HYDROGEOLOGIC FRAMEWORK OF THE VIRGINIA COASTAL PLAIN

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REGIONAL AQUIFER-SYSTEM ANALYSIS

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marine shelf with water levels that ranged from about 50 to 230 ft.

CHICKAHOMINY-PINEY POINT AQUIFER

The Chickahominy-Piney Point aquifer is defined for the most part by the predominantly sandy deposits of the Chickahominy and Piney Point Formations. The Piney Point comprises most of the aquifer unit, with the Chickahominy and the Woodstock Member of the Nanjemoy Formations comprising the remainder. These sediments are middle to late Eocene in age and correlate with the Piney Point-Nanjemoy aquifer in Maryland and the Castle Hayne aquifer in North Carolina (pl. 1). The Chickahominy-Piney Point aquifer crops out in most of the major stream valleys of the study area from the James River northward, just east of outcrops of the Nanjemoy-Marlboro Clay confining unit. It overlies the Nanjemoy-Marlboro Clay confining unit and is overlain and transgressed by the Calvert confining unit. The Chickahominy-Piney Point aquifer is wedge shaped in cross section, thickens eastward, and thins to nearly zero thickness along its western limit in the western part of the study area. Similar to the Aquia aquifer, this aquifer undergoes a sand-to-clay facies change that causes it to pinch-out in the vicinity of the Eastern Shore Peninsula (fig. 19). East of this line, the aquifer becomes predominantly clayey. The eastern limit (pinch-out) of this aquifer is an approximate boundary based on subsurface studies done in Maryland and Delaware by Hansen (1972), Leahy (1982), Chapelle and Drummond (1983) and extrapolated by the authors into the study area. Evidence for the exact position of this pinch-out is lacking due to the scarcity of borehole and stratigraphic data available in the northeastern and east-central parts of the study area. In the southeastern area, lithologic and geophysical log data indicate that the Chickahominy-Piney Point aquifer is continuous throughout the area and that the facies change probably occurs offshore. The Chickahominy-Piney Point aquifer dips eastward at approximately 12 ft/mi. In the western half of the study area, the contours of the top of the aquifer are more widely spaced than in the eastern half due to postdepositional erosion and subsequent beveling of the Piney Point Formation during the Oligocene and early Miocene (Otton, 1955; Hansen, 1972, 1977). Also, the northwestern limit is not the actual margin of the Piney Point Formation, but rather reflects the limit of the upper, predominantly sandy facies, of the underlying Nanjemoy Formation (the Woodstock Member) which are hydrologically connected to the Chickahominy-Piney Point aquifer. This aquifer attains a maximum known thickness of 140 ft at well 60L19, plates 2, A-A′ and 3, D-D′, in the north-central region of the study area, and 165 ft at well 61B2, plates 3, F-F′ and 4, K-K′, in the southeastern region. It generally ranges from 50 to 100 ft thick throughout most of the study area.

The Chickahominy-Piney Point aquifer consists of thickly bedded olive-green to dark greenish-gray, fine to coarse, glauconitic quartz sands interbedded with thin glauconitic/illitic clays and calcareously cemented shell beds. The Piney Point Formation was first identified (Shifflett, 1948) from characteristic foraminifera in cuttings of drilled wells in the Coastal Plain of southern Maryland. This unit was later named and defined by Otton (1955), again based on sample cuttings in Maryland, as a fine to medium glauconitic sand interspersed with thin shell rock layers, and containing a diagnostic late Eocene age foraminiferal assemblage. The Piney Point has since been redefined by Brown and others (1972) to be middle Eocene in age. Cushman and Cederstrom (1945, p. 2) identify and define the Chickahominy Formation as a highly glauconitic clay interbedded with glauconitic sands and shell rock layers, and containing characteristic foraminiferal fauna of late Eocene age. The type well for the Chickahominy Formation is located in Yorktown, Va., but many other wells throughout the lower York-James Peninsula penetrate this formation. During this study, the authors noticed no appreciable difference or distinction between the Chickahominy and Piney Point Formations based on lithologic and geophysical log-correlations; therefore, they were combined into the same aquifer unit. It should be noted that the Chickahominy-Piney Point aquifer also contains sediments of late Oligocene and early Miocene age. These sediments are very thin and typically consist of fine-grained, white, quartzose sands with glauconite and shells interspersed throughout. The glauconite is primarily reworked material (L.W. Ward, U.S. Geological Survey, oral commun., 1983) and the shells commonly form thin indurated layers in the subsurface, much like the shell layers of the Piney Point Formation. Ward (1985) has identified these sediments in outcrops along major streams in the central part of the study area and proposes the name "Old Church Formation" for this unit, assigning it to the basal part of the Chesapeake Group. Analyses (L.E. Edwards, U.S. Geological Survey, written commun., 1982 and 1983) of core samples from Gloucester County (well 58H4) and the cities of Suffolk (well 58B115) and Chesapeake (near well 58A2) have also identified the presence of these deposits. Electric-resistivity logs, in conjunction with paleontological analysis, indicate that these sandy deposits directly overlie the Piney Point and Chickahominy Formations and, for this reason, are included in the Chickahominy-Piney Point aquifer and are not further differentiated in this report.

