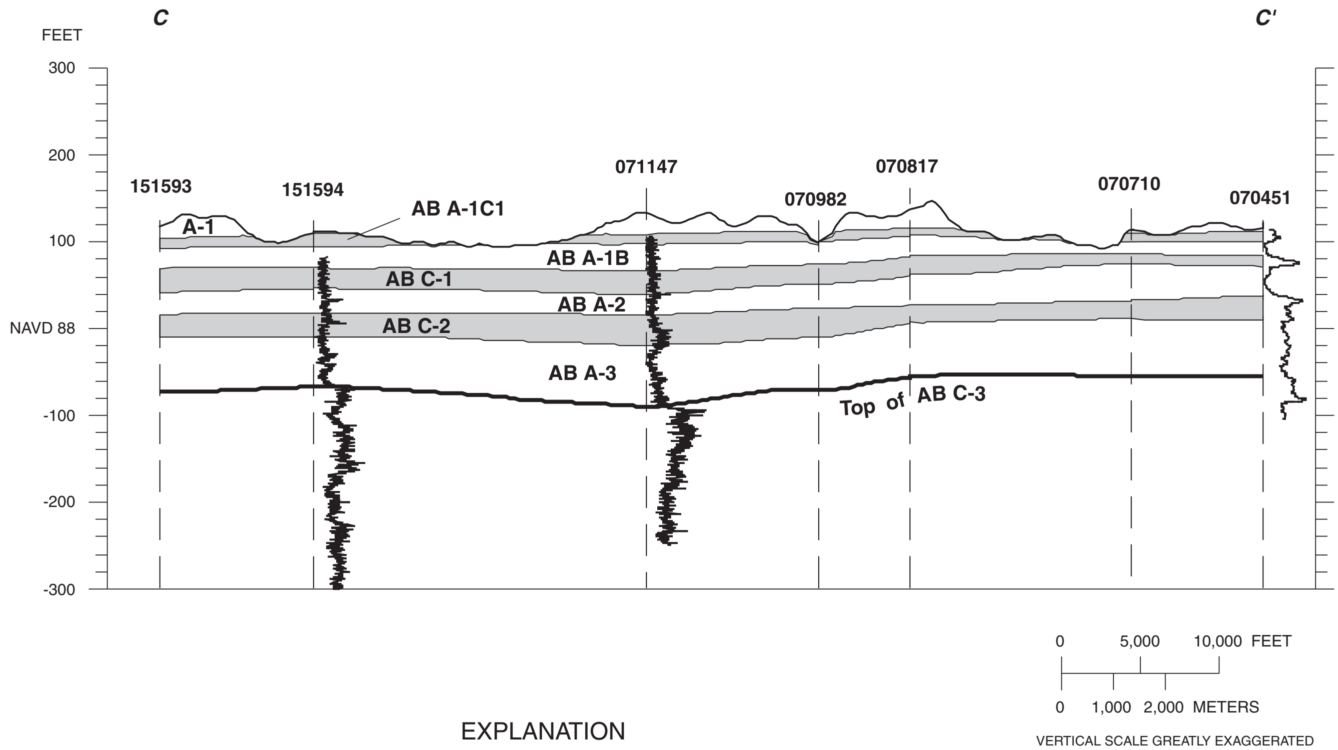
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Alberston Brook study area.

Layer	Description
AB A-1	Upper aquifer - upper layer
AB A-1C1	Upper leaky - confining layer
AB A-1B	Upper aquifer - lower layer
AB C-1	Middle leaky - confining layer
AB A-2	Middle aquifer
AB C-2	Lower leaky - confining layer
AB A-3	Lower aquifer
AB C-3	Lower Kirkwood - confining layer

Figure 9. Hydrogeologic section *B-B′*, Albertson Brook study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 7.)



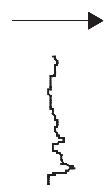
EXPLANATION

151593 Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

AB Albertson Brook

GAMMA LOG

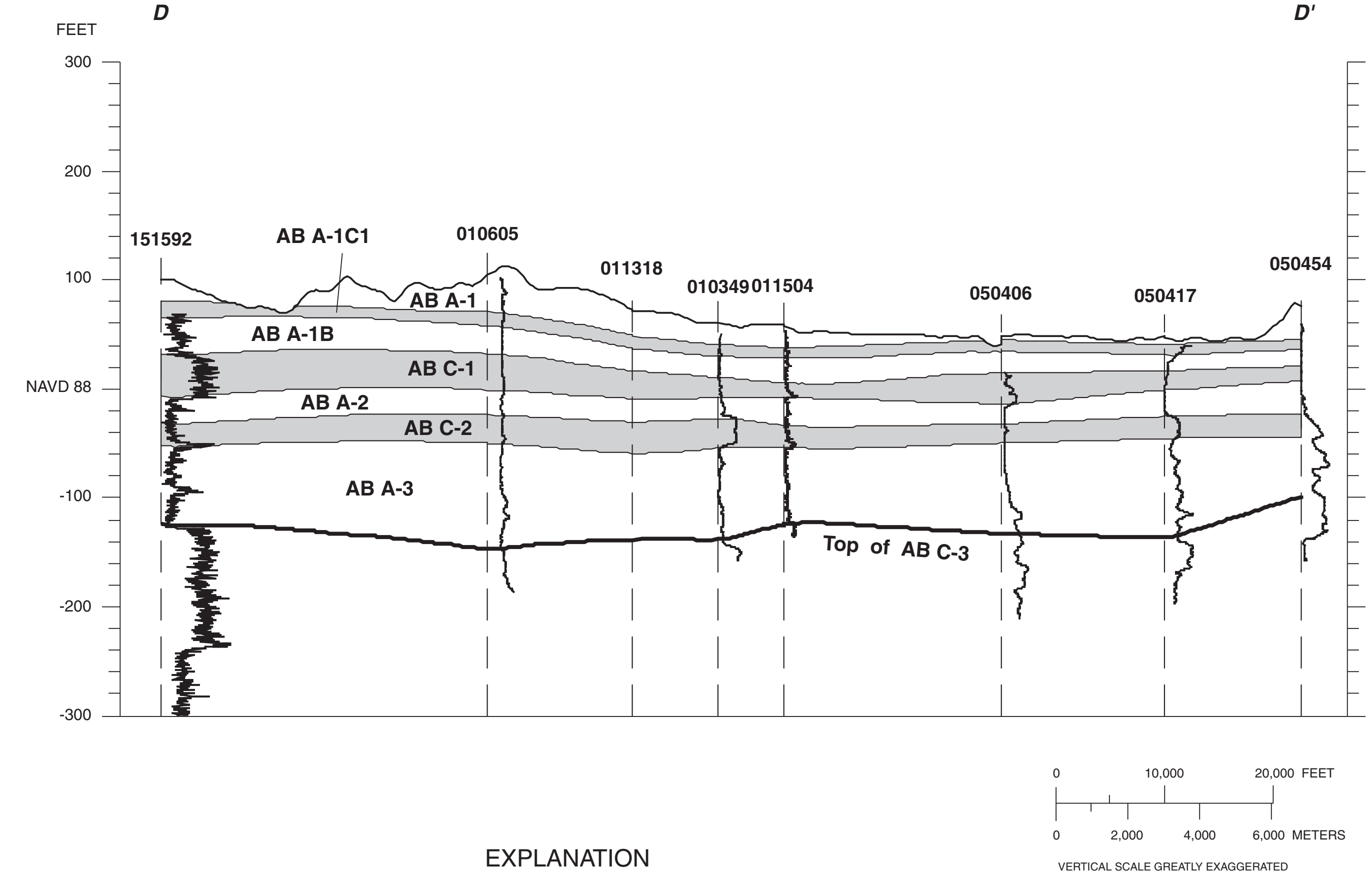
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Alberston Brook study area.

Layer	Description
AB A-1	Upper aquifer - upper layer
AB A-1C1	Upper leaky - confining layer
AB A-1B	Upper aquifer - lower layer
AB C-1	Middle leaky - confining layer
AB A-2	Middle aquifer
AB C-2	Lower leaky - confining layer
AB A-3	Lower aquifer
AB C-3	Lower Kirkwood - confining layer

Figure 10. Hydrogeologic section *C-C′*, Albertson Brook study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 7.)



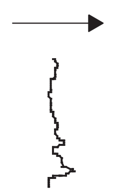
EXPLANATION

151592 Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

AB Albertson Brook

GAMMA LOG

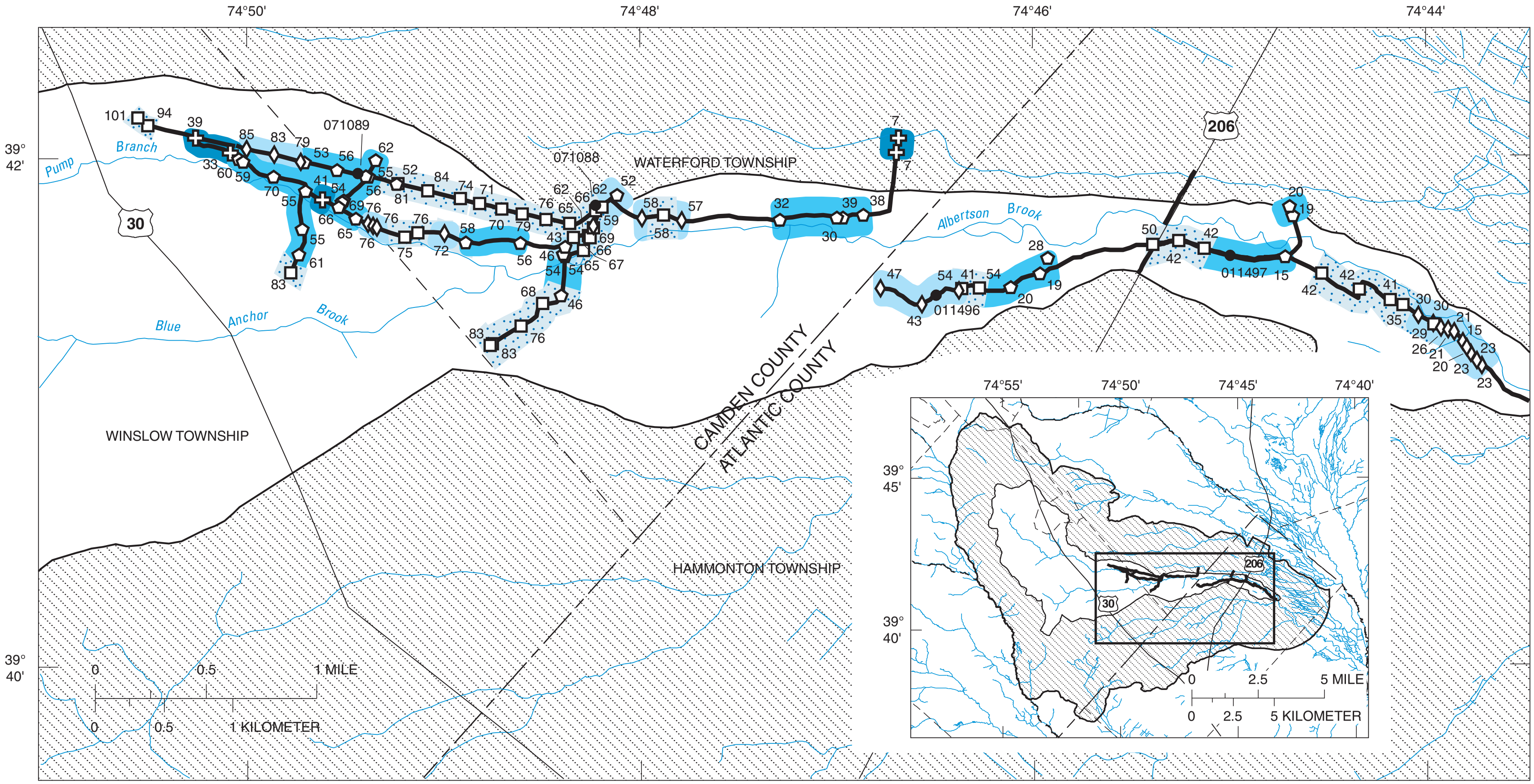
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Alberston Brook study area.

Layer	Description
AB A-1	Upper aquifer - upper layer
AB A-1C1	Upper leaky - confining layer
AB A-1B	Upper aquifer - lower layer
AB C-1	Middle leaky - confining layer
AB A-2	Middle aquifer
AB C-2	Lower leaky - confining layer
AB A-3	Lower aquifer
AB C-3	Lower Kirkwood - confining layer

Figure 11. Hydrogeologic section *D-D'*, Albertson Brook study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 7.)



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Estimated extent of clay along GPR survey lines

- AB A-1 aquifer layer
- AB A-1C1 leaky confining layer
- AB A-1B aquifer layer
- AB C-1 leaky confining layer
- Albertson Brook study area

Ground penetrating radar survey line

Albertson Brook drainage basin

50 Clay identified in the AB A-1 aquifer layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

47 Clay identified in the AB A-1C1 leaky confining layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

32 Clay identified in the AB A-1B aquifer layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

7 Clay identified in the AB C-1 leaky confining layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

051550 Shallow boreholes used to interpret GPR surveys. Number is the USGS well number (UID) (table 2).

Figure 12. Results of ground-penetrating radar (GPR) surveys used to describe the hydrogeologic framework of the Albertson Brook study area and vicinity, New Jersey Pinelands.

Hydrogeology of McDonalds Branch Study Area and Vicinity

The base of the Kirkwood-Cohansey aquifer system in the vicinity of the McDonalds Branch study area is the regionally extensive basal clay bed in the lower part of the Kirkwood Formation (Zapecza, 1989). This is the same basal confining bed as that described previously for the Albertson Brook study area; this determination is based on a comparison of the altitude of the top of this basal clay unit with that of Zapecza (1989). As in the Albertson Brook basin, the sands, gravels, and clays in the upper layers of the Kirkwood-Cohansey aquifer system grade to fine sand and eventually silts and clays near the base, forming a gradational contact with the basal clay bed in the lower part of the Kirkwood Formation (Zapecza, 1989; fig. 2).

The McDonalds Branch study area lies within the Central Uplands of the Coastal Plain. In this area, the heavily weathered and eroded upper surface of the Cohansey Sand is capped mostly with Quaternary terraces formed in extensively variable depositional environments. The present day physiographic features depict highly dissected terraces flanked by slope deposits and broad, low gradient valleys covered with sands and gravels eroded from nearby deposits (Newell and others, 2000). Surficial geologic maps by Newell and others (2000) illustrate localized exposures of the Cohansey Sand in the upper part of the McDonalds Branch basin. Pleistocene to Holocene age swamp deposits lie along the stream channels throughout most of the basin. The shallowest hydrogeologic framework layers consist of sediments of the surficial geology described by Newell and others (2000). These layers, depending on location, may contain clay and highly permeable sediments eroded from the Quaternary age terrace and slope deposits that cap much of the Cohansey Sand in this area, the Holocene to Pleistocene age deposits that are found near the streams and swamps, or sediments of the Cohansey Sand where it is exposed in the upper part of the drainage basin.

The headwaters of the McDonalds Branch basin lies on the western slope of the basin divide between the Delaware River and Atlantic Coast basins (not shown). The McDonalds Branch stream winds through an eroded westerly trending valley that drains to the Delaware River through the Rancocas Creek. Soils in the McDonalds Branch basin are principally well-drained deep or loamy sands except where hydric soils are present in areas where the water table is shallow and where muck is present in the vicinity of the swamps and streams (Lord and others, 1990).

The hydrogeologic framework of the McDonalds Branch study area is represented by four aquifer layers separated by three leaky confining layers and a basal confining layer generally represented by the clay confining bed in the lower part of the Kirkwood Formation described by Zapecza (1989). The following list describes the hydrogeologic framework layers for the McDonalds Branch study area and presents their identifiers.

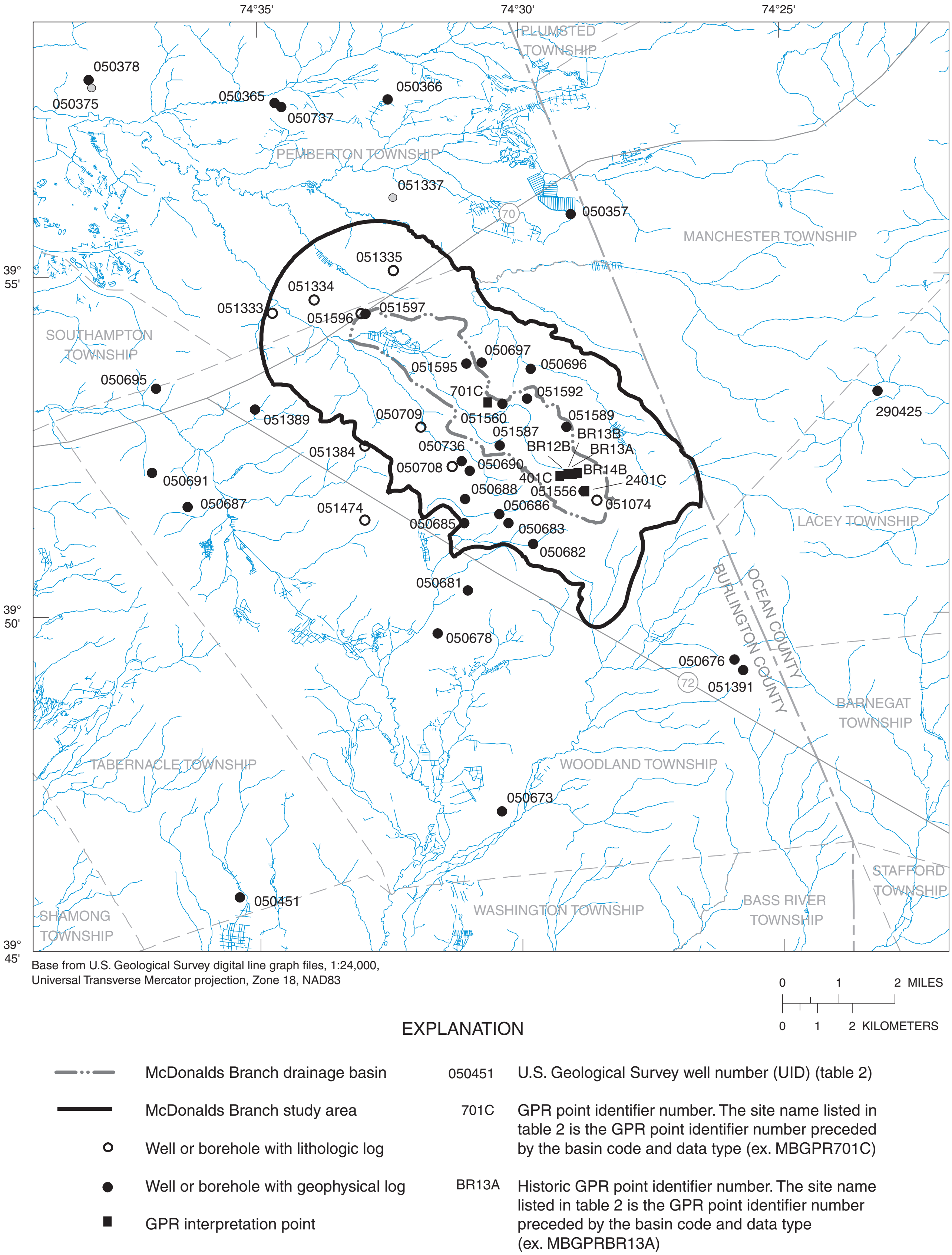
Layer identifier	Description of the hydrogeologic framework of the McDonalds Branch study area
MB A-1	Upper aquifer - upper layer
MB A-1C1	Upper - leaky confining layer
MB A-1B	Upper aquifer - lower layer
MB C-1	Middle leaky confining layer
MB A-2	Middle aquifer
MB C-2	Lower leaky confining layer
MB A-3	Lower aquifer
MB C-3	Lower Kirkwood basal clay

The locations of the 45 sites used to describe the hydrogeologic framework for the McDonalds Branch study area are shown in figure 13. Sites include wells, boreholes, and selected GPR data points. Detailed site information is provided in table 2. The altitudes of the tops of the hydrogeologic layers for the McDonalds Branch study area and vicinity are listed in table 6.

Four hydrogeologic sections (A-A', B-B', C-C', and D-D') were prepared from selected sites (table 2) for the McDonalds Branch study area. The locations of these sections are shown in figure 14. Section A-A' (fig. 15) traces from site to site northwest to the southeast, following the orientation of the drainage basin in the direction of the regional dip of Coastal Plain sediments. Section A-A' slices through the framework model showing the regional dip of the hydrogeologic layers and the land-surface altitude sloping toward the northwest away from the divide between the Delaware River and Atlantic Coastal basins (not shown). A 55-ft-thick medium-density clay is represented by MB C-2 a leaky confining layer at the location of well 051074. Locally, this clay is a substantial barrier to vertical ground-water flow that is absent at nearby well 051560 about 2 mi to the northwest, thus illustrating the discontinuity of thick clay layers typical of the Kirkwood-Cohansey aquifer system.

Three hydrogeologic sections, B-B', C-C', and D-D' (figs. 16, 17, and 18 respectively) are positioned approximately normal to section A-A' and cross the basin from southwest to northeast (fig. 14). These sections show that layer MB C-2 thickens toward the southeast. The shallow layers are deeply incised and absent in many areas in the lower part of the basin as a result of downcutting that also broadened the stream valleys toward the northwest. The distribution of fine-textured sediments illustrated by the gamma logs indicates the variable nature of the sands and clays associated with the framework layers.

Structure contours were prepared from the altitudes of the tops of seven of the hydrogeologic layers listed in table 6 using methods described previously. A contour map was not prepared for the top or the MB A-1 layer because it is the same as the land surface and is best described by the 10-meter DEM



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

Figure 13. Location of boreholes, wells, and ground-penetrating radar (GPR) data points used to describe the hydrogeologic framework of the McDonalds Branch study area and vicinity, New Jersey Pinelands.

Table 6. Altitudes of tops of hydrogeologic layers of the Kirkwood-Cohansey aquifer system at selected wells in the McDonalds Branch study area and vicinity, New Jersey Pinelands.

[UID, Unique Identification Number; *, no data; MB, McDonalds Branch; NAVD88, North American Datum 1988]

U.S. Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD 1988)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD 1988)							
			MB A-1	MB A-1C1	MB A-1B	MB C-1	MB A-2	MB C-2	MB A-3	MB C-3
050357	050357-- IRR	110	*	*	*	103	94	65	29	*
050365	050365-- PEMBERTON PW	94	*	*	*	*	*	*	72	28
050366	050366-- PEMBERTON 4	90	*	*	*	*	*	*	72	26
050375	050375-- BUR CO INST 3/9	71	*	*	*	*	*	*	65	28
050378	050378-- INSTITUTIONAL 5	66	*	*	*	*	*	*	66	28
050451	050451-- MULLICA 5D	64	*	*	64	49	30	-3	-54	-114
050673	050673-- TEST HOLE 14	83	*	*	83	60	33	-7	-59	-121
050676	050676-- COYLE AIRPORT	198	198	122	106	71	41	3	-44	-110
050678	050678-- MULLICA 8S	111		111	96	80	53	14	-29	-100
050681	050681-- TST HOLE 1	111	*	*	*	*	59	15	-24	-99
050682	050682-- TST HL 2	130	130	123	114	90	66	24	-24	-95
050683	050683-- BUTLER PLACE 1	139	139	123	111	87	65	26	-18	-88
050685	050685-- TST HL 4	128	129	121	106	88	67	26	-16	-84
050686	050686-- TST HL 3	136	136	124	111	89	65	29	-15	-84
050687	050687-- TST HL 10	101	*	*	*	95	71	28	-9	-66
050688	050688-- TST HL 8	124	*	*	*	*	*	35	-10	-74
050690	050690-- LEBANON SF 2	125	*	124	114	95	71	*	*	*
050691	050691-- TST HL 11	106	*	*	106	99	78	33	1	-55
050695	050695-- TEST HOLE 1-74	101	*	*	*	101	81	41	22	-36
050696	050696-- TST HL 5	134	*	*	*	98	81	52	12	-52
050697	050697-- TST HL 6	139	139	125	121	98	82	51	15	-45
050708	050708-- GLASSWORKS	123	*	*	112	97	74	40	*	*
050709	050709-- NJ WOODLAND	110	*	*	*	98	78	48	7	*
050736	050736-- SAW MILL 1	120	*	*	113	95	70	*	*	*
050737	050737-- 1961 WELL	73	*	*	*	*	*	*	73	29

Table 6. Altitudes of tops of hydrogeologic layers of the Kirkwood-Cohansey aquifer system at selected wells in the McDonalds Branch study area and vicinity, New Jersey Pinelands.—Continued

[UID, Unique Identification Number; *, no data; MB, McDonalds Branch; NAVD88, North American Datum 1988]

U.S. Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD 1988)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD 1988)							
			MB A-1	MB A-1C1	MB A-1B	MB C-1	MB A-2	MB C-2	MB A-3	MB C-3
051074	051074-- LEAD WELL	171	171	136	*	*	*	*	*	*
051333	051333-- DOM	115	*	*	110	101	95	58	37	*
051334	051334-- DOM	108	*	*	*	*	*	61	36	*
051335	051335-- IRR	119	*	*	116	103	93	65	*	*
051337	051337-- DOM 1995	84	*	*	*	*	*	75	54	*
051384	051384-- DOM	139	139	118	108	97	76	*	*	*
051389	051389-- NEW LISBON 1	106	*	*	106	99	81	41	5	-49
051391	051391-- COYLE 2 OBS	185	186	120	105	72	36	1	-43	-114
051474	051474-- IRR 5	120	*	116	107	89	67	27	-14	*
051556	051556-- MB OW-1D	151	151	134	112	95	72	32	-25	-84
051560	051560-- MB OW-2D	140	140	123	118	98	77	40	6	-59
051587	051587-- MB UP-2	128	128	123	113	*	*	*	*	*
051589	051589-- MB UP-1	139	139	123	*	*	*	*	*	*
051592	051592-- MB UP-3	138	138	119	113	*	*	*	*	*
051595	051595-- MB UP-4	135	135	127	123	*	*	*	*	*
051597	051597-- MB TB-1	113	*	*	111	101	92	60	33	-34
290425	290425-- WEBBS MILLS 2	127	*	127	116	96	81	36	-21	-107
*	MBGPR-0401C	149	149	134	*	*	*	*	*	*
*	MBGPR-0701C	138	138	123	*	*	*	*	*	*
*	MBGPR-2401C	157	157	135	*	*	*	*	*	*
*	MBGPR-BR12B	148	148	130	*	*	*	*	*	*
*	MBGPR-BR13A	149	149	131	*	*	*	*	*	*
*	MBGPR-BR13B	149	149	131	*	*	*	*	*	*
*	MBGPR-BR14B	150	150	132	*	*	*	*	*	*

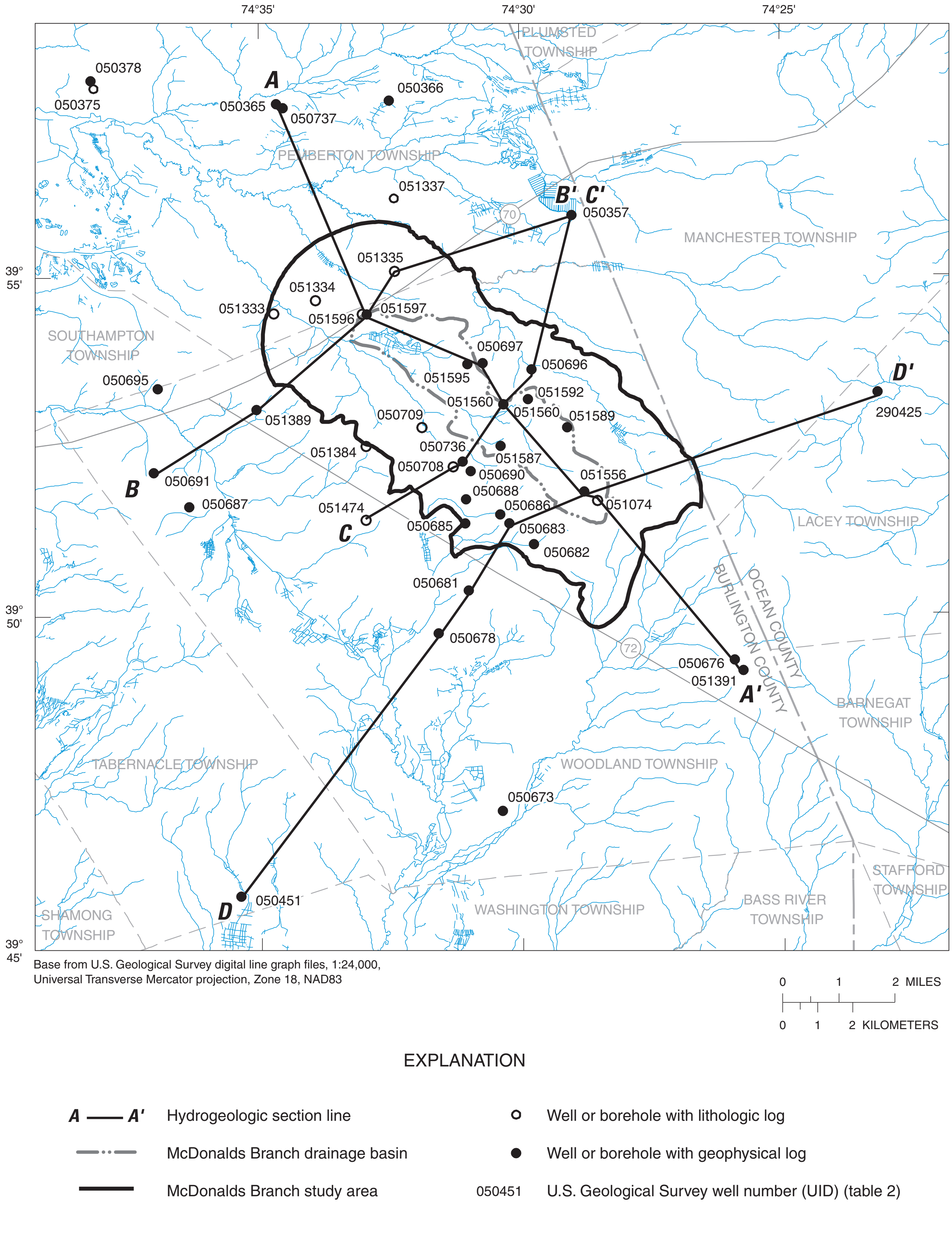
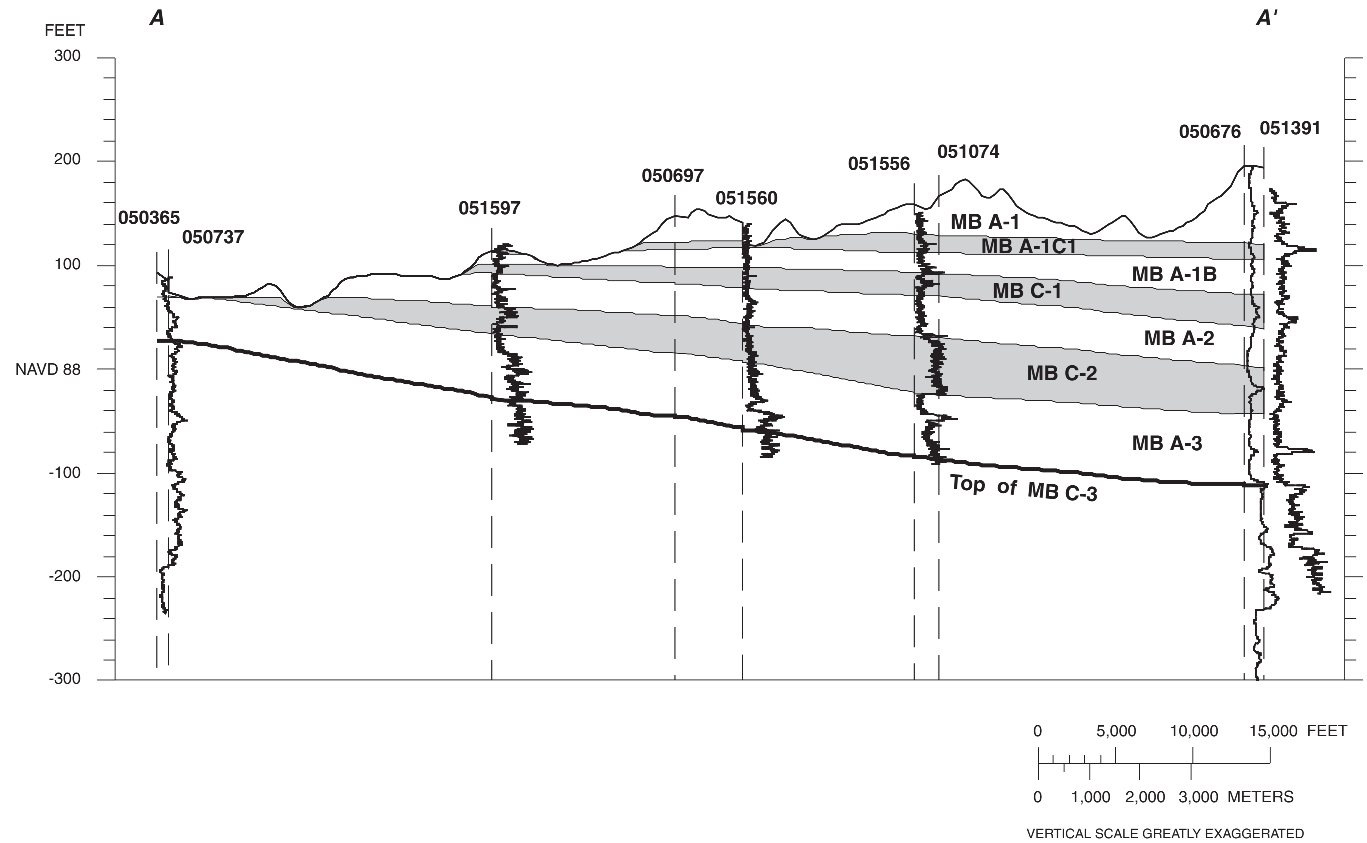


Figure 14. Location of hydrogeologic lines of section, and wells or boreholes with lithologic or geophysical data, McDonalds Branch study area and vicinity, New Jersey Pinelands.



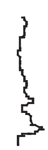
EXPLANATION

050697 Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MB McDonalds Branch

GAMMA LOG

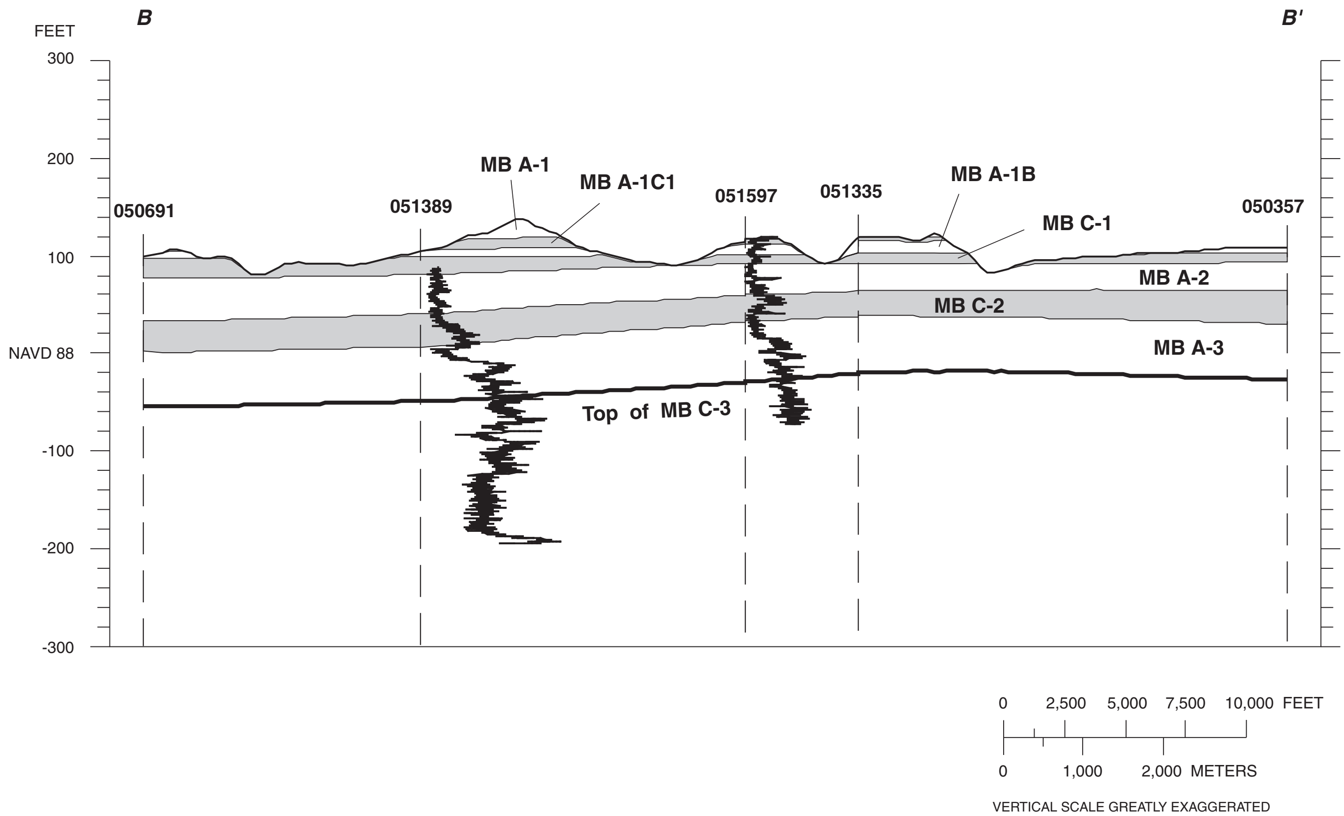
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the McDonalds Branch study area.

Layer	Description
MB A-1	Upper aquifer - upper layer
MB A-1C1	Upper leaky - confining layer
MB A-1B	Upper aquifer - lower layer
MB C-1	Middle leaky - confining layer
MB A-2	Middle aquifer
MB C-2	Lower leaky - confining layer
MB A-3	Lower aquifer
MB C-3	Lower Kirkwood - confining layer

Figure 15. Hydrogeologic section *A-A′*, McDonalds Branch study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 14.)



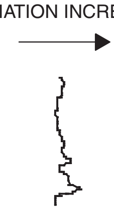
EXPLANATION

050691 Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MB McDonalds Branch

GAMMA LOG

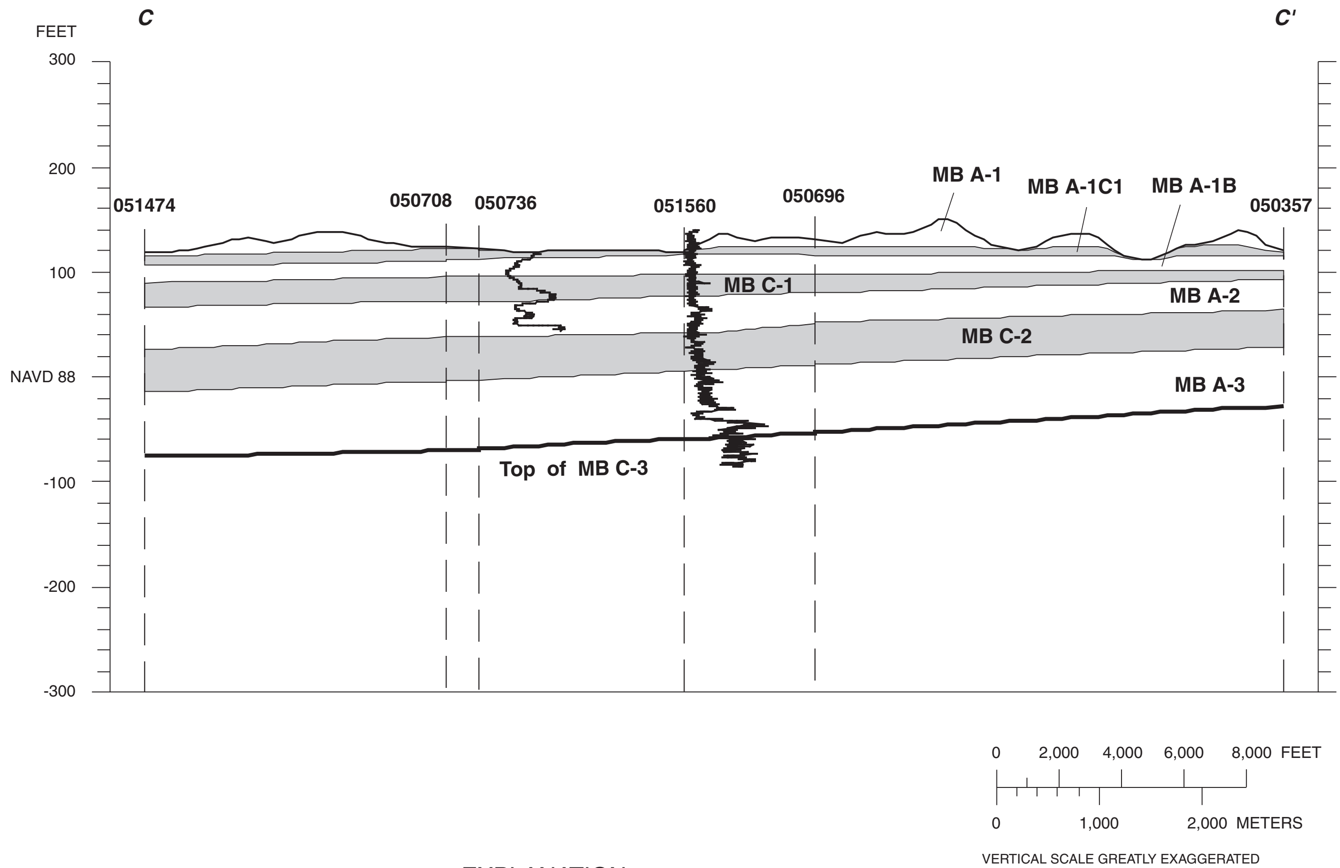
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the McDonalds Branch study area.

Layer	Description
MB A-1	Upper aquifer - upper layer
MB A-1C1	Upper leaky - confining layer
MB A-1B	Upper aquifer - lower layer
MB C-1	Middle leaky - confining layer
MB A-2	Middle aquifer
MB C-2	Lower leaky - confining layer
MB A-3	Lower aquifer
MB C-3	Lower Kirkwood - confining layer

Figure 16. Hydrogeologic section *B-B′*, McDonalds Branch study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 14.)



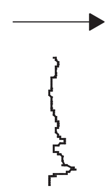
EXPLANATION

051474 — Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MB — McDonalds Branch

GAMMA LOG

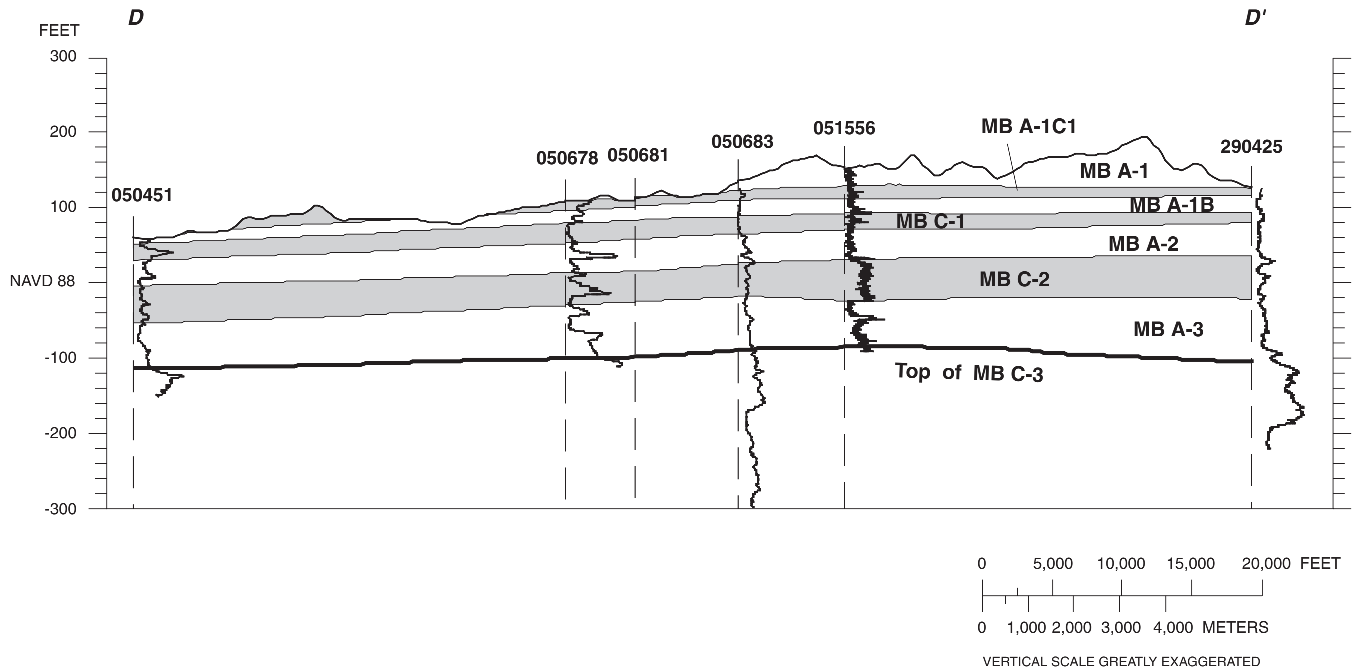
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the McDonalds Branch study area.

Layer	Description
MB A-1	Upper aquifer - upper layer
MB A-1C1	Upper leaky - confining layer
MB A-1B	Upper aquifer - lower layer
MB C-1	Middle leaky - confining layer
MB A-2	Middle aquifer
MB C-2	Lower leaky - confining layer
MB A-3	Lower aquifer
MB C-3	Lower Kirkwood - confining layer

Figure 17. Hydrogeologic section *C-C′*, McDonalds Branch study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 14.)



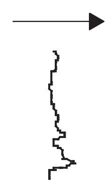
EXPLANATION

050681 — Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MB — McDonalds Branch

GAMMA LOG

RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the McDonalds Branch study area.

