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Pamphlet containing table 1 accompanies map

INTRODUCTION

Surficial deposits in the Chatham quadrangle include artificial fill, alluvial, swamp, eolian, and stream-terrace deposits, all of postglacial age; glacial deposits of late Wisconsinan (25,000 to 18,000 years ago), Illinoian (about 150,000 years ago), and pre-Illinoian (between 2.1 million and 800,000 years ago) age; weathered-rock material and hillslope deposits of early to late Pleistocene age, and a preglacial fluvial deposit of Pliocene age.

The accompanying map and sections show the surface extent and subsurface relations of these deposits. The composition and thickness of the deposits, and the events they record, are described in the *Description of Map Units*. Well and boring data used to construct bedrock-surface-elevation contours and to infer the subsurface distribution of the deposits are provided in table 1 (in pamphlet). The chronologic relationships of the deposits are shown in the *Correlation of Map Units*. The hydrology of the glacial deposits and the history of river drainage and glacial erosion in the quadrangle and adjacent areas are briefly described in the two sections below. Figure 1 shows geomorphic and glacial features of the quadrangle and vicinity. Figure 2 shows the surface texture of glacial meltwater, eolian, and postglacial stream-terrace deposits. Bedrock geology is provided by Monteverde and Volkert (2005).

HYDROLOGY OF GLACIAL DEPOSITS

The Chatham quadrangle includes the southern part of an extensive buried-valley aquifer system in the central Passaic River basin west of Second Watchung Mountain. This aquifer system consists of a network of pre-Illinoian fluvial valleys, deepened and reshaped in places by Illinoian and late Wisconsinan glacial erosion, that are filled with and buried by late Wisconsinan and Illinoian glaciolacustrine sediments and till. The principal water-producing beds in this system are glaciolacustrine sands laid down as fans and deltas in front of advancing late Wisconsinan ice (unit Qpc) or during the Illinoian glaciation (unit Qis). These sands occur in the subsurface beneath and north of the terminal moraine (fig. 1) and are overlain by till (units Qr, Qrtm) and, in places, glaciolacustrine silt and clay (units Qpml, Qpcl, Qisl). These overlying sediments are less permeable than the sands and act as confining or semiconfining layers.

The buried sands occur only in the northeastern corner of the Chatham quadrangle (sections AA', BB', and DD') and are tapped by several public-supply wells in Chatham Borough (wells 66 and 67, and several nearby wells without geologic logs). Just to the north and northeast of the quadrangle boundary, in the Morristown, Roselle, and Caldwell quadrangles, the buried sands are thick and extensive and are tapped by many public-supply wells (Thompson, 1932; Vecchioli and others, 1967; Meisler, 1976; Stanford, 1991; Hoffman and Quinlan, 1994; Stanford, 2005, 2006). In the Chatham quadrangle the buried sands thin and pinch out beneath the terminal moraine complex (units Qtmr, Qpmd), which marks the limit of advance of both the Illinoian and late Wisconsinan glaciers. South of the moraine complex the valley-fill sediment is almost entirely low-permeability glaciolacustrine silt and clay (units Qpml, Qpcl, Qisl) and is not an aquifer.

Till and glaciofluvial sand and gravel form a shallow valley fill to the east of First Watchung Mountain. Although the glaciofluvial deposits here (unit Qpf) are permeable, they are not sufficiently thick to be a significant aquifer. The glaciofluvial deposits, and thick till of the terminal moraine (unit Qtmr) store and transmit water to the underlying shale and sandstone bedrock aquifer.

Hydraulic conductivities of the surficial deposits may be estimated from statewide glacial aquifer-test data (Stanford, 2000; Mennel and Canace, 2002). Sand and gravel deposits (units Qis, Qpc, Qpmf, Qpmd, Qpf, and parts of Qe, Qal and Qst) are highly permeable, having estimated hydraulic conductivities that range from 10^1 to 10^3 feet per day (ft/d). Sandy till and silty sand till (parts of Qr and Qtmr) are also permeable, having estimated hydraulic conductivities from 10^{-1} to 10^2 ft/d. Silt and clay lake-bottom deposits (parts of units Qpml, Qpcl, Qisl), clayey silt till (parts of Qr, Qb, and Qpt), and clayey silt weathered rock and colluvium (parts of Qwb, Qws, Qcs, Qcb, and Qcbl) are of low permeability, having hydraulic conductivities of 10^{-5} to 10^{-3} ft/d. Vecchioli and others (1962) report an average permeability of $3x10^{-4}$ ft/d for several measurements on samples of lake clay from the Great Swamp area. Fine sand and silt lake-bottom, alluvial, eolian, and wetland deposits (parts of units Qpml, Qpcl, Qisl, Qal, Qst, Qe, and Qs), silty to sandy silt till (parts of Qr, Qtmr, Qry, Qb, and Qpt), and silty weathered rock and colluvium (parts of Qwb, Qws, Qcb, and Qcbl) are somewhat more permeable, having estimated hydraulic conductivities of 10^{-3} to 10^{-1} ft/d. Swamp deposits (Qs) and fill have variable hydraulic conductivities that depend on their clay and silt content. Peats with little mineral soil, and fill composed of sand, cinders, gravel, demolition debris, slag, and trash, may be highly permeable.

PREGLACIAL DRAINAGE AND GLACIAL EROSION

The elevation of the bedrock surface, taken as the top of weathered rock, is contoured at 50-foot interval from water-well, test-boring, and geophysical-survey data, including data from Vecchioli and others (1967), Nichols (1968), Nemickas (1974) and Hoffman and others (in review). Contours are shown where the elevation of the bedrock surface is 200 feet or lower. At elevations above 200 feet, the bedrock surface corresponds closely to the land surface.

West of Second Watchung Mountain, the rock surface defines a pre-Illinoian fluvial drainage system that has been locally modified by glacial scour during the Illinoian glaciation (fig. 1). The fluvial system is part of a pre-Illinoian drainage network buried beneath Illinoian and late Wisconsinan glacial deposits in the central Passaic River basin (Nichols, 1968; Hoffman and Quinlan, 1994; Hoffman and others, in review; Stanford, 2005, 2006). This drainage network formerly exited the basin through a notch within the Short Hills Gap in Second Watchung Mountain, about 3 miles east of Chatham (fig. 1). This gap is now filled with Illinoian and late Wisconsinan glacial deposits (Stanford, 1991), and the postglacial drainage now exits the basin at Little Falls, about 12 miles northeast of Chatham, where the rock surface is at an elevation of about 160 feet. The bedrock surface in the Short Hills notch is at an elevation of about 70 feet, based on geophysical and well data (Ghatge and Hall, 1991; Stanford, 1991). Thus, any rock surfaces below an elevation of about 70 feet to the west of the Short Hills Gap have been overdeepened by glacial scour. In the northeastern corner of the quadrangle, the Chatham, Long Hill, and Oakwood buried valleys (fig. 1) all contain areas with rock-surface elevations below 70 feet, some as low as 20 feet, indicating as much as 50 feet of scour during the Illinoian glaciation. The rock surface in these overdeepenings is directly overlain by Illinoian till (sections AA', BB'), indicating that Illinoian ice was in contact with the bedrock and so was capable of scour. Illinoian ice did not advance much beyond these overdeepenings, and there is no evidence of glacial scour south of these areas. The southern parts of the Green Village, Long Hill, and Oakwood buried valleys are entirely of fluvial origin.

East of First Watchung Mountain the rock surface defines part of a fluvial drainage system that was tributary to the pre-late-Wisconsinan Raritan River. Before late Wisconsinan glaciation the Raritan flowed easterly from the Bound Brook area to the Elizabeth area (Stanford, 1993). During late Wisconsinan glaciation this valley was blocked and filled with the Plainfield glaciofluvial deposit (unit Qpf) and the terminal moraine (unit Qtmr), and the Raritan was diverted southeast from Bound Brook to Perth Amboy. In the Chatham quadrangle, the tributary valleys include the pre-late-Wisconsinan routes of Stony Brook and Green Brook. Neither the Illinoian nor the late Wisconsinan glacier advanced into these valleys, so they are not overdeepened.

After the Illinoian glaciation, the Great Swamp lowland to the north of Long Hill, and the Passaic valley, were filled with Illinoian glacial sediment to an elevation of about 150 feet (sections AA', BB'). This elevation is low enough to prevent the Passaic River from crossing Long Hill at Millington (fig. 1) as it does today. Instead, it flowed northeasterly through the Great Swamp lowland, through the preexisting pre-Illinoian gap in Long Hill at Chatham, to exit the basin at the Short Hills Gap. The present Passaic valley between Stirling and Summit was drained by the Dead River, which joined the Passaic in the Chatham area. After the late Wisconsinan glaciation the terminal moraine complex blocked northeasterly drainage through the Great Swamp lowland, and the Passaic adopted a new course across a low gap in Long Hill at Millington. It then flowed northeasterly in the former Dead River valley, across the moraine at Summit, which was about 130 feet lower in elevation than the moraine complex east of the Great Swamp. At Millington, the Passaic River eroded fractured basalt from an elevation of about 260 feet to its present elevation of just below 220 feet, forming the Millington gorge (fig. 1). This erosion was completed shortly after drainage of the Great Notch stage of Lake Passaic (see below).

DESCRIPTION OF MAP UNITS

Postglacial Deposits--These include man-made fill, stream deposits in terraces (Qst, Qstu), fans (Qaf, Qpg), and modern channels and flood plains (Qal, Qcal), wetland deposits in swamps and marshes (Qs), and windblown sediments (Qe). They were all deposited since retreat of the late Wisconsinan glacier about 18,000 yrs B. P. (years before present).

ARTIFICIAL FILL--Artificially emplaced sand, gravel, silt, clay, and rock fragments, and man-made materials including cinders, ash, brick, concrete, wood, slag, asphalt, metal, glass, and trash. Color variable but generally dark brown, gray, or black. As much as 20 feet thick. A few areas of fill are inferred from the extent of swamps and alluvial deposits shown in Salisbury (1895).

aft — TRASH FILL--Trash mixed and covered with sand, silt, clay, and gravel. As much as 30 feet thick. In solid-waste landfills.

Qal — ALLUVIUM--Sand, silt, clay, pebble gravel, locally pebble-to-cobble gravel; dark brown, brown, reddish-brown, gray; moderately to well sorted, stratified to massive. Contains variable amounts of organic matter. Locally, in and downstream from urban areas, contains demolition debris and trash. As much as 15 feet thick.

Qaf — ALLUVIAL FAN DEPOSITS--Sand, silt, pebble-to-cobble gravel; reddish-brown, brown, yellowish-brown; moderately sorted, stratified. As much as 15 feet thick (estimated).

Qst — STREAM TERRACE DEPOSITS--Silt, very-fine-to-fine sand, fine-to-coarse sand, pebbly sand; brown, very pale brown, yellowish-brown, light reddish-brown, reddish-brown, light gray; moderately to well sorted, well stratified to massive. Cobble-to-boulder gravel occurs only in terrace deposits along the Passaic River in Chatham Borough and Summit. As much as 15 feet thick. Forms terraces with surfaces 5-15 feet above modern flood plains and wetlands in the Passaic valley, Loantaka Brook valley, and the Great Swamp. In the Passaic valley and the Great Swamp the stream terrace deposits were, in part, laid down in shallow postglacial lakes, including the Stanley and Millington stages of Lake Passaic (see below). The intricate pattern of the terraces in the Great Swamp, and their patchy distribution in the Passaic valley in the Stirling-Gillette area, were created by streams downcutting into, and eroding, the terraces as the level of the postglacial lakes declined when their dams were downcut by the Passaic River. In the Great Swamp, postglacial rebound raised the northern sector of the lowland relative to the southern, steepening streams and enhancing further incision and erosion of the terraces. In the Great Swamp, lakes drained, terraces were deposited, and then incised and eroded, by about 10,000 yrs B. P. This chronology is based on the age at which peat deposition began in the incised channels (see unit Qs, below), and on a radiocarbon date of 13,975+/-240 yrs B. P. (QC-1305) on concretions of likely organic origin within the upper 10 feet of the lacustrine silt and clay in a test boring a mile to the west of the quadrangle boundary on White Bridge Road (boring GS6 of Reimer, 1984). This date is probably somewhat older than the end of lake deposition. Wind erosion and ground-ice deformation also reshaped the morphology of the terraces, especially in the Great Swamp area.

Qstu — HIGH STREAM TERRACE DEPOSITS--Pebble-to-cobble gravel, fine-to-medium sand; brown, light reddish-brown; moderately sorted, weakly stratified. As much as 6 feet thick. Forms a small terrace 20-25 feet above the modern flood plain along the Passaic River in Summit. Deposited by the Passaic River during early downcutting through the moraine at Stanley. May mark the initial spillway level for the Stanley stage of Lake Passaic.

Qs — SWAMP AND MARSH DEPOSITS--Peat and organic silt, clay, and minor fine sand; black, dark brown, and gray. As much as 20 feet thick, but generally less than 10 feet thick (Waksman and others, 1943). Pine, spruce, and birch pollen in the basal 1.5 feet of a 5-foot core taken in these deposits near Meyersville (Meyerson, 1970) indicate that peat there began to accumulate before 9,000 yrs B. P., based on radiocarbon dates elsewhere of the youngest occurrence of these taxa in this region (Peteet and others, 1993).

Qcal — ALLUVIUM AND COLLUVIUM, UNDIVIDED--Interbedded colluvium as in units Qcb, Qcbl, and Qcs, and alluvium consisting of dark brown to yellowish-brown or reddish-brown silty sand, sandy silt, to clayey silt, with beds and lag veneers of angular to subangular basalt pebbles and cobbles (adjacent to unit Qwb) or shale chips and flagstones (adjacent to unit Qws). As much as 15 feet thick. In valley bottoms on uplands outside the late Wisconsinan glacial limit.

Qe — EOLIAN DEPOSITS--Very-fine-to-fine sand, silty fine sand, minor fine-to-medium sand; yellowish-brown to very pale brown; massive to weakly stratified. As much as 15 feet thick (estimated), generally less than 5 feet thick. Deposited in sheets and scattered low dunes along the base of the west slope of Long Hill and as patchy veneers on slopes adjacent to the Passaic River between Berkeley Heights and the Oakwood Park area. Mapped only where continuous and generally greater than 2 feet thick. Thin, patchy windblown silt and fine sand is present atop units Qst and Qpml in the Great Swamp lowland and the Passaic valley, and on the lower slopes of Long Hill and the west side of Second Watchung Mountain. Laid down during lowering of Lake Passaic from the Moggy Hollow stage, and during deposition of stream terrace deposits, when wind entrained newly exposed silt and fine sand from the lake bed and terrace surfaces and deposited it on adjacent hillslopes.