Numerous wells in the study area penetrate and provide information on this aquifer. Many light industrial, small municipal, and domestic users use the Chickahominy-Piney Point aquifer as a water-supply source. Chapelle and Drummond (1983, p. 75) report that ground water produced by the Piney Point in Maryland is capable of supplying large quantities of water suitable for most uses. The Chickahominy-Piney Point aquifer of Virginia is very similar in nature to the Piney Point-Nanjemoy aquifer of Maryland, and it is expected that generally similar ground-water conditions exist.

Typical electric-resistivity log patterns of the Chickahominy-Piney Point aquifer sediments are best illustrated on geophysical logs of wells 56N7, 58N3, 59L5, 60L19, plate 2, A-A'; 52K10, 53K17, 55L2, 56M10, 57P1, plate 2, C-C'; 55H1, 57J3, 58J11, 58J5, plate 3, D-D'; 54J4, 56G9, 57G22, 57G25, plate 3, E-E'; 56F42, 58D9, 59D1, 60C7, plate 3, F-F'; 57A1, plate 3, G-G'; 58B115, 58C51, plate 4, I-I'; and 59C28, 60C25, plate 4, J-J'. Generally, these resistivity patterns are both rectangular and spiky in profile, and commonly, two distinct sand units are recognized, especially in the eastern half of the aquifer's extent. The rectangular profiles indicate the thickly bedded, clean sands characteristic of this aquifer and the spiky profiles indicate the numerous calcareous-cemented shell beds also characteristically associated with this aquifer. The indurated shell beds within this aquifer are usually quite thin, a few inches to 1 or 2 ft, but may locally reach thicknesses of 8 ft or more. Resistivity logs generally exhibit very high resistance values for these sediments and the upper and lower contacts with the overlying Calvert and underlying Nanjemoy-Marlboro Clay confining units are commonly sharp and abrupt. Corresponding natural-gamma logs commonly exhibit a highly erratic pattern for these sediments, responding to the glauconite and quartz sands and interbedded clays. Generally, hydrogeologic boundaries cannot be determined from natural-gamma logs of these sediments because of the highly irregular responses and also because the glauconite produces a claylike response that masks the sand-clay contacts. Drillers commonly refer to the Chickahominy-Piney Point aquifer sediments as "black and white sands, or salt and pepper sands" containing "shell rock, limestone, and dark silty clay" interspersed throughout the sands. The Chickahominy-Piney Point aquifer is easily correlated among geophysical resistivity logs because of its characteristic pattern and because it generally lies between two thick clay beds, as illustrated on geophysical logs of wells 58J11, plate 3, D-D' and 56N7, plate 2, C-C'. The contour map delineating the top of this aquifer (fig. 19) can be used to indicate, fairly accurately, its approximate altitude throughout the study area. The top of this unit is fairly constant and uniform and can be predicted between points separated by large distances.

Studies (Hansen, 1972) indicate that the depositional environment of the Piney Point Formation consisted of a marine transgression and that the sediments were deposited on a shallow, inner to middle marine shelf dominated by longshore currents.