Layer	Description
MB A-1	Upper aquifer - upper layer
MB A-1C1	Upper leaky - confining layer
MB A-1B	Upper aquifer - lower layer
MB C-1	Middle leaky - confining layer
MB A-2	Middle aquifer
MB C-2	Lower leaky - confining layer
MB A-3	Lower aquifer
MB C-3	Lower Kirkwood - confining layer

Figure 18. Hydrogeologic section *D-D′*, McDonalds Branch study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 14.)

pared for seven hydrogeologic layers, but none was prepared for the lower Kirkwood confining layer, MB C-3, because the thickness of this layer was not investigated during this study. (See Zapecza, 1989.) The distribution and range of grain textures estimated for the hydrogeologic layers are shown on the thickness maps. In addition, those K values that represent individual framework layers (table 4) are shown on their respective thickness maps so that the distribution of K and the textures can be compared. K values estimated from well tests (table 4) in the McDonalds Branch basin ranged from 8 ft/day to 269 ft/day, and the average K was 98 ft/day.The structure contour and thickness maps are presented in appendix 3.

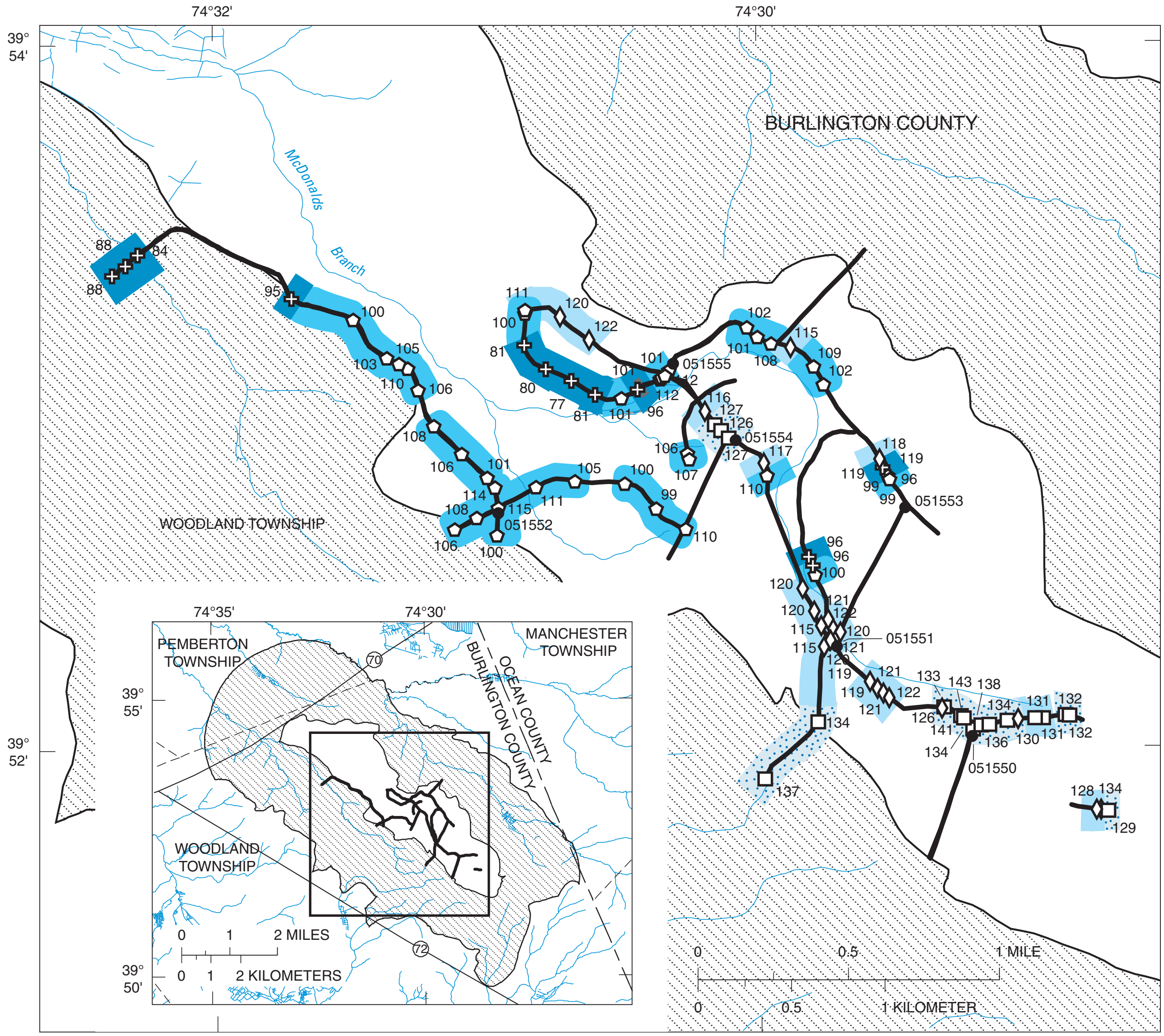
The results of the GPR surveys in the McDonalds Branch study area (fig. 19) confirm the differences in the altitudes of clay surfaces near the McDonalds Branch stream valley. In the areas investigated in the upper part of the basin, GPR records indicated an arealy extensive but discontinuous clay principally associated with the MB A-1C1 leaky confining layer. The top of this clay slopes gently with the shallow stream valley from the upper basin toward the northwest. Because of the slope and apparent discontinuity of this layer it could also represent various overlapping clays that have been eroded to the gradient of the valley. Shallower clays also were identified in the overlying MB A-1 aquifer layer in the upper part of the basin, but this layer is principally sand in most areas, allowing the GPR to penetrate to the deeper layers. Where shallow clays did not obscure the MB C-1 leaky confining layer, only a limited number of MB C-1 clays were identified by GPR surveys. In these areas, overlying sediments and possibly the upper part of the MB C-1 leaky confining layer is composed largely of coarse-grained sediments. Because the Cohansey Sand is exposed in this area, the observed discontinuity of clays most likely conforms to the depositional environment of the Cohansey Sand described by Carter (1978). In the lower part of the basin, GPR records identified the first clay in the MB A-1B aquifer layer over an extensive area. This area forms a low basin divide that is outside the main valley associated with the McDonalds Branch stream, where sediments may have been more resistant to weathering leaving the clay intact.

Hydrogeology of Morses Mill Stream Study Area and Vicinity

In the Morses Mill Stream study area, the basal confining layer of the Kirkwood-Cohansey aquifer system is the thick diatomaceous clay (fig. 2) that forms an extensive confining bed in the upper part of the Kirkwood Formation dividing the Kirkwood Formation into upper and lower sands. The estimated updip extent of this clay subcrops about 8 mi west of the Morses Mill Stream study area, which indicates either an abrupt change from sand to clay or that the clay was truncated (Zapecza, 1989). From its estimated updip edge, the diatomaceous clay thickens to as much as 200 ft in the vicinity of the study area (Zapecza, 1989, pl. 22-c), isolating the lower part of the Kirkwood Formation beneath it that is referred to locally as the Atlantic City 800-foot sand. The Atlantic City 800-foot sand is considered an artesian aquifer in this area, whereas the overlying the Kirkwood-Cohansey aquifer system is considered unconfined or, locally, a semi-artesian aquifer. The Kirkwood-Cohansey aquifer system overlying the diatomaceous clay is the focus of this study in the Morses Mill Stream study area.

The Kirkwood-Cohansey aquifer system in the Morses Mill study area is composed of sand, gravel, and clay that grade to fine sand, silt, and clay near the base of the aquifer system. Clays, although varying in extent and thickness, are most common in the upper part of the aquifer system probably as a result of the depositional environment of the Cohansey Sand. Many coarse-grained zones are distributed throughout the thickness of the aquifer system, but generally they lie well above the gradational contact with the basal diatomaceous clay. The surficial geology in the Morses Mill Stream study area is similar to that of Albertson Brook study area, as they both straddle the northern limits of the Bridgeton Formation deposits. Surficial geologic maps by Newell and others (2000) indicate that erosion has exposed the Cohansey Sand in some areas surrounding the Morses Mill Stream and its tributaries. Pleistocene to Holocene age swamp deposits have been identified as overlying the Cohansey Sand in the immediate vicinity of the stream channels. In the upper reaches of the basin, these deposits appear to lie directly on the weathered Bridgeton Formation. At the downstream limits of the study area, the Morses Mill Stream drains through a shallow valley eroded through Pleistocene age deposits of the Cape May Formation (Newell and others, 2000). Accordingly the shallowest hydrogeologic layers, depending on location, may contain any of the sediments that make up the surficial deposits within the study area. Soils in the Morses Mill Stream study area generally are moderately well-drained loamy sands with muck soils in the immediate vicinity of swamps and streams (Johnson, 1978).

The hydrogeologic framework of the Morses Mill Stream study area is represented by four aquifer layers separated by three leaky confining layers. The base of the hydrogeologic framework in the vicinity of the study area is the thick diatomaceous clay in the upper part of the Kirkwood Formation (Zapecza,1989). The following list describes the hydrogeologic framework layers for the Morses Mill Stream study area and presents their identifiers.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Estimated extent of clay along GPR survey lines

- MB A-1 aquifer layer
- MB A-1C1 leaky confining layer
- MB A-1B aquifer layer
- MB C-1 leaky confining layer
- McDonalds Branch study area
- Ground penetrating radar survey line
- McDonalds Branch drainage basin

137 □ Clay identified in the MB A-1 aquifer layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

120 ◊ Clay identified in the MB A-1C1 leaky confining layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

100 ⬠ Clay identified in the MB A-1B aquifer layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

84 ✚ Clay identified in the MB C-1 leaky confining layer. Number is altitude of top of clay layer, in feet. Datum is NAVD 88

051550 ● Shallow boreholes used to interpret GPR surveys. Number is the USGS well number (UID) (table 2).

Figure 19. Results of ground-penetrating radar (GPR) surveys used to describe the hydrogeologic framework of the McDonalds Branch study area and vicinity, New Jersey Pinelands.

Layer identifier	Description of the hydrogeologic framework of the Morses Mill Stream study area
MM A-1	Upper aquifer - upper layer
MM A-1C1	Upper - leaky confining layer
MM A1B	Upper aquifer - lower layer
MM C-1	Middle leaky confining layer
MM A-2	Middle aquifer
MM C-2	Lower leaky confining layer
MM A-3	Lower aquifer
MM C-3	Upper Kirkwood, Diatomaceous clay

The locations of the 63 sites used to describe the hydrogeologic framework for the Morses Mill Stream study area are shown in figure 20. Sites include wells and selected GPR data points. Detailed site information is provided in table 2. The altitudes of the tops of the hydrogeologic layers for the Morses Mill Stream study area and vicinity are listed in table 7.

Four hydrogeologic sections (A-A', B-B', C-C', and D-D') were prepared from selected sites (table 2) for the Morses Mill study area. The locations of these sections are shown in figure 21. Two sections, A-A' and B-B' (figs. 22 and 23), trace from site to site slicing through the framework model, in a southeasterly direction normal to the orientation of the drainage basin and in the general direction of the regional dip of Coastal Plain sediments. The two other sections C-C' and D-D' (figs. 24 and 25) lie along with the general orientation of the Morses Mill Stream drainage basin normal to sections A-A' and B-B'. The limited number of geophysial logs available in the vicinity of the Morses Mill Stream study area required a greater reliance on lithologic data than in the other study areas; the geophysical logs illustrated on the sections, although of good quality, tend to be localized within the drainage basin. The distribution of fine-textured sediments illustrated by the gamma logs indicate the variable nature of the sands and clays associated with the framework layers.

Structure contours were prepared from the altitudes of the tops of seven of the hydrogeologic layers at locations listed in table 7 using the methods described previously. A contour map was not prepared for the top or the MM A-1 layer because it is the same as the land surface where the layer exists and is best described by the 10-meter DEM. Thickness maps also were prepared for seven hydrogeologic layers, but none was prepared for the upper Kirkwood confining layer MM C-3 because the thickness of this layer was not investigated during this study. (See Zapecza, 1989.) The distribution and range of textures estimated for the hydrogeologic layers are shown on the thickness maps. In addition, those K values that represent individual framework layers (table 4) are shown on their respective thickness maps so that the distribution of K and sediment textures can be compared. K values estimated from well-performance tests (table 4) in the Morses Mill Stream basin ranged from 17 ft/day to 266 ft/day and the average K was 84 ft/day.The structure-contour and thickness maps are presented in appendix 4.

The results of the GPR surveys in the Morses Mill Stream study area (fig. 26) confirm only minor differences in the altitudes of clay surfaces identified within the drainage basin. The study area is relatively flat lying and capped locally in the upland parts of the basin with Bridgeton Formation delta plain deposits, and younger sediments locally flank the lower part of the drainage basin. Cohansey Sand sediments are exposed in the shallow erosional valley where Morses Mill Stream lies. The valley is not as deeply incised as those in the other two study areas, and the shallow clays identified in the Morses Mill Stream study area appear to be continuous. In the areas investigated in the upper part of the basin near well 011499, GPR records indicate an extensive continuous clay associated with the surficial MM A-1 aquifer layer. This surficial layer shows some clay in localized areas but the MM A-1 aquifer is generally represented by coarse-grained sediments, and most clays identified in the basin were in the MM A-1C1 leaky confining layer. Clays identified in the MM A-1B aquifer layer appear to be more common in the lower part of the basin, although these clays could be present elsewhere but are obscured in the GPR record by the overlying MM A-1C1 leaky confining layer.

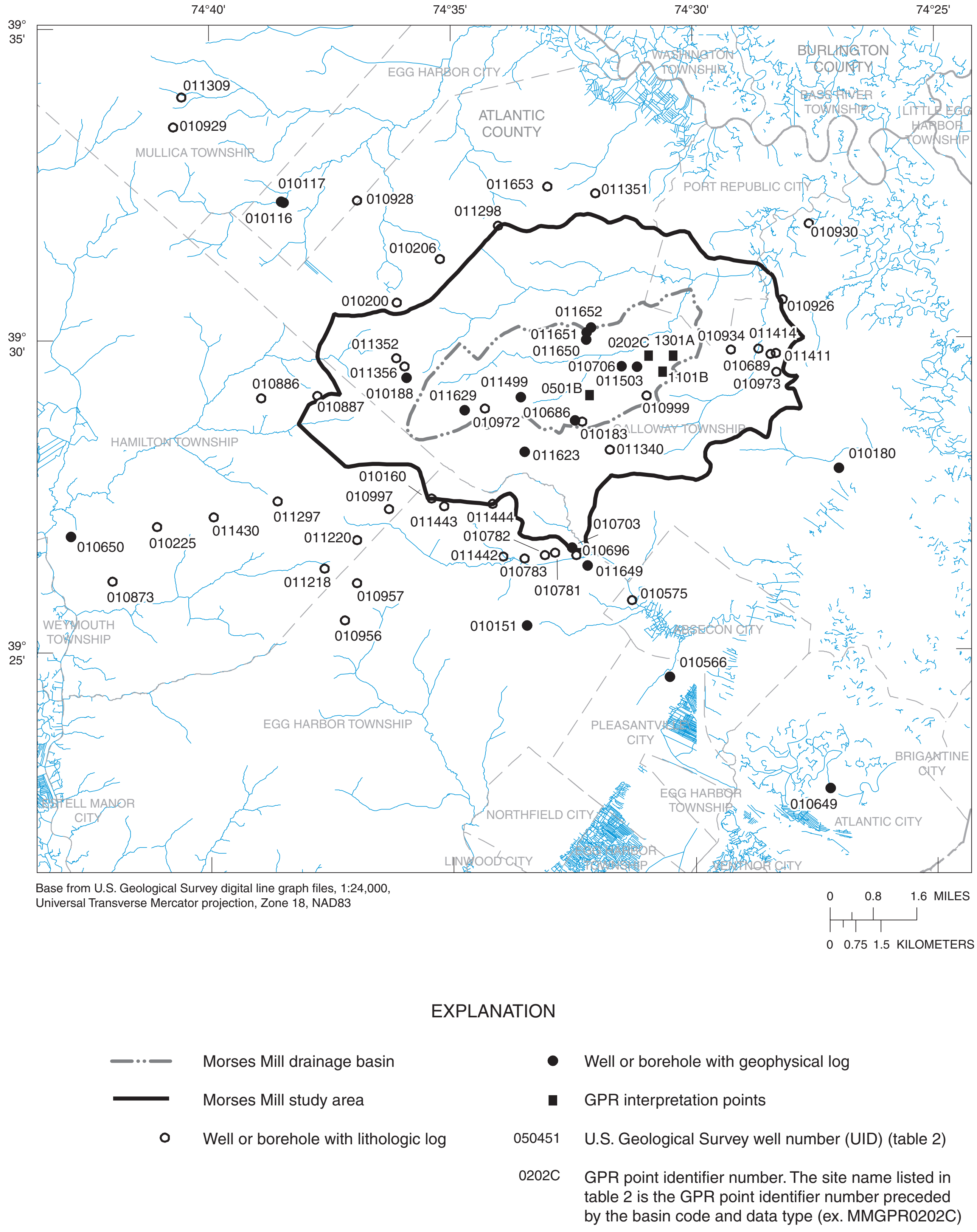


Figure 20. Location of boreholes, wells, and ground-penetrating radar (GPR) data points used to describe the hydrogeologic framework of the Morses Mill Stream study area and vicinity, New Jersey Pinelands.

Table 7. Altitudes of tops of hydrogeologic layers of the Kirkwood Cohansey aquifer system, Morses Mill study area and vicinity, New Jersey Pinelands.

[UID, Unique Identification Number; *, no data; MM, Morses Mill Stream; NAVD88, North American Vertical Datum 1988]

U.S. Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD88)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD88)							
			MM A-1	MM A-1C1	MM A-1B	MM C-1	MM A-2	MM C-2	MM A-3	MM C-3
010116	010116-- PW 3	40	*	*	*	*	36	8	-17	-75
010117	010117-- PW 5	40	*	*	*	*	37	3	-17	*
010151	010151-- SHORE-CANALE	42	42	23	8	-16	-42	-73	-120	*
010160	010160-- IND 1	34	*	39	29	8	-10	-42	-70	*
010180	010180-- OCEANVILLE 1 OBS	25	25	-8	-19	-48	-59	-78	-113	-201
010183	010183-- PW 1	68	68	23	11	-12	-19	-39	-75	
010188	010188-- 2 OBS	64	*	55	37	14	-4	-24	-49	-130
010200	010200-- IRR 1	61	*	*	50	30	2	-15	-39	*
010206	010206-- IRR	56	*	55	45	24	4	-16	-42	*
010225	010225-- IRR	76	76	73	58	40	14	-16	-48	-112
010566	010566-- 600	10	10	-9	-24	-48	-86	-116	-175	-259
010575	010575-- PW 12	4	*	-1	-11	-37	-55	-85	-134	*
010649	010649-- TW4-78	6	6	-45	-67	-124	-150	-185	-255	-312
010650	010650-- HAMILTON 2-73	21	*	*	*	*	*	7	-39	-96
010686	010686-- INSTITUTIONAL 2	68	68	23	11	-11	-18	-39	-77	*
010689	010689-- SWC 2	31	31	18	0	-27	-41	-68	-99	*
010696	010696-- PW 16	25	*	*	-6	-23	-35	-66	-103	*
010703	010703-- FAA POMONA	35	35	10	-3	-19	-34	-65	-103	-195
010706	010706-- STKTN ST COLL	40	*	26	12	-14	-23	-38	-76	-162
010781	010781-- PW 19	27	27	12	1	-14	-28	-62	-93	*
010782	010782-- PW 20	28	28	14	3	-11	-26	-60	-90	*
010783	010783-- PW 21	29	29	16	4	-8	-23	-56	-88	*
010873	010873-- SLF MW-1	61	*	*	*	40	15	*	*	*
010886	010886-- DOM	65	*	*	*	27	12	1	*	*
010887	010887-- DOM	61	*	59	46	21	8	-9	*	*
010926	010926-- DOM	20	*	*	*	-11	-24	*	*	*

Table 7. Altitudes of tops of hydrogeologic layers of the Kirkwood Cohansey aquifer system, Morses Mill study area and vicinity, New Jersey Pinelands.—Continued

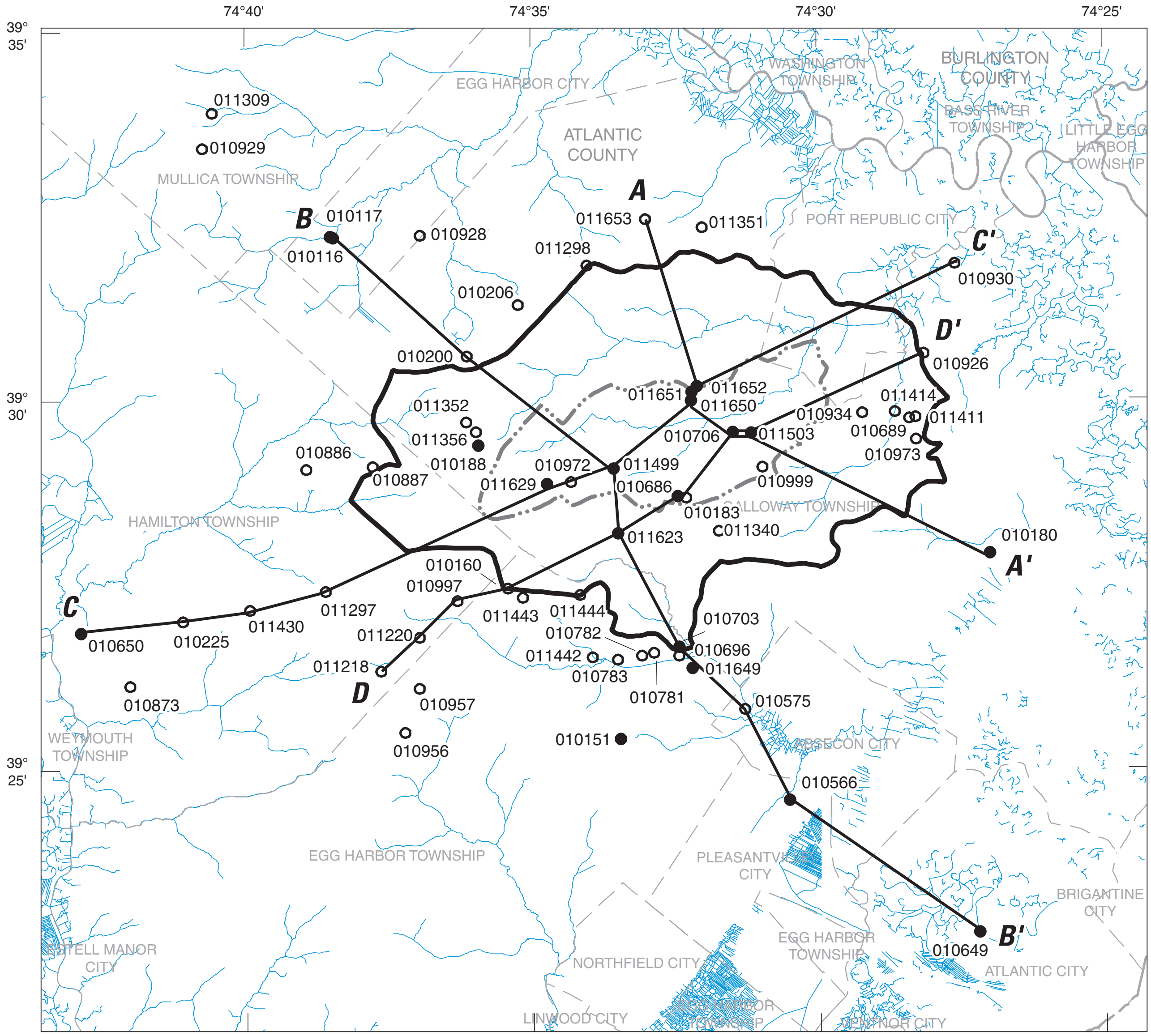
[UID, Unique Identification Number; *, no data; MM, Morses Mill Stream; NAVD88, North American Vertical Datum 1988]

U.S. Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD88)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD88)							
			MM A-1	MM A-1C1	MM A-1B	MM C-1	MM A-2	MM C-2	MM A-3	MM C-3
010928	010928-- DOM	60	*	*	*	48	35	*	*	*
010929	010929-- DOM	81	*	*	*	67	55	43	7	*
010930	010930-- NACOTE CRK RES.	10	*	*	*	1	-20	-49	-75	*
010934	010934-- DOMESTIC	40	40	21	4	-19	-35	-61	-94	*
010956	010956-- SOUTHERN DIV 15	58	58	48	29	10	-12	-41	-78	*
010957	010957-- 2/LAUNDRY RM	71	71	50	33	13	-9	*	*	*
010972	010972-- PW 1	63	63	38	24	4	-10	-28	-54	*
010973	010973-- 3/17 MOSSMILL	32	32	19	0	-28	-42	-68	-99	*
010997	010997-- IRR 2R	62	62	41	34	11	-10	-42	-69	*
010999	010999-- IRR	45	45	21	5	-15	-29	-46	-85	*
011218	011218-- CATES RD 1	66	66	51	37	16	-9	-41	-69	-164
011220	011220-- LOWELL AVE 1	65	65	44	34	13	-10	-43	-71	*
011297	011297-- IRR-3R	70	*	63	50	25	7	-28	-56	*
011309	011309-- IRR 2	72	*	*	*	72	63	57	*	*
011340	011340-- GSP-2	65	*	19	7	-15	-23	-42	*	*
011351	011351-- RW-2-93	65	*	*	*	27	4	*	*	*
011352	011352-- RW-2-91	68	*	58	44	18	*	*	*	*
011356	011356-- RW-6-91	63	*	57	42	16	*	*	*	*
011411	011411-- IRR C1	39	*	19	0	-27	-43	-67	-102	*
011414	011414-- IRR3	10	*	*	4	-26	-39	-68	-97	*
011430	011430-- UC-4E	67	*	*	*	*	*	-22	*	*
011442	011442-- DOM 10	31	31	19	11	-8	-20	-53	-85	*
011443	011443-- DOM 9	71	71	37	28	7	-11	-48	-74	*
011444	011444-- DOM 8	61	61	31	19	-1	-15	-50	-75	*
011499	011499-- MM OW-1D	56	55	32	16	-10	-17	-31	-58	-143
011503	011503-- MM OW-2D	39	40	27	11	-12	-23	-41	-75	-164

Table 7. Altitudes of tops of hydrogeologic layers of the Kirkwood Cohansey aquifer system, Morses Mill study area and vicinity, New Jersey Pinelands.—Continued

[UID, Unique Identification Number; *, no data; MM, Morses Mill Stream; NAVD88, North American Vertical Datum 1988]

U.S. Geological Survey well number (UID)	Site name	Altitude of land surface (in feet, NAVD88)	Altitude of top of hydrogeologic layer (in feet above or below (-) NAVD88)							
			MM A-1	MM A-1C1	MM A-1B	MM C-1	MM A-2	MM C-2	MM A-3	MM C-3
011623	011623-- POMONA MW-7D	50	50	25	15	-7	-15	-42	-75	-168
011629	011629-- POMONA MW-8D	68	68	40	26	6	-7	-25	-53	-137
011649	011649-- TEST 2	23	23	8	-4	-24	-40	-69	-111	-199
011650	011650--MW-104-D	55	56	32	16	-4	-12	*	*	*
011651	011651-- MW 2	60	61	33	19	-5	-16	-34	-61	*
011652	011652--MW106-D	56	57	34	18	-6	-13	-34	-60	*
011653	011653-- 110	65	*	*	*	30	8	-19	-41	*
*	MMGPR-0202C	45	*	34	*	*	*	*	*	*
*	MMGPR-0501B	55	*	37	*	*	*	*	*	*
*	MMGPR-1101B	41	*	29	*	*	*	*	*	*
*	MMGPR-1301A	39	*	28	*	*	*	*	*	*



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

0 0.8 1.6 MILES
0 0.75 1.5 KILOMETERS

EXPLANATION

A —— A' Hydrogeologic section line

Morses Mill Stream drainage basin

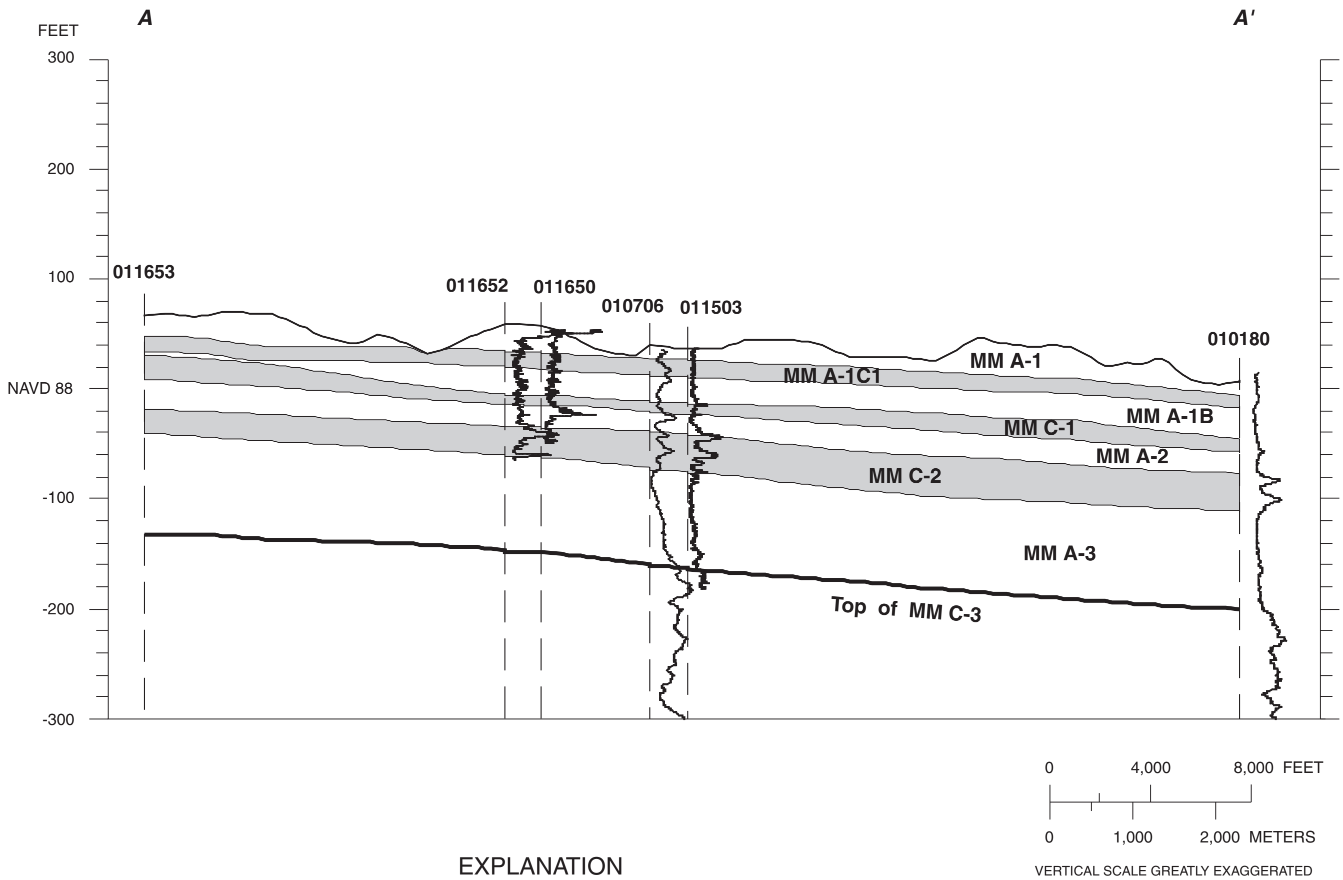
Morses Mill Stream study area

Well or borehole with lithologic log

Well or borehole with geophysical log

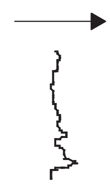
010349 U.S. Geological Survey well number (UID) (table 2)

Figure 21. Location of hydrogeologic lines of section, and wells or boreholes with lithologic or geophysical data, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



EXPLANATION

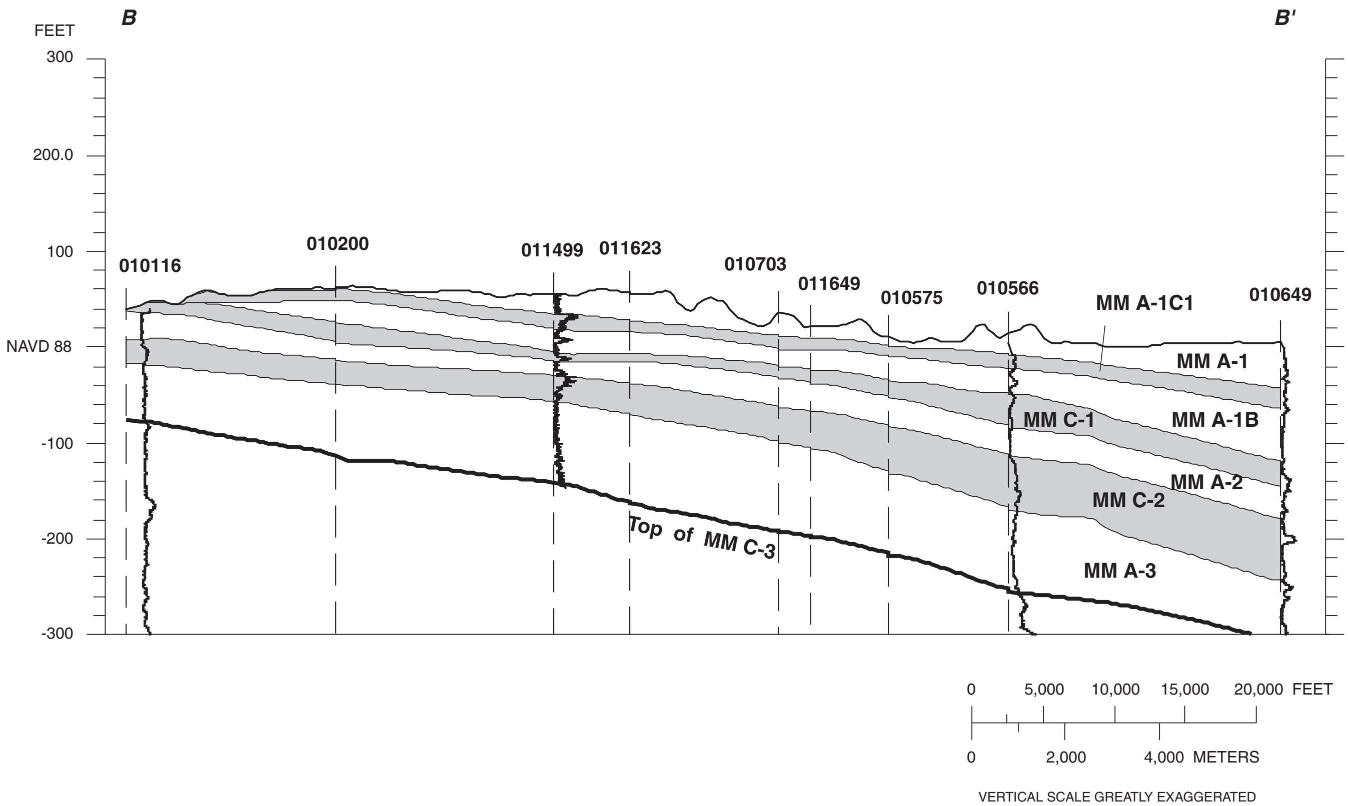
011653	Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)
MM	Morses Mill



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Morses Mill study area.

Layer	Description
MM A-1	Upper aquifer - upper layer
MM A-1C1	Upper leaky - confining layer
MM A-1B	Upper aquifer - lower layer
MM C-1	Middle leaky - confining layer
MM A-2	Middle aquifer
MM C-2	Lower leaky - confining layer
MM A-3	Lower aquifer
MM C-3	Upper Kirkwood - confining layer

Figure 22. Hydrogeologic section *A-A′*, Morses Mill Stream study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 21.)



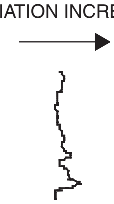
EXPLANATION

010116 — Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MM — Morses Mill

GAMMA LOG

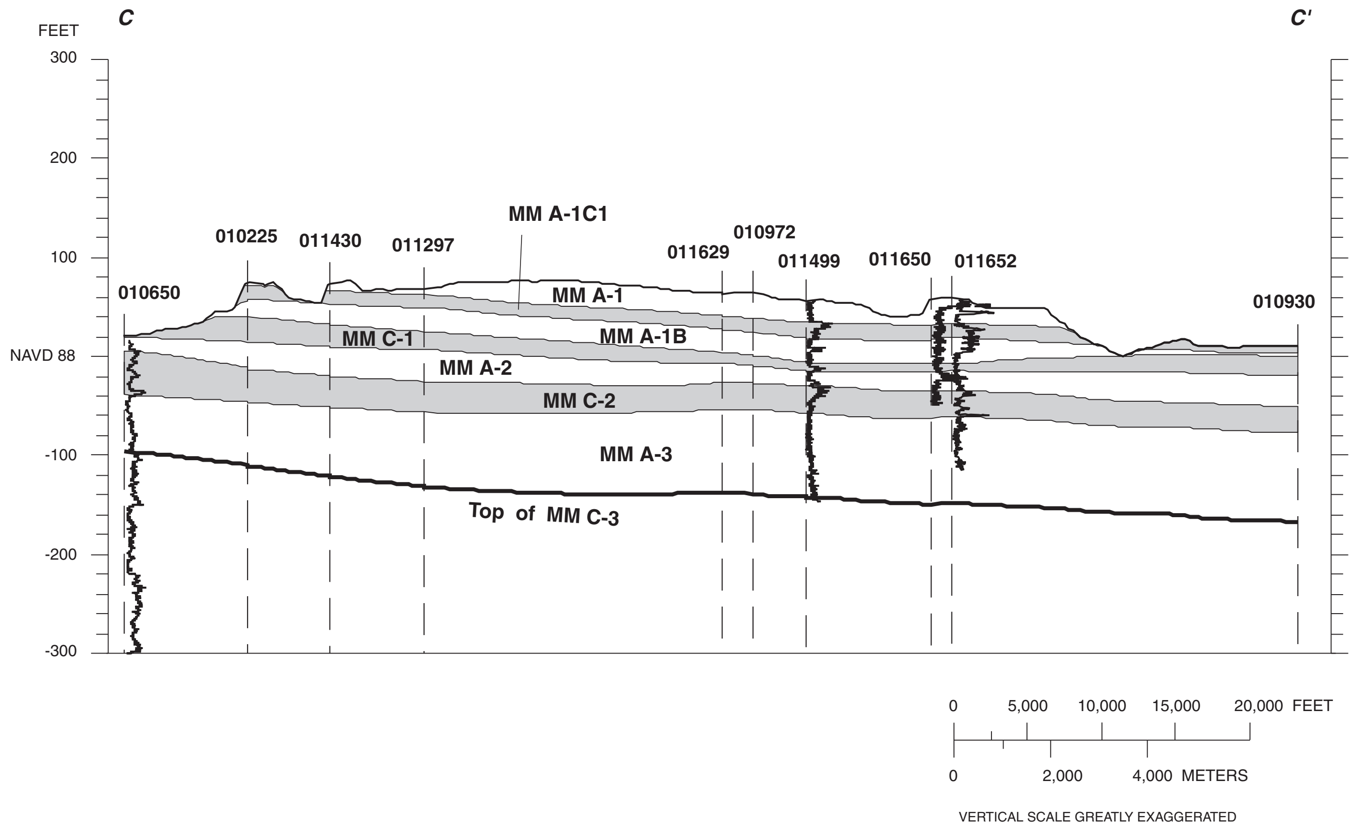
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Morses Mill study area.

Layer	Description
MM A-1	Upper aquifer - upper layer
MM A-1C1	Upper leaky - confining layer
MM A-1B	Upper aquifer - lower layer
MM C-1	Middle leaky - confining layer
MM A-2	Middle aquifer
MM C-2	Lower leaky - confining layer
MM A-3	Lower aquifer
MM C-3	Upper Kirkwood - confining layer

Figure 23. Hydrogeologic section *B-B′*, Morses Mill Stream study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 21.)



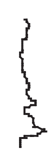
EXPLANATION

010116 — Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MM — Morses Mill

GAMMA LOG

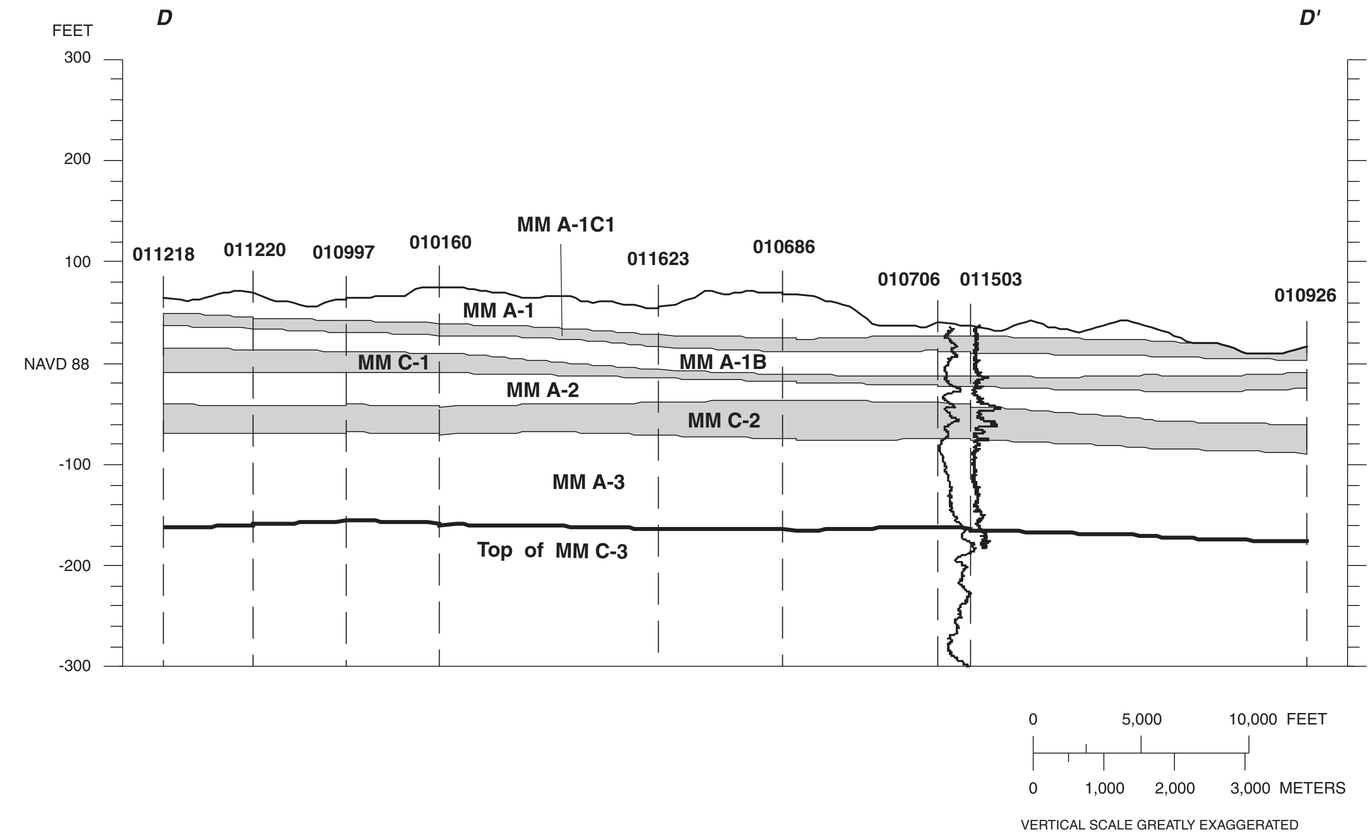
RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Morses Mill study area.

Layer	Description
MM A-1	Upper aquifer - upper layer
MM A-1C1	Upper leaky - confining layer
MM A-1B	Upper aquifer - lower layer
MM C-1	Middle leaky - confining layer
MM A-2	Middle aquifer
MM C-2	Lower leaky - confining layer
MM A-3	Lower aquifer
MM C-3	Upper Kirkwood - confining layer

Figure 24. Hydrogeologic section *C-C′*, Morses Mill Stream study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 21.)



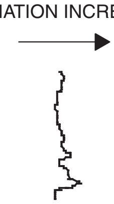
EXPLANATION

011218 — Location of well or borehole shown in hydrogeologic section. Number is U.S. Geological Survey well number (UID)

MM — Morses Mill

GAMMA LOG

RADIATION INCREASES



Hydrogeologic framework of the Kirkwood-Cohansey aquifer system in the Morses Mill study area.

Layer	Description
MM A-1	Upper aquifer - upper layer
MM A-1C1	Upper leaky - confining layer
MM A-1B	Upper aquifer - lower layer
MM C-1	Middle leaky - confining layer
MM A-2	Middle aquifer
MM C-2	Lower leaky - confining layer
MM A-3	Lower aquifer
MM C-3	Upper Kirkwood - confining layer

Figure 25. Hydrogeologic section *D-D′*, Morses Mill Stream study area and vicinity, New Jersey Pinelands. (Line of section shown on figure 21.)

