DELAWARE GEOLOGICAL SURVEY
University of Delaware
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HYDROGEOLOGIC UNITS

COLUMBIA AQUIFER

The shallowest water-bearing unit is the Columbia aquifer, which, depending on location, includes the coarser-grained beds of one or more lithostratigraphic units, unnamed swamp and eolian deposits, the Columbia Formation, the Scotts Corners Formation, the Lynch Heights Formation, and the Cheswold sand of the Calvert Formation. Over most of the map area, fine-grained beds of the Calvert Formation form the base of the aquifer. Marsh and swamp deposits cover the aquifer along Delaware Bay and larger tributary streams. Fine-grained beds of eolian and swamp deposits cover the aquifer in discontinuous patches in upland areas.

Because of its near land surface position and water-bearing characteristics, the Columbia aquifer is very important to the economy and environment of the Smyrna-Clayton area. The aquifer receives recharge from precipitation and yields much of the fresh water used in the area. It is also the receiving aquifer for discharges from individual on-site wastewater disposal and industrial wastewater spray irrigation systems.

Ground-water level data in areas unaffected by pumping indicate that flow is from higher topographic areas toward discharge areas along streams, rivers, and estuaries (Adams et al., 1964; Boggess et al., 1964). Natural discharge from the Columbia aquifer is the primary source of fresh water stream flow accounting for about 50 % to 75% of total fresh water stream flow (Cushing et al., 1973; Johnston, 1976). Locations of stream gaging stations and associated basin-area data shown on the map are from Doheny (1998).

The Columbia aquifer functions both as an unconfined and a semi-confined aquifer. Saturated thickness, or thickness of water-bearing beds, ranges from less than 5 ft to approximately 120 ft. The variation in aquifer type and thickness is due to the complex interlayering of aquifers and confining beds. Water levels in the aquifer usually range from less than one foot to about 20 feet below land surface (bls), with yearly fluctuations of 5 to 10 ft. Well yields range from as little as 5 gallons per minute (gpm) to more than 1000 gpm in a few locations. Specific capacities of wells range from about 2 to 111 gpm per foot of drawdown. Transmissivities are spatially variable because of local variations in permeability and saturated thickness. The aquifer is rated poor to excellent in water-yielding characteristics with the most transmissive portions of the aquifer occurring where it is composed of the Columbia Formation and the Cheswold sand.

Natural water quality in the Columbia aquifer is generally good, containing low concentrations of dissolved minerals (Marine and Rasmussen, 1955; Sundstrom and Pickett, 1968; Cherry, 1983; Denver, 1993). The aquifer is highly susceptible to contamination by surface or near-surface sources. For example, Denver (1993) found elevated concentrations of nitrate as a result of agricultural practices in monitoring wells located in the Blackbird area (Gb41, Gb42, and Gb51). Leaking underground gasoline storage tanks and industrial waste disposal have contaminated wells in Smyrna with organic chemicals. Locally, iron concentrations are high enough to require treatment for most uses. In some locations, low pH contributes to corrosion and dissolution of metallic plumbing components. Brackish water is common in wells constructed near bodies of brackish surface water along Delaware Bay and adjacent tidal marshes.

CHESWOLD AQUIFER

The Cheswold aquifer occurs within the Cheswold sand of the Calvert Formation and is another important source of ground water. Map areas with good to excellent recharge and resource potentials show where the Cheswold sand is in close proximity to the Columbia Formation and functions as part of the Columbia aquifer. In the southeastern-most portion of the map area and in areas located to the south of the map area, this sandy interval is covered by younger fine-grained beds of the Calvert Formation and, as a result, forms a discrete hydrologic unit, the Cheswold aquifer. Well yields range from about 10 gpm in areas where the aquifer is confined to about 1000 gpm where it is in hydraulic connection with the overlying Columbia aquifer. The Cheswold aquifer is a regionally important source of water for public supply wells owned and operated by the City of Dover, Dover Air Force Base, and several industries. A modeling study by Leahy (1982) found that water recharging the aquifer in the map area flows toward pumping centers in the Dover area.

