HYDROLOGY

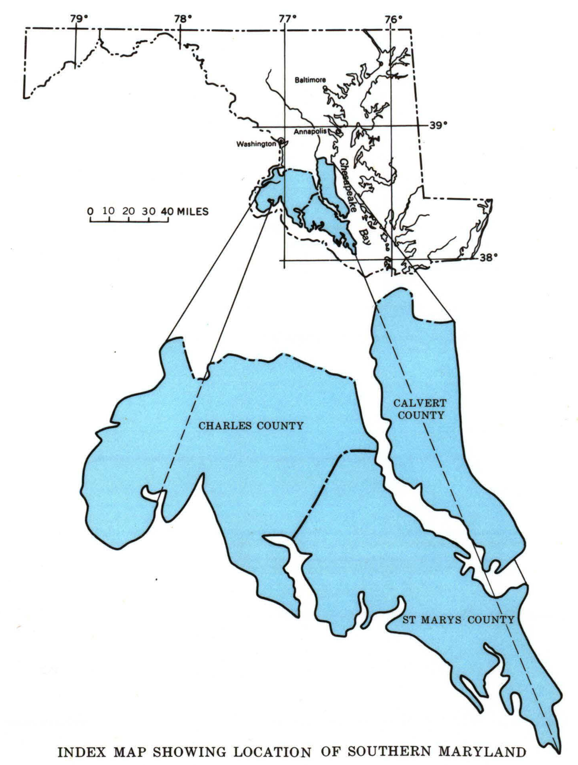
INTRODUCTION

This report summarizes the results of a water-resources investigation conducted in southern Maryland during 1966 and 1967 by the U.S. Geological Survey in cooperation with the Maryland Geological Survey. Southern Maryland as used in this report includes Calvert, Charles, and St. Marys Counties—the three-county area that lies between the Potomac River and Chesapeake Bay some 50 to 100 miles south of Baltimore (see index map).

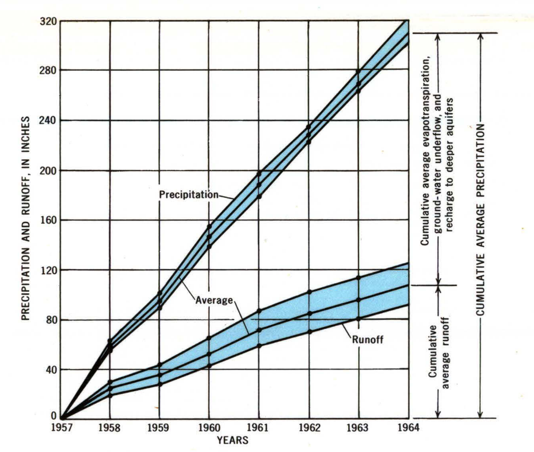
In view of the recent ground-water report on Charles County (Slaughter and Otton, 1968), the current report concentrates on conditions in Calvert and St. Marys Counties. This report and its future companion (Maryland Geological Survey Water Resources Basic Data Report No. 4), make the newly acquired information available to the public as a tool for planning the development and overall economy of southern Maryland.

Particular consideration is given the following questions concerning the hydrology of the area:

1. What is the relationship of ground water to surface water?
2. What significant changes in ground-water conditions have occurred in recent years?
3. How much water is available? That is, what yields are potentially obtainable from wells? What sustained yields are available? How much is available from streamflow?
4. What is the chemical quality of the water?
5. What is the likelihood of ground-water contamination by salt water from Chesapeake Bay or estuaries?



