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INTRODUCTION

The West Creek quadrangle is in the Barnegat Bay region of the New Jersey Coastal Plain, in the southeastern part of the state. Outcropping and shallow subsurface sediments in the map area include surficial deposits of late Miocene to Holocene age that overlie the Cohansey and Kirkwood formations, which are marginal-marine deposits of Miocene age. Shelf deposits of Oligocene age (the Atlantic City and Sewell Point formations) underlie the Miocene deposits. The surficial deposits include marine, estuarine, river, wetland, and windblown sediments. The Kirkwood Formation was deposited in marine-delta and shallow-shelf settings in the early and middle Miocene. The Cohansey Formation was deposited in coastal settings in the middle and late Miocene, when sea level in this region was at times more than 200 feet higher than at present. As sea level lowered after deposition of the Cohansey, rivers flowing on the emerging Coastal Plain deposited fluvial gravel. Continued lowering of sea level caused streams to erode into the gravel and the underlying Cohansey Formation. During the latest Miocene, Pliocene, and Pleistocene, about 8 million years ago (8 Ma) to 11,000 years ago (11 ka), stream and hillslope sediments were deposited in several stages as valleys were progressively deepened by stream incision, and widened by seepage erosion, in step with lowering sea level. During at least two interglacial periods in the middle and late Pleistocene, when sea level was higher than at present, marine and estuarine sediments were laid down in terraces that parallel the modern shoreline. Most recently, salt-marsh and estuarine deposits were laid down during Holocene sea-level rise.

A brief summary of the stratigraphy and depositional settings of the Kirkwood and Cohansey formations, and of the geomorphic history of the map area, follows. The age of the deposits and episodes of valley erosion are shown on the correlation chart. Lithologic logs of four test borings drilled for this study (West Creek 1 through 4) are in table 1. Table 2 (in pamphlet) lists the formations penetrated in selected wells and test borings, as interpreted from drillers' lithologic descriptions and downhole geophysical logs.

The sections show sediments to a depth of 500 to 700 feet (elevation -600 feet), which includes the Cohansey Formation, the Kirkwood Formation, and part of the Oligocene section. This depth includes water-producing sands in the Cohansey Formation, which supply most domestic wells and three public-supply wells (wells 2, 3, and 133 in table 2) in the map area, an aquifer sand in the Kirkwood Formation which supplies six public-supply wells (wells 90, 93, 125, 127, 132, and 146), and an aquifer sand in the Sewell Point Formation which is tapped by one public-supply well (well 91). Formations below an elevation of -600 feet are described in Owens and others (1998).

KIRKWOOD FORMATION

The Kirkwood Formation in the northeastern part of the quadrangle consists of six marine-delta and shallow-shelf units as penetrated in the Island Beach corehole (Miller and others, 1994). This corehole is located on the Island Beach barrier spit, about 12 miles northeast of Manahawkin. These units can be traced from geophysical well logs onto the mainland in the Forked River quadrangle, northeast of the West Creek quadrangle (Stanford, 2013), and into the northeast corner of the West Creek quadrangle (see tielines on sections BB' and CC'). The uppermost Kirkwood unit in the corehole (unit 1 of Miller and others, 1994) is an interbedded clay and sand that lacks definitive age control and is here placed in the Cohansey Formation, based on the elevation of the Cohansey-Kirkwood contact in mainland wells (between -90 and -130 feet) and its lithologic similarity to the Cohansey. Unit 2 in the corehole is a uniform gray to grayish-brown marine clay. It is as much as 40 feet thick and marks the top of the Kirkwood as picked from well logs, where the transition from interbedded, generally oxidized, medium-to-coarse sand and thin clay in the Cohansey to gray, fine sand and thicker clay in the Kirkwood is taken as the contact. Diatoms in this unit in the Island Beach corehole indicate a late early Miocene age (18-17 Ma) (Miller and others, 1994), corresponding to the Kirkwood 2 sequence of Sugarman and others (1993), or the Wildwood Member of Owens and others (1998). Unit 3 is medium-to-coarse sand with minor thin clay beds, as much as 100 feet thick. Gamma logs show a clay-over-sand unit (unit 3a on sections) as much as 40 feet thick below the unit 3 sand, although it was not described in the Island Beach corehole. Unit 4 is gray clay with a few thin sand beds and is 20 to 30 feet thick. Unit 5 is sand with a 10- to 15-foot-thick clayey bed in the middle. The total thickness of unit 5 is about 70 feet in the northeastern part of the map. Unit 5 is an aquifer and may correlate to the lower sand aquifer (the 800-foot sand) at Atlantic City (Miller and others, 1994; Sugarman and others, 2013). Unit 6 is silty clay to sandy silt and is about 50 feet thick. In the Island Beach corehole, unit 6 contains shells yielding a strontium stable-isotope ratio age of 21.8 Ma (Miller and others, 1994), placing the clay within the Kirkwood 1 sequence of Sugarman and others (1993), or the lower member of Owens and others (1998). The boundary between the Kirkwood 1 and 2 sequences may be at the base of the unit 4 clay (Miller and others, 1994).

Gamma logs of wells 146 and 132 in the southwestern corner of the quadrangle (section AA') show that units 2, 3, and 4 do not extend into that part of the map area. Instead, they are replaced by gray silty clay about 180 feet thick. This clay overlies aquifer sand that is 110 feet thick. Like the unit 5 sand in the northeastern part of the quadrangle, the sand here includes a 10- to 20-foot-thick clayey bed in the middle and is underlain by gray silty clay. This sand-over-clay sequence likely correlates to units 5 and 6. This stratigraphy is similar to that in the Bass River corehole, about 4 miles southwest of the southwest corner of the quadrangle (Miller and others, 1998). The Kirkwood in this corehole consists of an upper, dominantly clayey section about 200 feet thick over 160 feet of sand over basal clay about 60 feet thick. The basal clay contains shells yielding a strontium stable-isotope ratio age of 20-21 Ma. The sand and basal clay in the Bass River corehole, like units 5 and 6 in the Island Beach corehole, are placed within the Kirkwood 1 sequence. The uppermost clay is placed in the Kirkwood 2 sequence.

COHANSEY FORMATION

The Cohansey Formation consists of stacked successions composed of beach and shoreface sand overlain by interbedded sand and clay deposited in tidal flats, bays, and coastal swamps (Carter, 1972, 1978). Pollen and dinoflagellates recovered from peat beds in the Cohansey at Legler, about 25 miles north of Manahawkin, indicate a coastal swamp-tidal marsh environment (Rachele, 1976). The Legler pollen (Greller and Rachele, 1983), pollen recovered from a corehole near Mays Landing, New Jersey (Owens and others, 1988), and dinocysts obtained from coreholes in Cape May County, New Jersey (deVerteuil, 1997; Miller and others, 2001), indicate a middle to early-late Miocene age for the Cohansey. The Cohansey generally lacks datable marine fossils, particularly in updip areas where it has been weathered. Lower parts of the Cohansey in updip settings like those in the map area may be age-equivalent to the upper Kirkwood downdip (for example, Kirkwood sequence 2, about 17-15 Ma, and sequence 3, 12-14 Ma) and may represent the coastal facies of the Kirkwood shallow-shelf deposits. This relationship is illustrated by the dip of the Cohansey-Kirkwood contact, which is gentler than the dip of the Kirkwood units and the Cohansey clays (section BB'), suggesting that the formation contact is a facies change rather than an unconformity.

In the map area, clays in the Cohansey are in thin beds or laminas generally less than 6 inches thick, and are interbedded with sand. In outcrop they commonly are oxidized and multicolored but, in the subsurface, dark organic clays are reported in a few drillers' logs (abbreviated as "Tchco" in table 2). They were also sampled in test borings West Creek 2 and West Creek 3 (table 1), and in a hand-auger hole in the Westecunk Creek valley (labeled "Tchco" on map). Clay strata are generally less than 35 feet thick. In outcrop, some are traceable for as much as two miles, and, in the subsurface, some beds are continuous for as much as five miles. The two subsurface clays in the northeast area of the quadrangle (sections CC', BB') are likely continuous with clays at similar elevation mapped in the adjoining Forked River and Brookville quadrangles (Stanford, 2011, 2013), indicating continuity over distances of 8 to 10 miles. The laminated bedding and thin but areally extensive shape of the clayey beds indicate that they were deposited in bays or estuaries. Alluvial clays generally are thicker and more areally restricted because they are deposited in floodplains and abandoned river channels. The repetitive stacking of bay clays and beach sand (chiefly tidal delta and shoreface deposits) indicates that the Cohansey was deposited during several rises and falls of sea level during a period of overall rising sea level.

SURFICIAL DEPOSITS AND GEOMORPHIC HISTORY

Sea level in the New Jersey region began a long-term decline following deposition of the Cohansey Formation. As sea level lowered, the inner continental shelf emerged as a coastal plain. River drainage was established on this plain. The Beacon Hill Gravel, which caps the highest elevations in the Coastal Plain, is the earliest record of this drainage. It is absent in the map area but occurs at elevations above 165 to 180 feet to the north and west of the map area in the Brookville and Woodmansie quadrangles, and likely extended into the map area before being eroded in the late Miocene. The Beacon Hill consists of quartz-chert gravel deposited by rivers draining southward from the Valley and Ridge province in northwestern New Jersey and southern New York (Stanford, 2009). In the Beacon Hill, and in upland gravels reworked from the Beacon Hill, rare chert pebbles containing coral, brachiopod, and pelecypod fossils of Devonian age indicate that some of these rivers drained from north of what is now Kittatinny and Shawangunk Mountains, where chert-bearing Devonian rocks crop out.