Water quality in the shallowest portions of the Cheswold aquifer is very similar to that in the Columbia aquifer (Marine and Rasmussen, 1955; Sundstrom and Pickett, 1968; Cherry, 1983). In deeper, downdip portions of the aquifer, water has had time to react with sand and shell in the aquifer matrix and consequently contains more calcium, magnesium, and total dissolved solids. Total calcium and magnesium hardness may require treatment in these areas.

PINEY POINT AQUIFER

A limited number of descriptive and geophysical logs indicate that the Piney Point Formation occurs in the southern half of the map area, but is thin (< 25 ft) and fine-grained. It functions as a confining bed or confined aquifer and is a minor source of water to wells in the map area, yielding 10 gpm or less. The Piney Point aquifer is a major water supply source in the Dover area where yields over 300 gpm are reported (Marine and Rasmussen, 1955; Sundstrom and Pickett, 1968; Woodruff, 1972; Leahy, 1976, 1979, 1982). Water quality is generally good with low concentrations of dissolved solids, although sodium concentrations in excess of 10 mg/L are not uncommon. The sodium concentrations are a result of cation exchange reactions between water and glauconitic sediments (Spoljaric, 1986).

RANCOCAS AQUIFER

Sandier beds in the Vincentown and Hornerstown formations function as a confined aquifer and, in the map area, fine-grained beds of the overlying Shark River, Manasquan, and Calvert formations form the confining unit. Public supply wells for the town of Clayton (Hc32-15, Hc33-11, Hc32-24) and at the Delaware Correctional Center (Gc54-03, Hc14-03) withdraw water from this aquifer. The Rancocas yields up to 300 gpm to wells. Water quality is generally good with low concentrations of dissolved solids and iron.

Water levels in the Rancocas are affected by pumping wells in the Town of Clayton (Hc32-15, Hc32-24, and Hc33-11) and at the Delaware Correctional Center (Gc54-03, Hc14-03). Static water levels are reported to be in the range of 15 to 20 ft below land surface (bls). Pumping water levels range from approximately 100 to over 200 ft bls.

MT. LAUREL AQUIFER

Sandier beds in the Mt. Laurel Formation function as a confined aquifer and, in the map area, fine-grained beds of the overlying Navesink, Hornerstown, Manasquan, Shark River, and Calvert formations form the confining unit. A public supply well located near the Delaware Correctional Center (Hc14-17) has a reported yield of approximately 350 gpm. Limited data indicate that water quality is generally good, with low dissolved solids and iron. This aquifer is used more extensively in locations to the north of the map area. Water levels in well Gd33-04 reflect the long term increase in regional water use with a decline from about 14 ft bls in 1966 to about 17 ft bls in 2000.

DEEPER COASTAL PLAIN UNITS

Holes drilled through the Mt. Laurel will encounter, in order, the Marshalltown, Englishtown, Merchantville, Magothy, and Potomac formations. Readers are referred to Benson and Spoljaric (1996), and Pickett and Benson (1977) for additional information regarding these units. Well Gd33-05 is finished in the Magothy Formation (Km). The long-term hydrograph from monthly water level readings shows a significant decline in water levels between well construction in 1966 and the present. Data are insufficient to prove the reason for the decline, but it is likely that pumping from overlying and underlying aquifers outside of the map area is largely responsible for the reduced water levels. The results of single water analysis of a sample from this well collected shortly after completion report a chloride concentration of 270 milligrams per liter (mg/L) and dissolved solids of 780 mg/L. Because better quality water is available at shallower depths, further exploration of this and deeper units for water supply has not occurred.

GEOLOGIC UNITS

NEAR-SURFACE UNITS

Alluvial deposits consist of light yellow gray to orange brown, fine to medium sand, muddy fine sand, and rare fine to medium sand and pebbly sand, to light to moderate yellow brown to olive brown organic-rich mud to fine sandy mud. They are found as discontinuous patches adjacent to modern streams where they interfinger with swamp and marsh deposits. The deposits have very heterogeneous composition that vary considerably over short distances as does thickness.

Fresh water swamp deposits (tree covered) are mostly fine-grained, but can have very heterogeneous composition, occurring as fining upward sequences of light to moderate gray brown to olive brown, fine to medium sand to organic-rich fine sandy mud. Observed thickness ranges from less than 1 ft to about 15 ft. Swamp deposits are found on poorly drained, relatively flat areas on drainage divides, and in floodplains adjacent to modern streams.