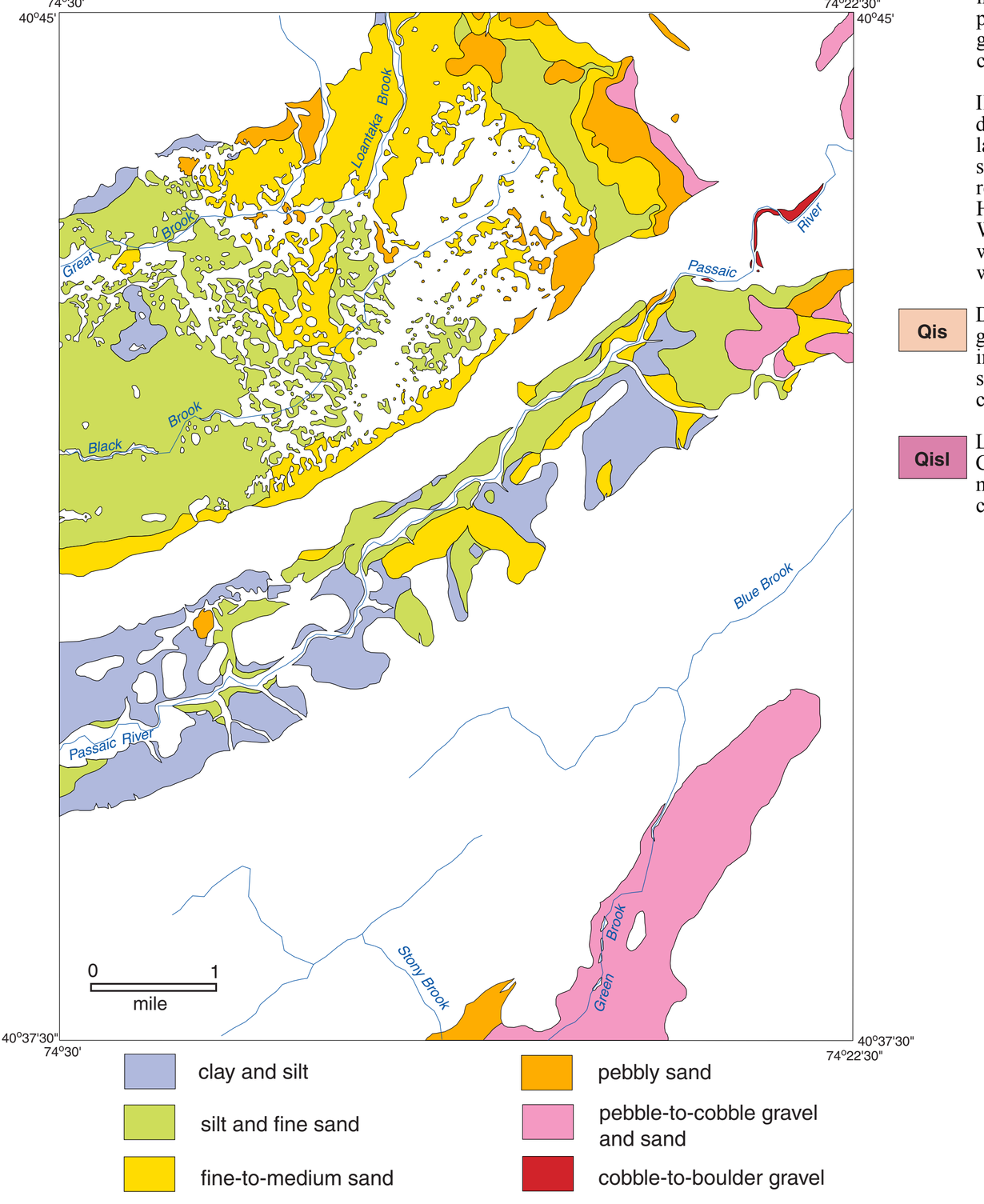


Figure 2. Surface texture of eolian deposits, glacial meltwater deposits, and postglacial stream-terrace deposits in the Chatham quadrangle. Uncolored areas are till, colluvium, weathered-rock materials, swamp and marsh deposits, and alluvium. These materials have mixed or variable texture.

Qpg — GREAT NOTCH-STAGE DEPOSITS--Fine-to-medium sand, pebbly sand, pebble-to-cobble gravel; yellowish-brown, very pale brown, light reddish-brown. As much as 15 feet thick. In alluvial fans laid down in the Great Notch stage of Lake Passaic (see below) or, for the deposits near Hickory Tree, in the Millington stage of Lake Passaic. These fans were deposited at the mouths of streams eroding sand and gravel from the adjacent Moggy Hollow-stage deltas (unit Qpmd).

Glacial Deposits--These include till and stratified sediments. Till is a poorly sorted, nonstratified sediment containing gravel clasts and boulders, deposited directly from glacial ice (units Qr, Qry, Qtmr, Qb, Qpt). The stratified sediments are generally well sorted. They include sand and gravel laid down by glacial meltwater in river plains (Qpf) and in glacial-lake deltas and fans (Qis, Qpc, Qpmf, Qpmd). The stratified sediments also include silt, clay, and fine sand deposited on the bottoms of glacial lakes (Qisl, Qpcl, Qpml). All of these deposits are of late Wisconsinan age except Qis, Qisl, and Qb, which are of Illinoian age, and Qpt, which is of pre-Illinoian age.

Pre-Illinoian till occurs in erosional remnants in upland valleys on Second Watchung Mountain, on low shale uplands in the Passaic valley in Berkeley Heights and New Providence, and on terraces in the Blue Brook valley in Watchung Reservation. Erratic pebbles and cobbles derived from pre-Illinoian deposits also occur in colluvium along the base of First Watchung Mountain to the north of the Mount St. Marys Academy area. This distribution, and the absence of pre-Illinoian till to the south and west in similar settings, indicate that pre-Illinoian ice advanced to position M1 (fig. 1). Pre-Illinoian deposits in New Jersey correlate to magnetically reversed glacial deposits in eastern and central Pennsylvania (Gardner and others, 1994; Sasowsky, 1994), indicating that they were laid down before 788 ka. In New Jersey, pollen associated with the deposits, and their close stratigraphic and geomorphic relation to the Pensauken Formation, suggest a Pliocene age (Stanford and others, 2001). Following retreat of pre-Illinoian ice there was a long period of erosion and stream incision. Valleys were cut as much as 100 feet below their level when the pre-Illinoian till was deposited.

Illinoian deposits are preserved beneath late Wisconsinan deposits within pre-Illinoian buried valleys west of Second Watchung Mountain. Illinoian ice advanced to a limit that generally coincides with, or is slightly north of, the late Wisconsinan limit in the area west of Second Watchung Mountain. To the east of Second Watchung Mountain the Illinoian limit is uncertain because Illinoian deposits in the region have been extensively eroded by the late Wisconsinan glacier. However, the absence of Illinoian deposits beneath the Plainfield glaciofluvial plain and adjacent terminal moraine suggests that Illinoian ice did not advance into the quadrangle east of Second Watchung Mountain. The Illinoian deposits include till (Qb), which generally rests directly on the bedrock surface, sand and gravel (Qis) and silt, fine sand, and clay (Qisl). In a few places (section DD'), Illinoian till overlies units Qis and Qisl, which in turn rest on bedrock. In the Short Hills Gap (3 miles east of Chatham), water-well records indicate that Illinoian till fills the gap to an elevation of between 150 and 200 feet (Stanford, 1991). The Short Hills Gap was the drain for the central Passaic basin in pre-Illinoian time (see section on preglacial drainage), and a glacial lake formed when the gap was blocked. When Illinoian ice covered the gap, a lake at an elevation similar to the Moggy Hollow stage of Lake Passaic (see below) filled the basin, with a lake level of about 345-355 feet in the Chatham quadrangle west of Second Watchung Mountain. Unit Qis and part of unit Qisl are lacustrine-fan and lake-bottom sediments deposited in this lake. When the Illinoian ice front receded from the Short Hills Gap, the 350-foot lake lowered to about 150-200 feet, which is the elevation of the top of the sediment dam filling the gap. The uppermost parts of unit Qisl are lake-bottom sediments laid down in this lake.

An alternative interpretation of the sand and gravel of unit Qis in the Chatham buried valley is that the Short Hills notch was not filled with Illinoian deposits during the Illinoian retreat, or during the following interglacial period, or during the late Wisconsinan advance, permitting fluvial drainage through the notch at all times (Stone and others, 2002). In this scenario, the stratified deposits above the Illinoian till and below the late Wisconsinan advance-stage lacustrine deposits (units Qpc, Qpcl) are glaciofluvial and interglacial fluvial sediments (the Wharton alluvial deposits and Florham Park outwash deposits of Stone and others, 2002). However, the interbedding of sand and gravel with thick clay and silt in these deposits, and their range in elevation regionally in the basin from 30 feet (40 feet below the rock floor of the notch) to 300 feet, favor a lacustrine setting. Also, it is unlikely, given the Illinoian deposits in the Short Hills Gap, and the widespread distribution of Illinoian till in the subsurface west of the gap, that the notch was open. Thus, the "Wharton" and "Florham Park" deposits are not mapped here.

The Illinoian deposits have not been dated in this region. Weathering characteristics, soil development on outcropping deposits, and correlation to tills in Long Island and southern New England, indicate that they predate the last interglacial period about 125,000 years ago (Stone and others, 2002), and likely were deposited during the late Illinoian glaciation about 150,000 years ago. Following retreat of Illinoian ice a long period of erosion preceded arrival of late Wisconsinan ice.

The regional orientation of striations and distribution of till indicate that late Wisconsinan ice advanced toward the southwest and west into the Chatham quadrangle. This ice was on the west side of an advancing lobe channeled between the Palisades Ridge to the east and the Highlands to the west (Salisbury, 1902; Stanford and Harper, 1991). The Watchung Mountains impeded ice flow, and ice to the west of First Watchung Mountain (hereafter referred to as the "Passaic lobe") did not advance as far to the south as ice to the east of First Watchung (hereafter referred to as the "Hackensack lobe"). The Chatham quadrangle includes areas glaciated by the western edge of the Hackensack lobe and the southern edge of the Passaic lobe.

As the Passaic lobe entered the quadrangle, it advanced into the Chatham stage of Lake Passaic (see below) and overran proglacial lacustrine deposits and earlier Illinoian sediments. The level of the Chatham stage in the quadrangle ranged from 290 to 300 feet, giving water depths of as much as 150 feet in front of the advancing ice. As the ice front reached its farthest extent (M2 in fig. 1), Lake Passaic rose to the Moggy Hollow stage, which was about 50 feet higher than the Chatham stage. The Moggy Hollow stage was maintained during deposition of the terminal moraine and recession of the glacier from the quadrangle. Till was deposited as a continuous sheet 10 to 110 feet thick on the overrun sediment. Several layers of till are stacked with lacustrine deposits beneath the terminal moraine, indicating several advances and retreats of the glacier margin during deposition at the terminal moraine complex. The final advance and retreat formed the ridge-and-basin topography of the moraine. The late Wisconsinan till includes two varieties: a reddish-brown silty sand, sandy silt, and clayey silt till (Rahway Till, Qr) derived from the local red shale and sandstone bedrock, and overrun lacustrine sediments; and a yellowish-brown clayey sandy silt till (Rahway Till, yellow phase, Qry), derived in part from weathered basalt bedrock.

East of Second Watchung Mountain the Hackensack lobe advanced westerly into the Blue Brook valley in Watchung Reservation. This advance is indicated by a thin sheet of Rahway till along the south bank of Blue Brook, within the channel cut by water draining from the Chatham-stage spillway (see below) This till extends about 1.5 miles beyond the edge of the terminal moraine in the valley (fig. 1), indicating an early advance before retreat and stabilization of the ice front to build the moraine. No such promoraine advance occurred east of First Watchung Mountain, where the outer edge of the moraine marks the limit of the till. Well data in this area indicate that ice overrode sand and gravel of unit Qpf as it advanced to its limit.

The ice front began to retreat from the terminal moraine before 20,000 yrs B. P. Deposition of till and glacial sand and gravel (units Qpmf, Qpf) ceased shortly thereafter. Deposition of silt and clay in the Moggy Hollow and Great Notch stages of Lake Passaic continued until about 18,000 yrs B. P., when the Great Notch stage drained. The age of Lake Passaic is based on a radiocarbon date of 20,100+/-500 (QC-1304) from several concretions of likely organic origin in lacustrine clay and silt, obtained from depths of 58 and 93 feet in a test boring just west of the quadrangle along Pleasant Plains Road (boring GS1 of Reimer, 1984). This date is a rough estimate of the onset of deposition in Lake Passaic. Above the lower concretions, 750 varves were counted in this boring and in boring 48 (table 1) near Green Village (boring GS5 of Reimer, 1984). Overlying microvarves in these borings indicate a minimum of 450 additional years of accumulation (Reimer, 1984), some or most of which may have been deposited in the glacial lake stages, indicating that the 750 varve years may be a minimum. Details of the history of lake stages and glacial streams are provided in the following description of map units. Names of the Chatham, Moggy Hollow, and Great Notch stages follow those of Stone and others (2002). The postglacial Millington and Stanley stages are named after informal reference in Salisbury and Kummel (1895, p. 317). Lake elevations are based on an uplift gradient of 2.1 feet per mile to the N21°E for Lake Passaic (Stone and others, 1989).

Glacial-Lake Deposits--These are stratified and generally well sorted. They include sand and gravel laid down in deltas and lacustrine fans; and clay, silt, and fine sand laid down on lake-bottom plains and in the basal parts of deltas and margins of fans. Bedding in the deltas includes inclined foreset beds of sand, pebbly sand, and minor pebble-to-cobble gravel, overlain at the surface in places by horizontal topset beds of sand and pebble-to-cobble gravel. Lacustrine fans contain gently dipping beds of sand and pebble-to-cobble gravel. Bedding in deltas and fans may be deformed locally by collapse, slumping, or shoving by glacial ice. Bedding in lake-bottom deposits is generally horizontal, laminated to thin-bedded, and undeformed, although on toeslopes adjacent to deltas and fans it may be folded and faulted due to slumping or loading. Nongravel sediment is yellowish-brown, light reddish-brown, and light gray. Sand consists chiefly of quartz, feldspar, mica, and fragments of gray and red-brown sandstone and mudstone, gray gneiss, and basalt. Gravel is chiefly white-to-gray gneiss, gray mudstone and sandstone, and reddish-brown mudstone and sandstone, with some white quartz, purple conglomerate, gray quartzite, and basalt.