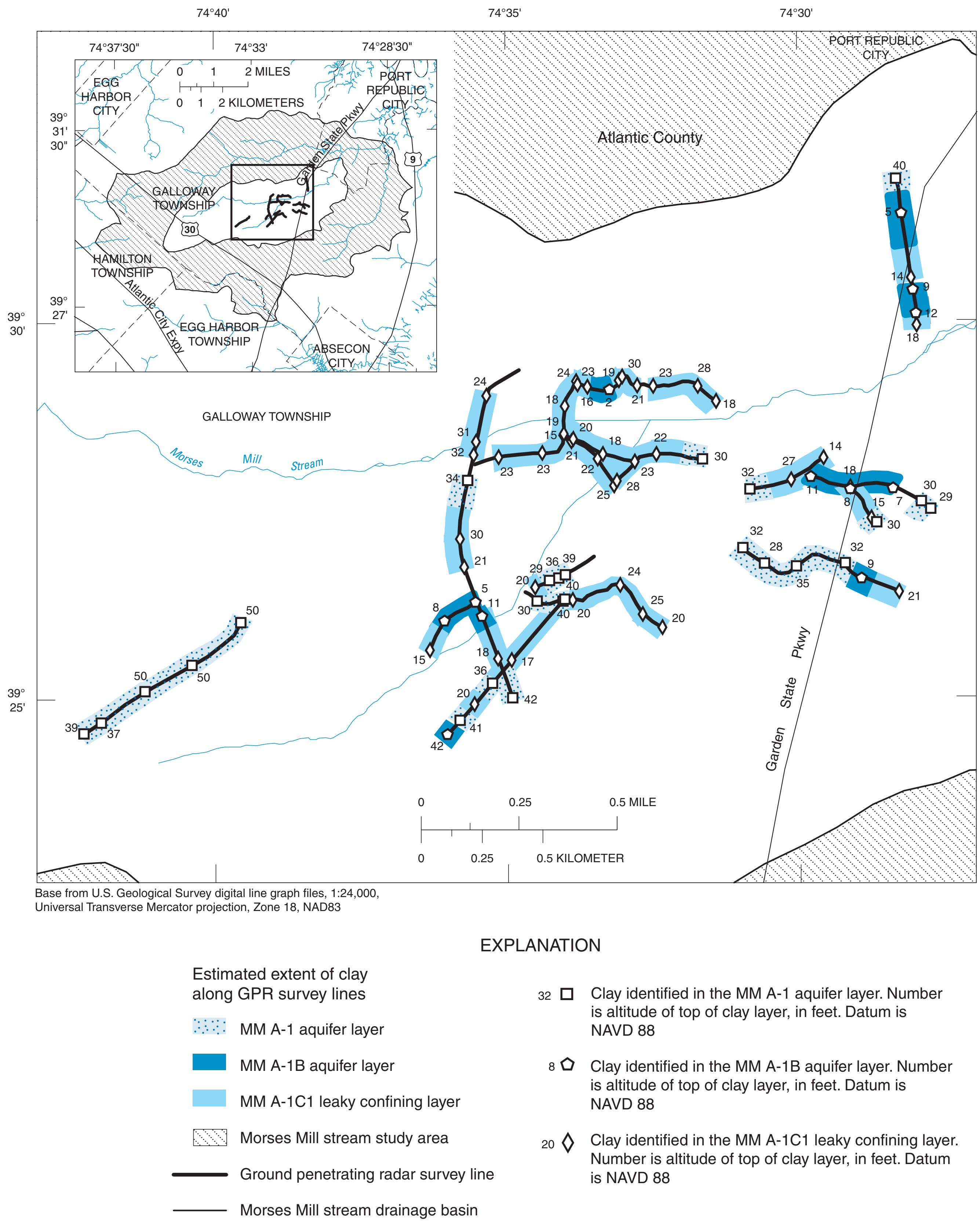


Figure 26. Results of ground-penetrating radar (GPR) surveys used to describe the hydrogeologic framework of the Morses Mill Stream study area and vicinity, New Jersey Pinelands.

Summary and Conclusions

The New Jersey Pinelands area (Pinelands) is a 1.1-million-acre natural reserve area 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. Cedar swamps, pine and oak forests, agricultural areas, and planned development dominate the landscape. Demand for water from the Kirkwood-Cohansey aquifer system is increasing as development within the area increases.

To assess the effects of ground-water withdrawals from the Kirkwood-Cohansey aquifer system on stream and wetland water levels, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Pinelands Commission, began a multi-phase hydrologic investigation in 2004 to characterize the hydrologic system that supports the Pinelands aquatic and wetland communities.

The Albertson Brook, McDonalds Branch, and the Morses Mill Stream drainage basins (study areas) were selected for detailed hydrologic assessment to provide the information needed to develop ground-water flow models that can predict the response of the aquifer system to increased ground-water withdrawals. The first phase of this assessment and the subject of this report is a comprehensive hydrogeologic investigation. During 2004-05, a database of hydrogeologic information was compiled, and a conceptual hydrogeologic framework model was prepared for each of the three study areas. Existing geophysical and lithologic data were assessed and new borehole geophysical data were obtained during the drilling of 21 new wells and one deep borehole within the three study areas. These data were added to the database and integrated into the analysis. In addition, surface geophysical data acquired using ground-penetrating radar (GPR) along more than 27 mi were analyzed for the three study areas. Five additional wells installed in upland areas of the McDonalds Branch basin provided shallow lithologic data. Ten shallow boreholes were completed, providing lithologic ground truth for analyzing the GPR records. The assessments of the shallow lithologic data were added to the analysis, and the hydrogeologic framework models were finalized.

The hydrogeologic framework models, developed in preparation for the construction of a ground-water flow model of each study area, subdivided the Kirkwood-Cohansey aquifer system described by Zapecza (1989) into seven layers, characterized by their predominant sediment textures, as aquifers or leaky confining layers. The hydrogeologic framework of each study area is represented by a model containing four aquifer layers, separated by three leaky confining layers, and a basal confining layer. The three hydrogeologic framework models are similar, but they are distinctly separate; each one is unique to a particular study area. Hydrogeologic sections, maps of structure tops, and thickness maps were produced for each study area model to show differences in sediment textures within each model layer; the sections and maps are based on geophysical and lithologic data. The key findings of this study area are listed below.

- The hydrogeology of the three study areas is similar even though the sediment textures may vary throughout the Kirkwood-Cohansey aquifer system.
- The leaky confining layers are more closely spaced and the presence of discontinuous clays is generally more common in the upper part of the aquifer system, which is principally represented by the Cohansey Sand and younger surficial deposits.
- With the exception of the basal clay confining layers, the variable and discontinuous nature of clay layers within the Kirkwood-Cohansey aquifer system was confirmed by the geophysical and lithologic records.
- Results of the investigation indicate considerable variability in the presence of different sediment textures; the extent to which this hydrogeologic variability can be characterized is constrained by the extent of the available geologic and lithologic data.
- Although the Kirkwood-Cohansey aquifer system has been considered a water-table aquifer in many areas, localized clays in the aquifers and leaky confining layers may act to impede the flow of ground water.
- In the Albertson Brook and McDonalds Branch study areas, sediment textures are typically coarser in the upper 100 ft of the aquifer system than was observed in the Morses Mill Stream study area.
- In the Albertson Brook and Morses Mill Stream study areas, sediments of layers AB A-3 Lower aquifer and MM A-3 Lower aquifer, respectively, tend to show increasing homogeneity as they dip and thicken toward the southeast. In contrast, the MB A-3 Lower aquifer in the McDonalds Branch does not thicken substantially within the study area, does contain clays, and does exhibit a thicker gradational interval approaching the base of the aquifer system.
- The base of the Kirkwood-Cohansey aquifer system for this study is generally represented by one of the two basal clay confining beds identified by Zapecza (1989).
    - The regionally extensive basal clay in the lower part of the Kirkwood Formation is common to both the Albertson Brook and McDonalds Branch study areas and is the only layer of the models that can be correlated between the study areas.
    - The base of the aquifer system in the vicinity of the Morses Mill Stream study area is the thick diatomaceous clay in the upper part of the Kirkwood Formation.

- The deeper hydrogeologic framework layers tend to dip to the southeast and generally conform to the slope of the top of the basal clays. The dip of the overlying layers appears to decrease slightly where the layers are closer to the land surface. The tops of the shallower layers generally follow the slope of the drainage basins, reflecting a closer relation to the erosion-incised valleys that form the basins.

The estimated mean horizontal hydraulic conductivity (K) values determined from various well tests in the the three study areas ranged from 84 to 130 feet/day. The estimated K values from well tests are consistent with those reported by other investigators for the Kirkwood-Cohansey aquifer system.

Acknowledgments

The authors gratefully acknowledge the local and State officials who provided assistance in identifying and accessing well drilling locations in Winslow Township in Camden County; Brenden Byrne State Forest in Burlington County; Wharton State Forest in Atlantic, Burlington, and Camden Counties; and Richard Stockton College in Atlantic County and for collection of surface-geophysical data. The authors wish to thank their USGS colleagues Christine Wieben, Donald Storck, Gregory Simpson, William Ellis, Ruth Larkins, Donald Rice, Steven Tessler, Nicholas Smith, Robert Rosman, Lawrence Feinson and Timothy Reilly for technical advice; help with well installation, slug tests, and analysis; report preparation, illustrations, and editing; database construction; and data validation. Lloyd Mullikin of the New Jersey Geological Survey provided numerous geophysical logs and well and borehole logs, as did representatives of the U.S. Environmental Protection Agency who arranged access to geophysical logs, well logs, and records for sites. The authors also thank the reviewers of this report Dr. Allison Brown of the New Jersey Pinelands Commission and Robert Nicholson, Emmanuel Charles, and Ronald Sloto of the USGS for insights and comments that greatly improved the quality of this report.

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Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
010286	010286-- IRR	3105052	AB	WP	89	DEM	5	02/01/1967	100	100	45	100	---
010324	010324-- IRR 1	---	AB	WP	100	DEM	5	10/07/1964	180	180	10	180	---
010349	010349-- MULLICA 2D	---	AB	FR	58	Level	0.01	06/27/1975	150	217	145	150	L, G (J)
010351	010351-- 23S	---	AB	FR	38	Level	0.01	07/07/1975	22	125	17	22	L, G (J, VSP, SPR)
010387	010387-- OBS 6	---	AB	FR	61	DEM	5	---	136	138	---	---	L, G (J)
010605	010605-- 30/BLK 1709 TW	3112437	AB	FR	110	DEM	5	01/18/1978	215	298	185	215	L, G (J)
010641	010641-- IRR	3113279	AB	WP	70	DEM	5	05/06/1979	58	58	48	58	---
010643	010643-- IRR-1978	3113371	AB	WP	70	DEM	5	05/02/1978	85	85	65	85	---
010645	010645-- IRR	3113281	AB	WP	78	DEM	5	04/06/1978	90	90	70	90	---
010658	010658-- DISCONT. 2	3101117	AB	WP	71	DEM	5	10/28/1953	43	43	33	43	---
011023	011023-- IRR 2	3104766	AB	WP	100	DEM	5	10/07/1964	180	180	10	180	---
011024	011024-- IRR 1988	3128718	AB	WP	61	DEM	5	06/14/1988	135	135	55	135	---
011317	011317-- IRR 5	3136991	AB	WP, FR	70	DEM	5	07/31/1991	160	160	100	160	L
011318	011318-- IRR 3	3123343	AB	FR	71	DEM	5	07/20/1985	55	56	45	55	L
011339	011339-- IRR 4	3130348	AB	WP, FR	64	DEM	5	02/23/1989	103	103	83	103	L
011343	011343-- IRR 6	3146313	AB	FR	85	DEM	5	04/04/1995	100	100	30	100	L
011344	011344-- IRR-7	3126341	AB	FR	60	DEM	5	04/30/1987	173	173	40	173	L
011375	011375-- IRR 7	3147267	AB	FR	72	DEM	5	07/21/1995	160	160	40	160	L
011496	011496-- ALB-B2	---	AB	GPR	61	DEM	5	06/02/04	---	12	---	---	L
011497	011497-- ALB-B1	---	AB	GPR	50	DEM	5	06/02/04	---	12	---	---	L

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

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011504	011504-- AB OW-2D	3227988	AB	FR, ST	56	DEM	5	08/10/2004	160	200	150	160	L, G (J, VSP, SPR)
011505	011505-- AB OW-2S	3227990	AB	ST	56	DEM	5	08/11/2004	50	55	40	50	---
011506	011506-- AB OW-2M	3227989	AB	ST	56	DEM	5	08/12/2004	92	100	82	92	---
050406	050406-- IW44 ATSN T B	---	AB	FR	45	DEM	5	---	262	262	62	262	G (J)
050417	050417-- MULLICA 10D	---	AB	FR	47	Level	0.01	09/01/1975	100	245	95	100	L, G (J)
050454	050454-- MULLICA 3D	---	AB	FR	65	Level	0.01	09/01/1975	142	225	137	142	G (J)
050488	050488-- BATSTO 2	3200913	AB	FR	36	DEM	5	11/01/1972	449	548	419	449	G (VSP, SPR)
050598	050598-- MULLICA 11D	---	AB	FR	33	Level	0.01	07/01/1975	150	212	145	150	L, G (J)
050608	050608-- MULLICA 4D	3201525	AB	FR	62	Level	0.01	07/10/1975	160	315	155	160	L, G (J, VSP, SPR)
070015	070015-- BERLIN PW 11	3106208	AB	FR	149	DEM	5	07/11/1972	745	747	675	745	L
070018	070018-- BERLIN PW 9	3102079	AB	FR	146	DEM	5	07/15/1955	713	955	650	713	L
070228	070228-- VOC&TECH 1	3105139	AB	FR	144	DEM	5	09/08/1967	401	475	325	400	L
070391	070391-- ORBRK HS 1	3105628	AB	FR	167	DEM	5	06/14/1971	335		315	335	G (J)
070430	070430-- MULLICA 7D	---	AB	FR	93	Level	0.01	06/23/1975	120	270	115	120	G (J)
070433	070433-- 2-IRR	3104942	AB	WP	90	DEM	5	04/13/1966	129	---	30	129	---

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
070434	070434-- IRR	3104941	AB	WP	91	DEM	5	04/12/1966	130	---	10	130	---
070435	070435-- DOM	3102225	AB	WP	91	DEM	5	08/11/1955	105	---	100	105	---
070436	070436-- IRR	3104953	AB	WP	118	DEM	5	04/29/1966	130	---	110	130	---
070437	070437-- DOM	3100778	AB	WP	108	DEM	5	11/08/1952	82	---	72	82	---
070447	070447-- DOM	3102059	AB	WP	168	DEM	5	05/18/1955	84	84	79	84	---
070448	070448-- WINSLOW 6	3104426	AB	FR	160	DEM	5	---	460	460	420	460	L, G (J)
070450	070450-- DOM 1	3105291	AB	WP	166	DEM	5	10/17/1968	81	---	71	81	---
070451	070451-- MULLICA 1D	---	AB	FR	121	Level	0.01	09/01/1975	166	225	161	166	L, G (J)
070455	070455-- IRR	3105239	AB	WP	102	DEM	5	---	122	---	30	122	---
070456	070456-- TEST 1	3105389	AB	WP, FR	98	DEM	5	07/28/1969	140	145	130	140	L
070457	070457-- DOM	---	AB	WP	98	DEM	5	11/20/1969	67	---	57	67	---
070458	070458-- DOM	---	AB	WP	102	DEM	5	---	103	---	97	103	---
070459	070459-- IRR	3104937	AB	WP	101	DEM	5	05/20/1966	180	---	40	180	---
070460	070460-- IND 1	---	AB	WP, FR	104	DEM	5	09/07/1965	53	261	33	53	L
070461	070461-- IRR	---	AB	WP	110	DEM	5	05/06/1966	200	---	20	200	---
070462	070462-- IND 1	3104906	AB	WP	109	DEM	5	11/16/1965	104	---	70	104	---
070466	070466-- DISCONT. 2	3100540	AB	FR	119	DEM	5	---	332	375	306	332	L
070467	070467-- DOM	---	AB	WP	90	DEM	5	---	71	---	65	71	---
070468	070468-- DOM-6	3105716	AB	WP	105	DEM	5	07/12/1971	165		145	165	---
070469	070469-- DISCONT. 3	3100539	AB	FR	110	DEM	5	---	356	450	326	356	L, G (J)

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

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U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
070470	070470-- TEST WELL 4	3100995	AB	WP, FR	110	DEM	5	---	167	176	141	167	L
070471	070471-- INSTITU-TIONAL 5	3100996	AB	WP	104	DEM	5	---	138	---	117	138	---
070473	070473-- FARM	---	AB	FR	104	DEM	5	---	325	325	---	---	L
070476	070476-- NEW BRK-LYN	---	AB	FR	110	Level	0.01	08/17/1960	1505	2090	1485	1495	L, G (J)
070480	070480-- IRR	3105078	AB	WP	139	DEM	5	04/14/1967	100	---	40	100	---
070481	070481-- 3-1973	3106874	AB	WP, FR	123	DEM	5	03/23/1973	111	124	74	107	L
070483	070483-- DOM-3	---	AB	WP	110	DEM	5	05/02/1968	139	---	118	139	---
070488	070488-- 2 OBS	3104446	AB	FR	113	DEM	5	---	103	131	77	103	L, G (J)
070489	070489-- DOM	---	AB	WP	135	DEM	5	02/11/1952	90	---	84	90	---
070490	070490-- PROD 1	3105542	AB	WP	116	DEM	5	12/20/1970	113	119	72	103	---
070497	070497-- PROD 2	3105543	AB	WP	122	DEM	5	---	101	136	64	90	---
070498	070498-- 4-1971 OBS	3105925	AB	FR	143	Level	0.01	---	76	76	71	76	L, G (J)
070501	070501-- IND 2	3105295	AB	WP	159	DEM	5	08/05/1969	141	156	116	141	---
070502	070502-- DEWATER 1	---	AB	WP	168	DEM	5	01/14/1966	130	---	120	130	---
070505	070505-- REGIONAL H S 1	3103277	AB	WP, FR	174	DEM	5	09/10/1957	110	170	102	110	L, G (SPR)
070506	070506-- EDGE-WOOD	3105342	AB	WP	178	DEM	5	06/10/1969	125	---	115	125	---
070508	070508-- DOM	---	AB	WP	149	DEM	5	---	97	---	90	97	---
070514	070514-- DOM	---	AB	WP	160	DEM	5	01/21/1956	67	---	61	67	---

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

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070572	070572-- WIN-SLOW10	3114078	AB	FR	107	DEM	5	10/08/1978	314	314	304	314	L
070598	070598-- WINSLOW 1	3120740	AB	FR	110	DEM	5	10/17/1983	175	190	150	175	L
070606	070606-- IRR 1	3104765	AB	WP	81	DEM	5	10/05/1964	162	---	16	162	---
070671	070671-- INSTITU-TIONAL 7	3108079	AB	FR	104	DEM	5	07/02/1974	144	186	116	141	L
070678	070678-- IRR	3124091	AB	WP	129	DEM	5	12/11/1985	100	100	80	100	---
070682	070682-- DOM	3108663	AB	WP	173	DEM	5	06/06/1975	74	74	64	74	---
070686	070686-- 31-3194	3103194	AB	WP	123	DEM	5	07/25/1957	50	50	40	50	---
070698	070698-- 8/REP. 4	3126123	AB	WP	104	DEM	5	03/25/1987	167	204	134	164	---
070699	070699-- DOM	3126654	AB	WP	127	DEM	5	09/10/1988	110	110	100	110	---
070705	070705-- DOM	3122181	AB	WP	144	DEM	5	03/14/1985	90	90	76	86	---
070708	070708-- TW-3	3122373	AB	WP	142	DEM	5	01/04/1985	120	120	90	120	---
070710	070710-- DOM	3124333	AB	WP, FR	110	DEM	5	11/10/1986	100	100	90	100	L
070713	070713-- DOM 5	3127938	AB	WP	154	DEM	5	03/04/1988	108	108	98	108	---
070715	070715-- DOM 1	3129999	AB	WP, FR	91	Map	5	12/15/1988	104	104	94	104	L
070736	070736-- PW 3	3105578	AB	WP	142	DEM	5	01/25/1971	97	157	81	96	---
070737	070737-- BERLIN-BA RD 2	3136453	AB	WP	161	DEM	5	05/03/1991	119	120	91	111	---
070740	070740-- PZ 3	3139312	AB	FR	70	DEM	5	06/12/1992	13	13	8	13	L
070807	070807-- IRR 3	3119894	AB	WP	90	DEM	5	03/14/1983	120	120	100	120	---
070808	070808-- IRR 1	3104940	AB	WP	107	DEM	5	05/06/1966	200	200	20	200	---

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

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070809	070809-- SPRING RD OW 7	3138740	AB	WP	104	DEM	5	04/13/1992	130	130	40	130	---
070810	070810-- 2-1954	3101469	AB	WP	76	DEM	5	10/25/1954	120	120	93	120	---
070812	070812-- IRR 2-1969	3105349	AB	WP	83	DEM	5	06/13/1969	151	151	121	151	---
070813	070813-- IRR 2	3105032	AB	WP, FR	138	DEM	5	02/02/1967	94	100	34	94	L
070814	070814-- IRR 1	3121345	AB	WP	130	DEM	5	06/08/1984	135	135	35	135	---
070815	070815-- IRR 1	3105210	AB	WP, FR	142	DEM	5	03/07/1968	84	90	25	84	L
070816	070816-- IRR 1	3113584	AB	WP	117	DEM	5	08/06/1978	128	128	77	128	---
070817	070817-- IRR 1988	3128888	AB	FR	136	DEM	5	07/07/1988	130	130	90	130	L
070818	070818-- N OF POND IRR	3104949	AB	WP	130	DEM	5	04/29/1966	130	137	110	130	---
070901	070901-- PW 8	3151329	AB	WP	153	DEM	5	07/08/1994	150	181	103	145	---
070982	070982-- ENVIRON CTR 1	3105229	AB	WP, FR	106	DEM	5	05/02/1968	139	149	119	139	L
070983	070983-- EDGE-WOOD	3129724	AB	WP	170	DEM	5	10/28/1988	136	136	116	136	---
070988	070988-- SUSCP29 DOM	3138324	AB	WP	148	DEM	5	05/28/1992	91	91	81	91	---
070990	070990-- IRR 6	3144532	AB	WP	73	DEM	5	08/23/1994	150	150	60	150	---
070991	070991-- PW 2	3105617	AB	WP	150	DEM	5	04/14/1971	105	110	85	105	---
070992	070992-- PW 1	3114167	AB	WP	151	DEM	5	08/16/1979	124	124	104	124	---
071000	071000-- IRR 2	3144392	AB	FR	125	DEM	5	07/09/1994	100	105	70	100	L
071002	071002-- IRR 3	3134400	AB	WP	120	DEM	5	07/10/1990	140	140	60	140	---

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
071003	071003-- IRR 2	3130945	AB	WP	125	DEM	5	06/01/1989	140	150	70	140	---
071084	071084-- ELEM. SCH	3124130	AB	WP	121	DEM	5	01/02/1986	93	95	83	93	---
071088	071088-- ALB-B3	---	AB	GPR	79	DEM	5	06/02/04	---	20	---	---	L
071089	071089-- ALB-B4	---	AB	GPR	91	DEM	5	06/03/04	---	28	---	---	L
071091	071091-- AB OW-1M	3168275	AB	ST	155	DEM	5	9/24/2004	95	99	85	95	---
071092	071092-- AB OW-1D	3168274	AB	FR, ST	156	DEM	5	08/27/2004	160	180	150	160	L, G (J, VSP, SPR)
071093	071093-- TW1	3159328	AB	WP	160	DEM	5	12/21/2000	155	160	110	150	---
071095	071095-- WELL 2	3164904	AB	FR	156	DEM	5	---	153	125	108	148	G (J, VSP, SPR)
071147	071147-- REPL	3164921	AB	FR	138	DEM	5	---	390	---	---	---	G (J, VSP, SPR)
151594	151594-- BL. HORSE TEST	3158697	AB	FR	113	DEM	5	---	420	---	---	---	G (J, VSP, SPR)
151593	151593-- COLES MILL TEST	3158698	AB	FR	117	DEM	5	---	460	---	---	---	G (J, VSP, SPR)
151592	151592--TEST 2	3158699	AB	FR	100	DEM	5	---	420	460	---	---	G (J, VSP, SPR)
---	ABGPR-0902A	---	AB	GPR, FR	48	DEM	5	---	---	---	---	---	---
---	ABGPR-0902B	---	AB	GPR, FR	43	DEM	5	---	---	---	---	---	---
---	ABGPR-0902C	---	AB	GPR, FR	41	DEM	5	---	---	---	---	---	---
---	ABGPR-1501B	---	AB	GPR, FR	71	DEM	5	---	---	---	---	---	---
---	ABGPR-1801E	---	AB	GPR, FR	89	DEM	5	---	---	---	---	---	---
050357	050357-- IRR	32-00581	MB	WP, FR	110	DEM	5	09/18/1968	192	250	40	98	L, G (VSP, SPR, J)
050365	050365-- PEMB. PW 4	3200386	MB	FR	94	DEM	5	09/15/1960	330	402	290	330	L, G (J)
050366	050366-- PEMB. 4 INCH OB	3200775	MB	FR	90	DEM	5	12/16/1971	323	323	301	323	L, G (J)

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
050375	050375-- BUR CO INST 3/9	3200276	MB	FR	71	DEM	5	10/12/1956	378	454	343	378	L
050378	050378-- INSTITU-TIONAL 5	3200795	MB	FR	66	DEM	5	03/03/1972	368	440	328	368	L, G (VSP, SPR)
050451	050451-- MULLICA 5D	---	MB	FR	64	Level	0.01	09/01/1975	170	215	165	170	L, G (VSP, SPR, J)
050673	050673-- TEST HOLE 14	5200032	MB	FR	83	DEM	5	---	1519	1519	---	---	L, G (VSP, SPR)
050676	050676-- COYLE AIRPORT	---	MB	FR	198	Level	0.01	---	540	595	530	540	G (J)
050678	050678-- MULLICA 8S	---	MB	FR	111	Level	0.01	09/01/1975	50	225	45	50	L, G (VSP, SPR, J)
050681	050681-- TST HOLE 1	5200025	MB	FR	111	DEM	5	3/11/1951	1140	1147	---	---	L, G (VSP, SPR)
050682	050682-- TST HL 2	5200026	MB	FR	130	DEM	5	3/16/1951	881	881	---	---	L, G (VSP, SPR)
050683	050683-- BUTLER PLACE 1	---	MB	FR	139	Level	0.1	09/30/1964	2117	2297	2102	2117	L, G (VSP, SPR, J)
050685	050685-- TST HL 4	5200028	MB	FR	129	DEM	5	3/27/1951	900	900	---	---	L, G (VSP, SPR)
050686	050686-- TST HL 3	5200027	MB	FR	136	DEM	5	3/22/1951	1207	1207	---	---	L, G (VSP, SPR)
050687	050687-- TST HL 10	5200030	MB	FR	101	DEM	5	5/2/1951	928	928	---	---	L, G (VSP, SPR)
050688	050688-- TST HL 8	5200029	MB	FR	124	DEM	5	4/19/1951	902	902	---	---	L, G (VSP, SPR)
050690	050690-- LEBANON SF 2	---	MB	FR	125	Level	0.1	---	81		76	81	G (J)
050691	050691-- TST HL 11	5200031	MB	FR	106	DEM	5	5/6/1951	954	954	---	---	L, G (VSP, SPR)
050693	050693-- R3-1974	3201315	MB	WP	120	DEM	5	---	87	---	66	87	---

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
050695	050695-- TEST HOLE 1-74	3201240	MB	FR	101	DEM	5	05/09/1974	496	549	428	496	L, G (VSP, SPR)
050696	050696-- TST HL 5	---	MB	FR	134	DEM	5	3/30/1951	900	900	---	---	L, G (VSP, SPR)
050697	050697-- TST HL 6	---	MB	FR	139	DEM	5	4/5/1951	900	900	---	---	L, G (VSP, SPR)
050708	050708-- GLASS-WORKS	3200727	MB	WP, FR	123	DEM	5	07/14/1971	92	97	77	92	L
050709	050709-- NJ WOOD-LAND	3200726	MB	WP, FR	110	DEM	5	07/14/1971	107	107	87	102	L
050736	050736-- SAW MILL 1	---	MB	FR	120	DEM	5	---	76	76	---	---	J
050737	050737-- 1961 WELL	3200378	MB	FR	73	DEM	5	04/28/1961	283	286	272	283	L,G (J)
051074	051074-- LEAD WELL	---	MB	FR	171	Level	0.1	09/18/1985	45	48	42	45	L
051092	051092-- INSTITU-TIONAL 2	3208688	MB	WP	119	DEM	5	12/15/1982	85	85	55	85	---
051173	051173-- DEV CEN-TER	3206083	MB	WP	130	DEM	5	05/27/1980	97	120	77	97	---
051333	051333-- DOM	3214363	MB	FR	116	DEM	5	02/08/1988	100	100	85	95	L
051334	051334-- DOM	3213114	MB	FR	108	DEM	5	12/18/1986	108	110	95	100	L
051335	051335-- IRR	3214492	MB	FR	119	DEM	5	03/30/1988	90	95	75	90	L
051337	051337-- DOM 1995	3220726	MB	WP, FR	84	DEM	5	06/02/1995	67	67	62	67	L
051384	051384-- DOM	3219191	MB	WP, FR	139	DEM	5	04/16/1993	80	80	70	80	L
051385	051385-- DOM	3219550	MB	WP	140	DEM	5	10/20/1994	105	105	95	105	---
051389	051389-- NEW LIS-BON 1	3222005	MB	FR	106	Level	0.1	04/03/1997	920	1016	900	920	L, G (VSP, SPR, J)

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

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U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
051391	051391-- COYLE 2 OBS	3221805	MB	FR	186	Level	0.1	06/01/1997	1441	1780	1416	1436	J
051474	051474-- IRR 5	3219150	MB	WP, FR	120	DEM	5	09/23/1993	182	182	72	182	L
051550	051550-- MDB-B1	---	MB	GPR	148	DEM	5	05/18/04	---	28	---	---	L
051551	051551-- MDB-B2	---	MB	GPR	129	DEM	5	05/18/04	---	19	---	---	L
051552	051552-- MDB-B3	---	MB	GPR	120	DEM	5	05/19/04	---	16	---	---	L
051553	051553-- MDB-B6	---	MB	GPR	135	DEM	5	05/20/04	---	28	---	---	L
051554	051554-- MDB-B4	---	MB	GPR	134	DEM	5	05/19/04	---	19	---	---	L
051555	051555-- MDB-B5	---	MB	GPR	123	DEM	5	05/19/04	---	19	---	---	L
051556	051556-- MB OW-1D	3227994	MB	FR, ST	151	DEM	5	09/14/2004	190	250	180	190	L, G (C, VSP, SPR, J)
051557	051557-- MB OW-1M	3227995	MB	ST	151	DEM	5	9/20/2004	90	95	80	90	---
051558	051558-- MB OW-2M	3227992	MB	ST	140	DEM	5	9/16/2004	100	100	90	100	---
051559	051559-- MB OW-2S	3227993	MB	ST	140	DEM	5	9/22/2004	35	35	25	35	---
051560	051560-- MB OW-2D	3227991	MB	FR, ST	140	DEM	5	09/03/2004	185	235	175	185	L, G (C, VSP, SPR, J)
051587	051587-- MB UP-2	3228096	MB	FR	128	DEM	5	9/16/2004	22	24	12	24	---
051589	051589-- MB UP-1	3228097	MB	FR	139	DEM	5	9/23/2004	29	29	19	29	---
051592	051592-- MB UP-3	3228095	MB	FR	139	DEM	5	9/17/2004	32	32	22	32	---
051595	051595-- MB UP-4	3228094	MB	FR	133	DEM	5	9/17/2004	25	27	15	27	---
051596	051596-- MB UP-5	3228093	MB	FR	113	DEM	5	9/22/2004	40	40	30	40	---
051597	051597-- MB TB-1	3228090	MB	FR	113	DEM	5	09/20/2004	---	200	---	---	L, G (C, VSP, SPR, J)

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290425	290425-- WEBBS MILLS 2	---	MB	FR	127	Level	0.1	---	348	---	---	---	L G (J)
---	MBGPR-0401C	---	MB	GPR, FR	149	DEM	5	---	---	---	---	---	---
---	MBGPR-0701C	---	MB	GPR, FR	138	DEM	5	---	---	---	---	---	---
---	MBGPR-2401C	---	MB	GPR, FR	157	DEM	5	---	---	---	---	---	---
---	MBGPR-BR12B	---	MB	GPR, FR	148	DEM	5	---	---	---	---	---	---
---	MBGPR-BR13A	---	MB	GPR, FR	149	DEM	5	---	---	---	---	---	---
---	MBGPR-BR13B	---	MB	GPR, FR	149	DEM	5	---	---	---	---	---	---
---	MBGPR-BR14B	---	MB	GPR, FR	150	DEM	5	---	---	---	---	---	---
010116	010116-- PW 3	---	MM	FR	40	DEM	5	03/18/1942	401	401	342	394	L, G (J)
010117	010117-- PW 5	3200477	MM	FR	40	DEM	5	11/11/1964	432	507	350	432	L, G (VSP, SPR)
010151	010151-- SHORE-CANALE	3600428	MM	WP, FR	42	DEM	5	11/21/1971	208	233	172	208	L, G (J)
010160	010160-- IND 1	3600367	MM	WP, FR	34	DEM	5	12/15/1964	167	167	141	166	L
010179	010179-- DOM	3600265	MM	WP	48	DEM	2.5	02/20/1957	64	64	58	64	---
010180	010180-- OCEAN-VILLE 1	3600294	MM	FR	25	DEM	5	---	570	1002	560	570	L, G (J, VSP, SPR)
010183	010183-- PW 1	3600443	MM	WP, FR	68	DEM	5	06/19/1974	192	206	172	192	L
010185	010185-- IND 2	3600392	MM	WP	65	DEM	5	04/28/1967	173	173	140	173	---
010186	010186-- WELL 2	---	MM	WP	53	Level	0.01	03/27/1969	62	---	40	62	---
010188	010188-- 2 OBS	3600418	MM	FR	64	DEM	5	---	208	208	---	---	L, G (VSP, SPR)
010189	010189-- TEST 1	3600420	MM	WP	64	DEM	5	10/27/1970	159	208	118	159	---

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U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
010190	010190-- TEST 2	3600421	MM	WP	64	DEM	5	10/29/1970	167	208	136	167	---
010191	010191-- TEST 3	3600422	MM	WP	64	DEM	5	11/11/1970	159	208	133	159	---
010193	010193-- INSTITU-TIONAL 1	3600425	MM	WP	32	DEM	5	06/07/1971	150	150	130	150	---
010194	010194-- INSTITU-TIONAL 2	3600424	MM	WP	30	DEM	5	05/24/1971	145	150	125	145	---
010197	010197-- WELL 1	3600415	MM	WP	53	DEM	5	04/15/1965	125	---	75	125	---
010200	010200-- IRR 1	3600390	MM	WP, FR	61	DEM	5	07/25/1966	120	125	30	120	L
010206	010206-- IRR	3600393	MM	WP, FR	56	DEM	5	04/04/1967	100	110	25	100	L
010218	010218-- IRR-10	3600439	MM	WP	58	DEM	5	11/26/1974	118	118	98	118	---
010225	010225-- IRR	3600260	MM	WP, FR	76	DEM	2.5	09/07/1956	160	288	137	157	L
010566	010566-- 600	---	MM	FR	10	Level	0.01	---	565		---	---	G (J)
010575	010575-- PW 12	5600033	MM	FR	4	Level	1	---	195	195	145	195	L
010649	010649-- TW4-78	---	MM	FR	6	DEM	2.5	---	1050	1050	971	1050	L, G (J, VSP, SPR)
010650	010650-- HAM. TEST2-73	---	MM	FR	21	DEM	2.5	---	380	380			G (J)
010686	010686-- INSTITU-TIONAL 2	3603110	MM	WP, FR	68	DEM	5	11/24/1982	172	175	149	169	L, G (VSP, SPR)
010689	010689-- SWC 2	3602433	MM	WP, FR	31	DEM	5	07/18/1981	180	202	130	180	L
010696	010696-- PW 16	3603934	MM	WP, FR	25	Level	0.1	02/21/1984	180	202	130	180	L
010703	010703-- FAA POMONA	3605092	MM	FR	35	DEM	5	03/11/1985	575	608	560	570	L, G (VSP, SPR)
010706	010706-- STKTN ST COLL	36049821	MM	FR	40	DEM	5	01/07/1985	535	680	520	530	L, G (VSP, SPR)
010708	010708-- IND 3	3600468	MM	WP	65	DEM	5	08/31/1976	168	185	128	168	---

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010761	010761-- SLF MW-2-1983	3603187	MM	WP	56	Level	0.1	01/12/1983	38	38	28	38	---
010781	010781-- PW 19	3605292	MM	WP, FR	27	DEM	5	05/20/1985	182	201	131	182	L
010782	010782-- PW 20	3605296	MM	WP, FR	28	DEM	5	05/15/1985	180	202	130	180	L
010783	010783-- PW 21	3605295	MM	WP, FR	29	DEM	5	---	183	202	132	183	L
010786	010786-- PW 24	3605297	MM	WP	33	DEM	5	06/20/1985	176	202	125	176	---
010873	010873-- SLF MW-1	36056472	MM	FR	61	Level	0.01	07/17/1985	62	62	42	62	L
010875	010875-- AC AIR-PORT	3603664	MM	WP	66	DEM	5	09/08/1983	100	100	90	100	---
010886	010886-- DOM	3610404	MM	WP, FR	65	DEM	2.5	08/18/1988	87	87	77	87	L
010887	010887-- DOM	3608224	MM	FR	61	DEM	2.5	03/12/1987	80	80	70	80	L
010896	010896-- DOM	3214365	MM	WP	60	DEM	5	12/30/1988	110	110	100	110	---
010916	010916-- DOM	3211428	MM	WP	12	DEM	5	01/21/1986	57	57	45	55	---
010926	010926-- DOM	3609935	MM	FR	20	DEM	5	04/04/1988	60	60	55	60	L
010928	010928-- DOM	3216822	MM	WP, FR	60	DEM	5	03/28/1990	65	65	50	65	L
010929	010929-- DOM	3214776	MM	WP, FR	81	DEM	5	11/23/1988	80	80	65	80	L
010930	010930-- NACOTE CRK RES.	3611742	MM	FR	10	DEM	5	04/20/1989	100	100	90	100	L
010934	010934-- DOM.	3614546	MM	FR	40	DEM	2.5	06/06/1991	145	145	140	145	L
010956	010956-- STHN DIV 15	3606252	MM	WP, FR	58	DEM	5	12/20/1985	166	179	146	166	L
010957	010957-- 2/LAUN-DRY RM	3603984	MM	WP, FR	71	DEM	5	03/07/1984	100	100	92	100	L

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
010970	010970-- WALDON-WAY	3602070	MM	WP	45	DEM	5	12/18/1980	200	200	170	200	---
010972	010972-- PW 1	3608845	MM	WP, FR	63	DEM	5	09/10/1987	156	210	120	152	L
010973	010973-- 3/17 MOSS-MILL	3614415	MM	WP, FR	32	DEM	5	05/06/1991	185	201	134	185	L
010977	010977-- DOM RE-PLACE	3602882	MM	WP	53	DEM	2.5	05/27/1982	85	85	80	85	---
010992	010992-- DOM-1988	3610247	MM	WP	65	DEM	5	09/11/1988	102	102	97	102	---
010997	010997-- IRR 2R	3609890	MM	WP, FR	62	DEM	5	03/30/1988	160	160	80	160	L
010999	010999-- IRR	3612213	MM	WP, FR	45	DEM	5	08/23/1989	195	200	170	190	L
011002	011002-- DUERER ST	3613067	MM	WP	60	DEM	5	03/20/1990	120	120	100	120	---
011218	011218-- CATES RD 1	3617655	MM	FR	65	DEM	2.5	05/21/1994	610	610	520	610	L
011220	011220-- LOWELL AVE 1	3617339	MM	FR	65	DEM	5	03/06/1994	602	643	552	602	L
011297	011297-- IRR-3R	3615811	MM	WP, FR	70	DEM	2.5	06/05/1992	150	150	60	150	L
011298	011298-- IRR	3605434	MM	WP	70	DEM	5	05/29/1985	101	101	85	101	---
011309	011309-- IRR 2	3213438	MM	FR	72	DEM	5	05/28/1987	200	200	100	200	L
011323	011323-- IRR-1	3600452	MM	WP	59	DEM	5	06/17/1975	70	70	40	70	---
011325	011325-- IRR-1	3615681	MM	WP	65	DEM	5	04/29/1992	190	220	140	190	---
011340	011340-- GSP-2	3600469	MM	WP, FR	65	DEM	5	09/02/1976	108	122	88	108	L
011351	011351-- RW-2-93	3219089	MM	FR	65	DEM	5	03/10/1993	77	77	67	77	L

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
011352	011352-- RW-2-91	3615206	MM	FR	68	DEM	5	11/12/1991	60	60	40	60	L
011356	011356-- RW-6-91	3615210	MM	FR	63	DEM	5	11/25/1991	65	65	45	65	L
011364	011364-- IRR-2	3615680	MM	WP	65	DEM	5	04/29/1992	190	220	140	190	---
011411	011411-- IRR C1	3621929	MM	FR	39	DEM	2.5	04/22/1998	180	200	140	180	L
011414	011414-- IRR3	3621195	MM	FR	10	DEM	2.5	05/01/1997	170	170	160	170	L
011430	011430-- UC-4E	3619152	MM	FR	67	DEM	2.5	12/21/1995	96	96	68	93	L
011442	011442-- DOM 10	3612503	MM	FR	31	DEM	5	10/10/1989	118	120	108	118	L
011443	011443-- DOM 9	3606592	MM	WP, FR	71	DEM	5	05/07/1986	210	210	152	162	L
011444	011444-- DOM 8	3609785	MM	FR	61	DEM	5	05/02/1988	175	175	165	175	L
011495	011495-- RW-1	3610833	MM	WP	65	DEM	5	11/29/1988	55	58	35	55	---
011498	011498-- MM OW-1M	3628385	MM	ST	57	DEM	5	08/19/2004	65	70	55	65	---
011499	011499-- MM OW-1D	3628384	MM	FR, ST	56	DEM	5	08/17/2004	165	220	155	165	L, G (VSP, SPR, J)
011500	011500-- MM OW-1S	3628386	MM	ST	56	DEM	5	9/21/2004	22	30	12	22	---
011501	011501-- MM OW-2S	3628383	MM	ST	40	DEM	5	9/10/2004	40	50	30	40	---
011502	011502-- MM OW-2M	3628382	MM	ST	40	DEM	5	9/10/2004	73	85	63	73	---
011503	011503-- MM OW-2D	3628381	MM	FR, ST	39	DEM	5	08/25/2004	170	235	160	170	L, G (VSP, SPR, J)
011623	011623-- POM. MW-7D	3610847	MM	FR	50	Level	5	12/19/1989	213	220	203	213	L, G (J)
011629	011629-- POM. MW-8D	36108481	MM	FR	68	Level	5	01/18/1989	206	214	196	206	L, G (J)
011649	011649-- TEST 2	3600454	MM	FR	23	DEM	5	8/11/1975	691	---	---	---	L, G (VSP, SPR)
011650	011650-- MW104-D	3625547	MM	FR	55	Level	0.1	---	105.5	104.7	95.5	105.5	L, G (J)
011651	011651-- MW 2	3624524	MM	FR	63	DEM	5	11/15/2000	178	180	168	178	L, G (J)

Table 2. Records of selected hydrologic investigation sites used to describe the hydrogeologic framework of the Kirkwood-Cohansey aquifer system in Pinelands study areas and vicinity, New Jersey.—Continued

[UID: Unique Identification Number. Study Area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream. NAVD88, North American Vertical Datum 1988; Data type: FR, hydrogeologic-framework data; GPR, Ground-penetrating radar data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well-performance data. Method of altitude measurement: DEM, 10-meter Digital Elevation Model; Level, leveling. Depth in feet: bls, below land surface. Log Type: L, drillers log; G, geophysical log; J, gamma; VSP, potential; SPR, resistivity. ---, no data]

U.S. Geological Survey well number (UID)	Site name	New Jersey permit number	Study area	Data type	Altitude of land surface, NAVD88 (feet)	Altitude method	Altitude accuracy (feet)	Date of construction	Well depth (feet bls)	Borehole depth (feet bls)	Screen top (feet bls)	Screen bottom (feet bls)	Log type
011652	011652-- MW106-D	3625387	MM	FR	55	Level	0.1	---	120.7	120	110.7	120.7	L, G (J)
011653	011653-- 110	5200018	MM	FR	65	DEM	5	3/28/1956	429	---	---	---	L
---	MMGPR-0202C	---	MM	GPR, FR	45	DEM	5	---	---	---	---	---	---
---	MMGPR-0501B	---	MM	GPR, FR	55	DEM	5	---	---	---	---	---	---
---	MMGPR-1101B	---	MM	GPR, FR	41	DEM	5	---	---	---	---	---	---
---	MMGPR-1301A	---	MM	GPR, FR	39	DEM	5	---	---	---	---	---	---

Table 4. Estimated Hydraulic conductivity (K) values for sites in the Pinelands study areas and vicinity, New Jersey.