Upland bog deposits, also named Delmarva Bay deposits (Phillips and Shedlock, 1993), have an internal stratigraphy consisting of a fining upward sequence of light yellow gray to moderate olive brown, fine to medium sand, in places organic-rich, and fine sandy mud to organic-rich mud where thicker than 5 ft. Thinner deposits usually consist of light yellow to orange gray, sand to silty sand. Upland bog deposits occur in small undrained depressions on upland areas that are underlain by the lowermost fine-grained portion of the Calvert Formation. Observed thickness ranges from about 1 ft to about 20 ft.

Eolian deposits consist of pale yellow gray, yellow orange, and gray, silty fine sand, fine sandy silt, and fine sand. They are typically less than 5 ft thick and occur on upland surfaces as a discontinuous sheet with thin dunes.

Marsh deposits (no tree cover) are mostly fine-grained but can have very heterogeneous composition, occurring as fining upward sequences of light to moderate gray brown to olive brown, fine to medium sand to organic-rich sandy mud and muddy organic beds. Marsh deposits cover large areas of the eastern portion of the map adjacent to Delaware Bay and tributary streams where they interfinger with swamp and alluvial deposits. Observed thickness ranges from about 1 foot to about 80 ft.

Beach deposits consist of pale gray to yellow gray, fine to coarse sand, silty sand, with variable amounts of pebbles and rare cobbles. They occur on the shore of Delaware Bay.

The **Scotts Corners Formation** consists of light gray to brown to light yellowish brown, coarse to fine sand with discontinuous beds of organic-rich silty clay, clayey silt, and coarse sand to pebble gravel. The Scotts Corners is the surficial unit between bay-fringing marshes and the sharp break in land surface elevations at about 30 ft. On the shaded relief map the Scotts Corners occurs in areas shaded light blue and green, and the sharp break in slope is marked by the color change from green to pink. Coarser-grained beds in the Scotts Corners function as part of the Columbia aquifer.

The **Lynch Heights Formation** consists of light yellowish and reddish brown to gray, medium sand with discontinuous beds of fine silty sand, clayey silt, and reddish brown to brown, organic-rich clayey silt to silty sand. Some beds of medium to coarse pebbly sand with scattered cobbles and coarse to granule sand. The presence of the Lynch Heights is indicated by geomorphic and lithologic characteristics but has not been confirmed by paleontologic data. Coarser-grained beds function as part of the Columbia aquifer.

The **Columbia Formation** consists primarily of light yellow to orange brown and gray, medium to coarse sand, gravelly sand, and sandy gravel with minor discontinuous lenses and layers of mud. Some beds of cobbles and pebbles, and rare boulders. The Columbia aquifer occurs in coarser-grained beds of the Columbia Formation.

The **Calvert Formation** occurs within 5 to about 30 ft of land surface in upland portions of the map area. Coarser-grained beds (Cheswold sand unit) have a similar composition to the Columbia Formation and can be very difficult to distinguish from the Columbia.

Basal fine-grained beds of the Calvert Formation are typically composed of mixtures of clay and silt with common to abundant shell fragments and less common beds of silty fine sand and shell. Colors range from light to medium blue-gray, green-gray, olive-gray, and gray. Sulfidic odor and colors indicate reducing geochemical conditions in which sulfide minerals occur. These beds subcrop in a southwest-northeast striking band in the northern portion of the map area.

The **Cheswold sand** consists of interbedded mixtures of medium to coarse sand, shell, and gravel, with discontinuous lenses and layers of fine sandy, shelly, clayey silt. Colors range from light to medium yellow-orange, yellow-gray, and red-orange, to blue-gray, green-gray, and olive-gray. This is sub-unit of the Calvert Formation subcrops in a southwest-northeast trending band in southern portion of the map area. Coarser-grained beds of the Cheswold sand form the Cheswold aquifer and in some areas can function as part of the Columbia aquifer.