INDEX MAP SHOWING LOCATION OF SOUTHERN MARYLAND



GRAPH SHOWING QUANTITATIVE RELATION BETWEEN RUNOFF AND PRECIPITATION, SHOWN CUMULATIVELY FOR PERIOD 1958-64

WATER BUDGET

The water budget in the area is two-phased: (1) the first phase applies to the upper 50 feet or so of materials—mostly of Holocene, Pleistocene, and Miocene age—where ground water occurs under water-table conditions and is replenished locally by precipitation on interstream areas, and (2) the second phase applies to the underlying aquifers of Eocene or older age where the ground water occurs under artesian conditions and receives only part of its recharge locally. An undetermined part of the ground water leaks downward from the upper zone into the artesian system or vice versa; otherwise little direct relation exists between the two phases of the water budget.

The precipitation-runoff graph shows, in simplified form, the natural water budget. As a unit, the base period (1958–64) is fairly representative of normal precipitation and runoff conditions in southern Maryland. The runoff records apply to only about one-tenth of the total area, but based on consideration of drainage-basin distribution with respect to geology and topography they are presumed to be representative of the entire area.

Runoff (stream discharge) is all the water in a particular stream flowing past a given place of measurement in that stream. It is the total volume of water that reaches that place on the stream from anywhere in the corresponding drainage basin, by whatever means. It includes water that travels rapidly overland to the stream after rain falls, and rainfall and snowmelt that percolate downward through the ground to the saturated zone beneath the water table and thence move laterally underground to the streams. Runoff is expressed here in inches of water and is assumed to be distributed evenly over the entire drainage basin. That part of the precipitation that does not run off overland or underground into the streams is accounted for primarily by evapotranspiration, and to a lesser extent by unmeasured ground-water flow out of the basins and by recharge to deeper aquifers.

The relation can be expressed thus (assuming the net change in ground-water storage is zero):

$$P = R + (ET + L),$$

where P = average annual precipitation, in inches;

R = measured streamflow, expressed as annual runoff in inches per year per square mile of drainage area;

ET = average annual evapotranspiration, in inches; and

L = leakage downward into underlying artesian aquifers, in inches.

The average relationship for the period 1958–64 is:

$P = R + (ET + L)$

$44 = 15 + 29$ (inches)

or $100 = 35 + 65$ (percent)

The average annual precipitation was 44 inches, and the average runoff was about 15 inches; the difference—about 29 inches—was lost chiefly by evapotranspiration. An estimated 50 percent of the runoff (7½ inches) was ground-water recharge which eventually discharged to the streams.

Comparable percentages were obtained for Charles County (Slaughter and Otton, 1968), the Patuxent River basin (Crooks and others, 1967), and for the Beaverdam Creek basin in Wicomico County, Md. (Rasmussen and Andreasen, 1959).

The water budget for the artesian aquifers is quite another matter. Some of the recharge to these aquifers is from precipitation in western Charles County and from areas north and west of the study area, and some is water that percolates downward very slowly through intervening beds many of which have low permeability. Total annual recharge to the artesian aquifers is estimated to be less than 1 inch. Except in western and northern Charles County and northern Calvert County, where the Nanjemoy and Aquia units are shallow and readily breached by streams, the artesian aquifers contribute only a minor part of the streamflow. Consequently, a precipitation-runoff graph for the artesian aquifers would show the same average precipitation curve, but the runoff curve would be very much flatter than that shown for the general southern Maryland water budget.

GEOHYDROLOGIC SETTING

Southern Maryland is underlain by a southeastward-thickening wedge of unconsolidated sediments (see block diagram). The old erosional surface at the top of the crystalline rocks slopes generally southeastward from the Fall Line and the overlying sediments correspondingly increase in thickness from approximately 750 feet in the northwestern part of the area to about 3,400 feet (estimated) at the southeastern end of St. Marys County. The individual geologic formations that comprise the sediments crop out at the land surface or subcrop under a relatively thin mantle of sand, gravel, and finer materials—in the northern and western parts of the area, and occur at successively greater depths toward the southeast.

