HYDROGEOLOGIC FRAMEWORK OF THE VIRGINIA COASTAL PLAIN

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VIRGINIA COASTAL PLAIN

By Andrew A. Meng III and John F. Harsh

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WILLIAM P. CLARK, Secretary

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Dallas L. Peck, Director

For additional information
write to:

Gary S. Anderson, Chief
Virginia Office
U.S. Geological Survey, WRD
200 W. Grace Street, Room 304
Richmond, Virginia 23220

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CONVERSION FACTORS

Factors for converting inch-pound units to the International System (SI) of units are given below:

Multiply	By	To obtain
ft (feet)	0.3048	m (meters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
ft/mi (feet/mile)	0.18943	m/km (meter per kilometer)

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by A. A. Meng III and J. F. Harsh

ABSTRACT

This report defines the hydrogeologic framework of the Virginia Coastal Plain and is a product of a comprehensive regional study to define the geology, hydrology, and geochemistry of the northern Atlantic Coastal Plain aquifer system extending from North Carolina to Long Island, New York.

The Virginia Coastal Plain consists of an eastward-thickening wedge of generally unconsolidated, interbedded sands and clays, ranging in age from Early Cretaceous to Holocene. These sediments range in thickness from more than 6,000 feet beneath the northeastern part of the Eastern Shore Peninsula to nearly 0 feet along the Fall Line. Eight confined aquifers, eight confining beds, and an uppermost water-table aquifer are delineated as the hydrogeologic framework of the Coastal Plain sediments in Virginia. The nine regional aquifers, from oldest to youngest, are lower, middle, and upper Potomac, Brightseat, Aquia, Chickahominy-Piney Point, St. Marys-Choptank, Yorktown-Eastover, and Columbia. The Brightseat is a newly identified and correlated aquifer of early Paleocene age. This study is one of other, similar studies of the Coastal Plain areas in North Carolina, Maryland-Delaware, New Jersey, and Long Island, New York. These combined studies provide a system of hydrogeologic units that can be identified and correlated throughout the northern Atlantic Coastal Plain.

Data for this study were collected and analyzed from October 1979 to May 1983. The nine aquifers and eight confining beds are identified and delineated by use of geophysical logs, drillers' information, and stratigraphic and paleontologic data. By correlating geophysical logs with hydrologic, stratigraphic, and paleontologic data throughout the Coastal Plain, a comprehensive multilayered framework of aquifers and confining beds, each with distinct lithologic properties, was developed.

Cross-sections show the stratigraphic relationships of aquifers and confining beds in the hydrogeologic framework of the Virginia Coastal Plain. Maps show confining-bed thicknesses and altitudes of aquifer tops, provide the basis for assigning aquifers to screened intervals of observation and production wells, and are used for the development of a comprehensive observation well network in the Virginia Coastal Plain.

INTRODUCTION

In 1977, Congress appropriated funds for a series of ground-water-assessment studies titled the "Regional Aquifer-System Analyses" (RASA) program; this program was designed to identify and evaluate the water resources of major aquifer systems on a regional scale in the United States. In 1979, the U.S. Geological Survey began a comprehensive regional investigation, as part of the RASA program, to define the hydrogeology and geochemistry, and to simulate ground-water flow, in the northern Atlantic Coastal Plain that extends from North Carolina to Long Island, New York (fig. 1). Subsequently, the northern Atlantic Coastal Plain RASA investigation was subdivided into five state-level RASA studies. The Virginia RASA, headquartered in the Virginia Office, Mid-Atlantic District, of the Geological Survey, was assigned the responsibility of defining a regional hydrogeologic framework and of simulating ground-water flow in the Coastal Plain province of Virginia (fig. 1). This report describes the hydrogeologic framework developed as part of the Virginia RASA study. Companion RASA studies were also conducted for the Coastal Plain areas of North Carolina, Maryland-Delaware, New Jersey, and Long Island, New York (fig. 1). Collectively, these individual studies form a regional system of hydrogeologic units that can be identified and correlated between adjoining states throughout the northern Atlantic Coastal Plain.

Purpose and Scope

This report is the result of part of the Virginia RASA study to (1) identify and define the regional hydrogeologic framework of the Coastal Plain sediments of Virginia; and (2) further understand the subsurface Coastal Plain geology and hydrology. The description of the hydrogeologic framework presented herein provides the basis for the RASA modeling study in Virginia.

Specific objectives of this report are to: (1) identify and divide the sediments of the Virginia Coastal Plain into regional hydrogeologic units; (2) delineate and describe the boundaries, stratigraphic relationships, and characteristics of the hydrogeologic units; (3) provide data to construct a digital model to simulate ground-water flow in the Virginia Coastal Plain; and (4) provide data to generate the regional hydrogeologic framework and to construct a regional ground-water flow model of the entire northern Atlantic Coastal Plain from North Carolina to Long Island, New York.

The scope of this study is to define a system of hydrogeologic units for the Virginia Coastal Plain that correlates with a regional hydrogeologic framework. The regional hydrogeologic framework is composed of ten aquifers and nine confining beds and based on published literature describing the hydrogeology in the Coastal Plain areas of New Jersey and Maryland. The Virginia Coastal Plain hydrogeologic units, as presented in this report, have been divided into nine regional aquifers with eight confining beds, encompassing nine geochronologic epochs that range in age from Early Cretaceous to Holocene. This hydrogeologic framework correlates areally and hydrologically with units in adjoining States. The hydrogeologic units in the Virginia Coastal Plain are described in terms of age, lithology, stratigraphic position, configuration, areal extent, depositional environment, regional correlations, and their characteristic geophysical log signatures; beginning with the oldest stratigraphic unit and ending with the youngest. Also, the aquifer-unit descriptions briefly refer to the general use and availability of ground

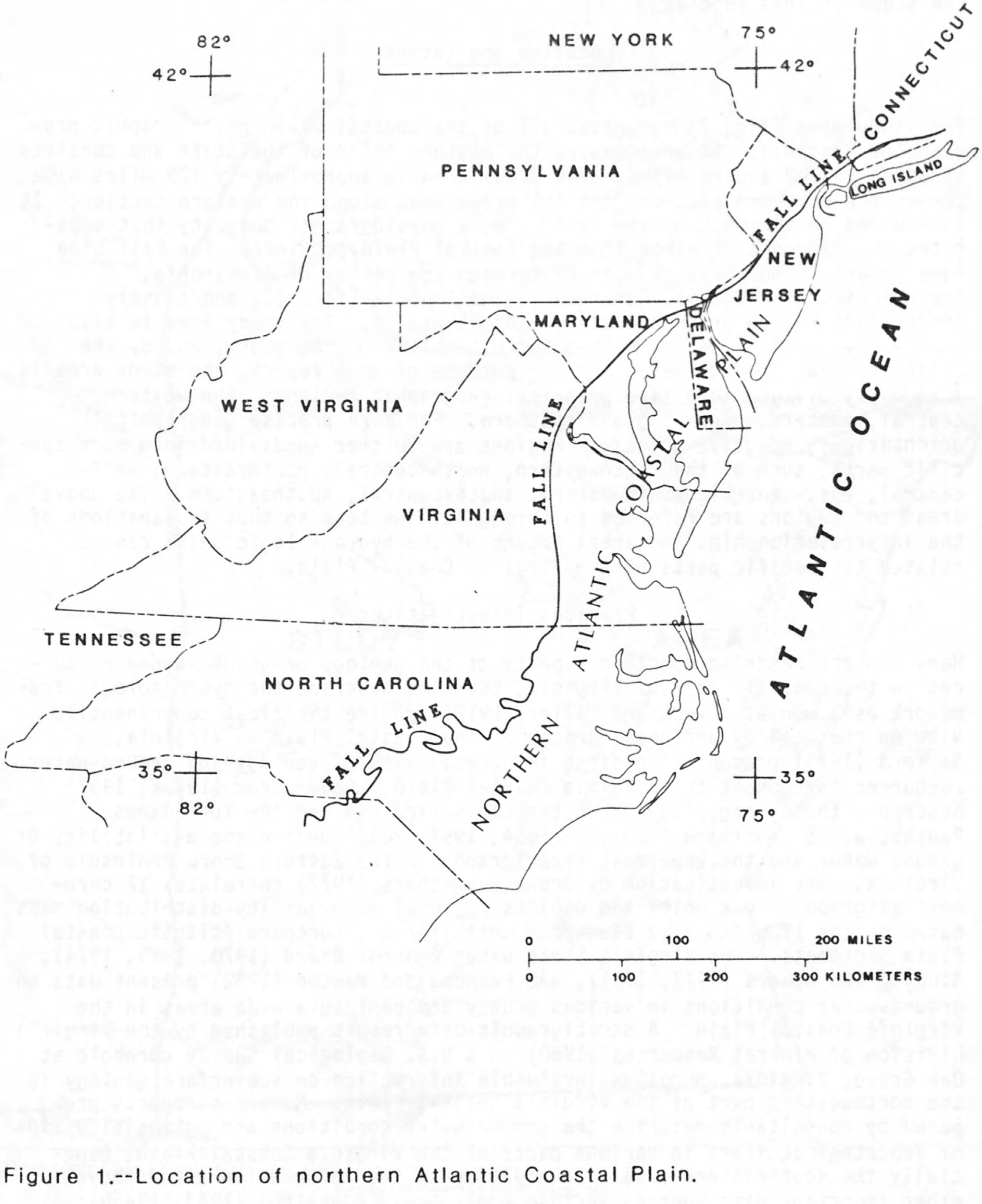


Figure 1.--Location of northern Atlantic Coastal Plain.

water, but a detailed discussion of water supply and water quality is beyond the scope of this report.

Location and Extent

The study area (fig. 2) comprises all of the Coastal Plain physiographic province of Virginia. It encompasses the eastern third of the State and consists of about 13,000 square miles. The study area is approximately 125 miles wide across the northern section, and 165 miles long along the western section. It is bounded on the west by the Fall Line, a physiographic boundary that separates the Piedmont province from the Coastal Plain province. The Fall Line runs generally north-south near or through the cities of Alexandria, Fredericksburg, Richmond, Petersburg, and Emporia (fig. 2), and closely corresponds to the present route of Interstate 95. The study area is also bounded by Maryland on the north, North Carolina on the south, and by the Atlantic Ocean on the east. For the purpose of this report, the study area is informally divided into five principal geographic regions: the western, central, eastern, northern, and southern. For more precise geographical orientations, the five principal regions are further subdivided into more specific parts, such as the northwestern, north-central, northeastern, west-central, east-central, southwestern, south-central, southeastern. The above areas and regions are referred to throughout the text so that explanations of the interrelationships and areal extent of the hydrogeologic units can be related to specific parts of the Virginia Coastal Plain.

Previous Investigations

Many reports describe specific aspects of the geology or ground-water resources in the Coastal Plain of Virginia, but none describe the hydrogeologic framework as a whole. Clark and Miller (1912) provide the first comprehensive view on the geology and physiography of the Coastal Plain in Virginia. Sanford (1913) presents the first integrated view of geology and ground-water resources throughout the Virginia Coastal Plain. Cederstrom (1945a, 1957) describes the hydrogeology of southeastern Virginia and the York-James Peninsula. Sinnott and Tibbitts (1954, 1957, 1968) define the availability of ground water and the uppermost stratigraphy in the Eastern Shore Peninsula of Virginia. The investigation by Brown and others (1972) correlates 17 chronostratigraphic rock units and depicts regional permeability-distribution maps based on the 17 delineated time-rock units for the northern Atlantic Coastal Plain sediments. The Virginia State Water Control Board (1970, 1973, 1974), Siudyla and others (1977, 1981), and Fennema and Newton (1982) present data on ground-water conditions in various county and peninsula-wide areas in the Virginia Coastal Plain. A stratigraphic-data report published by the Virginia Division of Mineral Resources (1980) on a U.S. Geological Survey corehole at Oak Grove, Virginia, supplies invaluable information on subsurface geology in the northwestern part of the Virginia Coastal Plain. Numerous reports prepared by consultants describe the ground-water conditions and potential yields of important aquifers in various parts of the Virginia Coastal Plain, especially the southeastern area. In addition to the information cited above, other important data sources include works by: Cederstrom (1943, 1945b); Richards (1945, 1948, 1967); Spangler and Peterson (1950); Hack (1957); Brenner (1963); Nogan (1964); Drobnyk (1965); Glaser (1969); Hazel (1969); Johnson and Goodwin (1969); Cushing, Kantrowitz, and Taylor (1973); Onuschak

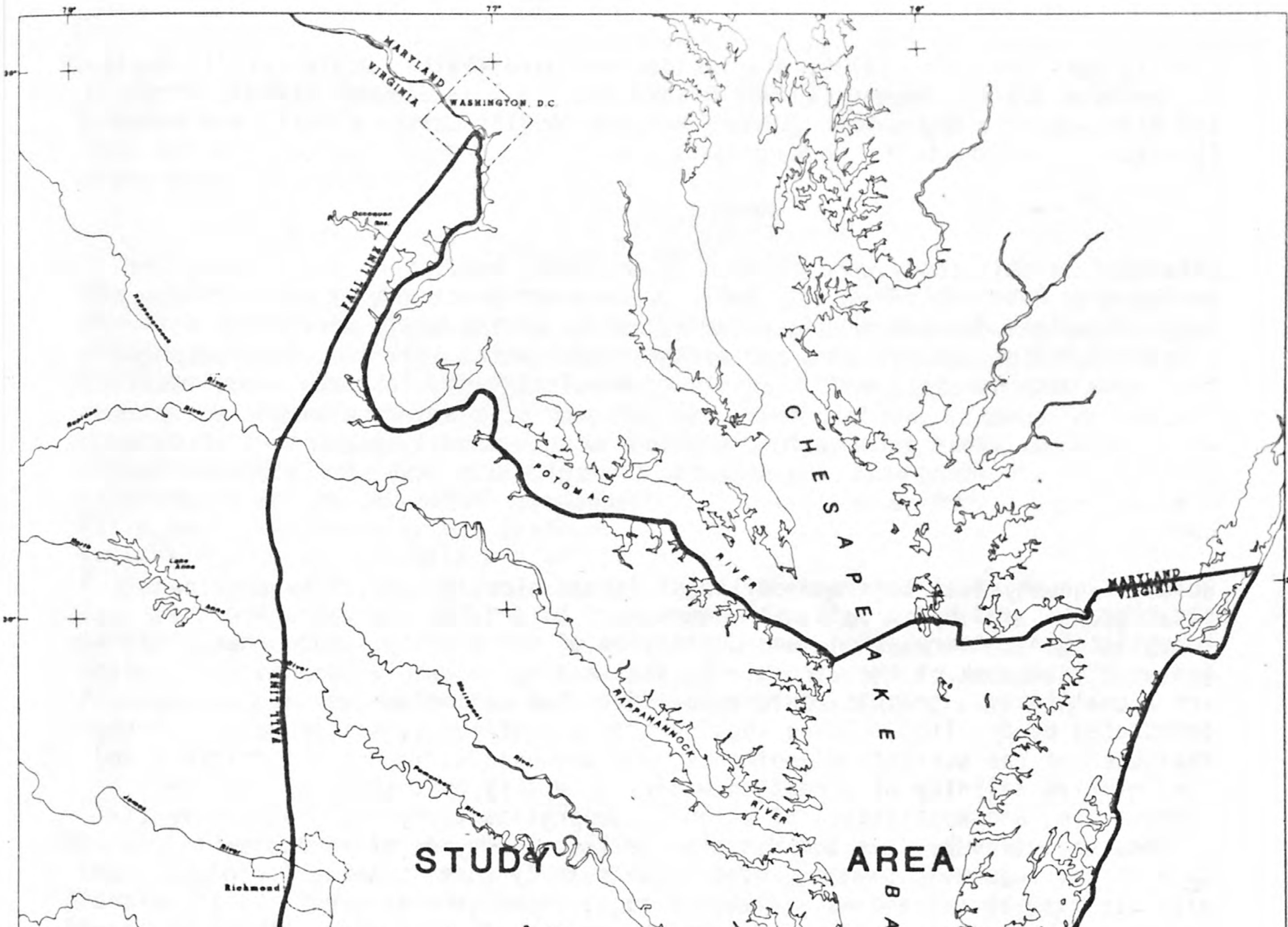


Figure 2.--Location of study area.

(1972); Oaks and Coch (1973); Blackwelder and Ward (1976); Doyle (1977); Doyle and Robbins (1977); Hansen (1978); Blackwelder (1980); Gleason (1980); Ward and Blackwelder (1980); Ward (1980); Meisler (1981); Larson (1981); and Gibson (1982).

Methods of Study

Data used in this study were collected, analyzed, and interpreted during the period from October 1979 to May 1983. Literature pertinent to the lithology, stratigraphy, and ground-water resources of the study area and the adjoining States was reviewed and synthesized. Water-well and stratigraphic test-hole data consisting of borehole-geophysical logs, drillers' logs, well completion reports, geologic logs, and paleontologic and core-sample analyses were compiled. This information, together with hydrogeologic interpretations provided by adjoining northern Atlantic Coastal Plain RASA studies, supplies the data used to define the regional hydrogeologic framework of the Virginia Coastal Plain.

Borehole-geophysical logs and drillers' information, supported by pertinent stratigraphic and hydrologic data, were used to provide the basis for the identification, correlation, and definition of the areally comprehensive hydrogeologic framework of the Virginia Coastal Plain. Borehole-geophysical logs are a qualitative, graphic representation of the subsurface environment penetrated by drilling. These logs portray a continuous, scaled record of the character of the subsurface sediments, and are used to identify formations and the relative salinity of formation waters. Details on the interpretation, correlation, and application of borehole geophysics to hydrogeologic investigations are given by Keys and MacCary (1971). The types of borehole-geophysical logs most commonly used in this study consist primarily of electric resistivity and natural-gamma logs. Spontaneous potential (S.P.) and single-point and multi-point electric resistivity logs identify lithologic contacts, determine gross sand-to-clay ratios in each hydrogeologic unit, and indicate the relative quality of water in the aquifer units. Natural-gamma logs define regional lithologic facies changes in units and dip directions of strata that contain particularly high gamma-emitting lithologies or marker beds. Drillers' information includes sample logs, commonly called drillers' logs or cuttings logs, and well-completion reports. Sample logs describe the physical properties of sediments penetrated during drilling operations. Well-completion reports provide information on depths to screened intervals and water levels in finished wells. Geologic logs provide a detailed, usually microscopic, description and identification of the lithology of cuttings collected from the drilled holes. Paleontologic analyses of cuttings and core samples provide biostratigraphic data on the ages of sediments. Core-sample analyses also provide information on specific lithologic and depositional characteristics of the subsurface sediments not otherwise obtainable from drill cuttings.

Lithologic trends in the type and distribution of sediments are apparent from analysis of stratigraphic, borehole, and water-well information. These trends were identified on the basis of stratigraphic and lithologic relationships obtained from different drilled holes over large areas and areally extensive lithologic and geophysical marker beds. Log signatures depicting sand lithologies are identified and labeled as aquifers on the geophysical logs; in contrast, log signatures depicting clay lithologies are identified and labeled as confining beds (fig. 3). A regional correlation of aquifers and confining beds in the Virginia Coastal Plain was developed by comparing geophysical logs and chronostratigraphic and lithostratigraphic units across adjoining State boundaries.

Well-numbering System

The well-numbering system used by the Geological Survey in Virginia is based on the "Index to Topographic Maps of Virginia" (U.S. Geological Survey, 1978). Topographic map quadrangles covering 7 1/2-minutes of latitude and longitude, published at a scale of 1:24,000, or 1 inch = 2,000 feet, are identified by numbers and letters starting in the southwest corner of the State. The quadrangles are numbered 1 through 69 from west to east beginning at 83°45' west longitude, and lettered A through Z (omitting letters I and O) from south to north, beginning at 36°30' north latitude. The area covered by the Coastal Plain includes generally the quadrangles numbered from 50 to 69 containing the letters from A to V. Wells are identified and numbered serially within each 7 1/2-minute quadrangle. As an example, figure 4 shows the south-central section of the study area. Well 53A2 is in quadrangle 53A and is the second well in that quadrangle for which the location and other data were recorded by the Geological Survey. All wells selected as controls for this hydrogeologic framework are listed by increasing well number in the Appendix of this report.

Acknowledgments

Acknowledgment is given to the Bureau of Surveillance and Field Studies and the Tidewater Regional Office of the Virginia State Water Control Board, for furnishing well information, selected stratigraphic cores, and geophysical logs. The authors wish to thank R. L. Magette Co., Gammon Well Co., and Layne-Atlantic Co. for providing single point electric-resistivity geophysical logs and well data, and to the many drillers in the Virginia Coastal Plain who have supplied valuable information concerning the nature of sediments and their water-bearing properties. Special thanks goes to Sydnor Hydrodynamics, Inc. for providing comprehensive well data, multipoint electric-resistivity and natural-gamma geophysical logs, and for their conscientious and continuous efforts in obtaining subsurface hydrogeologic information.

The authors express appreciation to the Virginia Division of Mineral Resources for providing a preliminary revised surficial geologic map of the Virginia Coastal Plain sediments. The authors also wish to convey appreciation to L. W. Ward, L. E. Edwards, R. B. Mixon, J. P. Owens, L. McCarten, and T. G. Gibson, of the U.S. Geological Survey, for providing valuable and timely stratigraphic information and analysis.

GENERAL GEOLOGY

The study area is part of the Atlantic Coastal Plain province that extends from Cape Cod, Massachusetts, southward to the Gulf of Mexico. The Coastal Plain province of Virginia consists of an eastward-thickening sedimentary wedge (fig. 5) composed principally of unconsolidated gravels, sands, silts, and clays, with variable amounts of shells. This sedimentary wedge generally is devoid of hard rocks, although calcareous cementations are present locally, forming thin lithified strata. The unconsolidated deposits rest on a rock