Another fine-grained confining unit that overlies the Cheswold is typically composed of interbedded mixtures of clay, silt, and shell, with discontinuous lenses and layers of shelly, muddy, fine to medium sand. Colors range from light to medium blue-gray, green-gray, olive-gray, and gray to yellow-orange and yellow-gray. Sulfidic odor and colors indicate reducing geochemical conditions in which sulfide minerals occur. Sulfate minerals occur where colors indicate oxidizing geochemical conditions. This unit occurs in southeastern portion of the map area and overlies the Cheswold sand.

SUBSURFACE UNITS

Only the lowermost portion of the **Piney Point Formation** is present in the map area where it consists of green glauconitic silt and clay with discontinuous beds of glauconitic sand. Farther south in the Dover area, the unit is thicker and its lithology is a "...bright green, fine to medium, glauconitic (20-40%), shelly sand, more clayey near the base where it is in gradational contact with the silty to clayey Deal Formation." (Benson and Spoljaric, 1996, p. 24). The sandy portion of the unit is known as the Piney Point aquifer.

The **Shark River and Manasquan formations** consist of moderate to dark green gray, glauconitic silt and fine sandy silt. These units function as a confining unit.

The **Vincentown Formation** is composed of moderate green gray and gray, glauconitic, fine to medium sand, silty fine sand, clayey silt, and fine sandy silt. The composition of the Vincentown varies considerably in the map area. The Rancocas aquifer (rn) occurs in this unit.

The **Hornerstown Formation** is a moderate green gray and gray, in places glauconitic, fine sandy silt, clayey silt, and silty fine sand. Sandier beds may function as part of the Rancocas aquifer (rn).

The **Navesink Formation** is composed of glauconitic, micaceous, medium to coarse silty sand, sandy silt, silt, and clayey silt. It is not used as source of water because of its depth and fine-grained composition.

BY A. SCOTT ANDRES, 2001

DISCUSSION

The Delaware Geological Survey Hydrologic Map Series provides basic information on the occurrence, availability, quantity, and quality of ground and surface waters. Much of the information summarized in this publication is obtained from the digital and paper format databases on file at the Delaware Geological Survey. This information is useful to those interested in understanding, developing, protecting, using, or regulating water resources in Delaware.

This report focuses on the surficial and near-surface geologic and hydrogeologic units that are most frequently encountered in the map area during construction of water supply and monitoring wells, and for engineering and environmental investigations. The properties and distributions of surficial geologic units also affect the distributions and types of soils that support plant and animal life. Beneath these units there are about 1400-1800 ft of Mesozoic and Cenozoic Coastal Plain sedimentary units (Benson and Spoljaric, 1996). Because these units are not currently used for water supply their hydrogeologic characteristics are poorly understood.

The hydrogeologic framework of the Smyrna-Clayton area is characterized by interlayered and interfingering aquifers and confining beds whose water-bearing characteristics are controlled by primary porosity. Individual hydrogeologic units may locally consist of two or more lithostratigraphic units. The spatial distributions of hydrogeologic units control the flow of water and affect water quality.

On this map I have used the stratigraphic nomenclature of Ramsey (1995, 1997), Benson and Spoljaric (1996), and Howard et al. (1997). This nomenclature is different from that shown by Pickett and Benson (1977) and reflects interpretation of data collected after completion of their work.

GROUND-WATER RECHARGE AND RESOURCE POTENTIAL

Ground-water recharge potential areas in the Kent County portion of the map area show the capabilities of earth materials to transmit water through a layer extending from land surface to a depth of 20 ft (Andres, 1991; Howard et al., 1997). In general, more water will move through the ground more rapidly in higher (excellent and good) recharge potential areas than in areas with lower (fair and poor) recharge potentials. Recharge potential maps are used by the Delaware Department of Natural Resources and Environmental Control and the Delaware Department of Agriculture to help manage waste disposal, underground storage tanks, and toxic material handling.

Recharge Resource Protection Areas show areas in New Castle County where Butoryak and Talley (1993) identified the best potential for ground-water recharge. Land areas in New Castle County were not classified as excellent, good, fair, or poor as was done in Kent County. Through Article 10 of the Unified Development Code, New Castle County government requires specific land use and wastewater disposal practices in these areas.