The age, lithology, depth, and water-bearing characteristics of the formations summarized in the table are described in detail by Overbeck (1951), Ferguson (1953), Otton (1955), and Slaughter and Otton (1968). In this report attention is focused on the Piney Point, Nanjemoy, and Aquia Formations. The Nanjemoy and Aquia Formations crop out at land surface or subcrop at shallow depths north and west of the study area and slope generally southeastward. The Piney Point Formation does not crop out; it occurs at the top of the Nanjemoy Formation, in the southeastern part of the area.

Although ground water occurs in all the geologic formations in southern Maryland, it can be withdrawn in significant quantities only where the materials in the formations are permeable enough to permit ground water to move fairly freely. Such materials are termed "water-bearing" and are referred to as "aquifers". By contrast, some geologic units are made up predominantly of silt or clay, and are relatively impermeable. These units, because they retard the movement of ground water, are termed "aquitards". In southern Maryland, the crystalline rocks generally are not aquifers. The overlying sediments are interbedded aquifers and aquitards.

Ground water occurs under both unconfined (water-table) and confined (artesian) conditions. A shallow water-table aquifer consisting of parts of several geologic units underlies the land surface throughout the area. This aquifer in turn is underlain by the deeper system of artesian aquifers.

GEOLOGIC UNITS IN SOUTHERN MARYLAND AND THEIR GEOHYDROLOGIC CHARACTERISTICS.