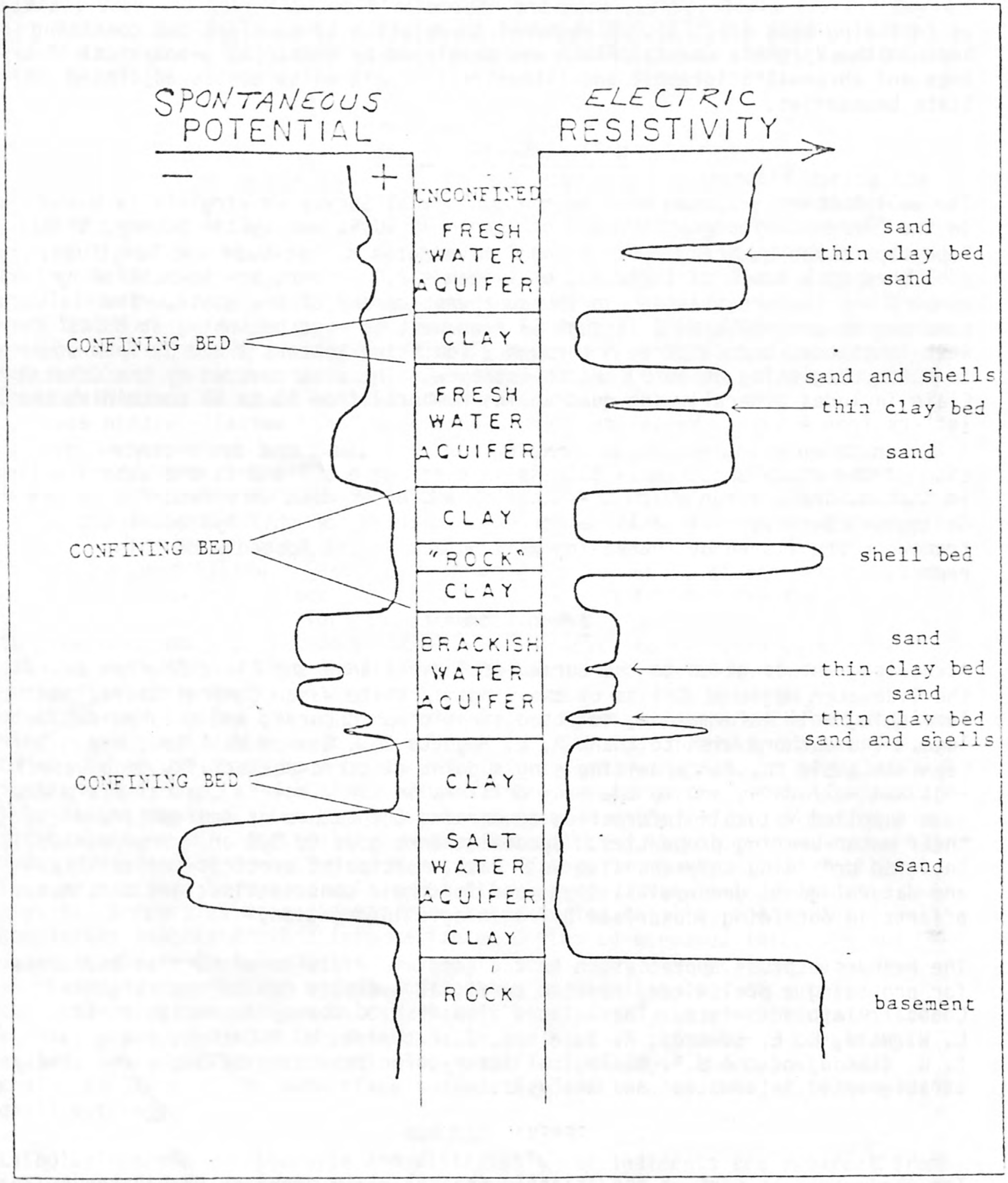
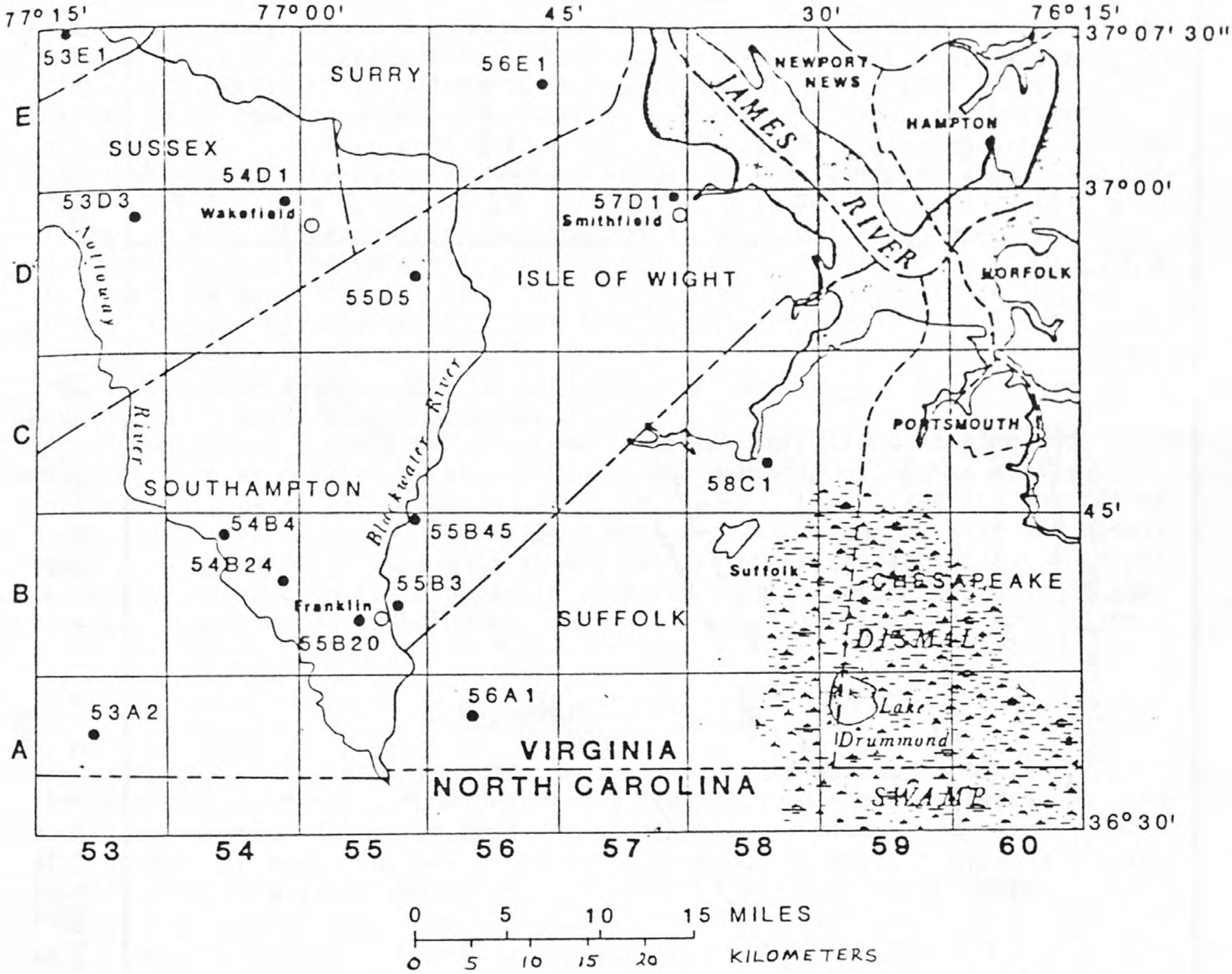


Figure 3.--Idealized geophysical log showing aquifers and confining beds and characteristic electric and spontaneous potential traces.



EXPLANATION

• 53A2 Control well location and well number

Figure 4.--Example of Virginia well-numbering system.

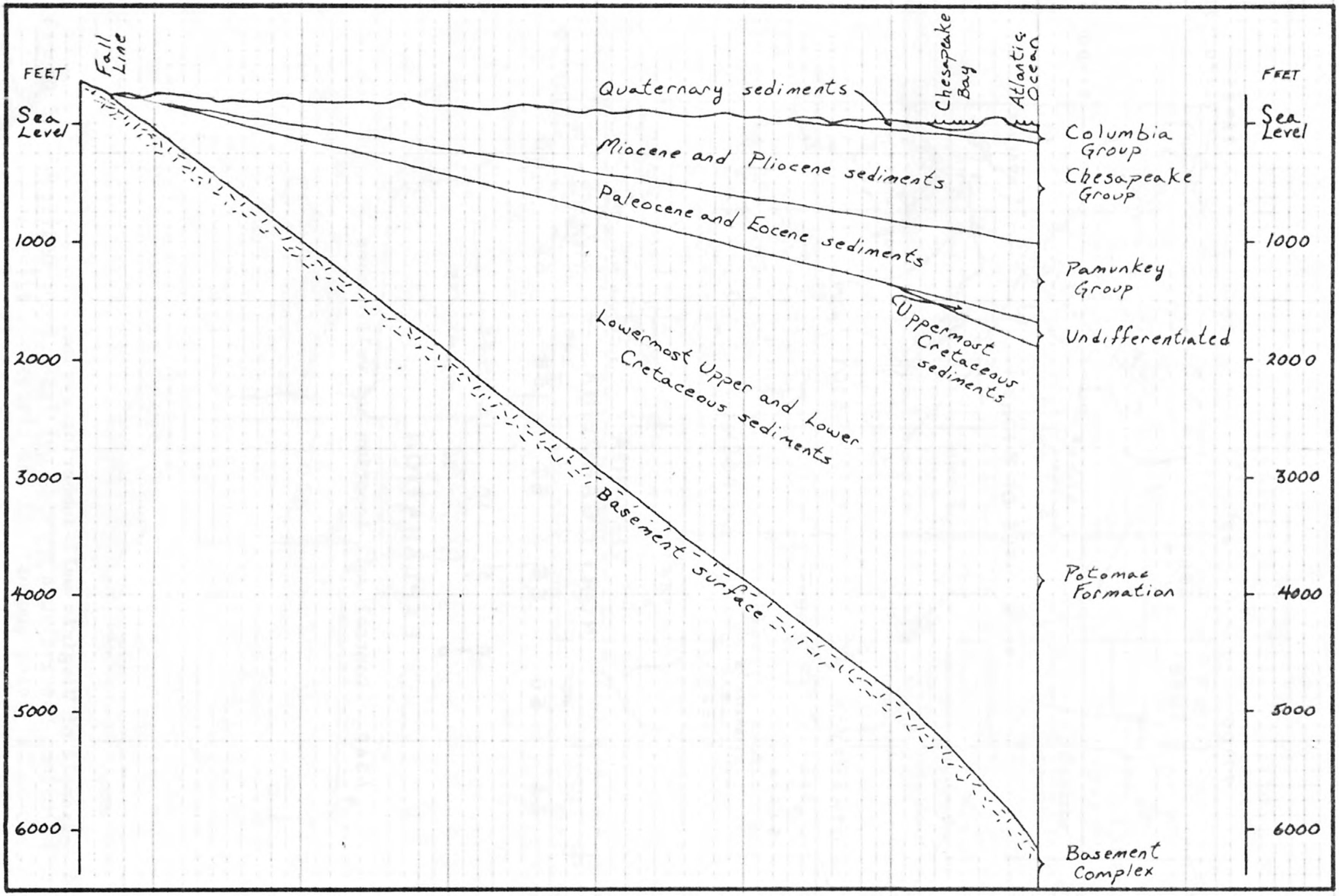


Figure 5.--Generalized geologic section showing eastward-thickening sedimentary wedge of Virginia Coastal Plain.

surface, commonly referred to as the "basement," that slopes gently eastward. The sediments attain a maximum thickness of over 6,000 ft in the northeastern part of the study area. Onuschak (1972) reports that the sediments are 6,186 ft thick beneath the Eastern Shore Peninsula at Temperanceville, Virginia (fig. 5). Coastal Plain sediments thin westward to nearly zero thickness at the Fall Line and are highly dissected by streams throughout the western region. Small, isolated erosional remnants of Coastal Plain deposits are common, just west of the main sedimentary wedge, in the Fall Line area. The surface of the Virginia Coastal Plain consists of a series of broad gently sloping, highly dissected terraces bounded by seaward-facing, ocean-cut escarpments extending generally north-south across the province. Most of the study area is less than 100 ft in altitude and one-fifth is covered by water, principally the Chesapeake Bay. The land surface is highest along the Fall Line, especially in the northwestern part of the study area. The sedimentary section, in general, consists of a thick sequence of nonmarine deposits overlain by a much thinner sequence of marine deposits. These deposits are, for the most part, undeformed throughout, except for slight warping and tilting, with associated local faulting. All depositional units strike approximately parallel, or subparallel, to the Fall Line. The average dip of each successively younger depositional unit decreases upward, with the oldest deposits dipping nearly the same as the basement-rock surface (about 40 ft/mi) and the youngest deposits dipping less than 3 ft/mi. Sediments range in age from Early Cretaceous to Holocene, and have a complex history of deposition and erosion.

Depositional History

Many different depositional environments existed during the formation of the Virginia Coastal Plain. Numerous marine transgressions and regressions, punctuated by varying periods of erosion, produced an assorted, but ordered, array of sediments in the study area. The shoreline has occupied positions far to the east of the present shoreline, as evidenced by offshore submerged Pleistocene barrier beach deposits, and positions at least as far west as the Fall Line, as evidenced by marine deposits at the Fall Line.

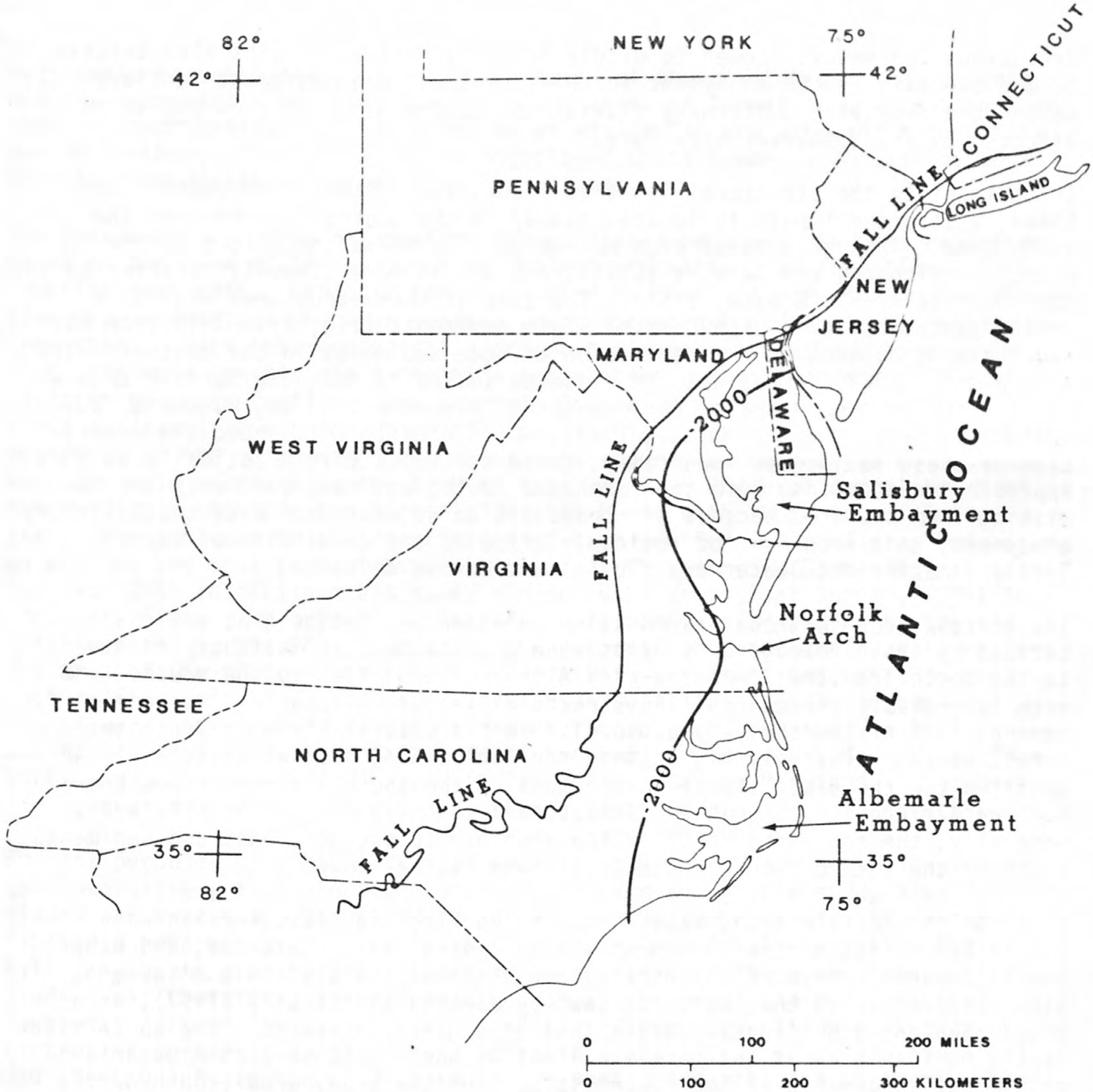
Ages of sediments exposed at the surface within the study area consist of Early Cretaceous, Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene. Sediments of Late Cretaceous age are overlain by younger sediments, and are not exposed at the surface in the study area. Sediments of Early Cretaceous and Paleocene age crop out extensively between the Fall Line and the Potomac River in the northwestern part of the study area. Sediments of Eocene, Oligocene, and Miocene age are exposed principally along the major stream valleys throughout the western and central regions of the study area. The uppermost sediments of Pliocene, Pleistocene, and Holocene age crop out extensively in broad areas throughout the eastern and southern regions, and, to a lesser extent, in the central and north-central parts of the study area. The Coastal Plain deposits of Virginia can be divided into five principal lithostratigraphic groups based primarily on their mode of deposition. These five groups, from oldest to youngest, are (1) Lower to lowermost Upper Cretaceous Potomac Formation; (2) Uppermost Cretaceous deposits; (3) lower Tertiary Pamunkey Group; (4) upper Tertiary Chesapeake Group; and (5) Quaternary Columbia Group.

Throughout the Early Cretaceous, the land area now comprising the study area was elevated in relation to sea level, and thick sequences of fluvial-deltaic continental and marginal marine sediments were deposited on a broad rock surface. These sediments, at first, were deposited by high-gradient streams, which formed large subaerial deltas that prograded into the Cretaceous seas. As the deltas developed, the depositional pattern gradually changed to a lower-gradient, subaqueous environment throughout the latter half of the Early Cretaceous. Early in the Late Cretaceous, the first major marine transgression occurred, which inundated the eastern half of the study area with shallow seas and broad estuaries. A marine regression soon followed that resulted in a long period of nondeposition which lasted throughout most of the remaining Late Cretaceous. Toward the end of the Late Cretaceous, marine seas once again transgressed into the study area, but only marginally along the northeastern and southeastern sections, where a very thin veneer of clays, sandy clays, and marls was deposited. Throughout the following Tertiary period, interbasinal marine seas covered the study area to varying degrees and deposited relatively thin, but areally extensive, sediments that consisted primarily of glauconite, diatoms, sands, silts, clays, and shells. These Tertiary marine deposits represent two major lithologically distinct groups: the glauconitic sands, silts, and clays of the Pamunkey Group; and the shelly clays, silts, and sandy clays of the Chesapeake Group. Sediments of Quaternary age, which compose the Columbia Group, overlie most of the Tertiary deposits. The Columbia Group includes fluvial and marine deposits that reflect Pleistocene sea-level fluctuations.

Structural Setting

Crustal deformation along the Atlantic continental margin has produced the regionally downwarped Atlantic Coastal Plain province, and the adjoining regionally uplifted Piedmont province. Weathered rock debris eroded from the uplifted areas were transported and deposited into the downwarped areas as Coastal Plain sediments. The Coastal Plain's thin western edge, defined by the Fall Line, marks the limit of the overlapping unconsolidated sediments onto the crystalline rocks of the Piedmont highlands. The Coastal Plain sediments thicken and extend eastward to the submerged margin of the Continental Shelf approximately 65 miles offshore of Virginia. Within the regionally downwarped area, local differential subsidence produced a series of structural highs and lows, commonly referred to as arches and embayments (basins). Thick accumulations of sediments were deposited within the embayments, with thinner accumulations over the arches. The arches, in effect, separated each of the basins, and together with other environmental factors, produced basins with characteristic depositional sequences. Deposition in the Virginia Coastal Plain was affected by three major structural deformation features. These structural features are, from north to south, the Salisbury embayment, the Norfolk arch, and the Albemarle embayment (fig. 6).

The Coastal Plain of northern and central Virginia forms the southern flank of the Salisbury embayment (Richards, 1948)--an eastward-plunging, open-ended sedimentary basin with an axis that trends across southern Maryland. Structure contours of the top of the basement rocks (fig. 6) bend noticably toward the northwest as they approach the axis of the Salisbury embayment. This structural low has had a pronounced influence on the deposition of sediments throughout the northern and central sections of the study area. Lower Cretaceous fluvial-deltaic deposits thicken considerably toward the axis of the embayment; Glaser (1968) reports that more than 70 percent of the sedimentary section in southern Maryland and northern Virginia is composed of Lower



EXPLANATION

——2000—— Contour showing altitude of top of basement surface, in feet. Datum is NGVD of 1929.

Figure 6.--Map showing major structural deformation basement features of the Virginia Coastal Plain and adjoining areas.

Cretaceous sediments. Lower to middle Tertiary marine deposits also thicken toward the axis of the embayment in this area, but the uppermost Tertiary marine and overlying Quaternary fluvial and marine deposits seem not to be affected by the embayment structure.

In contrast to the structural low that flanks the northern and central sections, a structural high is located midway in the southern section of the study area. This structural high was originally termed the "Fort Monroe High," by Richards and Straley (1953), and now is more commonly referred to as the "Norfolk Arch" (Gibson, 1967). The axis of this structural high dips gently eastward beneath the Coastal Plain sediments (fig. 6). This arch has had a strong control on the deposition of some sediments in the southern part of the study area. Stratigraphic evidence indicates that the Norfolk arch was most active throughout Late Cretaceous and Paleogene time (J. P. Owens, U.S. Geological Survey, oral commun., 1983), which greatly influenced the deposition of these sediments. Generally, these sediments thin drastically as they approach the arch from both the north and south, and some sediments are missing from the area because of nondeposition or erosion. Like the Salisbury embayment, this arch has not noticably affected the deposition of upper Tertiary marine and Quaternary fluvial and marine deposits.

The Norfolk arch separates two distinct sedimentary basins that are characterized by their Paleogene deposits--the glauconite-rich Salisbury embayment to the north from the limestone-rich Albemarle embayment to the south. The arch is probably the controlling structural feature responsible for the general lack of limestone-type deposits in the Coastal Plain areas to the north. Being relatively higher than the surrounding basinal areas, this arch modified the the depositional environment to the south and restricted the northward migration of southern limestone-depositing seas across the arch. Generally, the sediments north of the arch dip to the northeast and sediments south of the arch dip to the southeast into basinal lows.

South of the Norfolk arch, deposition in the Virginia Coastal Plain was influenced by yet another basement low in central North Carolina, and named the "Albemarle Embayment" by Straley and Richards (1950). This embayment, also referred to as the "Hatteras Low" by Johnson and Straley (1953), is a broad open-ended sedimentary basin that dips gently eastward. The south flank of the Norfolk arch is the northern limit of the limestone-rich Albemarle embayment. Sediments in the lowermost part of the study area (south of the structural basement high), are generally much finer grained than sediments to the north. In this area, limestone-stringers and limey-matrix deposits of Paleogene age are common. These limey deposits become more numerous and thicker in the northern North Carolina Coastal Plain (M. D. Winner, Jr., Geological Survey, oral commun., 1982), and eventually thicken into the extensive limestone beds of Eocene, Oligocene and Miocene age in the central North Carolina Coastal Plain.

HYDROGEOLOGIC FRAMEWORK

The regional hydrogeologic framework described in this report identifies and delineates eight major confined aquifers, eight major confining beds, and an uppermost water-table aquifer. Recognition of the nine aquifers and eight confining beds is based on lithologic and hydrologic characteristics of geologic formations, and is supported by analysis of water-level data.

Hydrogeologic units are defined on the basis of their water-bearing properties and not necessarily on stratigraphic boundaries. A formation may contain more than one hydrogeologic unit, or may be an aquifer in one area and a confining bed in another. Therefore, the hydrogeologic units commonly consist of combinations or divisions of geologic formations.

The hydrogeologic names of aquifers and confining beds used in this report are based on the name of the predominant geologic formation, or formations, that comprise each unit. Geologic names are used so that a clear and concise relationship is developed between stratigraphic formations and their hydrologic properties. With this geologically orientated nomenclature, the hydrogeologic unit name will immediately indicate a qualitative description and relative position to those familiar with Virginia Coastal Plain stratigraphy. For those not familiar with the Virginia Coastal Plain, each hydrogeologic unit is described in the following sections of this report and delineated on maps and hydrogeologic sections in the back of this report. Regional correlations of hydrogeologic units in the Virginia Coastal Plain with those in adjoining States are included in the description of each aquifer and confining bed based on written and oral communications with D. A. Vroblesky (U.S. Geological Survey, 1984) in Maryland and M. E. Winner (U.S. Geological Survey, 1984) in North Carolina. The correlative aquifer unit names in adjoining States are terms applied by the RASA studies in the respective States and usually reflect the name of the predominant geologic formation, or formations, that compose each aquifer unit. However, the correlative confining beds in adjoining States were not given hydrogeologic names, as was done for the Virginia Coastal Plain. These correlative confining beds are commonly denoted as "the confining bed overlying..." a particular aquifer and in Maryland, the confining beds are numbered serially 1 through 9, from oldest to youngest.

For the purposes of continuity and clarity, only one set of geologic names is used exclusively throughout the study area, even though the study area includes parts of two distinct sedimentary-basin systems--the Salisbury and Albemarle embayments. The geologic formations that developed within the Salisbury basin are the predominant depositional units throughout most of the study area; therefore, these formation names are used. The much smaller, lowermost part of the study area, in which sediment depositional history was controlled primarily by the Albemarle basin system, is similar in deposition and stratigraphy to the study area to the north, and, therefore, these units are denoted accordingly.

The regional hydrogeologic units identified in this study and the corresponding hydrogeologic units of adjoining RASA studies are illustrated on plate 1. Also illustrated are diagnostic and correlative ages, stages, pollen zones, corresponding group names and formation names, lithologies, origins, and areal distribution of each framework unit, together with a combined idealized single-point electric resistivity and lithologic log representative of the total hydrogeologic section. This plate provides a quick reference for the characteristics and correlations associated with the regional hydrogeologic units identified throughout the Virginia Coastal Plain. Table 1 provides an overview of significant Virginia Coastal Plain stratigraphic nomenclature, from a review of present and past literature, relative to the hydrogeologic units identified in this study and the corresponding modeling units used in the ground-water flow model developed under the Virginia RASA study (Harsh and Laczniak, 1983, p. 592).

Table 1.--Significant stratigraphic nomenclature in relation to hydrogeologic framework units and modeling units of Virginia Coastal Plain RASA study.