Ground-water resource potential areas show the capabilities of earth materials to transmit water through a layer extending from 20 ft (bls) to 60 ft below land surface. As in recharge potential areas, more water will move through the ground more rapidly in higher (excellent and good) resource potential areas than in areas with lower (fair and poor) resource potentials. The recharge and resource potentials map can be used to identify the areas having the best potential for transmitting water and contaminants into the Columbia aquifer.

STRUCTURES (FAULTS)

On the bases of well log analyses, correlations, and limited outcrop data, Benson and Spoljaric (1996), Andres and Howard (1998), and Howard et al. (1997) have postulated northeast-southwest trending faulting in and around the map area. Work done for this study corroborates the presence of faults. One possible interpretation shown in cross-section A-A' illustrates block faults juxtaposing aquifers and confining beds of the Miocene-age Calvert Formation and older units. Because of a lack of sufficient deep drill hole or seismic reflection data, specific details of the spatial distribution, orientation, and hydraulic properties of the faults are not known. There are no data that indicate that these faults have been active in the recent past.

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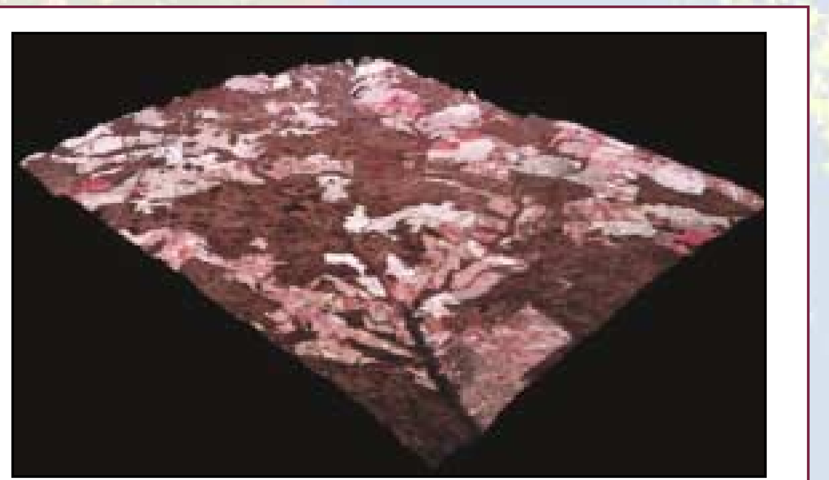
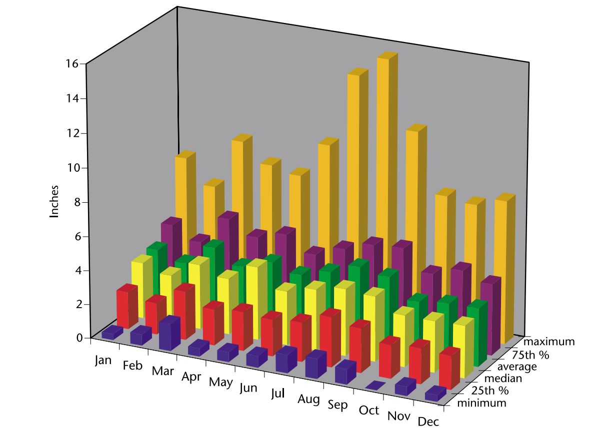
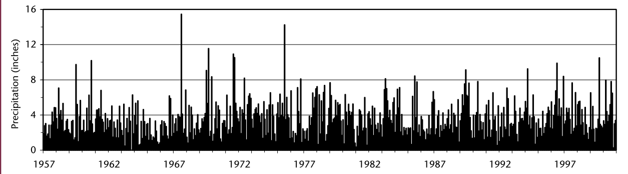


Seasonal ponds and wetlands (Delmarva Bays) appear as darker colored areas on this false-color infrared orthophotoquad of the northwest portion of the Clayton 7.5-minute map. These closed topographic depressions occur on the Columbia Formation where the Columbia overlies the lower fine-grained confining unit of the Calvert Formation. Ephemeral ponds form in many of these depressions during wet periods as a result of surface and shallow-subsurface drainage from the surrounding upland into the depressions (Phillips and Shedlock, 1993). Most of this water is taken up by plants or evaporation and a small amount slowly infiltrates through the fine-grained pond sediments (upland bog deposits) to the water table.