System	Series	Group	Geologic unit	Average thickness (feet)	Occurrence and extent	Physical character	Water-bearing characteristics and hydrology
QUATERNARY	Holocene and Pleistocene		Lowland deposits	0-140	Underlies near-shore terraces below 50± feet above sea level. Extends below sea level and beneath estuaries; deepest along southern shore of St. Marys and Charles Counties.	Tan to orange stratified clay, silt, medium to coarse sand, and gravel.	Yields limited quantities of water to large-diameter wells. Potential for larger yields, especially along southern shores of St. Marys and Charles Counties, probably accompanied by local susceptibility to resultant contamination by sea water.
QUATERNARY AND TERTIARY(?)	Pleistocene and Pliocene(?)		Upland deposits	0-50	Underlies dissected southeastward-sloping upland surfaces, above 50± feet; and below 200± feet above sea level. Little remains in southern Calvert County.	Tan to orange clay, silt, and sand mixture in upper loam member, and sand and gravel in lower gravel member.	Bottom few feet saturated. Yield moderate amounts of water to large-diameter wells. Primary source of water for shallow domestic and farm wells. Absorb precipitation and release it slowly to underlying deposits. Commonly, streams have cut downward through the deposits permitting the deposits to drain rapidly.
TERTIARY	Miocene	Chesapeake	St. Marys Formation	0-50	Underlies southern one-third of Calvert County and half of St. Marys County. Thickens southeastward.	Greenish-blue to yellowish-gray fossiliferous clay, sand, and sandy clay.	Yields limited supplies of water to wells. Functions generally as an aquitard.
			Choptank Formation	0-100	Underlies most of Calvert and St. Marys Counties. Thickens southeastward.	Interbedded brown to yellow clayey silt and fine to very fine sand. Fossiliferous and indurated layers.	Yields small amounts of water to wells. Functions generally as an aquitard.
			Calvert Formation	0-150	Underlies most of southern Maryland, except extreme western Charles County. Thickens southeastward.	Greenish, bluish, and gray fossiliferous, diatomitic sandy clay and fine sand. 10-20 feet of sand at base locally.	Yields small quantities of water to large-diameter wells. Basal sand yields some water. Functions generally as an aquitard.
	Eocene		Piney Point Formation	10-60	Underlies southern one-third of Calvert County and four-fifths of St. Marys County. Thickens southeastward.	Gray to brownish-yellow slightly glauconitic medium to coarse sand; interbedded layers of shell and sand, locally indurated.	A principal source of water in southern Calvert County and eastern and southern St. Marys County. Yields reported up to 200 gpm from wells. Vertical variations in permeability due to presence of interbeds of cemented shell. Is hydraulically connected with the underlying Nanjemoy Formation.
		Pamunkey	Nanjemoy Formation	175-250	Underlies southern Maryland except extreme western Charles County. Thickens eastward to about 250 feet under central Calvert County.	Dark-green to gray fine to medium glauconitic sand; layers of shell fragments, silt and clay. Marlboro Clay Member at base (20± feet thick) is pink, red, or gray plastic clay.	A principal source of water in Calvert and St. Marys Counties. Yields reported in excess of 60 gpm from wells. Permeability in western half of report area. Vertical variation in permeability low is considerable. Transmissibility increases eastward. Aquifer part of unit not restricted to one vertical position in unit. Hydraulically connected with overlying Piney Point Formation.
	Paleocene		Aquia Formation	100-170	Crops out in northwestern Charles County and dips southeastward under most of area.	Greenish to yellow-brown well-sorted glauconitic sand with locally-indurated shell beds. Interbedded very fine sand, silt, and clay in Charles County.	A principal source of water in Calvert and St. Marys Counties and southeastern Charles County. Yields reported as great as 300 gpm from wells. Permeability increases eastward and southeastward and transmissibility increases southeastward.
			Brightseat Formation	20-40	Extent not known.	Gray to dark-gray micaceous, silty, sandy clay.	Not known to supply water to wells in southern Maryland. Functions generally as an aquitard.
CRETACEOUS	Upper Cretaceous		Monmouth and Matawan Formations	20-60	Extent not known. Thicken northeastward.	Gray to gray-black glauconitic micaceous silt, clay, and fine sand.	Yield modest supplies locally from lenticular sand beds. Probably function generally as aquitards.
			Magothy Formation	0-100	Underlies Calvert County (at least as far south as Prince Frederick); parts of eastern Charles County; and northern St. Marys County. Thickens northward.	Light-gray to white "loose" sand and fine gravel, containing interbedded lignitic, pyritic, and clay layers.	Potentially economically important source of water where it occurs in southern Maryland, but not utilized there yet. Yields of several hundred gpm probably available. Aquifer thickens northward from Prince Frederick. Transmissibility increases northward.
			Raritan[1] Formation	100?	Probably underlies entire area.	Variegated gray, brown, red, and yellow clay and silt, containing interbedded lenses (?) of sand.	Moderate yields to wells in south-central Charles County. Not explored in Calvert and St. Marys Counties.
	Lower Cretaceous	Potomac	Patapsco Formation	(100-600)?	Probably underlies entire area and thickens southeastward.	Tan, brown, red, and yellow variegated fine sand, silt, and clay containing interbedded coarser sand.	Principal water-bearing formation in western half of Charles County. Wells commonly screened in more than one sand layer. Formation not tested elsewhere in southern Maryland.
			Arundel Clay	(100-200)?	Probably underlies entire area.	Red, brown, and gray clay, locally lignitic and sideritic.	Not generally a water-bearing formation.
			Patuxent Formation	(100-500)?	Probably underlies entire area.	Chiefly gray, yellow, and brown sand and interbedded silt and clay.	One of principal aquifers in western Charles County. Untested elsewhere in southern Maryland, but potentially important throughout area.
PRECAMBRIAN			Crystalline rocks		Underlies entire area. Top slopes southeastward from about 700 feet below sea level near northwest corner of Charles County to about 3,400 feet below sea level near southern tip of St. Marys County.	Untested. Probably gneiss and schist.	Not explored. Not considered a water source in southern Maryland.

[1] The Maryland Geological Survey considers the Raritan Formation to be in the Potomac Group.

AQUIFERS

The three aquifers of outstanding economic importance in Calvert and St. Marys Counties are the permeable, water-bearing parts of the Piney Point, Nanjemoy, and Aquia Formations. The Piney Point and Nanjemoy aquifers act hydraulically as a single unit. For purposes of discussion here they are referred to as the *Piney Point-Nanjemoy hydrologic unit,* and the Aquia Formation as the *Aquia hydrologic unit.*

The permeable, productive part of the Magothy Formation is a potentially important aquifer in at least the northern half of Calvert County but as yet is exploited little.