GLACIAL LAKE PASSAIC DEPOSITS--Deltaic, lake-bottom, and lacustrine-fan deposits laid down in glacial Lake Passaic. Lake Passaic filled the central Passaic River basin between Second Watchung Mountain and the Highlands. In the Chatham quadrangle, it includes five stages: one advance-phase stage, two recessional stages, and two postglacial stages. When the Hackensack lobe of the advancing late Wisconsinan glacier blocked Millburn Gap (4 miles east of Chatham, fig. 1), the Chatham stage of Lake Passaic flooded the central Passaic basin west of Second Watchung Mountain. This stage was controlled by a spillway at an elevation between 250 and 300 feet on a divide in the Blue Brook valley between First and Second mountains south of Millburn Gap ("Blue Brook spillway", fig. 1). This spillway drained into the Raritan basin down the Blue Brook valley. The substantial drainage from this spillway cut the narrow inner gorge along Blue Brook in Watchung Reservation, and led to the cutting of the narrow ravines by tributary streams on the south side of the valley. When Millburn Gap was blocked by the Hackensack lobe, the margin of the Passaic lobe likely was more than 5 miles north of the Chatham area. Chatham-stage deposits (Qpc, Qpcl) occur in the subsurface, beneath till and recessional lacustrine deposits, within this several-mile-wide belt (Stanford, 2006). With continued advance, the Hackensack lobe moved across Blue Brook valley and blocked the Blue Brook spillway. At this time Lake Passaic rose to the Moggy Hollow stage. The Moggy Hollow stage (units Qpmf, Qpmd, Qpml) was controlled by a spillway at an elevation of 340 feet near Far Hills, about 6 miles west of Stirling. Elevation of the lake level at this stage in the Chatham quadrangle was 340 to 355 feet. Deposition of the terminal moraine then filled the Short Hills Gap (fig. 1) to an elevation of 375-380 feet, holding the lake at the Moggy Hollow stage during deglaciation. A lower lake level, the Great Notch stage, was established when the retreating ice front uncovered Great Notch, a gap in First Watchung Mountain 14 miles northeast of Chatham. The Great Notch spillway is at an elevation of about 305 feet, and the elevation of the lake level at this stage in the Chatham quadrangle ranges from 265 to about 280 feet. The Great Notch stage drained when the gap through First Watchung Mountain at Paterson was deglaciated. After the Great Notch stage drained, the moraine dam at Stanley (the former local name for the vicinity of the railroad bridge over the Passaic River between Chatham and Summit) held in a postglacial lake (the Stanley stage) in the Passaic valley upstream from the dam. The initial level of the spillway here, marked by unit Qstu, was at an elevation of about 230 feet. Elevation of the lake ranged from 220 feet at Millington and Union Village to 225 feet at Murray Hill. Downcutting of the Passaic River into the moraine gradually cut the "Stanley gorge" (fig. 1), lowering the spillway and draining the lake, although postglacial rebound may have created shallow ponds in the valley upstream of the gorge afterwards. At the same time as the Stanley stage formed, the gap in Long Hill at Millington held in the Millington stage in the Great Swamp basin. The initial spillway here, marked by a topographic bench along the top of the Millington gorge, was at an elevation of about 260 feet. Elevation of the this lake level ranged from 265 feet at Meyersville to about 270-275 feet at Hickory Tree. Downcutting of the Passaic River into the fractured basalt at the gap gradually lowered the spillway and, along with postglacial rebound, drained the lake.

Qpmd — Deltaic deposits--Fine-to-coarse sand and pebble-to-cobble gravel, minor silt and very fine sand. As much as 70 feet thick. Includes deltas at Summit and along the front of the terminal moraine in Chatham and Madison. Deposited in the Moggy Hollow stage of Lake Passaic.

Qpmf — Lacustrine-fan deposits--Fine-to-coarse sand and pebble-to-cobble gravel, minor silt and very fine sand. As much as 80 feet thick (estimated). Deposited in the Moggy Hollow stage of Lake Passaic.

Qpml — Lake-bottom deposits--Silt, clay, minor very-fine-to-fine sand. As much as 120 feet thick. Deposited chiefly during the Moggy Hollow stage. Uppermost parts may have been laid down in the Great Notch, Stanley, and Millington stages.

Qpc — Deltaic and lacustrine-fan deposits--Fine-to-coarse sand, pebble gravel, minor cobble gravel, silt, and clay. As much as 50 feet thick. Deposited in Chatham stage of Lake Passaic. Contact with Qpcl is interfingered or gradational and is inferred from well records. In the subsurface only, except for a beach or spit gravel (the "Durie spit" of Salisbury and Kummel [1895, p. 257-258]) of rounded shale chips (from erosion of the local shale bedrock), and a few ice-rafted erratics, along the base of Long Hill west of New Providence. This deposit rises to the level of the Chatham stage, although parts of the deposit at lower elevation may have been laid down in the Great Notch stage. Similar shale-chip beach gravel deposits are likely present elsewhere along the east side of Long Hill, but are covered by colluvium (Qcb) or eolian sediment (Qe).

Qpcl — Lake-bottom deposits--Silt, clay, fine sand. As much as 80 feet thick. Deposited in Chatham stage of Lake Passaic. Contact with Qpc is interfingered or gradational and is inferred from well records. Contact with Qpml in the vicinity of the terminal moraine is picked at first report of coarser lake-bottom sediment, indicating closest approach of the glacier margin and blockage of Blue Brook valley. South of the terminal moraine the contact with Qpml is an inferred time line without sedimentary change.

ILLINOIAN LACUSTRINE DEPOSITS--Deltaic, lacustrine-fan, and lake-bottom deposits laid down in an Illinoian glacial lake occupying the central Passaic basin. This lake was controlled at first by the spillway at Moggy Hollow, probably at an elevation slightly higher than 340-foot elevation of the late Wisconsinan spillway. During Illinoian retreat, the lake was controlled by a much lower spillway across Illinoian till in the Short Hills Gap at an elevation of 150 to 200 feet. This spillway is now buried beneath late Wisconsinan deposits. Depending on the elevation of the spillway, this lake drained either when the gaps through the Watchungs at Little Falls and Paterson were deglaciated or when the spillway was lowered by erosion, thereby exposing the lake-bottom.

Qis — Deltaic and lacustrine-fan deposits--Fine-to-coarse sand, pebble gravel, minor cobble gravel, silt, and clay. As much as 60 feet thick. In subsurface only. Contact with Qisl is interfingered or gradational and is inferred from well records. Contact with Qpc or Qpcl in subsurface is picked at first report of coarser sand and gravel beneath fine sand, silt, or clay.

Qisl — Lake-bottom deposits--Silt, clay, fine sand. As much as 60 feet thick. In subsurface only. Contact with Qpcl or Qpml in subsurface is picked at report of color change to redder or more yellow color (indicating surface exposure and weathering), or at report of change to coarser grain size that may mark thin interglacial alluvial or eolian deposits atop Qisl.

Glacial Stream Deposit--Well stratified and sorted pebble-to-cobble gravel and sand forming a plain in the lower Green Brook valley. Sediment was deposited by meltwater draining from the terminal moraine on the east side of the valley. This plain grades southwesterly to the Raritan River at Bound Brook. Sand and gravel composition similar to that of glacial-lake deposits.

Qpf — PLAINFIELD GLACIOFLUVIAL DEPOSIT--Pebble-to-cobble gravel, fine-to-coarse sand. As much as 80 feet thick.

Till--Poorly sorted, nonstratified sediment deposited directly by glacial ice or by sediment flows from glacial ice. Sediment is matrix-supported and is generally compact below the soil zone due to consolidation by the weight of overlying ice. The matrix may show a coarse subhorizontal platy structure. Four tills are distinguished on the basis of color, grain size, and age. The Rahway Till (Qr) is a reddish-brown sandy silt till of late Wisconsinan age, derived from erosion of red shale and sandstone bedrock, and overrun glaciolacustrine and glaciofluvial sediment. The Rahway Till, yellow phase (Qry) is a yellowish-brown to brown sandy clayey silt till of late Wisconsinan age derived in part from erosion of basalt bedrock. The terminal moraine (Qtmr) is distinguished by surface morphology and is composed of Rahway Till. The Bergen (Qb) till is an Illinoian counterpart to the Rahway Till. Pre-Illinoian till (Qpt) is similar in composition to the Rahway and Bergen tills but is more weathered and eroded. The late Wisconsinan tills are in gradational contact with each other. Formal definition of the till units is in Stone and others (2002).

Qr, Qtmr, Qrt — RAHWAY TILL--Reddish-brown, light reddish-brown, reddish-yellow, yellowish-brown silty sand to clayey sandy silt, locally clayey silt, containing some to many (2-15% by volume) subrounded and subangular pebbles and cobbles and few (<2% by volume) subrounded boulders. Locally contains deformed lenses and blocks of laminated silt, clay, and sand from erosion of glaciolacustrine deposits. Matrix is compact, nonsticky to slightly sticky when clayey; nonplastic to slightly plastic where clayey, nonjointed, and may have subhorizontal fissility. Gravel clasts include chiefly red and gray sandstone and siltstone, gray gneiss, and a little white quartz, purple conglomerate and quartzite, and basalt. Boulders are chiefly gneiss with some conglomerate; a very few are gray and red sandstone and basalt. As much as 110 feet thick. Unit Qtmr delineates segments of the terminal moraine composed of Rahway Till. Unit Qrt delineates areas where Qr is less than 10 feet thick over bedrock.

Qry — RAHWAY TILL, YELLOW PHASE--Till as in unit Qr, except matrix color is yellowish-brown and matrix is dominantly sandy clayey silt. As much as 40 feet thick (estimated).

Qb — BERGEN TILL--Reddish-brown to reddish-yellow sandy clayey silt to sandy clay. Gravel content and composition similar to Rahway till. Matrix is compact, moderately sticky and plastic, and weakly jointed. Gneiss, sandstone, and mudstone clasts have weathering rinds; some are fully decomposed. As much as 50 feet thick. In subsurface only, generally on bedrock surface. Inferred from well records.

Qpt — PRE-ILLINOIAN TILL--Reddish-brown to reddish-yellow clayey silt to sandy clayey silt with some to many subrounded to subangular pebbles and cobbles and few subrounded boulders. Gravel includes, in approximate order of abundance, red and gray mudstone and sandstone, basalt, purple quartzite-conglomerate, gray quartzite, chert, quartz from the Pensauken Formation, and gneiss. Boulders are chiefly purple quartzite-conglomerate, gray quartzite, basalt, and gneiss. The mudstone, sandstone, gneiss, and basalt gravel clasts have weathering rinds or are completely decomposed. As much as 50 feet thick. Equivalent to the Port Murray Formation, till faces, of Stone and others (2002).

Hillslope Deposits--Nonstratified, poorly sorted sediment deposited at the foot of hillslopes by downslope movement of material on the slopes. Deposited primarily under cold climate conditions during the middle and late Pleistocene.

Qta — TALUS--Angular to subangular cobbles and small boulders of basalt forming a small, matrix-free apron at the base of cliffs along Green Brook south of Seelys Pond. As much as 15 feet thick.

Qcb — BASALT COLLUVIUM, BLOCKY PHASE--Reddish-brown, reddish-yellow, yellowish-brown, brown clayey silt, silty clay, minor fine-sandy silt with some to many subangular basalt pebbles and cobbles. As much as 60 feet thick. Includes chips and angular pebbles to fine cobbles of red shale and mudstone in deposits on the southeastern slopes of Long Hill and First and Second Watchung Mountain. In places, the interior parts of thick deposits consist of deeply weathered basalt and shale clasts, beneath a surface colluvium containing fresh clasts. This stratigraphy indicates repeated deposition of colluvium during glacial periods, and slope stability and weathering during interglacials. Along the base of First Watchung Mountain north of the Mt. St. Marys Academy area, at the base of Second Mountain in the Blue Brook valley, and along the base of Long Hill, the colluvium includes a few erratic pebbles and cobbles. These erratics are from glacial deposits that formerly were on the adjacent hillslopes. These glacial deposits include pre-Illinoian till on First and Second Watchung Mountain, late Wisconsinan till on lower slopes of the Blue Brook valley, and erratics deposited by icebergs in Lake Passaic on Long Hill.

Qcbl — BASALT COLLUVIUM, SILTY PHASE--Reddish-yellow, reddish-brown, light gray, very pale brown clayey silt to silty clay, minor fine sandy silt, with few subangular basalt pebbles. As much as 10 feet thick. At foot of long, gentle slopes or at distal edge of aprons of blocky colluvium. Deposited in part by ground-water seepage. Mapped only where continuous and generally greater than 3 feet thick. Occurs discontinuously along lower parts of most slopes on basalt bedrock.

Qcs — SHALE COLLUVIUM--Reddish-brown to yellowish-brown clayey silt with few to some shale chips. As much as 15 feet thick (estimated).

Weathered Bedrock Material--Nonstratified, poorly sorted sediment formed by mechanical and chemical weathering of bedrock. Owing to their variable thickness, these units are not shown on sections.

Qwb, Qwbt — WEATHERED BASALT--Reddish-yellow, reddish-brown, light gray, to yellowish-brown clayey silt, silty clay, to clayey coarse sand with some to many angular pebbles and cobbles of basalt and, in places on Second Watchung Mountain, gabbro. Most clasts have weathering rinds. Includes mixed clast-and-matrix sediment, fractured rock rubble, and saprolite that preserves original rock structure. Generally less than 10 feet thick over fractured, slightly weathered bedrock, which may be as much as 60 feet thick. Unit Qwbt indicates areas where weathered material is thin or absent and fractured rock rubble abundant.

Qws — WEATHERED SHALE--Reddish-brown, brown, yellowish-brown clayey silt to silty clay with many shale chips or angular pebbles and cobbles of mudstone. As much as 15 feet thick.

Preglacial Fluvial Deposit--Sand and pebble gravel of the Pensauken Formation preserved in two small erosional remnants on shale interfluves in North Plainfield. These are remnants of the Pensauken fluvial plain, which filled the broad lowland across central New Jersey from the New York City area to Trenton, and continued down the Delaware valley to the Delmarva peninsula. In the Chatham quadrangle this deposit formerly covered the entire area east of First Watchung Mountain. The river system that deposited this plain included the Hudson River and, possibly, drainage from southern New England (Stanford, 1993). Pollen and stratigraphic position with respect to Coastal Plain formations and the pre-Illinoian till suggest a Pliocene age (Stanford and others, 2001). This river system was active until the pre-Illinoian glaciation, when it was diverted southeasterly to the Atlantic Ocean in the New York City area. After this diversion, erosion and downcutting by local streams during the early and middle Pleistocene removed most of the deposit.

Tp — PENSAUKEN FORMATION--Reddish-yellow to yellowish-brown clayey medium-to-coarse sand, some fine sand, with few to some pebbles. Sand is feldspathic; the feldspar grains are weathered or fully decomposed to clay. Gravel is chiefly well-rounded white to gray quartz and quartzite and dark gray chert, with few to some shale, sandstone, and gneiss. The shale, sandstone, and gneiss are deeply weathered to fully decomposed. As much as 10 feet thick.

MAP SYMBOLS

Contact--Solid where well-defined by landforms, long-dashed where approximately located, short-dashed where gradational or feather-edged, dotted where exposed in excavations or concealed by water.

Material observed in hand-auger hole, exposure, or excavation

Meltwater channel--Line in base of channel, arrow indicates flow direction.

Postglacial fluvial scarp--Line at top, ticks on slope. Cut by fluvial erosion after drainage of Lake Passaic.

Excavation perimeter--Line at limit of excavation. Outlines quarries and former sand and gravel pits. Topography within these areas may differ from that on the base map.

Bedrock ridge--Line on crest. Low ridges formed on resistant flow units within the Orange Mountain Basalt on First Watchung Mountain.

Quarry--Active in 2005.

Quarry--Inactive in 2005.

Sand and gravel, or clay, pit--Inactive in 2005. Clay pits indicated by "c" following symbol.

147● Well with log in table 1--Location accurate within 100 feet.

47 Well with log in table 1--Location accurate within 500 feet.

90△ Elevation of bedrock surface in well or boring--From Nemickas (1974). Shown only where other data are sparse.

30▲ Elevation of bedrock surface from seismic survey--From Nichols (1968).