PERIOD	EPOCH	STAGE	STRATIGRAPHIC FORMATION	VIRGINIA RASA HYDROGEOLOGIC UNIT	VIRGINIA RASA MODEL UNIT	RADER 1983	TEIFKE 1973	CEDERSTROM 1957	CLARK AND MILLER 1912	BROWN, MILLER, AND SWAIN 1972
QUATERNARY	HOLOCENE	POST-GLACIAL	HOLOCENE deposits	Columbia Aquifer	AQ 10	alluvial deposits; Tabb Formation; Norfolk Formation; Windsor Formation	Columbia Group	Columbia Group	Columbia Group: Talbot Formation ? — ? Wicomico Formation ? — ? Sunderland Formation	Rocks of Post MIOCENE Age
	PLEISTOCENE	WISCONSIN TO NEBRASKAN	Columbia Group: Undifferentiated							
TERTIARY	PLIOCENE	PIACENZIAN	Chesapeake Group: Yorktown Formation	Yorktown Confining Bed	CB 9	Chesapeake Group: Bacons Castle Formation			Lafayette Formation	
		ZANCLEAN		Yorktown-Eastover Aquifer	AQ 9	Yorktown Formation & Eastover Formation (undifferentiated)				
	MIOCENE	MESSINIAN	Eastover Formation				Yorktown Formation	Chesapeake Group: Yorktown Formation	Chesapeake Group: Yorktown Formation	Rocks of Late MIOCENE Age
		TORTONIAN								
		SERRAVALLIAN	St. Marys Formation	St. Marys Confining Bed	CB 8	St. Marys Formation, Choptank Formation, & Calvert Formation (undifferentiated)		? — ? St. Marys Formation	? — ? St. Marys Formation	Rocks of Middle MIOCENE Age
			Choptank Formation	St. Marys-Choptank Aquifer	AQ 8					
		LANGHIAN	Calvert Formation	Calvert Confining Bed	CB 7		Calvert Formation	? — ? Calvert Formation	? — ? Calvert Formation	
		BURDIGALIAN								
		AQUITANIAN								
	OLIGOCENE	CHICKASAWHAYAN 1/	Old Church Formation	Chickahominy-Piney Point Aquifer	AQ 7					
		VICKSBURGIAN 1/	Not Present in Study Area							
	EOCENE	JACKSONIAN 1/	Pamunkey Group: Chickahominy Formation	Chickahominy-Piney Point Aquifer	AQ 7		Calvert Formation (continued)	Chickahominy Formation	Pamunkey Group: Nanjemoy Formation	Rocks of JACKSON Age
		CLAIBORNIAN 1/	Piney Point Formation			Pamunkey Group: Nanjemoy Formation		Nanjemoy Formation		Rocks of CLAIBORNE Age
		SABINIAN 1/	Nanjemoy Formation	Nanjemoy-Marlboro Clay Confining Bed	CB6		Nanjemoy Formation	? — ? Aquia Formation	? — ? Aquia Formation	Rocks of SABINE Age
	PALEOCENE		Marlboro Clay			Marlboro Clay				
		MIDWAYAN 1/	Aquia Formation	Aquia Aquifer	AQ 6	Aquia Formation	Mattaponi Formation	Mattaponi Formation		Rocks of MIDWAY Age
			Brightseat Formation	Brightseat Confining Bed	CB 3	Brightseat Formation				
				Brightseat Aquifer	AQ 3					
CRETACEOUS	LATE CRETACEOUS	MAASTRICHTIAN	Undifferentiated Sediments	Upper Potomac Confining Bed	CB 3	Unit A				Rocks of Unit A
		CAMPANIAN				Unit B				Rocks of Unit B
		SANTONIAN				Unit C				Rocks of Unit C
		CONIACIAN								
		TURONIAN				Unit D				Rocks of Unit D
		CENOMANIAN	Potomac Formation	Upper Potomac Aquifer	AQ 3	Unit E	"transitional beds"	? — ? Potomac Group		Rocks of Unit E
	EARLY CRETACEOUS	ALBIAN		Middle Potomac Confining Bed	CB 2	Unit F			Potomac Group: Patapsco Formation	Rocks of Unit F
				Middle Potomac Aquifer	AQ 2	Unit G			? — ?	Rocks of Unit G
		APTIAN		Lower Potomac Confining Bed	CB 1	Unit H	Patuxent Formation		Patuxent Formation	Rocks of Unit H
		BARREMIAN		Lower Potomac Aquifer	AQ 1					
		HAUTERIVIAN								
		VALANGINIAN								
		BERRIASIAN								

1/ Commonly used Stages in Atlantic Coastal Plain Province

Stratigraphic test-well and water-well data from more than 600 sites throughout the study area were compiled, analyzed, and interpreted. Of these, 185 control wells were selected as being representative of the hydrogeologic framework of the Virginia Coastal Plain. Control-well identifiers and their locations are shown on plate 2 together with the lines of hydrogeologic sections (plates 3-13) that were developed to illustrate the stratigraphic relationships of the hydrogeologic units. These control wells were selected on the basis of location and quality of the geophysical, hydrologic, and stratigraphic data.

Stratigraphic- and geophysical-log data necessary for the identification and correlation of each hydrogeologic unit are not available for some parts of the study area. Generally, the areas from the western shore of the Chesapeake Bay to the Fall Line, and south of the James River, contain the most complete data required for hydrogeologic correlations. In areas where data are not available, or where borehole information does not extend deeply enough, hydrogeologic units are correlated by projecting dips of the units from known data points, commonly from the updip sections, into those areas that lack sufficient data. Two major areas that commonly lack data are the Chesapeake Bay and the Eastern Shore Peninsula.

Hydrogeologic correlations of the lower hydrogeologic units beneath the Chesapeake Bay are, for the most part, approximate due to the general lack of borehole information. There are no wells that extend to the basement in this area. Water wells located on Tangier Island (63L1, plate 2) and the water-test well (62D2, plate 2) located at milemarker 3.7 on the Chesapeake Bay Bridge-Tunnel provide only partial borehole information to depths of 1,000 ft and 1,500 ft, respectively. The uppermost hydrogeologic units beneath the Chesapeake Bay and its tributaries were studied in detail because of interest in the erosional effects induced by sea-level lowering during Pleistocene glaciations. This erosion created deeply incised stream channels in the Coastal Plain sediments (Hack, 1957; Harrison and others, 1965), which caused a disruption in aquifer and confining-bed continuity and a change in the distribution of hydraulic heads within the affected aquifers.

The hydrogeology of the sediments beneath the Eastern Shore Peninsula have been previously investigated to a depth of approximately 450 ft (Sinnott and Tibbitts, 1954, 1957, 1968; Fennama and Newton, 1982). This area only has three wells--the J&J Taylor oil-test well, the Coast Guard Cobb Island well, and the New York, Philadelphia, and Norfolk Railroad Co. well--which were drilled to 1,000 ft or greater. Only the J&J Taylor well (66M1, plate 2) has either geophysical and geologic information available for analysis. The general lack of deeper hydrogeologic data throughout the Eastern Shore Peninsula area makes correlations of most hydrogeologic units only tentative south of well 66M1.

The information obtained from the interpretation and correlation of geophysical logs, as illustrated in the hydrogeologic sections, was then used to construct sets of hydrogeologic unit maps (plates 14-30) delineating thicknesses of confining beds and altitudes of aquifer tops. For the most part, the hydrogeologic sections and maps can be used to determine the relative positions of, and depths to, the major aquifers and confining beds. However, these hydrogeologic sections and maps are to be used only as a guide, and, because of the variable nature of subsurface sediments, should not be a substitute for test-hole drilling, especially in areas where data are sparse. Outcrop areas of the geologic formation, or formations, that form hydrogeologic units are illustrated on the Geologic Map of Virginia (Milici, Spiker, and Wilson, 1963). It is important to note that, in many cases, the hydrogeologic units constitute only the sandy or clayey facies of specific geologic formations and, therefore, represent an undefined part of the geologic outcrop areas.

Identification of each hydrogeologic unit is based on biostratigraphic and lithostratigraphic analysis obtained from literature describing outcrops, core samples and/or cuttings. A test hole (well 58H4, plate 2) was drilled, in cooperation with the Virginia State Water Control Board's Bureau of Surveillance and Field Studies, to obtain stratigraphic and hydrologic data by analyses of core samples, cuttings, water-level measurements, water samples, and geophysical logs. Correlation and delineation of the identified hydrogeologic units are based on compiled data in combination with the interpretation of geophysical logs, drillers' logs, and water-level data.

Basement Complex

The basement, which is overlain unconformably by the unconsolidated deposits of the Virginia Coastal Plain, generally consists of a gently eastward-dipping erosional surface of warped, crystalline rocks (plate 14). This basement rock emerges along the Fall Line and extends westward forming the Piedmont province. The exposed Piedmont complex consists mainly of massive igneous and highly deformed metamorphic rocks that range in age from Precambrian to Lower Paleozoic (Milici, Spiker, and Wilson, 1963), but also includes unmetamorphosed, consolidated sediments and igneous intrusives of probable Triassic age within isolated grabens and half grabens (plate 14). It seems reasonable to assume that basement rocks underlying the Coastal Plain in Virginia are similar to the adjacent exposed rocks of the Piedmont terrain. It should be noted that evidence is conflicting (Brown and others, 1972; Doyle and Robbins, 1977) concerning the presence of consolidated Jurassic sediments within the study area. If, in fact, these consolidated sediments are present, they would be considered as part of the basement complex in this report.

The slope of the basement-rock surface ranges from 50 to 100 ft per mile near the Fall Line and then decreases in slope to about 40 ft per mile to the Atlantic Coast (plate 14). Data from wells that penetrate basement rock in the Coastal Plain (plate 14) indicate an irregular, undulating surface composed of the aforementioned variable lithologies. Many authors document these irregularities in the basement surface beneath the Coastal Plain and suggest various origins. Cederstrom (1945b) interprets many of the local steep-sided basement features common throughout the Coastal Plain to be stream-cut channels and erosional scarps. Other studies, however, (Minard and others, 1974; Mixon and Newell, 1977) suggest that major breaks in slope of the basement surface can be attributed more to faulting and warping than to erosion. In wells that penetrate the basement, drillers' logs indicate that a saprolitic mantle overlies the basement surface in many places, which suggests that not all of the underlying basement surface was eroded. The basement surface forms the basal limit of the study area and is overlain principally by sediments of the lower Potomac aquifer. The basement surface is overlain by younger-age deposits only near the Fall Line.

Lower and lowermost Upper Cretaceous Potomac Formation

Fluvial-deltaic continental and marginal-marine deposits of Early to early Late Cretaceous age constitute the basal lithostratigraphic section known as the Potomac Formation (R. B. Mixon and A. J. Froelich, U.S. Geological Survey, oral commun., 1982). This stratigraphic section comprises the six lowermost hydrogeologic units and consists of three aquifers and three confining beds in the hydrogeologic framework of the Virginia Coastal Plain. These hydrogeologic units are the lower, middle, and upper Potomac aquifers and the corresponding lower, middle, and upper Potomac confining beds. The Potomac Formation, as used in this report, is commonly referred to in the literature as the Potomac Group. The Potomac sediments consist of a massive, eastward-thickening wedge of interlensing gravels, sands, silts, and clays. Throughout the study area, the Potomac Formation rests nonconformably upon the basement rock surface and is separated by major regional unconformities from the overlying latest Cretaceous and various Tertiary deposits.

The Potomac sediments crop out just east of the Fall Line in the major river valleys of the study area and in an extensive arcuate band extending from the northwestern part of the study area northeastward through Maryland. Clark and Bibbins (1897) divided the Potomac sediments into four formations based on characteristic lithofacies recognized in outcrops between Washington, D.C., and Baltimore. The four formations consist of, from oldest to youngest: the Patuxent Formation, Arundel Clay, Patapsco Formation, and rocks of the former "Maryland Raritan" now assigned to the Patapsco. Corresponding associated lithologies of these four formations consist of massively bedded, light-colored coarse arkosic clayey sands and sandy clays that commonly contain gravels; massively bedded clays and finely laminated carbonaceous clays, commonly light to dark in color; interbedded medium, lenticular sands and well-bedded, highly colored clays; and interbedded fine, blanket sands and thinly to thickly bedded, dark-colored clays. Similar lithologic units have been recognized (Cederstrom, 1945a; Spangler and Peterson, 1950; Richards, 1967) in the Potomac section throughout the study area, although they are not generally mapped as such because of their seemingly similar and discontinuous nature. Lack of definitive age relationships for the various Potomac sediments in the subsurface has, in the past, also hindered areal correlation of major lithic units owing to the sparsity of readily apparent guide fossils associated with these continental-deltaic deposits.

In Virginia, the Potomac sediments have not been as extensively studied as those in Maryland. Early studies of the Virginia Coastal Plain (Darton, 1901; Clark and Miller, 1912; Sanford, 1913) divided the Potomac sediments into the Patuxent and Patapsco Formations based primarily on lithologic and stratigraphic similarities with the type formations in Maryland. Later studies, however, generally have not recognized these formal divisions. These later studies can be divided into two basic groups: those that refer to the Potomac sediments as "Potomac Group undifferentiated" (primarily Cederstrom's works); and those that recognize the "Patuxent" with overlying "transitional beds" (Onuschak, 1972; Teifke, 1973; Daniels and Onuschak, 1974). The "Patuxent," as recognized and delineated by these later studies, is not correlative with the type Patuxent Formation of Maryland because it generally includes all Potomac sediments of Early Cretaceous age in the study area. This "Patuxent" should more properly be referred to as "Potomac Group undifferentiated," in comparison with other lithologic and stratigraphic studies (Brenner, 1963;

Glaser, 1969; Robbins, Perry, and Doyle, 1975; Doyle and Hickey, 1976; Christopher and Owens, 1980).

The characteristically variable lithologies and sparse macrofossils have made past stratigraphic correlation of these sediments as formations difficult, especially in the subsurface. The study of palynology, (pollens and spores) has recently produced a systematic zonation scheme that qualitatively identifies and correlates the age relationships of sediments. This zonation is based on the analysis and identification of index microfossil flora that resulted from the evolution of land plants and are recognized world-wide as age indicators. Palynologic studies of the Potomac sediments provide, for the first time, a comprehensive stratigraphic zonation that can be used to identify equivalent-age deposits of continental and marginal-marine origins that normally contain few other diagnostic fossils.

Brenner's (1963) analysis of Lower Cretaceous pollens in the Potomac section of Maryland and Virginia resulted in the development of the first comprehensive palynostratigraphic zonation that definitively correlates the ages of sediments in outcrop with the ages of sediments in the subsurface. Other detailed palynological studies by Groot, Penny, and Groot (1961), Brenner (1967), Doyle (1969), Wolf and Pakiser (1971), Sirkin (1974), and Doyle and Hickey (1976), have led to important modifications and a more complete zonation of the total Potomac section. Robbins, Perry, and Doyle (1975) recently refined Brenner's zonation based on palynologic analysis of samples from four deep oil test wells located within the Salisbury Embayment. The palynostratigraphic zonation scheme developed by the above studies is now recognized and used to define the standard stages of the Cretaceous Potomac Formation. Combined palynostratigraphic analyses (Brenner, 1963; Robbins, Perry, and Doyle, 1975; Doyle and Hickey, 1976; Doyle and Robbins, 1977; Reinhardt, Christopher, and Owens, 1980; L. A. Sirkin, Adelphi University, written commun., 1983) have identified five major pollen zones in the Cretaceous Potomac Formation of Virginia. These major pollen zones and their corresponding ages are: pre-Zone I, Berriasian to Barremian; Zone I, Barremian to early Albian; Zone II, middle to late Albian; Zone III, early Cenomanian; and Zone IV, middle to late Cenomanian (plate 1). Other studies (Glaser, 1969; Hansen, 1969a; Brown and others, 1972; Hansen, 1983) have proposed that correlatable lithological and depositional patterns are related to most of the major pollen zones and their corresponding "formations." In this study, the hydrogeologic units identified within the Potomac section of Virginia are based on palynostratigraphic zonation, mode of deposition, lithologic characteristics, and hydrologic data. These units are then correlated and delineated throughout the study area by interpreting of geophysical logs, drillers' logs, and water-level data. In general, all Cretaceous units strike approximately north-south and dip and thicken eastward. The delineated aquifer units are wedge shaped in cross section and consist of a series of interbedded sands and clays. The delineated confining bed units are highly variable in thickness and consist of a series of areally interlayered silty and clayey deposits.

Lower Potomac Aquifer

The lower Potomac aquifer, by definition, consists of sandy palynostratigraphic pre-Zone I and Zone I sediments of the Potomac Formation. These sediments are early to middle Early Cretaceous (Berriasian through early

Albian) in age and correlate with the Patuxent aquifer of Maryland, and the Lower Cretaceous aquifer of North Carolina (plate 1). The lower Potomac aquifer is the lowermost confined aquifer in the hydrogeologic framework. It rests entirely on the basement surface and is overlain throughout its extent by the lower Potomac confining bed, except where it crops out along the Fall Line in the northwestern part of the study area (plate 15). This aquifer attains a maximum thickness, 3,010 ft at well 66M1, in the northeastern part of the study area and thins to a featheredge along its western limit near the Fall Line. It dips eastward at about 30 ft per mile throughout the area. The lower Potomac aquifer consists predominantly of thick, interbedded sequences of angular to subangular coarse sands, clayey sands, and clays. This aquifer unit is equivalent to the Patuxent Formation of Maryland, of which numerous descriptions have been written concerning its characteristics.

From outcrops in Virginia, Berry (in Clark and Miller, 1912, p. 63) describes the Patuxent Formation as medium to coarse, light-colored quartz sands containing lenses and beds of interstratified yellow, gray, and brown clays. Berry also reports that, in general, the sands are highly arkosic, cross-bedded and clayey, commonly with micaceous and lignitic material, and that the Patuxent also contains varying amounts and sizes of gravels, either in beds, or sometimes interspersed through strata of finer materials. Analysis of the Lower Cretaceous deposits from the Oak Grove core (well 54P3, plate 2), by Reinhardt, Christopher, and Owens (1980), reveals that sediments of Cretaceous pollen zone I contain a massive lower interval of thickly bedded coarse sands and associated clay-clast conglomerates. This lower interval of pollen zone I sediments is herein identified in the hydrogeologic framework of the Virginia Coastal Plain as the lower Potomac aquifer. Typically, the sands of this series are composed of medium to very coarse subangular quartz, with abundant weathered potassium feldspar and some plagioclase. Reinhardt, Christopher, and Owens (1980) also note that the well-bedded clays of this lower interval are typically mixed-layer illite/smectite, whereas the interstitial and laminated clays are predominantly kaolinitic.

Few wells drilled in the study area penetrate the lower Potomac aquifer (plate 15). Generally, only deep stratigraphic test wells and high-capacity production wells provide data required to correlate this aquifer. The lower Potomac aquifer is capable of producing large quantities of water, but generally lie too deep for all but large industrial applications. The overlying middle and upper Potomac aquifers supply much of the water used for smaller industrial, municipal, and domestic purposes. In addition, this aquifer contains increasingly higher chloride concentrations in the downdip direction, which further restricts its usage as a potable source of water.

Typical electric-resistivity log patterns of the lower Potomac aquifer sediments are best illustrated in geophysical logs of wells 54P3, plate 4; 55H1, plates 7 and 8; 58F3, plate 8; 54G10, plates 7 and 8; 58A2, plates 9 and 14; and 53A3, plate 13. Generally, these resistivity patterns are characteristically "blocky" in profile, indicating massively bedded sequences with relatively sharp lithologic contacts among sands, clayey sands, and clays. Very few patterns of gradational, fining-upwards sequences are observed on resistivity logs of the lower Potomac aquifer. However, where these patterns occur, they are usually restricted to the uppermost part of the sand beds. Resistivity logs also characteristically show low resistance values for the sandy sediments. The low resistance values are probably caused by the high percentage of interstitial clays commonly found in the aquifer sands, or by the higher chloride concentrations generally associated with the eastern half of this aquifer unit. Corresponding natural-gamma log patterns commonly reflect a high interstitial clay content also characteristic of the aquifer sands. Drillers commonly refer to the lower Potomac aquifer sediments as "coarse gray sands" that may contain "gravels," and "light to drab-colored clays." Most of the larger gravels encountered in the drilling process are too heavy to be brought to the surface by the drilling fluid and are pushed away from the borehole by the drill bit. Drillers also commonly describe the sands as "hard" or "tough" and the clays as "tight" or "hard." Either of these conditions result in noticeably increased drilling resistance and drilling time. Commonly, the drilled clays reach the surface as small, angular pieces.

The lithologic heterogenity and discontinuous nature of the sediments in this unit makes correlation of individual sand and clay bodies extremely difficult, even over relatively short distances. The contour map delineating the top of this aquifer unit (plate 15) is based on the tops of the uppermost sands in the unit. Because of the sparse data base available and the large distances between control wells, this map should only be used as a guide to indicate the approximate altitude at any specific site. Also, the uppermost part of this aquifer, as it is presently delineated, may include sediments of younger age. As more definitive data becomes available, especially from pollen analysis and water-level information, structure contours that depict the top of the lower Potomac aquifer can be refined accordingly.

Numerous studies (Glaser, 1969; Hansen, 1969; Reinhardt, Christopher, and Owens, 1980; Hansen, 1982) of the lower Potomac sediments (pre-Zone I to middle Zone I) postulate that the paleoenvironment consisted of a subaerial high-gradient fluvial flood plain dominated by braided streams. Their interpretations are based on the predominance of coarse materials, the general lack of sorting, and overall bedding characteristics. Reinhardt, Christopher, and Owens (1980) observed glauconite and illitic clays in the lower Potomac sediments of the Oak Grove core (well 54P3). From this, they suggested that deposition occurred in a broad alluvial plain that was occasionally inundated by marine seas. The presence of glauconite was also observed by Anderson and others (1948) among alluvial sediments in cores from the lower Patuxent Formation at two deep oil test wells, the Hammond and J. D. Bethards, located in eastern Maryland, and a similar hypothesis was suggested. When viewed as a whole, sediments of the lower Potomac aquifer appear to represent the development of a continental delta (Reinhardt, Christopher, and Owens, 1980).

Lower Potomac Confining Bed

The lower Potomac confining bed is defined by the major clayey strata directly above the lower Potomac aquifer. These clay beds are predominantly restricted to upper palynostratigraphic zone I, but may also include younger sediments (basal pollen zone II). For the most part, this confining bed is middle Early Cretaceous (late Aptian to early Albian) in age. The lower Potomac confining bed correlates with confining bed 1 of Maryland and with the confining bed overlying the Lower Cretaceous aquifer of North Carolina (plate 1). This confining bed crops out in the northwestern part of the study area between the Fall Line and the Potomac River just east of the outcropping lower Potomac aquifer, and in the major stream valleys just east of the Fall Line (plate 15). It overlies and transgresses the lower Potomac aquifer throughout the study area, except where the aquifer crops out and is overlain by the middle Potomac aquifer. It attains a maximum known thickness of 173 ft (well 66M1) in the northeastern part of the study area and thins to a featheredge along its western limit near the Fall Line. The lower Potomac confining bed is usually the thickest bedded clay or, interbedded clay and sandy clay sequence, of pollen zone I sediments. Most of this sequence of clayey sediments correlates with the Arundel Clay of Maryland, although the Arundel Clay is not generally recognized as a continuous unit in the subsurface. From outcrops in Maryland, Clark and Bibbins (1897, p. 485) originally identified and defined the Arundel Clay as a series of large and small lenses of drab colored, tough clays, that are commonly highly carbonaceous and ferruginous. Analysis of the Cretaceous section in the Oak Grove core (well 54P3) by Reinhardt, Christopher, and Owens (1980), and Estabrook and Reinhardt (1980) provides the most definitive lithologic data for the lower Potomac confining bed. These studies identify and describe an upper interval of pollen zone I sediments as a massive clay-dominated interval composed of thick sequences of finely-laminated, carbonaceous clays interbedded with thin sandy clay beds. This upper interval of pollen zone I sediments is herein identified as the lower Potomac confining bed in the hydrogeologic framework described in this report. Typically, the thickly-bedded clays and sandy clays of this interval are mixed-layer illite/smectite that also contain a high percentage of expandable clays; while the laminated carbonaceous clays are predominantly kaolinitic (Reinhardt, Christopher and Owens, 1980; Estabrook and Reinhardt, 1980).

As with the underlying lower Potomac aquifer, few wells drilled in the study area penetrate the lower Potomac confining bed. Generally, only data from deep stratigraphic test wells and high-capacity production wells can be used to correlate this unit.

Clay beds comprising the lower Potomac confining bed are not a continuous, and areally extensive layer. Instead, these clays are a series of interlensing clayey deposits. Water-level measurements from observation wells indicate that these deposits act locally as confining beds and when viewed collectively, represent a single confining unit, as shown by the thickness map of the lower Potomac confining bed (plate 16). In some areas, such as in the western and central regions, the confining bed is relatively thin, ranging from 15 to 30 ft in thickness; in other areas, such as in the northern region, it attains a thickness of more than 200 ft.

Typical electric-resistivity log patterns of the lower Potomac confining bed sediments are best illustrated in geophysical logs of wells 51R5, plate 4; 53P4, plates 4 and 5; 54P3, plate 4; 52N16, plate 5; 57J3, plate 7; 58F3, plate 8, 54G10, plates 6 and 8; 53D3, plate 10; 55C12, plates 10 and 11; and 58A2, plates 10, 11 and 14. Generally, these resistivity patterns are "blocky" in profile, indicating relatively sharp lithologic contacts between the thickly-bedded confining clays with the overlying and underlying aquifer sands. Corresponding natural-gamma log patterns reflect the massively-bedded nature of these clays; few interbedded sands are present. Drillers often refer to the lower Potomac confining bed clays as "hard" or "tough" and as "gray, red, or brown clay." Like the underlying interbedded clays of the lower Potomac aquifer, drillers commonly observe an increase in drilling time and resistance when penetrating these sediments, and the resulting cuttings are commonly small, angular pieces. Also, the underlying interbedded clays of the lower Potomac aquifer usually contain significantly more interbedded sands and sandy clays than are present at this horizon.

Studies (Brenner, 1963; Glaser, 1969; Hansen 1969, 1982; Reinhardt, Christopher, and Owens, 1980) of correlative strata to the lower Potomac confining bed suggest a change in the paleoenvironment from that of the lower Potomac aquifer. These studies indicate that the depositional environment and drainage patterns changed from a high-gradient to a lower-gradient, fluvial flood plain, based on the predominance of finer grained clayey materials and their associated bedding characteristics. These studies also suggest that the resulting paleoenvironment consisted of quiet, shallow, discontinuous backswamp basins with little sediment input.