MIOCENE AND PLIOCENE CHESAPEAKE GROUP

Marine deposits of Miocene and Pliocene age constitute the upper Tertiary (Neogene) stratigraphic section known as the Chesapeake Group. This group consists of six formations (excluding the lowermost Old Church Formation, previously discussed), which are, from oldest to youngest, the Calvert, Choptank, St. Marys, Eastover, Yorktown, and Chowan River. The first five formations compose two aquifers and three confining units: the Calvert confining unit, St. Marys-Choptank aquifer, St. Marys confining unit, Yorktown-Eastover aquifer, and Yorktown confining unit, within the Chesapeake Group. Sediments of the Chowan River Formation are hydrologically part of the surficial unconfined aquifer system and are discussed in the section on the Columbia aquifer. The Pliocene Bacons Castle Formation as used by Oaks and Coch (1973) is included in the Yorktown-Eastover aquifer and the Yorktown confining unit because it is hydrologically part of both units.

Throughout the study area, major regional unconformities separate the Chesapeake Group from the underlying lower Tertiary Pamunkey Group and the overlying Quaternary sediments, undifferentiated. Within the Chesapeake Group lesser unconformities separate each of the formations. The Chesapeake Group generally consists of an eastward-thickening wedge of intermixed shelly sands, silts, and clays, which can be divided on the basis of sediment size into a very fine lower part, composed of the Calvert, Choptank, and St. Marys Formations; a very fine to medium intermediate part, composed of the Eastover Formation; and a fine to very coarse upper part, composed of the Yorktown Formation. The lower sequence typically consists of silty clays interbedded and intermixed with very fine sands, diatomite, and some shells. The intermediate part typically consists of shelly, silty to clayey, fine to medium sands; and the upper part typically consists of fine to medium shelly sands, with interbedded silty clays, shell layers, and very coarse basal lag deposits. For most of the Chesapeake Group, sedimentation occurred in a shallow, low-energy, inner-shelf marine basin that was below wave base, as indicated by the predominance of clays and silts. Throughout

Chesapeake time, effective sea level in the marine basin fluctuated, but generally declined during deposition of each successive formation; that is, sedimentation occurred in a progressively shoaling environment with deposition finally taking place in a shallow, embayed sublittoral marine environment, as indicated by barrier complexes and the diversity of near-shore sediments in the Yorktown Formation. Also, throughout Chesapeake time, the locus of deposition shifted continually southward with each succeeding formation, from the Salisbury embayment in southern Maryland past the Norfork arch in southern Virginia and into the Albemarle embayment of North Carolina (Ward, 1984, p. 68).

Recognition of the typical strata in the Chesapeake Group (clay, sand, and shell beds) in the Coastal Plain dates back to the late 1700's and throughout the 1800's. Exposures along the western shore of the Chesapeake Bay in Maryland were originally termed the "Chesapeake Formation" by Darton (1891, p. 433). In 1892, Dall and Harris changed Darton's term to "Chesapeake Group," and, in 1902 Shattuck named three formations—the Calvert, Choptank, and St. Marys—within the Chesapeake Group. Shortly following, Clark and Miller (1906) added a fourth formation—the Yorktown. In 1980, Ward and Blackwelder named the Eastover, and the Chowan River was named by Blackwelder (1981).

The Chesapeake Group crops out extensively throughout the study area. The lower formations are exposed mostly in the major stream valleys of the western area from the Appomattox and James Rivers northward, while the upper formations crop out in broad reaches throughout the western and central areas, and in major stream valleys of the southeastern area. Sediments of the Chesapeake Group thicken to the northeast, north of the Norfolk arch, and to the southeast, south of the arch. The predominantly sandy deposits of the upper Chesapeake Group yield large quantities of water that are generally suitable for most uses; whereas, the predominantly clayey deposits of the lower Chesapeake Group form thick confining units throughout the study area. These lower sediments consist of homogeneous and areally extensive blanket-type deposits that, for the most part, change little over large areas. However, the upper sediments tend to vary more in composition and thickness areally, owing to their nature of deposition and the effects of erosional processes.

CALVERT CONFINING UNIT

The Calvert confining unit is defined by the predominantly clayey deposits of the Calvert Formation. These sediments are early to middle Miocene in age and correlate with the lower Chesapeake confining unit in Maryland and the confining unit overlying the Castle Hayne aquifer in North Carolina (pl. 1). The Calvert confining unit crops out extensively in most of the major stream valleys in the western part of the study area, just east of the outcropping Chickahominy-Piney Point aquifer or the Nanjemoy-Marlboro Clay confining unit. It overlies the Chickahominy-Piney Point aquifer and is overlain primarily by the St. Marys confining unit. In the northeastern and east-central parts of the study area it is overlain by the St. Marys-Choptank aquifer and in the western part, by the Yorktown-Eastover aquifer. This confining unit is wedge shaped in cross section and thickens and dips eastward. It attains a maximum known thickness of 350 ft at well 66M1 (fig. 7) in the northeastern part of the study area and thins to nearly zero thickness along its western limit near the Fall Line.