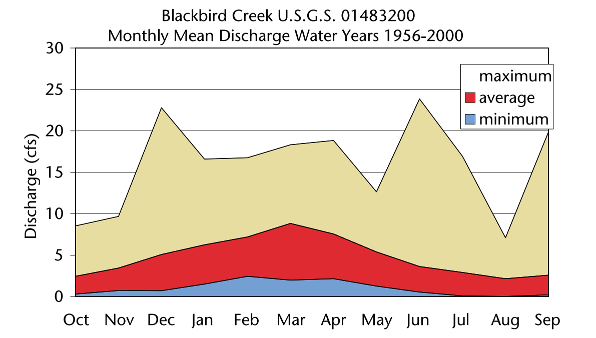
At left: Photograph of cobbles, gravel, and sand of the Columbia Formation overlying cross-bedded sands of the Cheswold sand member of the Calvert Formation at outcrop Hc25-a. The shovel handle is approximately 18 inches long. The exposure was photographed during construction of State Route 1 in 1991 after 4 to 6 ft of Columbia Formation materials were removed.

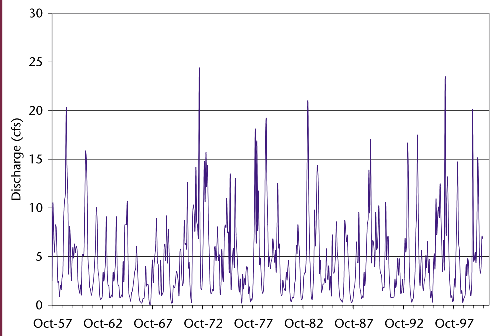
MONTHLY PRECIPITATION AT DOVER





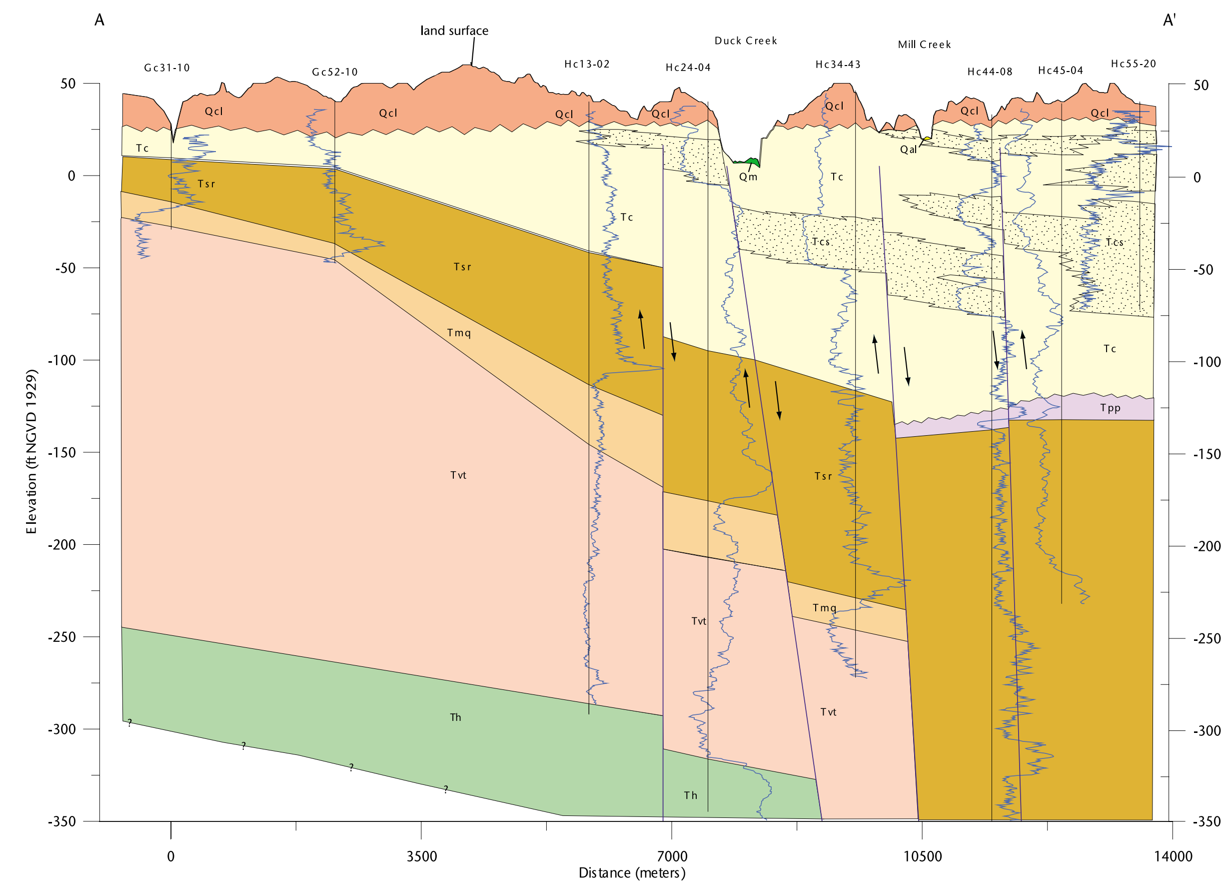
Monthly precipitation measured at National Oceanic and Atmospheric Administration Station No. 2730 located at the Delaware Department of Transportation in Dover. The period of record is 1949 through 2000.