Middle Potomac Aquifer

The middle Potomac aquifer, by definition, consists of sandy palynostratigraphic zone II sediments of the Potomac Formation. These sediments are late Early Cretaceous (middle to late Albian) in age and correlate with Patapsco sediments of the Raritan-Patapsco aquifer in Maryland and the lower Cape Fear aquifer of North Carolina (plate 1). The middle Potomac aquifer is the second lowest and thickest confined aquifer in the hydrogeologic framework. This aquifer crops out just east of the lower Potomac confining bed in the northwestern region of the study area and in a small area along the James and Appomattox Rivers near the Fall Line (plate 17). It overlies the lower Potomac confining bed and is overlain by the middle Potomac confining bed. The middle Potomac aquifer attains a maximum known thickness of 929 ft (well 66M1) in the northeastern part of the study area and thins to a featheredge along its western limit near the Fall Line. It dips eastward at approximately 15 ft per mile in the western half of the study area and at 25 ft per mile in the eastern half. The middle Potomac aquifer consists of interlensing medium sands, silts, and clays of differing thickness. This aquifer is equivalent to the Patapsco Formation in Maryland as defined by Brenner (1963).

From outcrops in Maryland, Glaser (1968, p.8) describes the Patapsco Formation as a thick sequence of interbedded variegated silty clay and fine to medium, gray to yellow sand. Glaser (1968) also reports that the clay lenses are typically thick, internally massive, and brightly mottled in red, yellow, gray, and purple, whereas the sands, occasionally with gravels, are similar to those in the Patuxent Formation, although they tend to be finer grained, more uniform, and more argillaceous. Berry (in Clark and Miller, 1912, p. 67) describes "Patapsco" sediments in Virginia much the same as Glaser describes them in Maryland, although Berry notes that the outcropping Virginia deposits are generally much more evenly colored than those in Maryland. Analysis of the Oak Grove core (well 54P3, plate 2) by Reinhardt, Christopher, and Owens (1980, p. 41) reveals that sediments of Cretaceous pollen zone II contain a lower sand-dominated interval characterized by distinct fining-upwards sand sequences interbedded with laminated or massive clays. This lower interval of pollen zone II strata is herein identified in the hydrogeologic framework of the Virginia Coastal Plain as the middle Potomac aquifer. Typically, the sands of these fining-upwards sequences are composed of coarse to fine, angular to subangular quartz, and some plagioclase. These sands are also commonly micaceous and contain abundant heavy minerals. Reinhardt, Christopher, and Owens (1980) also note that the laminated and massive clays of this sequence are composed of mixed kaolinite and highly expandable illite/smectite.

More wells drilled in the study area penetrate this aquifer (plate 17) than the underlying lower Potomac aquifer. Generally, most industrial and municipal wells throughout the western half of the study area use this aquifer, sometimes in combination with the underlying or overlying Potomac aquifers. This aquifer is capable of producing large quantities of high quality water in the western half of the study area, but, like the underlying lower Potomac aquifer, it contains increasingly higher chloride concentrations in the down-dip direction, which restricts its use as a source of potable water. In addition, the middle Potomac aquifer generally lies too deep for all but large industrial users in the eastern half of the study area.

Typical electric-resistivity log patterns of the middle Potomac aquifer sediments are best illustrated in geophysical logs of wells 53Q9, 53P4, and 54P3, plate 3; 52N16, 53P8, 53P4, 54Q11, and 54R3, plate 4; 52J5, plate 5; 52K6, 54J4, 55H1, and 58F3, plate 7; 54G10, 57E10, and 60C7, plate 8; 53D3, plate 9; and 53A3, 58B115, and 59C28, plate 12. Generally, these resistivity log patterns are both "triangular" and "saw-toothed" in profile. The "triangular" profiles indicate the fining-upwards sequences characteristically associated with the aquifer sands. The "saw-toothed" profiles indicate the extensively interbedded sequences of sands, silts, and clays also characteristic of these sediments. These electric-resistivity patterns are also both massive and narrow in profile and the sands usually contain sharp, lower lithologic contacts. Resistivity logs of the middle Potomac aquifer also characteristically show high resistance values for the sandy sediments that helps distinguish this aquifer from the underlying lower Potomac aquifer. The high resistance values are indicative of the relatively "clean" sands common to this aquifer and the relatively low concentrations of dissolved solids common of the water from this unit. Corresponding natural-gamma logs show pronounced "saw-toothed" clay and sand patterns with sharp lower and gradational upper lithologic contacts. The clay patterns of natural-gamma logs of the middle Potomac aquifer are more distinct than the sand patterns, indicating the well-bedded and massive nature of the clays. Drillers commonly refer to the middle Potomac aquifer sediments as "medium or coarse gray sands" with "red, brown, or multicolored clays." Drillers also commonly refer to the sands as "water sands" or "artesian sands." Generally, these sediments drill easily and the clays reach the surface as small, cohesive clay balls. The individual sand and clay beds of the middle Potomac aquifer, like the underlying lower Potomac aquifer, are also difficult to correlate between geophysical logs. The contour map delineating the top of this aquifer (plate 17) is based on the tops of the uppermost sand beds. This map should only be used as a guide to indicate the approximate altitude to the top of this aquifer between control wells because of the interlensing nature of these sediments, the large distances between control points in some areas, and the general lack of data in the eastern half of the study area.

Studies (Glaser, 1969; Hansen, 1969; Reinhardt, Christopher, and Owens, 1980) of Potomac strata herein defined as the middle Potomac aquifer and the correlative Patapsco strata in Maryland suggest that the paleoenvironment consisted of a low gradient, subaerial, fluvial flood plain dominated by meandering streams. These deposits, which represent multiple fluvial processes, are dominated by channel sands, point bars, levees, flood plains, and backswamps. Reinhardt, Christopher, and Owens (1980, p. 41) note that no glauconite was observed in the cored sediments of the middle Potomac aquifer strata in the Oak Grove core and suggest that these deposits represent a more landward sedimentary assemblage than do the sediments of the underlying lower Potomac aquifer strata (p. 48). They also note (p. 47) that these deposits are distinctly continental in origin and together with the underlying lower Potomac aquifer sediments, appear to represent the development of a continental delta.

Middle Potomac Confining Bed

The middle Potomac confining bed is defined by the major clayey strata directly above the middle Potomac aquifer. These clay beds are predominantly restricted to upper palynostratigraphic zone II, but may also consist of younger sediments (basal zone III), especially in the eastern half of the study area. The middle Potomac confining bed correlates with the western half of confining bed 2 of Maryland and with the confining bed that overlies the lower Cape Fear aquifer of North Carolina (plate 1). This confining bed crops out in the northwestern part of the study area between the middle Potomac aquifer and the Potomac River, and in the stream valleys of the Rappahannock, Pamunkey, James, and Appomattox Rivers just east of the outcropping middle Potomac aquifer (plate 18). It overlies the middle Potomac aquifer and is overlain by the upper Potomac aquifer, except in the western part of the study area where it is transgressed by the Aquia aquifer. This confining bed attains a maximum known thickness of 203 ft at well 66M1 (plate 2) in the northeastern part of the Eastern Shore Peninsula and thins to nearly zero thickness along its western limit near the Fall Line (plate 18). Its thickness is highly variable, but the middle Potomac confining bed is commonly the thickest-bedded clay or interbedded clay and sandy clay sequence of pollen zone II sediments.

Definitive lithologic data are obtained from analysis of the Cretaceous section in the Oak Grove core (well 54P3) by Reinhardt, Christopher, and Owens (1980), and Estabrook and Reinhardt (1980). Reinhardt, Christopher, and Owens (1980, p. 41) identify and describe an upper interval of pollen zone II sediments as a clay-dominated sequence characterized by highly sheared and locally mottled montmorillonitic red clay. This upper interval of pollen zone II sediments in the Oak Grove core (well 54P3) is herein identified as the middle Potomac confining bed in the hydrogeologic framework of the Coastal Plain of Virginia. Typically, the clays of this confining bed are massive to thick bedded, but are also finely laminated in places. These clays are similar in composition to the clays of the lower Potomac confining bed in that they consist primarily of mixed kaolinite and highly expandable illite/smectite (Reinhardt, Christopher, and Owens, 1980, p. 41). The laminated clays are silty, sandy, micaceous, and highly carbonaceous, whereas the massive clays are mottled, highly oxidized, and highly fractured. The middle Potomac confining bed is commonly characterized by a thick sequence of brightly-colored, variegated, plastic clays. These variegated clays are used to identify this confining bed on drillers' logs.

Numerous water wells drilled in the western and central regions of the study area penetrate this confining bed. In areas where the upper Potomac aquifer overlies this unit, drillers commonly cease drilling upon reaching this thick variegated clay horizon. The clays identified as the middle Potomac confining bed are not a single, continuous and areally extensive layer, but rather, are a series of interfingering deposits. Water-level data indicate that these clays act locally as confining beds and, when viewed collectively, constitute a single confinement, as shown by the thickness map of the middle Potomac confining bed (plate 18).

Typical electric-resistivity log patterns of the middle Potomac confining bed sediments are best illustrated in geophysical logs of wells 51R5, 54P3, 56N7, plate 3; 52N16, 54R3, plate 4; 52K6, 54J4, 54H11, 55H1, plate 7; 53D3, 54D2, 55C8, plate 9; and 52A1, 53A3, 54A3, 55A1, 56B9, plate 12. Generally, these resistivity patterns are "blocky" in profile, indicating thickly bedded clays in relatively sharp lithologic contact with the aquifer sands above and in gradational lithologic contact with the aquifer sands below. The lithologies indicated by the resistivity patterns range from massive clays, as in wells 54P3, plate 3, and 56N7, plate 5, to thick clays interbedded with thin sands and sandy clays, as in well 55A1, plate 10. Corresponding natural-gamma log patterns also commonly indicate massively-bedded clays with few interbedded sands or sandy clays. Drillers commonly refer to the middle Potomac confining bed clays as "slick or sticky" and as "multicolored or mixed colored clays." These multicolored clays, which are commonly red, purple, gray, brown, olive, and yellow, are also referred to as mottled clays.

Studies on the paleoenvironment of the Potomac strata suggest that deposition of the middle Potomac confining bed occurred on broad, low-gradient, fluvial deltaic plains containing extensive flood plains and swampy interfluves (Glaser, 1969, p. 73). Reinhardt, Christopher, and Owens (1980, p. 47) note that this clay-dominated upper pollen zone II interval is a product of over-bank deposition that was modified by weathering and diagenesis, and that these backswamp and flood basin deposits are distinctly continental in origin.

Upper Potomac Aquifer

The upper Potomac aquifer, by definition, consists of sandy palynostratigraphic zone III and zone IV sediments of the Potomac Formation. These sediments are early Late Cretaceous (Cenomanian) in age and correlate with the Raritan sediments of the Raritan-Patapsco aquifer in Maryland and the upper Cape Fear aquifer in North Carolina (plate 1). This aquifer is restricted to the subsurface; it overlies most of the middle Potomac confining bed and is overlain by the upper Potomac confining bed. The upper Potomac aquifer dips eastward at approximately 15 ft per mile, attains a maximum known thickness of 425 ft at well 66M1 in the northeastern part of the study area, and pinches out along its western subsurface limit throughout the west-central part of the study area. The upper Potomac aquifer, like the other underlying Potomac aquifers, is a multizone unit consisting of stratified sands and clays.

The presence of lower Upper Cretaceous sediments at the top of the Potomac Formation in the study area has been alluded to by many investigators (Cederstrom, 1945, 1957; Spangler and Peterson, 1950; Dorf, 1952; Richards, 1967), but the actual presence of these sediments in Virginia was not verified until the use of pollen analysis as a stratigraphic indicator. Palynostratigraphic analyses by Robbins, Perry, and Doyle (1975), Doyle and Robbins (1977), and L. A. Sirkin (Adelphi University, written commun., 1982, 1983) have indicated the presence of pollen zones III and IV as the top of the Potomac Formation throughout the eastern half of the study area. These sediments are correlatable with the Raritan Formation of New Jersey and comprise the uppermost aquifer of the Potomac Formation in the study area.

The sands of the upper Potomac aquifer, as described from drillers' logs, are characteristically white, micaceous, very fine to medium quartz, and commonly contain carbonaceous material. Gravel is uncommon, and very coarse sand is rare. The interbedded clays of this aquifer, as described from drillers' logs, are characteristically dark, silty, highly micaceous, and commonly contain carbonaceous material. Little data are available that describe the lithologic characteristics of the upper Potomac aquifer in the study area; only one set of core samples from this unit has ever been analyzed. These core samples were obtained as part of the "Artificial Recharge" project conducted by the Geological Survey in cooperation with the city of Norfolk at the Moore's Bridge Water Treatment facility, and are represented by well 61C1 on plate 2. Brown and Silvey (1977, p. 4) report that this unit consists of moderately sorted, angular to subangular, micaceous, fine to medium quartz sands that contain wood fragments and minor interstitial clays. Typical on-site core descriptions (D. L. Brown, U.S. Geological Survey, written commun. 1971) of the sandy intervals indicate that they are light yellow to greenish gray, clayey to "clean," micaceous, slightly calcareous, poor to well sorted, subangular to subrounded, and very fine to medium grained. Similarly, the interbedded silty-clay intervals are described as yellow green to dark greenish gray, glauconitic, calcareous, micaceous, plastic, locally sandy, and containing shell fragments. More wells drilled in the study area penetrate the upper Potomac aquifer (plate 19) than the underlying middle and lower Potomac aquifers. Generally, most light industrial and municipal ground-water users throughout the central part of the study area use this aquifer. This aquifer is capable of producing large quantities of generally good quality water suitable for most uses, but like the underlying Potomac aquifers, this aquifer contains water having high chloride concentrations that increase down-dip, thus precluding the use of the aquifer as a potable source of water.

Typical electric-resistivity log patterns of the upper Potomac aquifer sediments are best illustrated in geophysical logs of wells 58J11, 58J5, plate 6; 57G25, 57F2, plate 7; 56F42, 57E10, 58D9, 60C7, plate 8; 55D5, 55E3, plate 10; 58B115, 58C51, plate 11; and 54A3, 55A1, 59C28, 60C25, plate 12. Generally, these resistivity patterns are very similar to the resistivity patterns of the underlying middle Potomac aquifer, but they are characteristically more massive and rounded in profile and are more easily correlated among logs. Also, the characteristic massively-bedded sand sequences are commonly separated by thinner interbedded clays, as shown by the logs of well 59C28 (plate 12). Corresponding natural-gamma logs commonly indicate the presence of interbedded sands and clays.

Drillers commonly refer to the upper Potomac aquifer sediments as "fine, white micaceous sands" and "dark micaceous clays," that commonly contain "wood fragments." Drillers also note that these sediments are penetrated easily. On drillers' logs, sediment descriptions of the upper Potomac aquifer are noticeably absent of the "variegated clay" and "red, brown and yellow clay" descriptions commonly used to describe the underlying Potomac clays.

The contour map delineating the top of the upper Potomac aquifer (plate 19) is based on the tops of the uppermost sand bodies identified at the control wells. Therefore, this map should only be used as a guide to indicate the approximate altitude of the top of this aquifer between control wells because of the interlensing nature of these sediments, the large distances between control points in some areas, and the general lack of data in the northern and eastern sections of the study area.

Sediments of the upper Potomac aquifer represent the effects of the first major marine transgression that inundated the study area. As the seas progressively encroached onto the delta complex, deposition occurred in ever-widening estuaries and intertidal basins. Brown and Silvey (1977, p. 4) postulate that, based on grain size, deposition of the lower Upper Cretaceous sediments at well 61C1 (Moore's Bridge Water Treatment facility) took place in a littoral environment, possibly a tidal flat, with a semiprotected shoreline. Other studies of equivalent sediments in Maryland (Glaser, 1969; Hansen, 1969) note the absence of typical marine transgressive strandline features, such as barrier beach and dune sediments, and suggest that deposition occurred in a marginal marine outer-delta environment with a vegetated, swampy shoreline.

Upper Potomac Confining Bed

The upper Potomac confining bed is defined by the major clayey strata directly above the upper Potomac aquifer. These clay beds are predominantly restricted to upper palynostratigraphic zone IV, but also include clay beds of palynostratigraphic zone III in the west-central parts of the study area and undifferentiated clays of latest Cretaceous age in the eastern regions of the study area. The upper Potomac confining bed correlates with part of confining bed 2 (that which overlies the Raritan aquifer strata of the Raritan-Patapsco aquifer) in Maryland and the confining bed that overlies the upper Cape Fear aquifer in North Carolina (plate 1). This confining bed is restricted to the subsurface; it overlies the upper Potomac aquifer and is overlain by the Brightseat aquifer in the north-central and northeastern regions of the study area, and by the Aquia aquifer throughout the remainder of its extent (plate 20). It attains a maximum known thickness of 126 ft at well 66M1 in the northeastern part of the study area and pinches out along its western subsurface limit in the west-central part of the study area. The thickness of this confining bed is variable, but generally it thickens and dips to the northeast.

As in the case for the underlying upper Potomac aquifer, detailed lithologic data is available to the authors only from core samples obtained at well 61C1 located at the City of Norfolk during the "Artificial Recharge" project. The core information indicates (Brown and Silvey, 1977, p. 7) that the confining bed clays consist of highly expandable silty-clay to clayey-silt mixed-layer illite and montmorillonite, and minor amounts of kaolinite. Onsite core descriptions (D. L. Brown, U.S. Geological Survey, written commun., 1971) describe this confining bed as a dark greenish-gray, micaceous, calcareous, slightly glauconitic and sandy, silty clay.

Numerous water wells drilled throughout the central and east-central regions of the study area penetrate and provide information on this confining bed. The clay beds identified as the upper Potomac confining bed are not a single, areally extensive layer, but rather, a series of interlayered clayey deposits. These individual clay layers are more extensive than the clayey deposits of the underlying middle and lower Potomac confining beds and, therefore, are more easily correlated between wells. Water-level data indicate that individual clay units act locally as confining beds and when viewed collectively, they constitute a single confining bed as depicted by the thickness map of the upper Potomac confining bed (plate 20).

Typical electric resistivity log patterns of the upper Potomac confining bed sediments are best illustrated in geophysical logs of wells 58J11, 58J5, plate 6; 57G22, 57G25, plate 7; 57A1, plate 9; and 60B1, plate 13. Generally, these resistivity logs show broad U-shaped profiles that commonly contain numerous thin, interbedded sequences of sands and sandy clays. These thin interbedded sequences of sands and sandy clays produce an erratic appearance to resistivity logs of the thick clay deposits of the upper Potomac confining bed. Drillers commonly refer to the upper Potomac confining bed sediments as "dark micaceous clays" or "dark sandy clays," that may contain "shells" or "wood."

Like the underlying sediments of the upper Potomac aquifer, these confining beds also result from the first major marine transgression in the sedimentary section. The depositional environment was similar to that of the upper Potomac aquifer, but was a lower-energy regime in a broad, low-lying outer delta.

Uppermost Cretaceous Sediments Undifferentiated

Marine deposits of latest Cretaceous age represent the next distinctive group of sediments in the sedimentary section. These deposits are sparsely presented in the eastern part of the study area. Uppermost Cretaceous sediments typically form relatively thin veneers of glauconitic clays, sandy clays, and chalky marls. The sediments attain a maximum known thickness of 70 ft at well 66M1 in the northeastern part of the study area and approximately 50 ft at well 61C1 in the southeastern part. These sediments are included as part of the upper Potomac confining-bed sequence and are not further differentiated in this report because of their restricted areal extent and their predominantly clayey composition.

After the region-wide Turonian erosional period, marine seas extensively covered the downwarped Coastal Plain areas of Maryland and North Carolina, depositing thick, extensive Upper Cretaceous marine sediments in the structural lows of the Salisbury and Albemarle embayments. Based on lithologic and paleontologic evidence, it appears that most of the Virginia Coastal Plain was elevated, in relation to sea level, throughout this time. Hansen (1978) proposes basement faulting along the southern limb of the Salisbury embayment as the mechanism responsible for the truncation or nondeposition of the uppermost Cretaceous deposits in the north-central and northwestern parts of the study area.

Cederstrom (1945a) suggests a Late Cretaceous age for deposits in the southeastern part of the study area based on paleontological analysis of well cuttings. These sediments are reported to range from 10 to 100 ft thick and consist predominantly of clays and sandy clays. From correlation of geophysical logs and recent stratigraphic data, the authors determined that the thickness is 10 to 30 ft in southeastern Virginia. Brown and others (1972) also found the uppermost Cretaceous deposits in the southernmost part of the study area and, like Cederstrom, determined that the deposits are thin, predominantly clayey sediments, interbedded with a few thin sands. The Norfolk arch is undoubtedly the predominant controlling influence for the northern limit of these Upper Cretaceous deposits in southeastern Virginia.

Paleocene and Eocene Pamunkey Group

Marine deposits of Paleocene and Eocene age constitute the lower Tertiary (Paleogene) stratigraphic section known as the Pamunkey Group. From oldest to youngest, six formations consisting of the Brightseat, Aquia, Marlboro Clay, Nanjemoy, Piney Point and Chickahominy comprise this group. From these six formations, five hydrogeologic units--three aquifers and two confining beds--are identified. Throughout the study area, major regional unconformities separate the Pamunkey Group from the underlying Cretaceous deposits and the overlying upper Tertiary deposits. Within the Pamunkey Group lesser unconformities separate most of the formations. Generally, the Pamunkey Group consists of glauconitic sands, silts, and clays, with varying amounts of shells. The notable exception is the Marlboro Clay, which consists solely of non-glauconitic, dense, plastic clay. Within the Aquia, Nanjemoy, and Piney Point Formations, cobble and boulder-sized calcareous concretions are common, as are thin layers of calcareous-cemented shell beds. By studying the sediment core collected at Oak Grove, Reinhardt, Newell, and Mixon (1980, p. 2) report that the depositional structures and sedimentary fabrics within the Pamunkey Group are representative of a depositional environment that was either extremely stable or a somewhat restricted marine shelf. Sedimentation occurred in a shallow, low energy, inner to middle-marine basin in the area north of the Norfolk Arch (L. W. Ward, Geological Survey, personal commun., 1981). In the immediate area of the Norfolk Arch, drillers' logs indicate that the Pamunkey Group sediments thin considerably and become slightly coarser and less glauconitic, thus indicating a higher energy environment. South of the arch, the sediments again become noticeably finer, more glauconitic, and commonly contain a limey-mud matrix with numerous thin layers of limestone.

The reported presence of exposed greensand sediments in the study area dates back to the early 1800's. In 1891, the name Pamunkey was applied by Darton (1891) to these greensand sediments exposed along the Pamunkey River in Virginia, which he defined as a single formation of Eocene age. Shortly thereafter, Clark (1896, p. 3) identified two distinct "stages"--the Aquia Creek and Woodstock of the "Eocene Pamunkey Formation." Subsequently, Clark and Martin (1901, p. 5) raised the Pamunkey Formation to group status and named the Aquia and Nanjemoy Formations within that group based on exposures along the Potomac River. The identifications of the remaining formations within the Pamunkey Group came much later and are discussed under the respective hydrogeologic sections.

The Pamunkey Group crops out extensively in the major stream valleys throughout the western parts of the study area. As a whole, this group of sediments thickens to the northeast north of the Norfolk arch and to the southeast south of the arch. Generally, the sands of the Pamunkey Group yield abundant quantities of water that is suitable for most uses. Unlike the fluvial-deltaic deposits of the underlying Cretaceous sediments, the marine sediments of the Pamunkey Group generally consist of homogeneous and extensive blanket-type deposits that change little over large areas. Therefore, the depths to the tops of aquifers and the thicknesses of confining beds tend to be fairly predictable, even between control wells separated by large distances.

Brightseat Aquifer

The Brightseat aquifer is herein defined as all interbedded sands of early Paleocene (Danian) age in the study area. The Brightseat aquifer correlates with the lower Paleocene aquifer of Maryland and pinches out southward against the north flank of the Norfolk arch (plate 21). Therefore, no correlative hydrogeologic unit exists from the area of the Norfolk arch southward into

North Carolina. This aquifer is the lowest Tertiary age aquifer in the study area. It overlies the upper Potomac confining bed and is overlain by the Brightseat confining bed throughout its extent (plate 21). The Brightseat aquifer dips eastward at approximately 14 ft per mile and is lens shaped in cross section. It attains a maximum thickness of more than 150 ft in the north-central part of the study area beneath the Chesapeake Bay and thins to nearly zero thickness along its western and southern limits.

As a result of this study, the Brightseat aquifer became an identifiable and correlatable hydrogeologic unit in the Virginia Coastal Plain. Previous studies placed these interbedded sediments within the Lower Cretaceous Potomac strata, with the exception of Darton (1901), who placed these beds in the Late Cretaceous. Recognition of this aquifer is based on geophysical-log correlations, in combination with analysis of drillers' logs and water-level data, throughout the north-central part of the study area and adjoining parts of southern Maryland. Subsequently, a definitive age for the unit was determined by formaninifers and pollen analysis of core samples recently obtained from a test well in Lexington Park, located in southern Maryland (H. J. Hansen, Maryland State Geological Survey, written commun., 1983). Hansen and Wilson (1984, p. 11), from information obtained at the Lexington Park test well, tentatively identify correlative sediments in Maryland as the Mattaponi(?) Formation, and the sands as the Mattaponi(?) aquifer, based on Cederstrom's (1957) designation of Colonial Beach-type well. This report does not use the term "Mattaponi." Geophysical log interpretations, supported by paleontologic and lithologic data, have led the authors to doubt the existence of a Mattaponi Formation, as described by Cederstrom (1957) and later modified by Teifke (1973), within the study area. Definitive stratigraphic analysis obtained from the core hole at Oak Grove (Virginia Division of Mineral Resources, 1980), which is located near Cederstrom's designated Colonial Beach-type well, also raises serious doubt as to the existence of a Mattaponi Formation (Reinhardt, Newell, and Mixon, 1980, p. 4). In addition, Cederstrom uses two drilled wells at Oak Grove (1957, p. 19) to support his Mattaponi hypothesis, which, when compared to the Oak Grove core hole, show that correlative strata have been positively identified as the Aquia Formation and the Potomac Formation (Reinhardt, Newell, and Mixon, 1980; Reinhardt, Christopher, and Owens, 1980).