Continued decline of sea level through the late Miocene and early Pliocene (approximately 8 to 3 Ma) caused the regional river system to erode into the Beacon Hill plain. As it did, it shifted well to the west of the map area into what is now the Delaware River basin. The map area became an upland from which local streams drained eastward to the Atlantic Ocean. These local streams eroded shallow valleys into the Beacon Hill Gravel. Groundwater seepage, slope erosion, and channel erosion reworked the gravel and deposited it in floodplains, channels, and pediments, 40 to 60 feet below the level of the former Beacon Hill plain. These deposits are mapped as Upland Gravel, High Phase (unit Tg). Today, owing to topographic inversion, they cap ridgetops above an elevation of between 110 and 140 feet in the northern part of the quadrangle. Orange arrows on figure 1 show drainage routes of streams at this time, as inferred from the location and elevation of the ridgetop deposits.

A renewed period of lowering sea level in the late Pliocene and early Pleistocene (approximately 2 Ma to 800 ka) led to another period of valley incision. Groundwater seepage and channel and slope erosion reworked the Upland Gravel, High Phase and deposited the Upland Gravel, Lower Phase (unit TQg) in shallow valleys 20 to 50 feet below the higher gravels. These deposits today cap interfluves and form more extensive mantles in head-of-valley areas and upper slopes. Stream drainage at this time, inferred from interfluve deposits, is shown by green arrows on figure 1.

Continuing incision in the middle and late Pleistocene (about 800 to 20 ka) formed the modern valley network. Fluvial sediments laid down in modern valleys include Upper and Lower Terrace Deposits (units Qtu and Qtl), inactive floodplain deposits in dry valleys (unit Qald), and active floodplain and wetland (Qals) deposits in valley bottoms. Like the upland gravels, the terrace and floodplain deposits indicate erosion, transport, and redeposition of sand and gravel reworked from older surficial deposits and the Cohansey Formation by streams, groundwater seepage, and slope processes. Wetland deposits are formed by accumulation of organic matter in swamps and bogs.

Stream incision and seepage were enhanced in the headwaters and upper reaches of the Westecunk Creek and Mill Creek basins because these basins gain groundwater from the Oswego River basin in the northwest corner of the map area (the topographic basin divide is shown on fig. 1). Long-term basin-wide recharge, based on 60 years of streamflow data, is 25 inches for the Mill Creek basin, 28 inches for the Westecunk Creek basin, and 14 inches for the Oswego River basin (Gordon, 2004). The larger recharge in the Mill and Westecunk basins indicates diversion of groundwater from the Oswego basin. This diversion is due in part to the steeper topographic gradient of the upper reaches of Mill and Westecunk creeks, and to southeastward movement of groundwater above clay beds within the Cohansey Formation beneath the topographic basin divide (section AA'). Groundwater diversion is also documented by 1) capture of Dry Brook headwaters by Mill Creek just north of the quadrangle boundary (Stanford, 2011), and 2) recharge rates in the Oyster Creek, Forked River, and Cedar Creek basins, which, like the Westecunk and Mill Creek basins, lie east of the Oswego basin in the Brookville quadrangle (Gordon, 2004; Stanford, 2011).

Upper Terrace Deposits form terraces and pediments 5 to 25 feet above modern wetlands. They were laid down chiefly during periods of cold climate in the middle Pleistocene. During cold periods, permafrost impeded infiltration of rainfall and snowmelt and this, in turn, accelerated groundwater seepage and slope erosion. Seepage and slope erosion washed sediment into valleys, leading to deposition of what are now terraces. Some of the deposits may have been laid down during periods of temperate climate when sea level was high, because at their seaward limit the upper terraces grade to the Cape May 2 marine terrace (see below). This topographic equivalence indicates that some of the upper terrace deposits aggraded during the Cape May 2 highstand. In a few places, for example, along Mill Branch in the southwest corner of the quadrangle, the upper terrace is slightly inset into the marine terrace, indicating that it is somewhat younger than the Cape May 2 highstand in those locations.

Lower Terrace Deposits (unit Qtl) form low terraces with surfaces less than 10 feet above modern valley bottoms. They are most prominent where Westecunk Creek, Cedar Run, and Mill Creek discharge to the bayshore lowland. In these locations, the lower terrace deposits spread out as broad, gently sloping fans onto the Cape May marine platform. Inland from the bayshore, the lower terraces are discontinuous and of much smaller extent than the upper terraces. They formed from stream and seepage erosion of the upper terrace deposits and Cape May Formation (see below), probably during or slightly after the last period of cold climate above 20,000 radiocarbon years ago (20 ka). Dry-valley alluvium (unit Qald) was likely also laid down at this time. Northeast of Manahawkin, in the Ship Bottom quadrangle, sand and gravel of one of the fan-like lower terrace deposits on the Cape May platform overlie an organic silt dated to 34,890±960 radiocarbon years BP (GX-16789-AMS, Newell and others, 1995), indicating that the fan here was deposited after 35 ka. Plant fibers from an organic silt beneath 4 feet of pebbly sand on a fan-like lower terrace on the Cape May platform near Staffordville (shown on map) dated to 13,920±40 radiocarbon years BP (17,015-16,760 calibrated years) (Beta 384710), indicating that the overlying pebbly sand was deposited after about 14 ka. The 35 ka to post-14 ka age range of the lower terraces indicates that they were laid down during the late Wisconsinan cold period, before the return of temperate forest stabilized slopes and reduced erosion. After permafrost melted and slopes stabilized, the amount of sediment washing into streams was sharply reduced. Streams downcut slightly (5 to 10 feet) into the lower terraces, and then stream and seepage erosion eroded laterally to form floodplains. Modern floodplain and wetland deposits (unit Qals) were laid down within the past 10 ka, based on radiocarbon dates on basal peat in other alluvial wetlands in the region (Buell, 1970; Florer, 1972; Stanford, 2000), indicating that incision of the lower terraces took place between about 14 ka and 10 ka.

Eolian deposits (Qe) include windblown sand forming dunes on the uplands between Rail Branch, Log Swamp Branch, and Governors Branch, west of Westecunk Creek; an area of dunes on the east side of Eightmile Branch in the Mill Creek valley; and two small areas of dunes on the Cape May marine platform east of Spraguetown. The Spraguetown dunes and several of the Westecunk dunes are bordered to the west and north by deflation basins. The Westecunk dunes are generally elongate in the east-west direction. The dunes are atop, and so are younger than, the Cape May 2 marine platform, the upper terrace deposits, the Cape May 1 marine terrace, and the upland gravel, lower phase. The form and landscape position of the eolian deposits indicate that they were deposited by winds blowing from the west and northwest during the Wisconsinan glacial stage; and, for dunes atop the Cape May 1 terrace and the upland gravel, possibly during earlier glacial stages.

During at least two periods of higher-than-present sea level in the middle and late Pleistocene, beach and estuarine deposits were laid down in terraces along the bayshore and in the lower reaches of main valleys (fig. 1). These marine deposits are grouped into the Cape May Formation. The Cape May includes an older, eroded terrace (Cape May Formation, unit 1, Qcm1) having a maximum surface elevation of 70 feet; a younger, less eroded terrace having a maximum surface elevation of 35 feet (Cape May Formation, unit 2, Qcm2); a platform deposit that slopes gently seaward from the foot of the Cape May 2 terrace (Qcm2p); and clay, silt, and fine sand in the subsurface beneath the platform and lower terrace deposits (Qcm2f, section BB').

Amino-acid racemization ratios (AAR), optically stimulated luminescence ages, and radiocarbon dates from the Delaware Bay area (Newell and others, 1995; Lacovara, 1997; O'Neal and others, 2000; O'Neal and Dunn, 2003; Sugarman and others, 2007) suggest that the Cape May 1 is of middle Pleistocene age (possibly oxygen-isotope stage 11, 420 ka, or stage 9, 330 ka, or older) and that the Cape May 2 is of Sangamonian age (stage 5, 125-80 ka). AAR data from vibracores off Long Beach Island east of the quadrangle indicate that the Cape May correlate there is of Sangamon age (Uptegrove and others, 2012).

Modern bay and salt-marsh deposits were laid down during Holocene sea-level rise, chiefly within the past 7 ka in the map area. As sea level rose, salt-marsh peat and fine-grained bay deposits (Qm) were deposited on the submerging Cape May platform. Freshwater wetland deposits (Qs) aggraded on the platform directly inland from the salt marsh, where groundwater discharge kept the land surface saturated. Groundwater discharge was most active, and the wetland deposits thickest and most continuous, along the bayshore between Mayetta and Spraguetown, where the Cape May 2 terrace is narrow and backed by extensive upland. The upland provides hydraulic head in the Cohansey and Cape May sand to feed the discharge. On valley bottoms inland from the bayshore, sand and gravel stream-channel deposits and peat (Qals) were laid down in floodplains and wetlands as the water table rose in step with rising sea level at the downstream end of the valleys.

DESCRIPTION OF MAP UNITS

afl ARTIFICIAL FILL—Sand, pebble gravel, minor clay and organic matter; gray, brown, very pale brown, white. In places includes man-made materials such as concrete, asphalt, brick, cinders, and glass. Unstratified to poorly stratified. As much as 15 feet thick. In road and railroad embankments, dams, dikes, infilled pits, filled wetlands, and land made from dredged material in bayfront residential developments.

afd DREDGE SPOIL—Sand, silt, minor clay, gravel, and organic matter; gray to brown. As much as 10 feet thick (estimated). In diked impoundments, from dredging of channels.

aft TRASH FILL—Trash mixed and covered with silt, clay, sand, and minor gravel. As much as 40 feet thick.