The Calvert confining unit consists of interbedded shelly sandy clays, silty clays, and diatomite, and is typically dark grayish-green in color. A characteristic lag deposit consisting of coarse quartz sand and pebbles, phosphate pebbles and phosphatic sharks' teeth, shells, and bone fragments, generally marks the basal contact of the Calvert confining unit with the underlying Chickahominy-Piney Point aquifer. The Calvert Formation was named by Shattuck in 1902 from exposures along the western shore of the Chesapeake Bay at Calvert Cliffs, Md. From analysis of the Oak Grove core hole (well 54P3), Reinhardt and others (1980, p. 8) described the Calvert as a gray and very fine-textured sediment with fine, angular quartz sand in a silt to clay matrix in the upper part of the formation underlain by a thin diatomite and basal clay intermixed with coarse quartz sand.

Typical electric-resistivity log patterns of sediments in the Calvert confining unit are best illustrated on geophysical logs of wells 56N7, 58N3, 59L5, 60L19, plate 2, A-A'; 55L2, 57P1, plate 2, C-C'; 57J3, 58J11, 59K17, plate 3, D-D'; 56G9, 57G22, 57G25, 57F2, 58F3, plate 3, E-E'; and 57E10, 58D9, 59D1, 60C7, plate 3, F-F'. Generally, the resistivity patterns are "flat" in profile, characteristic of massively-bedded predominantly clayey deposits. Noticeable, however, within the typically flat profile are small, short "spikes" and "hills," which reflect the interbedded shell, sand, and diatomaceous layers. The resistivity pattern for well 54P3 (the Oak Grove core hole), plate 2, A-A', is typical of a profile of the Calvert confining unit because of abundant diatomite in this region. Diatomaceous sediments are high in silica, and thus produce higher resistivity profiles on geophysical logs that should normally show a flat clayey pattern. The lower contact with the underlying Chickahominy-Piney Point aquifer is very sharp and pronounced, and the upper contact with the St. Marys confining unit is usually marked by a series of spikes representing thin sandy layers on resistivity logs. In the western part of the study area, where the Calvert confining unit is overlain by the Yorktown-Eastover aquifer, the contact is usually marked by a steady increase in resistivity on geophysical logs. Likewise, in the eastern part of the study area, where the Calvert confining unit is overlain by the St. Marys-Choptank aquifer, the contact is also marked on geophysical logs by a steady increase in resistivity. Corresponding natural-gamma log patterns also indicate massively-bedded predominantly clayey deposits for this confining unit, and its base is marked by a very high gamma-response spike. This very high gamma spike is the most characteristic and diagnostic natural-gamma log pattern in the Virginia Coastal Plain. It is caused by the basal phosphate lag deposit mentioned previously and is used as one of the primary marker-bed features in geophysical log correlations. The only place in which this characteristic gamma-log pattern is missing is in the western part of the study area near the Fall Line where, presumably, the phosphate was never deposited.

Drillers commonly refer to the sediments in the Calvert confining unit as "blue, gray, or green clays or marls" sometimes containing sands or shells. The Calvert confining unit is easily correlated on geophysical resistivity logs because its characteristic flat pattern is directly above the high resistivity pattern of the Chickahominy-Piney Point aquifer. The contour map delineating the thickness of the confining unit (fig. 20) can be used to predict, fairly accurately, its approximate thickness between points that are separated by large distances.

Studies (Reinhardt and others, 1980, p. 2; Blackwelder and Ward, 1976, p. 11; and Gibson, 1982, p. 11) indicate that the depositional environment of the Calvert Formation was below wave-base in a siliceous, inner to middle-marine shelf that oscillated between semiprotected embayment to open-ocean circulation.