The Raritan, Patapsco, and Patuxent units (see table) occur at greater depths in Calvert and St. Marys Counties, but their extent and productivity there are not known. The Patuxent and Patapsco Formations are the principal water-producing units in Charles County (Slaughter and Otton, 1968).

In all these aquifers, water occurs predominantly under artesian conditions, but under water-table conditions in areas where the aquifers crop out.

The Nanjemoy aquifer (the productive part of the Nanjemoy Formation) is generally thicker, less permeable, and less sharply defined than the Aquia and Piney Point aquifers. It is concentrated in the upper part of the formation, and its approximate thickness in eastern Calvert and St. Marys Counties generally ranges from 40 to 80 feet.

The Piney Point aquifer averages from 20 to 30 feet in thickness where it occurs in southern Maryland. It is thinner and generally more permeable than the Nanjemoy aquifer, and is rather sharply defined. The Piney Point aquifer and underlying Nanjemoy aquifer comprise a hydraulically interconnected unit whose permeability, aggregate thickness, and transmissibility increase eastward.

The Aquia aquifer (the important water-bearing part of the Aquia Formation) is about 40 feet thick in southern Maryland and is sharply defined. It is concentrated in the upper part of the Aquia Formation. The constituent sand is coarser, cleaner, and more permeable toward the southeast, and becomes fine and includes an increasing proportion of clay or silt toward the northwest. The increasing permeability southeastward is reflected by greater well yields and transmissibilities in that direction. The northwestward decrease in permeability is gradual; no sharp boundary limits the extent of the aquifer in that direction.

Ground-water recharge.—Ground water is replenished directly or indirectly from precipitation. Recharge to the shallow water-table aquifers in southern Maryland is by direct downward percolation of rainfall or snowmelt into the aquifer. Recharge to the artesian aquifers occurs in their outcrop areas by direct downward percolation into the aquifers or from overlying shallow permeable materials; elsewhere it occurs by movement of water from adjacent formations.

The Nanjemoy Formation receives most of its recharge not in the outcrop area but to the south in Calvert and St. Marys Counties by water moving from adjacent units or percolating slowly downward from the land surface. The Piney Point Formation, which does not crop out or subcrop near land surface, presumably is recharged almost entirely by water from adjacent units.

Potential recharge by streams traversing the outcrop areas generally is rejected, because the water-bearing strata are full. However, increased ground-water withdrawals may lower water levels sufficiently to induce stream loss to these strata where they are incised by the streams.

Ground-water movement and discharge.—Movement of ground water in southern Maryland is slow and generally to the south, southeast, and east.

In the Aquia hydrologic unit water moves southeastward from the outcrop area, and probably under Chesapeake Bay and the Potomac River (see map showing ground-water movement and discharge areas—Aquia hydrologic unit). Locally, the flow is deflected toward centers of ground-water withdrawal at Lexington Park, Leonardtown, the northern coast of Calvert County, and elsewhere. In southeastern Charles County flow in the Aquia hydrologic unit is deflected to the south and southwest, probably around a permeability barrier in the Aquia west of La Plata, and perhaps in response to discharge upward through permeable materials underlying the Potomac River or to discharge or withdrawals across in the river in Virginia. West of La Plata the Aquia is a poor aquifer (Slaughter and Otton, 1968), suggesting locally low permeability.

Water in the Piney Point-Nanjemoy hydrologic unit flows generally southeastward in Calvert and St. Marys Counties and under parts of Chesapeake Bay and the Potomac River (see map showing ground-water movement and discharge areas—Piney Point–Nanjemoy hydrologic unit). Flow is deflected toward a center of withdrawal near Lexington Park. It is also deflected toward the Patuxent River and the east coast of Calvert County, to replace water discharging from flowing wells on the beach or submerged offshore and to replace water discharging upward through overlying materials into the Patuxent River and Chesapeake Bay. In eastern Charles County, southern Prince Georges County, and western St. Marys County water in the Nanjemoy Formation moves southeastward very slowly owing to poor permeability there.