Qals WETLAND AND ALLUVIAL DEPOSITS—Fine-to-medium sand and pebble gravel, minor coarse sand; light gray, yellowish-brown, brown, dark brown; overlain by brown to black peat and gyttja. Peat is as much as 10 feet thick. Sand and gravel consist chiefly of quartz and are generally less than 3 feet thick. Sand and gravel are stream-channel deposits; peat and gyttja form from the vertical accumulation and decomposition of plant debris in swamps and marshes. In alluvial wetlands on modern valley bottoms.

Qm SALT-MARSH AND ESTUARINE DEPOSITS—Peat, clay, silt, fine sand; brown, dark brown, gray, black; minor medium-to-coarse sand and pebble gravel. Contains abundant organic matter and shells. As much as 40 feet thick. Deposited in salt marshes, tidal flats, and bays during Holocene sea-level rise.

Qs FRESHWATER SWAMP AND MARSH DEPOSITS—Peat and gyttja, black to dark brown, with wood in places. As much as 8 feet thick (Waksman and others, 1943). Deposited in areas of groundwater seepage on the Cape May 2 platform along the bayshore.

Qald DRY-VALLEY ALLUVIUM—Fine-to-medium sand and pebble gravel, minor coarse sand; very pale brown, white, brown, dark brown, light gray. As much as 5 feet thick. Sand and gravel consist of quartz. In dry valley bottoms forming headwater reaches of streams. These valleys lack channels or other signs of surface-water flow. They may have formed during periods of cold climate when permafrost impeded infiltration, increasing surface runoff. The deposits are therefore largely relict.

Qe EOLIAN DEPOSITS—Fine-to-medium quartz sand; very pale brown, white. As much as 20 feet thick. Form dunes on the upper terrace and the Cape May terraces.

Qtl LOWER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; light gray, very pale brown, brown, dark brown. As much as 15 feet thick. Sand and gravel consist of quartz and a trace (<1%) of chert in places. Form terraces and pediments in valley bottoms with surfaces 2 to 10 feet above modern wetlands, and broad fans spread onto the Cape May platform along the bayshore. Include both stratified stream deposits and unstratified pebble concentrates formed by seepage erosion of older surficial deposits. Gravel generally is more abundant in lower terrace deposits than in upper terrace deposits and the Cape May Formation due to removal of sand from the older deposits by seepage erosion.

Qtu UPPER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; very pale brown, brownish-yellow, yellow. As much as 30 feet thick. Sand and gravel consist of quartz and a trace of chert in places. Form terraces and pediments with surfaces 5 to 25 feet above modern wetlands. Include stratified stream-channel deposits and poorly stratified to unstratified deposits laid down by groundwater seepage on pediments.

CAPE MAY FORMATION—Beach, nearshore, and estuarine deposits of middle and late Pleistocene age. Includes marine-terrace sand and gravel (Qcm1, Qcm2), platform sand (Qcm2p), and bay and estuarine clay, silt, and fine sand (Qcm2f).

Qcm1 CAPE MAY FORMATION, UNIT 1—Fine-to-medium sand, pebble gravel, minor clayey sand to sandy clay, and coarse sand; yellowish-brown, yellow, reddish-yellow, very pale brown. As much as 35 feet thick. Sand and gravel consist of quartz and a trace to few (<5%) white and yellow weathered chert. Forms eroded terraces with a maximum surface elevation of 70 feet.

Qcm2 CAPE MAY FORMATION, UNIT 2—Fine-to-medium sand, pebble gravel, minor coarse sand; yellow, very pale brown, yellowish-brown. Sand and gravel consist of quartz and a trace of chert. As much as 20 feet thick. Forms terrace with a maximum surface elevation of 40 feet.

Qcm2p CAPE MAY FORMATION, UNIT 2, PLATFORM DEPOSIT—Fine-to-medium sand, with pebbles in places, minor clayey sand to sandy clay; very pale brown, light gray, yellowish-brown. As much as 40 feet thick. Forms a platform that slopes gently bayward from the foot of the Cape May 2 terrace, and extends beneath Holocene salt-marsh and estuarine deposits to the inner shelf. Includes beach and shoreface deposits laid down during sea-level decline from the Cape May 2 highstand. Groundwater seepage is common across the platform outcrop, facilitating accumulation of organic deposits in low areas. Where continuous and more than 3 feet thick, these seepage deposits are mapped as unit Qs; elsewhere they are patchy and not mapped separately from unit Qcm2p.

Qcm2f CAPE MAY FORMATION, UNIT 2, FINE-GRAINED DEPOSITS—Clay, silt, fine sand, minor organic matter; light gray to gray. As much as 40 feet thick. In subsurface only, inferred from well records (section BB'). Deposited in a bay during sea-level rise to, and decline from, the Cape May 2 highstand.

TQg UPLAND GRAVEL, LOWER PHASE—Fine-to-medium sand, clayey in places, and pebble gravel; minor coarse sand; yellow, very pale brown, reddish-yellow. Sand and gravel consist of quartz and a few white, yellow, and brown weathered and decomposed cherts in the coarse sand-to-pebble gravel fraction. Clay is chiefly from weathering of chert. As much as 30 feet thick, but generally less than 10 feet thick. Occurs as erosional remnants on interfluves, and as more continuous deposits in headwater valleys. Maximum elevation of the top of the deposit declines from 140 feet in the northwest corner of the quadrangle, on the divide between the Oswego River and Mill and Westecunk creeks, to 80 feet on the upland back of the Cape May 2 terrace along the bayshore. Elevation of the base of the deposit declines from 120 feet to about 60 feet over the same distance. Includes stratified and cross-bedded stream deposits (fig. 2), poorly stratified deposits laid down by groundwater seepage on pediments (fig. 3), and pebble concentrates formed by winnowing of sand from older surficial deposits and the Cohansey Formation by groundwater sapping or surface runoff.

Tg UPLAND GRAVEL, HIGH PHASE—Fine-to-medium sand, some coarse sand, clayey in places, and pebble gravel; yellow, brownish-yellow, reddish-yellow, very pale brown, rarely red. Sand and gravel consist of quartz, and as much as 5% chert, and traces of weathered feldspar, in the coarse sand-to-fine pebble gravel fraction. Most chert is weathered to white and yellow clay, some chert pebbles are gray to dark gray and unweathered to partially weathered. Clay-size material chiefly is from weathering of chert and feldspar. As much as 25 feet thick. Occurs as erosional remnants on ridgetops and hilltops. Elevation of base of the deposit declines from 140 feet in the northwest corner of the quadrangle, on the divide between the Oswego River and Mill and Westecunk creeks, to 110 feet north of Stafford Forge, at the southernmost erosional remnant. Includes stratified and cross-bedded stream deposits and poorly stratified to unstratified pebble concentrates formed by washing of sand and clay by groundwater sapping or surface runoff.

COHANSEY FORMATION—Fine-to-medium quartz sand, with some strata of medium-to-very coarse sand, very fine sand, and interbedded clay and sand, deposited in estuarine, bay, beach, and inner shelf settings. The Cohansey is here divided into two map units: a sand facies and a clay-sand facies, based on gamma-ray well logs and surface mapping using 5-foot hand-auger holes, exposures, and excavations. Total thickness of the Cohansey in the map area is as much as 280 feet.

Tchs Sand Facies—Fine-to-medium sand, some medium-to-coarse sand, minor very fine sand, minor very coarse sand to very fine pebbles, trace of fine-to-medium pebbles; very pale brown, brownish-yellow, white, reddish-yellow, rarely reddish-brown, red, and light red. Well-stratified to unstratified; stratification ranges from thin, planar, subhorizontal beds (fig. 3) to large-scale trough and planar cross-bedding. Sand consists of quartz; coarse-to-very coarse sand may include as much as 5% weathered chert and a trace of weathered feldspar. Coarse-to-very coarse sands (fig. 4) commonly are slightly clayey; the clays occur as grain coatings or as interstitial infill. This clay-size material is from weathering of chert and feldspar rather than from primary deposition. Pebbles are chiefly quartz with minor gray chert and rare gray quartzite. Pebbles commonly are subangular. Some chert pebbles are light gray, partially weathered, pitted, and partially decomposed; some are fully weathered to white clay. In a few places, typically above clayey strata, sand may be hardened or cemented by iron oxide, forming reddish-brown hard sands or ironstone masses. Locally, sand facies includes isolated lenses of interbedded clay and sand like those within the clay-sand facies described below. The sand facies is as much as 100 feet thick.

Tchc Clay-Sand Facies—Clay interbedded with clayey fine sand, very fine-to-fine sand, fine-to-medium sand, less commonly with medium-to-coarse sand and pebble lags. Clay beds are commonly 0.5 to 3 inches thick, rarely as much as 2 feet thick; sand beds are commonly 1 to 6 inches thick but are as much as 2 feet thick (fig. 5). Clays are white, yellow, very pale brown, reddish-yellow, light gray; sands are yellow, brownish-yellow, very pale brown, reddish-yellow. Rarely, clays are black, dark gray, and dark brown and contain organic matter. As much as 35 feet thick.