ST. MARYS-CHOPTANK AQUIFER

The St. Marys-Choptank aquifer is defined by the predominantly sandy facies of the St. Marys and Choptank Formations. These sediments are middle Miocene in age and correlate with the lower Chesapeake aquifer in Maryland and the Pungo River aquifer in North Carolina (pl. 1). The St. Marys-Choptank aquifer is restricted to the subsurface in the northeastern and east-central parts of the study area and its updip limit has not been defined owing to the lack of sufficient borehole and paleontologic information. It partially overlies the Calvert confining unit and is overlain by the St. Marys confining unit. The St. Marys-Choptank aquifer is wedge shaped in cross section, thickens northeastward, and pinches out updip beneath the Chesapeake Bay (fig. 21). It also pinches out southward against the Norfolk arch and, thus, no direct connection exists across the southeastern area with the Pungo River aquifer in North Carolina. This aquifer strikes generally north-south and is 160 ft thick at well 66M1. The St. Marys and Choptank Formations were names applied by Shattuck (1902) for exposures in Maryland's St. Marys County and along the Choptank River, respectively.

Only two wells—66M1 and 68M2 (fig. 7)—located in the northeastern part of the Eastern Shore Peninsula of Virginia penetrate deeply enough to provide information on the St. Marys-Choptank aquifer in Virginia. All other wells on the Eastern Shore Peninsula, for which there are reliable data, penetrate only to the overlying Yorktown-Eastover or Columbia aquifers. Therefore, identification and analysis of the St. Marys-Choptank aquifer is primarily from previous hydrogeologic studies (Rasmussen and Slaughter, 1955; Hansen, 1972; Cushing and others, 1973) conducted in the eastern part of Maryland. Based on these studies, sparse geophysical data, and thickness and structure-contour maps of overlying and underlying hydrogeologic units in the area, the St. Marys-Choptank aquifer has been extrapolated into the eastern part of the study area (fig. 21). In these previous studies, equivalent strata to the St. Marys-Choptank aquifer are described as fine to medium-grained, gray, quartzose sands, often containing shells and interlayered with clays and silts. The driller's log from well 68M2 describes the sediments as fine sands with soft clays and hard streaks. Sinnott and Tibbetts (1954, p. 16; 1968, p. 29 and 81) concluded, after studying the ground-water resources of the Eastern Shore Peninsula, that water from sands below 300 ft is likely to be of a quality unsuitable for most uses. More recent ground-water studies by Hansen (1972, p. 112-115) and Cushing and others (1973, pls. 6-8) utilizing water-quality analyses from wells in nearby Maryland support Sinnott and Tibbetts' premise about poor quality water below 300 ft. In Virginia, there are no known users of the St. Marys-Choptank aquifer. The depositional environment of the sandy facies in the St. Marys and Choptank Formations reflect the influence of delta outbuilding (southward) into the Salisbury embayment from New Jersey (Gibson, 1982, p. 1-18). Generally, the depositional environment consisted of a shallow, open-marine, inner-shelf setting that was modified by varying water depths and sporadic influxes of terrigenous clastic sediments from the north (Gibson, 1984, p. 5).

ST. MARYS CONFINING UNIT

The St. Marys confining unit is defined by the predominantly clayey facies of the St. Marys Formation, but also includes, in places, the lower clayey facies of the Eastover Formation. These sediments are middle to late Miocene in age and correlate with the St. Marys confining unit in Maryland and the confining unit overlying the Pungo River aquifer in North Carolina (pl. 1). The St. Marys confining unit is restricted to the subsurface except where it crops out in the Rappahannock River valley in the northwestern part of the study area. It overlies the St. Marys-Choptank aquifer in the eastern part of the study area and overlies the Calvert confining unit throughout the central part. It is overlain by the Yorktown-Eastover aquifer throughout its extent. This confining unit is wedge shaped in cross section and thickens and dips eastward. It attains a maximum known thickness of 318 ft at well 68M2 (fig. 7) in the northeastern part of the study area and thins to nearly zero thickness along its western limit (fig. 22). The lower part of this confining unit (the St. Marys Formation) is restricted to the central, north-central, and northeastern parts of the study area (Blackwelder and Ward, 1976, p. 19). Its southern limit was probably influenced by the effects of the Norfolk arch. The upper part of this confining unit (the clayey facies of the Eastover Formation) is extensive throughout the study area, probably contributing much of this confining unit's thickness in the central and western areas and certainly all of it in the southeastern area.