[Study area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; Data type: FR, hydrogeologic-framework-interpretation data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well performance data; ft/d, feet per day; NAVD88, North American Vertical Datum 1988; --, data unavailable]

U.S. Geological Survey well number (UID)	Study area	Data type	Estimated hydraulic conductivity (K) (ft/d)	Well depth (feet)	Altitude of land surface, NAVD 88 (Feet)	Screen top (feet below land surface)	Screen bottom (feet below land surface)	Altittude of screen top (feet)	Altitude of screen bottom (feet)	Hydrogeologic/ model layer with well screen
010286	AB	WP	63	100	89	45	100	44	-11	A1C1-C1
010324	AB	WP	66	180	99	10	180	89	-81	A1-A3
010641	AB	WP	116	58	70	48	58	22	12	A1B-C1
010643	AB	WP	218	85	70	65	85	5	-15	C1-A2
010645	AB	WP	140	90	78	70	90	8	-12	C1-A2
010658	AB	WP	361	43	71	33	43	38	28	A1B
011023	AB	WP	66	180	100	10	180	90	-80	A1-A3
011024	AB	WP	47	135	61	55	135	6	-74	C1-A3
011317	AB	WP, FR	48	160	70	100	160	-30	-90	C2-A3
011339	AB	WP, FR	38	103	64	83	103	-19	-39	A2-C2
011504	AB	FR, ST	32	160	56	150	160	-94	-104	A3
011505	AB	ST	115	50	56	40	50	16	6	A1B
011506	AB	ST	70	92	56	82	92	-26	-36	A2-C2
070433	AB	WP	115	129	90	30	129	60	-39	A1B-A3
070434	AB	WP	98	130	91	10	130	81	-39	A1C1-A3
070435	AB	WP	136	105	91	100	105	-9	-14	C2
070436	AB	WP	608	130	118	110	130	8	-12	C2-A3
070437	AB	WP	125	82	108	72	82	36	26	A2
070447	AB	WP	146	84	168	79	84	89	84	A2
070450	AB	WP	108	81	166	71	81	95	85	A2
070455	AB	WP	69	122	102	30	122	72	-20	A1-C2
070456	AB	WP, FR	99	140	98	130	140	-32	-42	A3
070457	AB	WP	62	67	98	57	67	41	31	C1
070458	AB	WP	57	103	102	97	103	5	-1	A2
070459	AB	WP	84	180	96	40	180	56	-84	A1B-A3

Table 4. Estimated Hydraulic conductivity (K) values for sites in the Pinelands study areas and vicinity, New Jersey.—Continued

[Study area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; Data type: FR, hydrogeologic-framework-interpretation data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well performance data; ft/d, feet per day; NAVD88, North American Vertical Datum 1988; --, data unavailable]

U.S. Geological Survey well number (UID)	Study area	Data type	Estimated hydraulic conductivity (K) (ft/d)	Well depth (feet)	Altitude of land surface, NAVD 88 (Feet)	Screen top (feet below land surface)	Screen bottom (feet below land surface)	Altittude of screen top (feet)	Altitude of screen bottom (feet)	Hydrogeologic/ model layer with well screen
070460	AB	WP, FR	29	53	104	33	53	71	51	A1B
070461	AB	WP	65	200	110	20	200	90	-90	A1-A3
070462	AB	WP	40	104	109	70	104	39	5	C1-A2
070467	AB	WP	22	71	90	65	71	25	19	C1
070468	AB	WP	106	165	102	145	165	-43	-63	A3
070470	AB	WP, FR	60	167	110	141	167	-31	-57	A3
070471	AB	WP	64	138	104	117	138	-13	-34	C2-A3
070480	AB	WP	14	100	139	40	100	99	39	A1B-C2
070481	AB	WP, FR	162	111	123	74	107	49	16	A3
070483	AB	WP	224	139	109	118	139	-9	-30	A3
070489	AB	WP	56	90	135	84	90	51	45	A2-C2
070490	AB	WP	231	113	116	72	103	44	13	C2-A3
070497	AB	WP	192	101	122	64	90	58	32	C2-A3
070501	AB	WP	144	141	166	116	141	50	25	A3
070502	AB	WP	184	130	169	120	130	49	39	C2-A3
070505	AB	WP, FR	485	110	174	102	110	72	64	A2-C2
070506	AB	WP	104	125	178	115	125	63	53	C2
070508	AB	WP	207	97	149	90	97	59	52	C2
070514	AB	WP	11	67	160	61	67	99	93	A2
070606	AB	WP	79	162	81	16	162	65	-81	A1-A3
070678	AB	WP	148	100	127	80	100	47	27	C1-A2
070682	AB	WP	57	74	160	64	74	96	86	A2
070686	AB	WP	374	50	121	40	50	81	71	A1B-C1
070698	AB	WP	222	167	101	134	164	-33	-63	A3
070699	AB	WP	55	110	128	100	110	28	18	C2

Table 4. Estimated Hydraulic conductivity (K) values for sites in the Pinelands study areas and vicinity, New Jersey.—Continued

[Study area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; Data type: FR, hydrogeologic-framework-interpretation data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well performance data; ft/d, feet per day; NAVD88, North American Vertical Datum 1988; --, data unavailable]

U.S. Geological Survey well number (UID)	Study area	Data type	Estimated hydraulic conductivity (K) (ft/d)	Well depth (feet)	Altitude of land surface, NAVD 88 (Feet)	Screen top (feet below land surface)	Screen bottom (feet below land surface)	Altittude of screen top (feet)	Altitude of screen bottom (feet)	Hydrogeologic/ model layer with well screen
070705	AB	WP	345	90	149	76	86	73	63	A2-C2
070708	AB	WP	63	120	142	90	120	52	22	C2-A3
070710	AB	WP, FR	47	100	110	90	100	20	10	C2-A3
070713	AB	WP	124	108	154	98	108	56	46	C2
070715	AB	WP, FR	86	104	98	94	104	4	-6	C2
070736	AB	WP	80	97	142	81	96	61	46	A2-C2
070737	AB	WP	470	119	161	91	111	70	50	C2
070807	AB	WP	53	120	90	100	120	-10	-30	C2
070808	AB	WP	65	200	107	20	200	87	-93	A1-A3
070809	AB	WP	52	130	104	40	130	64	-26	A1B-C2
070810	AB	WP	39	120	76	93	120	-17	-44	A2-C2
070812	AB	WP	199	151	87	121	151	-34	-64	C2-A3
070813	AB	WP, FR	12	94	138	34	94	104	44	A-1B-C2
070814	AB	WP	42	135	130	35	135	95	-5	C1-A3
070815	AB	WP, FR	58	84	142	25	84	117	58	A1B-A2
070816	AB	WP	89	128	116	77	128	39	-12	A2-A3
070818	AB	WP	608	130	120	110	130	10	-10	C2-A3
070901	AB	WP	259	150	153	103	145	50	8	C2-A3
070982	AB	WP, FR	228	139	106	119	139	-13	-33	A3
070983	AB	WP	81	136	170	116	136	54	34	C2
070988	AB	WP	345	91	148	81	91	67	57	A2-C2
070990	AB	WP	32	150	73	60	150	13	-77	C1-A3
070991	AB	WP	123	105	154	85	105	69	49	C1-A2
070992	AB	WP	43	124	151	104	124	47	27	A2-C2
071002	AB	WP	67	140	120	60	140	60	-20	C1-A3

Table 4. Estimated Hydraulic conductivity (K) values for sites in the Pinelands study areas and vicinity, New Jersey.—Continued

[Study area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; Data type: FR, hydrogeologic-framework-interpretation data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well performance data; ft/d, feet per day; NAVD88, North American Vertical Datum 1988; --, data unavailable]

U.S. Geological Survey well number (UID)	Study area	Data type	Estimated hydraulic conductivity (K) (ft/d)	Well depth (feet)	Altitude of land surface, NAVD 88 (Feet)	Screen top (feet below land surface)	Screen bottom (feet below land surface)	Altittude of screen top (feet)	Altitude of screen bottom (feet)	Hydrogeologic/ model layer with well screen
071003	AB	WP	39	140	130	70	140	60	-10	C1-C2
071084	AB	WP	137	93	121	83	93	38	28	A2
071091	AB	ST	23	95	155	85	95	70	60	A2
071092	AB	FR, ST	97	160	155	150	160	5	-5	A3
071093	AB	WP	88	155	157	110	150	47	7	C2-A3
050357	MB	WP, FR	106	192	110	40	98	70	12	A2-A3
050693	MB	WP	269	87	120	66	87	54	33	A2-C2
050708	MB	WP, FR	221	92	123	77	92	46	31	A2-C2
050709	MB	WP, FR	23	107	110	87	102	23	8	C2
051092	MB	WP	208	85	121	55	85	66	36	A2-C2
051173	MB	WP	8	97	129	77	97	52	32	A2-C2
051337	MB	WP, FR	22	67	84	62	67	22	17	A3
051384	MB	WP, FR	19	80	139	70	80	69	59	A2
051385	MB	WP	75	105	143	95	105	48	38	A2-C2
051474	MB	WP, FR	61	182	120	72	182	48	-62	A2-C3
051556	MB	FR, ST	110	190	151	180	190	-29	-39	A3
051557	MB	ST	156	90	151	80	90	71	61	A2
051558	MB	ST	83	100	140	90	100	50	40	A2
051559	MB	ST	69	35	140	25	35	115	105	A1B
051560	MB	FR, ST	40	185	140	175	185	-35	-45	A3
010151	MM	WP, FR	201	208	42	172	208	-130	-166	A3
010160	MM	WP, FR	228	167	74	141	166	-67	-92	C2-A3
010179	MM	WP	38	64	48	58	64	-10	-16	A1B
010183	MM	WP, FR	28	192	68	172	192	-104	-124	A3
010185	MM	WP	44	173	65	140	173	-75	-108	A3

Table 4. Estimated Hydraulic conductivity (K) values for sites in the Pinelands study areas and vicinity, New Jersey.—Continued

[Study area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; Data type: FR, hydrogeologic-framework-interpretation data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well performance data; ft/d, feet per day; NAVD88, North American Vertical Datum 1988; --, data unavailable]

U.S. Geological Survey well number (UID)	Study area	Data type	Estimated hydraulic conductivity (K) (ft/d)	Well depth (feet)	Altitude of land surface, NAVD 88 (Feet)	Screen top (feet below land surface)	Screen bottom (feet below land surface)	Altittude of screen top (feet)	Altitude of screen bottom (feet)	Hydrogeologic/ model layer with well screen
010186	MM	WP	72	62	53	40	62	13	-9	A1B-A2
010189	MM	WP	24	159	64	118	159	-54	-95	A3
010190	MM	WP	57	167	64	136	167	-72	-103	A3
010191	MM	WP	49	159	64	133	159	-69	-95	A3
010193	MM	WP	103	150	36	130	150	-94	-114	A3
010194	MM	WP	94	145	33	125	145	-92	-112	A3
010197	MM	WP	141	125	53	75	125	-22	-72	A2-A3
010200	MM	WP, FR	52	120	61	30	120	31	-59	A1B-A3
010206	MM	WP, FR	144	100	56	25	100	31	-44	A1B-A3
010218	MM	WP	155	118	58	98	118	-40	-60	C2-A3
010225	MM	WP, FR	91	160	76	137	157	-61	-81	A3
010686	MM	WP, FR	155	172	68	149	169	-81	-101	A3
010689	MM	WP, FR	125	180	31	130	180	-99	-149	A3
010696	MM	WP, FR	83	180	25	130	180	-105	-155	A3
010708	MM	WP	95	168	65	128	168	-63	-103	A3
010761	MM	WP	63	38	56	28	38	28	18	A1
010781	MM	WP, FR	71	182	27	131	182	-104	-155	A3
010782	MM	WP, FR	106	180	28	130	180	-102	-152	A3
010783	MM	WP, FR	78	183	29	132	183	-103	-154	A3
010786	MM	WP	81	176	33	125	176	-92	-143	A3
010875	MM	WP	35	100	66	90	100	-24	-34	A2
010886	MM	WP, FR	143	87	65	77	87	-12	-22	C2
010896	MM	WP	40	110	60	100	110	-40	-50	C2-A3
010916	MM	WP	63	57	11	45	55	-34	-44	A2-C2
010928	MM	WP, FR	39	65	60	50	65	10	-5	A2-C2

Table 4. Estimated Hydraulic conductivity (K) values for sites in the Pinelands study areas and vicinity, New Jersey.—Continued

[Study area: AB, Albertson Brook; MB, McDonalds Branch; MM, Morses Mill Stream; Data type: FR, hydrogeologic-framework-interpretation data; ST, hydraulic conductivity derived from slug test data; WP, hydraulic conductivity derived from well performance data; ft/d, feet per day; NAVD88, North American Vertical Datum 1988; --, data unavailable]

U.S. Geological Survey well number (UID)	Study area	Data type	Estimated hydraulic conductivity (K) (ft/d)	Well depth (feet)	Altitude of land surface, NAVD 88 (Feet)	Screen top (feet below land surface)	Screen bottom (feet below land surface)	Altittude of screen top (feet)	Altitude of screen bottom (feet)	Hydrogeologic/ model layer with well screen
010929	MM	WP, FR	39	80	81	65	80	16	1	C2-A3
010956	MM	WP, FR	138	166	58	146	166	-88	-108	A3
010957	MM	WP, FR	83	100	71	92	100	-21	-29	A2
010970	MM	WP	59	200	45	170	200	-125	-155	A3
010972	MM	WP, FR	187	156	63	120	152	-57	-89	A3
010973	MM	WP, FR	107	185	32	134	185	-102	-153	A3
010977	MM	WP	70	85	53	80	85	-27	-32	A1B
010992	MM	WP	98	102	60	97	102	-37	-42	C2
010997	MM	WP, FR	30	160	62	80	160	-18	-98	A2-A3
010999	MM	WP, FR	17	195	45	170	190	-125	-145	A3
011002	MM	WP	58	120	60	100	120	-40	-60	C2-A3
011297	MM	WP, FR	19	150	70	60	150	10	-80	C1-A3
011298	MM	WP	59	101	70	85	101	-15	-31	A2-C2
011323	MM	WP	90	70	59	40	70	19	-11	A1B-A2
011325	MM	WP	36	190	65	140	190	-75	-125	A3
011340	MM	WP, FR	102	108	65	88	108	-23	-43	A2-C2
011364	MM	WP	36	190	65	140	190	-75	-125	A3
011443	MM	WP, FR	25	210	71	152	162	-81	-91	A3
011495	MM	WP	266	55	65	35	55	30	10	A1B-C1
011498	MM	ST	74	65	56	55	65	1	-9	A1B-C1
011499	MM	FR, ST	36	165	55	155	165	-100	-110	A3
011500	MM	ST	65	22	56	12	22	44	34	A1
011501	MM	ST	121	40	40	30	40	10	0	A1B
011502	MM	ST	71	73	40	63	73	-23	-33	C1-A2
011503	MM	FR, ST	45	170	40	160	170	-120	-130	A3

Appendix 1

Lithologic and geophysical logs of selected boreholes and newly installed wells in Kirkwood-Cohansey aquifer system, New Jersey Pinelands.

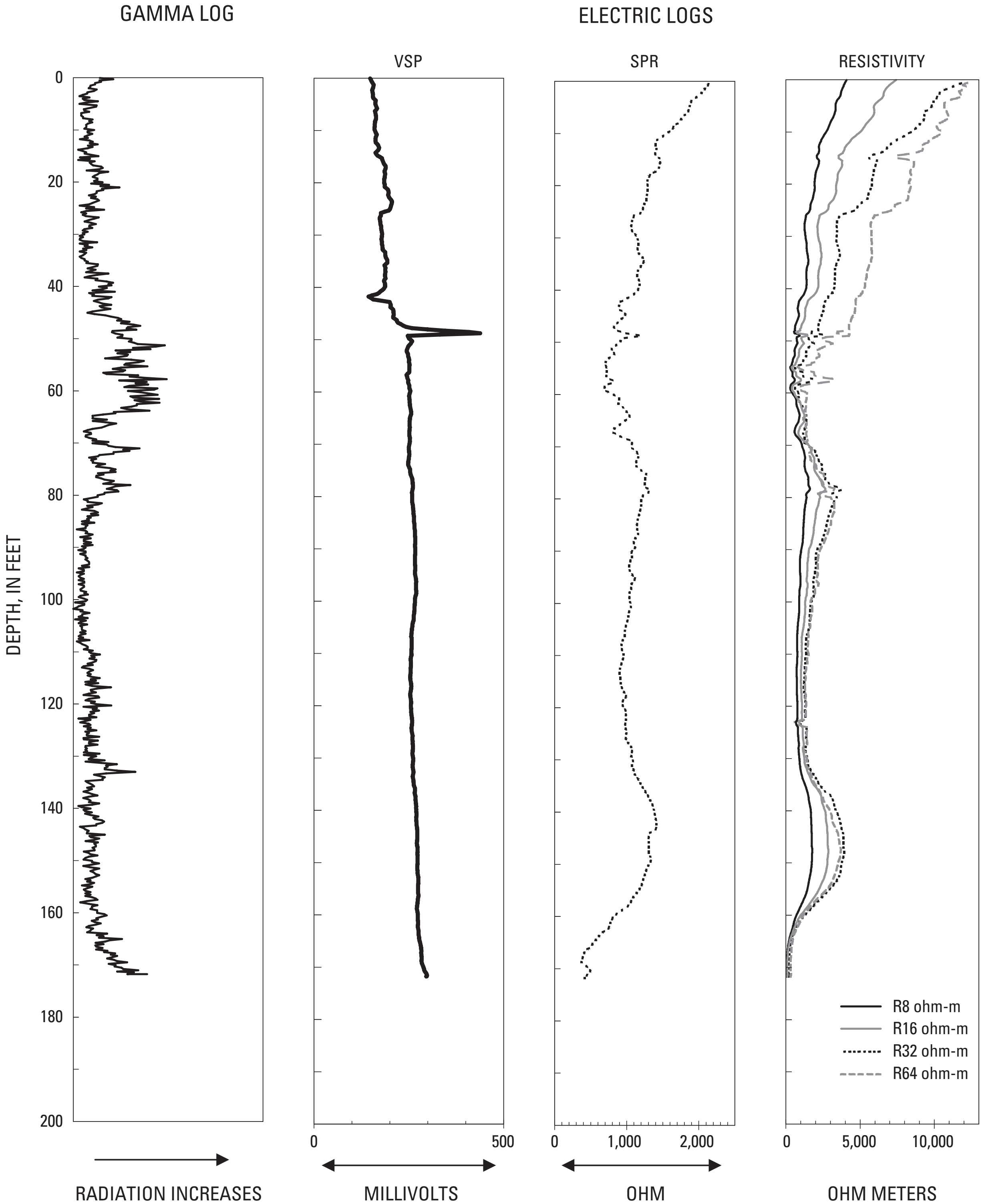


Figure 1-1. Geophysical logs of AB OW-1D (Well number 071092).

AB OW-1D Boring Log (Well Number 071092, location shown on figure 6.)

Top of interval (ft)[1]	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	20	Sand and gravel, medium to very coarse, orange brown and brownish yellow
20	25	Sand and gravel, medium to very coarse, contains thin clay layers, tan
25	30	Sand and gravel, medium to very coarse, trace iron cemented sand, with some layers of clay, medium dense, silty, yellow, 10yr7/6
30	40	Fine sand indicated by drilling - cuttings contain fine sand and soft clay
40	45	Sand indicated by drilling – cuttings contain sand medium to very coarse gravel fine and some clay, very soft, tan
45	50	Sand, very coarse, gravel fine, some iron cemented sand, cuttings contain 30% to 40% clay, silty, soft, tan
50	60	Clay indicated by drilling from 53 ft to 55 ft – cuttings contain clay, light gray some heavily oxidized to yellow, 10YR 7/6 and fine gravel, 20%
60	65	Clay, tan and very dark gray, trace lignite, mud color turns brown at about 63 feet
65	70	Clay, yellow and very dark gray with little gravel, fine grained
70	76	Clay, sandy, silty, tan/yellow oxidized to orange and clay, very dark gray 10YR 3/1
76	85	Sand indicated by drilling – cuttings contain fine to very coarse sand and about 50 % clay
85	90	Sand, fine to very coarse, trace iron cemented sand
90	95	Sand, fine to very coarse, trace iron cemented sand, and 30% clay, sandy in cuttings
95	100	Sand, medium to very coarse and gravel, fine, and 10% clay, sandy in cuttings
100	105	Sand, medium to very coarse and gravel, fine 20%
105	110	Gravel, fine to coarse and 20% sand, medium to very coarse
110	115	Gravel, medium to very coarse and 20% sand, medium to very coarse, trace clay
115	120	Gravel, medium to very coarse and 20% sand, medium to very coarse, 20 % clay
120	135	Sand, very coarse and gravel, medium to very coarse, trace cemented sand
135	140	Gravel, very coarse. Clay layer indicated by drilling at 137 feet
140	145	Gravel, fine to medium, cuttings contain about 20% clay, soft, sandy, mixed with gravel. Drilling indicates sand and gravel. Lenses of sand and gravel are likely
145	150	Gravel, fine to medium, trace clay, trace cemented sand
150	160	Gravel, fine to medium, trace clay, trace cemented sand
160	169	Sand, very fine to coarse, trace clay
169	176	Clay, very dark gray, soft, organic
176	180	Clay, medium dense, very dark gray 10YR 3/1, 10 % mica
180	181.8	Clay, very dark gray 10 YR 3/1, <10% mica, silty, dense--Split spoon sample, 100% recovery

[1]The soil matrix and color descriptions for all newly drilled boreholes were determined by comparing appropriate samples using the Munsell Soil Color Charts (1975 ed.), available from Macbeth Division, Kollmorgen Instruments Corporation, 405 Little Britain Rd. New Windsor, N.Y. 12553

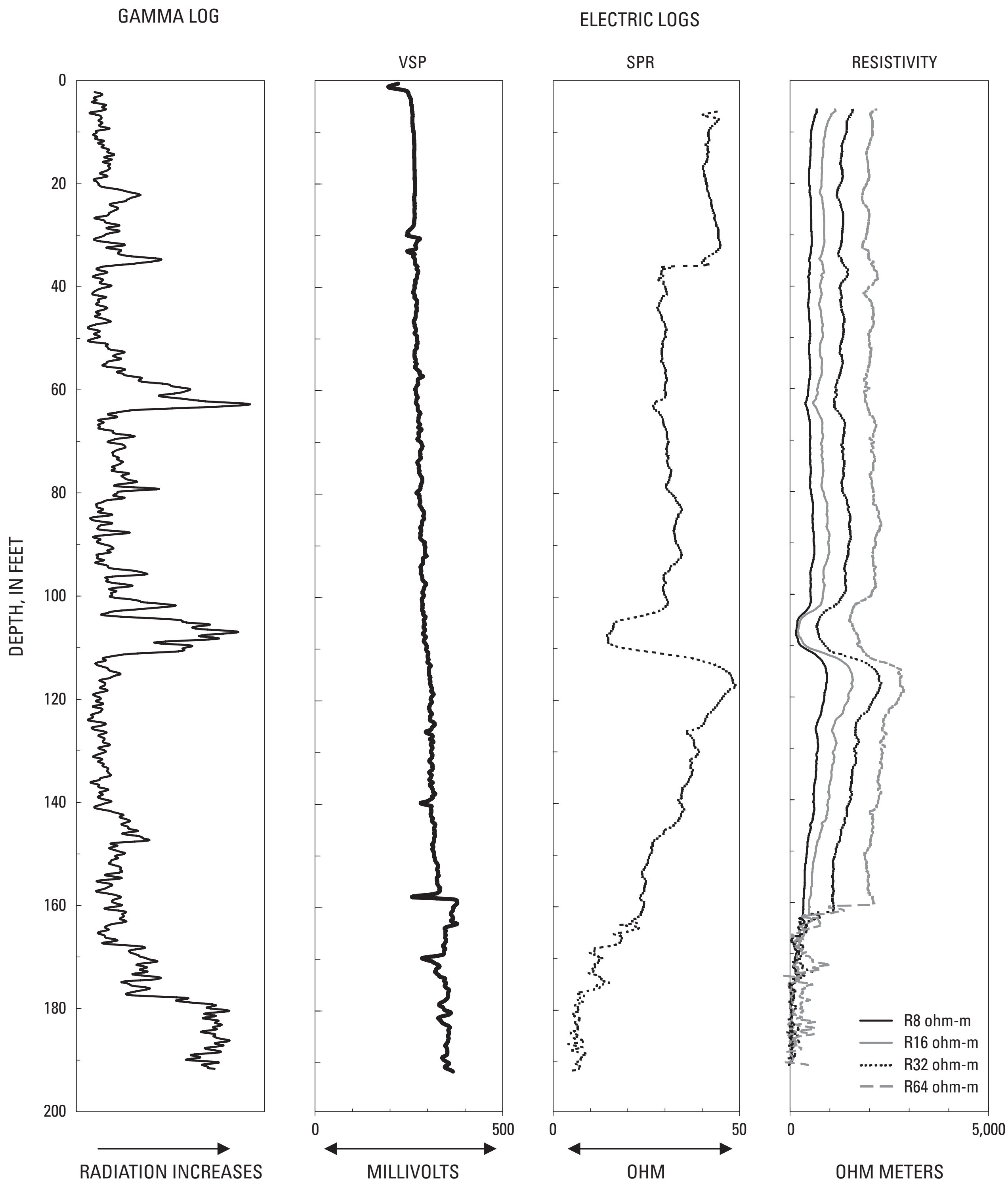


Figure 1-2. Geophysical logs of AB OW-2D (Well number 011504)

AB OW-2D Boring Log (Well Number 011504 location shown on figure 6.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	40	Sand, fine to medium and fine gravel, drilling indicates 1-ft thick white clay at 38ft
40	45	Sand, fine to medium, some gravel, trace clay
45	50	Sand, fine to medium, some gravel, with some layers of clay
50	65	Sand, fine to coarse, and gravel, iron cemented grains, some clay
65	70	Sand, fine to coarse, and gravel, iron cemented grains, some clay, increasing clay content
70	75	Sand, fine to coarse, and gravel, iron cemented grains, some clay
75	80	Sand, fine to very coarse, and gravel, and Clay – 50% clay in cuttings
80	82	Split spoon sample, 50% recovery – Clay, light gray and yellow layers bedded with sand, fine to medium with some silt, little gravel
82	89	Sand, fine to coarse, abundant rose quartz, increasing coarseness with depth, 10% clay
89	100	Sand, coarse, abundant rose quartz, iron cemented sand
100	105	Sand, medium
105	111	Clay, indicated by drilling – cuttings contain sand very coarse, and gravel and dark clay, dark brown, 10YR2/2
111	120	Sand, fine to medium
120	130	Sand, medium to coarse, fine, medium brown, trace tan clay in cuttings from 125-130 ft.
130	140	Sand, very coarse, 10% clay, very dark gray
140	145	Sand, medium to very coarse, trace very dark gray clay
145	150	Sand, medium to very coarse, clay becomes soft, and color changes to red
150	155	Sand, medium to very coarse, 40% clay, very dark gray, change noted at 154 ft.
155	160	Sand, medium to very coarse, 40% clay, very dark gray, clay appears to be in thin layers
160	178	Sand, fine – very little cuttings returned, 20% clay, dark brown
178	180	Clay, medium dense, very dark gray, 10YR3/1, trace mica
180	200	Clay, silty, very dark gray (10YR3/1), trace sand, trace to little lignite

Shallow boreholes completed in the Albertson Brook basin using Geoprobe® sediment sampling equipment and used in the interpretation of GPR records.

ALB-B1 (Well Number 011497, location shown on figure 12.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	4	Sand, fine to medium grained, poorly sorted – saturated at 3 feet
4	6.2	Sand, fine to medium with some coarse sand and gravel
6.2	8	Sand, fine to medium grained
8	12	Sand, fine to coarse grained

ALB-B2 (Well Number 011496, location shown on figure 12.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	1.2	Sand, fine to very fine grained
1.2	2.3	Sand, fine to coarse grained, becoming fine to very fine at 2.3 feet
2.3	4.0	No recovery
4.0	6.4	Sand, fine grained, saturated at 6 feet
6.4	8.0	Alternating layers of clay and sand, very fine to fine grained
8.0	11.4	Sand, fine, well sorted, clay present in thin layers, some oxidized zones

ALB-B3 (Well Number 071088, location shown in figure 12.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	6.7	Sand, fine grained, poorly sorted
6.7	7	Clayey sand
7	16	Sand, fine to coarse grained, little clay layers, occasional gravel, saturated at 9 feet
16	20	Sand, fine to very fine grained, with thin clay layers in the interval from 16 to 17.6 feet

ALB-B4 (Well Number 071089, location shown on figure 12.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	4	Sand, fine to medium grained little gravel
4	8	Sand, fine grained to gravel, small amount of clay
8	13.5	Sand, fine grained to gravel, saturated at 12 feet
13.5	14.2	Clay with fine grained sand
14.2	16	Sand, fine grained to gravel
16	20	Sand, fine to medium, with coarse sand and gravel
20	23.5	Sand, fine to very fine grained
23.5	24	Sand, fine to coarse grained
24	28	Sand, fine to very fine grained

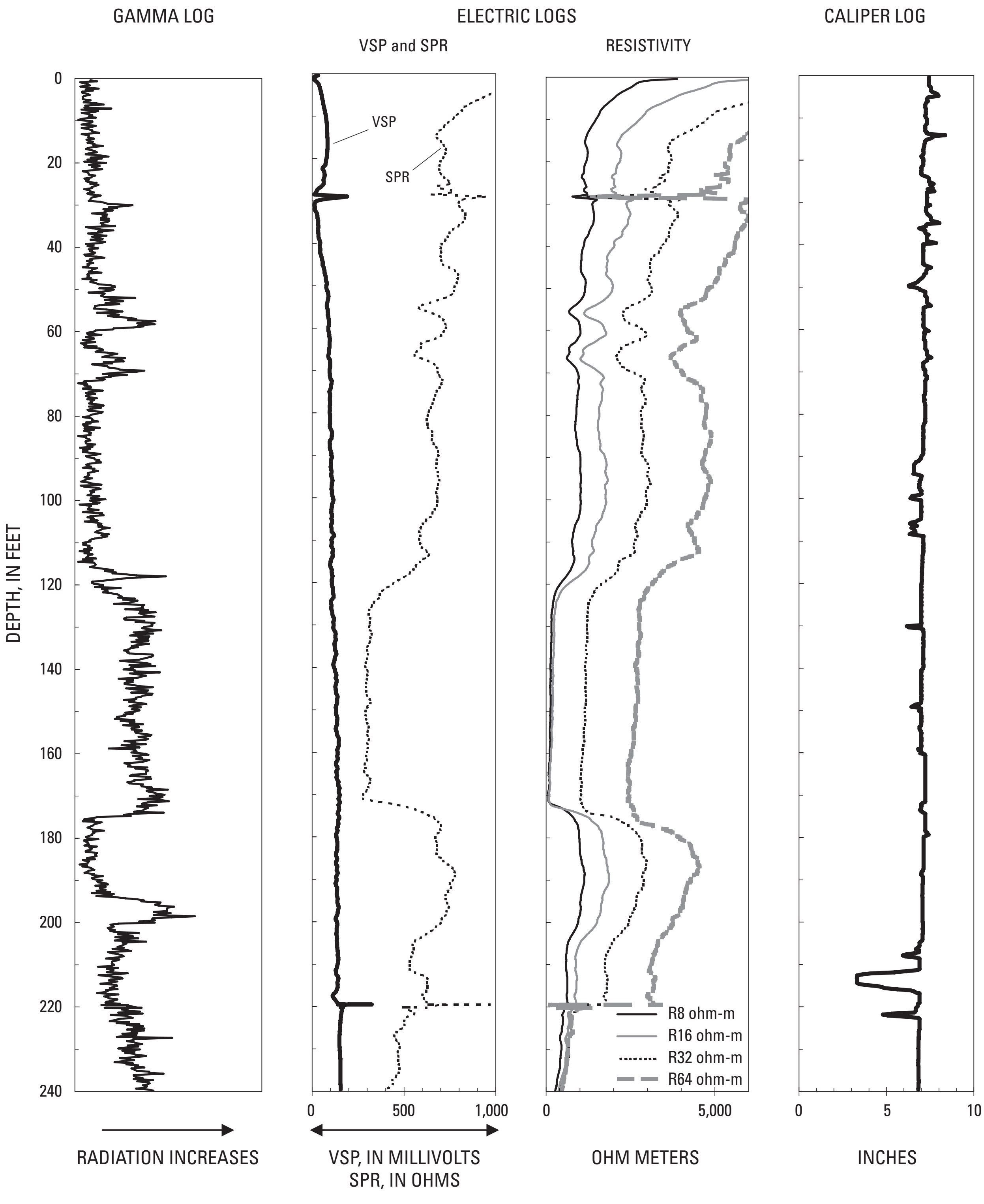


Figure 1-3. Geophysical logs of MB OW-1D (Well number 051556).

MB OW-1D Boring Log (Well Number 051556, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	1	Clay
1	5	Sand, fine to very coarse, trace gravel
5	15	Sand, fine to very coarse, 20% gravel
15	23	Sand, fine to very coarse, 20% gravel, clay indicated by drilling at 23 ft
23	25	Sand, fine to very coarse, 20% gravel, trace yellow sandy clay in cuttings
25	34	Sand, fine to very coarse, 20% gravel
34	40	Clay indicated by drilling, cuttings: Clay, medium dense, mottled red and gray and very coarse grave, trace iron cemented sand
40	50	Sand, medium to very coarse, 20% fine gravel, clay in cuttings
50	53	Sand, fine to very coarse, 10% clay
53	54	Clay indicated by drilling
54	61	Clay and sand and gravel layers - cuttings contain clay red, white, and yellow and 30% gravel
61	80	Sand and clay layers indicated by drilling – cuttings contain clay, silty and sandy, mottled, yellow, light gray and tan and 30% sand medium to very coarse with iron cemented sand
80	83	Sand, medium to very coarse and fine gravel
83	85	Sand and Clay, light to medium gray layers, fine to very coarse, trace iron cemented sand, and 30% clay, sandy in cuttings
85	93	Sand, coarse to very coarse, layered with 20% clay, light gray
93	100	Sand and gravel indicated by drilling- cuttings contain sand medium to very coarse and gravel fine to coarse
100	110	Sand, fine to very coarse and gravel, fine
110	115	Sand, coarse to very coarse and gravel, fine to coarse, 20% clay
115	119	Sand, coarse to very coarse and gravel, fine to coarse, increased clay content, sandy, light gray, cuttings contain iron cemented sand, chert, friable limestone fragments
119	120	Clay, light gray – drilling mud turns gray
120	126	Sand indicated by drilling, cuttings contain 60% clay
126	140	Clay, medium dense, silty, very dark gray 10YR 2/2
140	145	Clay, medium dense, silty, very dark brown, trace mica
145	160	Clay, medium dense, silty, very dark brown, trace mica, increasing mica content, trace, yellow clay
160	178	Sand indicated by drilling – cuttings contain only clay
178	200	Sand, medium to very coarse – principally clay in cuttings
200	220	Finer sediments indicated by drilling – cuttings contain 10% gravel, 10% yellow sand, fine and 80% clay
220	228	Sand or silt indicated by drilling - no cutting returned
228	240	Clay and fine silt or sand layers indicated by drilling
240	250	Clay, brown and dark gray, occasional sand layers indicated by drilling

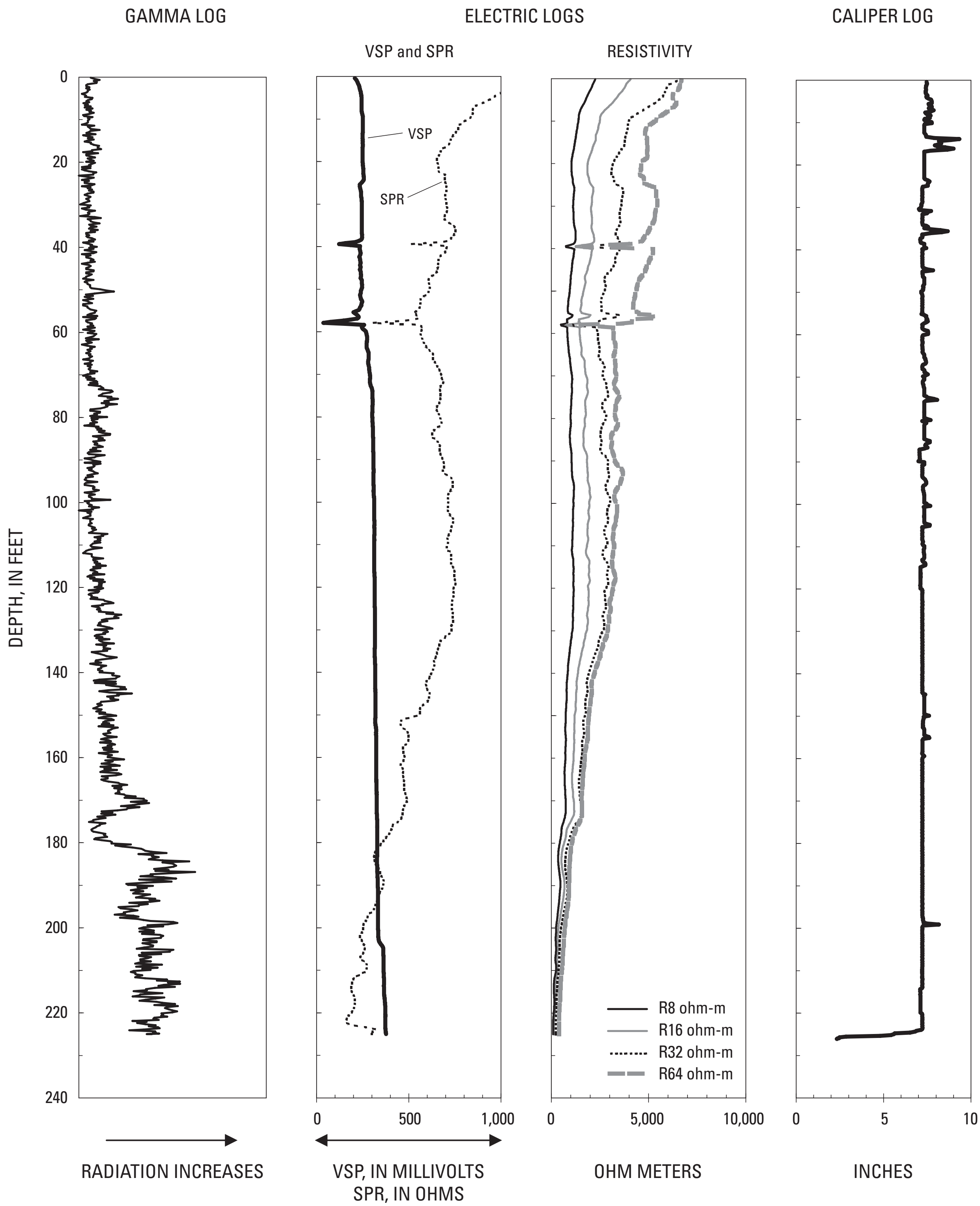


Figure 1-4. Geophysical logs of MB OW-2D (Well number 051560).

MB OW-2D Boring Log (Well Number 051560; location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	10	Sand, medium, heavily oxidized,
10	15	Sand, medium, heavily oxidized – Thin clay indicated by drilling at about 11-12 ft
15	19	Sand, fine to coarse, 10% very coarse gravel – cuttings contain clay, medium light brown and yellow
19	21	Clay, mottled yellow, 10YR 7/6 and light gray with very fine sand in matrix
21	25	Sand and gravel, poorly sorted, trace clay – sand is oxidized yellow and brown – (Drill crew mixes mud)
25	40	Sand and gravel, poorly sorted, 15% clay – Coarse sediments may be due to increased mud viscosity
40	50	Sand and gravel, fine to very coarse, poorly sorted, trace clay, yellow sandy
50	55	Sand and gravel, poorly sorted, 15% clay, yellow, 10YR 7/6 in cuttings not identified by drilling
55	63	Sand and gravel, poorly sorted, 15% clay, yellow, 10YR 7/6 in cuttings not identified by drilling, 10% iron cemented sand
63	80	Sand, coarse to very coarse and gravel coarse to very coarse
80	90	Gravel, coarse to very coarse
90	95	Gravel, coarse to very coarse, trace gray clay
95	100	Gravel, medium to very coarse, 25% iron cemented sand, trace light gray clay, sandy
100	117	Gravel, coarse to very coarse
117	140	Sand and gravel, fine to coarse, poorly sorted with clay layers - 20% clay, soft, sandy, light gray and yellow
140	150	Sand, fine to coarse, cuttings contain up to 30% light gray clay
150	155	Sand, fine to coarse, cuttings contain up to 60% yellow and light gray clay
155	160	Sand, fine to coarse, cuttings contain 20% clay, very dark gray, 10YR 3/1
160	160.6	Split spoon sample – sand, very fine, grading to clay, yellow and white with very coarse gravel in matrix, grading to sand, silty very fine, trace mica
160	165	Sand indicated by drilling, cuttings contain clay, soft, silty – Mud turns grayish yellow
165	175	Sand indicated by drilling- cuttings contain up to 70% clay, sand coarse to very coarse and fine gravel, trace clear mica – drilling mud turns very dark gray
175	180	Sand, medium to very coarse, well sorted, very dark gray 10YR4/1
180	185	Sand, medium to very coarse, well sorted, very dark gray 10YR4/1, trace lignite
185	190	Sand, medium to very coarse, well sorted, very dark gray 10YR4/1, 10 % lignite, trace very dark gray silty clay
190	195	Sand, very coarse, dark gray
195	200	Sand, very coarse, dark gray, clay 10%, very dark gray - appears to be thin layers of clay
200	219	Sand, very fine, dark gray – cuttings contain clay, sand trace mica and lignite
219	229	Clay, very soft, dark gray, trace mica
229	235	Clay, medium dense, very dark gray, trace mica

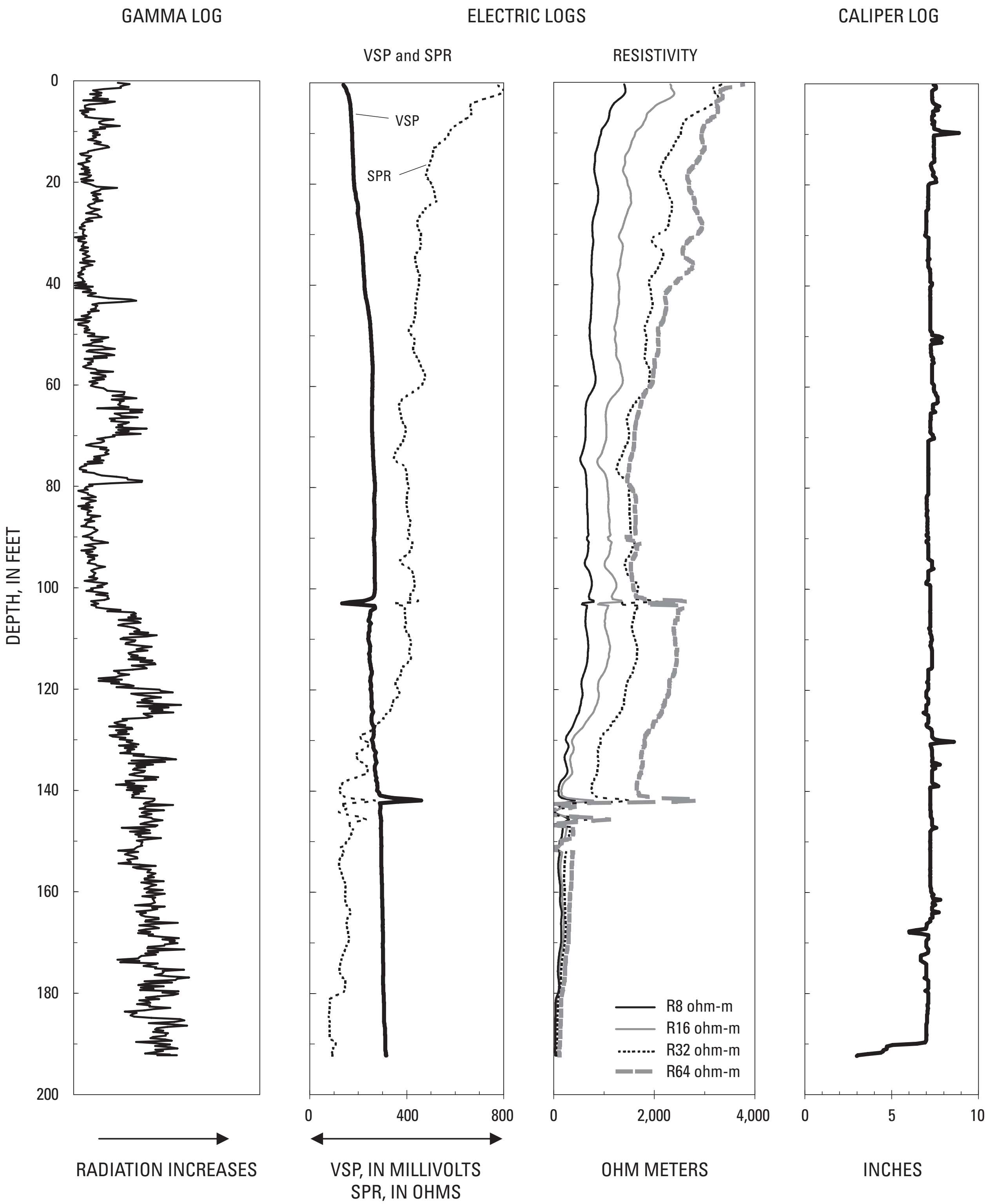


Figure 1-5. Geophysical logs of MB TB-1 (Well number 051597).

MB TB-1 Boring Log (Well Number 051597, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	6	Clay layers, trace gravel
6	17	Drilling indicates sand and clay layers – clay is medium dense, light gray
17	20	Sand, medium to coarse, well sorted, trace gravel
20	30	Sand indicated by drilling – cuttings contain sand, very coarse and 50% clay
30	35	Sand indicated by drilling – cuttings contain sand, iron cemented sand and some clay
35	40	Sand, fine to very coarse, trace fine gravel some iron cemented grains
40	50	Sand, very fine to coarse, some iron cemented grains, 20% clay and silt, mud turns from yellow to gray by 50 feet
50	60	Sand indicated by drilling – cuttings contain sand very fine to very coarse and up to 15% clay, low density, silty, mottled, grayish yellow 10YR6/6
60	70	Sand, fine to very coarse, trace gravel, 10% clay - drilling indicates thin clay layers in section
70	75	Sand, 10% clay, very dark gray 10YR3/1, mud turns dark gray at 72 feet
75	80	Sand, very fine to very coarse – cuttings contain sand, gravel, iron cemented grains, 10 % clay
80	90	Sand, coarse to very coarse, well sorted, very dark brown, 10YR2/2
90	100	Brown sand grades to gray (10YR5/1) sand, very coarse, well sorted, trace iron cemented sand, trace fine white coarse gravel
100	106	Sand, medium to coarse, trace lignite and dark gray clay in cuttings
106	110	Sand or silt indicated by drilling – cuttings contain fine to medium gray sand, trace lignite, mud turns very dark gray
110	115	Sand, medium to coarse and clay soft, very dark gray, trace lignite
115	120	Sand with clay layers indicated by drilling – cuttings contain sand, very coarse and clay, dark gray, silty
120	139	Sand, very coarse, gray, trace soft dark gray, trace lignite in cuttings 125 to 139
139	140	Clay, soft, black (10YR2/1), mica rich, organic
140	145	Sand indicated by drilling, cuttings contain sand, very coarse and soft silty very dark gray clay
145	150	Very file sand or silt indicated by drilling – cuttings contain silty clay, very dark gray, trace mica
150	155	Sand, very fine, very dark gray – cuttings include soft silty clay, abundant mica
155	165	Clay, soft silty, very dark gray, trace mica
165	170	Drilling indicates layers of soft silty clay bedded with sand – cuttings contain clay, very dark gray, soft silty, trace gravel
170	175	Clay, silty a few sand or gravel layers
175	188	Sand, very fine, clay - soft easy drilling, possibly sand and clay layers or sandy clay
188	195	Clay, very dark brown – traces of olive gray clay with dark sand grains
195	200	Clay, olive gray (5YR4/2) containing dark sand grains, abundant mica

Boring logs for the five shallow wells completed in the upland areas of the McDonalds Branch basin.