This report follows Ward's (1984, p. 14) analysis and recommendation that the name Mattaponi be dropped from further usage because it was defined on age determinations derived from foraminifera, and that the designated strata of this formation had been previously assigned to other lithic units. The name Brightseat is derived from the Brightseat Formation, identified by Bennett and Collins (1952) from outcrops near the Town of Brightseat, Maryland; the Brightseat is described as a dark gray, micaceous, sandy clay, 4 to 8 ft thick, of early Paleocene age. The interbedded sand and clay facies of the Brightseat Formation, herein designated as the Brightseat aquifer, have never been recognized as a hydrogeologic unit previous to this study.

The Brightseat aquifer is restricted to the subsurface and its eastern areal extent is not well defined owing to the lack of sufficient borehole and paleontologic information throughout the Eastern Shore Peninsula area. Thus far, correlation of this aquifer is limited to its area of extent, as shown on the aquifer top map (plate 21), plus a small adjoining area in southern Maryland.

The Brightseat aquifer consists of interstratified blanket sands and silty clays. The sands, as described in drillers' log, consist predominantly of fine, well-sorted, white quartz but also contain shells, lignite, mica, and minor amounts of glauconite. The clays, as described in drillers' logs, consist of dark, micaceous, silt and clay, commonly gray, dark green, and black, but also contain minor amounts of shells, sand, and lignite. From core samples of their Mattaponi(?) aquifer, Hansen and Wilson (1984, p. 11-13) describe the sands as typically gray, medium, moderately well sorted, "clean" and dominantly quartzose, and the clays as generally gray, but often mottled, with organic inclusions and thin laminae of light-colored, fine, micaceous sand and silt.

Numerous industrial and municipal ground-water users, especially the seafood-processing industries in the northern part of the study area, use this aquifer. This aquifer is capable of producing large quantities of high quality water suitable for most uses. Hansen and Wilson (1984, p. 24) note that the water from this aquifer in Maryland is of excellent quality, relatively low in dissolved solids, and can be used with a minimum of treatment.

Typical electric-resistivity log patterns of the Brightseat aquifer sediments are best illustrated on geophysical logs of wells 56N7 and 60L19, plate 3; 57P1, plate 5; and 57J3, 58J11, and 59K17, plate 6. Generally, the resistivity patterns are a series of U-shaped profiles. The U-shaped profiles indicate the characteristic interbedded clean sand and silty clay sequences associated with these aquifer sediments. In the updip section of this aquifer, the U-shaped patterns are commonly narrow, as in well 56N7, plate 3, and contain only one or two well-defined sand beds. In the downdip section, many more U-shaped patterns are evident; the silty clays and sands become thicker, as in well 60L19, plate 3, and commonly are interstratified with thin clay beds. Corresponding natural-gamma logs exhibit well-defined clay and sand patterns with sharp lithologic contacts, which again indicate their well-bedded and alternating nature.

Drillers commonly refer to the Brightseat aquifer sediments as "fine white sands with some black sands" and "gray, dark, or black, micaceous clays," both sometimes containing "shells and/or lignite." Drillers also note that these sediments are readily pentrated in comparison to the underlying Potomac sediments. Individual sand and clay beds of the Brightseat aquifer are easily correlated among geophysical well logs because of their well-defined interbedded patterns. The contour map delineating the top of this aquifer (plate 21) is based on the uppermost sand identified at each control well. Because of the interbedded characteristics of these sands, this map can only be used to indicate, with a fair degree of accuracy, the approximate altitude of the top of this aquifer throughout its extent.

Based on its interbedded nature, lithologic characteristics, and its equivalent age and stratigraphic position with the type Brightseat Formation, this aquifer's environment of deposition seems to be dominated by intertidal marine processes and probably represents a near-shore or lagoonal environment. Hansen and Wilson (1984, p. 13) note that core analysis of their equivalent Mattaponi(?) aquifer reveals a sparse inner shelf fauna which indicates a water depth of less than 65 ft. Hansen (Maryland State Geological Survey, oral commun., 1983) also suggests that these deposits probably represent a near-shore facies of the open-marine type Brightseat Formation.

Brightseat Confining Bed

The Brightseat confining bed is defined by the uppermost clay bed of the interbedded sand and clay sequence of early Paleocene (Danian) age deposits. This confining bed correlates with confining bed 6a of Maryland. The Brightseat confining bed pinches out southward against the north flank of the Norfolk arch (plate 22) and, therefore, has no correlative unit from the area of the Norfolk arch southward into North Carolina. It should be noted that geophysical and lithologic log correlations indicate the Brightseat confining bed is, for the most part, a continuation of the Brightseat Formation. The Brightseat Formation, as defined by Bennett and Collins (1952), is an early Paleocene, dark-gray, silty and sandy, micaceous clay that underlies the Aquia greensands. In the area of study, the Brightseat confining bed is areally restricted to that part of the Brightseat Formation that overlies the Brightseat aquifer. The Brightseat Formation crops out throughout the northwestern part of the study area, but its hydrogeologic significance changes. In the northwestern part of the study area, the Brightseat Formation comprises the upper part of the middle Potomac confining bed that separates the underlying middle Potomac aquifer from the overlying Aquia aquifer. In contrast, the Brightseat Formation in the northcentral and northeastern parts of the study area wholly comprises the Brightseat confining bed that separates the underlying Brightseat aquifer from the overlying Aquia aquifer.

The Brightseat confining bed is restricted to the subsurface and its eastern areal extent is not well defined owing to the lack of sufficient borehole and paleontological information throughout the Eastern Shore Peninsula area. This confining bed attains a maximum known thickness of 62 ft at well 63L1 (plate 2) in the northern part of the study area beneath the Chesapeake Bay and thins to nearly zero thickness along its western and southern limits (plate 22). Its northwestern limit, where the Brightseat Formation continues northwestward as part of the middle Potomac confining bed, is an arbitrary break dependent on the limit of the underlying Brightseat aquifer.

The Brightseat confining bed consists of an areally extensive, silty clay bed which locally is interbedded with very thin sands or sandy clays. These clays are micaceous, commonly dark in color, although light gray, red and mottled clays are noted, and may contain shells and carbonaceous material. Hansen and Wilson (1984, p. 41) describe a core sample obtained from a correlative unit in the Lexington Park test well as a clayey silt, that contains very fine quartz sand, and is micaceous, slightly calcareous and lignitic, yellowish greenish gray, oxidized to dark orange in places.

Typical electric-resistivity log patterns of the Brightseat confining bed sediments are best illustrated on geophysical logs of wells 56N7 and 60L19, plate 3; 56M10 and 57P1, plate 5; and 58J11 and 59K17; plate 6. Generally, these resistivity patterns are U-shaped in profile, indicating a well-bedded, silty clay in sharp lithologic contact with overlying and underlying aquifer sands. In some areas, the lower contact with the underlying Brightseat aquifer is graditional, as illustrated in geophysical well logs 57P1, plate 5, and 59K17, plate 6. Also noted, this confining bed may contains thin interbedded sands or clayey sands, as illustrated in geophysical well log 60L19, plates 3 and 6. Corresponding natural-gamma log patterns commonly exhibit a pronounced clayey response to this confining-bed interval, again indicating a well-bedded clay or silty clay in sharp lithologic contact with overlying and underlying sands. Drillers commonly refer to Brightseat confining bed clays as "dark, micaceous clays," sometimes containing "sands, shells, and lignite." This confining bed is easily correlated among geophysical well logs because it has a large areal extent and, when used in combination with drillers' logs, it immediately underlies the greensands (or "blacksands") of the Aquia aquifer and overlies the predominantly white sands of the Brightseat aquifer.

Aquia Aquifer

The Aquia aquifer is defined by the predominantly sandy facies of the Aquia Formation. These sediments are late Paleocene (Thanetian) in age and correlate with the Rancocas-Aquia aquifer in Maryland and the Beaufort aquifer in North Carolina (plate 1). The Aquia aquifer crops out extensively in most major stream valleys of the study area just east of outcrops of the middle Potomac confining bed and in a small area in the northwestern region just west of the Potomac River. It overlies three separate hydrogeologic units--the Brightseat confining bed in the north-central area; the upper Potomac confining bed in the central and southern regions; and the middle Potomac confining bed throughout the western region. In turn, the Aquia aquifer is overlain by the Nanjemoy-Marlboro Clay confining bed. The Aquia aquifer is a continuous, elongate-lenticular sand body that thins slightly to the west and thins greatly to the east, pinching out near the western shore of the Chesapeake Bay and along the southeast part of the study area. In the northern and central regions the aquifer pinches out eastward. This pinch out is based on subsurface studies by Hansen (1974) and Chapelle and Drummond (1983) in Maryland and was extrapolated into the study area by the authors. Evidence for the exact position of this pinch out is lacking owing to the scarcity of borehole and stratigraphic data available in the eastern region of the study area. In the southern region, the eastern limit is based on lithologic and geophysical log data, but again its position is approximate because of the scarcity of data. The eastern pinch out is due to a sand-to-clay facies change in the downdip section of this aquifer unit (Hansen, 1974, p. 15). The Aquia aquifer dips eastward at approximately 10 ft per mile and attains a maximum known thickness of 147 ft at well 54R3 (plate 4) in the northwestern part of the study area. Generally, this aquifer is thickest in the northwestern and west-central regions of the study area, attaining an average thickness of 100 ft or more. In the north-central and central regions, its thickness commonly ranges from 40 to 70 ft, and in the southern regions its thickness is usually about 20 ft. It rapidly thins westward to nearly zero thickness and extends mainly in the subsurface to just east of the Fall Line along most of its length.

The Aquia aquifer consists of a predominantly massively bedded unit composed of very fine to medium glauconite and quartz sands, in variation and with minor amounts of shells and clay. From outcrops in its type area, Aquia Creek of Stafford County, Virginia, Clark (1896) first described the Aquia Formation as a marine unit consisting of greensands and greensand marls interbedded with local thin layers composed almost entirely of shells. From analysis of the Oak Grove core (well 54P3), Gibson and others (1980, p. 16) describe the Aquia Formation as very well-sorted, medium- to dark-green, massive, fine to medium glauconitic sand with sparse shelly intervals. Reinhardt, Newell, and Mixon (1980, p. 5), who also analyzed the Aquia section of the Oak Grove core, note that the Aquia contains illitic clay matrices (generally less than 10 percent by weight), carbonate cemented intervals, and a basal part containing coarse sands, pebbles, small bones, and fish teeth.

Numerous wells drilled in the study area penetrate this aquifer, and many light industrial, small municipal, and domestic users use the Aquia as a water-supply source. Chapelle and Drummond (1983, p. 75) report that ground water produced from the Aquia in Maryland is capable of supplying large quantities of water suitable for most uses. The Aquia in the northern two-thirds of the study area is very similar to the Aquia of Maryland, although somewhat thinner, and similar ground-water conditions exist. However, in the southern part of the study area, the Aquia is much finer grained, commonly contains a limey-mud matrix, and thin limestone beds, and is is not commonly used as an aquifer.

Typical electric-resistivity log patterns of the Aquia aquifer sediments are illustrated on geophysical logs of wells 53P4, 54P3, 56N7, plate 3; 52N16, 54Q11, 54R3, plate 4; 53K17, 56M10, 57P1, plate 6; 54H11, 55H1, 57G22, 57G25, plate 8; and 54G10, 55F20, 56F42, plate 9. Generally, these resistivity patterns are wave-shaped in profile, commonly a series of two or three waves which often contain sharp spikey peaks. The wave-shaped profiles indicate the massively-bedded sequences of glauconitic sands characteristic of this aquifer, whereas the sharp spikey peaks indicate the shell beds and related, calcareously cemented shell layers also common in this aquifer. Also noted in many resistivity logs, especially in the updip sections, is a pronounced thin U-shaped profile in the lowermost part of this aquifer. This U-shaped profile indicates the basal coarser part of this unit, as described previously from the Oak Grove core analysis. Resistivity logs generally indicate medium resistivity values for these sediments, except for the basal part, which generally has a high resistivity value. Also, resistivity logs exhibit sharp lower and upper lithologic contacts for the massive Aquia sand unit. Corresponding natural-gamma logs have a characteristically high erratic gamma response to these sediments, which appear to suggest an unusually high clay content, but in fact, is an indication of the high glauconite content. The hydrogeologic boundaries cannot be determined from natural-gamma logs because the lithologic contacts with the overlying and underlying clays are masked by the high gamma response to the glauconite. Drillers commonly refer to the Aquia aquifer sediments as "fine, blacksands or greensands" that often contain "shells and/or hardstreaks." Drillers note that these sediments are generally quite "soft" and at times refer to them as "running sands or caving sands." The Aquia aquifer is easily correlated among geophysical logs because the resistivity pattern changes little from log to log and shows numerous correlatable shell-bed spikes. By using the combination of drillers' logs and geophysical logs, Aquia aquifer sands can be located between two distinctive clays--an upper pink, light gray, or dark brown clay and a lower dark gray or black clay. The contour map delineating the top of this aquifer (plate 23) can be used to indicate, very accurately, the altitude of the top of this aquifer throughout its extent. Thus, the top of this unit is fairly constant and can be predicted between control wells separated by large distances.

Studies (Drobnyk, 1965; Hansen, 1974; Gibson and others, 1980) on the depositional environment of the Aquia Formation suggest that the Aquia was deposited in a shallow, inner-shelf marine basin, below wave base, with slight fluctuation of water depths (100- to 330-ft range).

Nanjemoy-Marlboro Clay Confining Bed

The Nanjemoy-Marlboro Clay confining bed is defined as the predominantly clayey deposits of the Nanjemoy and Marlboro Clay Formations. This confining bed is composed of two distinctly different formations--the lower Marlboro Clay and the upper Nanjemoy. These sediments are latest Paleocene to middle Eocene in age and correlate with confining bed 6b in Maryland and the confining bed overlying the Beaufort aquifer in North Carolina (plate 1). The Nanjemoy-Marlboro Clay confining bed crops out extensively in most of the major stream valleys of the study area just east of outcrops of the Aquia aquifer. It overlaps the Aquia aquifer and is overlain by the Chickahominy-Piney Point aquifer throughout most of the study area. This confining bed attains a maximum known thickness of 172 ft at well 66M1 in the northeastern part of the Eastern Shore Peninsula and thins to nearly zero thickness along its western limit near the Fall Line. Its thickness is somewhat variable (plate 24), but generally this unit is wedge shaped and thickens towards the northeast. The lower formation (the Marlboro Clay) of this confining unit is areally restricted to the northern half of the study area and its eastern extent beneath the Chesapeake Bay and Eastern Shore Peninsula is not known owing to the lack of lithologic and stratigraphic data in these areas. The upper formation (the Nanjemoy) is areally extensive throughout the study area and comprises most of the thickness of this unit. In the southern area, the Marlboro Clay pinches out against the northern flank of the Norfolk arch and the Nanjemoy directly overlies the Aquia aquifer. The Marlboro Clay was first identified and described by Clark and Martin (1901) as a red clay and was considered, until just recently, to be the lowest member of the Nanjemoy Formation. Glaser, in 1971, raised the Marlboro Clay to formation status based on its mappability as a unit, and Gibson and others (1980, p. 29) report that it straddles the Paleocene-Eocene boundary. The name Nanjemoy also was first applied by Clark and Martin (1901) for highly argillaceous greensands and was divided into two members--a lower clayey Patapaco Member and an upper sandy Woodstock Member. In the northwestern part of the study area, the upper Woodstock Member of the Nanjemoy is considered to be part of the overlying Chickahominy-Piney Point aquifer because of its predominantly sandy facies. However, geophysical logs indicate that the Woodstock Member becomes increasingly clayey downdip and throughout the rest of the study area and is, therefore, considered as part of the Nanjemoy-Marlboro Clay confining bed.

Lithologic analysis of the Tertiary section from the Oak Grove core hole (well 54P3) by Reinhardt, Newell, and Mixon (1980) indicates that the Marlboro Clay consists of a compact, massively bedded, extensively burrowed, predominantly red to gray, mottled clay composed mostly of a kaolinite-illite mixture. They also note that this formation is essentially structureless, but contains irregular lenses of locally laminated and cross-laminated fine silt. Reinhardt, Newell, and Mixon's analysis of the Nanjemoy reveals that it consists of a thick, massively bedded, dark green to dark brown-green, variably clayey and shelly, micaceous greensand. The clay content ranges from 15 to 80 percent and is composed mostly of illite. They also note that this unit is extensively burrowed, which produces a mottled appearance to the sediments, and that the Nanjemoy becomes increasingly sandy in its upper part (i.e., Woodstock Member). The Marlboro Clay commonly ranges from 2 to 20 ft thick and the Nanjemoy commonly ranges from 20 to over 120 ft thick.

Typical electric-resistivity log patterns of the Nanjemoy-Marlboro Clay confining bed sediments are best illustrated on geophysical logs of wells 53P4, 54P3, 56N7, 59L5, 60L19, plate 3; 52N13, 54Q11, 54R3, plate 4; 52K10, 53K17, 56M10, 57P1, plate 5; 55H1, 57J3, 58J11, 58J5, 59K17, 59K19, plate 6; 52K6, 54J4, 54H11, 55H1, 57G22, 57G25, 58F3, plate 7; 56F42, 57E10, 57D3, 58D9, 59D1, 60C6, plate 8; and 58B115, 58C51, 58C8, plate 11. Generally, the resistivity patterns are "flat" in profile, characteristic of massively bedded, predominantly clayey deposits. Commonly these flat profiles contain interbedded sandy clays or sands, which cause an erratic appearance to the generally flat resistivity patterns. The lower contact with the underlying Aquia aquifer is generally sharp and pronounced, and the upper contact with the Chickahominy-Piney Point aquifer is also sharp and pronounced, but can be gradational, especially where the upper Woodstock Member of the Nanjemoy is predominantly sandy. In the southern part of the study area, this confining bed becomes considerably thinner as it approaches and transgresses the Norfolk arch area. Also, this confining bed becomes more interbedded with sands and sandy clays in the southeast, as illustrated in well logs 59C28 and 60C25, plate 11. Corresponding natural-gamma log patterns indicate the presence of massively bedded glauconitic clayey sediments. Drillers commonly refer to the Nanjemoy-Marlboro Clay confining bed sediments as "pink, gray, or sometimes white clay" and "slick or sticky" for the Marlboro Clay, and as "dark green or brown-green, silty clays or sandy clays" commonly with "shells and black sands" for the Nanjemoy. These clayey confining-bed sediments are easily recognized on resistivity logs and drillers' logs by its characteristic thick clay pattern and stratigraphic position above the Aquia greensands. The Nanjemoy-Marlboro Clay confining bed is easily identified and correlated on resistivity logs because it is overlain and underlain by characteristic sands of the Chickahominy-Piney Point and Aquia aquifers, respectively.

Analysis from the Oak Grove core hole (Reinhardt, Newell, and Mixon, 1980; Gibson and others, 1980) indicates that the paleoenvironment, for the Marlboro Clay, consisted of a shallow and protected (ponded), low-energy, brackish water basin, such as an estuary or lagoon, and for the Nanjemoy, a stable or protected inner to middle 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 (plate 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 bed. It overlies the Nanjemoy-Marlboro Clay confining bed and is overlain and transgressed by the Calvert confining bed. 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 (plate 25). 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 per mile. 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 western 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 3 and 6, in the north-central region of the study area, and 165 ft at well 61B2, plates 8 and 13, 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 Otten (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, Virginia, 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, quartoze 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 (1984, in press) 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. Analysis (L. E. Edwards, U.S. Geological Survey, 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 3; 52K10, 53K17, 55L2, 56M10, 57P1, plate 5; 55H1, 57J3, 58J11, 58J5, plate 6; 54J4, 56G9, 57G22, 57G25, plate 7; 56F42, 58D9, 59D1, 60C7, plate 8; 57A1, plate 9; 58B115, 58C51, plate 11; and 59C28, 60C25, plate 12. Generally, these resistivity patterns are both rectangular and spikey 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 spikey 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 one or two feet, 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 beds 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 can not 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 6 and 56N7, plate 5. The contour map delineating the top of this aquifer (plate 25) 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 regression and that the sediments were deposited on a shallow, inner to middle marine shelf dominated by long-shore 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 five formations, including, from oldest to youngest, the Calvert, Choptank, St. Marys, Eastover, and Yorktown. These five formations comprise two aquifers and three confining beds. The hydrogeologic units are the Calvert confining bed, St. Marys-Choptank aquifer, St. Marys confining bed, Yorktown-Eastover aquifer, and Yorktown confining bed. Throughout the study area, major regional unconformities separate the Chesapeake Group from the underlying lower Tertiary Pamunkey Group and the overlying Quaternary Columbia Group. Within the Chesapeake Group lesser unconformities separate each of the formations. Generally, the Chesapeake Group consists of an eastward-thickening wedge of intermixed shelly sands, silts, and clays. On the basis of sediment size, the Chesapeake Group can be divided into a lower part, composed of the Calvert, Choptank, and St. Marys Formations; an intermediate part, composed of the Eastover Formation; and an upper part, composed of the Yorktown Formation. The lower sequence typically consists of shelly, silty clays interbedded and intermixed with angular to subangular very fine sands and diatomite. The intermediate part typically consists of shelly, silty to clayey, fine sands, and the upper part typically consists of fine to medium shelly sands, with interbedded shelly, silty clays and thin to thickly bedded shell layers. From analyses of the Oak Grove core, Gibson and others (1980) report that the depositional structures and sedimentary fabrics of the Chesapeake Group are characterized by alternations of dominantly marine components and unworked terrigenous materials, indicating a somewhat unstable tectonic setting, especially when compared with the underlying Pamunkey Group.

For most of the Chesapeake Group, sedimentation occurred in a shallow, low-energy, inner-shelf marine basin that was below wave base, as is indicated by the predominance of clays and silts. Throughout Chesapeake time, effective sea level in the marine basin fluctuated, but generally decreased during deposition of each successive formation--that is, sedimentation occurred in a progressively shoaling environment until finally deposition took place in a shallow, open-shelf sublittoral marine environment, as indicated by barrier complexes and the coarseness of sediments in the Yorktown Formation. The recognition of typical Chesapeake Group strata (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). In 1892, Dall changed Darton's term to "Chesapeake Group," and, in 1906, Clark and Miller named four formations--the Calvert, Choptank, St. Marys, and Yorktown--within the Chesapeake Group. Ward and Blackwelder (1980) added a fifth formation--the Eastover--which is between the St. Marys and Yorktown Formations, and redefined the Yorktown.

The Chesapeake Group sediments crop out extensively in the major stream valleys throughout the study area. As a whole, this group of sediments thickens 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, in most places, is suitable for most uses. The predominantly clayey deposits of the lower Chesapeake Group form a thick confining bed throughout the study area. These marine sediments consist of homogeneous and extensive blanket-type deposits that, for the most part, change little over large areas. Only in the Eastover and Yorktown Formations, which are highly dissected by subsequent stream erosion, are the thicknesses and extents of sediments highly variable. Generally, the depths to the tops of aquifers and the thicknesses of confining beds tend to be fairly predictable, even between control points separated by large distances.

Calvert Confining Bed

The Calvert confining bed is defined by the predominantly clayey deposits of the Calvert Formation. These sediments are early middle Miocene in age and correlate with confining bed 7 in Maryland and the confining bed overlying the Castle Hayne aquifer in North Carolina (plate 1). The Calvert confining bed crops out extensively in most of the major stream valleys of the study area just east of the outcropping Chickahominy-Piney Point aquifer. It overlies the Chickahominy-Piney Point aquifer and is overlain primarily by the St. Marys confining bed. In the northeastern and east-central regions it is overlain by the St. Marys-Choptank aquifer and in the western region it is overlain by the Yorktown-Eastover aquifer. This confining bed is wedge shaped in cross section and dips and thickens eastward. It attains a maximum known thickness of 350 ft at well 66M1 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 bed consists of interbedded shelly sandy clays, shelly silty clays, and diatomite, and is characteristically dark greyish-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 bed 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, Maryland. From analysis of the Oak Grove core hole (well 54P3), Reinhardt, Newell, and Mixon (1980, p. 8) describe the Calvert as a yellow-gray, fine-grained sediment consisting of very fine, angular quartz sand in a fine silt to clay matrix for the upper part of the confining bed, about 80 feet in thickness, and underlain by a 10-foot-thick diatomite and a basal 10-foot-thick of clay with coarse quartz sand.

Typical electric-resistivity log patterns of the Calvert confining bed sediments are best illustrated on geophysical logs of wells 56N7, 58N3, 59L5, 60L19, plate 3; 55L2, 57P1, plate 5; 57J3, 58J11, 59K17, plate 6; 56G9, 57G22, 57G25, 57F2, 58F3, plate 7; and 57E10, 58D9, 59D1, 60C7, plate 8.