The St. Marys confining unit consists of interbedded silty and sandy clay with varying amounts of shells and is typically bluish-gray to gray in color. Gibson (1982, p. 14) described the St. Marys Formation as dominantly clay and sandy clay, generally finer grained and more clayey than the underlying formations of the Chesapeake Group, somewhat massive, and slightly fossiliferous. The lower clayey facies of the Eastover Formation, as described by Ward and Blackwelder (1980, p. 12), consists of poorly sorted, sandy clay that fines upward to clay, is greenish-gray in color, and sparsely fossiliferous.

Typical electric-resistivity log patterns of sediments in the St. Marys confining unit are best illustrated on geophysical logs of wells 56N7, 59L5, 60L19, plate 2, A-A'; 57J3, 58J11, 59K17, plate 3, D-D'; 57G25, 57F2, 58F3, 59D20, plate 3, E-E'; and 58D9, 59D1, 60C7, plate 3, F-F'. Generally, the resistivity patterns are "flat" in profile, characteristic of massively bedded, predominantly clayey deposits. Commonly these flat profiles contain interbedded sandy clays which cause a "hilly" or "spiky" appearance to the generally flat resistivity patterns. The contact with the underlying Calvert confining unit is usually marked by a small spike or hill on resistivity logs (see logs previously mentioned), indicating a basal shelly and (or) sandy clay layer. The upper contact with the Yorktown-Eastover aquifer is generally marked by a gradual but steady increase in resistivity on geophysical logs, indicating progressively more sandy sediments. Corresponding natural-gamma log patterns also indicate the presence of massively bedded clayey sediments. Drillers commonly refer to the sediments of the St. Marys confining unit as "blue or gray clays, or sandy clays."

Ward (1984, p. 68) described the depositional environment as a broad, shallow, open-marine to partially embayed, inner-shelf area.

YORKTOWN-EASTOVER AQUIFER

The Yorktown-Eastover aquifer is defined, for the most part, by the predominantly sandy deposits of the Yorktown Formation and the upper part of the Eastover Formation in the Chesapeake Group, but also includes the sandy facies of the Bacons Castle Formation as used by Oaks and Coch (1973). These sediments are late Miocene and Pliocene in age and correlate with the upper Chesapeake aquifer in Maryland and the Yorktown aquifer in North Carolina (pl. 1). The Yorktown-Eastover aquifer overlies the St. Marys confining unit in the eastern and central parts of the study area, and the Calvert confining unit in the western and south-central parts. It is overlain by the Yorktown confining unit in the central and eastern parts of the study area, and is generally unconfined throughout the western part. This aquifer extends throughout the study area except in the middle to upper reaches of major stream valleys and their larger tributaries where it has been removed by erosion (fig. 23). It crops out in a broad area covering most of the uplands in the western and north-central parts of the study area. It is also exposed along stream valleys throughout the central and southeastern parts. The aquifer is much thinner and more highly dissected in the northern, western, and central parts of the Virginia Coastal Plain than in the southern part, where it thickens considerably. The Yorktown-Eastover aquifer is wedge shaped in cross section, thickens and dips eastward, and thins to nearly zero thickness along its western and stream-eroded limits. It attains a maximum known thickness of 296 ft at well 68M2 (fig. 7) in the northeastern area, and 240 ft at well 63C1 (fig. 7) in the southeastern part. In the eastern half of the study area its thickness generally ranges between 100 to 200 ft.

The Yorktown-Eastover aquifer typically consists of interlayered, thick to massively-bedded shelly sands separated by thinner clay beds. In the western half of the study area the clays of this aquifer are very thin and areally discontinuous; however, in the downdip region the clays become more massive and extensive, subdividing the aquifer into three distinct subunits (Converse, Ward, Davis, and Dixon, 1981).