130△ Elevation of bedrock surface from seismic survey--From Hoffman and others (in review).

Qst5/Qpml ● Multiple surficial units exposed--Observed in 2004-2005. Number following unit symbol is thickness of unit in feet.

50 Elevation of bedrock surface--Contour interval 50 feet. Includes top surface of weathered bedrock.

r Large bedrock outcrop--Many small outcrops within units Qwb, Qwbt, and Qws are not shown.

47 Well on sections--Projected to line of section. Owing to projection, depths of contacts on section may not be identical to those in well.

Qe/Qwb Unit to left of slash overlies unit to right--Shows extent of underlying deposits beneath thin eolian or stream-terrace sediments.

●Qpmb Beach deposits--Sand and pebble gravel deposited at shoreline of the Moggy Hollow stage of Lake Passaic. Shown only where observed in 2004-2005. Additional occurrences noted by Salisbury and Kummel (1895) are now obscured by urbanization.

(Tp)/Qws Pebble lag--Pebbles from the Pensauken Formation on surface and in the upper several feet of weathered shale.

Thermokarst basin--Pattern within basin. Most are on stream-terrace sand, formed chiefly from melting of ground ice. A few basins may have been formed by wind erosion or, possibly, groundwater seepage. May contain thin peat deposits. Larger basins with thicker peat are mapped as unit Qs.

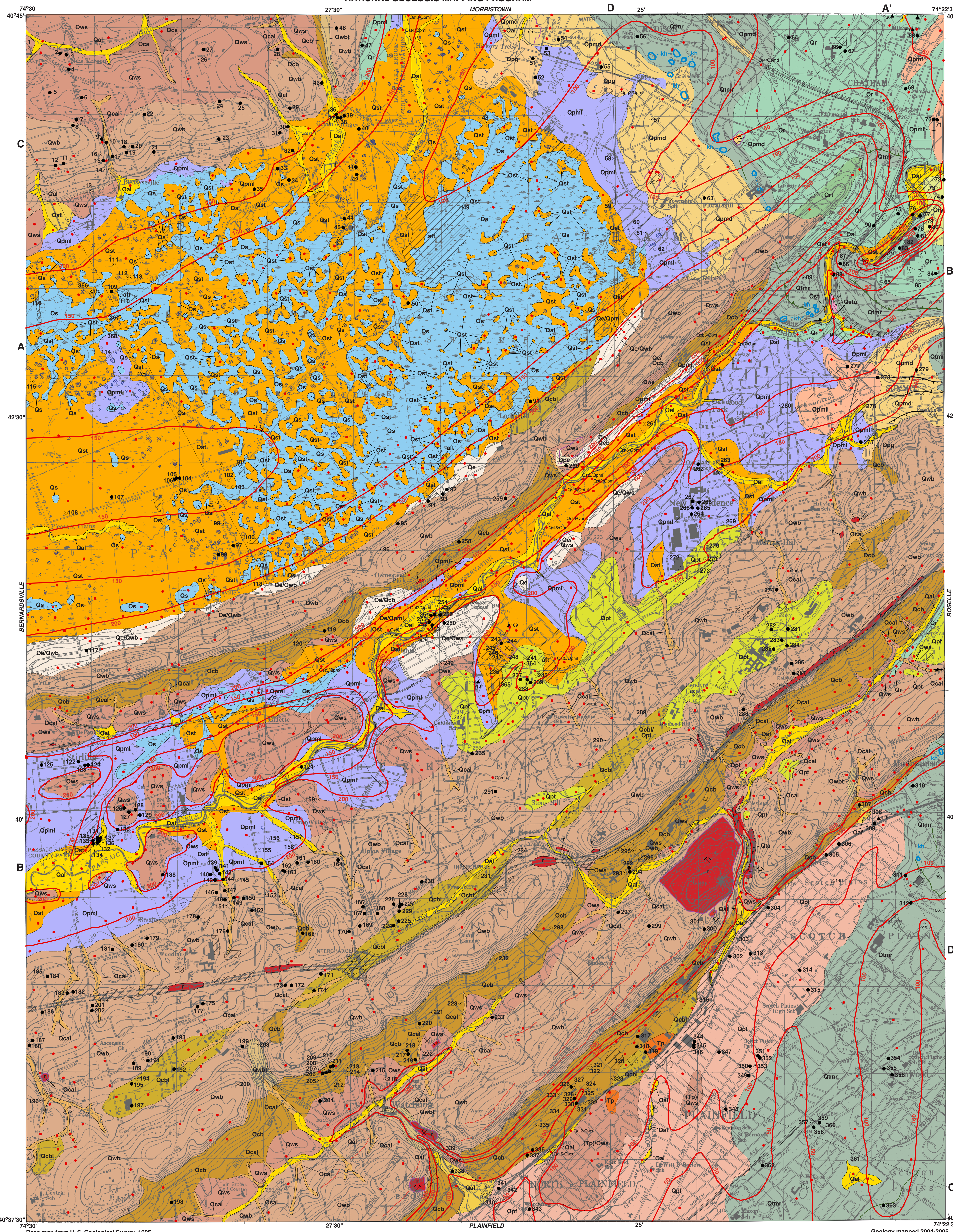
Topographic features of the terminal moraine

Narrow ridge--Line on crest.

Broad ridge--Line on crest.

Asymmetric ridge--Line on crest, barbs on gentle slope.

kh Kettle--Line on perimeter.



Base map from U. S. Geological Survey, 1995
Corner ticks are on North American Datum of 1983. Geology and base map do not edge-match adjoining published quadrangles with corner ticks on North American Datum of 1927. Overlap of information occurs at the west and south edge of the quadrangle, and a gap of information occurs at the east and north edge.

Geology mapped 2004-2005
Cartography by S. Stanford and M. Girard

Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 04HQAG0043. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

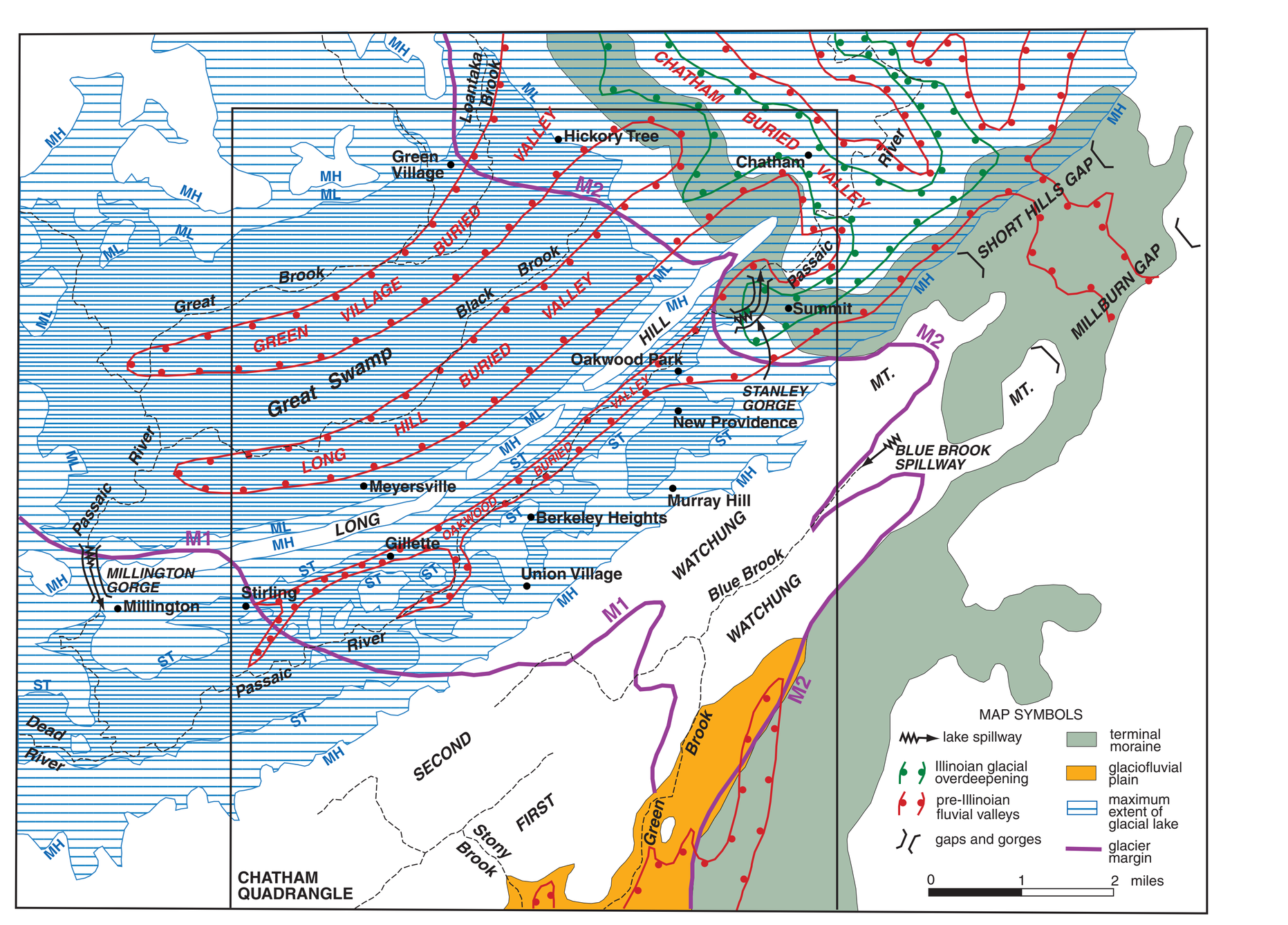
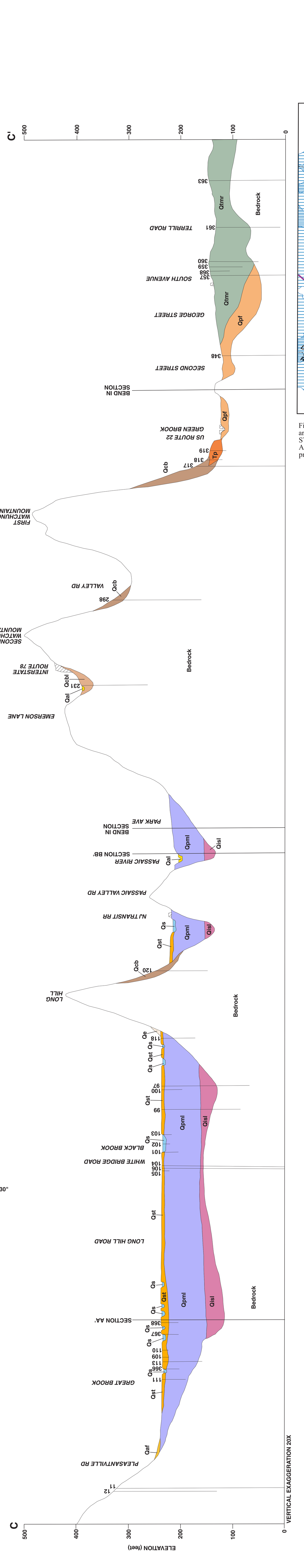
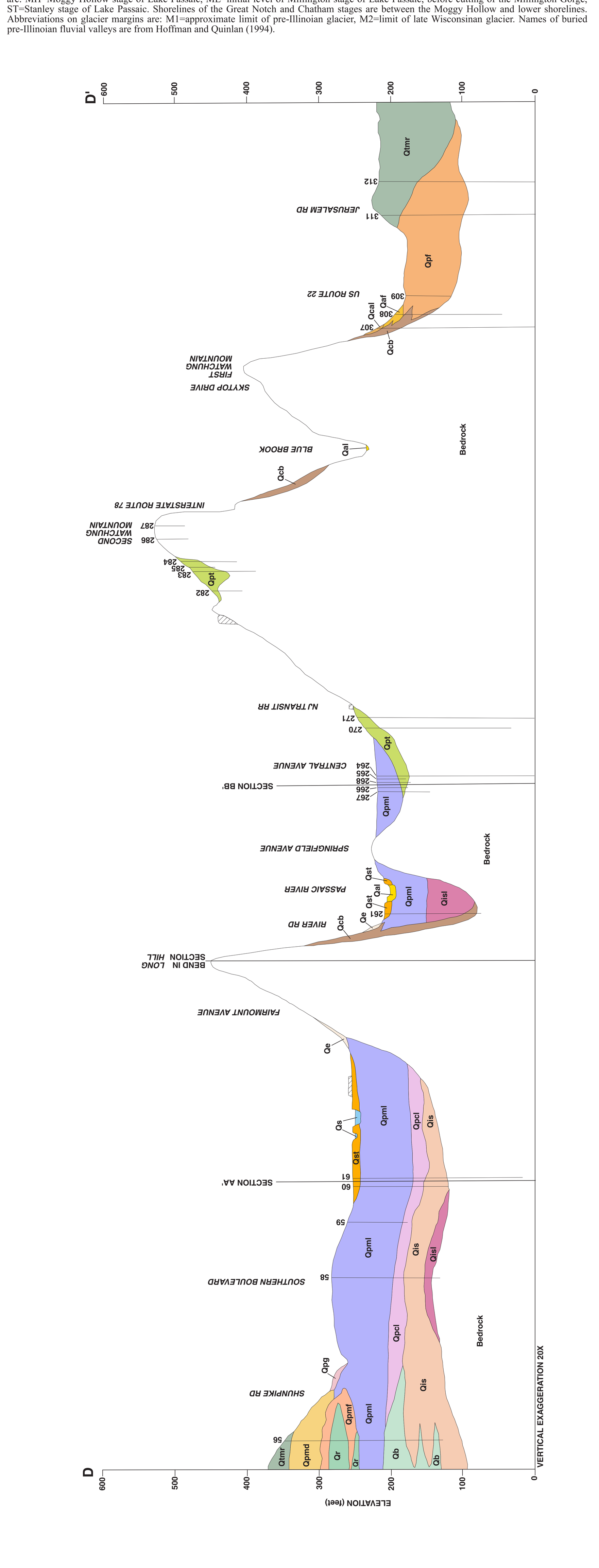
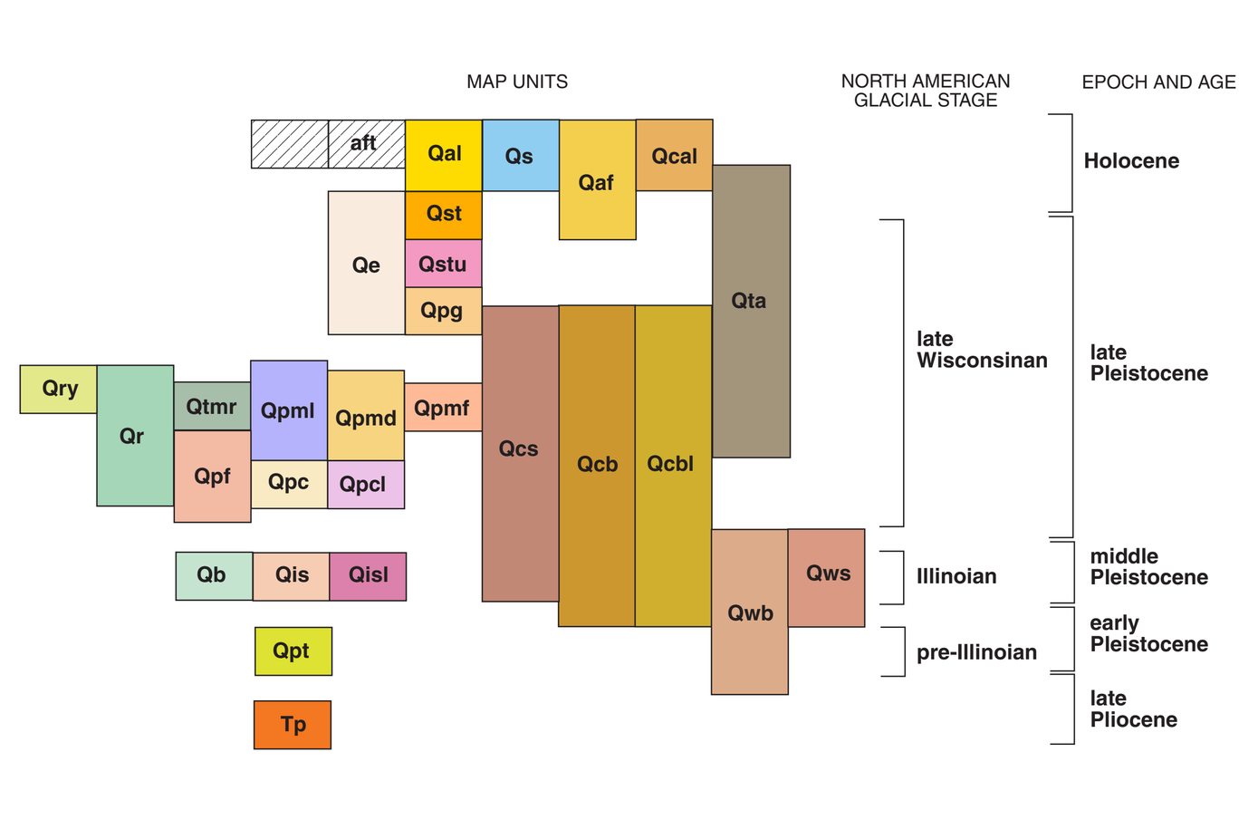