Tkw KIRKWOOD FORMATION—Fine sand, fine-to-medium sand, sandy clay, and clay, minor medium-to-coarse sand; gray, dark gray, brown. Sand consists of quartz and some mica and lignite. In subsurface only. Approximately 250 feet thick in northeastern part of the quadrangle, thickens to about 400 feet in southwest part of quadrangle, based on the thickness of Kirkwood penetrated in the Bass River corehole (Miller and others, 1998). In the northeast part of the quadrangle the Kirkwood consists of five clay-sand units traceable on gamma logs and described in the Island Beach corehole (Miller and others, 1994) (see discussion above). These units are shown by tielines on sections BB' and CC'. In the southwest, the Kirkwood consists of an upper fine-grained unit about 180 feet thick, over sand about 110 feet thick, over a basal clay more than 30 feet thick (section AA').

Tac ATLANTIC CITY FORMATION—Clay with minor sand; glauconitic, micaceous; gray to olive; with shells and lignite. In subsurface only. As much as 90 feet thick. Assigned to Atlantic City Formation of Pekar and others (1997) based on the presence of this formation in the Island Beach and Bass River coreholes (Miller and others, 1994, 1998). Of Oligocene age, based on strontium stable-isotope ratios (Miller and others, 1994, 1998; Pekar and others, 1997).

Tsp SEWELL POINT FORMATION—Fine-to-coarse glauconitic sand and minor clay; olive green, olive, gray; with some shells. In subsurface only. As much as 100 feet thick. Assigned to Sewell Point Formation based on the presence of this formation in the Island Beach corehole (Pekar and others, 1997). Of Oligocene age, based on planktonic foraminifera and strontium stable-isotope ratios (Pekar and others, 1997).

MAP SYMBOLS

Contact of surficial deposits—Solid where well-defined by landforms as visible on 1:12,000 stereo airphotos and LiDAR imagery, long-dashed where approximately located, short-dashed where gradational or featheredged, dotted where excavated. Some contacts of units Qtu and Qcm1 are based on LiDAR imagery.

Contact of Cohansey facies—Approximately located. Dotted where covered by surficial deposits.

(Tchc) Cohansey facies—Covered by surficial deposits.

4; Qe7/Qtu Material penetrated by hand-auger hole, or observed in exposure or excavation. Number indicates thickness of surficial material, in feet, where penetrated. Symbols within surficial deposits without a thickness value indicate that surficial material is more than 5 feet thick. Where more than one unit was penetrated, the thickness (in feet) of the upper unit is indicated next to its symbol and the lower unit is indicated following the slash. Open circle indicates data from N. J. Geological Survey archive.

West Creek 3 Test boring—Log in table 1.

47 Well or test boring showing formations penetrated—Location accurate to within 200 feet. List of formations penetrated provided in table 2.

145 Well or test boring showing formations penetrated—Location accurate to within 500 feet. List of formations penetrated provided in table 2.

13920+/-30 (Beta 384710) Radiocarbon date—Age in radiocarbon years, with error and lab number.

47 Gamma-ray log—On sections. Radiation intensity increases to right.

Seepage scarp—Line at top of scarp, ticks on slope. At head of small valleys and hillslope embayments formed by seepage erosion.

Active seepage—Line at position of groundwater emergence, seepage drains downslope from this position.

Dry valley—Line in bottom of narrow, incised, dry stream channel. These channels have little to no active drainage and were likely formed during cold climate in the late Pleistocene when the water table was higher than at present. Mapped from LiDAR imagery.

Shallow topographic basin—Line at rim, pattern in basin. Includes thermokarst basins formed from melting of permafrost and a few deflation basins, bordered by eolian deposits, formed from wind erosion.

Paleocurrent direction—Arrow indicates direction of streamflow inferred from dip of planar, tabular cross beds, observed at point marked by "x".

Iron-cemented sand—Extensive iron cementation or hardening in upper several feet of mapped formation.

Excavation perimeter—Line encloses excavated area.

Sand pit—Active in 2014.

Sand pit—Inactive in 2014.

c Clay pit—Inactive in 2014, perimeter approximate.

figure 4 Photograph location.

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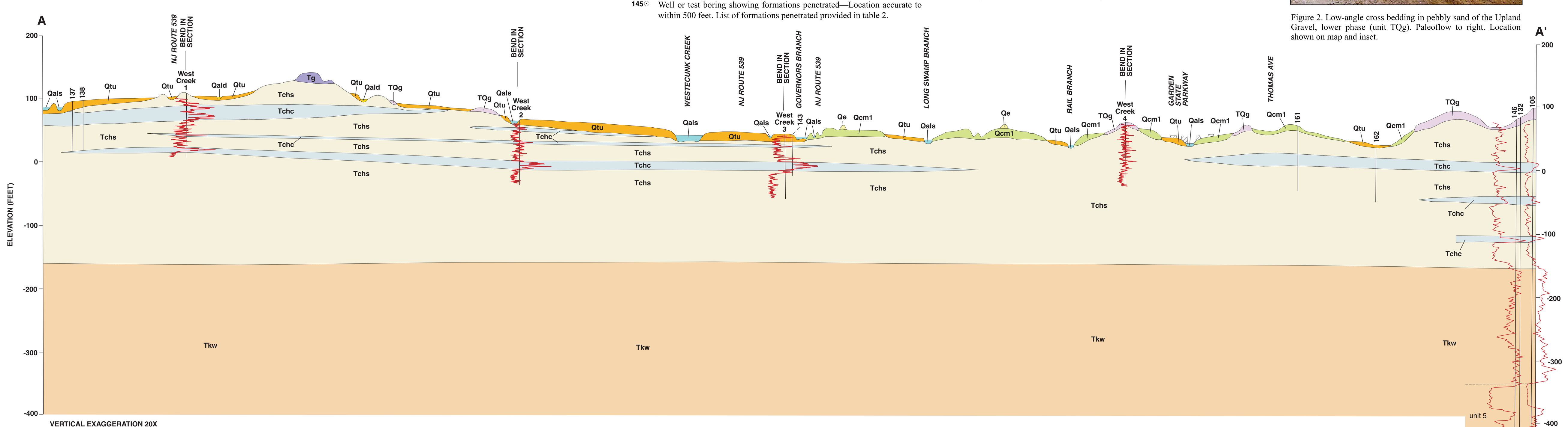
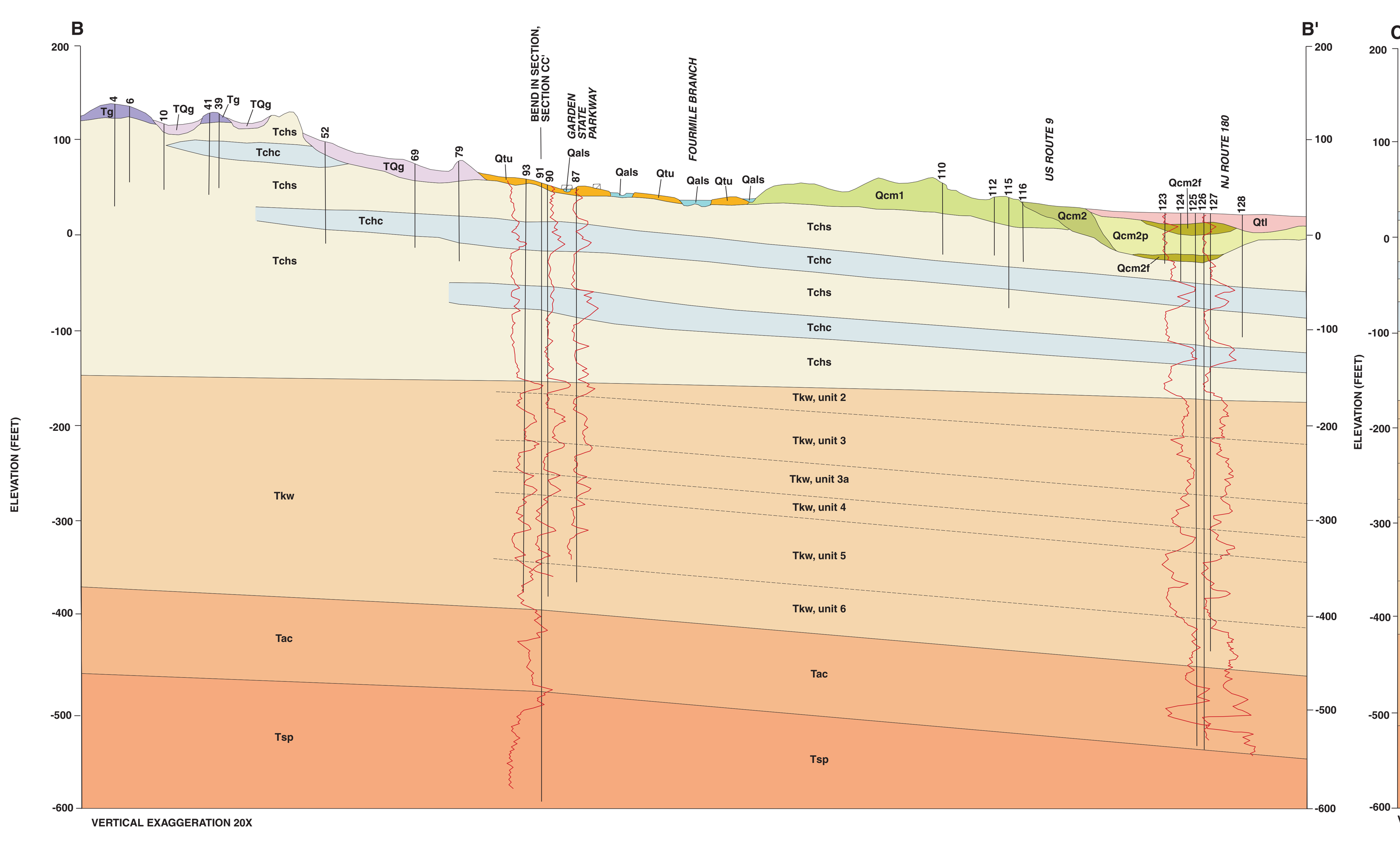
Table 1.—Lithologic logs of test borings. Gamma-ray logs provided on section AA'.