MB UP-1 (Well Number 051589, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	5	Sand, fine to coarse, trace gravel
5	16	Sand, fine to very coarse, gravel (20%), trace iron cemented sand, trace clay, mud color change to yellow
16	20	Sand, medium to very coarse, (20%) iron cemented sand, trace clay, mud color change to brown
20	27	Sand, medium to coarse grained, tan, trace clay

MB UP-2 (Well Number 051587, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	5	Sand, medium to coarse
5	15	Sand, medium to coarse, and clay, sandy, yellow
15	20	Sand, coarse to very coarse, with fine to medium gravel, layer of iron cemented sand at 17 feet
20	22	Sand, coarse to very coarse, with fine to medium gravel
22	23	Clay, light gray, silty with very fine sand, medium dense
23	24	Clay, very dark grayish brown (10YR 3/2), silty

MB UP-3 (Well Number 051592, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	7	Sand and gravel, yellowish brown, clay (20%), yellow, sandy
7	10	Sand and gravel, fine to medium, some clayey sand in cuttings
10	19	Sand and gravel, fine to medium, some clayey sand in cuttings with stringers of medium to coarse iron cemented sand
19	20	Clay, sandy, silty, very soft, contains 60% sand
20	24	Clay, sandy, silty, very soft, contains 60% sand
24	32	Sand, medium to coarse, well sorted, gravel at 31 feet, contains iron cemented sand

MB UP-4 (Well Number 051595, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	8	Sand and gravel
8	11	Clay, soft, sandy
11	20	Sand, medium to very coarse and gravel, fine to medium
20	27	Sand, tan, medium to coarse, well sorted, trace very coarse grains

MB UP-5 (051596, location shown on figure 13.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	20	Sand, coarse to very coarse with clay layers
20	40	Sand fine to very coarse, trace clay in cuttings

Shallow borings completed in the McDonalds Branch basin using Geoprobe® sediment sampling equipment and used as ground truth for analyzing the GPR survey lines.

MDB-B1 (Well Number 051550, location shown on figure 19.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	6.0	Sand, fine to coarse grained
6.0	6.2	Clay
6.2	7.5	Sand, very fine grained
8.6	9.2	Sandy clay
9.2	11.5	Sand, fine grained, with some clay in matrix, saturated at 11.5
11.5	15.5	Sand, medium to fine grained, trace clay in layers
15.5	16.1	Clay with some thin sand stringers
16.1	19.5	Clay, organic rich
19.5	19.6	Sand layer
19.6	22.5	Clay, organic rich
22.5	27.5	Sand, fine to coarse grained

MDB-B2 (Well Number 051551, location shown on figure 19.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	8	Sand, fine to coarse grained, saturated at 6 feet
8	9	Clay
9	15.1	Sand, medium to fine grained
15.1	19.1	Sand, very fine to coarse grained

MDB-B3 (Well Number 051552, location shown on figure 19.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	1.5	Sand, fine grained
1.7	2.3	Sand, some silt and clay
3.5	6.9	Sand with some clay, saturated at 3.5 feet
7.5	15.5	Sand, very fine to fine grained, some clay

MDB-B4 (Well Number 051554, location shown on figure 19.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	11.4	Sand, fine, with some very fine and medium grained sand
11.4	15.4	Sand, very fine, well sorted grading to poorly sorted at 15.2 feet
15.4	19.4	Sand, medium and fine grained

Shallow borings completed in the McDonalds Branch basin using Geoprobe® sediment sampling equipment and used as ground truth for analyzing the GPR survey lines.—Continued

MDB-B5 (Well Number 051555, location shown on figure 19.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	3.4	Sand and gravel
3.4	11.4	Sand, medium grained, saturated at 8 feet
11.4	15.4	Sand, coarse, grading to medium and some fine sand at base, clay 13.8 to 14.0
15.4	17.5	Sand, medium and some fine sand
17.5	19.4	Sand, coarse

MDB-B6 (Well Number 051553, location shown on figure 19.)

Top of interval (ft)	Bottom of interval (ft)	Description of sediments from core samples
0	7.8	Sand, fine grained, little gravel, trace silt and clay
7.8	9.4	Silt, clay and sand, fine grained
9.4	12.0	Layers of clay, silt and fine sand
12	13.1	Sandy clay, with clay layers, saturated at 12.7 feet
13.1	16	Sand, medium with some fine grains
16	20	Sand, medium to fine, grading to coarse sand with some gravel at 20 feet
20	24	Sand, medium with some fine sand, trace coarse sand near 24 feet
24	28	Sand, fine and medium trace silt

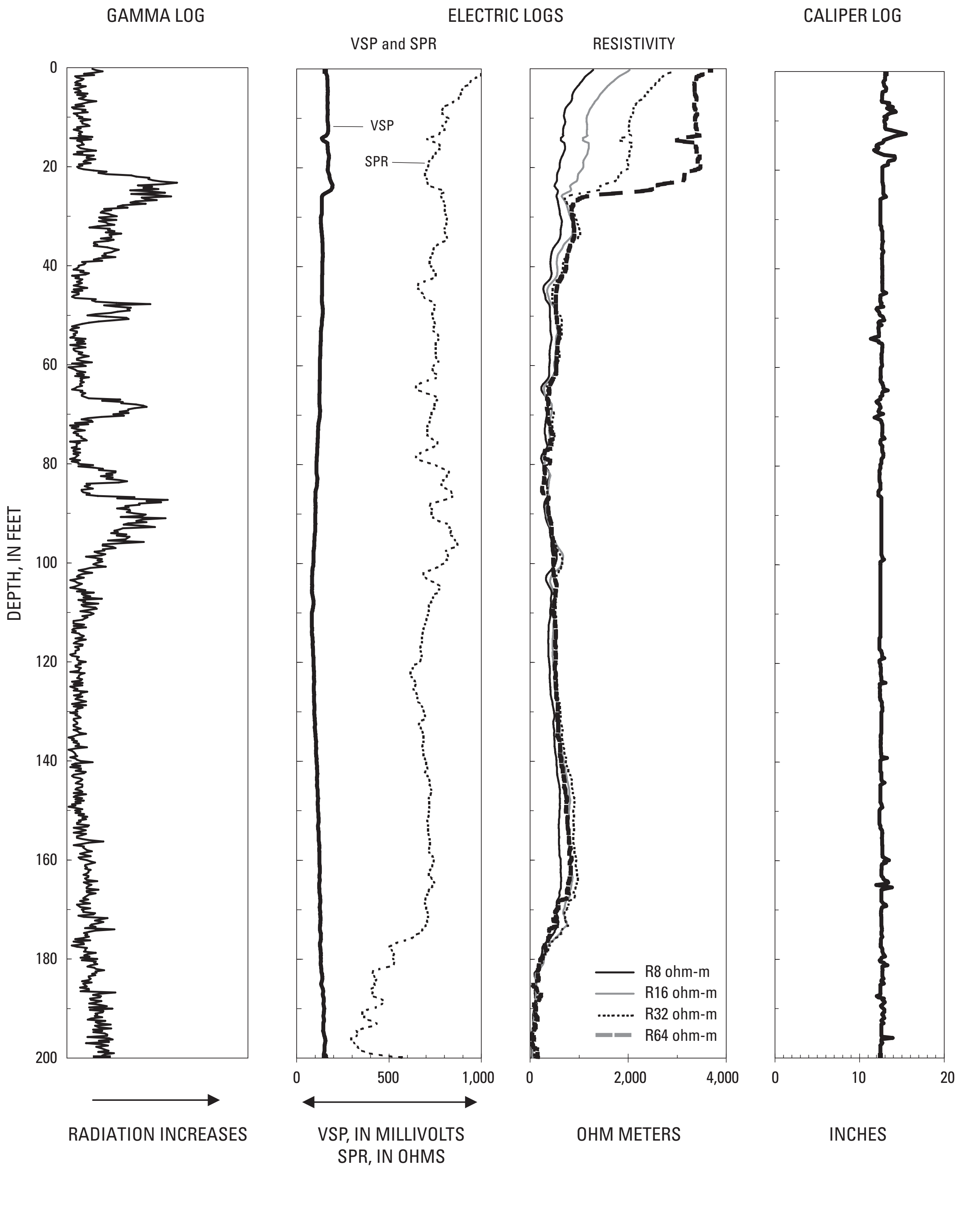


Figure 1-6. Geophysical logs of MM OW-1D (Well number 011499).

MM OW-1D Boring Log (Well Number 011499, location shown on figure 20.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	8	Sand and gravel coarse
8	15	Sand tan clayey in (?) gravel
15	20	Gravel very coarse with layers of white dense sandy clay
20	23	Sand and gravel fine to coarse color changes to tan
23	34	Clay tan and oxidized silt and very fine sand in matrix
34	45	Sand and gravel very coarse some clay between 40 and 45
45	50	Sand and gravel very coarse 50% clay in layers
50	55	Sand fine to very coarse with very coarse gravel
55	60	Clay yellow and very dark gray with little gravel fine grained
60	70	Sand fine to very coarse, drilling indicates one thin (?) clay layer in the 60-65 interval
70	74	Clay indicated by drilling
74	80	Sand fine to very coarse little gravel (20%)
80	84	Sand fine to very coarse and gravel very coarse trace limestone like grains
84	88	Clay light grayish brown sandy
88	91	Sand very coarse
91	100	Clay light gray sandy contains very coarse gravel grades to light brownish gray (10yr 6/2)
100	100.8	Split spoon sample: 100 ft to 100.2 ft - Clay light gray soft silty over 100.2 to 100.8 - Sand fine to medium well sorted about 15% clay in matrix
100	104	Sand soft contains clay
104	109	Sand fine to coarse
109	110	Sand coarse gravel and 50% clay in cuttings
110	115	Layered sand and clay - clay very dark gray(5yr 3/1) sandy and contains lignite
120	125	Sand fine to medium
125	130	Drilling indicates very coarse sand and gravel: Cuttings contain clay sand fine to medium and gravel
130	140	Sand fine to medium some clay and gravel in cuttings
140	145	Sand fine to very coarse
145	150	Sand fine to very coarse fine gravel some (30%) clay
150	155	Sand ranges from very fine to very coarse some gravel little clay; possibly in thin layers
155	160	Sand very fine to medium trace very coarse grians grayish brown (2.5yr 5/2)
160	189	Sand gray (5yr 5/1) fine well sorted lignite content increases from 170 to 180 - 175 to 180 includes traces of mica
189	212	Clay dark gray (5y 4/1) lignite and mica no sand in cuttings
212	216	Drilling indicates very fine sand or soft clay
216	220	Clay

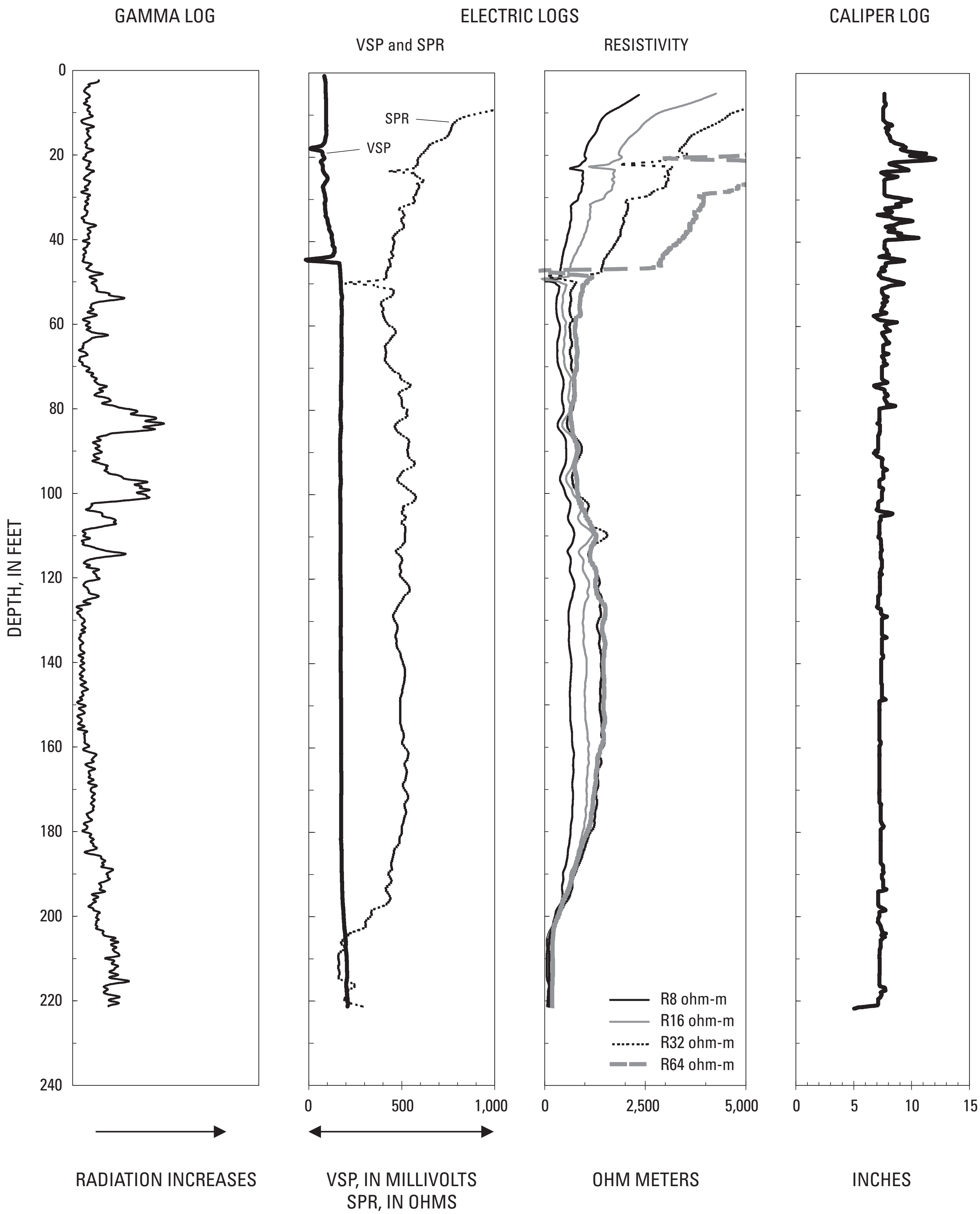


Figure 1-7. Geophysical logs of MM OW-2D (Well number 011503).

MM OW-2D Boring Log (Well Number 011503, location shown on figure 20.)

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
0	20	Sand medium to very coarse and gravel fine to very coarse encountered thin lense of clay at 17.2 feet
20	25	Sand medium to very coarse trace clay
25	30	Sand medium to very coarse little clay (20%)
30	35	Sand medium to very coarse trace clay
35	40	Sand medium to very coarse - drilling indicates no clay from 20-40 ft
40	60	Sand and gravel very coarse trace clay 20% friable limestone like gravel size pieces
60	74	Sand and gravel very coarse limestone like pieces little (20%) sandy clay
74	76	Clay sandy brownish yellow (10YR 6/8)
76	77	Sand and gravel very coarse
77	80	Clay very pale brown (10YR 8/2) sandy
74	80	Sand fine to very coarse little gravel (20%)
80	98	Clay very pale brown sandy soft and sand and gravel color change to darker brown at 89 feet
98	100	Clay dark gray (7.5YR 4/0) sandy and clay gray (10YR 6/1) fine sand in martix
100	108	Sand and clay layers Rod change at 100 feet indicated 4 feet of wash in bottom hole
108	115	Sand very fine cuttings contain clay
115	120	Clay very dark brown (10YR 2/1)
120	130	Drilling indicates sand cuttings contain sand medium and up to 50% clay
135	140	Sand fine to coarse
109	110	Sand coarse gravel and 50% clay in cuttings
110	115	Layered sand and clay - clay very dark gray(5yr 3/1) sandy and contains lignite
115	120	Clay very dark brown (10YR 2/1)
120	125	Drilling indicates sand cuttings contain sand medium and up to 50% clay
125	130	Drilling indicates sand cuttings contain sand medium little clay
135	140	Sand fine to medium driller indicates sand but some clay in cuttings
140	145	Sand tan fine to very coarse
145	150	Sand tan medium to very coarse
150	155	Sand coarse to very coarse fine gravel trace clay in cuttings
155	160	Sand coarse to very coarse fine gravel trace dark gray silt stone
160	170	Sand tan fine to very coarse trace black grains and white friable hard clay like minerals
170	175	Sand indicated by drilling; cuttings contain coarse to very coarse sand trace dark gray sandy clay
175	180	Sand coarse to very coarse with fine gravel trace medium dark gray clay and white friable hard clay like minerals
180	185	Sand indicated by drilling; cuttings contain little light and dark gray clay trace to 15% lignite and coarse to very coarse sand
185	190	Sand some clay and lignite

MM OW-2D Boring Log (Cont.) (Well Number 011503, location shown on figure 20.)—Continued

Top of interval (ft)	Bottom of interval (ft)	Description of cuttings unless noted otherwise
190	195	Clay, gray, very soft organic 20% lignite mud change color
195	200	Sand fine and clay (50%) dark gray lignite trace mica
200	209	Sand very fine well sorted micaeous
209	216	Clay, gray, soft, micaeous, easy drilling
216	220	Clay with sand layers
220	225	Sand grading to clay gray soft
225	230	Clay very dark gray (5y 3/1), soft, contains silt

Appendix 2

Altitude, thickness, estimated sand content, and (or) horizontal hydraulic conductivity of hydrogeologic layers of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

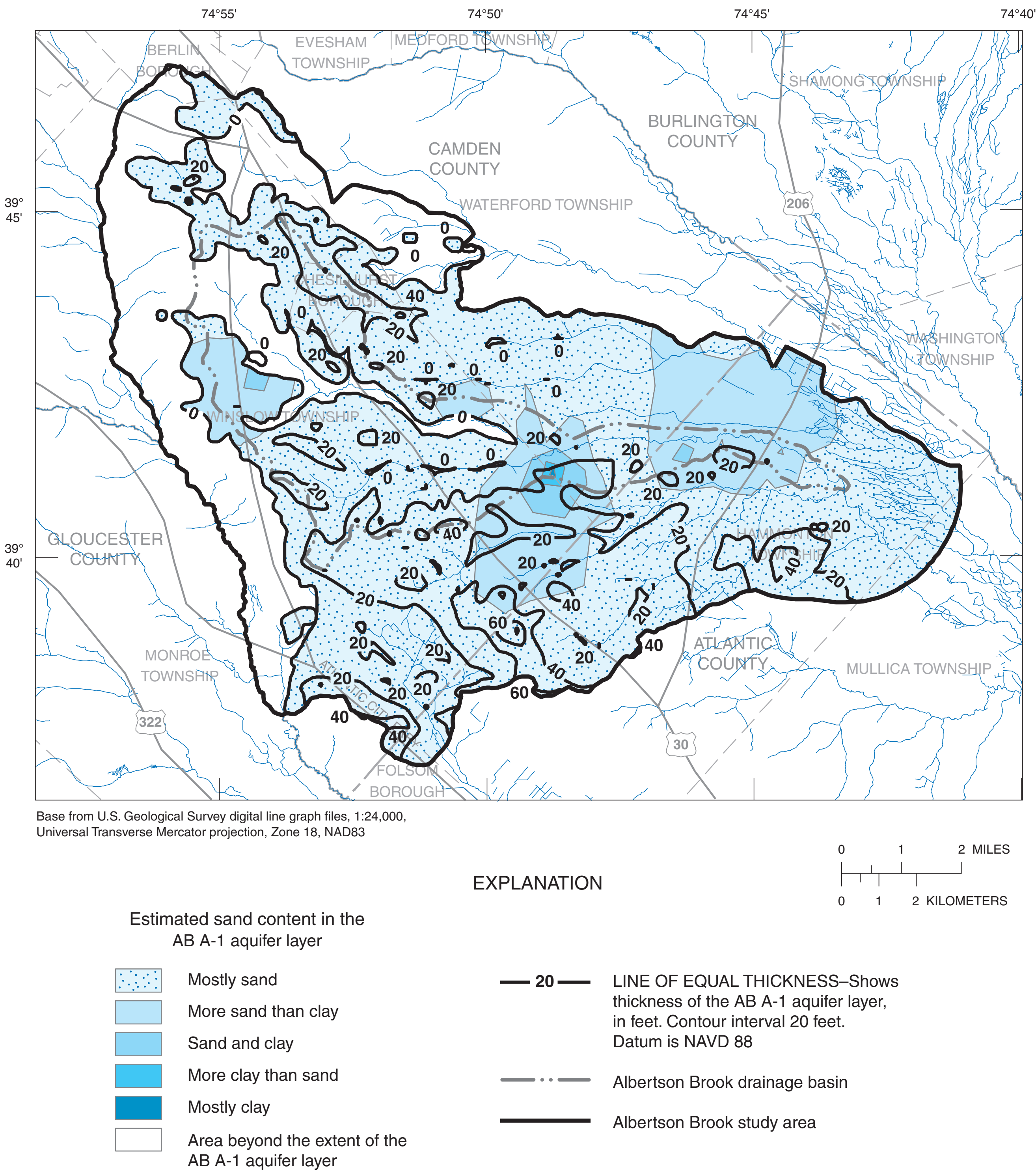
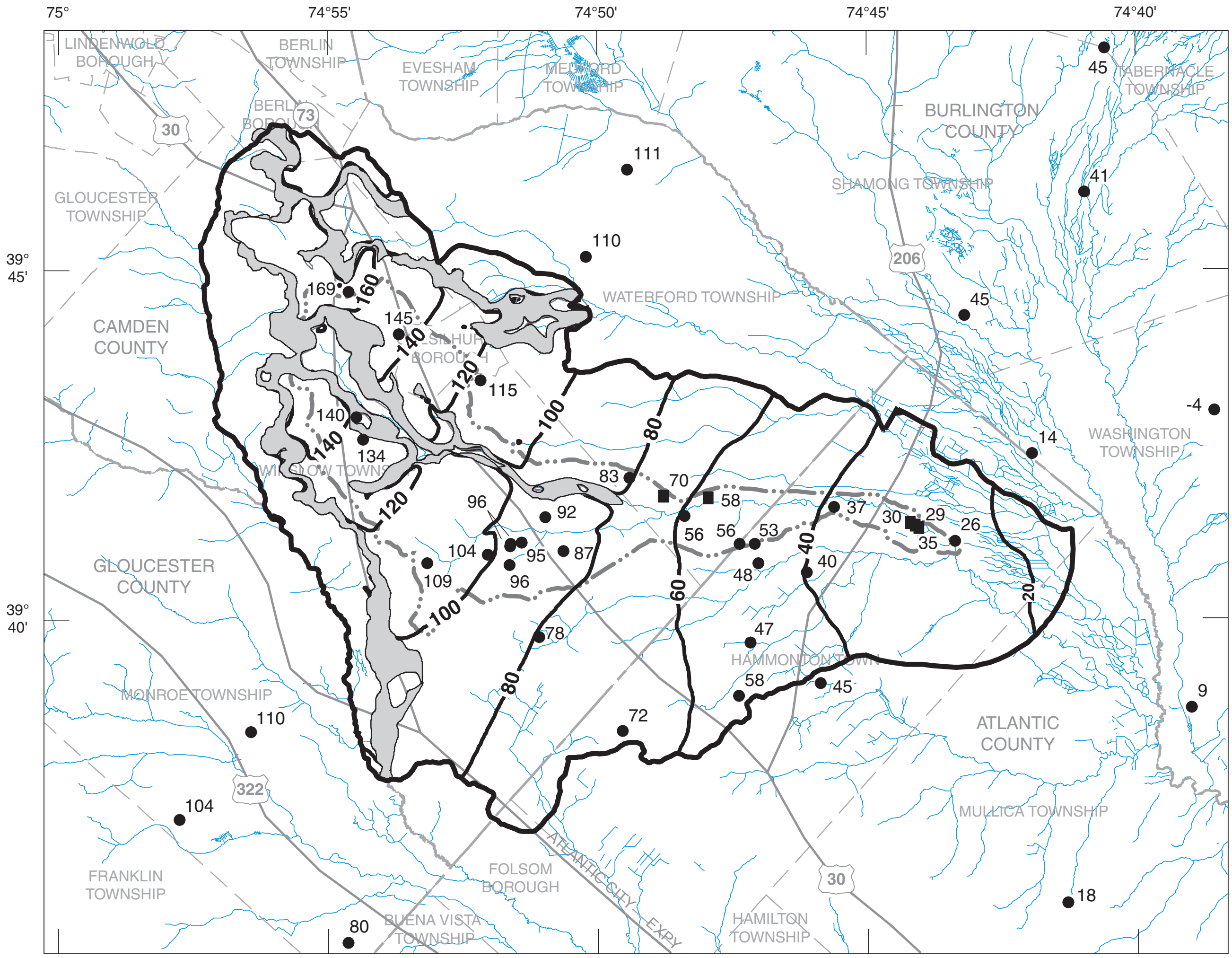


Figure 2-1. Thickness and estimated sand content of the AB A-1 aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

0 2 4 MILES
0 2 4 KILOMETERS

EXPLANATION

Outcrop area of the AB A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system

—120— STRUCTURE CONTOUR–Shows approximate altitude of the top of the AB A-1C1 leaky confining layer, in feet. Contour interval 20 feet. Datum is NAVD 88

Albertson Brook drainage basin

Albertson Brook study area

110 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

70 ■ Ground penetrating radar (GPR) survey site. Number is altitude of the top of the clay layer, in feet. Datum is NAVD 88

Figure 2-2. Structure contours of the top of the AB A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

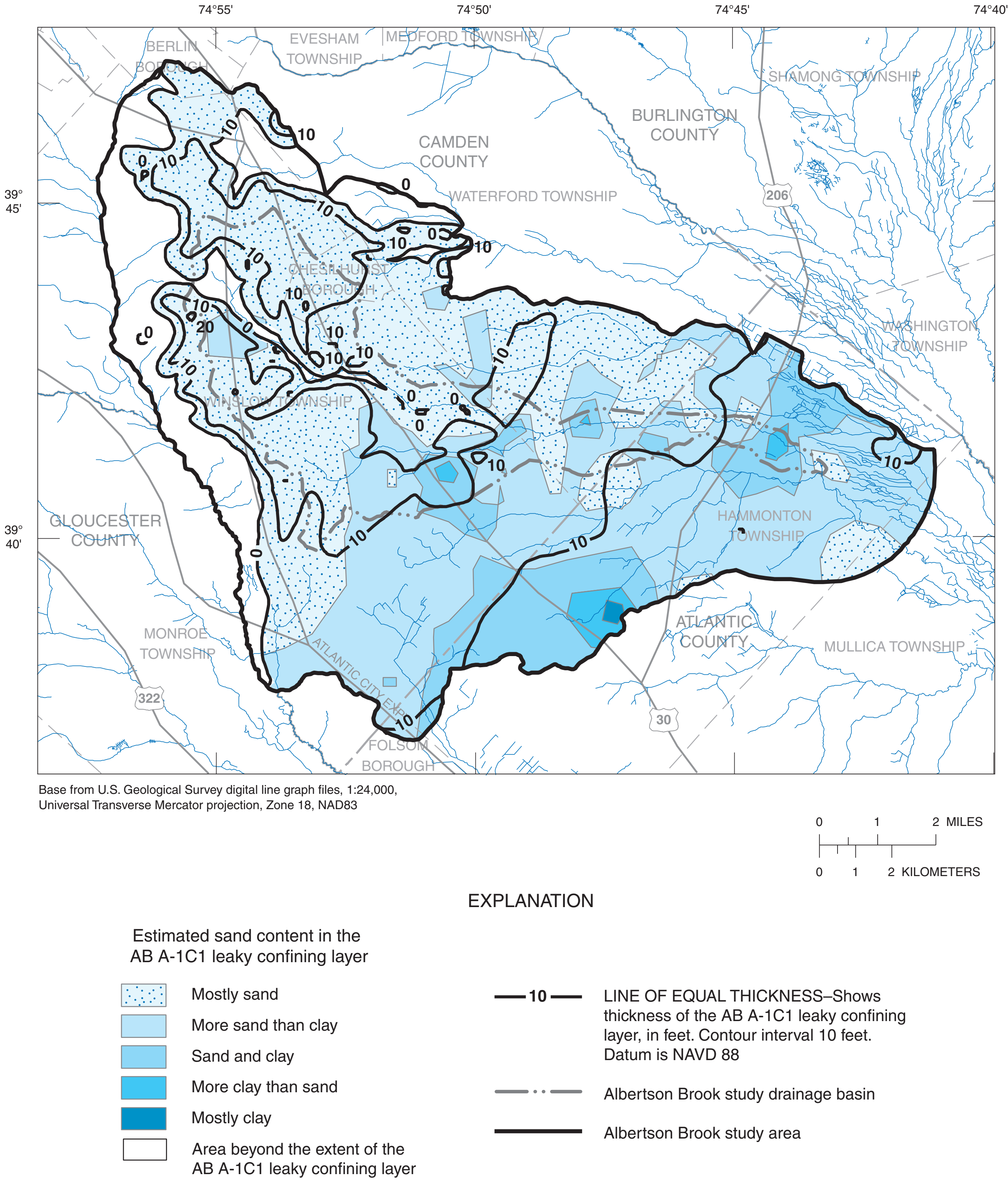
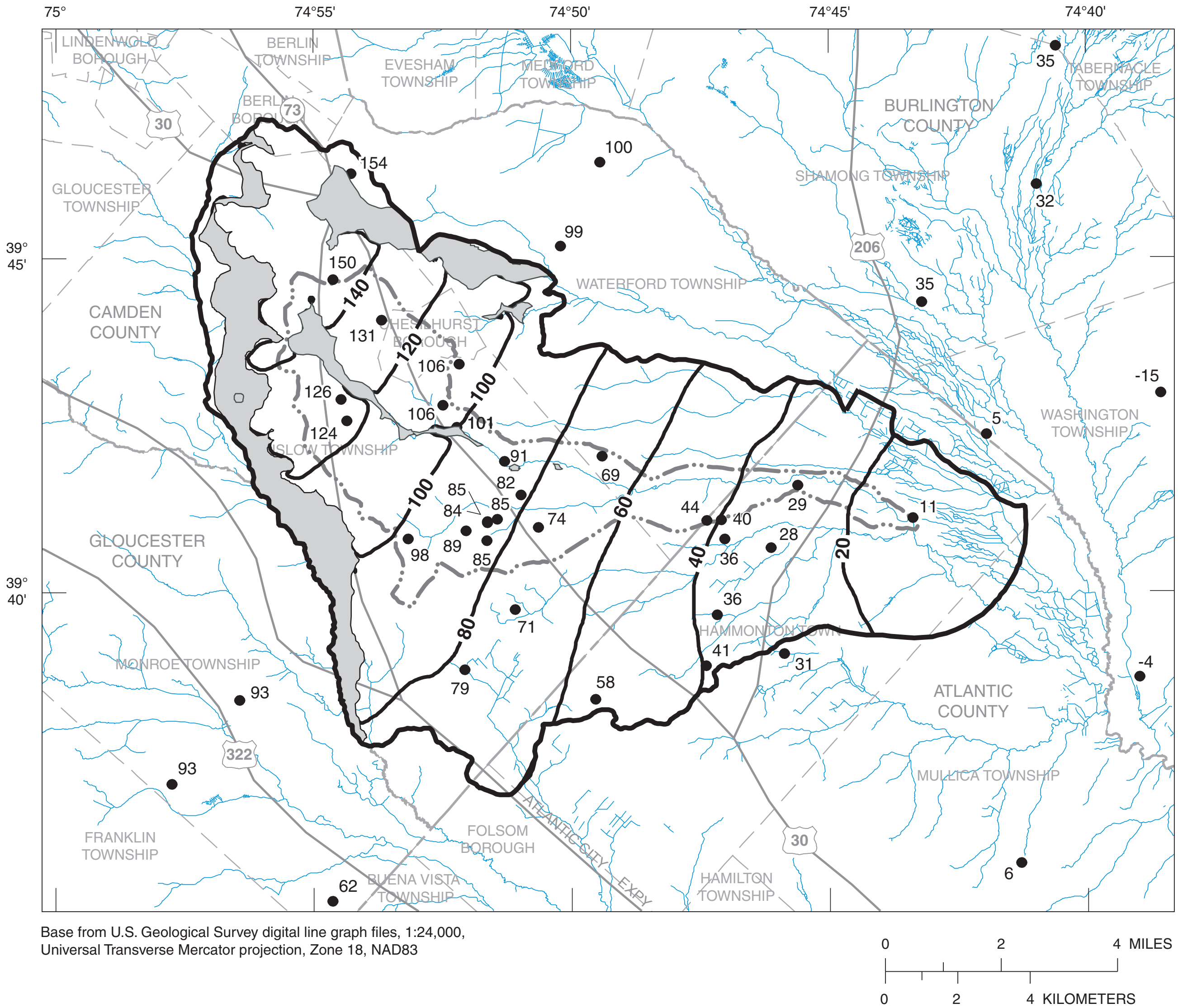


Figure 2-3. Thickness and estimated sand content of the AB A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Outcrop area of the AB A-1B aquifer layer of the Kirkwood-Cohansey aquifer system

—120— STRUCTURE CONTOUR–Shows approximate altitude of the top of the AB A-1B aquifer layer, in feet. Contour interval 20 feet. Datum is NAVD 88

Albertson Brook drainage basin

Albertson Brook study area

100 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 2-4. Structure contours of the top of the AB A-1B aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

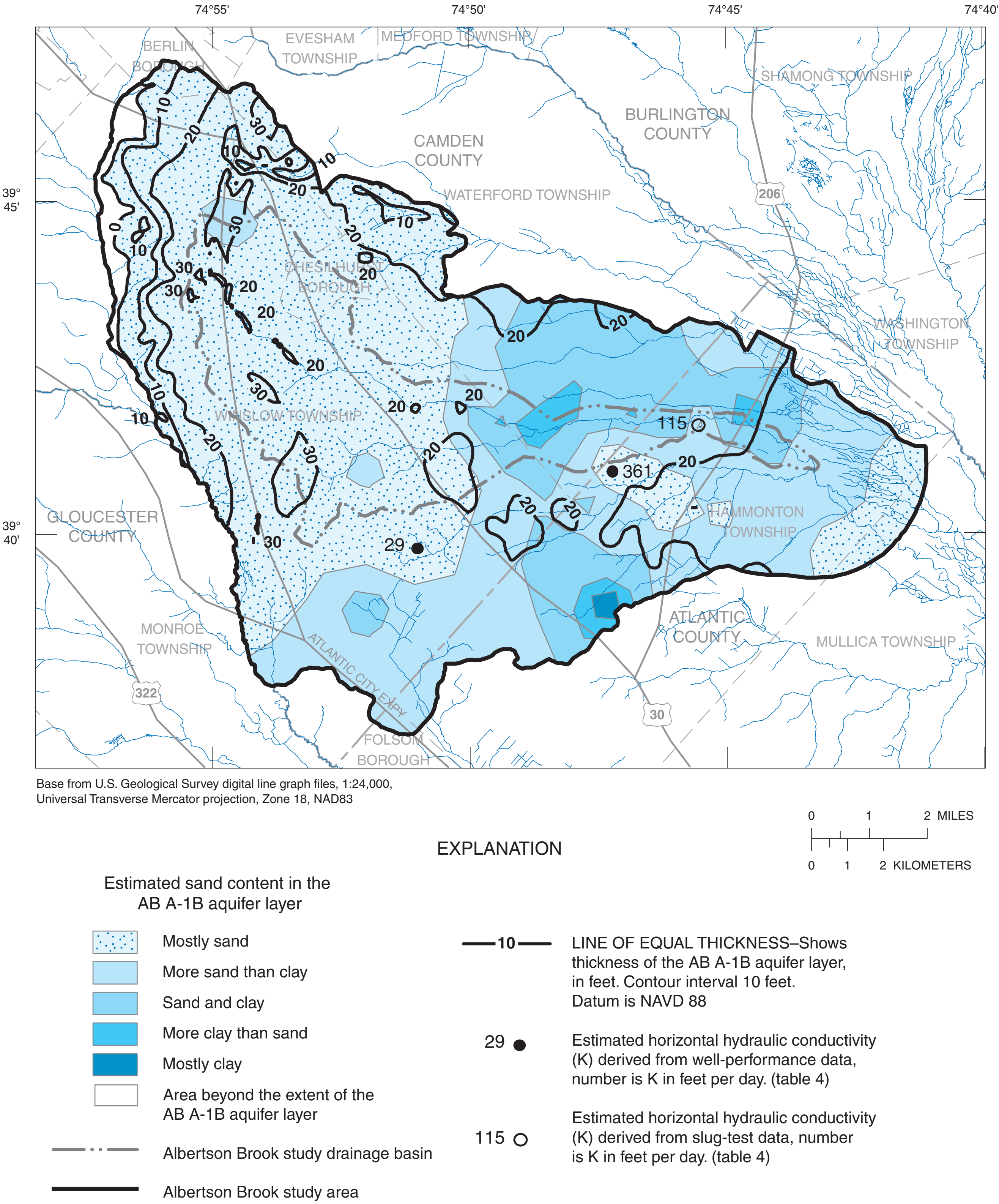
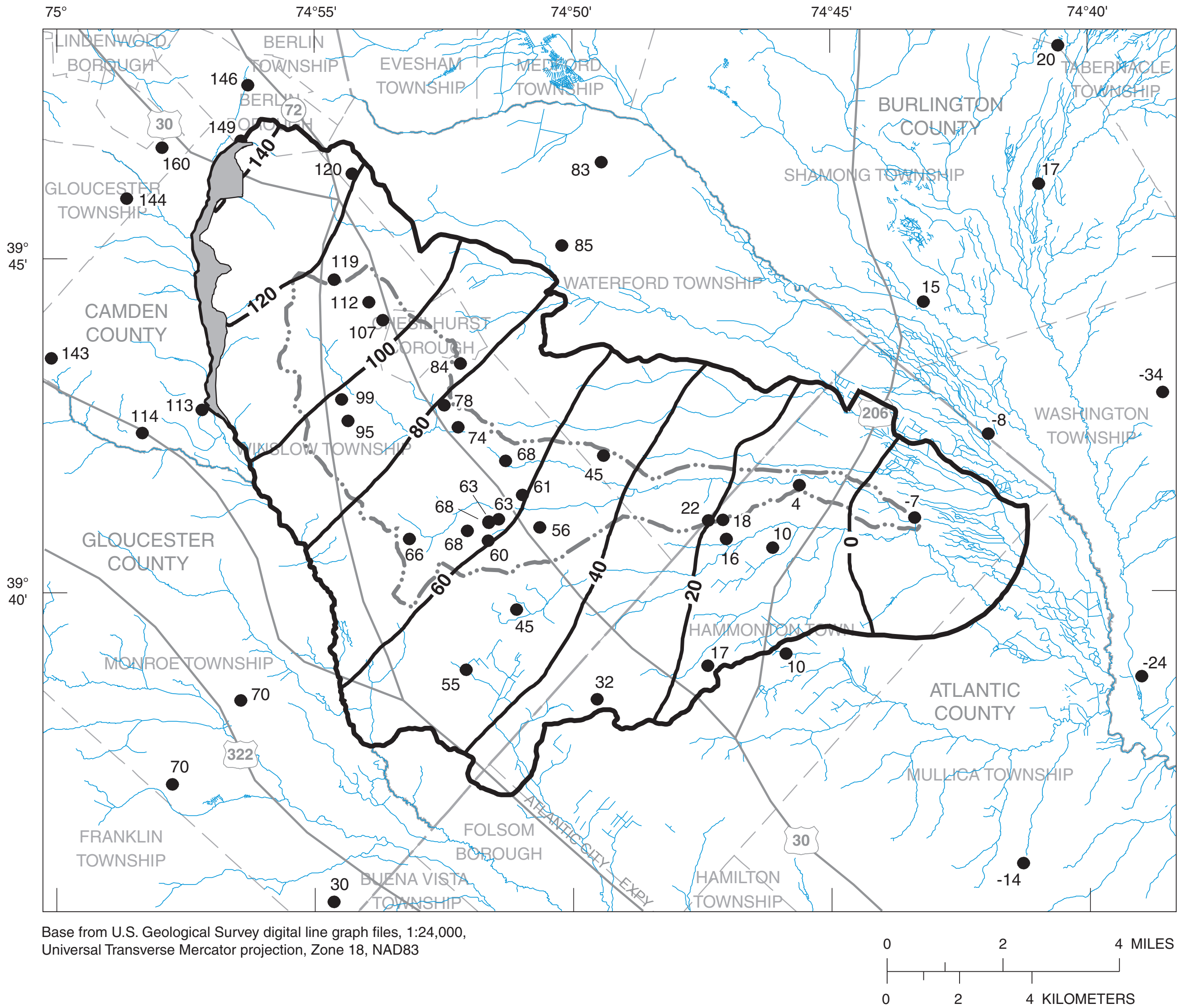


Figure 2-5. Thickness, estimated sand content, and horizontal hydraulic conductivity of the AB A-1B aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.