Figure 1.--Geomorphic and glacial features in the Chatham quadrangle and vicinity, and places named in text. Abbreviations on lake shorelines are: MH=Moggy Hollow stage of Lake Passaic, ML=initial level of Millington stage of Lake Passaic, before cutting of the Millington Gorge, ST=Stanley stage of Lake Passaic. Shorelines of the Great Notch and Chatham stages are between the Moggy Hollow and lower shorelines. Abbreviations on glacier margins are: M1=approximate limit of pre-Illinoian glacier, M2=limit of late Wisconsinan glacier. Names of buried pre-Illinoian fluvial valleys are from Hoffman and Quinlan (1994).





CORRELATION OF MAP UNITS



SURFICIAL GEOLOGY OF THE CHATHAM QUADRANGLE MORRIS, UNION, AND SOMERSET COUNTIES NEW JERSEY

by
Scott D. Stanford

2007

SCALE 1:24 000

1 MILE — 1000 0 1000 2000 3000 4000 5000 6000 7000 FEET — 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

APPROXIMATE MEAN DECLINATION, 1999

LOCATION IN NEW JERSEY

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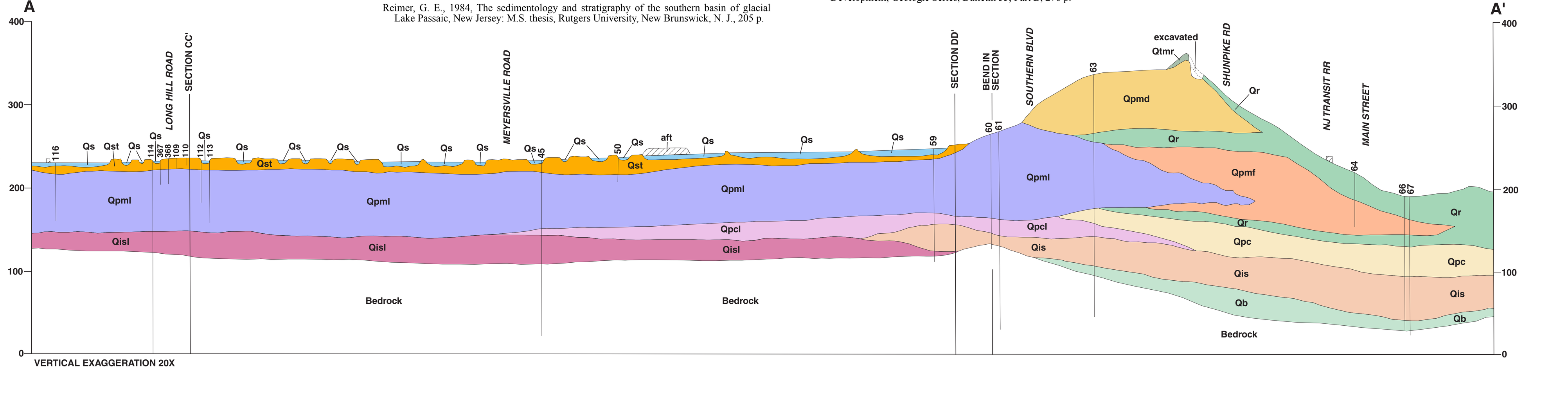

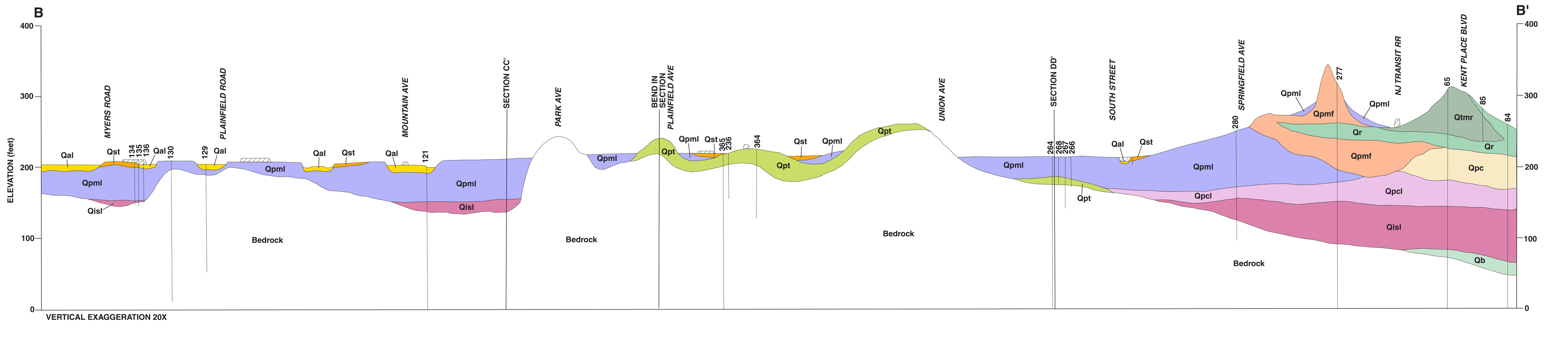

Surficial Geology of the Chatham Quadrangle
Morris, Union, and Somerset Counties, New Jersey

New Jersey Geological Survey
Open-File Map 69
2007

pamphlet to accompany map

Table 1.--Selected well and boring records.

Well no.	Identifier[1]	Depth to bedrock or driller's log with depth and description[2]	
1	25-23739	4	
2	25-37270	0-5	soil (Qws)
		5-10	soft shale (Qws)
		10-175	shale
		175-440	argillite
3	25-24588	5	
4	25-23669	0-14	red clay, sand (Qws)
		14-198	red shale
5	25-27121	0-12	clay (Qws)
		12-260	argillite, shale
6	25-19827	0-26	clay and sand-gravel (Qws)
		26-148	red and gray shale
7	25-20227A	0-12	clay and shale (Qws)
		12-99	red shale
8	25-20305	0-12	overburden (Qwb)
		12-85	trap rock
		85-174	red rock and shale
9	25-40120	0-17	brown clay and cobbles (Qwb)
		17-30	fractured rock and clay (Qwb)
		30-84	trap rock, gray
		84-173	red shale
10	25-26095	0-20	unconsolidated rock (Qwb)
		20-400	rock
11	25-19138	0-5	overburden (Qwb)
		5-200	limestone (basalt)
		200-350	red rock
		350-400	gray rock
12	25-20307	0-13	clay and stones (Qwb)
		13-198	trap rock
13	25-352	0-20	clay and boulders (Qwb)
		20-183	trap rock
14	25-22466	0-10	loose stones and dirt (Qwb)
		10-130	trap rock

15	25-42820	0-28	loose stones, rock, and brown clay-like soil (Qwb)
		28-150	hard trap rock
16	25-25075	0-40	broken rock (Qwb)
		40-140	trap rock
17	25-27582	0-18	rocky overburden (Qcal over Qwb)
		18-160	granite (basalt)
18	25-25559	0-8	hardpan (Qwb)
		8-170	trap rock
		170-348	red and gray shale
19	25-27380	0-15	rocky overburden (Qwb)
		15-340	rock
20	25-25592	0-40	unconsolidated rock and gravel (Qwb)
		40-300	blue rock
21	25-28776	0-20	overburden (Qwb)
		20-25	broken black rock (Qwb, basalt)
		25-174	hard black-gray rock (basalt)
		174-300	reddish-brown rock
22	25-32292	0-25	brown soil with stones (Qwb)
		25-35	hard trap rock
		35-310	medium hard red shale
23	25-25283	0-15	loose dirt and stones (Qwb)
		15-30	broken trap
		30-130	hard trap rock
24	25-25037	0-15	loose stones (Qwb)
		15-210	red shale
25	25-24830	0-25	light brown soil (Qwb)
		25-110	trap rock
		110-230	red and gray shale
26	25-30696	0-5	sand, clay, gravel overburden (Qws)
		5-300	red shale
27	25-20395	0-46	red rock
		46-55	sand (Qws)
		55-298	gray shale
28	25-27875	0-40	overburden (Qws and shale)
		40-250	green and red rock
29	25-38836	0-3	soil
		3-15	broken trap and soil (Qwb)
		15-25	weathered trap rock (Qwb)
		25-90	trap rock
		90-150	argillite
30	25-25962	0-20	sandy clay overburden (Qwb)
		20-165	trap rock
		165-173	red shale
31	25-35188	0-7	brown dry soil, stable (Qwb)
		7-15	brown trap rock
		15-150	hard blue trap rock
32	25-30084	0-23	red-orange clay (Qst over Qpml)
		23-34	gray clay (Qpml)
		34-273	trap rock
33	25-32240	0-15	sand with some water (Qst)

		15-52	gray clay (Qpml)
		52-105	mixed red and gray shale
34	25-28692	0-7	sandy soil with water (Qst)
		7-63	gray clay (Qpml)
		63-145	red shale
35	25-45237	0-6	clay (Qst)
		6-14	sand (Qst)
		14-28	clay (Qpml)
		28-183	red shale
		183-450	trap
36	25-27525	0-40	sand (Qst over Qpml)
		40-100	brown rock
37	25-23164	0-78	clay (Qst over Qpml)
		78-90	rock
38	25-40328	0-3	soil
		3-75	red sand, some clay mixture (Qst over Qpml)
		75-200	red shale rock
39	25-42156	0-5	clay (Qst)
		5-21	red sand (Qst)
		21-78	red clay (Qpml)
		78-200	trap
40	25-31241	0-15	sand and gravel (Qst)
		15-90	gray clay (Qpml)
		90-95	weathered rock (Qwb)
		95-125	trap rock
41	25-31368	0-15	brown sand (Qst)
		15-90	gray clay (Qpml)
		90-120	fine gray sand (Qis or Qisl)
		120-128	broken shale and rock
		128-200	red shale
42	25-45181	0-2	soil
		2-15	sand (Qst)
		15-95	clay (Qpml)
		95-117	sand (Qis or Qisl)
		117-300	trap
43	25-28535	0-85	trap
		85-200	red shale
44	25-34396	0-12	gray sand (Qst)
		12-42	hard gray clay (Qpml)
		42-210	medium hard red shale (anomalously high bedrock surface, may include some Qpml, well is cased to 71 feet)
45	25-27001	0-80	gray clay (Qst over Qpml)
		80-120	fine gray sand (Qpcl over Qisl)
		120-210	red shale
46	25-20707	0-10	brown sand and clay (Qwb)
		10-70	hard blue basalt
		70-210	red and gray shale
47	25-39863	0-7	gray clay-like soil (Qwb)
		7-18	mixed brown soil, some loose stones (Qwb)
		18-100	hard blue trap rock
48	boring GS5	0-10	sand and silt (Qst)
	Reimer (1984)	10-87	laminated silt and clay (Qpml)
		87-126	sand and silt (Qpcl over Qisl or Qis)

		126-154	laminated silt and clay (Qisl)
		154-157	sand and silt (Qisl)
		at 157	shale
49	25-36268	0-12	gray silty sand with some gray clay (Qst)
		12-19	gray clay (Qpml)
50	25-36270	0-22	gray and tan silty sand, medium-to-coarse sand (Qst)
		22-30	gray clay (Qpml)
51	N 25-14-847	well shows almost 200 feet to bedrock	
52	N 25-14-871	0-62	sand and gravel over lacustrine clay (Qpg over Qpml)
53	25-21429	0-30	gravel, clay (Qpml and Qpmd)
		30-80	clay (Qpml)
		80-100	sand (Qpc)
		100-220	clay (Qpcl over Qisl)
		220-230	sand (Qis)
		230-300	red shale
54	25-13396	abbreviated log	
		0-20	clay and gravel (Qpmd and Qpml)
		20-50	clay and fine sand (Qpml)
		50-80	clay, fine sand, and trace of gravel (Qpcl over Qpc)
		80-90	small gravel (Qpc)
		90-130	sand (Qpc)
		130-185	clay and fine sand (Qpcl)
		185-205	red clay (Qisl)
		205-215	fine sand and silt (Qisl)
		215-260	clay and silt (Qisl)
		260-280	gray rock
		280-420	red rock
55	25-38283	abbreviated log	
		0-10	brown clay, fine sand, silt (Qpmd)
		10-12	stiff gray clay (Qpml)
56	90-86	abbreviated log	
	U. S.	0-48	sand, silt, fines downward (Qtmr over Qpmd)
	Geological	48-50	pebbles, cobbles (Qpmf)
	Survey	50-85	till (Qr)
	test boring	85-93	coarse sand (Qpmf)
		93-98	till (Qr)
		98-132	silt, sand, clay, laminated (Qpml)
		132-160	clay-rich till (Qb)
		160-182	fine-to-coarse sand, fines downward (Qis)
		182-185	till (Qb)
		185-207	sand, silt, a little clay, laminated (Qis)
		207-211	possibly till (Qb)
		211-220	(no report)
		at 220	shale
57	N 25-14-886	0-165	sand, clayey sand, and fine sediment, no rock struck (Qpmd over Qpml, Qpcl, and Qisl)
58	25-3476	0-5	dirt (Qpml)
		5-20	sand, stones, and clay (Qpml)
		20-50	silt and stones (Qpml)
		50-100	clay (Qpml over Qpcl)
		100-115	fine water-bearing sand (Qis)
		115-130	clay and sand (Qis over Qisl)
		130-138	clay (Qisl)
		138-150	red rock
59	boring GS4	0-5	(no report, Qst)
	Reimer (1984)	5-15	brown, dark-brown laminated silty clay (Qpml)
		15-20	brown, dark-brown sand and silt (Qpml)