Vertical movement of ground water between water-bearing units occurs to some extent in southern Maryland. Permeable materials in the upland deposits, for example, release water downward into underlying formations. Water is free to move upward or downward between the Piney Point unit and the underlying Nanjemoy unit. Quality-of-water and well-drilling data suggest that water may be free to move vertically between the Aquia and Piney Point-Nanjemoy hydrologic units in extreme southern St. Marys County.

Elsewhere vertical movement is restricted by the relative impermeability of intervening beds. In the Lexington Park and Leonardtown areas large-scale withdrawals of water from the Aquia Formation have increased the head differences between piezometric surfaces to about 20 feet under areas several square miles in extent. The leakage induced into the Aquia from the Piney Point-Nanjemoy or other water-bearing units in these areas may be significantly large.

PIEZOMETRIC SURFACES

The Piney Point-Nanjemoy piezometric surface slopes generally southeastward (see piezometric map for Piney Point-Nanjemoy hydrologic unit). Its shape is complicated by several features, the more prominent of which are the ridge in Calvert County and corresponding trough along the Patuxent River valley, and the cone of depression centered near Lexington Park. The configuration of the piezometric surface suggests that ground water is being discharged from the Piney Point-Nanjemoy hydrologic unit into overlying units along much of the Patuxent River, under Breton Bay at Leonardtown, and under Chesapeake Bay along the northern coast of Calvert County. The Lexington Park cone, although shallower than in 1951, includes two centers on opposite sides of the Patuxent River, and by 1966–67 had expanded southward toward the Potomac River or had incorporated the drawdown effect of other withdrawals there.

The Aquia piezometric surface slopes southeastward regionally, but its shape in St. Marys County almost defies generalization (see piezometric map for Aquia hydrologic unit). The large cone of depression at Lexington Park in 1966–67 coincides essentially with the cone in the 1951 piezometric surface, except in one respect: the cone now extends slightly to the northwest up the valley of the Patuxent River, due perhaps to growth of the cone or to the incorporation of other drawdown effects in that area. The main cause of the cone is, as in 1951, continued large-scale withdrawal of ground water from the Aquia unit at Patuxent Naval Air Station near Lexington Park.

The small, well-defined cone of depression centered at Leonardtown is caused by ground-water withdrawals for the public supply. It is larger and about 20 feet deeper than in 1951. The smaller cone centered over the Patuxent River west of Prince Frederick is associated with withdrawals in that area and probably with several free-flowing wells near the river.

Changes from 1951 to 1966–67.—In general the patterns of change are consistent with the local history of water use and precipitation. Some of the changes may be illusory, arising from differences in interpretation of the data, but most of the changes are believed to be real. Individual changes from 0 to ±10 feet may have little meaning, but even these small changes probably are significant where they are consistent within large areas.

To some extent the area of net decline in the Piney Point-Nanjemoy piezometric surface in northern Calvert County reflects widespread increased withdrawal, chiefly for domestic and institutional purposes. In larger part, however, the decline may be the result of the drought near the end of the 15-year period, inasmuch as the Piney Point-Nanjemoy hydrologic unit is shallow there and correspondingly sensitive to fluctuations in precipitation. Within the negative-change area is a northeasterly oriented stream-centered embayment of "no change", where the 1966–67 piezometric map indicates areas of depression. The configuration of the piezometric surface suggests that the Piney Point-Nanjemoy hydrologic unit discharges ground water locally to the stream or its valley, and the "no-change" embayment further suggests that the piezometric surface there is sufficiently depressed normally that it was unaffected by the general decline.