Discharge shown in cubic feet per second (cfs).

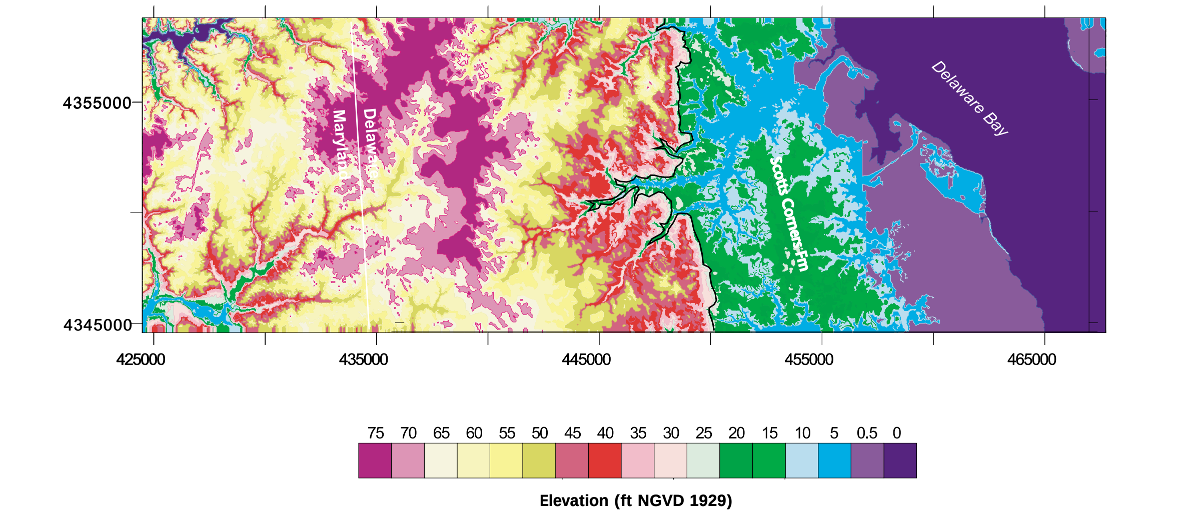
Source of data is U.S. Geological Survey