Geologically, the Yorktown-Eastover aquifer consists of three formations that each represent marine transgressions resulting in shallow, embayed areas, with each having similar characteristic depositional patterns. Generally, the formations fine upwards from a basal coarse sand and gravel lag deposit, through a fine to medium, shelly, sand facies, and are capped by a very fine silty clay facies. These various lithofacies represent a succession of depositional environments from estuarine to marine. Besides fining upwards, the units also fine towards the east, with the majority of sediments being coarser in the western area and finer near the coast. The Eastover Formation was recently identified and named by Ward and Blackwelder (1980) for exposures along the James River, Surry County, Va. This formation consists of a series of sediments that stretches from Maryland south into North Carolina. Its upper sandy facies, which comprises the lower part of the Yorktown-Eastover aquifer, is described as consisting of a fine to medium-grained, well-sorted, shelly sand with occasional clay layers, and grayish-blue in color. The Yorktown Formation, which constitutes the greater part of this aquifer, was originally named by Clark and Martin (1906) for exposures along the York River near Yorktown, Va. Johnson (1969) recognized eight lithofacies within the Yorktown ranging from sand through sandy shell and shell beds to silty clays. The surficial Bacons Castle Formation was named by Coch (1965) for deposits west of Surry Scarp, a north-northeast trending erosional feature (Bick and Coch, 1969), and consists of a lower sandy facies and an upper bedded-silt facies. The exposed lower sandy facies defines the eastern limit of the unconfined Yorktown-Eastover aquifer. Most wells in the study area penetrate and provide information on this aquifer. The Yorktown-Eastover aquifer is primarily used for light industrial and domestic supply; however, in the eastern part of the study area it supplies most of the water for all users. Also, in the eastern part of its area, the lower part of the aquifer contains water that tends to be high in chlorides, thus limiting its use.

Typical electric-resistivity log patterns of sediments in the Yorktown-Eastover aquifer are best illustrated on geophysical logs of wells 57G22, 57G25, 57F2, 59D20, plate 3, E-E'; 56F42, 57D3, 59D1, 60C7, plate 5, F-F'; and 54A3, 55A1, 56B9, 58B115, 60C25, plate 6, J-J'. Generally, these resistivity patterns are highly variable and erratic, indicating its interbedded nature of sands and clays. Commonly though, there are distinct sandy zones and clayey zones that are easily correlated from one log to another. Resistivity logs generally exhibit very high values for these sediments, and the upper and lower contacts with the overlying Yorktown confining unit and the underlying St. Marys or Calvert confining units are easily recognized. Corresponding natural-gamma logs of these sediments generally indicate a highly sandy unit with interbedded clays. Drillers commonly refer to the sediments in the Yorktown-Eastover aquifer as "sands, shells, and clays," frequently with hard shell layers and gray to yellow in color. Studies (Johnson, 1969, 1972; Blackwelder and Ward, 1976; Ward and Blackwelder, 1980) indicate that the depositional environment of the Eastover, Yorktown, and Bacons Castle Formations consisted of a large, very shallow, embayed shelf that was alternately exposed and submerged by temperate marine seas.

YORKTOWN CONFINING UNIT

The Yorktown confining unit is defined by the predominantly clayey deposits of the upper parts of the Yorktown Formation and the Bacons Castle Formation (Oaks and Coch, 1973). These sediments are Pliocene in age and correlate with the upper Chesapeake confining unit in Maryland and the confining unit overlying the Yorktown aquifer in North Carolina (pl. 1). The Yorktown confining unit crops out along the major stream valleys of the central area just east of the outcropping Yorktown-Eastover aquifer. It overlies the Yorktown-Eastover aquifer throughout the central and eastern part of the study area and is overlain by the Columbia aquifer wherever land-surface elevation is less than 100 ft. The Yorktown confining unit is not a single, areally extensive clay layer, but rather, is a series of coalescing clay layers at or near the top of the Yorktown or Bacons Castle Formations. These clay layers are the final stage of the fining-upwards depositional sequences which initially formed the underlying sandy sediments of the Yorktown-Eastover aquifer. This confining unit is wedge shaped in cross section, dips eastward, and attains a maximum known thickness of 109 ft at well 68M2 (fig. 7) in the northeastern part of the study area. Its thickness is variable (fig. 24), but generally increases eastward. The Yorktown confining unit consists of very fine sandy to silty clays that are highly variable in color, varying from multicolored to dark gray. This confining unit lies at or very near the surface throughout the central part of the study area where it is highly dissected or thinned by streams. In the northern and central parts, the confining unit is correlated primarily by drillers' logs and natural-gamma logs, because electric-resistivity logs commonly stop recording within 20 to 40 ft of the surface. In the eastern and southern parts, however, it is easily recognized in all types of logs. Typical electric-resistivity log patterns of sediments of the Yorktown confining unit are best illustrated on geophysical logs of wells 54D2, 56B1, 57A1, plate 3, G-G'; 55D5, plate 4, H-H'; 58B115, 58C51, plate 4, I-I'; 54A3, 56B9, 56B1, plate 4, J-J'; and 60B1, 61B2, 62C5, plate 4, K-K'. Commonly, the resistivity patterns exhibited are a broad U-shaped profile indicating the uppermost competent clay unit in the stratigraphic section. These clays were deposited on a shallow, marine shelf in broad lagoonal and bay areas.