		20-56	brown, dark-brown laminated silt and clay (Qpml)
		56-75	dark grayish-brown sand and silt (Qpcl)
		75-89	brown, reddish-brown, reddish-gray laminated silty clay (Qpcl)
		89-125	brown to dark yellowish-brown sand and silt, coarsening upward (Qis)
		125-136	brown, reddish-brown, reddish-gray laminated silty clay (Qisl)
		at 136	shale
60	25-485	0-70	light-brown clay (Qpml)
		70-100	brown silt (Qpml)
		100-118	red sticky clay (Qpcl or Qisl)
		118-132	red and blue gravel, some water (Qis)
		132-137	red sandstone rock
61	25-534	0-10	blue clay (Qpml)
		10-64	brown clay (Qpml)
		64-107	light-brown clay (Qpml)
		107-117	fine green sand (Qpcl or Qis)
		117-128	red clay and stones (Qis or Qb)
		128-238	red and blue shale
62	N 25-24-226	0-10	gray clay, occasional small pebble (Qpml)
		10-100	pinkish-gray clay (Qpml)
		100-107	pinkish-gray clayey fine sand (Qpcl)
		107-117	red clayey silt (Qisl)
		117-128	red clay (Qisl or Qb)
		128-238	gray and red shale
63	25-15137	0-225	clay and sand (Qpmd over Qpml, Qpcl, Qis)
		225-250	red shale
		250-293	hard gray trap rock
64	25-38209	0-5	asphalt fill
		5-35	boulders and brown silty sand (Qr)
		35-65	brown silty sand (Qpmd)
65	25-7298	0-20	clay and stones (Qr, Qtmr)
		20-70	clay and gravel (Qtmr, Qr)
		70-120	clay (Qpcl)
		120-150	sandy clay (Qisl)
		150-183	clay (Qisl)
		183-196	hardpan (Qb)
		196-335	red rock
		335-375	gray rock
		375-503	red rock
		503-585	red and gray rock
		585-710	gray rock
		710-719	hard trap rock
66	25-5687A	0-4	fill
		4-20	sand, clay, stones, and gravel (Qr)
		20-25	hardpan, large stones (Qr)
		25-26	sand and gravel (Qpmf)
		26-87	clay, sand, boulders, gravel, and hardpan (Qr and Qpmf)
		87-95	coarse-to-fine sand (Qpc)
		95-105	coarse sand, large and small gravel (Qis)
		105-149	coarse sand and gravel, small boulders (Qis)
		149-157	hardpan, boulders (Qb)
		157-162	shale
		screened 94-150, yield 1200 gpm	
67	25-5688A	0-5	fill
		5-11	hardpan (Qr)
		11-16	sandy clay (Qr)
		16-25	fine sand (Qpmf)
		25-32	hardpan (Qr)
		32-35	sand and gravel (Qpmf)
		35-37	fine sand and clay (Qpmf)
		37-46	sand and gravel (Qpmf)

		46-86	clay, hardpan, and boulders (Qr)
		86-91	fine sand (Qpc)
		91-151	sand and gravel (Qis)
		151-157	hardpan (Qb)
		157-162	red and gray shale
68	25-4986	0-8	brown clay (Qr)
		8-13	brown sand, clay, stones (Qr)
		13-17	gray sand, clay, stones (Qr)
		17-21	large rocks, stones (Qr)
		21-36	fine brown sand (Qpc)
		36-43	brown sand, clay (Qpc, Qpcl)
		43-61	brown sand (Qpc)
		61-90	red clay (Qisl)
		90-101	coarse brown sand (Qis)
		101-104	gray clay, sand (Qis, Qisl)
		104-119	gray sand, stones, gravel (Qis)
		119-124	yellow clay (Qb?)
		screened 111-117, yield 50 gpm	
69	25-14164	0-38	till, silty, sandy, pebbly, boulders from 0-20, brown (Qr)
		38-42	medium sand, well sorted (Qpc)
		42-62	silty clay, and clayey silt, laminated, brown (Qpcl)
		62-73	medium sand, some coarse sand, well sorted (Qis)
		73-76	clayey silt, brown (Qisl)
		76-98	medium-to-coarse sand with little fine gravel (Qis)
		98-110	silty clay with some fine sand below 105, brown (Qisl)
		110-120	very fine-to-very coarse sand, with fine gravel (Qis)
		120-161	medium-to-coarse sand to fine gravel, silty (Qis)
		161-191	till, sandy, silty, pebbly, compact, brown (Qb)
		191-197	shale and sandstone
		screened 140-150, yield 201 gpm	
70	25-35153	abbreviated log	
		0-25	brown coarse-to-fine sand (Qpmf)
		25-40	brown silty clay, trace sand and gravel (Qr)
		40-53	brown coarse-to-fine sand, little clayey silt (Qpc)
		53-56	brown silty clay (Qpcl)
71	25-38696	abbreviated log	
		0-31	layered coarse-to-fine sand, cobbles, boulders (Qpmf)
		31-40	silt, medium sand, and gravel (Qr)
		40-50	fine-to-medium sand, fine gravel, silt lenses (Qpc)
72	25-38742	0-10	light brown sand, trace clay, some silt (Qry)
		10-26	light brown sand, some cobbles and gravel, trace clay, some silt (Qry)
73	25-24-331	0-168	sand, gravel, boulders, clay, etc. (Qr, Qry over Qpc, Qis)
		168-225	red rock
74	25-34229	abbreviated log	
		0-31	brown to reddish-brown silty clay, trace sand and gravel (Qry, Qr)
75	25-40089	0-22	red-brown fine sand and gravel with silty clay and trace cobbles (Qr)
76	25-35447	abbreviated log	
		0-11	gray silty medium-to-fine sand, trace gravel (Qal)
		11-19	red-brown clayey till (Qr)
		19-20	sandstone
77	25-36821	abbreviated log	
		0-11	reddish-brown to gray sand and silt, little clay and gravel (Qr)
		11-12	yellowish weathered rock
		12-18	gray shale
78	25-41273	0-15	till (Qr)
		15-27	bedrock

79	25-37644	0-10	clay, silt, trace sand, gravel (Qr)
		10-14	red shale
80	25-41718	0-15	till (Qry)
		15-95	bedrock
81	25-41724	0-11	till (Qr)
		11-150	bedrock
82	25-44795	0-18	overburden (Qr)
		18-820	red and gray sandstone
		820-830	trap rock
83	25-33784	abbreviated log	
		0-25	rocky sand and gravel (Qr)
		25-810	red, brown, gray sandstone
		810-825	gray trap rock
84	25-8476	0-45	gravel and clay (Qr)
		45-57	sand, gravel, boulders (Qpc)
		57-90	sand and gravel (Qpc)
		90-106	fine sand (Qpc)
		106-120	solid brown clay (Qpcl)
		120-125	very fine brown sand (Qisl)
		125-165	brown clay (Qisl)
		165-175	very fine sand (Qisl)
		175-195	brown clay (Qisl)
		195-207	sand and clay mixed (Qb)
		207-624	red and blue shale
		624-642	trap rock
85	25-37672	abbreviated log	
		0-49	clay, a little fine-to-medium sand and gravel (Qr)
86	25-10863	0-90	hardpan (Qtmr)
		90-126	clay (Qpml or Qpcl)
		126-172	red sandstone
87	25-3353	0-10	stones and clay (Qtmr)
		10-70	clay (Qtmr over Qpml)
		70-135	dirty sand (Qis)
		135-145	red rock
88	N 25-24-319	196	
89	25-19990	200	
90	25-36966	0-25	clayey silt with some gravel (Qr)
		25-64	clayey silt with large gravel (Qr)
		64-80	fine sand, some silt (Qpc)
91	25-19177A	0-40	clay (Qst over Qpml)
		40-85	basalt
92	25-10269	0-22	rotten rock (Qwb)
		22-142	basalt rock
93	25-30605	0-20	brown sand (Qe)
		20-25	broken rock and loose stones (Qwb)
		25-135	hard trap rock
94	25-36692	0-4	rocky fill
		4-12	brown soil, some decomposed rock (Qwb)
		12-125	mixed hard trap rock
95	25-10194	0-12	hardpan and boulders (Qwb)
		12-130	trap rock

96	25-14346	2	
97	25-25476	0-108	clay and fine sand (Qst over Qpml over Qisl)
		108-170	mixed red and gray shale
98	25-9160	0-90	clay (Qst over Qpml over Qisl)
		90-135	red shale
		135-158	gray rock
		158-200	red rock
99	25-30374	0-90	clay (Qst over Qpml over Qisl)
		90-150	shale
100	25-41821	0-40	silty clay (Qst over Qpml)
101	25-41784	0-8	fill
		8-20	soft brown peat-like material (Qs)
		20-35	soft gray-brown moist clay (Qs or Qpml)
102	25-46904	0-15	tan, brown moist to wet silty clay (Qst over Qpml)
103	25-46902	0-15	dark brown moist to wet silty clay (Qst over Qpml)
104	25-52389	0-77	clay (Qst over Qpml over Qisl)
		77-250	shale
105	25-49449	0-3	light brown fine-to-medium silty sand (Qst)
		3-14	light brown clayey silt (Qpml)
106	25-48748	0-80	clay (Qst over Qpml over Qisl)
		80-275	red shale
107	25-11658	0-70	clay (Qst over Qpml over Qisl)
		70-155	red rock
108	25-7226	0-70	sand and mud (Qst over Qpml over Qisl)
		70-100	shale
109	25-53430	0-7	brown fine-to-coarse sand, little silty clay (Qst)
		7-12	brown fine sand, some medium sand and silt (Qst)
110	25-28393	0-8	sandy clayey silt (Qst)
		8-10	clay (Qpml)
111	25-49108	0-5	fill
		5-7	black clayey sand (Qst)
		7-35	green clay (Qpml)
		35-40	red green clay (Qpml)
		40-45	red green clay and weathered bedrock (Qpml)
112	25-49100	0-4	brown silty sand (Qst)
		4-10	black clayey sand (Qst)
		10-50	green clay (Qpml)
113	25-49104	0-4	fill
		4-10	black clayey sand
		10-60	green clay (Qpml)
		60-65	red green silty clay (Qpml)
		65-70	silty red clay (Qws)
		70-75	silty red clay with weathered shale
114	25-14791A	0-130	clay, sand (Qst over Qpml over Qisl, 130 is depth of casing)
		130-300	red shale
115	90-139	0-3	broken gray silty clay (Qst)
		3-9	broken varied (varved?) silty clay (Qst)
		9-17	broken varied silty clay and sand (Qst)
		17-77	gray broken varied silty clay (Qpml)

116	90-136	0-3	gray and brown silty clay and vegetation (Qst)
		3-7	brown silty clay, gravel, varied (Qst)
		7-12	brown silty clay and fine sand, varied (varved?) (Qst)
		12-32	gray brown varied silty clay (Qpml)
		32-66	gray brown silty clay (Qpml)
		66-67	brown decomposed shale
117	25-26289	0-8	sandy soil (Qe)
		8-190	trap rock
118	25-6870	24	
119	25-26201	0-6	sandy hardpan (Qcb)
		6-173	red shale
120	25-9354	0-40	gray clay (Qcb, possibly over Qws or Qpml)
		40-100	red shale
121	25-30207	0-10	fine-to-medium sand (Qal)
		10-28	sand, cobbles, and silt (anomalous log, should be Qpml clay)
		28-60	sand, gravel, and clay (anomalous log, should be Qpml clay)
		60-400	red shale
		400-900	trap rock
122	25-10198	0-56	clay (Qpml)
		56-91	red shale and sandstone
123	25-26421	0-38	pure red clay (Qpml)
		38-147	red shale
124	25-28114	0-40	gray clay (Qpml)
		40-150	mixed red and gray shale
125	25-20337	0-30	clay (Qpml)
		30-145	red shale
126	25-41707	0-10	yellow highly fractured rock, with some fine sand (Qws, with Qe)
		10-16	highly fractured red-brown shale
127	25-31947	0-5	fill
		5-12	gray clay (Qws and Qpml)
		12-130	medium hard red shale
128	25-23687	0-30	gray clay (Qws and Qpml)
		30-150	hard red shale
129	25-28113	0-12	gray clay (Qpml)
		12-150	red shale
130	25-39964	0-10	clay overburden (Qpml)
		10-200	shale
131	EEC B2A	0-9	fill
		9-15	brown clayey silt, trace fine sand (Qal)
		15-52	gray-brown varved silty clay (Qpml)
		52-56	red-brown silt and decomposed shale (Qws)
132	EEC B21A	0-9	fill
		9-25	dark gray clayey silt, little fine sand (Qal)
		25-58	gray-brown varved silty clay, with fine sand partings (Qpml)
		58-64	red-brown shale fragments, silt and sand (Qws)
		64-65	red-brown fractured shale
133	EEC B11A	0-9	fill
		9-15	brown clayey silt, trace fine sand (Qal)
		15-60	dark gray to gray-brown varved silty clay, trace fine sand (Qpml)
		60-65	red-brown clayey silt with shale fragments (Qws)

		65-66	red-brown fractured shale
134	EEC B18A	0-3	fill
		3-10	gray-brown mottled clayey silt, little fine sand (Qst)
		10-56	gray to gray-brown varved silty clay, with fine sand partings (Qpml)
		56-61	red-brown clayey silt with shale fragments (Qws)
		61-62	red-brown highly fractured shale
135	EEC B16A	0-6	fill
		6-16	gray-brown varved silty clay, varves of fine sand at 8 feet (Qst?)
		16-24	gray varved silty clay (Qpml)
		24-58	gray-brown silty clay, with fine sand partings (Qpml)
		58-61	gray-brown clayey silt with shale fragments (Qws)
136	EEC B23A	0-4	fill
		4-15	light brown mottled silty clay, trace fine sand (Qal)
		15-31	gray varved silty clay, trace fine sand (Qpml)
		31-56	gray-brown and red-brown varved silty clay, trace fine sand (Qpml)
		56-57	red-brown highly decomposed shale (Qws)
137	EEC B1A	0-2	fill
		2-4	gray, brown clayey silt with trace vegetation (Qal)
		4-20	brown varved silt and clayey silt (Qpml)
		20-52	brown , red-brown silty clay (Qpml)
138	25-23988	0-20	clay (Qpml over Qws)
		20-170	red and gray shale
139	25-28888	0-35	gray clay (Qpml)
		35-40	red shale
		40-125	soft trap rock
140	25-25158	0-24	clay (Qpml)
		24-27	large gravel and water (Qwb)
		27-130	soft blue trap rock
141	25-25159	0-28	clay (Qpml)
		28-31	water gravel (Qwb)
		31-150	soft trap rock
142	25-25155	0-15	clay and mixed stones (Qpml over Qwb)
		15-150	layered trap rock
143	25-25157	0-28	clay (Qpml)
		28-34	broken trap rock, water (Qwb)
		34-185	medium hard rock
144	25-25156	0-22	clay (Qpml)
		22-35	decomposed trap and water (Qwb)
		35-230	hard trap rock
145	25-14887	0-18	clay (Qwb)
		18-100	gray rock
146	25-25112	20	
147	25-25110	0-28	clay (Qwb)
		28-31	broken rock and water (Qwb)
		31-150	soft blue trap rock
148	25-23476	0-20	clay and stones (Qwb)
		20-450	trap rock
149	25-28978	5	
150	25-20072	0-8	clay and broken rock (Qwb)
		8-299	trap rock