EXPLANATION

Outcrop area of the AB C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system

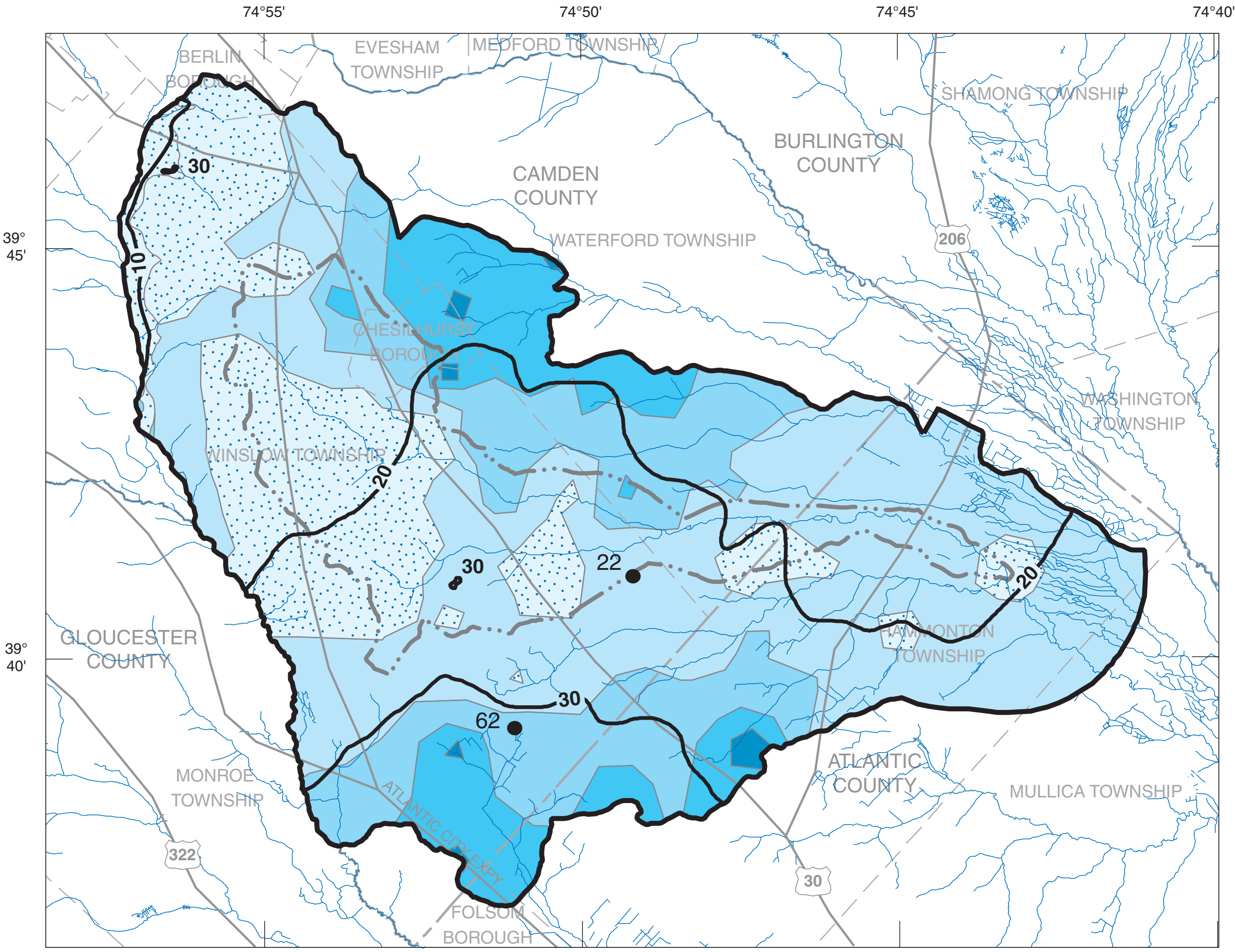
—120— STRUCTURE CONTOUR–Shows approximate altitude of the top of the AB C-1 leaky confining layer, in feet. Contour interval 20 feet. Datum is NAVD 88

Albertson Brook drainage basin

Albertson Brook study area

99 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 2-6. Structure contours of the top of the AB C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

0 1 2 MILES

0 1 2 KILOMETERS

EXPLANATION

Estimated sand content in the AB C-1 leaky confining layer

- Mostly sand
- More sand than clay
- Sand and clay
- More clay than sand
- Mostly clay
- Albertson Brook drainage basin

—10— LINE OF EQUAL THICKNESS–Shows thickness of the AB C-1 leaky confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

Albertson Brook study area

22 ● Estimated horizontal hydraulic conductivity (K) derived from well-performance data, number is K in feet per day. (table 4)

Figure 2-7. Thickness, estimated sand content, and horizontal hydraulic conductivity of the AB C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

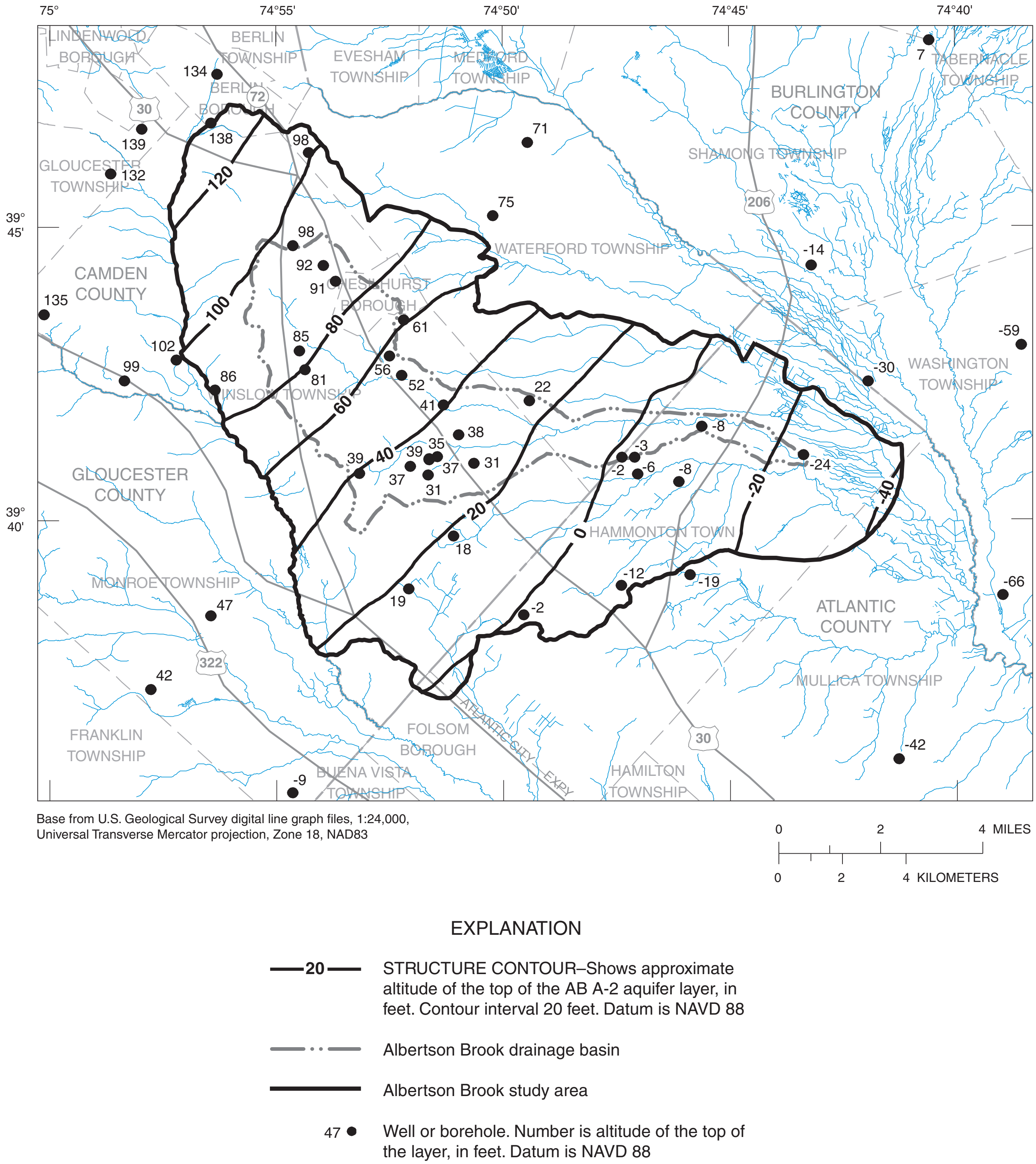


Figure 2-8. Structure contours of the top of the AB A-2 aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

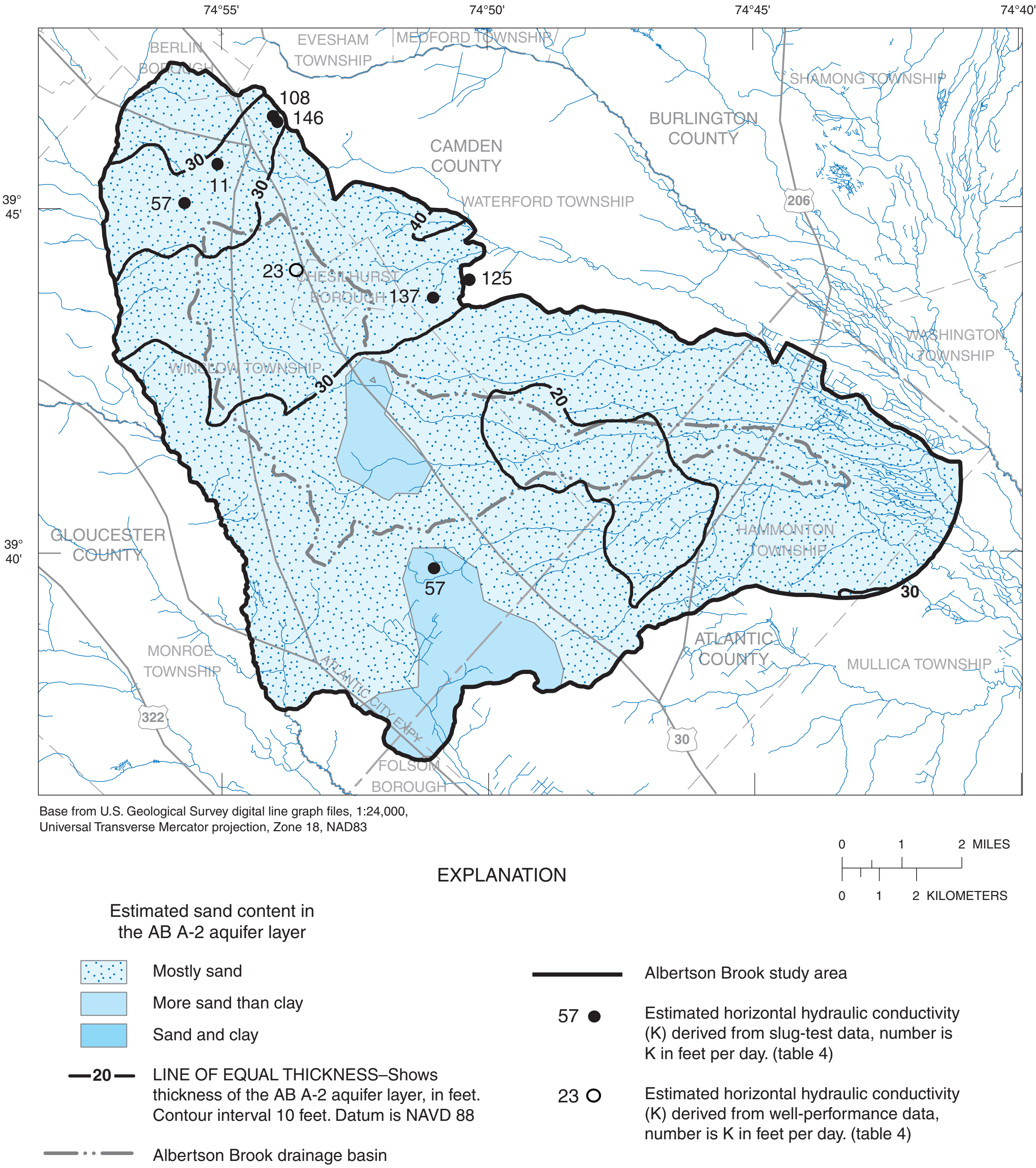
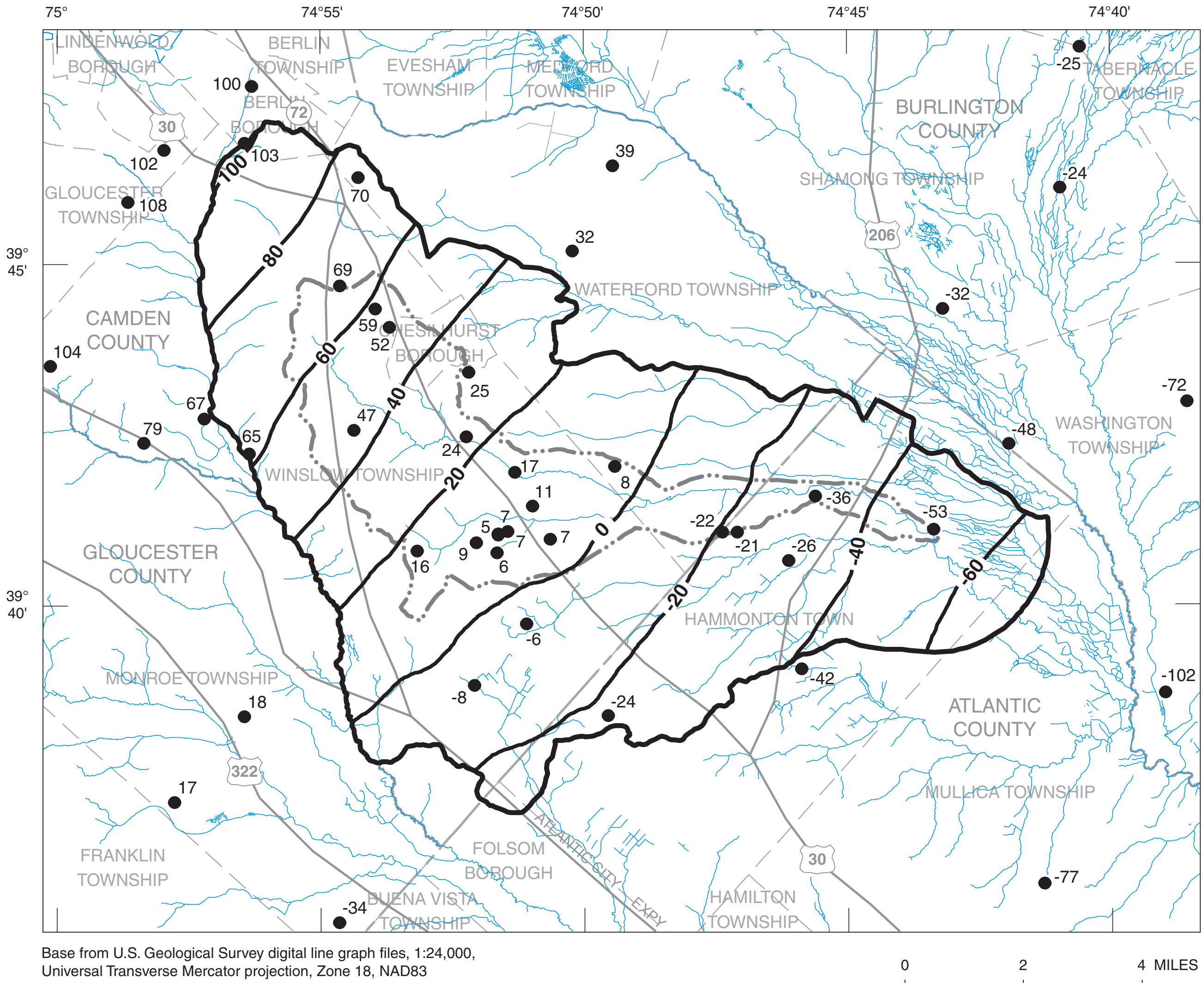


Figure 2-9. Thickness, estimated sand content, and horizontal hydraulic conductivity of the AB A-2 aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.



EXPLANATION

—20— STRUCTURE CONTOUR–Shows approximate altitude of the top of the AB C-2 leaky confining layer, in feet. Contour interval 20 feet. Datum is NAVD 88

Albertson Brook drainage basin

Albertson Brook study area

99 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 2-10. Structure contours of the top of the AB C-2 leaky confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

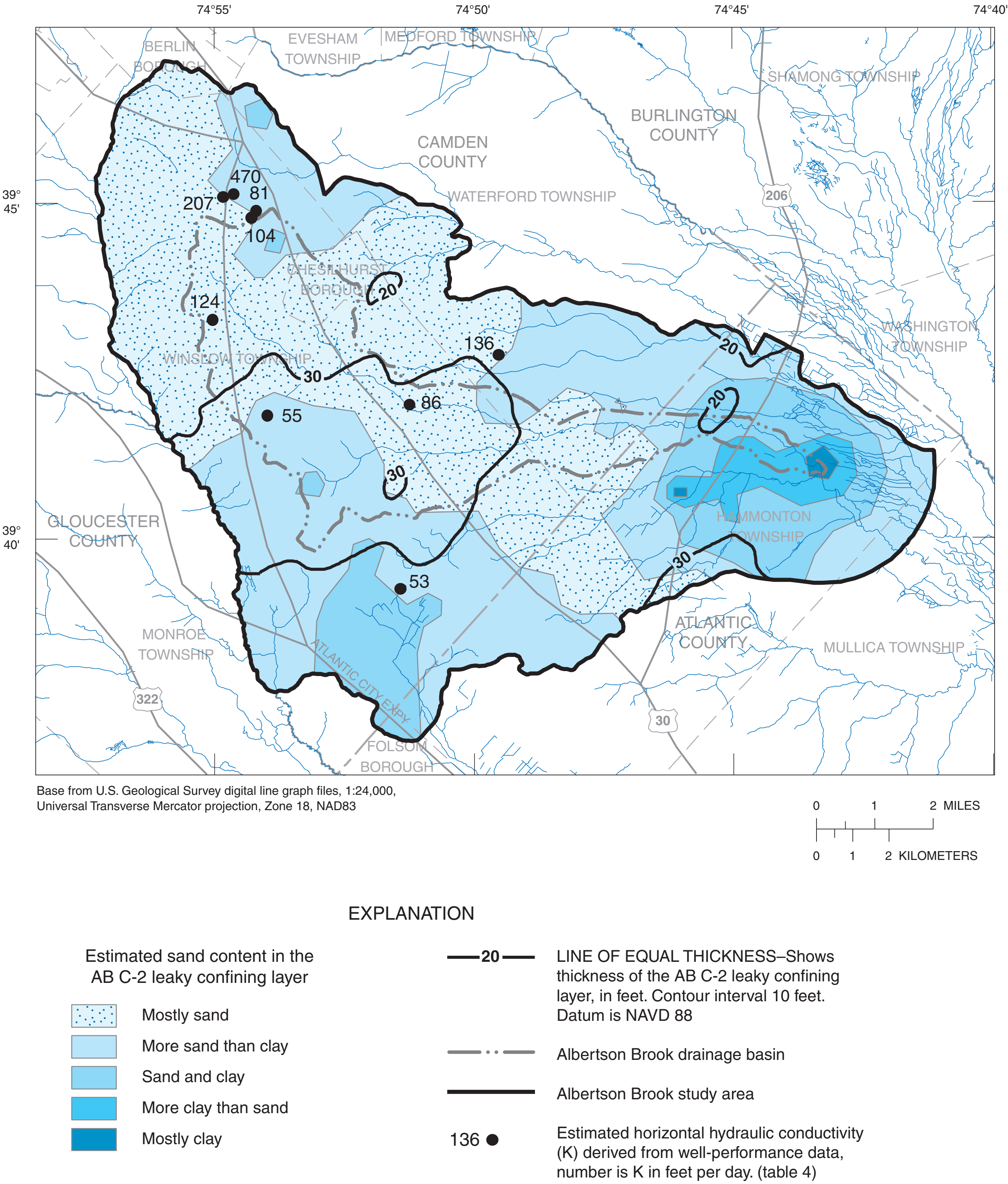


Figure 2-11. Thickness, estimated sand content, and horizontal hydraulic conductivity of the AB C-2 leaky confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

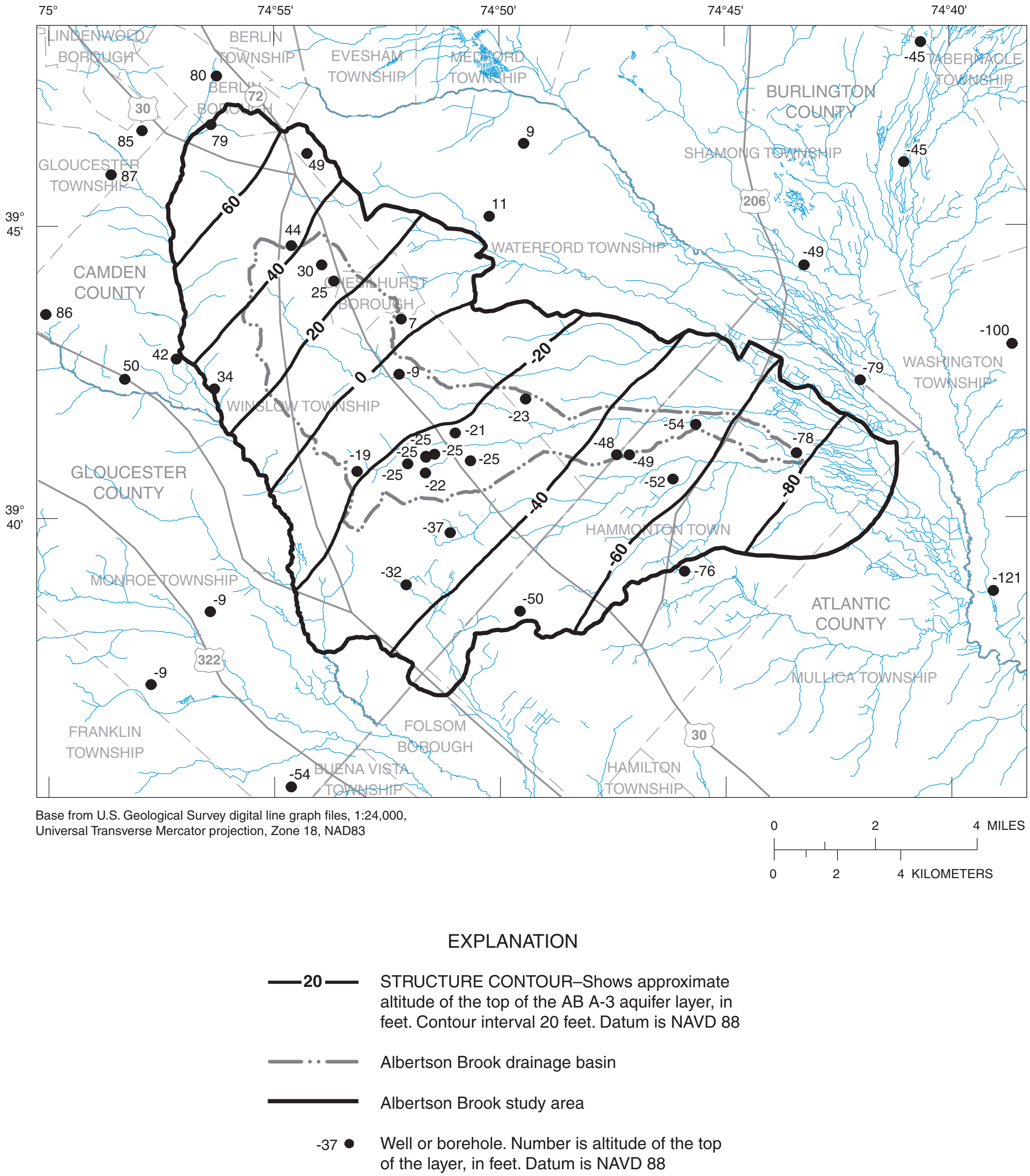


Figure 2-12. Structure contours of the top of the AB A-3 aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

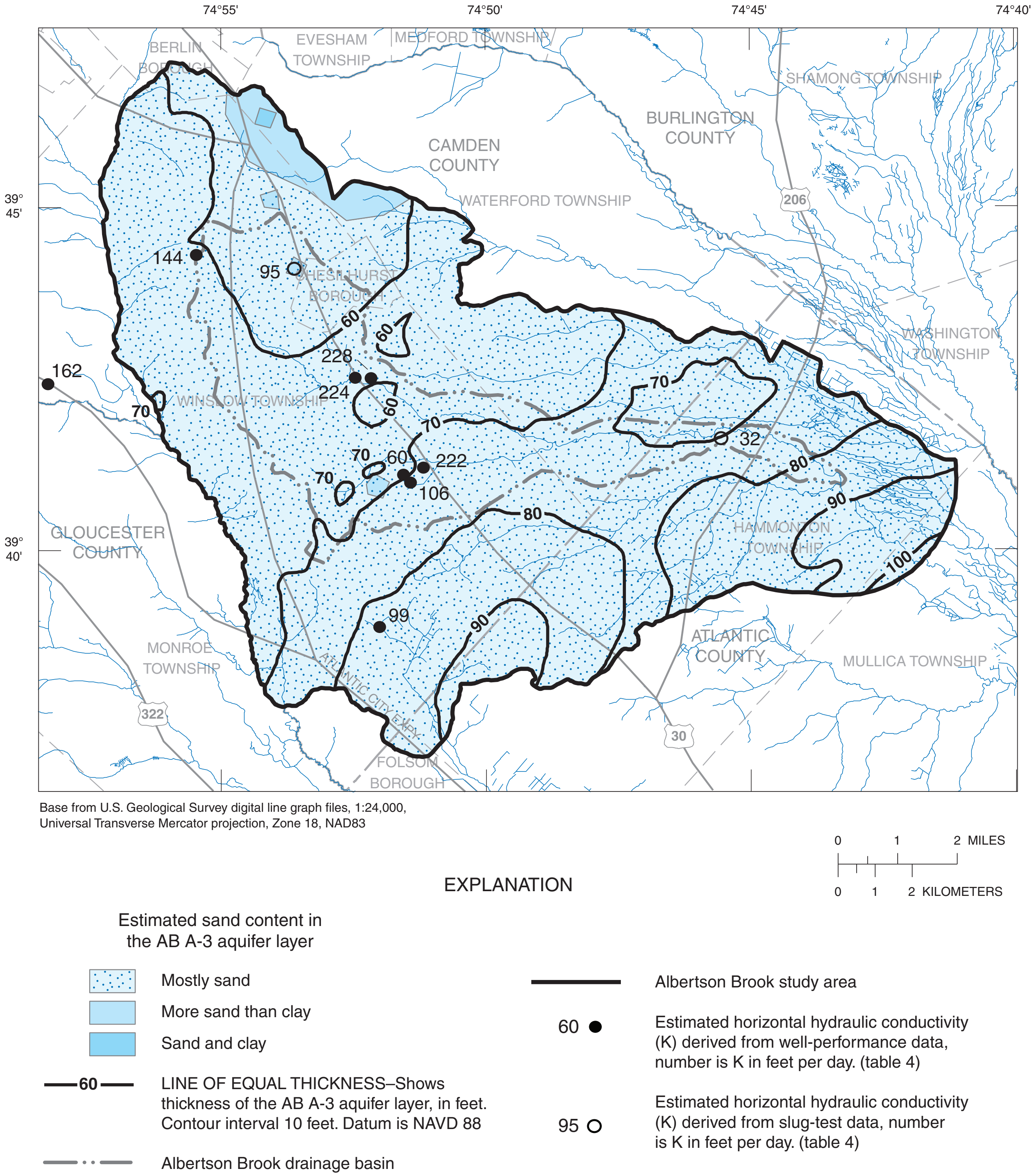
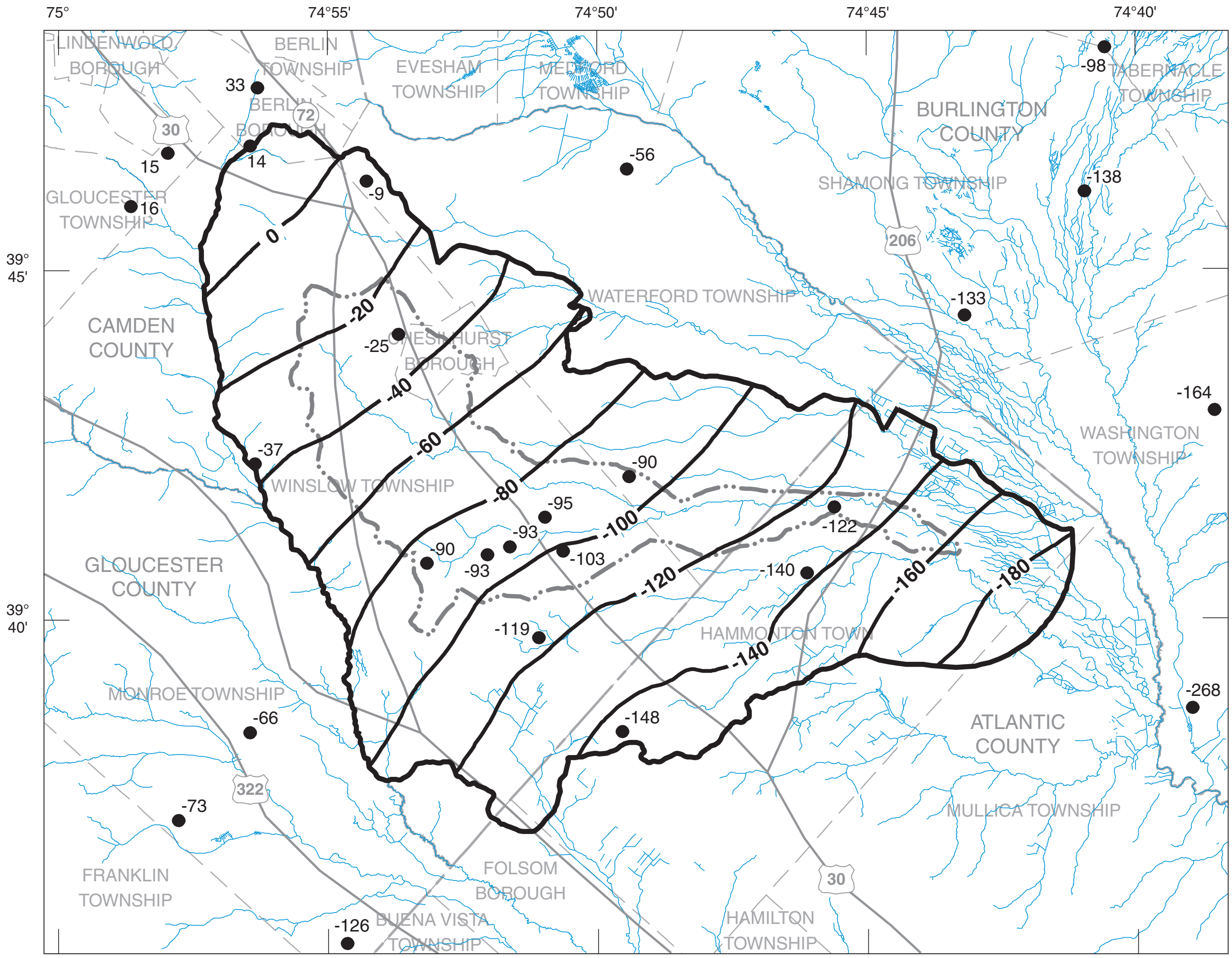


Figure 2-13. Thickness, estimated sand content, and horizontal hydraulic conductivity of the AB A-3 aquifer layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

0 2 4 MILES
0 2 4 KILOMETERS

EXPLANATION

—**-20**— STRUCTURE CONTOUR–Shows approximate altitude of the top of the AB C-3 lower Kirkwood confining layer, in feet. Contour interval 20 feet. Datum is NAVD 88

Albertson Brook drainage basin

Albertson Brook study area

33 ● Well or borehole. Number is altitude of the top of the unit, in feet. Datum is NAVD 88

Figure 2-14. Structure contours of the top of the AB C-3 lower Kirkwood confining layer of the Kirkwood-Cohansey aquifer system, Albertson Brook study area and vicinity, New Jersey Pinelands.

Appendix 3

Altitude, thickness, estimated sand content, and (or) horizontal hydraulic conductivity of hydrogeologic layers of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

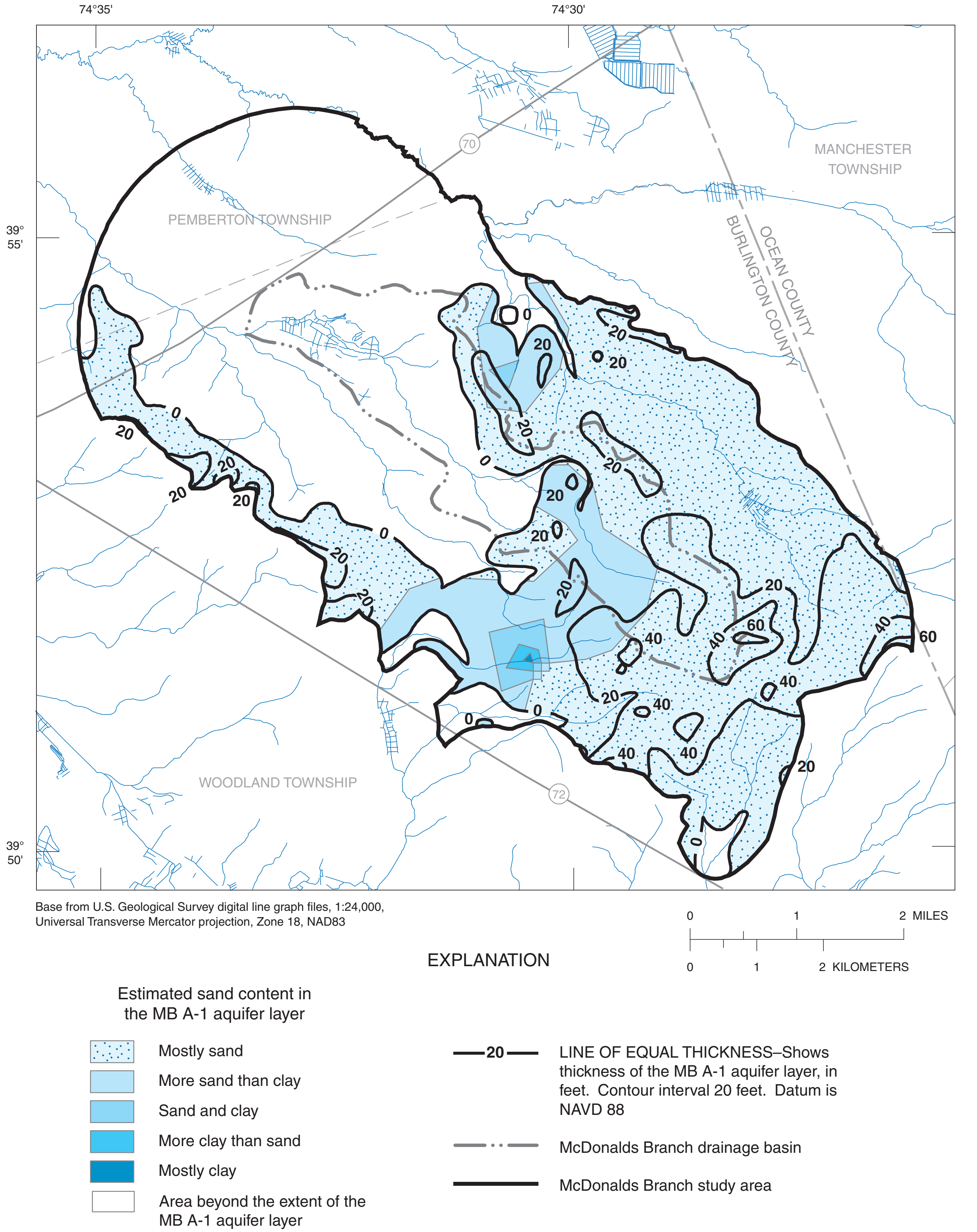


Figure 3-1. Thickness and estimated sand content of the MB A-1 aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

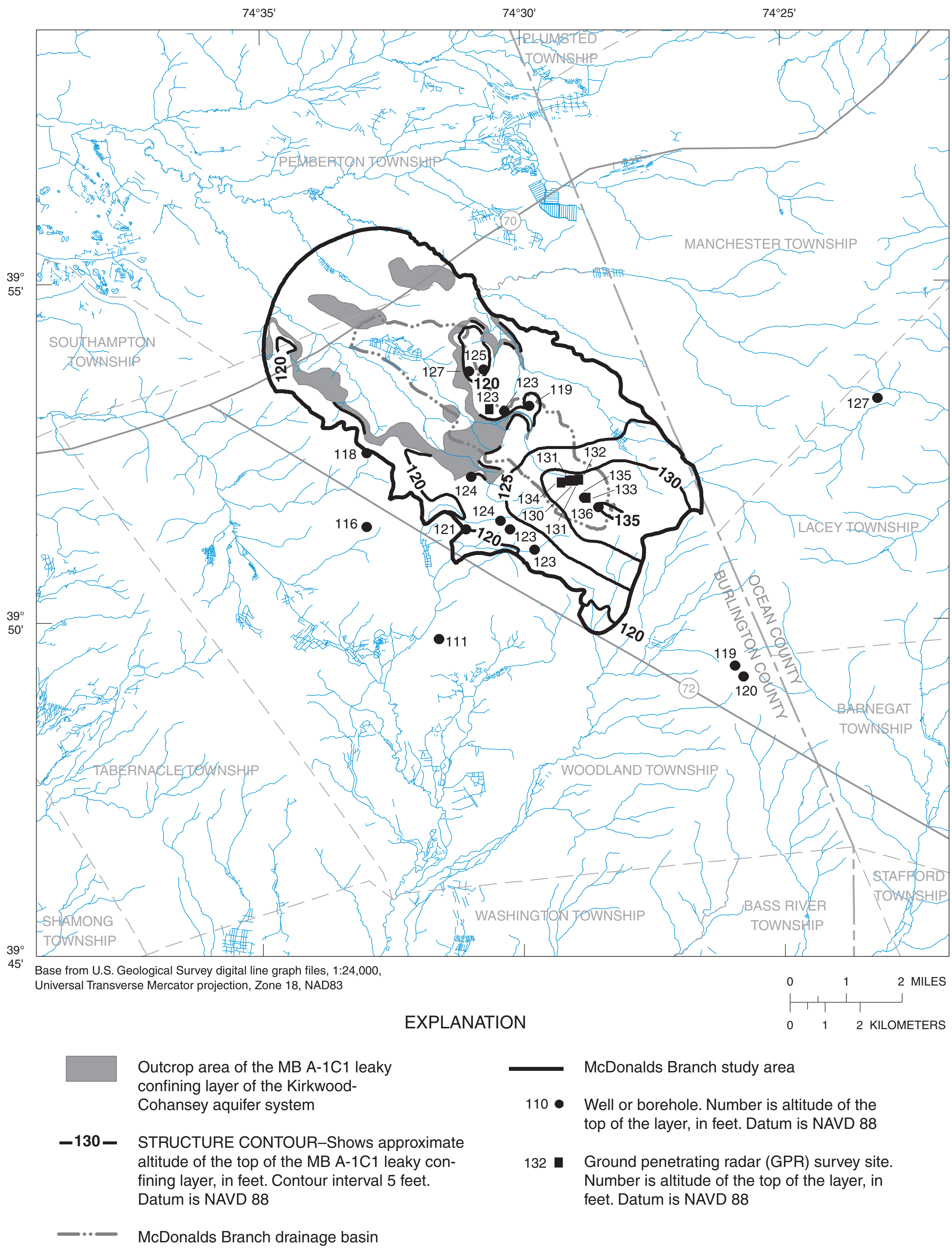


Figure 3-2. Structure contours of the top of the MB A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

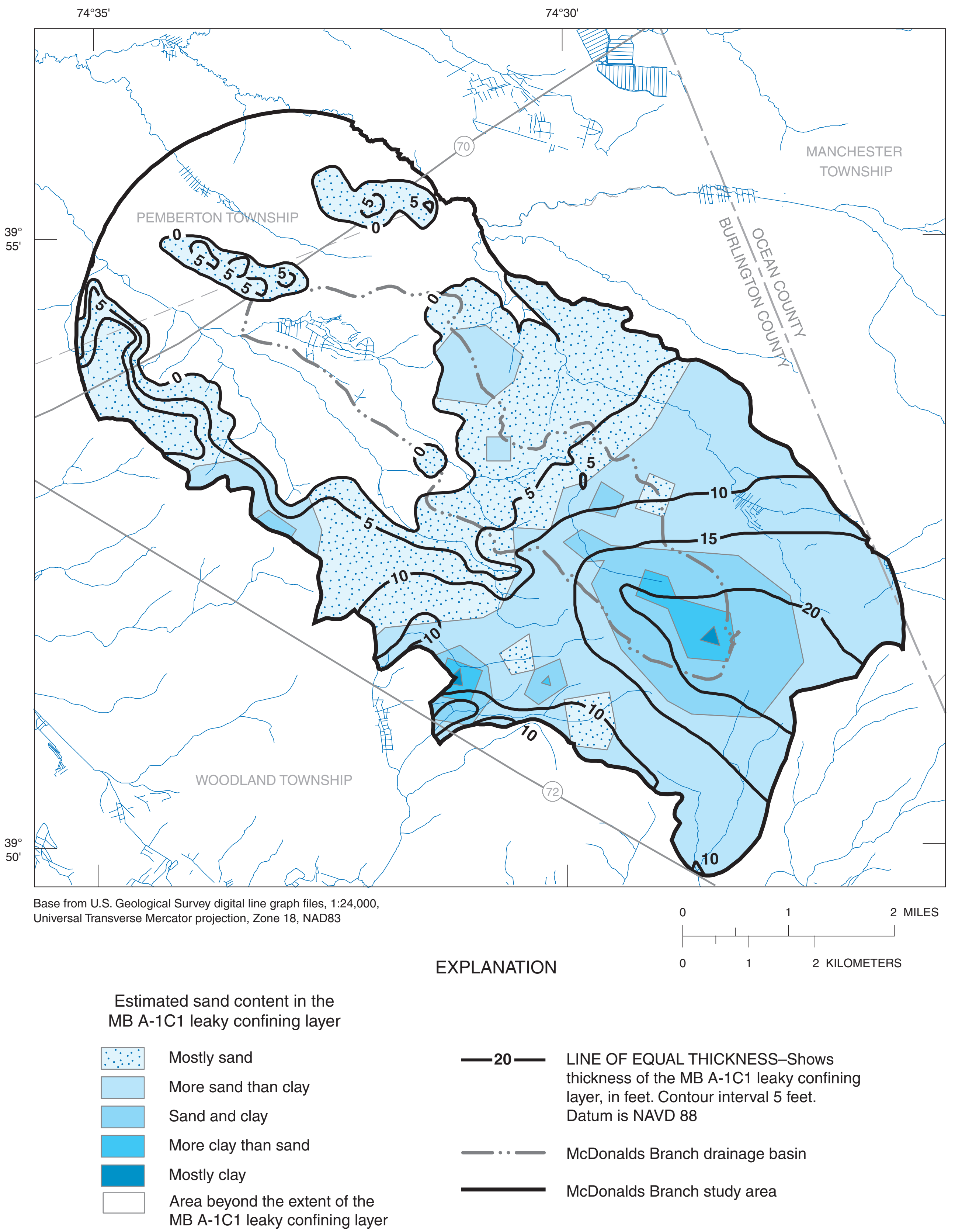
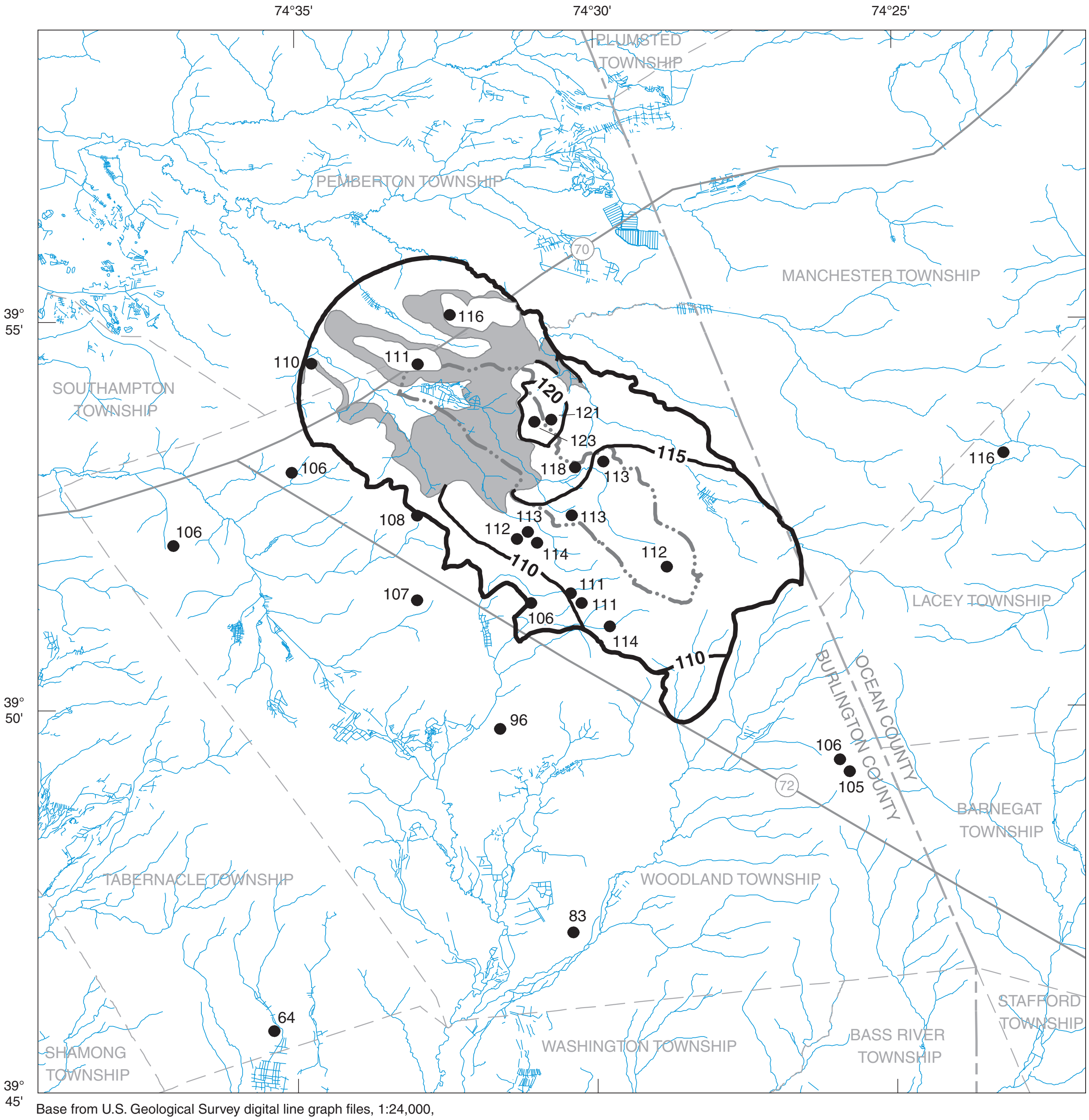


Figure 3-3. Thickness and estimated sand content of the MB A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Outcrop area of the MB A-1B aquifer layer of the Kirkwood-Cohansey aquifer.