N. J. permit number and identifier	Lithologic log: Depth (feet below land surface)	Lithologic log: Description (map unit assignment in parentheses) Color names from Munsell Soil Color Charts, 1975
E201403507 West Creek 1	0-10	fine-to-medium sand, strong brown to brownish-yellow, with a few quartz pebbles (Tchs)
	10-18	fine sand, fine-to-medium sand, brownish-yellow (Tchs)
	18-36	fine sand, brownish-yellow to yellow, interbedded with white to very pale brown clay (Tchc)
	36-83	fine sand, brownish-yellow, yellow; slightly clayey (Tchs); gamma log shows clay bed from 61-63 (Tchc)
	83-87	fine sand, brownish-yellow to yellow, interbedded with white to very pale brown clay (Tchc)
	87-104	fine-to-medium sand, brownish-yellow to yellow (Tchs)
E201403508 West Creek 2	0-10	medium-to-coarse sand, brown to brownish-yellow, with a few quartz pebbles (Qtu)
	10-30	medium-to-coarse sand, brownish-yellow to light yellowish-brown (Tchs); gamma log shows clay bed from 11-15 (Tchc)
	30-83	medium sand, yellowish-red to strong brown, some coarse sand and angular to subangular fine quartz pebbles (Tchs); gamma log shows clay bed from 61-63
	83-87	clay, black, dark gray, white, yellow (Tchc and Tchco)
	87-104	fine-to-medium sand, yellowish-red (Tchs)
E201403510 West Creek 3	0-10	fine-to-medium sand, brown to brownish-yellow, with a few quartz pebbles (Qtu)
	10-42	fine sand, fine-to-medium sand, yellow to brownish-yellow (Tchs); laminas of white clay from 17-19 and 35-38 (Tchc)
	42-54	clay, black, gray, white, yellow; laminas of fine, very dark brown organic matter (Tchc and Tchco)
	54-104	medium sand, fine-to-medium sand, yellow (Tchs)
E201403512 West Creek 4	0-10	medium sand, fine-to-medium sand, brownish-yellow, reddish-yellow, with a few quartz pebbles (TQg)
	10-75	medium sand, medium-to-coarse sand, reddish-yellow, strong brown, yellow, with a few quartz pebbles (Tchs)
	75-104	fine sand, fine-to-medium sand, yellow (Tchs)





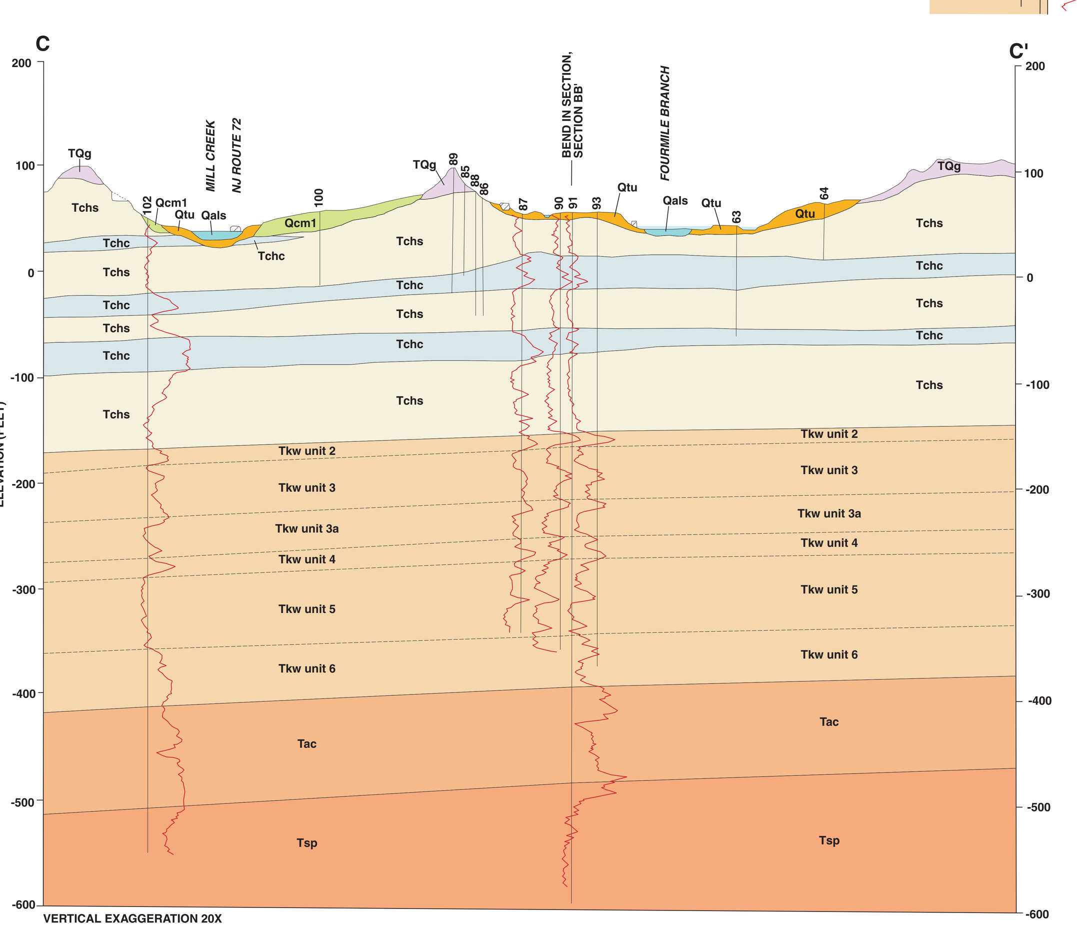
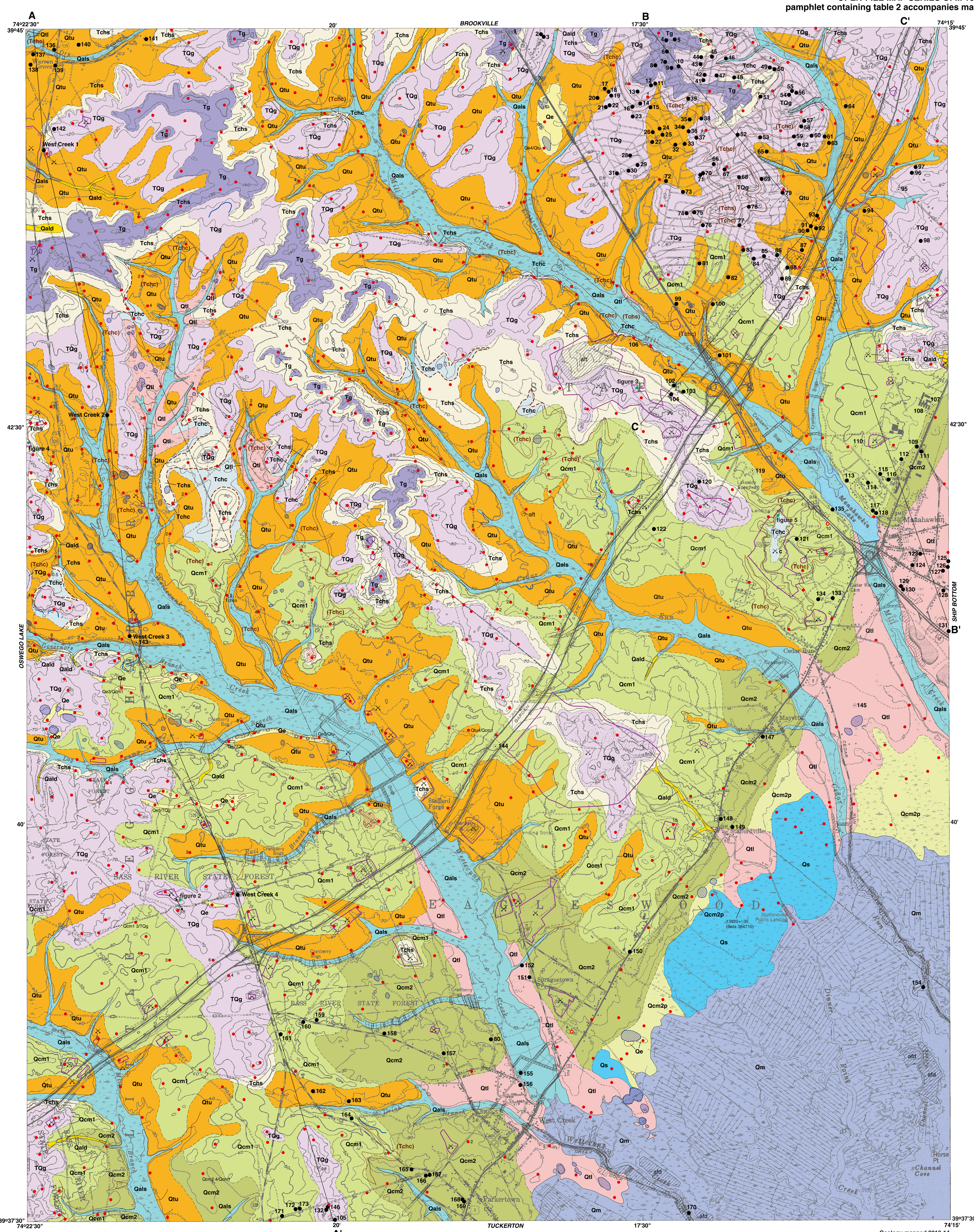


Figure 2. Low-angle cross bedding in pebbly sand of the Upland Gravel, lower phase (unit TQg). Paleoflow to right. Location shown on map and inset.