151	25-25672	0-12	sandy hardpan (Qwb)
		12-323	trap rock
152	25-28793	0-12	yellow clay, some loose stones (Qwb)
		12-255	hard trap rock
153	25-26204	0-20	clay (Qwb)
		20-35	broken trap rock
		35-270	solid gray trap rock
154	25-30242	0-30	clay, gravel, boulders (Qpml over Qwb)
		30-200	argillite
155	25-25157	0-28	clay (Qpml)
		28-34	broken trap rock and water
		34-185	medium hard rock
156	25-9168	0-33	blue clay (Qpml)
		33-85	shale
157	25-8892	0-40	blue clay (Qpml)
		40-95	red shale
158	25-8785	0-47	dirt, clay (Qpml)
		47-63	sand rock
159	25-7410	0-20	red clay (Qws)
		20-100	red shale
160	25-16030	0-35	stony soil (Qwb)
		35-110	trap rock
161	25-15993	0-15	clay (Qwb)
		15-120	trap rock
162	25-27201	0-20	unconsolidated rock (Qwb)
		20-600	blue stone
163	25-25207	0-20	clay and stones (Qwb)
		20-35	loose trap rock
		35-235	trap rock
164	25-33746	0-4	brown soil and stones (Qwb)
		4-20	fractured trap rock
		20-310	trap rock
		310-355	softer red trap rock
		355-375	hard trap
165	25-15104	0-15	overburden (Qcb)
		15-165	hard trap
		165-189	baked shale
166	25-27337	0-6	clay, some loose stones (Qwb)
		6-135	hard trap
		135-180	red shale
		180-190	trap
167	25-25423	0-6	clay and stones (Qwb)
		6-150	trap rock
		150-170	red shale
168	25-40258	0-40	red-brown clay with some stones (Qwb)
		40-75	hard trap rock
		75-110	mixed red shale and trap rock
169	25-33153	0-7	loose and broken trap rock with some dry brown soil (Qwb)
		7-75	hard trap rock
		75-150	mixed red shale and soft volcanic rock

170	25-25373	0-6	clay and stones (Qwb)
		6-210	trap rock
171	25-15740	25	
172	25-9112	0-50	loose stone (Qwb and fractured basalt)
		50-72	trap rock
173	25-9786	62 (includes fractured basalt)	
174	25-33152	0-12	brown clay soil (Qcbl)
		12-18	weathered rock (Qwb)
		18-300	hard blue trap rock
175	25-28862	0-15	loose stones and clay (Qwb)
		15-90	hard trap rock
		90-150	shale and red rock
176	25-22676	0-25	clay and broken rock (Qwb)
		25-160	trap rock
177	25-28860	0-12	yellow clay and stones (Qwb)
		12-105	trap rock
		105-125	red rock
		125-145	trap rock
		145-180	red shale
178	25-37923	0-17	yellow, gray clay-like loam with some silt (Qwb)
		at 17	rock
179	25-27161	0-25	clay (Qwb)
		25-225	trap rock
180	25-23106	0-25	clay (Qwb)
		25-190	trap rock
181	25-35338	0-6	brown soil and stones (Qwb)
		6-200	blue trap rock
		200-240	red trap rock
		240-310	gray trap rock
182	25-29564	38	
183	25-29563	36	
184	25-29080	0-12	yellow clay soil with some stones (Qwb)
		12-230	hard trap rock
185	25-15855	35	
186	25-19297	0-50	clay and boulders (Qwb and fractured basalt)
		50-250	trap rock
187	25-24068	0-6	mixed dirt and stones (Qwb)
		6-90	trap rock
188	25-25376	0-12	clay and stones (Qwb)
		12-130	trap rock
189	25-25276	0-20	clay and stones (Qwb)
		20-45	red hardpan (shale)
		45-55	decomposed trap rock
		55-125	trap rock
190	25-8627	0-26	clay (Qwb)
		26-100	blue rock

191	25-27604	30	
192	25-24-718	0-7	overburden
		7-480	trap rock
		480-600	red rock
193	25-14809	0-40	clay (Qwb)
		40-125	trap rock
194	25-11111	0-12	clay, gravel (Qwb)
		12-32	rotten rock (Qwb)
		32-215	basalt
195	25-31812	0-14	hardpan (Qcbl over Qwb)
		14-28	fractured rock
		28-523	blue trap
		523-723	red rock
196	25-7229	0-75	clay and stone (Qwb and fractured basalt)
		75-150	rock
197	25-42061	abbreviated log	
		0-5	orange-brown clayey silt and little fine sand (Qcbl)
		5-18	orange-tan and brown fine sand (Qwb)
198	25-8153	0-30	loose rock (Qcb)
		30-200	red shale
199	25-24860	0-30	overburden (Qwb)
		30-350	trap rock
		350-540	red rock
200	25-25915	0-25	clay and some loose stones (Qwb)
		25-340	hard trap rock
		340-410	red shale
201	25-32375	0-12	yellow-brown soil (Qwb)
		12-40	trap rock
202	25-30359	0-6	clay (Qwb)
		6-60	fractured rock
		60-460	trap rock
203	25-7237	0-10	dirt (Qwb)
		10-300	trap rock
		300-525	red rock
204	25-104	0-8	clay (Qws)
		8-152	red shale and sandstone
205	25-634	0-50	clay (Qcb)
		50-140	red shale and sandstone
206	25-525	0-60	clay (Qcb)
		60-185	red shale and sandstone
207	25-1142	0-35	red clay (Qcb)
		35-190	red shale and sandstone
208	25-682	0-60	clay (Qcb)
		60-184	red shale
209	25-644	0-65	red clay (Qcb)
		65-181	red shale
210	25-1399	0-70	clay (Qcb)
		70-180	shale and sandstone

211	25-840	0-60	clay
		60-185	red shale and sandstone
212	25-378	0-55	clay (Qcb)
		55-142	red shale and sandstone
213	25-269	0-10	clay (Qcb)
		10-113	red shale and sandstone
214	25-324	0-15	red clay (Qcb)
		15-126	red shale and sandstone
215	25-10577	0-20	soft shale (Qws)
		20-80	hard shale
		80-110	sandstone
216	25-1153	0-45	red clay (Qws)
		45-90	red shale
		90-117	sandstone
217	25-24667	0-40	clay (Qcb)
		40-160	red shale
218	25-1660	0-15	red clay (Qcb)
		15-105	red shale and sandstone
219	25-27076	40	
220	25-1429	0-30	red clay (Qcb)
		30-138	red shale and sandstone
221	25-833	0-35	red clay (Qcb)
		35-177	red shale and sandstone
222	25-646	0-35	filled-in land, dirt, stones
		35-50	loose, rotten brown rock (Qws)
		50-91	blue trap rock
223	25-20371	0-15	overburden (Qcb)
		15-150	shale
224	25-26584	0-25	clay (Qcbl and Qwb)
		25-190	trap rock
225	25-28664	0-22	clay (Qcbl over Qwb)
		22-100	trap
226	25-29424	0-15	stones and clay soil (Qwb)
		15-90	trap rock
		90-125	red shale
227	25-31951	0-35	clay (Qwb)
		35-96	red shale
		96-123	trap rock
228	25-31950	0-20	clay (Qwb)
		20-47	clay and gravel (Qwb)
		47-98	red shale
229	25-34205	0-40	sand and gravel (Qwb)
		40-125	trap rock
230	25-21539	0-88	clay and chunks of trap rock (Qcbl over Qwb and fractured basalt)
		88-123	trap rock
231	25-842	abbreviated log	
		0-25	soft clay (Qcbl)
		25-56	harder clay, like hardpan (Qwb)

		56-130	rock becoming harder with depth
232	23-6787	0-20	dirt and clay (Qcb)
		20-120	shale
233	25-34296	0-7	yellow brown clay soil (Qws)
		7-22	soft red shale
		22-150	trap rock
234	25-43605	18	
235	25-10126	0-22	dirt and stone (Qwb)
236	25-37135	0-13	fill
		13-32	red clay (Qpt)
		32-46	gray shale
		46-65	red shale
237	25-15315	0-48	clay (Qpt)
		48-130	shale
		130-400	sandstone and trap rock
238	25-15314	0-48	overburden (Qpt)
		48-300	argillite
239	25-40290	0-39	red clay (Qpt)
240	25-13238	0-70	hard red clay (Qpt over Qws)
		70-150	red rock
		150-195	trap rock
241	25-13038	0-35	clay (Qpt)
		35-41	sand (Qpt)
		41-303	red rock
242	25-32128	abbreviated log	
	B2	0-2	medium sand (Qst)
		2-32	silt and clay, trace gravel and sand (Qpt)
		at 32	bedrock
243	25-37624	0-52	gray clay (Qst over Qpml)
		52-56	weathered red shale (Qws)
		56-102	red shale
244	25-32128	abbreviated log	
	B8	0-13	fine-to-coarse sand and silt (Qst)
		13-51	varved silt and clay, 348 varves counted between 23 and 51 feet (Qpml)
		51-52	bedrock
245	25-32128	abbreviated log	
	B7	0-4	silt and sand (Qst)
		4-6	sand and gravel (Qst)
		6-9	clayey silt, fine-to-medium sand (Qst)
		9-50	varved silt and clay
		50-52	bedrock
246	25-37222	0-51	gray clay (Qst over Qpml)
		51-53	weathered red shale
		53-202	red shale
247	25-37226	0-50	silt and clay (Qst over Qpml)
		50-140	shale bedrock
248	25-32128	abbreviated log	
	B4	0-11	fill
		11-21	varved clay (Qpml)
		21-31	reddish-brown silt, clay, fine-to-coarse sand, trace weathered grains (Qpt)
		31-32	shale

249	25-38361	0-16	soft wet clay (Qws)
		16-35	dry red clay (Qws)
		35-173	red shale
250	25-26681	0-4	brown sandy silt (Qe)
		4-15	red-brown silty clay (Qws)
		15-16	red shale
251	25-24316	abbreviated log	
		0-5	fill
		5-6	gray fine sandy silt (Qst)
		6-56	gray-brown to red-brown varved silt and clay (Qpml)
		56-58	gray-brown clayey fine sandy silt, trace fine-to-medium gravel and rock fragments (preglacial alluvium or Qws)
		58-60	red-brown decomposed shale
252	25-24318	abbreviated log	
		0-4	fill
		4-9	silty clay to fine-to-medium sandy clayey silt (Qst)
		9-49	red-brown varved silty clay (Qpml)
		49-50	brown fine-to-medium sand and rock pieces (preglacial alluvium or Qws)
		50-54	decomposed shale
253	25-24221	abbreviated log	
		0-12	fill
		12-14	gray-brown clay, trace silt and rock pieces (Qst)
		14-34	varved gray-brown clay, some silt (Qpml)
		34-40	red-brown clayey silt and decomposed rock fragments (Qws)
254	25-24322	abbreviated log	
		0-4	fill
		4-14	brown-to-gray clayey silt, silty fine sand, trace fine-to-medium sand (Qst)
		14-48	brown, gray, reddish-brown varved silty clay (Qpml)
		48-52	decomposed shale
255	25-24256	abbreviated log	
		0-6	fill
		6-15	gray, brown clayey silt, silty fine sand, little medium sand (Qst)
		15-55	gray to red-brown varved silty clay (Qpml)
		55-58	red-brown clayey silt and decomposed shale (Qws)
256	25-24223	abbreviated log	
		0-4	fill
		4-8	sandy clayey silt to silty fine sand (Qst)
		8-43	gray to reddish brown varved silty clay (Qpml)
		43-44	dark gray-brown fine sandy clayey silt, with rock fragments (preglacial alluvium and Qws)
		44-46	red-brown decomposed shale
257	25-24315	abbreviated log	
		0-10	fill
		10-12	brown-gray clayey silt, silty fine sand, fine-to-medium sand (Qst)
		12-44	red-brown varved silty clay (Qpml)
		44-48	brown, gray-brown fine sandy silt, some rock fragments (preglacial alluvium and Qws)
		48-49	decomposed shale
258	25-21724	0-20	hard-packed light tan sand (Qcb)
		20-40	red shale
		40-135	sandstone
259	25-23653	15	
260	25-10363	0-80	decomposed shale and rock (Qws over shale)
		80-151	red rock
261	25-24-285	0-10	pinkish-gray sandy clay (Qst)

		10-110	pinkish-gray clay (Qpml over Qisl)
		110-118	well-rounded pebbles and sand (preglacial alluvium)
		118-130	clayey gravel and sand (Qcb)
		130-137	hard red shale
262	25-10530	0-72	clay and silt (Qpml over Qisl)
		72-300	red shale
263	25-40710	0-5	gray silt and fine sand (Qst)
		5-7	gray silt, little medium-to-fine sand, trace medium-to-fine gravel (Qst)
		7-12	brown clay (Qpml)
264	25-9445	0-82	black muck and fill over clay (Qpml)
		82-260	red sandstone
265	25-41127	0-7	silty clay with sand (Qpml)
		7-10	gray clay with silt (Qpml)
		10-32	reddish-brown till (Qpt)
		32-39	weathered shale
266	25-37717	abbreviated log	
		0-31	red, brown, grayish-brown silty clay (Qpml)
		31-35	silty fine sand (Qpt?)
		35-40	weathered shale
267	25-39750	0-5	sand, clay (Qpml)
		5-55	clay (Qpml
		55-75	shale
268	25-41131	0-7	silt, sand (Qpml)
		7-15	gray clay (Qpml)
		15-25	silty clay with gravel (Qpml)
		25-35	red till (Qpt)
		35-37	weathered shale
269	25-10632	0-26	red clay (Qpml)
		26-45	blue clay (Qpml)
		45-310	hard gray rock
270	25-9823	0-19	clay and broken rock (Qpt)
		19-207	trap rock
271	25-12855	0-12	dirt and boulders (Qpt)
		12-45	yellow clay (Qwb)
		45-285	gray rock
272	25-10333	0-20	clay (Qpml)
		20-30	soft trap rock (Qwb)
		30-200	trap rock
273	25-15684	0-163	trap rock (cased to 41 feet, Qpt less than 40 feet thick)
274	Healy	10 borings show	
	3/14/61	0-5 to 9	brown clay, sand, gravel, boulders (Qwb)
	borings	at 5 to 9	bedrock
275	25-3200	0-10	earth and fill (Qpg)
		10-33	clay (Qpml)
		33-196	trap rock
276	25-36559	0-5	boulders and cobbles (Qal)
		5-14	gray-brown silty clay (Qpml)
277	25-9176	0-53	sand (Qpmf)
		53-160	clay, gravel, and sand (Qr over Qpmf)
		160-223	clay (Qpml over Qpcl over Qisl)
		223-512	red rock