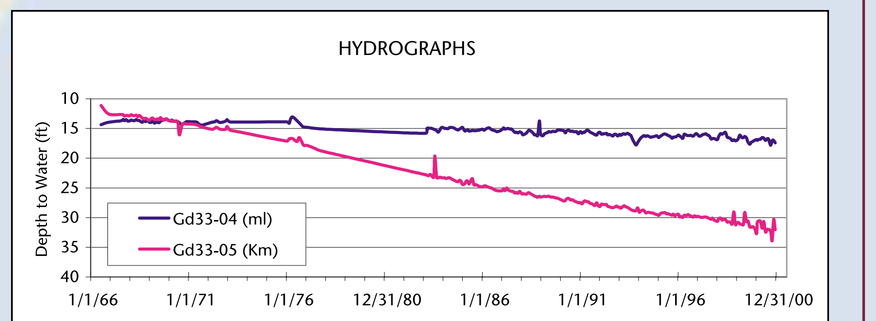
Key to cross section symbols

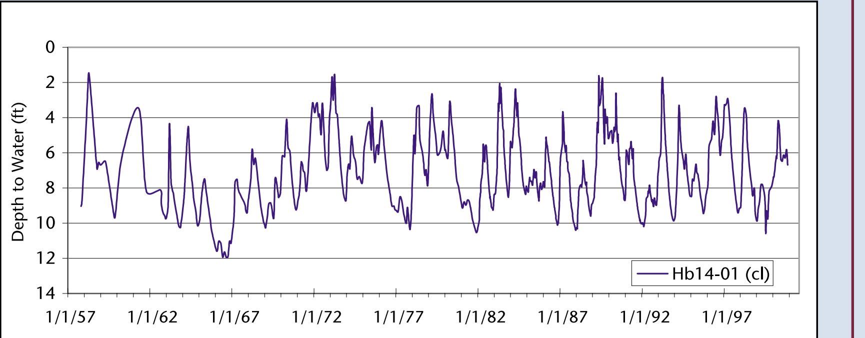
unconformity	Qm	marsh deposits
formation contact	Qal	alluvial deposits
facies change	Qcl	Columbia Fm — Columbia aquifer
fault and relative motion	Tc / Tcs	Calvert Fm/Cheswold sand — Cheswold aquifer & confining beds
Hc34-43 DGS well/borehole identifier	Tpp	Piney Point Fm — Piney Point aquifer
well/borehole trace	Tsr	Shark River Fm — confining beds
natural gamma radiation log increasing clay content to right	Tmq	Manasquan Fm
	Tvt	Vincentown Fm — Rancocas aquifer
	Th	Hornerstown Fm

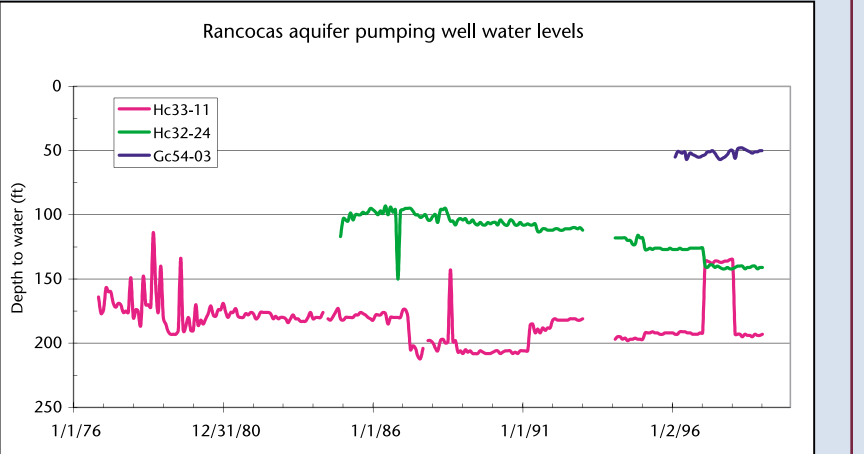
Formation contacts for Hc24-04 and Hc44-08 are from Benson and Spoljaric (1998). Formation contacts for Hc13-04 are from the files of the DGS (Benson, written communication). Formation contacts for Hc34-43, Gc31-10, Gc52-10, and Hc55-20 were picked by the author. Horizontal scale in meters.



Combination shaded relief and color contour map. Elevation data are from a 30-meter digital elevation model produced by John MacKenzie (University of Delaware College of Agriculture and Natural Resouces). Coordinates are UTM-18, NAD 1983 in meters.







Depth to water shown as feet below land surface. Pumping water levels are those reported to the Department of Natural Resources and Environmental Control by the well owners. Levels in wells Gd33-04, Gd33-05, and Hb14-01 were measured by staff of the Delaware Geological Survey and U.S. Geological Survey. The measurement frequency is approximately monthly.

Note: cl=Columbia aquifer, ml=Mt. Laurel aquifer, Km=Magothy Formation

DESIGN BY KATHLENE WHEATLEY AND DON MCELROY