Base from U. S. Geological Survey, 1951
Photorevised 1972
Corner ticks on North American Datum of 1927

Geology mapped 2013-14
Drilling by G. Steidl, B. Buttari, and J. Curran
Drilling assistance by I. Snook
Geophysical logging by M. Gagliano and M. Kuhn
Cartography by S. Stanford

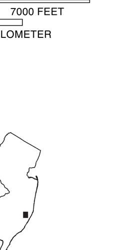
GEOLOGY OF THE WEST CREEK QUADRANGLE
OCEAN COUNTY, NEW JERSEY

by
Scott D. Stanford
2014

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

APPROXIMATE MEAN DECLINATION, 1972



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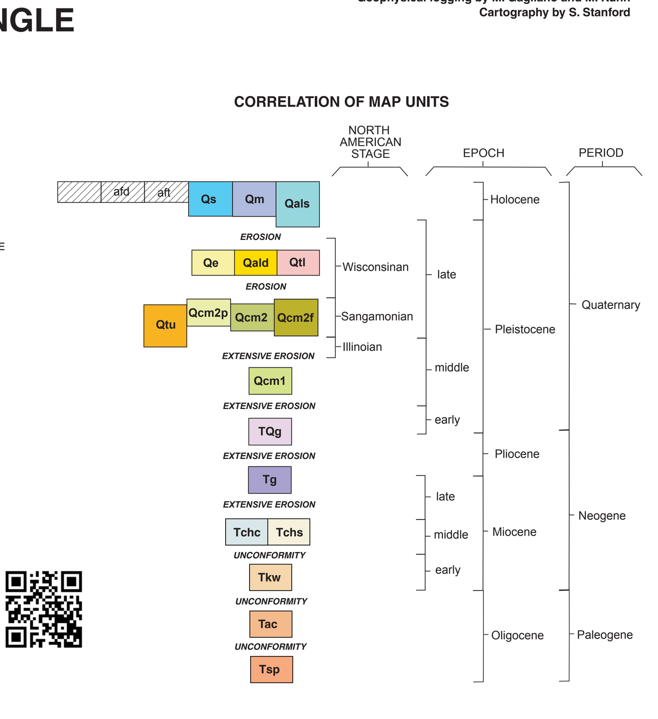
CORRELATION OF MAP UNITS



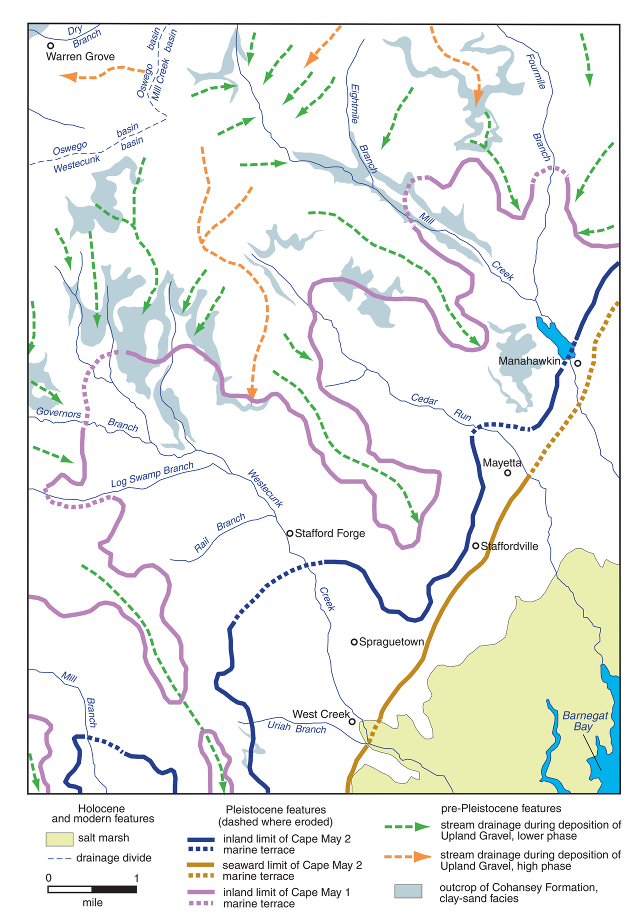


Figure 1.--Geomorphic features, modern drainage, and outcrop of clay-sand facies of the Cohansey Formation, in the West Creek quadrangle.

Figure 3. Poorly stratified Upland Gravel, lower phase (TQg) (above shovel head) overlying plane-bedded to low-angle cross bedded sand of the Cohansey Formation, sand facies (Tchs). Location shown on map and inset.

Figure 4. Interbedded coarse sand and fine-to-medium sand of the Cohansey Formation, sand facies (Tchs). Location shown on map and inset.

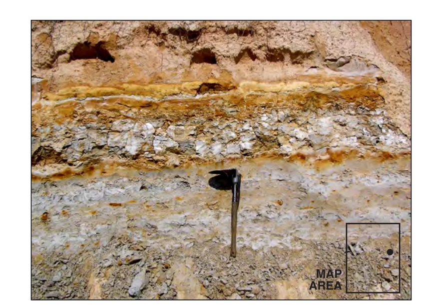


Figure 5. Interbedded clay (gray and white layers) and fine sand (yellow and orange layers) of the Cohansey Formation, clay-sand facies (Tchc). Location shown on map and inset.

Geology of the West Creek Quadrangle
Ocean County, New Jersey

New Jersey Geological and Water Survey
Open-File Map OFM 103
2014

pamphlet with table 2 to accompany map

Table 2. Selected well and boring records.

Well Number	Identifier[1]	Formations Penetrated[2]
1	33-23056	18 Q 24 Tchc 43 Tchs 52 Tchc 70 Tchs
2	33-2009	8 Q 21 Tchs+Tchc 29 Tchs 42 Tchc 60 Tchc+Tchs 62 Tchc 83 Tchc+Tchs 148 Tchs+Tchc
3	33-2010	5 Q 8 Tchs 21 Tchs+Tchc 29 Tchs 30 Tchc 40 Tchs 42 Tchc 60 Tchc+Tchs 62 Tchc 83 Tchc+Tchs 148 Tchs 165 Tchc 200 Tchs
4	33-18933	5 Q 13 Tchs 35 Tchc 45 Tchs 57 Tchs+Tchc 83 Tchs 94 Tchco 109 Tchs
5	33-6271	8 Q 17 Tchs+Tchc 18 Tchc 75 Tchs
6	33-5396	5 Q 70 Tchs 80 Tchc
7	33-5417	11 Q 45 Tchs 46 Tchc 100 Tchs
8	33-17071	8 Q 17 Tchs 37 Tchc 49 Tchs+Tchc 68 Tchs 81 Tchco 95 Tchs+Tchc 125 Tchs
9	33-6265	9 Q 17 Tchs+Tchc 75 Tchs
10	33-10117	11 Q 70 Tchs
11	33-23902	28 Tchs 31 Tchc 44 Tchs 47 Tchc 60 Tchs 66 Tchc 90 Tchs 96 Tchc 140 Tchs 148 Tchc 153 Tchs 155 Tchc 225 Tchs 230 Tchc
12	33-5416	70 Tchs 74 Tchs+Tchc 95 Tchs
13	33-6857	5 Tchs 30 Tchs+Tchc 40 Tchs 55 Tchc 60 Tchs
14	33-25637	20 Tchs+Tchc 40 Tchc 60 Tchs+Tchc 80 Tchs
15	33-27997	18 Tchs 26 Tchc 48 Tchs 52 Tchc 70 Tchs 78 Tchc 83 Tchs 90 Tchc 96 Tchs 102 Tchc 123 Tchs 125 Tchc
16	33-21190	8 Q 15 Tchs 23 Tchc 35 Tchs 47 Tchc 59 Tchs 68 Tchc 85 Tchs 86 Tchc
17	33-17457	10 Q 15 Tchc 41 Tchs 75 Tchc 88 Tchs 95 Tchc 115 Tchs
18	33-5432	25 Tchs 35 Tchc 50 Tchs
19	33-5441	25 Tchs 35 Tchc 50 Tchs
20	33-5364	30 Tchs 40 Tchc 50 Tchs
21	33-19897	7 Q 23 Tchs 42 Tchc 68 Tchs 69 Tchc
22	33-5431	10 Q 20 Tchs+Tchc 35 Tchc 51 Tchs
23	33-5539	5 Tchs 15 Tchs+Tchc 25 Tchc 35 Tchs 45 Tchc 50 Tchs
24	33-27165	19 Tchs 26 Tchc 47 Tchs 50 Tchc 98 Tchs 102 Tchc 125 Tchs 133 Tchc 160 Tchs
25	33-6276	25 Tchs 28 Tchc 52 Tchs 61 Tchc 80 Tchs
26	33-7196	10 Tchs 12 Tchc 63 Tchs
27	33-16967	26 Tchs 38 Tchc+Tchs 55 Tchs 63 Tchc 68 Tchc+Tchs 80 Tchs
28	33-5367	30 Tchs 35 Tchc 50 Tchs
29	33-6465	30 Tchs 40 Tchc 50 Tchs
30	33-7399	5 Tchs 25 Tchc 35 Tchs 40 Tchc 50 Tchs 60 Tchc 61 Tchs
31	33-6635	5 Tchs 10 Tchs+Tchc 40 Tchs 55 Tchc 70 Tchs
32	33-6077	40 Tchs 65 Tchc 79 Tchs 80 Tchc
33	33-7400	25 Tchs 40 Tchc 45 Tchs 65 Tchc 70 Tchs
34	33-6463	10 Q 25 Tchs 35 Tchc 50 Tchs
35	33-6264	4 Q 6 Tchs 8 Tchc 55 Tchs