278	25-5068	0-108	clay and gravel (Qpmf over Qr)
		108-186	clay (Qpml over Qpcl over Qisl)
		186-190	broken rock (Qwb)
		190-348	trap rock
279	25-20602	0-150	brown quick sand (Qpmd)
		150-190	loose red shale
		190-195	gray rock
280	25-3271	0-90	gray clay (Qpml over Qpcl)
		90-125	red clay (Qisl)
		125-155	red sandstone
281	E10	abbreviated log	
		0-54	brown, orange-brown clayey silt to silty clay, little sand, little gravel of varied lithology--glacial till (Qpt)
		54-58	brown, greenish-gray dense sand, little silt--residual soil (Qwb)
		58-77	basalt
282	E9	abbreviated log	
		0-9	brown, grayish-brown clayey silt, little sand and gravel--glacial till (Qpt)
		9-24	brown, grayish-brown sand, little silt, dense, relict fractures--residual soil (Qwb)
		24-41	weathered basalt
283	E11	abbreviated log	
		0-52	brown to orange-brown clayey silt to silty clay, little sand, little gravel of varied lithology--glacial till (Qpt)
		52-69	orange-brown sand, little silt, relict structure--residual soil (Qwb)
		69-86	basalt
284	E12	abbreviated log	
		0-55	brown, orange-brown clayey silt to silty clay, little sand, little gravel--glacial till (Qpt)
		55-58	light brown decomposed granular basalt--residual soil (Qwb)
		58-77	basalt
285	E13	abbreviated log	
		0-20	brown, orange-brown clayey silt to silty clay, little sand, little gravel of varied lithology--glacial till (Qpt)
		20-28	reddish-brown sand and clayey silt, mixed with granular weathered rock--residual soil (Qwb)
		28-46	basalt
286	E14	abbreviated log	
		0-5	fill
		5-14	brown, light-gray sand, little silt, relict structure--residual soil (Qwb)
		14-47	basalt
287	E16	abbreviated log	
		0-5	brown clayey silt, little sand, little gravel (Qwb)
		5-23	brown, greenish-gray sand, little silt, fragments of competent rock, relict structure--residual soil (Qwb)
		23-41	basalt
288	25-34897	0-8	clay fill and stones (Qwb)
		8-22	brown clay overburden (Qwb)
		22-195	hard blue trap rock
		195-300	red shale and sandstone
289	25-30372	0-55	clay (Qwb)
		55-400	trap rock
290	N25-24-584	0-12	soil and wash with trap boulders (Qwb)
		12-59	reddish vesicular basalt
291	Healy	8 borings show	
	3/15/61	0-15	fine brown sand, clay, gravel, with some silt (Qwb)

	borings		
292	25-43712	abbreviated log	
		0-19	red-brown sand, silt, little gravel, clay (Qcb)
		19-27	red-brown shale and siltstone
293	25-43711	abbreviated log	
		0-12	red-brown silt, sand, clay, some gravel (Qcb)
		12-16	red-brown siltstone and shale
294	25-43717	abbreviated log	
		0-13	red-brown sand, some gravel and clay (Qcb)
		13-61	red-brown shale and sandstone
295	25-34163	0-7	fill
		7-14	gray silt (Qcb)
		14-57	red shale
296	25-34165	0-10	brown silt (Qcb)
		10-14	brown fine sand (Qcb)
		14-22	brown silt (Qcb)
		22-80	weathered rock
297	25-22397	6	
298	25-656	0-60	red clay (Qcb)
		60-173	shale and clay mixed
299	25-20471	0-8	loose stone (Qwb)
		8-340	blue stone
300	25-24994	0-6	overburden (Qwb)
		6-200	trap rock
		200-300	shale
301	25-9536	0-15	earth, clay, and broken rock (Qwb)
		15-130	trap rock
		130-430	red rock
		430-447	red sandstone
302	25-40355	0-11	yellow-brown and green sands and boulder, fractured rock (Qpf)
		11-52	red-brown fractured rock with sand and sandstone chips (Qws)
		52-57	shale
303	25-24963	0-30	sand and gravel (Qpf)
		30-100	shale
304	25-34304	abbreviated log	
		0-24	red-brown silt and gravel, trace fine-to-medium sand (Qpf)
		24-29	weathered red shale
305	25-24376	0-50	overburden (Qpf, maybe over Qcb)
		50-300	gray and red rock
306	25-27355	0-39	brown clayey silt, trace coarse-to-fine sand and coarse-to-fine gravel, occasional boulders (Qpf)
		39-45	shale
307	25-7173	0-5	earth and clay (Qcal)
		5-27	broken trap rock (Qcb)
		27-540	red rock
308	25-3533	0-21	clay and stones (Qaf over Qcb)
		21-49	red rock with streaks of gravel (Qcb and Qpf?)
		49-147	red sandstone
309	25-40357	0-60	red-brown silty clay with gray layers throughout (Qpf)

310	25-7528	0-78	sand and hardpan (Qtmr over Qpf)
		78-150	red rock
311	25-649	0-22	soil and small stone (Qtmr)
		22-39	sand and gravel (Qpf)
		39-120	coarse gravel (Qpf)
		120-663	red shale
312	25-11966	0-110	hardpan, sand and gravel (Qtmr over Qpf)
		110-320	red shale
313	25-20264	40	
314	25-34889	0-30	red sand and gravel (Qpf)
315	25-18778	0-70	gravel, sand (Qpf)
		70-200	shale
316	25-10615	0-12	sand, gravel (Qpf)
		12-32	soft shale (Qws)
		32-52	some gray rock
		52-305	hard shale
317	25-8131	0-50	sand, clay, boulders (Qcb)
		50-350	red shale
318	25-42327	abbreviated log	
		0-6	topsoil, stone fill (Qcb)
		6-12	reddish-brown silt, clay (Qcb)
		12-26	light-brown fine-to-medium sand (Tp)
		at 26	dark-gray, gray phyllite (shale bedrock)
319	25-42440	0-10	miscellaneous soil fill (Qcbl)
		10-23	reddish-brown silt, clay (Qcbl)
		23-32	light-brown fine-to-medium sand (Tp)
		at 32	dark-gray, gray phyllite (shale bedrock)
320	25-43824	0-20	clay, cobbles, wood, red fill
		20-27	clay, some silt, cobbles, red (Qcb)
		27-47	clay, trace silt, red and dry (Qcb)
		47-48	sand, medium-to-fine gravel, white to red (Tp)
		48-201	red shale
321	25-40982	0-11	red clay with sand seams (Qcb)
		11-47	red clay, silty sand (Qcb)
		47-65	weathered shale
322	25-40983	0-14	red clay (Qcb)
		14-50	silty red clay and sand 9Qcb)
		50-63	weathered shale
323	25-6425	0-14	clay, gravel (Qcb)
		14-351	shale
324	25-41913	0-35	reddish-brown clay (Qcb)
		35-45	light and dark brown sands (Qcb or Tp)
		45-65	reddish-brown decayed shale
325	25-43025	0-7	brown silty gravelly sand (Qcb)
		7-12	brown silty clay with fine sand layers (Qcb)
		12-29	brown fine-to-medium sand with silt layers (Qcb)
		29-60	brown gravel (Qcb or Tp)
		60-95	reddish-brown shale
326	25-40987	0-12	brown, red clay, dry (Qcb)
		12-24	medium-to-fine sand, wet (Qcb)
		24-60	clay, red, wet (Qcb)
		60-94	weathered shale

		94-303	red shale
327	25-36684	0-8	brown clay with gravel (Qcb)
		8-26	brown clay, trace fine sand (Qcb)
		26-46	brown fine sand, trace silt (Qcb)
		46-60	decomposed red shale
328	25-36685	0-13	brown clay (Qcb)
		13-29	fine-to-medium brown sand, trace silt (Qcb)
		29-39	decomposed red shale
		39-47	rock
329	25-40989	0-20	brown-red dry clay (Qcb)
		20-28	moist brown medium-to-fine sand (Qcb)
		28-30	basalt boulder (Qcb)
		30-129	red shale
330	25-40985	0-63	medium sand and gravel (Qcb)
		63-138	red shale, weathered to competent
331	25-40984	0-14	brown fine sand, medium sand with some cobbles (Qcb)
		14-40	red shale
332	25-36686	0-16	brown clay, some rock (Qcb)
		16-33	decomposed red shale
333	25-43825	0-10	boulders, cobbles, clay, red (Qcb)
		10-45	clay, some cobbles, trace fine sand, red, wet (Qcb)
		45-52	boulders, cobbles, clay, red (Qcb)
		52-62	cobbles, clay, red (Qcb)
		62-64	boulder (Qcb)
		64-423	red shale
334	25-43821	0-35	clay, silt, red (Qcb)
		35-43	clay, trace of fine sand and cobbles, red, wet (Qcb)
		43-153	red shale
335	25-43525	0-10	clay, trace cobbles, red (Qcb)
		10-23	medium-to-fine sand, clay, red (Qcb)
		23-48	clay, silt, trace fine sand (Qcb)
		48-263	red shale
336	25-43518	0-10	silty sand (Qcb)
		10-100	shale
337	25-10665	0-12	sand, gravel (Qcb)
		12-20	soft shale
		20-260	hard shale
338	25-42672	0-9	fine sand and silt, gravel, some clay, red-brown (Qaf)
		9-20	weathered shale
339	25-20812	0-16	dirt, small rock (Qwb)
		16-290	trap rock
		290-500	shale
340	25-4358	0-30	clay and gravel (Qaf over Qpf)
		30-538	red shale
341	25-29395	0-10	red clay (Qpf)
		10-15	weathered shale
342	25-287	0-8	fill
		8-20	hard brown sand with some gravel (Qpf)
		20-118	clay and shale
343	25-22048	0-50	sand (Qpf)
		50-160	red shale

344	25-30967	0-14	red-brown clay silt, trace medium-to-fine sand, trace coarse-to-fine gravel (Qpf)
		14-15	decomposed shale
345	25-34910	0-17	red-brown clay, trace medium-to-fine sand (Qpf)
		17-25	shale
346	25-31000	0-16	red-brown coarse-to-fine sand and coarse-to-fine gravel, trace silt and clay (Qpf)
		16-43	red shale
347	25-40751	0-16	red-brown coarse-to-fine sand, gravel, cobbles (Qpf)
		16-30	red shale
348	25-8687	0-18	sand (Qpf)
		18-130	red shale
349	25-37026	0-5	overburden (Qpf)
		5-50	broken red shale
350	25-38203	0-22	reddish-brown fine-to-coarse sand and silt, some gravel (Qpf)
		22-27	weathered shale
		27-80	competent shale
351	25-48331	0-60	silt, sand, gravel (Qpf)
		60-65	weathered rock
		65-85	siltstone
352	25-48330	0-70	silts, sand and gravel (Qpf)
		70-75	weathered siltstone
		75-100	siltstone
353	25-38662	0-28	red-brown fine-to-coarse gravel, trace clay (Qpf)
		28-50	red shale
354	25-39836	0-42	reddish-brown medium-to-coarse gravel, some fine-to-coarse sand, silt, pockets of gray clay (Qtmr)
355	25-35562	0-6	red medium-to-fine sand, some clay and silt, some angular gravel (Qtmr)
		6-43	red-brown silty mudstone
356	25-41843	0-38	red-brown silty clay, trace coarse-to-fine sand, trace coarse-to-fine gravel, trace cobbles (Qtmr)
		38-50	soft weathered shale
		50-60	red shale
357	25-719	0-89	earth, sand, and gravel (Qtmr over Qpf)
		89-805	red shale
358	25-42796	0-30	red-brown clay, medium-to-fine sand, trace coarse-to-fine gravel, some cobbles (Qtmr)
		30-38	multi-colored coarse-to-fine rounded gravel, little silt, trace medium-to-fine sand (Qtmr or Qpf)
359	25-42249	0-62	red-brown medium-to-fine sand, trace silt, trace medium-to-fine gravel (Qtmr)
360	25-46543	0-71	brown clay, trace medium-to-fine sand and medium-to-fine gravel, some cobbles--glacial till (Qtmr)
		71-95	weathered siltstone
361	25-6890	0-68	red clay (Qtmr)
		68-125	red rock
362	25-13694	0-54	sand and gravel (Qtmr over Qpf)
		54-58	red clay (Qpf or Qws)
		58-400	red shale

363	25-24733	0-40	sand (Qtmr)
		40-180	shale
364	25-9127	0-20	clay (Qpt)
		20-95	red shale
365	25-17255	0-15	clay and sand (Qpt)
		15-135	baked shale
		135-285	trap rock
366	25-42115	0-2	brown fine-to-medium sand and silt (Qst)
		2-10	gray-brown silty clay (Qpml)
		10-37	gray clayey silt (Qpml)
367	25-42114	0-2	brown fine-to-medium sand and organics (Qst)
		2-37	gray silty clay (Qpml)
368	25-42116	0-2	brown fine-to-coarse sand, little gravel, road fill
		2-7	mottled brown-gray silty clay, embedded medium sand (Qst)
		7-37	gray clay (Qpml)

[1]Identifiers of the form 25-xxxx are well permit numbers issued by the N. J. Department of Environmental Protection, Bureau of Water Allocation. Identifiers of the form “xx-xx-xxx”, are N. J. Atlas Sheet grid coordinates for logs in the Bureau of Water Allocation well-record files that do not have a permit number. Identifiers of the form “N xx-xx-xxx”, are entries in the N. J. Geological Survey permanent note collection. Identifiers accompanied by a reference, for example, “GS4, Reimer, 1984” are from the cited publication. Identifiers of the form “90-xxx” are from Hoffman and others (in review). Identifiers prefixed by “EEC” are test borings for the Passaic Township sewage treatment plant (drilled for Environmental Engineering Corporation in 1991) on file at the N. J. Geological Survey. Identifiers prefixed by “E” are monitor-well borings for the AT&T Laboratories (drilled for Eckenfelder, Inc. in 1990) on file at the N. J. Geological Survey. Identifiers of the form “Healy, x/xx/xx” are test borings made by Philip J. Healy, Inc., on the date indicated, on file at the N. J. Geological Survey.

[2]A number without a log is the depth, in feet below land surface, to bedrock reported for wells where the surficial material is either not identified or identified only as “overburden” or other non-informative terminology. For wells and borings with logs of the surficial materials, the depth (in feet below land surface) and driller’s or logger’s description, or the description contained in the cited publication, is provided. Inferred map units and comments are indicated in parentheses. All descriptions are reproduced as they appear in the original source, except for minor format, punctuation, and spelling changes. Logs identified as “abbreviated” have been condensed for brevity, or have minor details omitted. Many bedrock descriptions have been condensed; these are not identified as abbreviated. For wells completed in surficial materials, the screened interval, or depth to which the well is cased, and yield (in gallons per minute, gpm) are reported beneath the log. Map units are inferred from the known extent of materials at the surface and from known depositional settings, in addition to the drillers’ descriptions.