St. Marys-Choptank Aquifer

The St. Marys-Choptank aquifer is defined by the predominantly sandy sediments of the St. Marys and Choptank Formations. This aquifer is middle Miocene in age; it is overlain by the St. Marys confining bed and overlies the Calvert confining bed. The St. Marys-Choptank aquifer is identified primarily from regional studies in Maryland. Only two wells--66M1 and 68M2 (plate 2)--located in the northern part of the Eastern Shore Peninsula, penetrate deep enough to reach this aquifer in Virginia. All other known wells on the Eastern Shore Peninsula, tap the overlying Yorktown-Eastover aquifer. The St. Marys-Choptank aquifer is extrapolated throughout the eastern part of the study area based on (1) electric-log correlations among wells in Maryland and the two wells on the Eastern Shore Peninsula, and (2) thickness and structure-contour maps of other hydrogeologic units in the area.

The St. Marys-Choptank aquifer consists of very fine to fine shelly quartz sands interbedded with sandy and silty clays; it ranges from light yellow to drab, greenish gray. It correlates with the lower Chesapeake aquifer in Maryland and with the Pungo River aquifer in North Carolina.

The St. Marys-Choptank aquifer strikes generally north-south and dips eastward at about 10 feet per mile (plate 27). This aquifer is wedge shaped in cross section and is 160 feet thick at well 66M1. The Choptank-St. Marys aquifer pinches out updip before it reaches the western shore of the Chesapeake Bay.

St. Marys Confining Bed

The St. Marys confining bed is defined by the predominantly clayey deposits of the St. Marys Formation. In places, this confining bed also possibly includes, in part, the lower clay beds of the Eastover Formation. These sediments are middle to late Miocene in age. It overlies the St. Marys-Choptank aquifer and underlies the eastern and central regions of the study area (plate 28). The St. Marys confining bed is, in turn, overlain by the Yorktown-Eastover aquifer. This confining bed correlates with confining bed 8 in Maryland and the confining bed overlying the Pungo River aquifer in North Carolina.

The St. Marys confining bed consists of very fine-grained, sandy, shelly clays that are typically light gray.

Yorktown-Eastover Aquifer

The Yorktown-Eastover aquifer is defined by the predominantly sandy deposits of the Yorktown and Eastover Formations. These sediments are late Miocene and Pliocene in age and correlate with the upper Chesapeake aquifer in Maryland the Yorktown aquifer in North Carolina. The Yorktown-Eastover aquifer is generally a sequence of thick sand beds separated by thinner clay beds. The Yorktown-Eastover aquifer is found throughout the study area, except in the middle to upper reaches of major stream valleys and their tributaries where it has been removed by erosion. The aquifer crops out in a broad area in the central part of the northern half of the study area, subparallel to the Fall Line and the western part in the southern half (plate 29). In outcrop areas, ground water in the aquifer is generally unconfined. The aquifer is highly dissected in the northern and central regions of the Coastal Plain and, in the southern areas, this aquifer thickens considerably and is not as highly dissected (plate 29).

The Yorktown-Eastover aquifer overlies the middle Miocene clays throughout most of the study area and is overlain by the Yorktown confining bed throughout the eastern half of the study area.

The Yorktown-Eastover aquifer typically consists of interbedded layers of shelly, very fine to coarse sands, clayey sands, and sandy clays. Shell beds, which may be indurated, are common.

Yorktown Confining Bed

The Yorktown confining bed is defined as the predominantly clayey deposits overlying the Yorktown-Eastover aquifer. This confining bed is Pliocene in age and separates the underlying Yorktown-Eastover aquifer from the overlying Columbia aquifer. The updip limit of this unit generally extends from the north-central to southwestern regions of the study area. In the central and northern regions (plate 30) the Yorktown confining bed has been highly eroded by major streams. In the southern parts, this confining bed has generally not been dissected by streams, but has been considerably thinned along the stream valleys.

The Yorktown confining bed consists of massive, well-bedded clays and silty clays, commonly containing shells, fine sand, and mica. These clays are usually yellow gray to greenish gray. This unit was deposited on a shallow, open-marine shelf and represents deposition in broad lagoonal areas and quiet bays.

Clay layers within the confining bed are generally extensive, but do not represent a single depositional unit. Rather, they form a series of coalescing clay beds at the top of the Yorktown-Eastover aquifer and are represented as a single confining unit in this report.

Pleistocene Columbia Group and Holocene Deposits

Columbia Aquifer

The Columbia Group undivided, of Pleistocene age and deposits of Holocene age, are collectively referred to in this report as the Columbia aquifer. These deposits are the youngest sediments in the Virginia Coastal Plain. They typically consist of interbedded gravels, sands, silts and clays. The Columbia Group has a wide areal extent and tends to cover much of the older Coastal Plain sediments, especially in the eastern and southern regions of the study area. The sediments of the Columbia Group typically represent fluvial channel fills and fluvial-marine terrace deposits along the major streams and tributaries throughout the study area (plate 30). The sediments also form a veneer of marine deposits covering much of the southern and eastern parts of the study area. Generally, all land surfaces of less than 180 feet above sea level are overlain by the Columbia Group.

The Columbia Group mainly represents deposition during the interstadial, pluvial intervals of Pleistocene time. During the major glacial episodes of Pleistocene time, sea level was lowered 300 to 450 feet (Donn and others, 1962) below present sea level, which caused streams to incise deep erosional channels into previously deposited Coastal Plain sediments. Hack (1957) documents stream channels cut to depths of 200 feet below present sea level in the Chesapeake Bay and to 125 feet at the mouth of the James River. This stream downcutting removed large amounts of sediment from the exposed parts of the Coastal Plain.

During the warmer interglacial stages of Pleistocene time, sea levels rose to as much as 180 feet above present sea level, depositing sheets of marine sediments over the submerged land surface. Also, reduced stream gradients resulted in the infilling of stream channels with fluvial deposits. Fluvial-marine terraces were formed as the drowned river valleys readjusted to the rise in sea level.

The Columbia aquifer is the uppermost aquifer in the study area and is generally unconfined. It is commonly referred to as the "water-table aquifer." The Columbia aquifer is used primarily for domestic purposes, especially on the Eastern Shore Peninsula and the southeastern region 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 beds 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 beds 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 Coastal Plain in Virginia. 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-bed 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, New York. 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, basin-wide, 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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APPENDIX

Appendix--Record of control wells and hydrogeologic data.

Example

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	TYPES OF LOGS USED
51B 3	36 41 09 N	077 23 07 W	USGS	123	-124 BSMT	E,G,J

CB1 33	CB2 38	CB3 M	CBB M	CB6 M	CB7 M	CB8 M	CB9 M		
AQ1 M	AQ2 +55	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +123	AQ10 M	

Explanation of abbreviations and symbols

BSMT	Basement
D	Driller's log
E	Electric log
G	Geologic log
J	Gamma log

Confining-bed name

CB1	lower Potomac	CB6	Nanjemoy-Marlboro Clay
CB2	middle Potomac	CB7	Calvert
CB3	upper Potomac	CB8	St. Marys
CBB	Brightseat	CB9	Yorktown

M	Confining bed not present in well
38	Thickness in feet of confining bed
--	No data

Aquifer name

AQ1	lower Potomac	AQ7	Chickahominy-Piney Point
AQ2	middle Potomac	AQ8	St. Marys-Choptank
AQ3	upper Potomac	AQ9	Yorktown-Eastover
AQB	Brightseat	AQ10	Columbia
AQ6	Aquia		

M	Aquifer not present in well
+55	Altitude of top of aquifer in feet above (+) or below (-) sea level
--	No data

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
51B 3	36 41 09 N	077 23 07 W	USGS	123	-124 BSMT	E,G,J
51D 1	36 56 36 N	077 23 57 W	TOWN OF STONY CREEK	75	-35 BSMT	D,E
51G 3	37 20 44 N	077 22 40 W	SAFEWAY STORES, INC.	180	-96 BSMT	D,E
51H 6	37 25 16 N	077 25 31 W	RICHMOND NAT. BATTLEFIELD PARK	85	-56 BSMT	D,E,J
51J 10	37 30 50 N	077 22 48 W	COMMONWEALTH SAND & GRAVEL CO.	155	-128	D,E
51K 7	37 39 22 N	077 22 34 W	SYDNOR HYDRODYNAMICS, INC.	180	-126 BSMT	D,E
51K 11	37 37 38 N	077 22 55 W	MAYFIELD FARMS	190	-126 BSMT	D,E,G,J
51P 4	38 14 54 N	077 25 16 W	SYDNOR HYDRODYNAMICS, INC.	75	-198 BSMT	D,E

Control Well Number									
51B 3	CB1 33	CB2 16	CB3 M	CB8 M	CB6 M	CB7 M	CB8 M	CB9 M	
	AQ1 M	AQ2 +8	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +123	AQ10 M
51D 1	CB1 M	CB2 20	CB3 M	CB8 M	CB6 M	CB7 M	CB8 M	CB9 M	
	AQ1 M	AQ2 +25	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 M	AQ10 +75
51G 3	CB1 46	CB2 32	CB3 M	CB8 M	CB6 22	CB7 M	CB8 M	CB9 M	
	AQ1 M	AQ2 +58	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +180	AQ10 M
51H 6	CB1 --	CB2 10	CB3 M	CB8 M	CB6 M	CB7 M	CB8 M	CB9 M	
	AQ1 --	AQ2 +70	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 M	AQ10 +85
51J 10	CB1 M	CB2 15	CB3 M	CB8 M	CB6 41	CB7 17	CB8 M	CB9 M	
	AQ1 M	AQ2 +17	AQ3 M	AQB M	AQ6 +52	AQ7 M	AQ8 M	AQ9 +155	AQ10 M
51K 7	CB1 M	CB2 25	CB3 M	CB8 M	CB6 50	CB7 52	CB8 M	CB9 M	
	AQ1 M	AQ2 +13	AQ3 M	AQB M	AQ6 +46	AQ7 M	AQ8 M	AQ9 +180	AQ10 M
51K 11	CB1 M	CB2 10	CB3 M	CB8 M	CB6 52	CB7 34	CB8 M	CB9 M	
	AQ1 M	AQ2 +14	AQ3 M	AQB M	AQ6 +34	AQ7 M	AQ8 M	AQ9 +190	AQ10 M
51P 4	CB1 >8	CB2 44	CB3 M	CB8 M	CB6 12	CB7 M	CB8 M	CB9 M	
	AQ1 --	AQ2 -35	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 M	AQ10 +75

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
51Q 1	38 22 20 N	077 22 32 W	RESEARCH HOMES, INC.	185	-145	D,E,J
	CB1 -- CB2 28 CB3 M CBB M CB6 24 CB7 M CB8 M CB9 M					
	AQ1 -- AQ2 +64 AQ3 M AQB M AQ6 +117 AQ7 M AQ8 M AQ9 +185 AQ10 M					
51Q 19	38 19 49 N	077 25 08 W	STAFFORD SCHOOL BOARD	200	-40	D,E
	CB1 -- CB2 42 CB3 M CBB M CB6 39 CB7 M CB8 M CB9 M					
	AQ1 -- AQ2 +58 AQ3 M AQB M AQ6 +113 AQ7 M AQ8 M AQ9 +200 AQ10 M					
51Q 20	38 17 13 N	077 25 59 W	SYDNOR HYDRODYNAMICS, INC.	150	-277 BSMT	D,E
	CB1 40 CB2 42 CB3 M CBB M CB6 24 CB7 M CB8 M CB9 M					
	AQ1 -226 AQ2 +20 AQ3 M AQB M AQ6 +86 AQ7 M AQ8 M AQ9 +150 AQ10 M					
51R 4	38 25 26 N	077 24 21 W	STAFFORD COUNTY SCHOOL BOARD	210	-85 BSMT	D,E
	CB1 -- CB2 28 CB3 M CBB M CB6 15 CB7 M CB8 M CB9 M					
	AQ1 -- AQ2 +98 AQ3 M AQB M AQ6 +160 AQ7 M AQ8 M AQ9 +210 AQ10 M					
51R 5	38 23 38 N	077 25 50 W	FREDERICKSBURG MOTOR COURT	240	-24 BSMT	D,E
	CB1 56 CB2 38 CB3 M CBB M CB6 44 CB7 M CB8 M CB9 M					
	AQ1 M AQ2 +90 AQ3 M AQB M AQ6 +156 AQ7 M AQ8 M AQ9 +240 AQ10 M					
52A 1	36 34 10 N	077 15 08 W	L. W. GRIZZARD	45	-181	D,E
	CB1 M CB2 26 CB3 22 CBB M CB6 29 CB7 M CB8 M CB9 12					
	AQ1 M AQ2 -69 AQ3 M AQB M AQ6 M AQ7 M AQ8 M AQ9 +28 AQ10 +44					
52B 3	36 42 45 N	077 18 20 W	TOWN OF DREWRYVILLE	110	-188	D,E
	CB1 34 CB2 19 CB3 11 CBB M CB6 M CB7 M CB8 M CB9 M					
	AQ1 -163 AQ2 +21 AQ3 M AQB M AQ6 M AQ7 M AQ8 M AQ9 +110 AQ10 M					
52D 1	36 55 09 N	077 15 29 W	SUSSEX COUNTY SCHOOL BOARD	85	-105	D,E
	CB1 -- CB2 33 CB3 10 CBB M CB6 18 CB7 M CB8 M CB9 M					
	AQ1 -- AQ2 -53 AQ3 M AQB M AQ6 +15 AQ7 M AQ8 M AQ9 +85 AQ10 M					

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
52F 5	37 09 33 N	077 17 04 W	PRINCE GEORGE COUNTY	140	-185	D,E,G

CB1 M	CB2 14	CB3 M	CBB M	CB6 33	CB7 14	CB8 M	CB9 M		
AQ1 M	AQ2 -14	AQ3 M	AQB M	AQ6 +27	AQ7 +68	AQ8 M	AQ9 +140	AQ10 M	

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52G 11	37 20 33 N	077 17 12 W	PHILLIP MORRIS, INC.	20	-194 BSMT	D,E

CB1 24	CB2 15	CB3 M	CBB M	CB6 M	CB7 M	CB8 M	CB9 M	
AQ1 M	AQ2 -20	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 M	AQ10 +20

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52H 8	37 28 59 N	077 22 03 W	HENRICO COUNTY SCHOOL BOARD	150	-135 BSMT	D,E,G

CB1 M	CB2 20	CB3 M	CBB M	CB6 35	CB7 19	CB8 M	CB9 M	
AQ1 M	AQ2 +22	AQ3 M	AQB M	AQ6 +65	AQ7 M	AQ8 M	AQ9 +150	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52J 11	37 37 11 N	077 19 30 W	SYDNOR HYDRODYNAMICS, INC.	170	-240 BSMT	D,E

CB1 —	CB2 30	CB3 M	CBB M	CB6 73	CB7 50	CB8 M	CB9 M	
AQ1 —	AQ2 -77	AQ3 M	AQB M	AQ6 -23	AQ7 +70	AQ8 M	AQ9 +170	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52J 18	37 32 40 N	077 21 37 W	HECKLER VILLAGE	150	-180	D,E

CB1 —	CB2 30	CB3 M	CBB M	CB6 43	CB7 16	CB8 M	CB9 M	
AQ1 —	AQ2 -38	AQ3 M	AQB M	AQ6 +25	AQ7 +86	AQ8 M	AQ9 +150	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52J 30	37 30 34 N	077 19 20 W	BYRD INTERNATIONAL AIRPORT	160	-88	D,E

CB1 M	CB2 35	CB3 M	CB8 M	CB6 46	CB7 26	CB8 M	CB9 M	
AQ1 M	AQ2 -58	AQ3 M	AQB M	AQ6 +30	AQ7 +88	AQ8 M	AQ9 +160	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52J 31	37 34 31 N	077 19 18 W	F. D. THARPS	70	-236	D,E

CB1 M	CB2 28	CB3 M	CBB M	CB6 34	CB7 14	CB8 M	CB9 M	
AQ1 M	AQ2 -84	AQ3 M	AQB M	AQ6 -28	AQ7 M	AQ8 M	AQ9 +70	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
52K 6	37 39 15 N	077 21 46 W	SYDNOR HYDRODYNAMICS, INC.	180	-190	D,E

CB1 M	CB2 20	CB3 M	CBB M	CB6 66	CB7 42	CB8 M	CB9 M	
AQ1 M	AQ2 -54	AQ3 M	AQB M	AQ6 -6	AQ7 +72	AQ8 M	AQ9 +180	AQ10 M

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used			
52K 9	37 42 28 N	077 22 01 W	E. S. ROBERTSON	170	-90	D,E			
CB1 M	CB2 10	CB3 M	CB8 M	CB6 47	CB7 32	CB8 M	CB9 M		
AQ1 M	AQ2 -32	AQ3 M	AQB M	AQ6 +5	AQ7 +70	AQ8 M	AQ9 +170	AQ10 M	
52K 10	37 37 31 N	077 17 49 W	CONTINENTAL TELEPHONE, INC.	190	-177	D,E,G			
CB1 —	CB2 11	CB3 M	CB8 M	CB6 67	CB7 34	CB8 M	CB9 15		
AQ1 —	AQ2 -80	AQ3 M	AQB M	AQ6 -44	AQ7 +68	AQ8 M	AQ9 +175	AQ10 M	
52K 11	37 41 10 N	077 21 15 W	COLONIAL FORREST SUBDIV.	185	-145	D,E			
CB1 —	CB2 35	CB3 M	CB8 M	CB6 54	CB7 44	CB8 M	CB9 M		
AQ1 —	AQ2 -70	AQ3 M	AQB M	AQ6 -1	AQ7 +71	AQ8 M	AQ9 +185	AQ10 M	
52L 2	37 47 51 N	077 19 55 W	KIWANIS CLUB OF RICHMOND	190	-130	D,E,G			
CB1 —	CB2 26	CB3 M	CB8 M	CB6 62	CB7 28	CB8 M	CB9 M		
AQ1 —	AQ2 -62	AQ3 M	AQB M	AQ6 -2	AQ7 +72	AQ8 M	AQ9 +190	AQ10 M	
52L 4	37 46 05 N	077 16 43 W	C. W. ENGEL	60	-210	D,E			
CB1 —	CB2 60	CB3 M	CB8 M	CB6 62	CB7 M	CB8 M	CB9 M		
AQ1 —	AQ2 -112	AQ3 M	AQB M	AQ6 -30	AQ7 M	AQ8 M	AQ9 M	AQ10 +60	
52M 2	37 54 02 N	077 19 05 W	D. C. BURRUSS	105	-157	D,E			
CB1 —	CB2 74	CB3 M	CB8 M	CB6 61	CB7 17	CB8 M	CB9 M		
AQ1 —	AQ2 -103	AQ3 M	AQB M	AQ6 -1	AQ7 +76	AQ8 M	AQ9 M	AQ10 +105	
52N 13	38 06 15 N	077 16 47 W	USGS	180	-31	E,G,J			
CB1 —	CB2 —	CB3 —	CB8 —	CB6 48	CB7 44	CB8 M	CB9 M		
AQ1 --	AQ2 --	AQ3 —	AQB --	AQ6 +30	AQ7 +96	AQ8 M	AQ9 +180	AQ10 M	
52N 14	38 01 06 N	077 21 22 W	USGS	145	-7	E,G,J			
CB1 --	CB2 >20	CB3 M	CB8 M	CB6 56	CB7 M	CB8 M	CB9 M		
AQ1 --	AQ2 —	AQ3 M	AQB M	AQ6 +75	AQ7 M	AQ8 M	AQ9 +145	AQ10 M	

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
52N 15	38 05 48 N	077 18 21 W	U.S. ARMY, FORT A. P. HILL	230	-280	D,E
52N 16	38 03 23 N	077 20 47 W	TOWN OF BOWLING GREEN	205	-314	D,E
52P 8	38 10 48 N	077 17 33 W	U.S. ARMY, FORT A. P. HILL	205	-217	D,E
52P 9	38 08 56 N	077 19 45 W	U.S. ARMY, FORT A. P. HILL	160	-340	D,E
53A 3	36 35 04 N	077 11 53 W	TOWN OF BOYKINS	40	-445 BSMT	D,E,G
53B 3	36 42 18 N	077 14 14 W	W. TURNER	105	-85	E
53C 1	36 46 22 N	077 10 28 W	UNION CAMP EXP. FARM	105	-273	E
53D 3	36 58 43 N	077 09 02 W	VASWCB	95	-448 BSMT	D,E,J

Control Well Number										
52N 15	CB1 —	CB2 28	CB3 M	CBB M	CB6 30	CB7 47	CB8 M	CB9 M		
	AQ1 —	AQ2 -58	AQ3 M	AQB M	AQ6 +50	AQ7 +100	AQ8 M	AQ9 +230	AQ10 M
52N 16	CB1 57	CB2 54	CB3 M	CBB M	CB6 21	CB7 34	CB8 M	CB9 M	
	AQ1 -266	AQ2 -43	AQ3 M	AQB M	AQ6 +78	AQ7 +111	AQ8 M	AQ9 +205	AQ10 M
52P 8	CB1 —	CB2 8	CB3 M	CBB M	CB6 59	CB7 44	CB8 M	CB9 M	
	AQ1 —	AQ2 -105	AQ3 M	AQB M	AQ6 +1	AQ7 +95	AQ8 M	AQ9 +205	AQ10 M
52P 9	CB1 >20	CB2 60	CB3 M	CBB M	CB6 78	CB7 40	CB8 M	CB9 M	
	AQ1 —	AQ2 -140	AQ3 M	AQB M	AQ6 +10	AQ7 +108	AQ8 M	AQ9 +160	AQ10 M
53A 3	CB1 16	CB2 24	CB3 21	CBB M	CB6 M	CB7 M	CB8 M	CB9 11	
	AQ1 -352	AQ2 -77	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +16	AQ10 +40
53B 3	CB1 M	CB2 23	CB3 5	CBB M	CB6 M	CB7 M	CB8 M	CB9 63	
	AQ1 M	AQ2 -53	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +26	AQ10 +103
53C 1	CB1 40	CB2 22	CB3 M	CBB M	CB6 M	CB7 10	CB8 M	CB9 30	
	AQ1 -201	AQ2 -19	AQ3 M	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +45	AQ10 +105
53D 3	CB1 46	CB2 40	CB3 14	CBB M	CB6 16	CB7 10	CB8 M	CB9 22	
	AQ1 M	AQ2 -101	AQ3 -27	AQB M	AQ6 -3	AQ7 M	AQ8 M	AQ9 +60	AQ10 +95

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used				
53G 13	37 21 05 N	077 11 36 W	CHARLES CITY COUNTY	75	-250	D,E				
	CB1 —	CB2 20	CB3 17	CBB M	CB6 44	CB7 9	CB8 M	CB9 M		
	AQ1 —	AQ2 -127	AQ3 M	AQB M	AQ6 -39	AQ7 +35	AQ8 M	AQ9 +75	AQ10 M	
53J 7	37 30 58 N	077 13 59 W	BRADLEY ACRES	130	-521 BSMT	D,E,G				
	CB1 26	CB2 8	CB3 M	CBB M	CB6 41	CB7 42	CB8 M	CB9 M		
	AQ1 -288	AQ2 -98	AQ3 M	AQB M	AQ6 -38	AQ7 +44	AQ8 M	AQ9 +130	AQ10 M	
53K 17	37 43 42 N	077 08 39 W	C&N CORPORATION	160	-240	D,E				
	CB1 —	CB2 18	CB3 18	CBB M	CB6 48	CB7 58	CB8 20	CB9 M		
	AQ1 —	AQ2 -198	AQ3 M	AQB M	AQ6 -86	AQ7 +22	AQ8 M	AQ9 +160	AQ10 M	
53K 18	37 38 15 N	077 07 50 W	D. FLEET	30	-338	D,E				
	CB1 --	CB2 44	CB3 34	CBB M	CB6 58	CB7 21	CB8 M	CB9 M		
	AQ1 —	AQ2 -240	AQ3 M	AQB M	AQ6 -92	AQ7 -6	AQ8 M	AQ9 M	AQ10 +30	
53L 2	37 45 40 N	077 09 21 W	L. A. LIPSCOMB	140	-290	D,E				
	CB1 —	CB2 46	CB3 12	CBB M	CB6 64	CB7 60	CB8 30	CB9 M		
	AQ1 --	AQ2 -244	AQ3 M	AQB M	AQ6 -108	AQ7 +4	AQ8 M	AQ9 +140	AQ10 M	
53P 4	38 14 18 N	077 09 16 W	MT. ROSE CANNING CO.	180	-720	D,E				
	CB1 86	CB2 62	CB3 M	CBB M	CB6 94	CB7 38	CB8 25	CB9 M		
	AQ1 -662	AQ2 -230	AQ3 M	AQB M	AQ6 -58	AQ7 +64	AQ8 M	AQ9 +180	AQ10 M	
53P 8	38 09 48 N	077 12 04 W	A. J. GOULDMAN	35	-375	D,E				
	CB1 --	CB2 42	CB3 M	CBB M	CB6 66	CB7 M	CB8 M	CB9 M		
	AQ1 --	AQ2 -141	AQ3 M	AQB M	AQ6 -51	AQ7 M	AQ8 M	AQ9 M	AQ10 +35	
53Q 7	38 17 33 N	077 14 43 W	USGS	150	-85	E,G,J				
	CB1 --	CB2 45	CB3 M	CBB M	CB6 65	CB7 20	CB8 16	CB9 M		
	AQ1 --	AQ2 -85	AQ3 M	AQB M	AQ6 +15	AQ7 +94	AQ8 M	AQ9 +150	AQ10 M	