Well Number	Identifier[1]	Formations Penetrated[2]
36	33-21727	10 Tchs 22 Tchs+Tchc 26 Tchc 80 Tchs
37	33-6830	15 Q 65 Tchs 66 Tchc
38	33-7398	5 Tchs 20 Tchc 65 Tchs
39	33-8833	4 Tchc or Q 10 Tchs or Q 35 Tchc 80 Tchs
40	33-7611	60 Tchs 70 Tchc 90 Tchs
41	33-24986	22 Q 47 Tchs+Tchc 54 Tchc 84 Tchs
42	33-24501	24 Tchs 30 Tchc 44 Tchs 52 Tchc 70 Tchs 115 Tchc 128 Tchco 155 Tchs
43	33-26180	21 Tchs 23 Tchc 52 Tchs 54 Tchc 75 Tchs 90 Tchc 94 Tchs 110 Tchc 114 Tchs 115 Tchc 119 Tchs 120 Tchc 148 Tchs 155 Tchc
44	33-6269	46 Tchs 60 Tchc 70 Tchs
45	33-6140	10 Tchc 55 Tchs
46	33-24581	28 Tchs or Q 35 Tchc 80 Tchs
47	33-28077	23 Tchs 31 Tchc 48 Tchs 51 Tchc 80 Tchs
48	33-17155	8 Q 15 Tchs 31 Tchco 42 Tchs 49 Tchs+Tchc 65 Tchs
49	33-7131	14 Tchs 16 Tchc 57 Tchs
50	33-7133	20 Q or Tchs 30 Tchs 37 Tchc 50 Tchs+Tchc 70 Tchs
51	33-17689	14 Q or Tchs 17 Tchc 47 Tchs 65 Tchs+Tchc 90 Tchs 94 Tchc 110 Tchs
52	33-17889	15 Q 35 Tchc 41 Tchs+Tchc 71 Tchs 79 Tchc 88 Tchco+Tchs 105 Tchs
53	33-27639	15 Tchs 35 Tchc 45 Tchc+Tchs 60 Tchs+Tchc 80 Tchs
54	33-7498	25 Tchs 35 Tchc 50 Tchs 60 Tchs+Tchc 65 Tchc 70 Tchs
55	33-13047	45 Tchs 58 Tchs+Tchc 65 Tchs 70 Tchc
56	33-18048	77 Tchs 83 Tchs+Tchc 92 Tchc 103 Tchco 122 Tchs
57	33-23939	60 Tchs 66 Tchc 80 Tchs+Tchc 90 Tchs
58	33-23478	25 Q or Tchs 45 Tchs 55 Tchc+Tchs 80 Tchs+Tchc 85 Tchs
59	33-23654	6 Tchs+Tchc 8 Tchc 33 Tchs 50 Tchc 83 Tchs 90 Tchco 99 Tchc 122 Tchs 130 Tchco
60	33-26126	15 Tchs 16 Tchc 40 Tchs 44 Tchc 83 Tchs 92 Tchc 100 Tchs 108 Tchc 125 Tchs
61	33-21349	14 Q 21 Tchs 23 Tchc 28 Tchs 32 Tchc 58 Tchs 62 Tchc 70 Tchs 81 Tchc 90 Tchco 94 Tchc 112 Tchs 115 Tchc
62	33-13574	30 Tchs 80 Tchs+Tchc 100 Tchc 120 Tchs
63	33-21708	27 Tchs+Tchc 36 Tchs 60 Tchs+Tchc 69 Tchc 108 Tchs 110 Tchc
64	33-5344	10 Q 25 Tchs 35 Tchc 50 Tchs
65	33-6545	40 Tchs 50 Tchc 55 Tchc+Tchs 70 Tchs
66	3328078	20 Q 29 Tchs 34 Tchc 38 Tchs+Tchc 75 Tchs 82 Tchs+Tchc 90 Tchc
67	33-27621	3 Q 8 Tchc 30 Tchs 34 Tchc 58 Tchs 61 Tchc 82 Tchs
68	33-6075	8 Q 16 Tchs 18 Tchc 85 Tchs
69	33-25698	21 Tchs 26 Tchc 50 Tchs 56 Tchc 61 Tchs 65 Tchc 80 Tchs 90 Tchco
70	33-6346	10 Tchc 55 Tchs
71	33-17994	10 Q 27 Tchc 33 Tchs 54 Tchc+Tchs 73 Tchs 95 Tchc 103 Tchs 118 Tchc+Tchs
72	33-27148	26 Tchs 31 Tchc 53 Tchs 56 Tchc 85 Tchs
73	33-2194	30 Tchs 37 Tchs+Tchc 59 Tchs 63 Tchs+Tchc 85 Tchs
74	33-32717	18 Q 30 Tchs 45 Tchc+Tchs 52 Tchs 55 Tchc+Tchs 65 Tchc 70 Tchs
75	33-24069	20 Q 22 Tchc 57 Tchs 62 Tchc 81 Tchs 86 Tchc 115 Tchs 120 Tchco
76	33-22381	9 Q 15 Tchs 30 Tchc 35 Tchs 55 Tchc 65 Tchs 85 Tchc 128 Tchs 130 Tchc
77	33-24002	23 Q 30 Tchc 36 Tchs 42 Tchc 76 Tchs 78 Tchc
78	33-18258	14 Q 42 Tchc 65 Tchs 77 Tchc 90 Tchco+Tchs 95 Tchco 105 Tchc 135 Tchs
79	33-17412	22 Q 41 Tchs 57 Tchc 72 Tchc+Tchs 81 Tchs 89 Tchco 105 Tchs
80	33-21573	15 Q 30 Tchs 45 Tchc 63 Tchs
81	33-14799	15 Tchs 29 Tchc+Tchs 55 Tchs 63 Tchs+Tchc 80 Tchs
82	33-27638	28 Tchs 33 Tchc 58 Tchs 63 Tchc 85 Tchs
83	33-11634	20 Tchs 30 Tchs+Tchc 55 Tchs 60 Tchc 75 Tchs 80 Tchco 90 Tchco+Tchs
84	33-16313	25 Q or Tchs 35 Tchs 40 Tchc 65 Tchs
85	33-25237	28 Q or Tchs 34 Tchc 35 Tchs 38 Tchc 82 Tchs 83 Tchc
86	33-11559	27 Tchc+Tchs 55 Tchs+Tchc 74 Tchs 91 Tchc 110 Tchs
87	33-43692, G	45 Tchs 52 Tchc 62 Tchs 73 Tchc 117 Tchs 147 Tchc+Tchco 171 Tchs 176 Tchc 195 Tchs 430 Tkw
88	33-17319	19 Q 25 Tchs 42 Tchc 65 Tchs 85 Tchc 110 Tchs
89	33-26081	23 Tchs 26 Tchc 64 Tchs 68 Tchc 74 Tchs 77 Tchc 100 Tchs