QUATERNARY SEDIMENTS, UNDIFFERENTIATED

COLUMBIA AQUIFER

The Columbia aquifer is defined by the predominantly sandy surficial deposits above the Yorktown confining unit. These sediments are, for the most part, Pleistocene and Holocene in age, but also include sandy Pliocene sediments that lie above the clayey deposits of the Yorktown confining unit. The aquifer correlates with the surficial aquifers in Maryland and North Carolina. The Columbia aquifer is generally unconfined; however, clayey sediments within it may produce local confined or semi-confined conditions. This aquifer is highly variable in thickness, but generally thickens eastward and attains its maximum known thickness along the southeastern coast of the study area.

The sediments composing this aquifer mostly consist of a series of formations that are the result of Pleistocene marine transgressions. The Pleistocene sediments consist of formations locally known as the Windsor, Charles City, Chuckatuck, Shirley, and Tabb (G.H. Johnson, College of William and Mary, oral commun., 1984). In this report the Columbia aquifer also includes the upper Pliocene Chowan River Formation of the Chesapeake Group. Each formation is similar in lithology and mode of deposition and generally is characterized by a fining-upwards depositional sequence, much like the sediments of the Yorktown-Eastover aquifer. Each is composed of a very coarse gravelly lag deposit that grades up through sands to fine silts and clays. Generally, all land surfaces less than 100 ft above sea level are covered by sediments of the Columbia aquifer (fig. 24). The Columbia aquifer is used primarily for domestic water supply, especially throughout the eastern parts of the study area.

SUMMARY AND CONCLUSIONS

The sediments of the Virginia Coastal Plain form an eastward-thickening wedge of unconsolidated gravel, sand, silt, and clay, with differing amounts of shells. This wedge forms a multilayered aquifer system that lies on a warped surface of basement rocks. The major part of the aquifer system consists of a thick sequence of discontinuous nonmarine sands and interbedded clays, overlain by a thinner sequence of generally continuous marine sands and clays. The sediments range in age from Early Cretaceous to Holocene and have a complex depositional and erosional history.

The sediments of the Virginia Coastal Plain were divided into nine aquifers and eight confining units as part of the northern Atlantic Coastal Plain Regional Aquifer-System Analysis study. The nine aquifers identified and described in this report are the lower Potomac, middle Potomac, upper Potomac, Brightseat, Aquia, Chickahominy-Piney Point, St. Marys-Choptank, Yorktown-Eastover, and Columbia. The Brightseat is a newly named and defined aquifer in the Virginia Coastal Plain.

The nine aquifers and eight confining units were identified, correlated, and traced by use of borehole geophysical logs, drillers' information, lithologic, paleontologic, and water-level data. Patterns of characteristic geophysical log signatures and characteristic lithologies provide the basis for defining the hydrogeologic units throughout the Virginia Coastal Plain. Data required for the identification and correlation of regional hydrogeologic units are sparse or lacking in some areas of the Virginia Coastal Plain. The authors recognize that new geologic and hydrologic data from test holes and water wells will help refine this framework in those areas of recognized data deficiencies and that alternative local hydrogeologic interpretations are possible.

The hydrogeologic framework is illustrated by use of hydrogeologic sections and maps of confining-unit thickness and altitude of tops of aquifers. The Virginia Coastal Plain hydrogeologic framework is continuous with those simultaneously developed in the Coastal Plains of Maryland and North Carolina, and forms part of a regional hydrogeologic framework of the northern Atlantic Coastal Plain from North Carolina to Long Island, N.Y. It also forms part of the conceptual basis for the regional digital ground-water flow model of the northern Atlantic Coastal Plain and the ground-water flow model for the Virginia Coastal Plain.

It is intended that the results of this study be used to provide a basic conceptual framework for other hydrogeologic studies within the Virginia Coastal Plain area, such as county, basinwide, or site-specific investigations. Results of this study will also provide a basis for the development and siting of a comprehensive observation well network in the Coastal Plain of Virginia.

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