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used			
53Q 9	38 19 45 N	077 14 11 W	SYDNOR HYDRODYNAMICS, INC.	45	-453	D,E			
	CB1 >2	CB2 64	CB3 M	CB8 M	CB6 15	CB7 M	CB8 M	CB9 M	
	AQ1 —	AQ2 -115	AQ3 M	AQB M	AQ6 +10	AQ7 M	AQ8 M	AQ9 M	AQ10 +45
54A 1	36 37 22 N	077 01 46 W	W. BRITT	35	-231	D,E			
	CB1 —	CB2 25	CB3 40	CB8 M	CB6 33	CB7 M	CB8 M	CB9 17	
	AQ1 —	AQ2 -170	AQ3 -105	AQB M	AQ6 -66	AQ7 M	AQ8 M	AQ9 +3	AQ10 +35
54A 3	36 35 21 N	077 06 36 W	J. T. PARKER	100	-248	E			
	CB1 --	CB2 37	CB3 16	CB8 M	CB6 M	CB7 M	CB8 M	CB9 26	
	AQ1 --	AQ2 -116	AQ3 -48	AQB M	AQ6 M	AQ7 M	AQ8 M	AQ9 +26	AQ10 +100
54B 1	36 39 15 N	077 00 11 W	HERCULES POWDER CO.	20	-595	D,E			
	CB1 >10	CB2 29	CB3 15	CBB M	CB6 12	CB7 M	CB8 M	CB9 19	
	AQ1 --	AQ2 -188	AQ3 -110	AQB M	AQ6 -65	AQ7 M	AQ8 M	AQ9 -5	AQ10 +20
54B 7	36 42 04 N	077 00 49 W	A. SIPINZSKY	40	-309	D,E			
	CB1 —	CB2 28	CB3 35	CBB M	CB6 13	CB7 17	CB8 M	CB9 18	
	AQ1 —	AQ2 -179	AQ3 -103	AQB M	AQ6 -46	AQ7 M	AQ8 M	AQ9 +17	AQ10 +40
54B 18	36 42 11 N	077 05 43 W	F. E. NOTTINGHAM	50	-213	E			
	CB1 —	CB2 22	CB3 44	CBB M	CB6 8	CB7 M	CB8 M	CB9 13	
	AQ1 --	AQ2 -115	AQ3 -73	AQB M	AQ6 -18	AQ7 M	AQ8 M	AQ9 +30	AQ10 +50
54B 19	36 44 47	077 03 52	HYDER	50	-296	E			
	CB1 --	CB2 17	CB3 18	CBB M	CB6 16	CB7 M	CB8 M	CB9 —	
	AQ1 —	AQ2 -150	AQ3 -91	AQB M	AQ6 -34	AQ7 M	AQ8 M	AQ9 —	AQ10 —
54C 4	36 50 09 N	077 03 54 W	A. WILLIAMS	115	-240	D,E			
	CB1 —	CB2 18	CB3 17	CBB M	CB6 10	CB7 19	CB8 M	CB9 44	
	AQ1 --	AQ2 -142	AQ3 -62	AQB M	AQ6 -39	AQ7 M	AQ8 M	AQ9 +37	AQ10 +115

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner			Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used		
54D 1	36 58 45 N	077 00 21 W	T. W. SPAIN			110	-678 BSMT	E,J		
	CB1 17	CB2 44	CB3 26	CBB M	CB6 24	CB7 28	CB8 M	CB9 23		
	AQ1 -486	AQ2 -262	AQ3 -123	AQB M	AQ6 -60	AQ7 -36	AQ8 M	AQ9 +54	AQ10 +110	
54D 2	36 53 31 N	077 02 08 W	R. H. WHITE			115	-255	D,E		
	CB1 —	CB2 51	CB3 33	CBB M	CB6 18	CB7 20	CB8 M	CB9 20		
	AQ1 —	AQ2 -184	AQ3 -92	AQB M	AQ6 -44	AQ7 -19	AQ8 M	AQ9 +43	AQ10 +115	
54E 7	37 01 56 N	077 06 38 W	TOWN OF WAVERLY			110	-343	D,E		
	CB1 —	CB2 20	CB3 36	CBB M	CB6 18	CB7 10	CB8 M	CB9 26		
	AQ1 —	AQ2 -148	AQ3 -58	AQB M	AQ6 -14	AQ7 M	AQ8 M	AQ9 +64	AQ10 +110	
54G 10	37 19 56 N	077 05 52 W	VASWCB			35	-545 BSMT	E,G,J		
	CB1 12	CB2 26	CB3 M	CBB M	CB6 42	CB7 17	CB8 M	CB9 M		
	AQ1 -455	AQ2 -174	AQ3 M	AQB M	AQ6 -95	AQ7 -22	AQ8 M	AQ9 M	AQ10 +35	
54H 4	37 29 51 N	077 07 19 W	WOODHAVEN SHORES, INC.			110	-390	D,E		
	CB1 —	CB2 14	CB3 15	CBB M	CB6 44	CB7 53	CB8 M	CB9 M		
	AQ1 —	AQ2 -204	AQ3 -146	AQB M	AQ6 -100	AQ7 +22	AQ8 M	AQ9 +110	AQ10 M	
54H 11	37 29 58 N	077 02 36 W	VIRGINIA DEPT. OF HIGHWAYS			65	-338	D,E,J		
	CB1 --	CB2 28	CB3 14	CBB M	CB6 42	CB7 33	CB8 M	CB9 M		
	AQ1 --	AQ2 -255	AQ3 -193	AQB M	AQ6 -129	AQ7 -14	AQ8 M	AQ9 +65	AQ10 M	
54J 4	37 32 07 N	077 06 52 W	KENWOOD FARMS, INC.			160	-343	D,E,J		
	CB1 —	CB2 24	CB3 18	CBB M	CB6 41	CB7 58	CB8 M	CB9 M		
	AQ1 —	AQ2 -207	AQ3 -142	AQB M	AQ6 -101	AQ7 +18	AQ8 M	AQ9 +160	AQ10 M	
54P 3	38 10 10 N	077 02 19 W	USGS			180	-1180	D,E,G,J		
	CB1 100	CB2 110	CB3 M	CBB 14	CB6 116	CB7 68	CB8 52	CB9 M		
	AQ1 -890	AQ2 -324	AQ3 M	AQB M	AQ6 -160	AQ7 -14	AQ8 M	AQ9 +180	AQ10 M	

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
54Q 9	38 17 55 N	077 02 55 W	U.S. NAVY	25	-719	D,E

CB1 --	CB2 26	CB3 M	CB8 M	CB6 74	CB7 20	CB8 M	CB9 M		
AQ1 --	AQ2 -278	AQ3 M	AQB M	AQ6 -115	AQ7 M	AQ8 M	AQ9 M	AQ10 +25	

54Q 10	38 20 00 N	077 02 15 W	U.S. NAVY	20	-990	D,E

CB1 118	CB2 44	CB3 M	CB8 M	CB6 80	CB7 M	CB8 M	CB9 M	
AQ1 -890	AQ2 -266	AQ3 M	AQB M	AQ6 -88	AQ7 M	AQ8 M	AQ9 M	AQ10 +20

54Q 11	38 20 21 N	077 05 18 W	TOWN OF OWENS	130	-760	D,E

CB1 >6	CB2 48	CB3 M	CB8 M	CB6 86	CB7 30	CB8 36	CB9 M	
AQ1 --	AQ2 -260	AQ3 M	AQB M	AQ6 -74	AQ7 +34	AQ8 M	AQ9 +130	AQ10 M

54R 3	38 22 42 N	077 03 47 W	J. B. CRALLE	110	-567	D,E

CB1 --	CB2 42	CB3 M	CB8 M	CB6 83	CB7 35	CB8 37	CB9 M	
AQ1 --	AQ2 -272	AQ3 M	AQB M	AQ6 -83	AQ7 M	AQ8 M	AQ9 +110	AQ10 M

55A 1	36 36 07 N	076 56 00 W	H. DARDEN	22	-340	E,G

CB1 --	CB2 56	CB3 4	CB8 M	CB6 18	CB7 8	CB8 M	CB9 M	
AQ1 --	AQ2 -254	AQ3 -128	AQB M	AQ6 -110	AQ7 M	AQ8 M	AQ9 +18	AQ10 +22

55B 49	36 43 36 N	076 57 56 W	LANKFORD NURSERY	95	-289	D,E

CB1 --	CB2 25	CB3 17	CB8 M	CB6 17	CB7 23	CB8 M	CB9 33	
AQ1 --	AQ2 -250	AQ3 -128	AQB M	AQ6 -97	AQ7 -42	AQ8 M	AQ9 +14	AQ10 +95

55B 63	36 41 21 N	076 54 51 W	UNION CAMP	30	-680	D,E,J

CB1 47	CB2 28	CB3 22	CB8 M	CB6 12	CB7 42	CB8 M	CB9 M	
AQ1 -677	AQ2 -244	AQ3 -188	AQB M	AQ6 -136	AQ7 -62	AQ8 M	AQ9 +5	AQ10 +30

55C 1	36 46 30 N	076 59 17 W	M. HOLT	90	-240	D,E

CB1 --	CB2 17	CB3 12	CB8 M	CB6 32	CB7 31	CB8 M	CB9 47	
AQ1 --	AQ2 -187	AQ3 -124	AQB M	AQ6 -94	AQ7 -37	AQ8 M	AQ9 +17	AQ10 +90

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
55C 8	36 51 24 N	076 58 34 W	H. W. WADE	80	-250	D,E
55C 12	36 46 05 N	076 53 18 W	CITY OF VIRGINIA BEACH	15	-899 BSMT	D,E,J
55D 5	36 54 15 N	076 53 20 W	TOWN OF IVOR	90	-420	D,E,J
55D 12	36 55 00 N	076 54 31 W	VIRGINIA DEPT. OF AGRICULTURE	80	-370	D,E
55E 1	37 02 45 N	076 56 06 W	TOWN OF DENDRON	110	-400	D,E,G
55E 3	37 04 51 N	076 54 18 W	SURRY COUNTY	90	-390	D,E,G
55F 20	37 13 21 N	076 57 06 W	TOWN OF CLAREMONT	90	-313	D,E
55G 4	37 18 45 N	076 56 13 W	CHARLES CITY COUNTY	35	-303	D,E

Control Well Number										
55C 8	CB1 --	CB2 33	CB3 20	CBB M	CB6 20	CB7 22	CB8 M	CB9 34		
	AQ1 --	AQ2 -179	AQ3 -96	AQB M	AQ6 -56	AQ7 -32	AQ8 M	AQ9 +26	AQ10 +80
55C 12	CB1 54	CB2 64	CB3 22	CBB M	CB6 20	CB7 20	CB8 M	CB9 M	
	AQ1 -683	AQ2 -313	AQ3 -185	AQB M	AQ6 -141	AQ7 -71	AQ8 M	AQ9 -20	AQ10 +15
55D 5	CB1 --	CB2 26	CB3 14	CBB M	CB6 28	CB7 33	CB8 M	CB9 34	
	AQ1 --	AQ2 -271	AQ3 -160	AQB M	AQ6 -112	AQ7 -69	AQ8 M	AQ9 +32	AQ10 +90
55D 12	CB1 --	CB2 34	CB3 24	CBB M	CB6 21	CB7 32	CB8 M	CB9 24	
	AQ1 --	AQ2 -268	AQ3 -154	AQB M	AQ6 -96	AQ7 -67	AQ8 M	AQ9 +38	AQ10 +80
55E 1	CB1 --	CB2 55	CB3 32	CBB M	CB6 21	CB7 40	CB8 20	CB9 27	
	AQ1 --	AQ2 -323	AQ3 -192	AQB M	AQ6 -96	AQ7 -66	AQ8 M	AQ9 +45	AQ10 +110
55E 3	CB1 --	CB2 46	CB3 24	CBB M	CB6 29	CB7 32	CB8 26	CB9 25	
	AQ1 --	AQ2 -356	AQ3 -198	AQB M	AQ6 -121	AQ7 -68	AQ8 M	AQ9 +44	AQ10 +90
55F 20	CB1 --	CB2 28	CB3 11	CBB M	CB6 33.	CB7 34	CB8 M	CB9 10	
	AQ1 --	AQ2 -217	AQ3 M	AQB M	AQ6 -113	AQ7 -58	AQ8 M	AQ9 +80	AQ10 M
55G 4	CB1 --	CB2 30	CB3 22	CBB M	CB6 44	CB7 23	CB8 M	CB9 15	
	AQ1 --	AQ2 -269	AQ3 -209	AQB M	AQ6 -153	AQ7 -58	AQ8 M	AQ9 +10	AQ10 +35

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
55H 1	37 24 28 N	076 56 15 W	CITY OF NEWPORT NEWS	10	-768	D,E,J
55L 2	37 49 32 N	076 56 42 W	SYDNOR HYDRODYNAMICS, INC.	170	-130	D,E
55P 3	38 11 22 N	076 55 31 W	NATIONAL PARK SERVICE	20	-790	D,E,J
56A 9	36 36 25 N	076 52 26 W	VASWCB	80	-983 BSMT	D,E,J
56A 10	36 33 45 N	076 47 02 W	VASWCB	45	-1155 BSMT	E,G,J
56A 11	36 36 53 N	076 45 54 W	VASWCB	80	-1098	E,G,J
56B 1	36 41 13 N	076 45 47 W	PEARCE	80	420	D,E
56B 9	36 38 57 N	076 49 46 W	J. E. RAWLS	85	-440	D,E

Control Well Number									
55H 1	CB1 22	CB2 20	CB3 12	CBB M	CB6 44	CB7 42	CB8 M	CB9 M	
	AQ1 -650	AQ2 -304	AQ3 -242	AQB M	AQ6 -168	AQ7 -60	AQ8 M	AQ9 M	AQ10 +10
55L 2	CB1 --	CB2 --	CB3 --	CBB --	CB6 >8	CB7 85	CB8 65	CB9 15	
	AQ1 --	AQ2 --	AQ3 --	AQB --	AQ6 --	AQ7 -59	AQ8 M	AQ9 +155	AQ10 M
55P 3	CB1 --	CB2 30	CB3 M	CBB 10	CB6 110	CB7 40	CB8 M	CB9 M	
	AQ1 --	AQ2 -361	AQ3 M	AQB M	AQ6 -199	AQ7 -39	AQ8 M	AQ9 M	AQ10 +20
56A 9	CB1 37	CB2 36	CB3 14	CBB M	CB6 18	CB7 34	CB8 M	CB9 20	
	AQ1 -720	AQ2 -336	AQ3 -170	AQB M	AQ6 -140	AQ7 -82	AQ8 M	AQ9 0	AQ10 +80
56A 10	CB1 30	CB2 58	CB3 44	CBB M	CB6 18	CB7 22	CB8 M	CB9 9	
	AQ1 -841	AQ2 -401	AQ3 -229	AQB M	AQ6 -177	AQ7 -105	AQ8 M	AQ9 +23	AQ10 +45
56A 11	CB1 50	CB2 72	CB3 25	CBB M	CB6 28	CB7 25	CB8 M	CB9 21	
	AQ1 34	AQ2 -394	AQ3 -267	AQB M	AQ6 -204	AQ7 -121	AQ8 M	AQ9 +9	AQ10 +80
56B 1	CB1 --	CB2 67	CB3 20	CBB M	CB6 15	CB7 28	CB8 M	CB9 37	
	AQ1 --	AQ2 -400	AQ3 -250	AQB M	AQ6 -204	AQ7 -119	AQ8 M	AQ9 -12	AQ10 +84
56B 9	CB1 --	CB2 37	CB3 16	CBB M	CB6 11	CB7 29	CB8 M	CB9 52	
	AQ1 --	AQ2 -344	AQ3 -191	AQB M	AQ6 -160	AQ7 -123	AQ8 M	AQ9 -23	AQ10 +85

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used			
56C 1	36 50 06 N	076 50 03 W	ZUNI PRESBYTERIAN SCHOOL	75	-421	D,E			
	CB1 --	CB2 30	CB3 33	CBB M	CB6 24	CB7 30	CB8 M	CB9 44	
	AQ1 --	AQ2 -299	AQ3 -198	AQB M	AQ6 -137	AQ7 -89	AQ8 M	AQ9 +5	AQ10 +75
56C 2	36 46 14 N	076 50 53 W	W. HOLLAND	45	-295	E			
	CB1 --	CB2 >7	CB3 54	CBB M	CB6 28	CB7 22	CB8 M	CB9 29	
	AQ1 --	AQ2 --	AQ3 -205	AQB M	AQ6 -137	AQ7 -89	AQ8 M	AQ9 +6	AQ10 +45
56F 16	37 14 34 N	076 48 15 W	SYDNOR HYDRODYNAMICS, INC.	30	-465	D,E,G			
	CB1 --	CB2 60	CB3 16	CBB M	CB6 53	CB7 32	CB8 8	CB9 20	
	AQ1 --	AQ2 -368	AQ3 -254	AQB M	AQ6 -211	AQ7 -94	AQ8 M	AQ9 0	AQ10 +30
56F 42	37 08 32 N	076 50 27 W	SYDNOR HYDRODYNAMICS, INC.	110	-375	D,E,G			
	CB1 --	CB2 28	CB3 12	CBB M	CB6 33	CB7 38	CB8 22	CB9 24	
	AQ1 --	AQ2 -308	AQ3 -226	AQB M	AQ6 -156	AQ7 -82	AQ8 M	AQ9 +56	AQ10 +110
56G 6	37 19 05 N	076 47 12 W	JAMES CITY SERVICE AUTHORITY	120	-306	D,E,G,J			
	CB1 --	CB2 --	CB3 19	CBB M	CB6 62	CB7 59	CB8 M	CB9 24	
	AQ1 --	AQ2 --	AQ3 -279	AQB M	AQ6 -232	AQ7 -104	AQ8 M	AQ9 +56	AQ10 +120
56G 9	37 21 49 N	076 46 12 W	JAMES CITY SCHOOL BOARD	105	-195	D,E			
	CB1 --	CB2 --	CB3 --	CBB --	CB6 >24	CB7 57	CB8 M	CB9 24	
	AQ1 --	AQ2 --	AQ3 --	AQB --	AQ6 --	AQ7 -109	AQ8 M	AQ9 +57	AQ10 +105
56J 5	37 32 46 N	076 48 30 W	CHESAPEAKE CORPORATION	25	-1255 BSMT	D,E,J			
	CB1 34	CB2 72	CB3 38	CBB 10	CB6 82	CB7 40	CB8 18	CB9 4	
	AQ1 -885	AQ2 -503	AQ3 -343	AQB -295	AQ6 -251	AQ7 -85	AQ8 M	AQ9 +2	AQ10 +25
56J 11	37 31 26 N	076 45 41 W	CHESAPEAKE CORPORATION	15	-1255 BSMT	D,E,G			
	CB1 32	CB2 50	CB3 81	CBB 21	CB6 86	CB7 50	CB8 20	CB9 6	
	AQ1 -931	AQ2 -557	AQ3 -434	AQB -330	AQ6 -279	AQ7 -119	AQ8 M	AQ9 -5	AQ10 +15

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
56M 9	37 57 33 N	076 45 18 W	TOWN OF WARSAW	130	-570	D,E

CB1 —	CB2 >18	CB3 19	CB8 10	CB6 97	CB7 96	CB8 88	CB9 10		
AQ1 —	AQ2 —	AQ3 -493	AQB -416	AQ6 -297	AQ7 -122	AQ8 M	AQ9 +120	AQ10 M	

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
56M 10	37 55 41 N	076 51 43 W	TOWN OF TAPPAHANNOCK	20	-533	D,E

CB1 —	CB2 42	CB3 22	CB8 12	CB6 99	CB7 96	CB8 52	CB9 M	
AQ1 —	AQ2 -466	AQ3 -370	AQB -340	AQ6 -242	AQ7 -84	AQ8 M	AQ9 M	AQ10 +20

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
56N 7	38 05 16 N	076 47 30 W	ARROWHEAD ASSOCIATES	145	-672	D,E

CB1 —	CB2 110	CB3 38	CB8 11	CB6 132	CB7 73	CB8 88	CB9 M	
AQ1 —	AQ2 -643	AQ3 -497	AQB -383	AQ6 -283	AQ7 -92	AQ8 M	AQ9 +145	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
56P 2	38 10 08 N	076 52 09 W	WESTMORELAND STATE PARK	135	-425	D,E

CB1 --	CB2 —	CB3 11	CBB 15	CB6 127	CB7 76	CB8 80	CB9 M	
AQ1 --	AQ2 --	AQ3 -391	AQB -370	AQ6 -240	AQ7 -63	AQ8 M	AQ9 +135	AQ10 M

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
57A 1	36 36 08 N	076 40 07 W	VIRGINIA DEPT. OF HIGHWAYS	70	-550	E

CB1 —	CB2 45	CB3 53	CBB M	CB6 22	CB7 20	CB8 M	CB9 40	
AQ1 —	AQ2 -494	AQ3 -379	AQB M	AQ6 -272	AQ7 -172	AQ8 M	AQ9 -10	AQ10 +70

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
57B 6	36 42 48 N	076 39 13 W	CITY OF SUFFOLK	55	-661	D,E,J

CB1 --	CB2 22	CB3 42	CB8 M	CB6 35	CB7 47	CB8 M	CB9 22	
AQ1 —	AQ2 -503	AQ3 -298	AQB M	AQ6 -245	AQ7 -158	AQ8 M	AQ9 +3	AQ10 +55

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
57C 7	36 48 47 N	076 44 38 W	M. H. ROBINSON	85	-375	D,E

CB1 —	CB2 --	CB3 40	CBB M	CB6 39	CB7 36	CB8 M	CB9 33	
AQ1 —	AQ2 —	AQ3 -267	AQB M	AQ6 -194	AQ7 -137	AQ8 M	AQ9 +12	AQ10 +85

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface	Altitude of Bottom of Logged Hole	Types of Logs Used
57C 17	36 48 10 N	076 39 21 W	CITY OF NORFOLK	40	-850	D,E,G

CB1 --	CB2 28	CB3 65	CB8 M	CB6 42	CB7 23	CB8 M	CB9 40	
AQ1 --	AQ2 -450	AQ3 -338	AQB M	AQ6 -247	AQ7 -150	AQ8 M	AQ9 -24	AQ10 +40

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
57D 3	36 59 27 N	076 37 58 W	SMITHFIELD PACKING COMPANY	30	-570	E
	CB1 -- CB2 31 CB3 22 CBB M CB6 47 CB7 50 CB8 26 CB9 18					
	AQ1 -- AQ2 -502 AQ3 -310 AQB M AQ6 -279 AQ7 -200 AQ8 M AQ9 -28 AQ10 +30					
57D 20	36 52 32 N	076 40 56 W	CITY OF VIRGINIA BEACH	50	-910	D,E
	CB1 -- CB2 30 CB3 30 CBB M CB6 45 CB7 38 CB8 M CB9 35					
	AQ1 -- AQ2 -412 AQ3 -290 AQB M AQ6 -238 AQ7 -140 AQ8 M AQ9 -25 AQ10 +50					
57E 10	37 02 36 N	076 42 59 W	VASWCB	85	-615	D,E
	CB1 -- CB2 24 CB3 11 CBB M CB6 40 CB7 46 CB8 24 CB9 25					
	AQ1 -- AQ2 -405 AQ3 -272 AQB M AQ6 -215 AQ7 -145 AQ8 M AQ9 +14 AQ10 +85					
57F 2	37 14 21 N	076 38 28 W	WILLIAMSBURG COUNTRY CLUB	80	-513	D,E
	CB1 -- CB2 24 CB3 20 CBB M CB6 68 CB7 80 CB8 56 CB9 24					
	AQ1 -- AQ2 -476 AQ3 -308 AQB M AQ6 -320 AQ7 -214 AQ8 M AQ9 +16 AQ10 +80					
57F 3	37 09 16 N	076 40 19 W	VEPCO	25	-390	D,E
	CB1 -- CB2 -- CB3 31 CBB M CB6 78 CB7 52 CB8 48 CB9 30					
	AQ1 -- AQ2 -- AQ3 -352 AQB M AQ6 -294 AQ7 -187 AQ8 M AQ9 -23 AQ10 +25					
57F 7	37 13 43 N	076 40 08 W	BUSCH PROPERTIES, INC.	55	-455	D,E,G,J
	CB1 -- CB2 16 CB3 22 CBB M CB6 69 CB7 68 CB8 58 CB9 16					
	AQ1 -- AQ2 -453 AQ3 -361 AQB M AQ6 -301 AQ7 -195 AQ8 M AQ9 +13 AQ10 +53					
57F 26	37 09 51 N	076 41 57 W	VEPCO	35	-385	D,E
	CB1 -- CB2 -- CB3 26 CBB M CB6 72 CB7 70 CB8 47 CB9 12					
	AQ1 -- AQ2 -- AQ3 -323 AQB M AQ6 -285 AQ7 -167 AQ8 M AQ9 -19 AQ10 +35					
57G 22	37 19 34 N	076 44 14 W	SYDNOR HYDRODYNAMICS, INC.	100	-325	D,E,G
	CB1 -- CB2 -- CB3 >35 CBB M CB6 62 CB7 66 CB8 20 CB9 21					
	AQ1 -- AQ2 -- AQ3 -- AQB M AQ6 -250 AQ7 -134 AQ8 M AQ9 +44 AQ10 +100					