Well Number	Identifier[1]	Formations Penetrated[2]
90	33-44705, G	57 Tchs 72 Tchc 112 Tchs 126 Tchc 210 Tchs 432 Tkw
91	33-43693, G	57 Tchs 75 Tchc 112 Tchs 127 Tchc 210 Tchs 450 Tkw 535 Tac 650 Tsp
92	33-44706	13 Q or Tchs 20 Tchs 50 Tchc+Tchs 56 Tchs 58 Tchc 91 Tchs 111 Tchc+Tchs 190 Tchs 391 Tkw
93	33-44707	30 Q or Tchs 57 Tchc+Tchs 83 Tchs+Tchc 105 Tchc+Tchs 108 Tchs 130 Tchc 219 Tchs 432 Tkw
94	33-22741	20 Q or Tchs 25 Tchs 30 Tchc 65 Tchs 95 Tchc+Tchco 110 Tchs 132 Tchc 153 Tchs
95	33-23057	25 Q 30 Tchs 35 Tchc 90 Tchs 110 Tchco 130 Tchs
96	33-27184	6 Q 10 Tchc 68 Tchs 78 Tchs+Tchc 88 Tchs
97	33-27039	15 Q 45 Tchs 60 Tchc 88 Tchs
98	33-24413	50 Tchs 80 Tchc+Tchs 100 Tchs
99	33-23869	18 Tchs 23 Tchc 40 Tchs 48 Tchc 70 Tchs
100	33-17059	11 Q 28 Tchs 31 Tchc 42 Tchs+Tchc 47 Tchc 52 Tchs+Tchc 60 Tchs
101	33-2593	31 Q 45 Tchs+Tchc 57 Tchs
102	33-15626, G	20 Tchs 30 Tchc 70 Tchs 90 Tchc 120 Tchs 170 Tchc 220 Tchs 460 Tkw 560 Tac 609 Tsp
103	33-1334	8 Q 29 Tchs 31 Tchc 53 Tchs 70 Tchc+Tchs 81 Tchs 82 Tchco
104	33-17910	36 Q+Tchs 38 Tchc 57 Tchs+Tchc 90 Tchs 92 Tchc
105	32-23971	64 Tchs 160 Tchs+Tchc 166 Tchs 210 Tchc+Tchs 517 Tkw 543 Tac
106	33-16043	45 Tchs 50 Tchc 80 Tchs
107	33-1255	70 Tchs 110 Tchs+Tchc 120 Tchs 125 Tchc 159 Tchs 160 Tchs+Tchc
108	33-760	25 Q 42 Tchs+Tchc 68 Tchc+Tchs 76 Tchs 78 Tchc 132 Tchs 141 Tchs+Tchc 163 Tchs
109	33-14242	35 Q 100 Tchs
110	33-20715	7 Q 20 Tchs or Q 30 Tchs 31 Tchc 65 Tchs
111	33-24504	45 Q or Tchs 135 Tchs 137 Tchc 177 Tchs 180 Tchc
112	33-27149	5 Q 28 Tchs or Q 32 Tchc 43 Tchs 50 Tchc 60 Tchs
113	33-13177	30 Q or Tchs 60 Tchs 70 Tchs+Tchc 130 Tchs
114	33-13209	30 Q 40 Tchs or Q 70 Tchs
115	33-24406	12 Q 35 Tchs or Q 90 Tchs 101 Tchc 118 Tchs
116	33-21598	22 Q 48 Tchs 55 Tchc 64 Tchs
117	33-22987	5 Q 32 Tchs or Q 36 Tchc 60 Tchs
118	33-24602	34 Q 72 Tchs 76 Tchc 130 Tchs
119	33-12336	25 Q or Tchs 28 Tchc 120 Tchs
120	33-8241	32 Tchs 35 Tchc 45 Tchs 60 Tchs+Tchc 118 Tchs 127 Tchc+Tchs 136 Tchc 154 Tchs
121	33-19372	10 Q 50 Tchs+Tchc 150 Tchs
122	33-20317	30 Q 45 Tchs 60 Tchc 85 Tchs
123	33-11508	11 Q 45 Tchs or Q 46 Tchco or Qcm2f 50 Tchs
124	33-12612	49 Q 54 Tchs or Q 57 Tchc or Qcm2f 61 Tchs+Tchc 70 Tchs
125	33-26875, G	50 Q 75 Tchs 85 Tchc 90 Tchs 100 Tchc 140 Tchs 160 Tchc 190 Tchs 475 Tkw 560 Tac
126	33-23901, G	50 Q 70 Tchs 85 Tchc 90 Tchs 95 Tchc 135 Tchs 160 Tchc 190 Tchs 475 Tkw 566 Tac
127	33-35371	81 Q+Tchs 89 Tchs+Tchc 140 Tchs 155 Tchs+Tchc 196 Tchs 458 Tkw
128	33-13028	20 Q 30 Tchs or Q 35 Tchc 130 Tchs
129	33-13837, G	52 Q 56 Tchc 76 Tchs 82 Tchc 105 Tchs 110 Tchc 136 Tchs 152 Tchc 174 Tchs
130	33-13839, G	52 Q 56 Tchc 76 Tchs 89 Tchc 136 Tchs 158 Tchc 190 Tchs
131	33-19125	38 Q 75 Tchs+Tchc
132	32-27684; 32-23972, G	70 Tchs 86 Tchc 126 Tchs 136 Tchc 188 Tchs 192 Tchc 236 Tchs 554 Tkw
133	33-20314	50 Q+Tchs 58 Tchc 80 Tchs 90 Tchc 112 Tchs
134	33-26938	45 Q or Tchs 58 Tchs 66 Tchc+Tchs 69 Tchc 80 Tchc+Tchs 105 Tchc 116 Tchs
135	33-24023	10 Q 35 Q or Tchs 45b Tchs 75 Tchc
136	32-20211	20 Q 25 Tchc+Tchs 32 Tchc 50 Tchc+Tchs 60 Tchs
137	32-21217	5 Q 12 Tchs 25 Tchs+Tchc 35 Tchc 47 Tchs+Tchc 80 Tchs
138	32-20900	10 Q 22 Tchs 25 Tchs+Tchc 32 Tchc 48 Tchs+Tchc 80 Tchs
139	32-18823	31 Tchs 35 Tchc 50 Tchs 54 Tchc 75 Tchs
140	32-21996	5 Q 12 Tchs 25 Tchs+Tchc 35 Tchc 47 Tchs+Tchc 80 Tchs
141	32-11426	15 Tchs 40 Tchc 50 Tchc+Tchs 63 Tchs 64 Tchc
142	32-19061	12 Q 16 Tchs+Tchc 35 Tchs 48 Tchc 90 Tchs

Well Number	Identifier[1]	Formations Penetrated[2]
143	32-8640	27 Q 30 Tchs 32 Tchc 67 Tchs
144	33-988	15 Q 29 Tchs or Q 32 Tchs 56 Tchc+Tchs 67 Tchs
145	33-2866, E	25 Q 44 Tchc or Q 80 Tchs 90 Tchc 105 Tchs 115 Tchc 130 Tchs 157 Tchc
146	32-27575; 32-23935, G	77 Tchs 82 Tchc 187 Tchs 191 Tchc 237 Tchs 532 Tkw
147	33-20223	6 Q 40 Tchs 42 Tchc+Tchs 53 Tchs
148	33-1838	25 Q 37 Tchs 40 Tchc 60 Tchs+Tchc 80 Tchs
149	33-11395	18 fill+Q 30 Tchs 58 Tchs+Tchc 80 Tchs
150	33-27427	20 Q 40 Tchs+Tchc 57 Tchs 60 Tchc 80 Tchs
151	33-18053	10 Q 70 Tchs
152	33-23671	30 Q 40 Tchs+Tchc 60 Tchs
153	33-27044	30 Tchs 32 Tchc 70 Tchs 90 Tchc+Tchs 120 Tchs
154	33-16637	2 fill 20 Qm 30 Qcm2p 45 Qcm2f 55 Tchs
155	33-4140	7 fill 17 Q 23 Tchc 31 Tchs 86 Tchc+Tchs 100 Tchs 145 Tchc+Tchs 152 Tchc
156	33-25093	6 Q 36 Tchs 41 Tchc 65 Tchs 70 Tchs+Tchc 86 Tchs
157	33-23232	40 Tchs 60 Tchc 80 Tchs
158	33-12583	105 Tchs 110 Tchc 130 Tchs
159	32-11543	15 Q 80 Tchs
160	32-14638	40 Tchs 60 Tchc 80 Tchc+Tchs 103 Tchs
161	32-14669	40 Tchs 60 Tchc 80 Tchc+Tchs 103 Tchs
162	32-6668	48 Tchs 54 Tchc 62 Tchs 64 Tchc 90 Tchs
163	32-13646	20 Q 35 Tchs 40 Tchc 55 Tchs
164	33-18897	10 Q 45 Tchs 60 Tchs+Tchc 72 Tchs
165	33-23215	25 Q 80 Tchs
166	32-13061	20 Tchc+Tchs or Q 65 Tchs
167	32-13062	20 Tchc+Tchs or Q 40 Tchs or Q 65 Tchs
168	33-27263	10 Tchs 20 Tchs+Tchc 30 Tchs 35 Tchc 60 Tchs 80 Tchc 100 Tchs 160 Tchc+Tchs
169	33-27151	10 Q or Tchs 20 Tchs+Tchc 30 Tchs 37 Tchc 60 Tchs 67 Tchc 110 Tchs
170	33-28019	10 fill 43 Qm 78 Qcm2p
171	33-21700	55 Tchs 57 Tchco 100 Tchs
172	32-12072	18 Tchs 23 Tchc 28 Tchs+Tchc 109 Tchs
173	32-12071	15 Tchs 25 Tchc 109 Tchs

[1]N. J. Department of Environmental Protection well-permit numbers. A “G” following the identifier indicates that a gamma-ray log is available for the well; an “E” indicates that an electric log (resistivity and spontaneous potential) is available. Where two well-permit numbers are reported, the first is for a production well and the second is for a test well at the same location. The geologic log is from the test well.

[2]Number is depth (in feet below land surface) of base of unit indicated by abbreviation following the number. Final number is total depth of well rather than base of unit. For example, “12 Tchs 34 Tchc 62 Tchs” indicates Tchs from 0 to 12 feet below land surface, Tchc from 12 to 34 feet, and Tchs from 34 to bottom of hole at 62 feet. Formation abbreviations and the corresponding drillers’ descriptive terms used to infer the formation are: Q=yellow and white sand and gravel surficial deposits, undifferentiated west of the bayshore area (units Tg, TQg, Qtu, Qtl, Qals, Qcm1, Qcm2). Surficial units along the bayshore are differentiated as follows: Qm=peat, meadow mat, and gray to brown mud, Qcm2p =yellow, white, gray sand and gravel, Qcm2f=gray to brown clay, silt, fine sand. Bedrock formations are: Tchs=white, yellow, gray, brown (minor red, orange) fine, medium, and coarse sand (and minor fine gravel) (Cohansey Formation); Tchc=yellow, white, gray (minor red and orange) clay, silty clay, and sandy clay (Cohansey Formation); Tchco=dark gray to black clay with wood or lignite (Cohansey Formation); Tkw=gray and brown clay, silt and sand (Kirkwood Formation); Tac=gray to olive glauconitic clay and silt with shells (Atlantic City Formation); Tsp=gray to olive glauconitic fine-to-medium sand with some clay (Sewell Point Formation). A “+” sign indicates that units are mixed or interbedded. Units are inferred from drillers’ or geologists’ lithologic descriptions on well records filed with the N. J. Department of

Environmental Protection, and from geophysical well logs. Units shown for wells may not match the map and sections due to variability in drillers' descriptions and the thin, discontinuous geometry of many clay beds in the Cohansey Formation. In many well logs, surficial deposits cannot be distinguished from Cohansey sands; thus, the uppermost Tchs unit in well logs generally includes overlying surficial deposits.