—110— STRUCTURE CONTOUR–Shows approximate altitude of the top of the MB A-1B aquifer layer, in feet. Contour interval 5 feet. Datum is NAVD 88

McDonalds Branch drainage basin

McDonalds Branch study area

106 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 3-4. Structure contours of the top of the MB A-1B aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

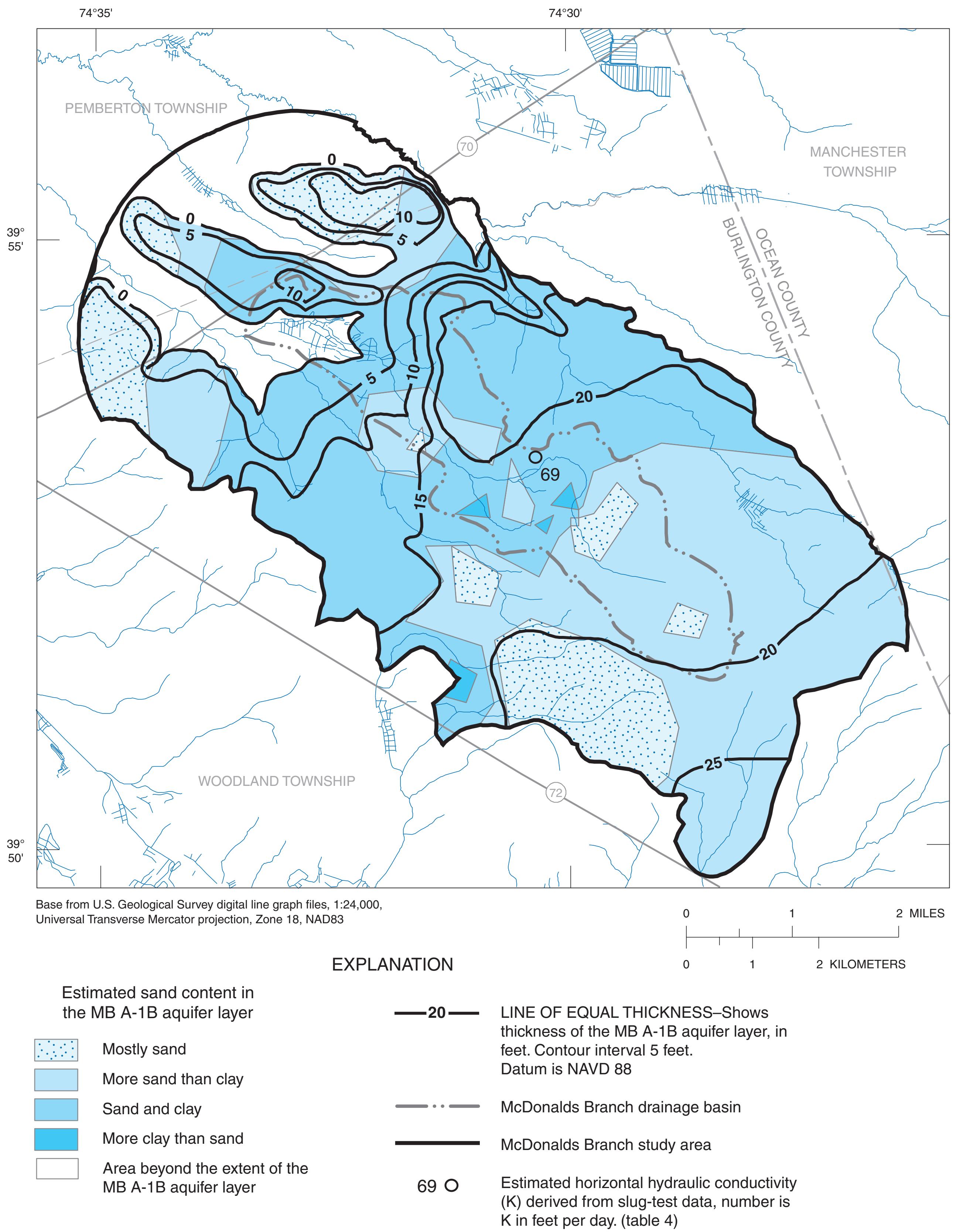
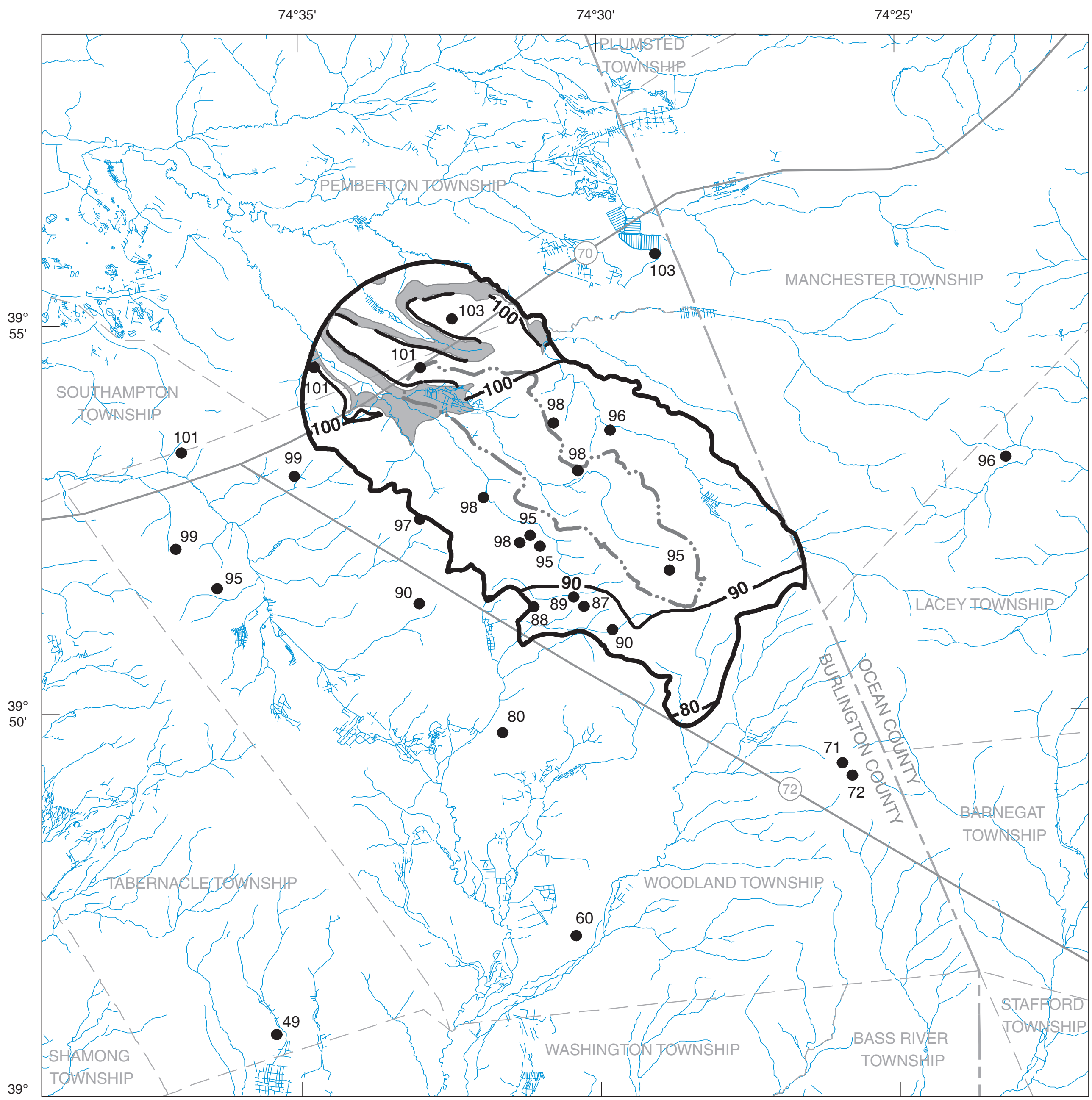


Figure 3-5. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MB A-1B aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

0 1 2 MILES
0 1 2 KILOMETERS

EXPLANATION

Outcrop area of the MB C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system

—100— STRUCTURE CONTOUR–Shows approximate altitude of the top of the MB C-1 leaky confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

McDonalds Branch drainage basin

McDonalds Branch study area

71 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 3-6. Structure contours of the top of the MB C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

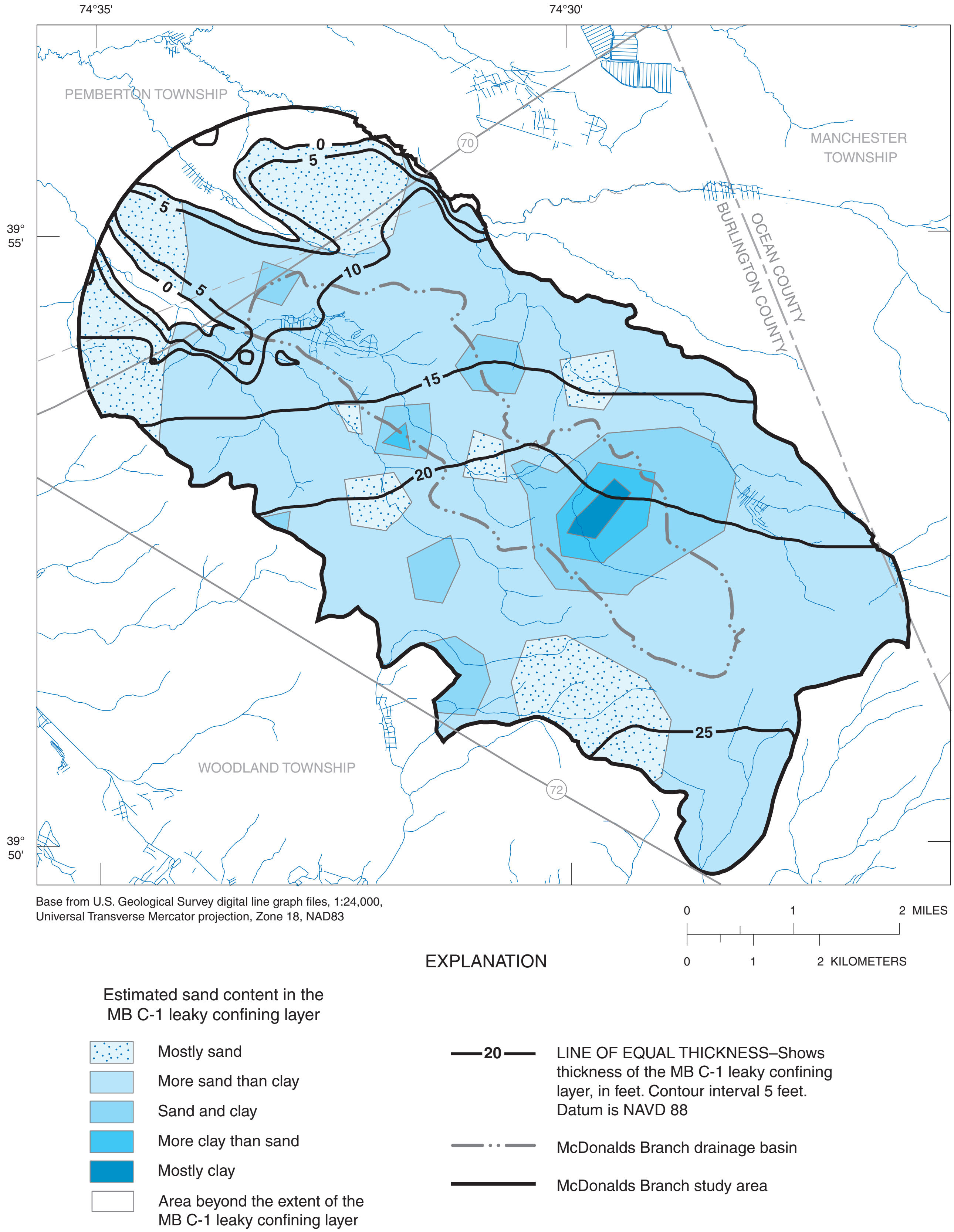


Figure 3-7. Thickness and estimated sand content of the MB C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

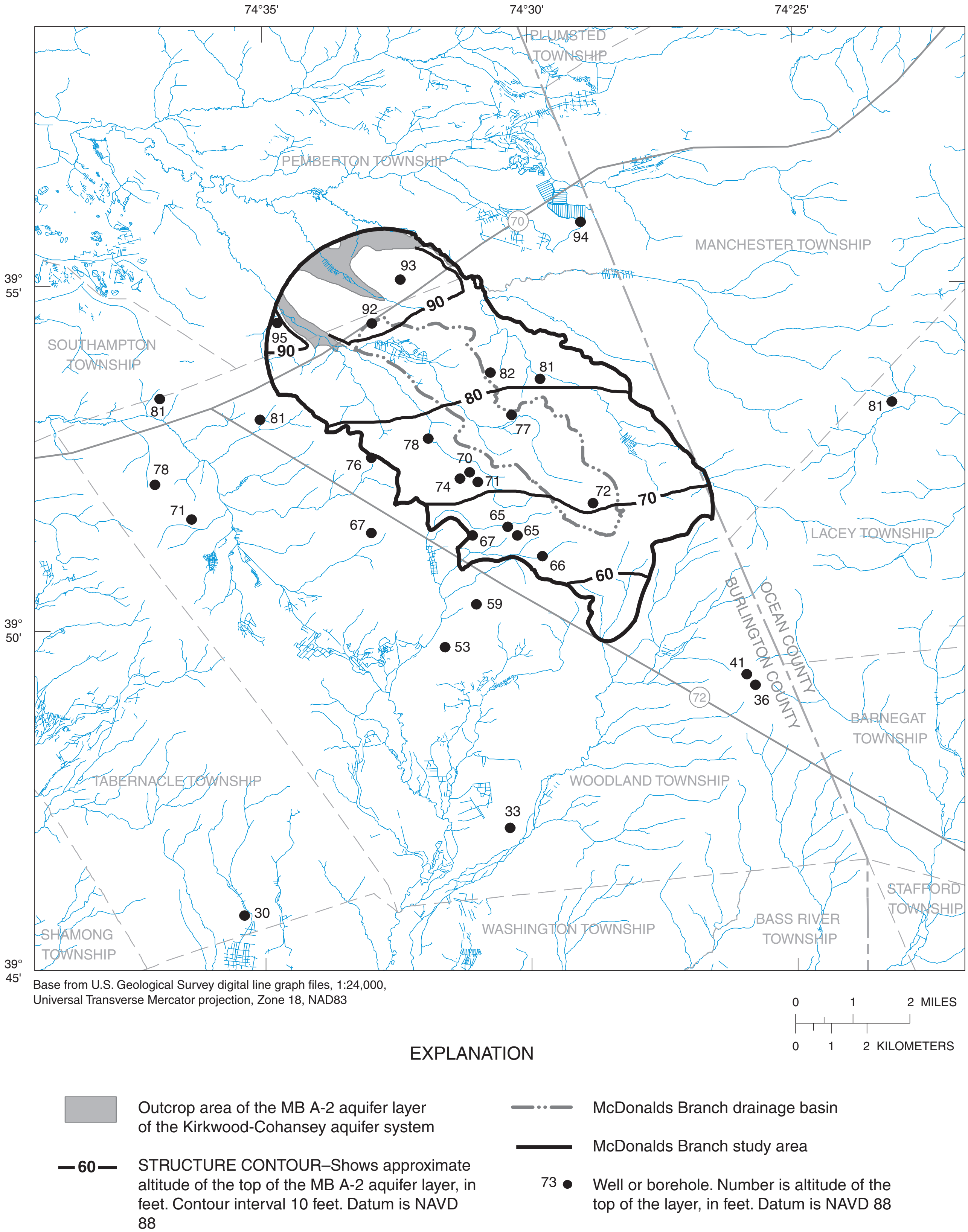
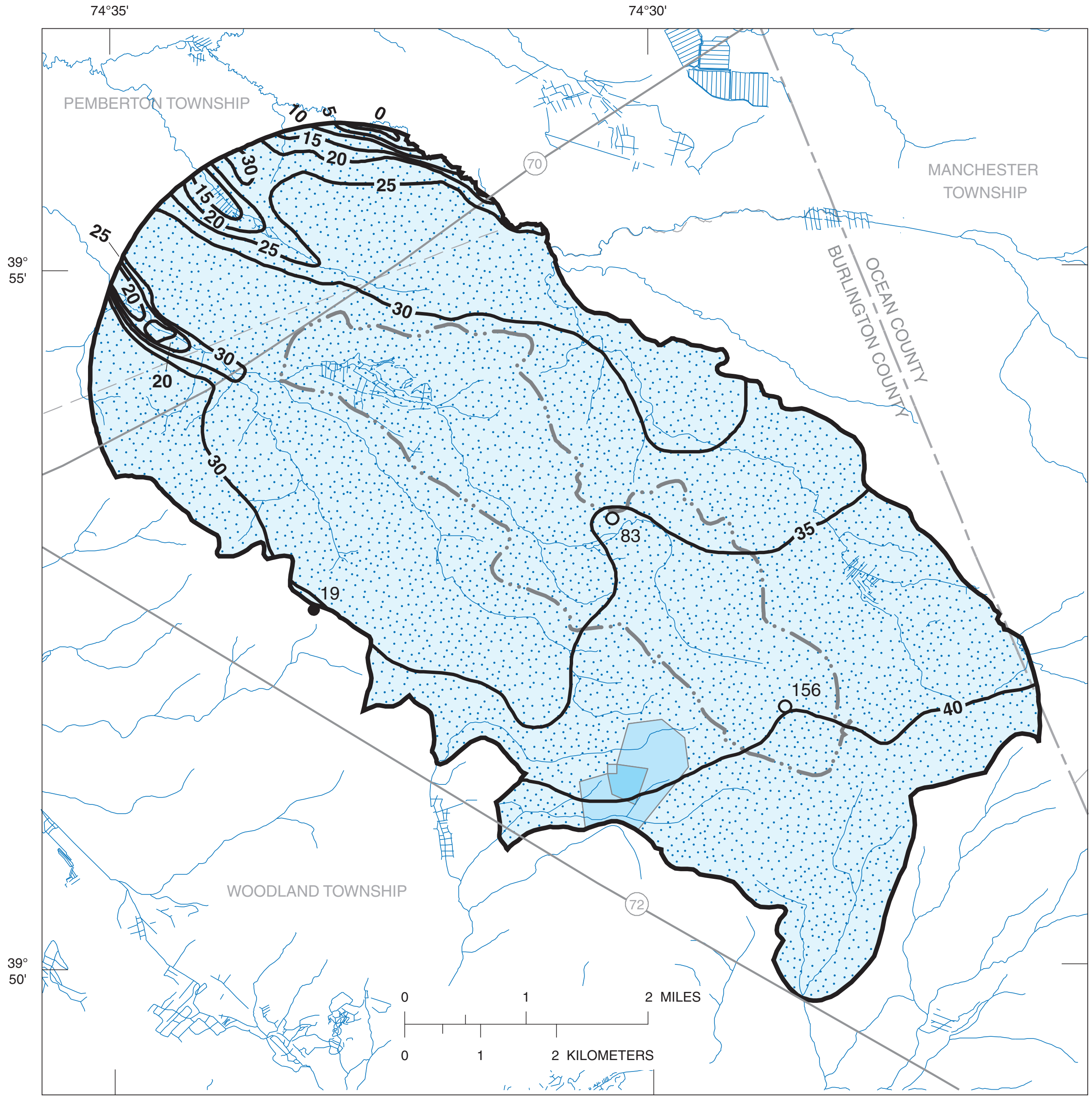


Figure 3-8. Structure contours of the top of the MB A-2 aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Estimated sand content in the MB A-2 aquifer layer

Mostly sand

More sand than clay

Sand and clay

McDonalds Branch drainage basin

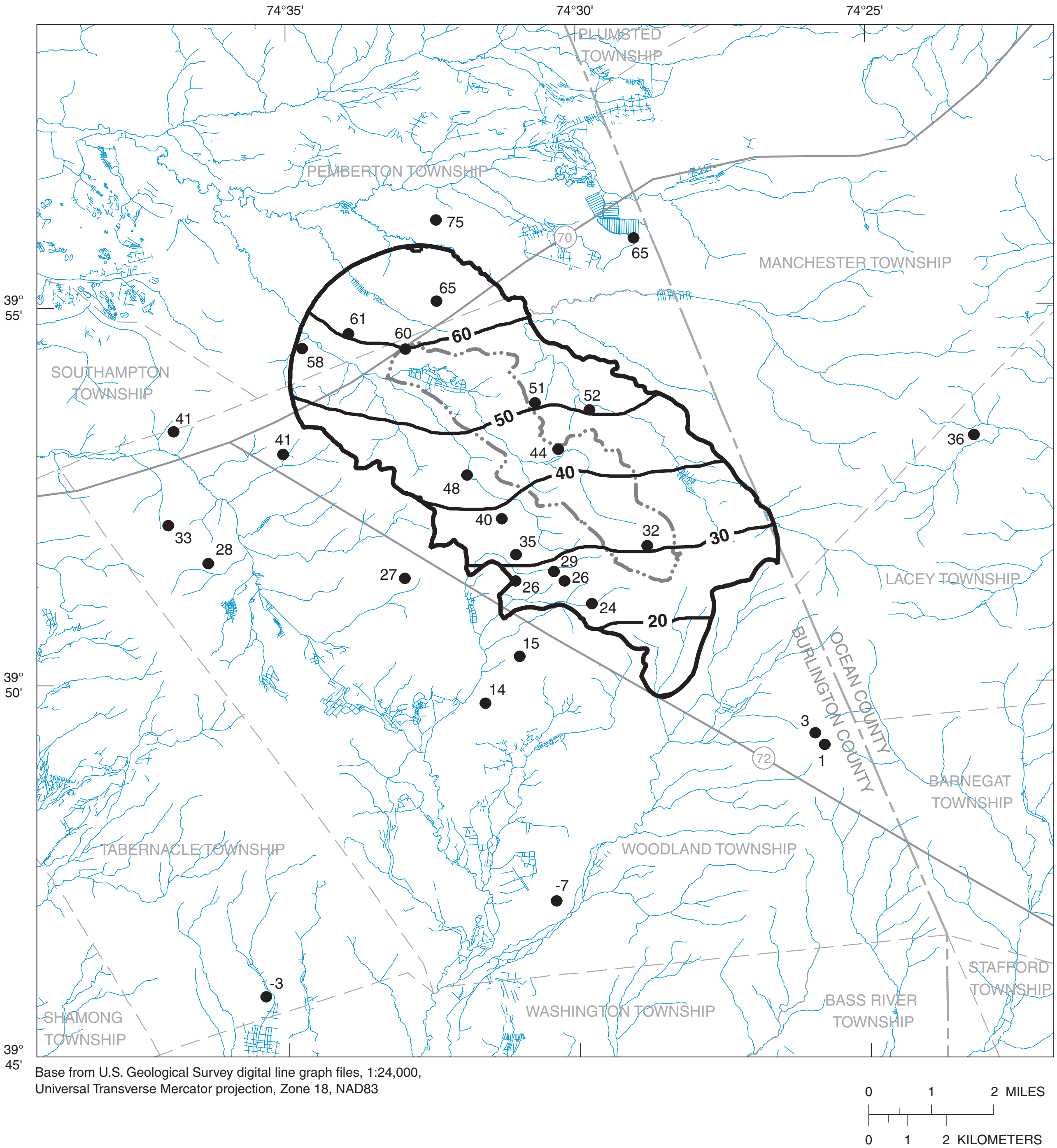
20 LINE OF EQUAL THICKNESS–Shows thickness of the MB A-2 aquifer layer, in feet. Contour interval 5 feet. Datum is NAVD 88

McDonalds Branch study area

83 Estimated horizontal hydraulic conductivity (K) derived from slug-test data, number is K in feet per day. (table 4)

19 Estimated horizontal hydraulic conductivity (K) derived from well-performance data, number is K in feet per day. (table 4)

Figure 3-9. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MB A-2 aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.



EXPLANATION

—60— STRUCTURE CONTOUR–Shows approximate altitude of the top of the MB C-2 leaky confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

McDonalds Branch drainage basin

McDonalds Branch study area

39 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 3-10. Structure contours of the top of the MB C-2 leaky confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

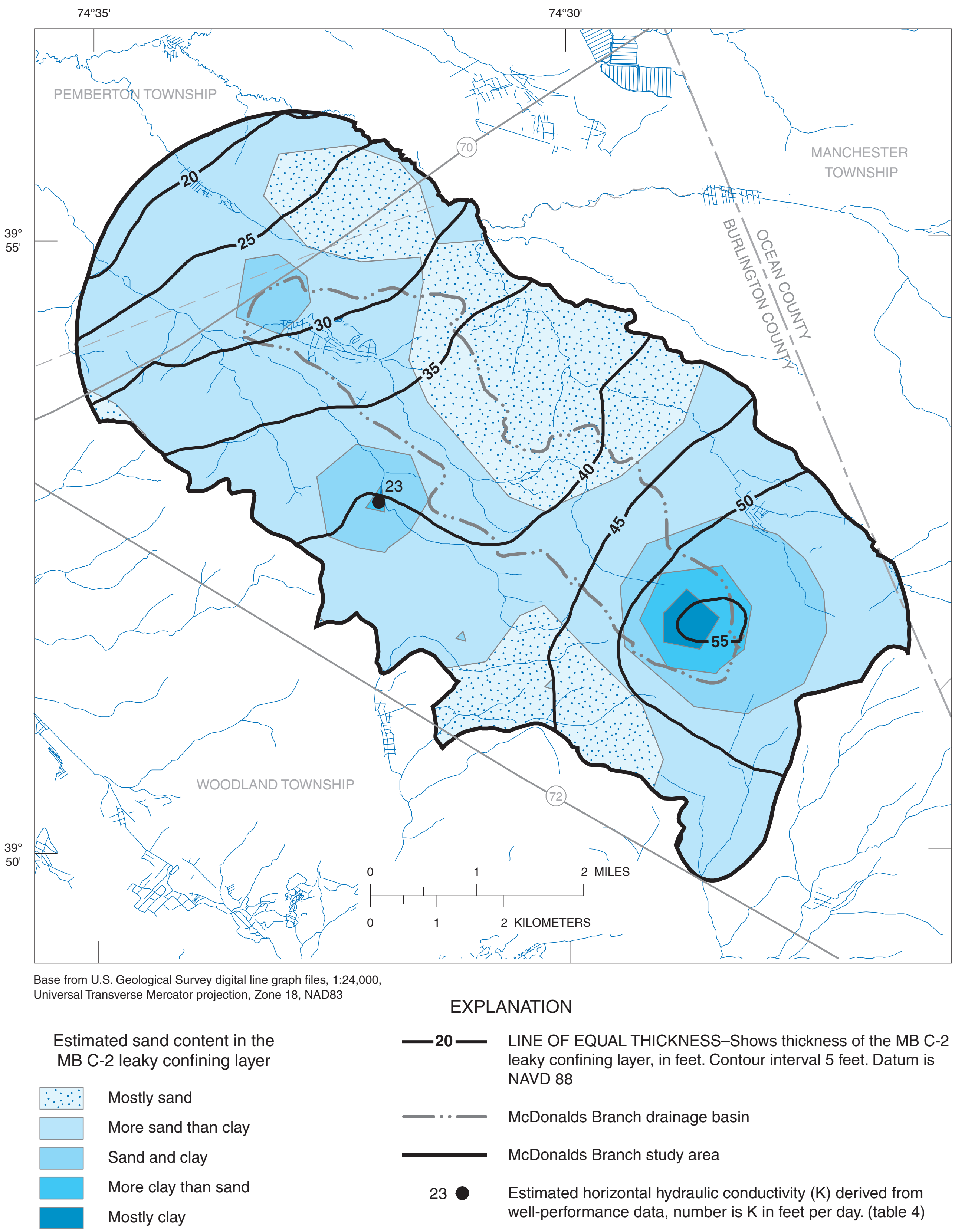


Figure 3-11. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MB C-2 leaky confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

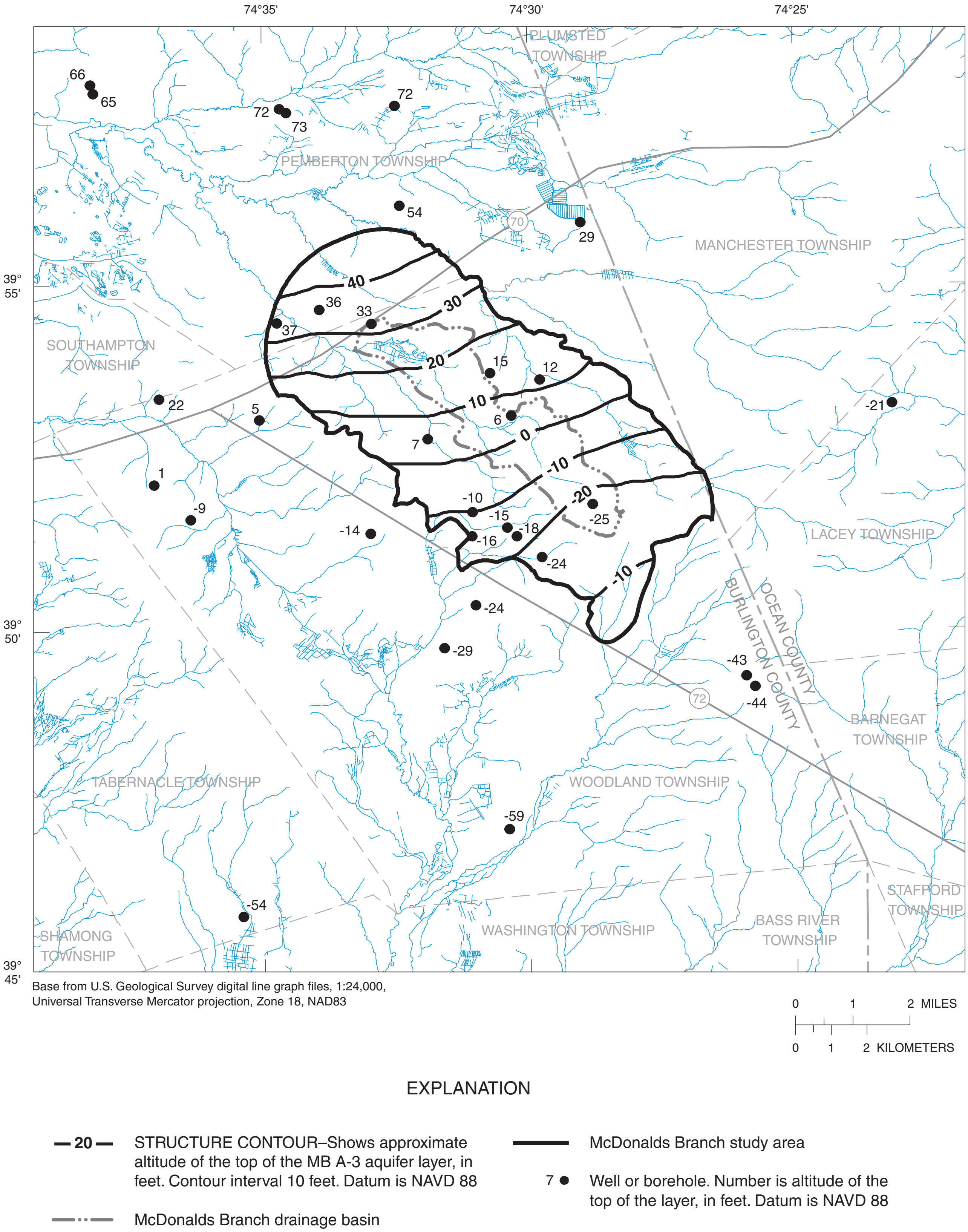
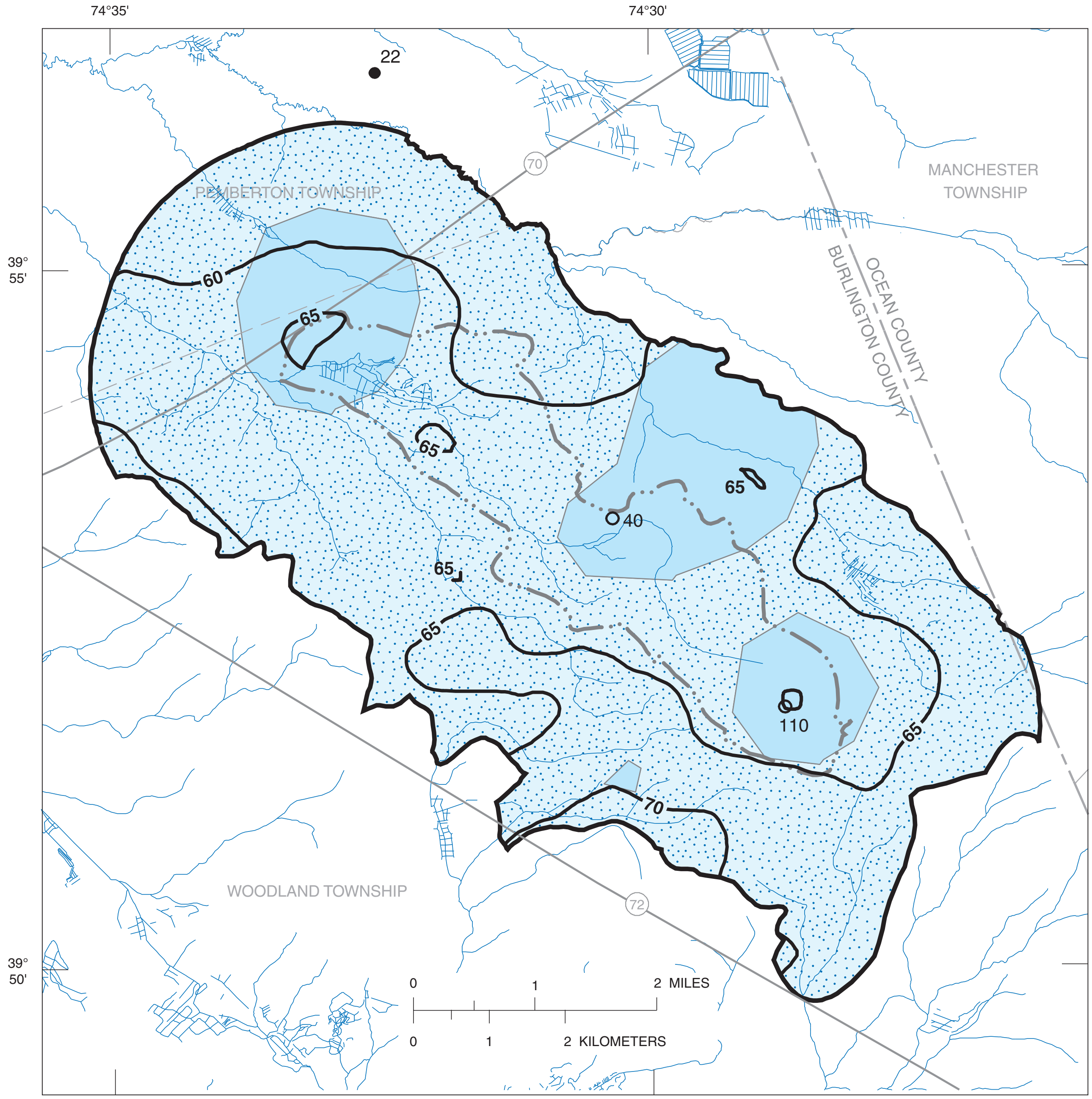


Figure 3-12. Structure contours of the top of the MB A-3 aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Estimated sand content in the MB A-3 aquifer layer

Mostly sand

Sand and clay

70 LINE OF EQUAL THICKNESS–Shows thickness of the MB A-3 aquifer layer, in feet. Contour interval 5 feet. Datum is NAVD 88

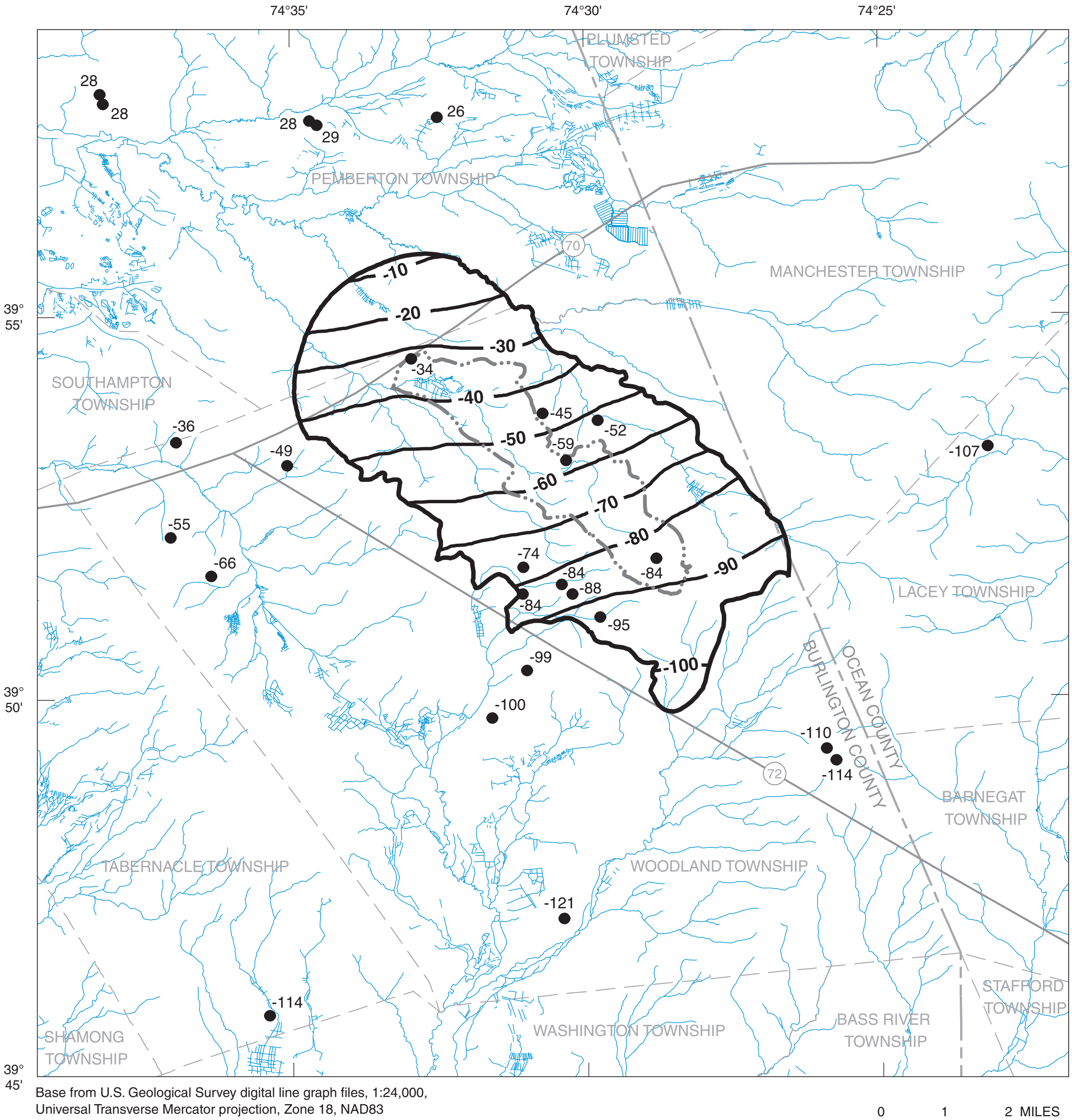
McDonalds Branch drainage basin

McDonalds Branch study area

40 Estimated horizontal hydraulic conductivity (K) derived from slug-test data, number is K in feet per day. (table 4)

22 Estimated horizontal hydraulic conductivity (K) derived from well-performance data, number is K in feet per day. (table 4)

Figure 3-13. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MB A-3 aquifer layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.



EXPLANATION

-20 STRUCTURE CONTOUR–Shows approximate altitude of the top of the MB C-3 Lower Kirkwood confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

McDonalds Branch drainage basin

McDonalds Branch study area

-66 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 3-14. Structure contours of the top of the MB C-3 Lower Kirkwood confining layer of the Kirkwood-Cohansey aquifer system, McDonalds Branch study area and vicinity, New Jersey Pinelands.

Appendix 4

Altitude, thickness, estimated sand content, and (or) horizontal hydraulic conductivity of hydrogeologic layers of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

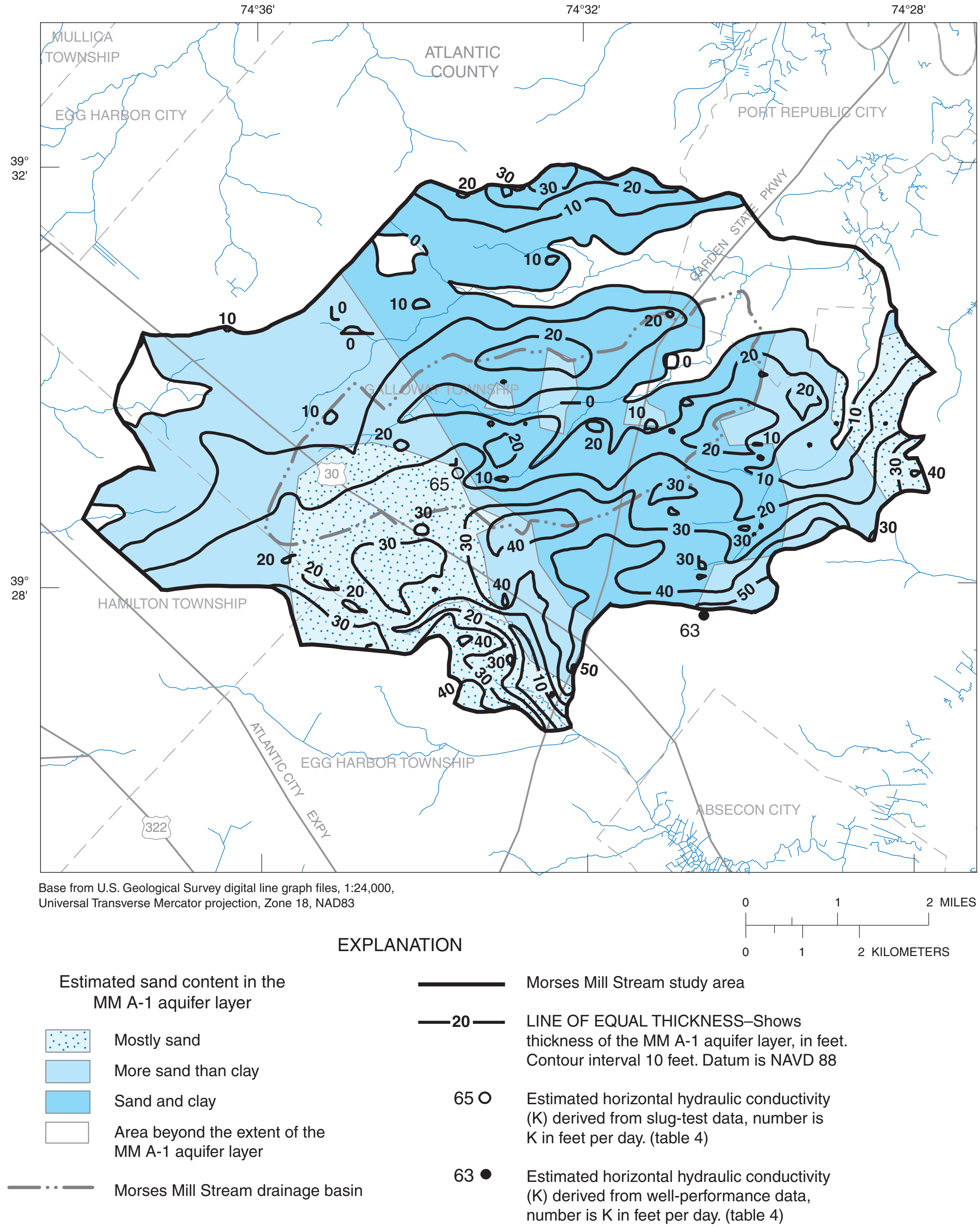
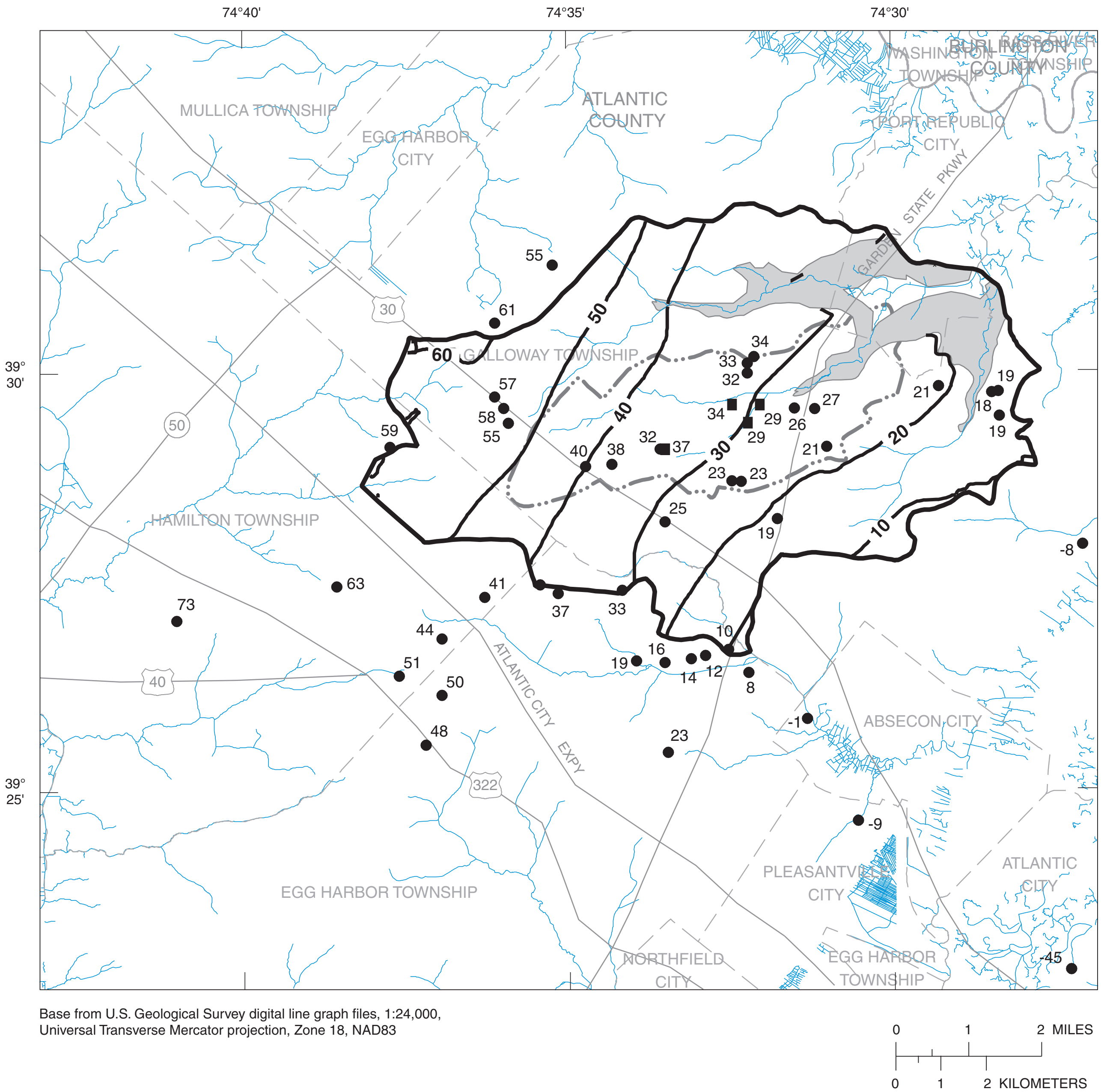


Figure 4-1. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MM A-1 aquifer layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

Outcrop area of the MM A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system

— 50 — STRUCTURE CONTOUR–Shows approximate altitude of the top of the MM A-1C1 leaky confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

Morses Mill Stream drainage basin

Morses Mill Stream study area

19 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

34 ■ Ground penetrating radar (GPR)survey site. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 4-2. Structure contours of the top of the MM A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