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used			
57G 25	37 16 05 N	076 42 03 W	COLONIAL WILLIAMSBURG	70	-428	D,E			
	CB1 —	CB2 >28	CB3 18	CB8 M	CB6 66	CB7 60	CB8 36	CB9 22	
	AQ1 —	AQ2 —	AQ3 -334	AQB M	AQ6 -288	AQ7 -176	AQ8 M	AQ9 +24	AQ10 +70
57H 6	37 23 10 N	076 41 14 W	TIDEWATER WATER COMPANY	50	-503	D,E			
	CB1 —	CB2 30	CB3 14	CB8 6	CB6 74	CB7 68	CB8 30	CB9 24	
	AQ1 —	AQ2 -436	AQ3 -362	AQB M	AQ6 -296	AQ7 -168	AQ8 M	AQ9 +6	AQ10 +50
57J 3	37 30 08 N	076 42 58 W	CHESAPEAKE CORPORATION	50	-1000	D,E			
	CB1 60	CB2 34	CB3 22	CB8 36	CB6 90	CB7 56	CB8 32	CB9 16	
	AQ1 -951	AQ2 -511	AQ3 -440	AQB -369	AQ6 -297	AQ7 -137	AQ8 M	AQ9 +11	AQ10 +50
57N 3	38 04 28 N	076 40 25 W	WESTMORELAND COUNTY	120	-373	D,E			
	CB1 —	CB2 --	CB3 —	CB8 —	CB6 114	CB7 94	CB8 100	CB9 10	
	AQ1 —	AQ2 --	AQ3 —	AQB --	AQ6 -332	AQ7 -154	AQ8 M	AQ9 +90	AQ10 +120
57P 1	38 08 55 N	076 40 22 W	H.T.E. CORPORATION	10	-765	D,E			
	CB1 —	CB2 >57	CB3 45	CB8 32	CB6 131	CB7 88	CB8 50	CB9 M	
	AQ1 --	AQ2 —	AQ3 -649	AQB -492	AQ6 -328	AQ7 -136	AQ8 M	AQ9 M	AQ10 +10
58A 2	36 34 09 N	076 35 00 W	VASWCB	60	-1822 BSMT	D,E,G,J			
	CB1 67	CB2 44	CB3 54	CB8 M	CB6 15	CB7 38	CB8 M	CB9 28	
	AQ1 -1156	AQ2 -596	AQ3 -416	AQB M	AQ6 -321	AQ7 -222	AQ8 M	AQ9 -26	AQ10 +60
58B115	36 44 52 N	076 35 14 W	CITY OF SUFFOLK	30	-980	D,E			
	CB1 --	CB2 31	CB3 57	CB8 M	CB6 48	CB7 29	CB8 M	CB9 29	
	AQ1 --	AQ2 -538	AQ3 -378	AQB M	AQ6 -306	AQ7 -219	AQ8 M	AQ9 -39	AQ10 +30
58C 7	36 48 38 N	076 37 09 W	CITY OF NORFOLK	40	-899	D,E,G			
	CB1 —	CB2 12	CB3 41	CB8 M	CB6 55	CB7 36	CB8 M	CB9 54	
	AQ1 —	AQ2 -493	AQ3 -357	AQB M	AQ6 -291	AQ7 -182	AQ8 M	AQ9 -46	AQ10 +40

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
58C 8	36 52 18 N	076 31 30 W	G. A. NIMMO	20	-558	E
58C 10	36 46 05 N	076 32 24 W	CITY OF SUFFOLK	25	-599	D,E,J
58C 51	36 49 04 N	076 33 05 W	CITY OF NORFOLK	5	-993	D,E
58D 6	36 59 39 N	076 33 30 W	RESCUE WATER COMPANY	20	-528	E
58D 9	36 57 27 N	076 31 39 W	VIRGINIA TIDEWATER PROPERTIES, INC.	15	-539	D,E
58E 2	37 00 31 N	076 36 12 W	V. H. MONETTE CO.	25	-475	E
58F 3	37 11 20 N	076 36 54 W	DOW BADISCHE, INC.	20	-1540	D,E,G,J
58F 48	37 13 49 N	076 32 57 W	YORK COUNTY PUBLIC WORKS	80	-100	D,E,J

Control Well Number	CB1	CB2	CB3	CBB	CB6	CB7	CB8	CB9
58C 8	--	>14	20	M	63	52	26	34
58C 10	--	20	48	M	26	50	12	30
58C 51	--	14	54	M	50	46	12	38
58D 6	--	14	16	M	52	46	25	42
58D 9	--	--	9	M	56	49	21	15
58E 2	--	>17	45	M	50	34	32	33
58F 3	46	10	30	M	56	77	49	30
58F 48	--	--	--	--	--	--	>48	20

Control Well Number	AQ1	AQ2	AQ3	AQB	AQ6	AQ7	AQ8	AQ9	AQ10
58C 8	--	--	-403	M	-364	-252	M	-40	+20
58C 10	--	-551	-389	M	-325	-249	M	-35	+20
58C 51	--	-533	-401	M	-334	-241	M	-49	+5
58D 6	--	-510	-361	M	-322	-191	M	-46	+20
58D 9	--	--	-384	M	-363	-233	M	-20	+15
58E 2	--	--	-358	M	-273	-193	M	-19	+25
58F 3	-1124	-498	-398	M	-348	-234	M	-42	+20
58F 48	--	--	--	--	--	--	--	+2	+80

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
58H 4	37 23 31 N	076 31 26 W	VASWCB	75	-1772 BSMT	D,E,G,J
58J 5	37 36 30 N	076 31 26 W	BARNHARDT FARMS	40	-702	D,E
58J 11	37 33 52 N	076 37 28 W	RAPPAHANOCK COMMUNITY COLLEGE	110	-590	D,E
58K 6	37 38 18 N	076 34 42 W	TOWN OF URBANNA	20	-630	D,E
58L 7	37 46 21 N	076 30 50 W	SYDNOR HYDRODYNAMICS, INC.	90	-607	D,E
58N 3	38 01 43 N	076 34 00 W	BELRUH OYSTER COMPANY	20	-300	D,E
58N 4	38 05 21 N	076 34 45 W	SANFORD CANNING COMPANY	15	-283	D,E
59C 2	36 48 08 N	076 23 15 W	VIRGINIA DIVISION OF FORESTRY	20	-633	E,G

Control Well Number									
58H 4	CB1 18	CB2 52	CB3 25	CBB 21	CB6 92	CB7 78	CB8 87	CB9 34	
	AQ1 -1179	AQ2 -755	AQ3 -667	AQB -600	AQ6 -539	AQ7 -323	AQ8 M	AQ9 -44	AQ10 +75
58J 5	CB1 —	CB2 —	CB3 34	CBB 11	CB6 86	CB7 60	CB8 73	CB9 24	
	AQ1 —	AQ2 —	AQ3 -584	AQB -466	AQ6 -446	AQ7 -230	AQ8 M	AQ9 0	AQ10 +40
58J 11	CB1 —	CB2 54	CB3 21	CBB 10	CB6 97	CB7 55	CB8 80	CB9 22	
	AQ1 —	AQ2 -590	AQ3 -462	AQB -384	AQ6 -350	AQ7 -174	AQ8 M	AQ9 +26	AQ10 +110
58K 6	CB1 --	CB2 >16	CB3 28	CBB 18	CB6 114	CB7 58	CB8 98	CB9 10	
	AQ1 --	AQ2 —	AQ3 -528	AQB -448	AQ6 -411	AQ7 -202	AQ8 M	AQ9 +10	AQ10 M
58L 7	CB1 --	CB2 —	CB3 --	CBB 16	CB6 136	CB7 80	CB8 88	CB9 14	
	AQ1 —	AQ2 --	AQ3 —	AQB -510	AQ6 -466	AQ7 -230	AQ8 M	AQ9 +10	AQ10 +90
58N 3	CB1 --	CB2 --	CB3 —	CB8 —	CB6 >44	CB7 98	CB8 88	CB9 M	
	AQ1 —	AQ2 --	AQ3 —	AQB --	AQ6 —	AQ7 -171	AQ8 M	AQ9 M	AQ10 +20
58N 4	CB1 —	CB2 —	CB3 —	CBB --	CB6 >32	CB7 105	CB8 80	CB9 M	
	AQ1 —	AQ2 —	AQ3 —	AQB --	AQ6 —	AQ7 -174	AQ8 M	AQ9 M	AQ10 +15
59C 2	CB1 —	CB2 —	CB3 30	CBB M	CB6 86	CB7 86	CB8 53	CB9 32	
	AQ1 --	AQ2 --	AQ3 -582	AQB M	AQ6 -532	AQ7 -366	AQ8 M	AQ9 -30	AQ10 +20

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used			
59C 13	36 52 18 N	076 27 47 W	TIDEWATER WATER COMPANY	15	-640	D,E,J			
	CB1 --	CB2 >13	CB3 29	CBB M	CB6 66	CB7 62	CB8 52	CB9 38	
	AQ1 --	AQ2 --	AQ3 -492	AQB M	AQ6 -404	AQ7 -314	AQ8 M	AQ9 -42	AQ10 +15
59C 28	36 47 02 N	076 24 55 W	CITY OF CHESAPEAKE	20	-980	D,E,J			
	CB1 --	CB2 30	CB3 43	CBB M	CB6 33	CB7 72	CB8 43	CB9 32	
	AQ1 --	AQ2 -685	AQ3 -517	AQB M	AQ6 -440	AQ7 -341	AQ8 M	AQ9 -67	AQ10 +20
59D 1	36 52 55 N	076 23 11 W	TIDEWATER WATER COMPANY	15	-573	D,E			
	CB1 --	CB2 --	CB3 13	CBB M	CB6 55	CB7 98	CB8 54	CB9 30	
	AQ1 --	AQ2 --	AQ3 -507	AQB M	AQ6 -475	AQ7 -363	AQ8 M	AQ9 -41	AQ10 +15
59D 20	36 58 40 N	076 25 50 W	CITY OF NEWPORT NEWS	20	-890	D,E			
	CB1 --	CB2 24	CB3 72	CBB M	CB6 53	CB7 95	CB8 51	CB9 30	
	AQ1 --	AQ2 -770	AQ3 -592	AQB M	AQ6 M	AQ7 -356	AQ8 M	AQ9 -40	AQ10 +20
59E 5	37 05 38 N	076 22 43 W	NASA RESEARCH CENTER	10	-2053 BSMT	D,E,J			
	CB1 78	CB2 34	CB3 26	CBB M	CB6 56	CB7 130	CB8 70	CB9 30	
	AQ1 -1364	AQ2 -858	AQ3 -696	AQB M	AQ6 M	AQ7 -440	AQ8 M	AQ9 -80	AQ10 +10
59J 6	37 32 01 N	076 26 12 W	BAPTIST GEN. ASSN. OF VIRGINIA	55	-795	D,E			
	CB1 --	CB2 >15	CB3 22	CBB 41	CB6 115	CB7 126	CB8 114	CB9 28	
	AQ1 --	AQ2 --	AQ3 -674	AQB -579	AQ6 -523	AQ7 -384	AQ8 M	AQ9 -40	AQ10 +55
59J 11	37 34 31 N	076 23 38 W	E. ANDERSON	25	-673	D,E			
	CB1 --	CB2 --	CB3 >18	CBB 34	CB6 102	CB7 164	CB8 103	CB9 27	
	AQ1 --	AQ2 --	AQ3 --	AQB -575	AQ6 -531	AQ7 -406	AQ8 M	AQ9 -47	AQ10 +25
59K 17	37 39 41 N	076 25 48 W	SYDNOR HYDRODYNAMICS, INC.	15	-655	D,E			
	CB1 --	CB2 --	CB3 >36	CBB 10	CB6 111	CB7 104	CB8 110	CB9 20	
	AQ1 --	AQ2 --	AQ3 --	AQB -539	AQ6 -512	AQ7 -295	AQ8 M	AQ9 -20	AQ10 +15

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used			
59K 18	37 40 36 N	076 26 14 W	TIDES INN RESORT	25	-720	D,E			
CB1 --	CB2 —	CB3 80	CBB 4	CB6 118	CB7 99	CB8 78	CB9 20		
AQ1 --	AQ2 —	AQ3 -664	AQB -526	AQ6 -504	AQ7 -283	AQ8 M	AQ9 0	AQ10 +25	
59K 19	37 42 12 N	076 23 09 W	TOWN OF KILMARNOCK	75	-707	D,E			
CB1 —	CB2 —	CB3 >12	CB8 16	CB6 99	CB7 128	CB8 114	CB9 36		
AQ1 --	AQ2 —	AQ3 —	AQB -588	AQ6 -539	AQ7 -313	AQ8 M	AQ9 -16	AQ10 +75	
59L 5	37 52 27 N	076 24 04 W	SYDNOR HYDRODYNAMICS, INC.	75	-475	D,E			
CB1 --	CB2 —	CB3 —	CBB --	CB6 >104	CB7 76	CB8 130	CB9 21		
AQ1 —	AQ2 —	AQ3 —	AQB --	AQ6 —	AQ7 -271	AQ8 M	AQ9 0	AQ10 +75	
60B 1	36 38 11 N	076 22 22 W	CANAL BANK MOTOR LODGE	15	-723	D,E			
CB1 —	CB2 --	CB3 92	CBB M	CB6 46	CB7 87	CB8 44	CB9 31		
AQ1 --	AQ2 —	AQ3 -717	AQB M	AQ6 -559	AQ7 -413	AQ8 M	AQ9 -71	AQ10 +15	
60B 2	36 41 49 N	076 20 19 W	J. LENSEY	15	-807	D,E			
CB1 --	CB2 --	CB3 80	CBB M	CB6 16	CB7 94	CB8 52	CB9 24		
AQ1 —	AQ2 --	AQ3 -687	AQB M	AQ6 -580	AQ7 -459	AQ8 M	AQ9 -87	AQ10 +15	
60B 3	36 38 36 N	076 20 17 W	VASWCB	15	-965	E,J			
CB1 --	CB2 56	CB3 76	CBB M	CB6 26	CB7 126	CB8 54	CB9 35		
AQ1 --	AQ2 -950	AQ3 -752	AQB M	AQ6 -601	AQ7 -470	AQ8 M	AQ9 -124	AQ10 +15	
60C 6	36 48 53 N	076 17 09 W	LONE STAR CEMENT CORPORATION	10	-790	D,E,G			
CB1 --	CB2 —	CB3 42	CBB M	CB6 86	CB7 112	CB8 100	CB9 29		
AQ1 --	AQ2 --	AQ3 -728	AQB M	AQ6 -670	AQ7 -482	AQ8 M	AQ9 -53	AQ10 +10	
60C 7	36 51 15 N	076 19 17 W	CITY OF PORTSMOUTH	10	-1444	D,E,G,J			
CB1 38	CB2 25	CB3 46	CBB M	CB6 95	CB7 95	CB8 65	CB9 27		
AQ1 -1306	AQ2 -875	AQ3 -646	AQB M	AQ6 -582	AQ7 -422	AQ8 M	AQ9 -61	AQ10 +10	

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
60C 25	36 51 31 N	076 18 29 W	CAMPBELL SOUP COMPANY	10	-890	D,E,J
60C 40	36 47 02 N	076 21 56 W	CITY OF CHESAPEAKE	20	-940	D,E,G,J
60E 8	37 00 43 N	076 22 03 W	DIXIE HOSPITAL	15	-383	D,E
60J 1	37 31 58 N	076 19 50 W	SYDNOR HYDRODYNAMICS, INC.	10	-782	D,E
60L 19	37 49 47 N	076 16 34 W	HAYNIE PRODUCTS, INC.	10	-799	D,E
61A 2	36 34 48 N	076 12 12 W	CITY OF CHESAPEAKE	10	-690	D,E,G
61B 2	36 42 27 N	076 07 47 W	VASWCB	20	-1180	E,J
61C 1	36 52 21 N	076 12 15 W	USGS	15	-2457	E,G,J

Well										
60C 25	CB1 —	CB2 >30	CB3 25	CBB M	CB6 94	CB7 105	CB8 70	CB9 25	
	AQ1 —	AQ2 —	AQ3 -648	AQB M	AQ6 -592	AQ7 -435	AQ8 M	AQ9 -44	AQ10 +10
60C 40	CB1 --	CB2 22	CB3 22	CBB M	CB6 80	CB7 92	CB8 42	CB9 16	
	AQ1 —	AQ2 -845	AQ3 -604	AQB M	AQ6 -564	AQ7 -376	AQ8 M	AQ9 -78	AQ10 +20
60E 8	CB1 —	CB2 —	CB3 —	CBB M	CB6 —	CB7 —	CB8 >168	CB9 25	
	AQ1 —	AQ2 —	AQ3 —	AQB M	AQ6 —	AQ7 —	AQ8 —	AQ9 -65	AQ10 +15
60J 1	CB1 --	CB2 —	CB3 21	CBB 25	CB6 136	CB7 170	CB8 118	CB9 38	
	AQ1 --	AQ2 --	AQ3 -707	AQB -615	AQ6 -580	AQ7 -422	AQ8 M	AQ9 -60	AQ10 +10
60L 19	CB1 —	CB2 —	CB3 >26	CBB 58	CB6 78	CB7 100	CB8 123	CB9 30	
	AQ1 —	AQ2 —	AQ3 —	AQB -658	AQ6 -574	AQ7 -356	AQ8 M	AQ9 -50	AQ10 +10
61A 2	CB1 --	CB2 —	CB3 —	CBB —	CB6 —	CB7 70	CB8 113	CB9 25	
	AQ1 --	AQ2 —	AQ3 —	AQB —	AQ6 —	AQ7 -536	AQ8 M	AQ9 -100	AQ10 +10
61B 2	CB1 --	CB2 --	CB3 65	CBB M	CB6 59	CB7 103	CB8 137	CB9 25	
	AQ1 —	AQ2 --	AQ3 -895	AQB M	AQ6 -778	AQ7 -603	AQ8 M	AQ9 -75	AQ10 +20
61C 1	CB1 60	CB2 35	CB3 25	CBB M	CB6 58	CB7 170	CB8 110	CB9 30	
	AQ1 -1580	AQ2 -1015	AQ3 -741	AQB M	AQ6 M	AQ7 -555	AQ8 M	AQ9 -75	AQ10 +15

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
61D 5	36 54 25 N	076 10 50 W	CITY OF VIRGINIA BEACH	25	-1593	E,G,J

CB1 —	CB2 55	CB3 27	CB8 M	CB6 57	CB7 190	CB8 132	CB9 46		
AQ1 —	AQ2 -1103	AQ3 -870	AQB M	AQ6 M	AQ7 -625	AQ8 M	AQ9 -75	AQ10 +25	

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
62C 2	36 47 15 N	076 03 08 W	VASWCB	20	-378	E,G,J

CB1 --	CB2 —	CB3 —	CB8 --	CB6 --	CB7 --	CB8 >120	CB9 52	
AQ1 --	AQ2 —	AQ3 --	AQB --	AQ6 —	AQ7 --	AQ8 —	AQ9 -92	AQ10 +20

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
62C 4	36 47 11 N	076 06 00 W	VASWCB	15	-385	E,G,J

CB1 --	CB2 --	CB3 —	CB8 --	CB6 —	CB7 —	CB8 >126	CB9 54	
AQ1 --	AQ2 --	AQ3 —	AQB --	AQ6 --	AQ7 —	AQ8 —	AQ9 -95	AQ10 +13

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
62C 5	36 45 04 N	076 03 13 W	VASWCB	20	-380	D,E,G

CB1 —	CB2 —	CB3 —	CB8 —	CB6 —	CB7 —	CB8 >92	CB9 40	
AQ1 --	AQ2 —	AQ3 —	AQB --	AQ6 —	AQ7 —	AQ8 —	AQ9 -88	AQ10 +20

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
62D 2	36 57 59 N	076 06 47 W	CHES. BAY BRIDGE TUNNEL AUTH.	3	-1502	D,J

CB1 —	CB2 --	CB3 —	CB8 --	CB6 --	CB7 --	CB8 --	CB9 --	
AQ1 —	AQ2 —	AQ3 --	AQB ---	AQ6 —	AQ7 --	AQ8 --	AQ9 —	AQ10 —

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
62G 9	37 15 39 N	076 01 14 W	BAYSHORE CONCRETE COMPANY	10	-213	D,E

CB1 --	CB2 --	CB3 --	CB8 —	CB6 --	CB7 --	CB8 —	CB9 51	
AQ1 —	AQ2 --	AQ3 —	AQB --	AQ6 —	AQ7 —	AQ8 —	AQ9 -84	AQ10 -10

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
63C 1	36 52 00 N	075 58 51 W	BUSH DEVELOPMENT CORPORATION	20	-1567	D,E,J

CB1 --	CB2 82	CB3 44	CB8 M	CB6 68	CB7 215	CB8 155	CB9 60	
AQ1 —	AQ2 -1404	AQ3 -1049	AQB M	AQ6 M	AQ7 -790	AQ8 M	AQ9 -174	AQ10 +20

Control Well Number	Latitude	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
63F 1	37 11 59 N	075 57 32 W	NORTHAMPTON SCHOOL BOARD	30	-461	D,E,G,J

CB1 --	CB2 —	CB3 —	CB8 —	CB6 --	CB7 --	CB8 >93	CB9 30	
AQ1 --	AQ2 —	AQ3 --	AQB --	AQ6 --	AQ7 --	AQ8 --	AQ9 -56	AQ10 +30

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
63G 19	37 20 22 N	075 56 12 W	USGS	35	-200	E,G,J
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 — CB9 55					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -75 AQ10 +35					
63L 1	37 49 48 N	075 59 47 W	TANGIER CRAB COMPANY	2	-991	G,J
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 — CB9 —					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 — AQ10 +2					
64H 3	37 28 30 N	075 51 55 W	NORTHAMPTON HOSPITAL	35	-315	D,E
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 >24 CB9 76					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -91 AQ10 +35					
64J 1	37 36 00 N	075 46 38 W	ACCOMACK SCHOOL BOARD	45	-405	D,E,J
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 >138 CB9 48					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -89 AQ10 +45					
64J 8	37 32 01 N	075 49 16 W	EXMORE FOODS, INC.	35	-245	D,E
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 — CB9 36					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -85 AQ10 +35					
65J 4	37 35 28 N	075 42 08 W	GULF STREAM NURSERY	10	-290	D,E
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 >7 CB9 58					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -78 AQ10 +10					
65K 8	37 44 03 N	075 39 37 W	PERDUE FOODS, INC.	50	-290	D,E
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 >37 CB9 56					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -74 AQ10 +50					
65K 17	37 42 33 N	075 44 29 W	TOWN OF ONANCOCK	15	-265	D,E
	CB1 — CB2 — CB3 — CB8 — CB6 — CB7 — CB8 — CB9 72					
	AQ1 — AQ2 — AQ3 — AQB — AQ6 — AQ7 — AQ8 — AQ9 -85 AQ10 +15					

Control Well Number	Latitude (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Owner	Altitude of Land Surface (feet)	Altitude of Bottom of Logged Hole (feet)	Types of Logs Used
65L 6	37 45 30 N	075 40 10 W	BYRD PACKING COMPANY	35	-251	D,E

CB1 -- CB2 -- CB3 -- CB8 -- CB6 -- CB7 -- CB8 -- CB9 74
AQ1 -- AQ2 -- AQ3 -- AQ8 -- AQ6 -- AQ7 -- AQ8 -- AQ9 -105 AQ10 +35

66M 1	37 53 03 N	075 31 01 W	J&J TAYLOR ENTERPRISES	40	-6279	E,G,J

CB1 173 CB2 115 CB3 126 CB8 60 CB6 172 CB7 372 CB8 250 CB9 70
AQ1 -3210 AQ2 -2108 AQ3 -1458 AQ8 -1286 AQ6 M AQ7 M AQ8 -588 AQ9 -106 AQ10 +40

66M 7	37 55 38 N	075 33 02 W	ATLANTIC HIGH SCHOOL	25	-425	D,E

CB1 -- CB2 -- CB3 -- CB8 -- CB6 -- CB7 -- CB8 >129 CB9 54
AQ1 -- AQ2 -- AQ3 -- AQ8 -- AQ6 -- AQ7 -- AQ8 -- AQ9 -91 AQ10 +25

66M 12	37 53 21 N	075 33 44 W	HOLLY FARMS, INC.	40	-290	D,E

CB1 -- CB2 -- CB3 -- CB8 -- CB6 -- CB7 -- CB8 -- CB9 60
AQ1 -- AQ2 -- AQ3 -- AQ8 -- AQ6 -- AQ7 -- AQ8 -- AQ9 -91 AQ10 +40

67L 2	37 52 20 N	075 26 54 W	NASA	10	-171	D,E

CB1 -- CB2 -- CB3 -- CB8 -- CB6 -- CB7 -- CB8 -- CB9 78
AQ1 -- AQ2 -- AQ3 -- AQ8 -- AQ6 -- AQ7 -- AQ8 -- AQ9 -120 AQ10 +10

68M 2	37 53 24 N	075 20 25 W	NATIONAL PARK SERVICE	10	-790	D,E

CB1 -- CB2 -- CB3 -- CB8 -- CB6 -- CB7 -- CB8 318 CB9 109
AQ1 -- AQ2 -- AQ3 -- AQ8 -- AQ6 -- AQ7 -- AQ8 -748 AQ9 -134 AQ10 +10