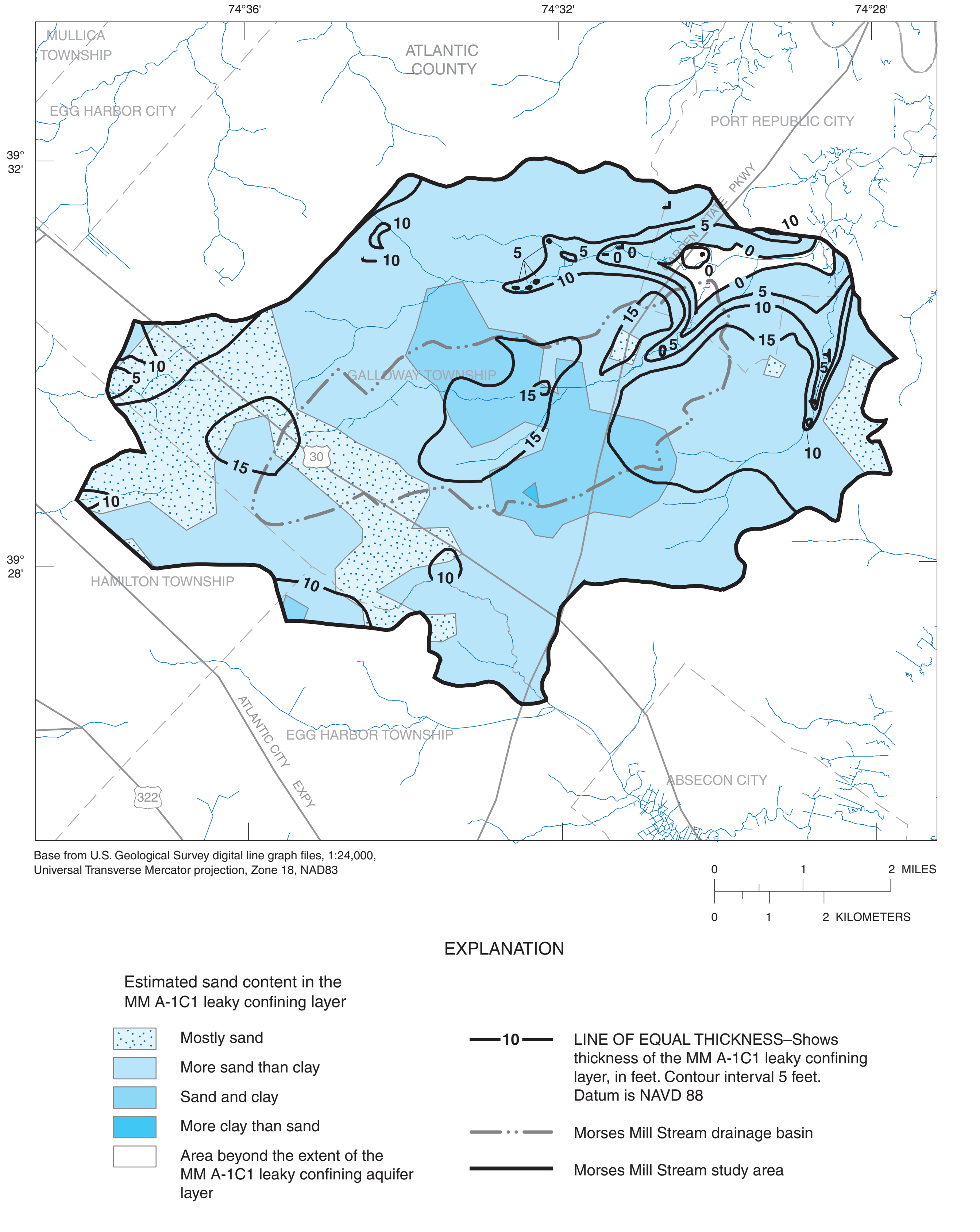


Figure 4-3. Thickness and estimated sand content of the MM A-1C1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

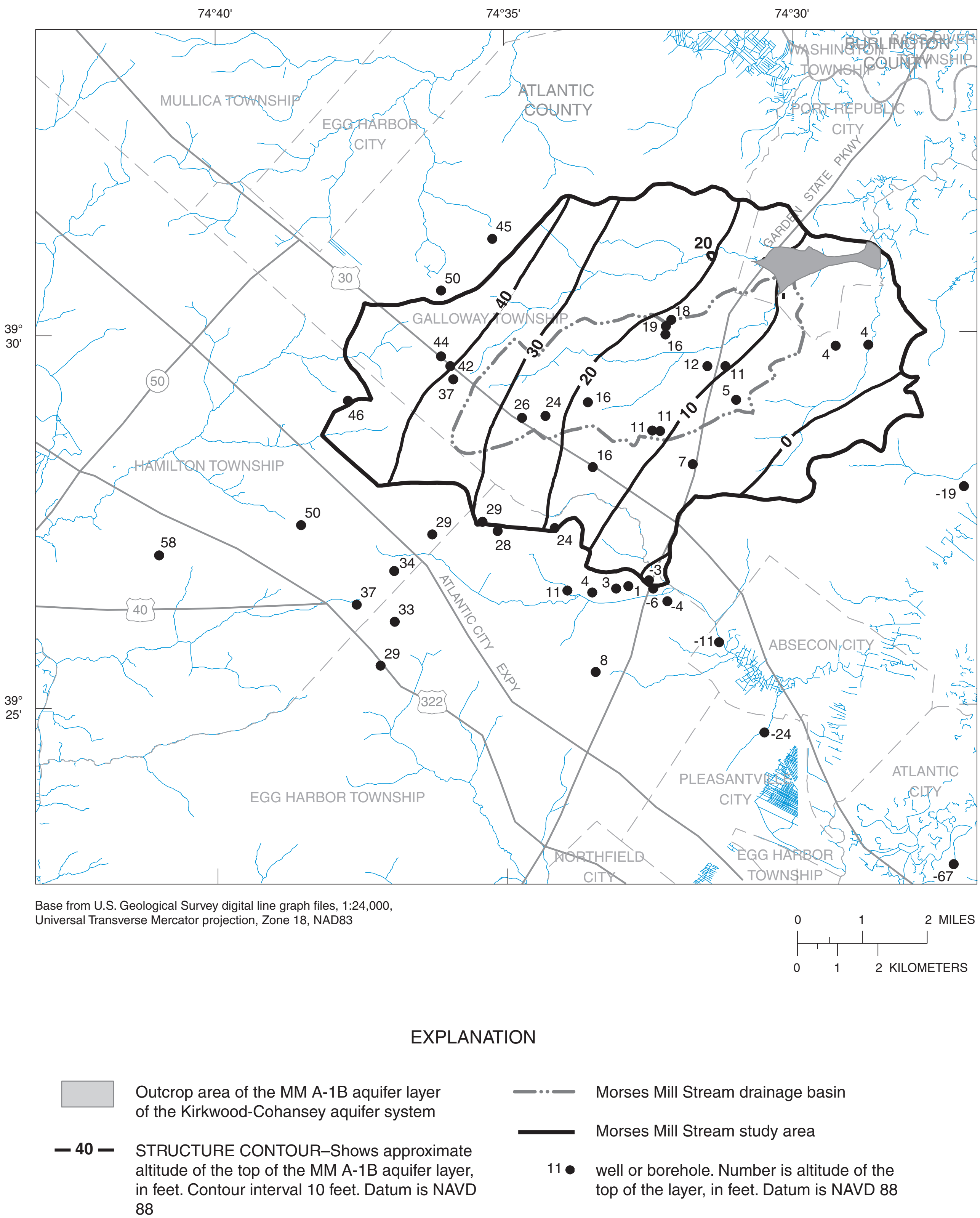


Figure 4-4. Structure contours of the top of the MM A-1B aquifer layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

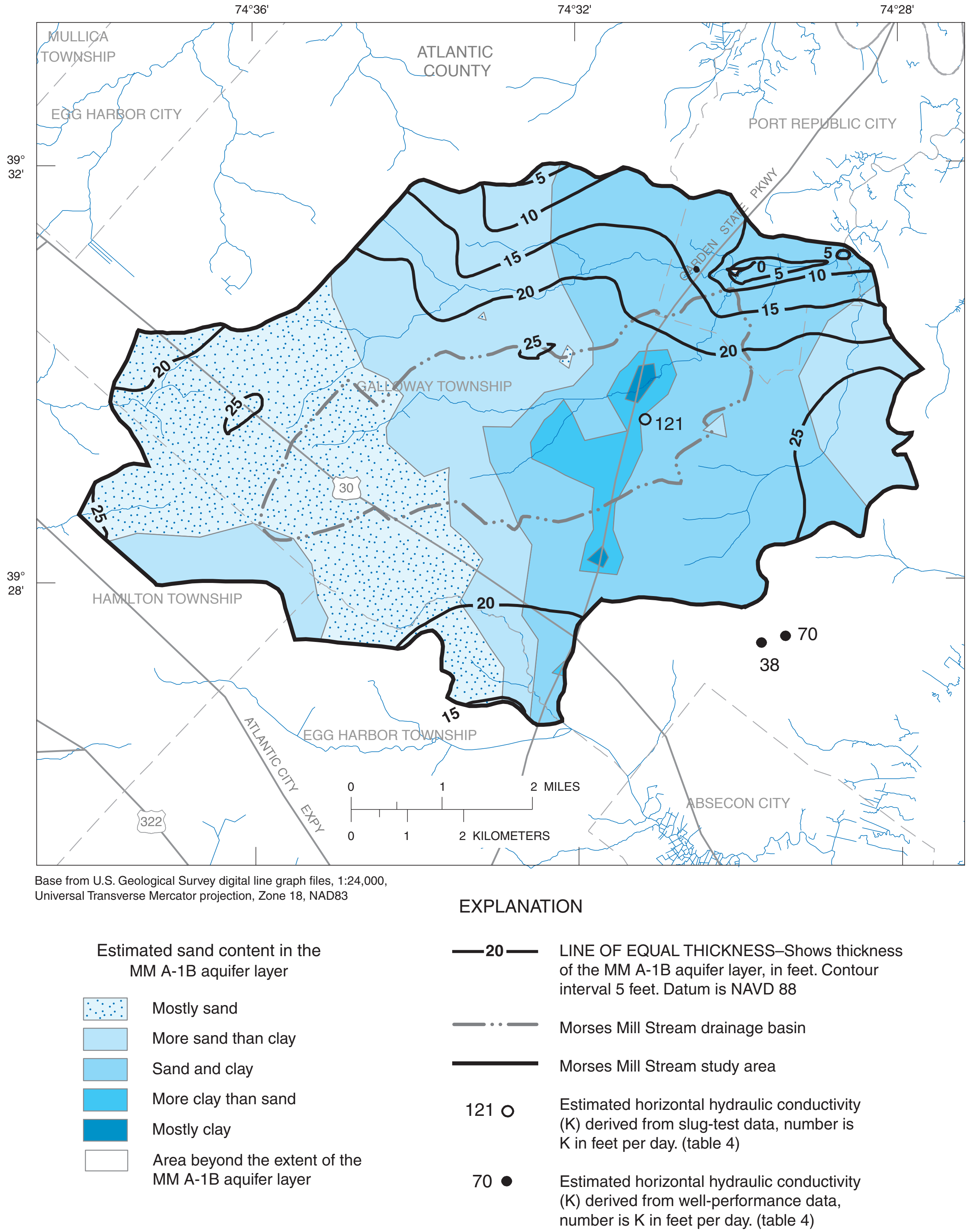
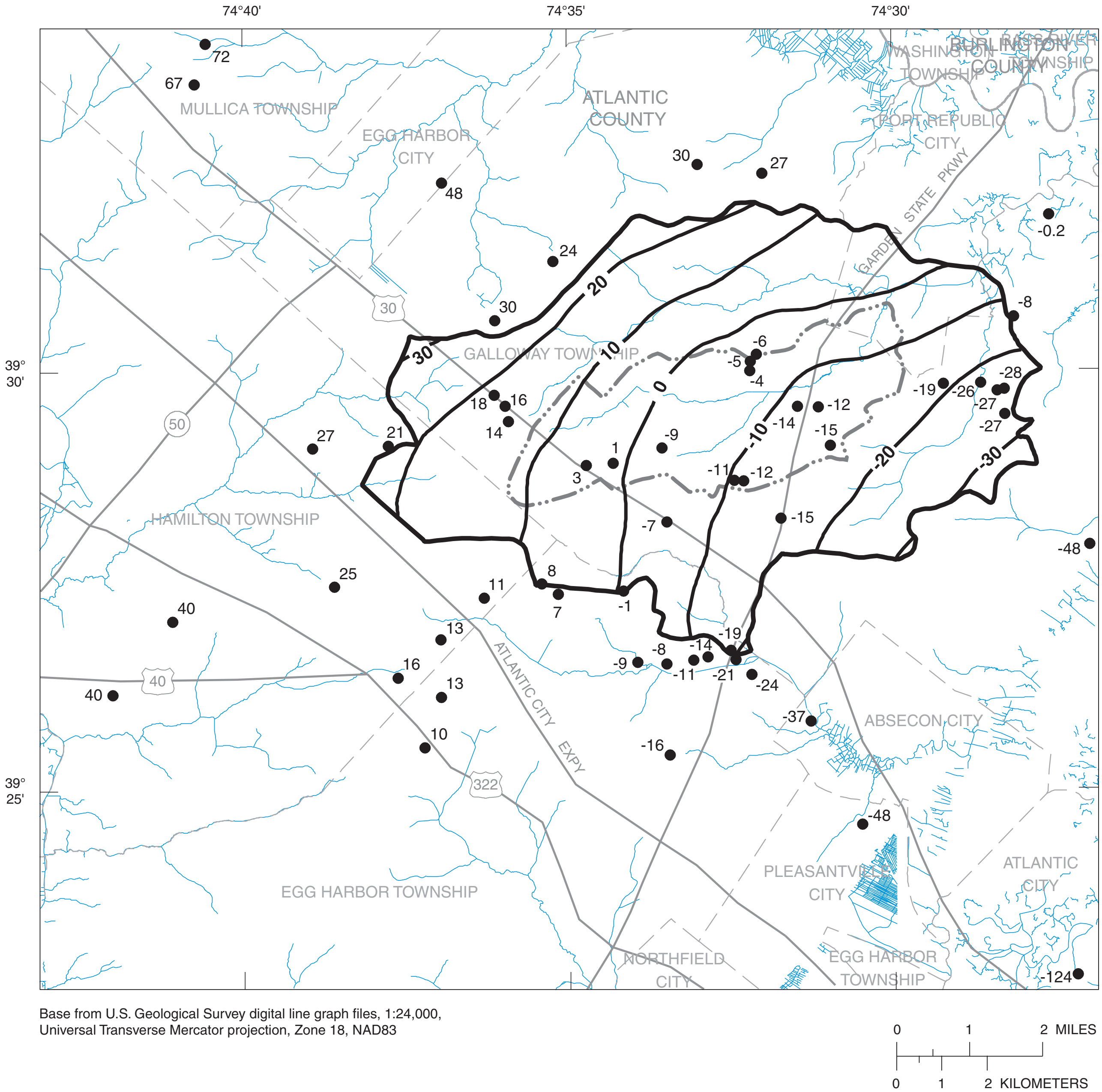


Figure 4-5. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MM A-1B aquifer layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



EXPLANATION

-20 STRUCTURE CONTOUR–Shows approximate altitude of the top of the MM C-1 leaky confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

Morses Mill Stream drainage basin

Morses Mill Stream study area

40 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 4-6. Structure contours of the top of the MM C-1 leaky confining layer of the Kirkwood-Cohansey aquifer ststem, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

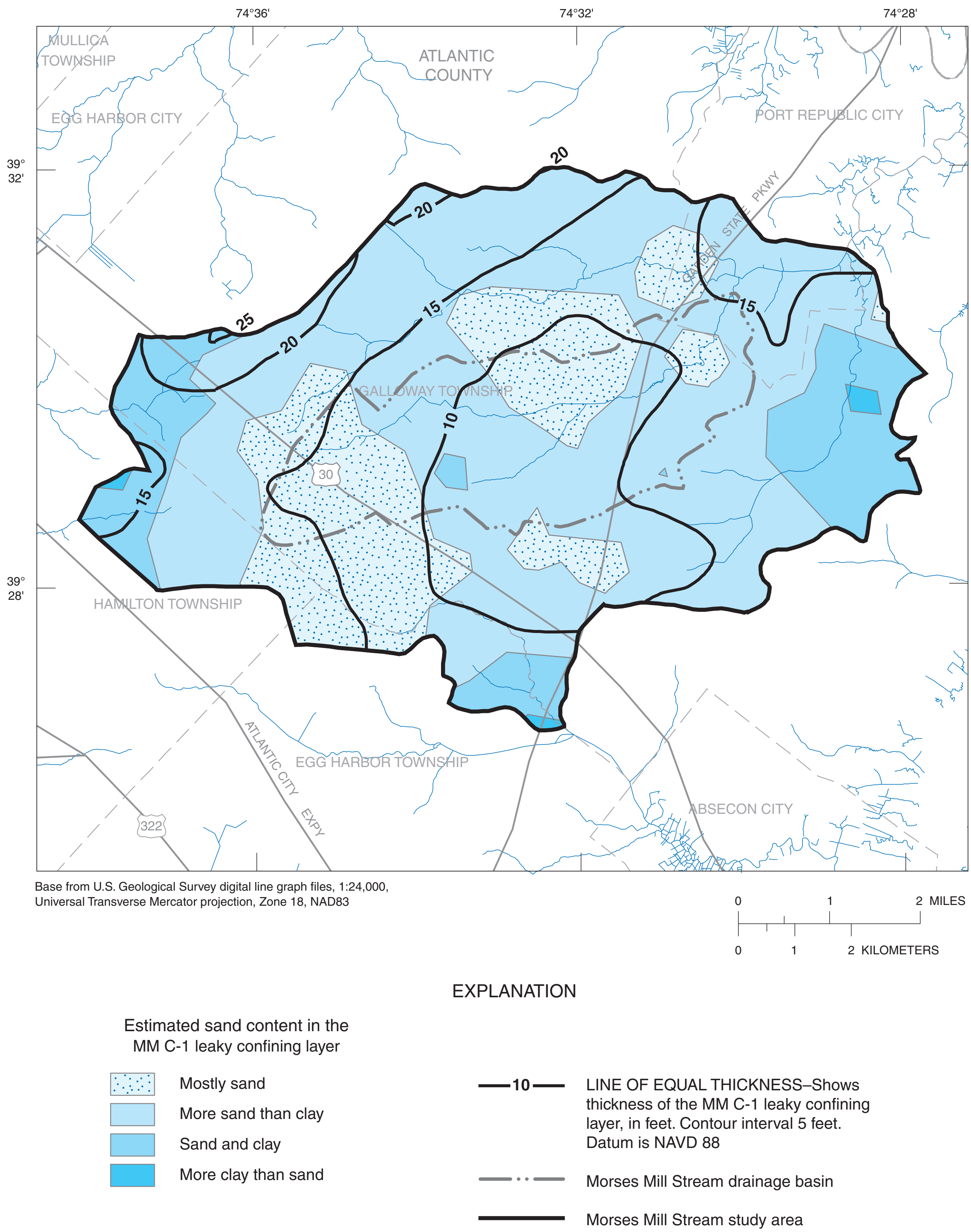
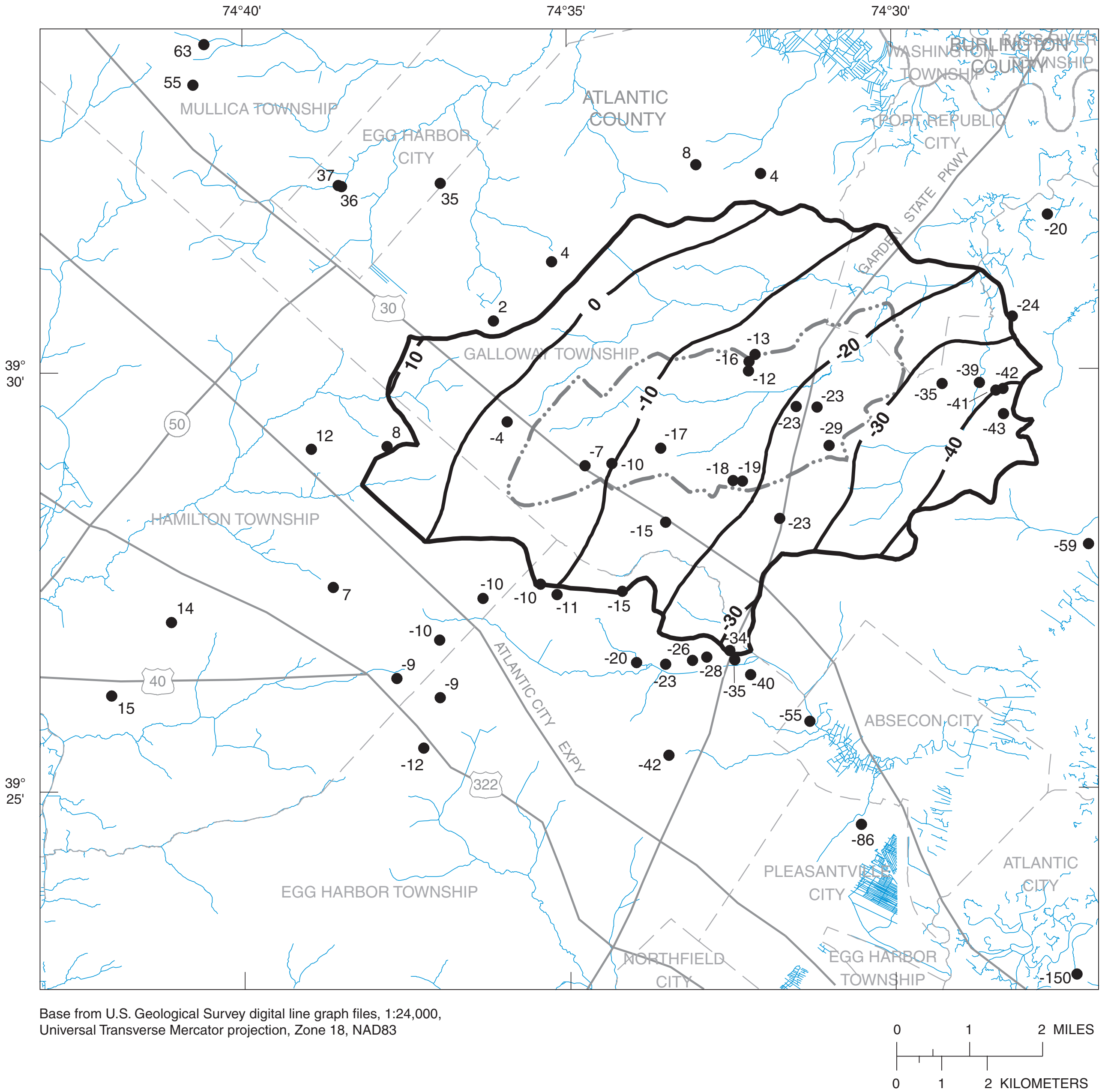


Figure 4-7. Thickness and estimated sand content of the MM C-1 leaky confining layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

EXPLANATION

-20 STRUCTURE CONTOUR–Shows approximate altitude of the top of the MM A-2 aquifer layer, in feet. Contour interval 10 feet. Datum is NAVD 88

Morses Mill Stream drainage basin

Morses Mill Stream study area

-20 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 4-8. Structure contours of the top of the MM A-2 aquifer layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

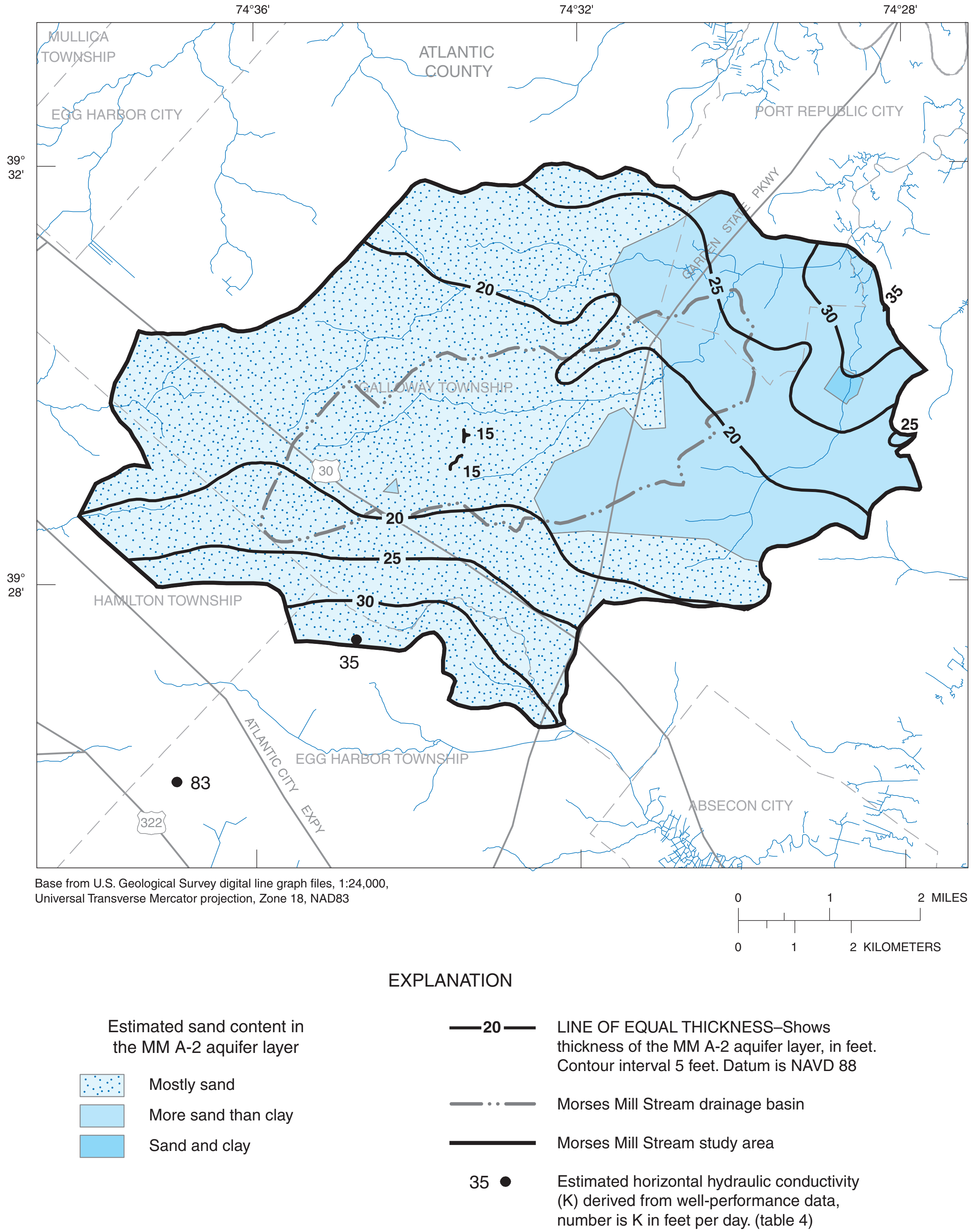
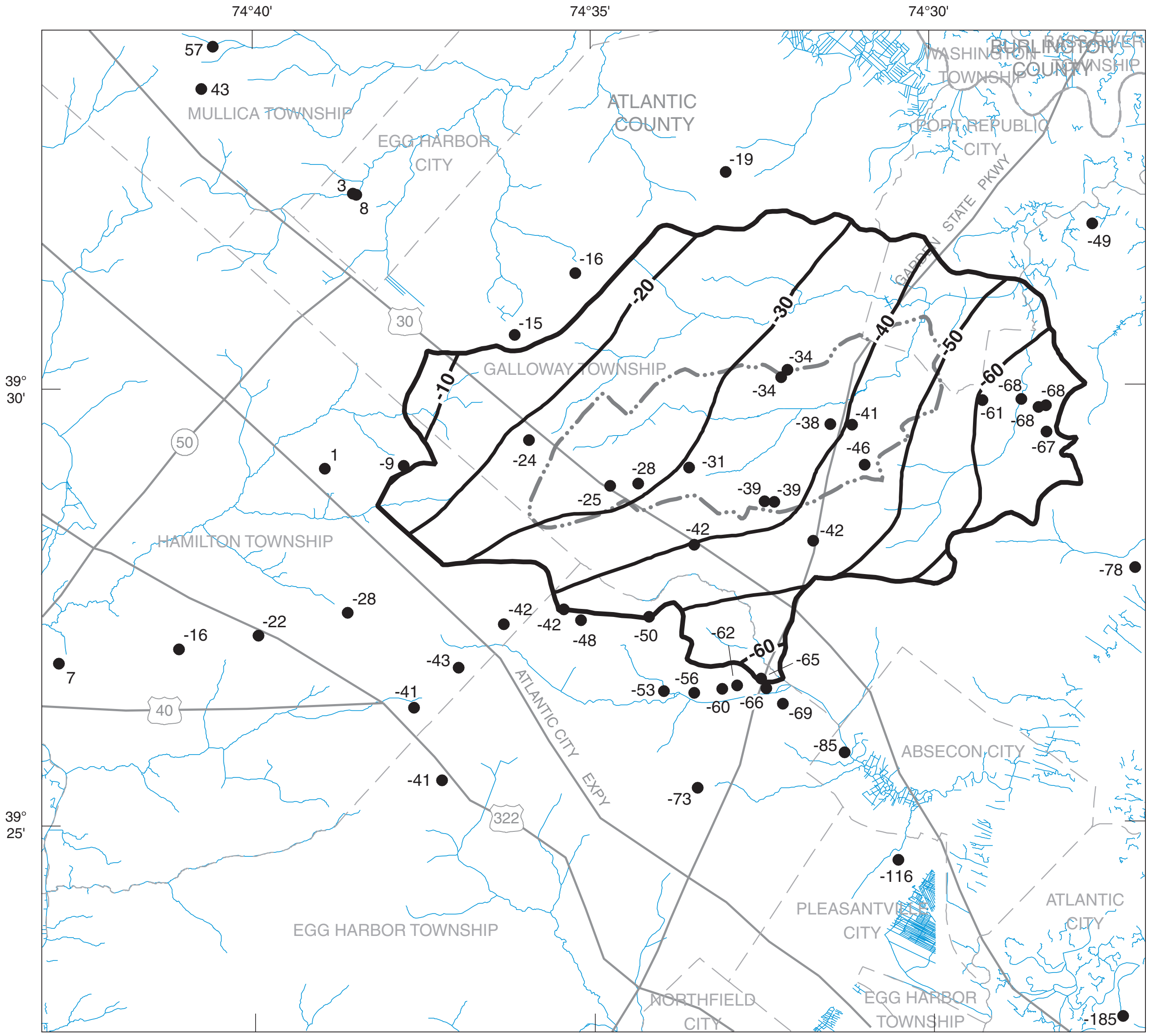


Figure 4-9. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MM A-2 aquifer layer of the Kirkwood-Cohansey aquifer ststem, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

0 1 2 MILES

0 1 2 KILOMETERS

EXPLANATION

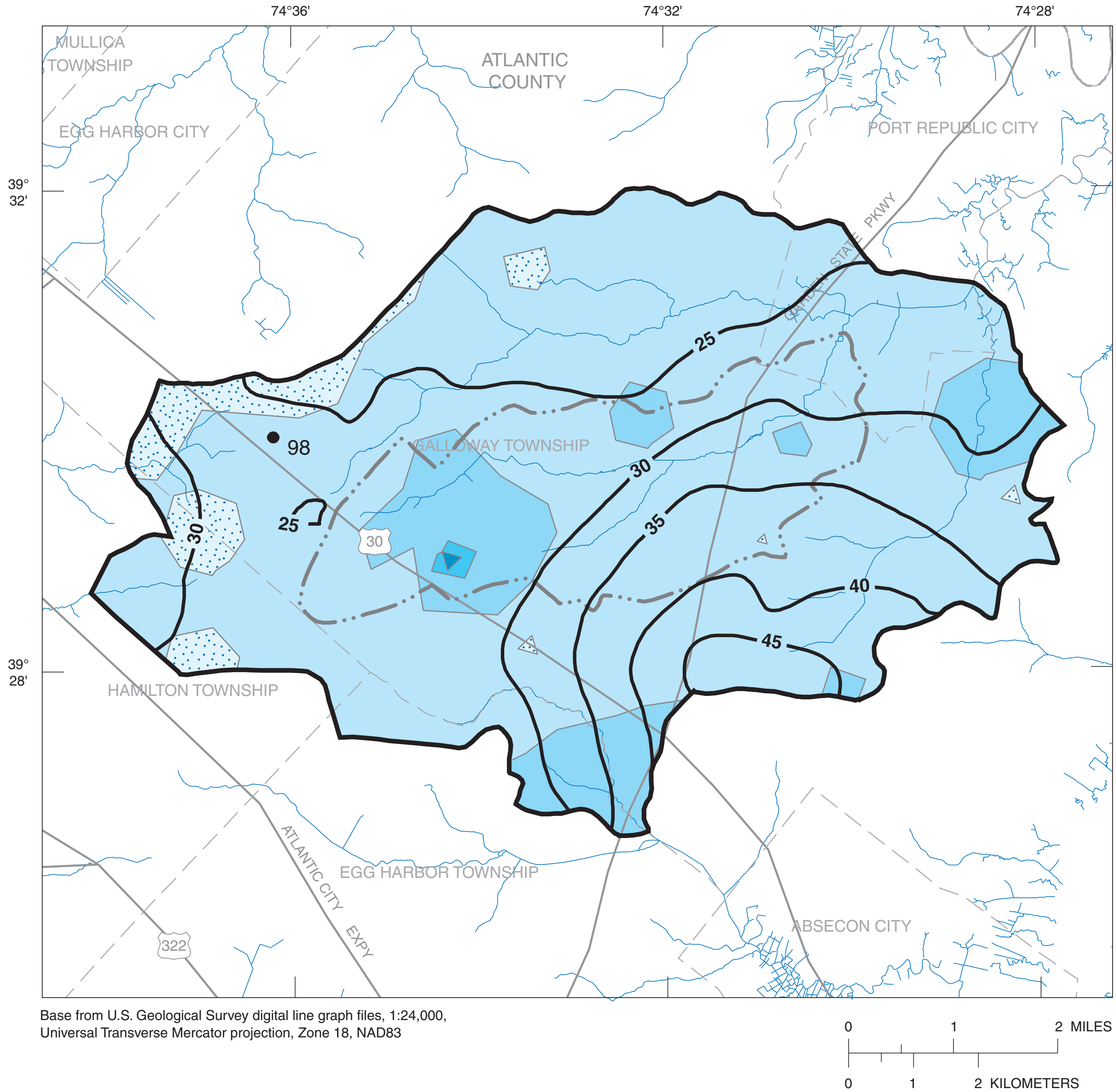
-20 STRUCTURE CONTOUR–Shows approximate altitude of the top of the MM C-2 leaky confining layer, in feet. Contour interval 10 feet. Datum is NAVD 88

Morses Mill Stream drainage basin

Morses Mill Stream study area

-41 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 4-10. Structure contours of the top of the MM C-2 leaky confining layer of the Kirkwood-Cohansey aquifer ststem, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



EXPLANATION

Estimated sand content in the MM C-2 leaky confining layer

- Mostly sand
- More sand than clay
- Sand and clay
- More clay than sand
- Mostly clay

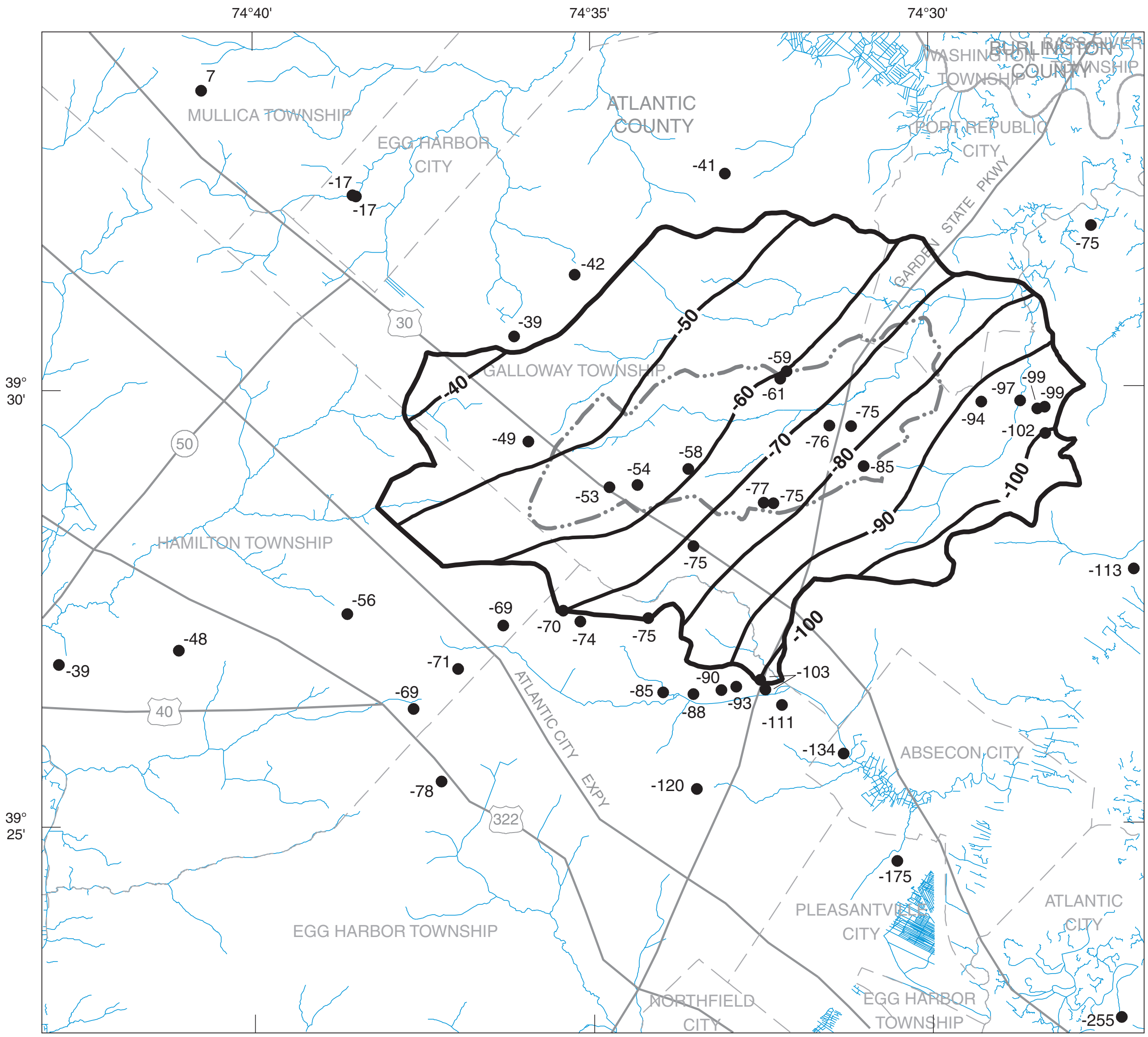
—25— LINE OF EQUAL THICKNESS–Shows thickness of the MM C-2 leaky confining layer, in feet. Contour interval 5 feet. Datum is NAVD 88

Morses Mill Stream drainage basin

Morses Mill Stream study area

98 ● Estimated horizontal hydraulic conductivity (K) derived from well-performance data, number is K in feet per day. (table 4)

Figure 4-11. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MM C-2 leaky confining layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

0 1 2 MILES

0 1 2 KILOMETERS

EXPLANATION

—-40— STRUCTURE CONTOUR–Shows approximate altitude of the top of the MM A-3 aquifer layer, in feet. Contour interval 10 feet. Datum is NAVD 88

Morses Mill Stream drainage basin

Morses Mill Stream study area

-85 ● Well or borehole. Number is altitude of the top of the layer, in feet. Datum is NAVD 88

Figure 4-12. Structure contours of the top of the MM A-3 aquifer layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

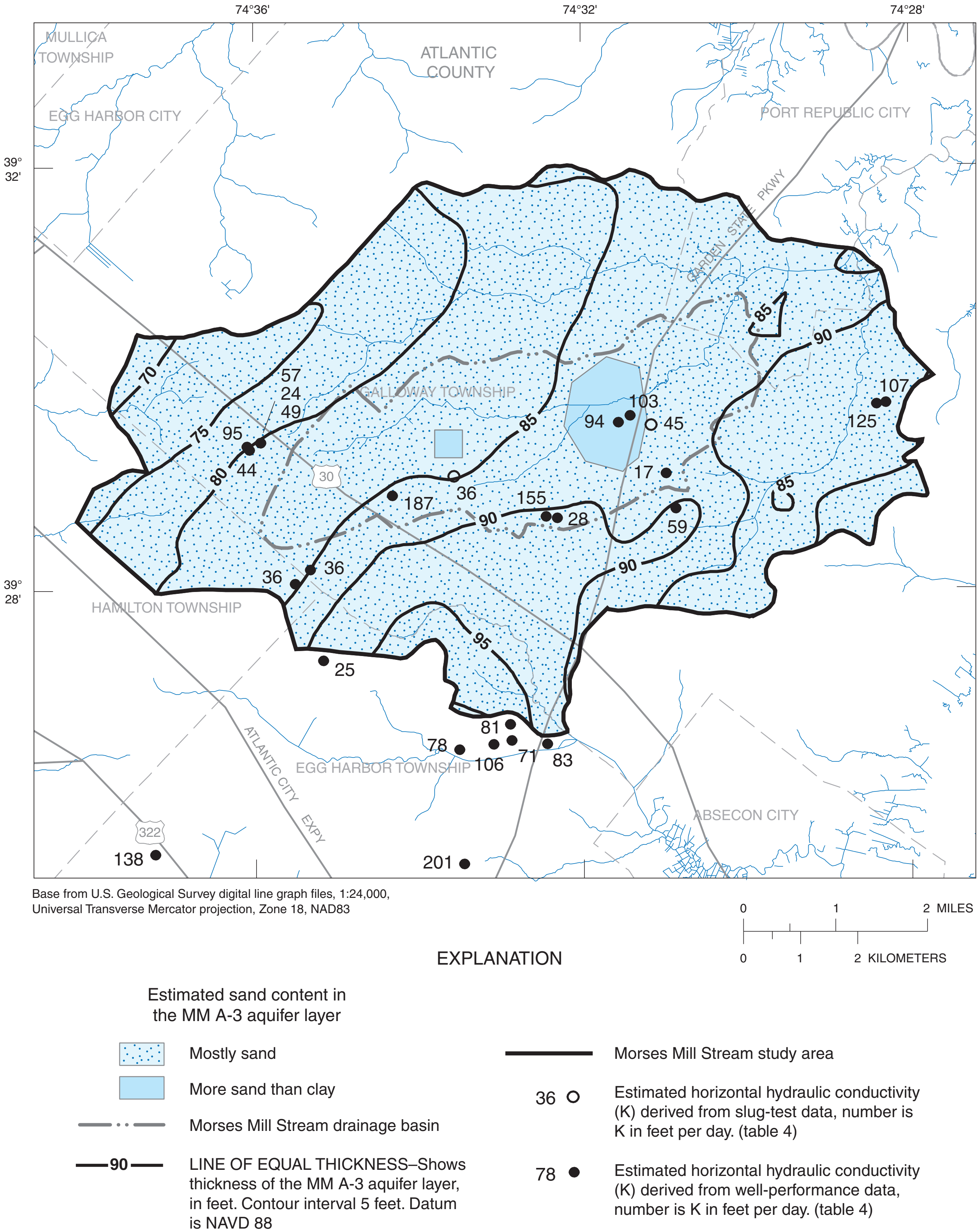


Figure 4-13. Thickness, estimated sand content, and horizontal hydraulic conductivity of the MM A-3 aquifer layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

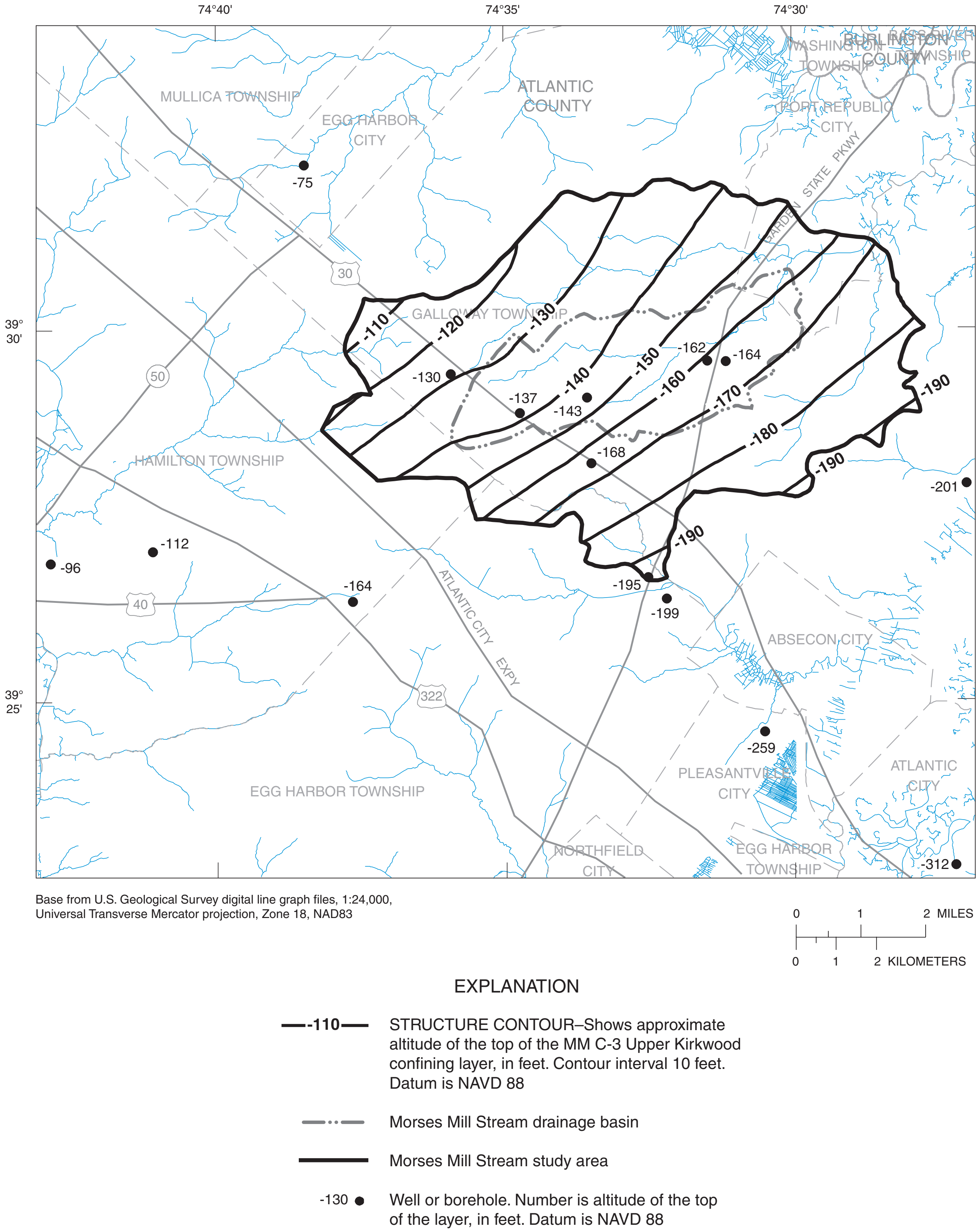


Figure 4-14. Structure contours of the top of the MM C-3 Upper Kirkwood confining layer of the Kirkwood-Cohansey aquifer system, Morses Mill Stream study area and vicinity, New Jersey Pinelands.

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/

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Walker and others—**Hydrogeologic Framework in Three Drainage Basins in the New Jersey Pinelands, 2004-06**—Scientific Investigations Report 2008-5061

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