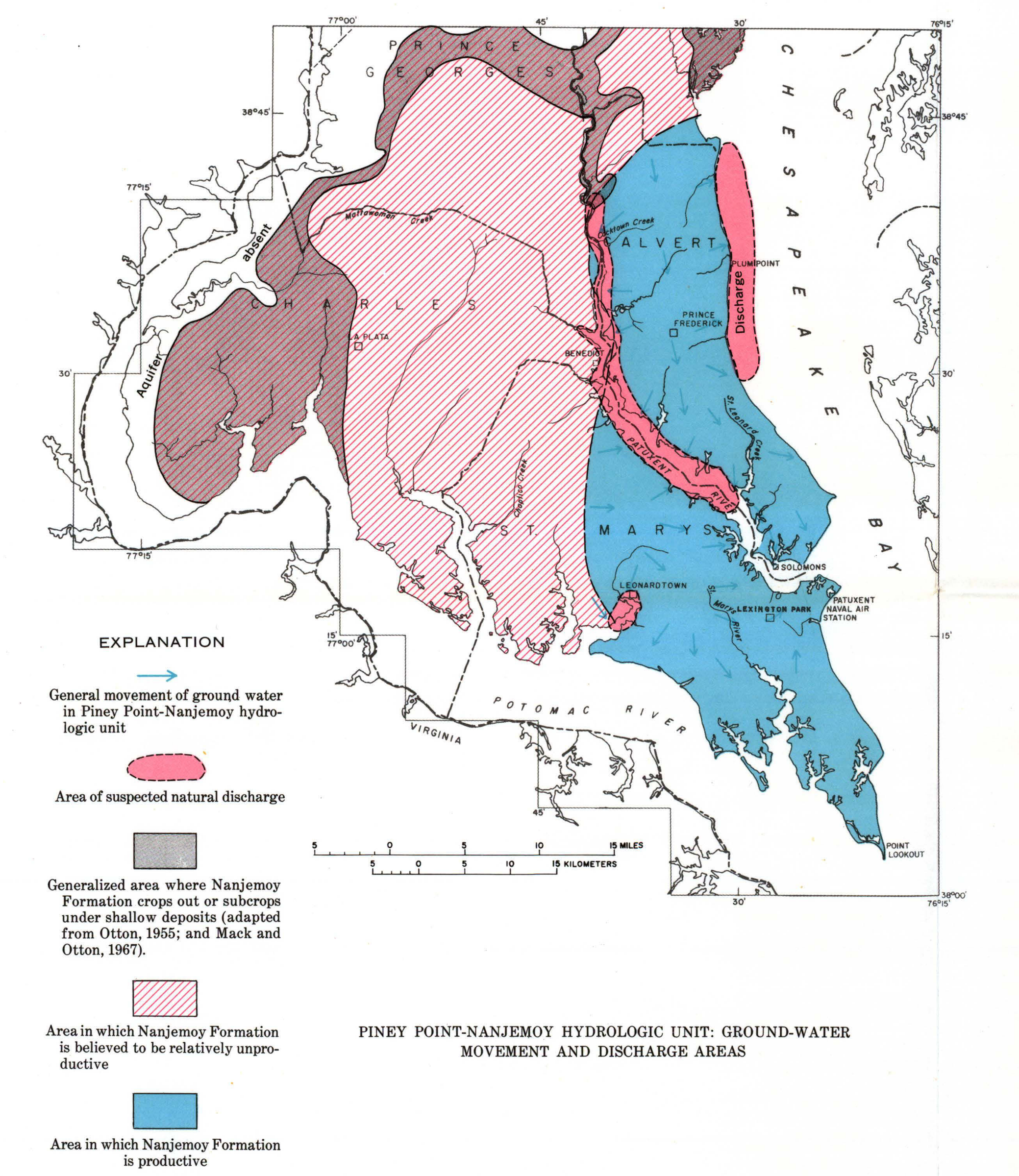
The net rise in the Piney Point-Nanjemoy piezometric surface near Lexington Park is associated with a post-World War II decrease in ground-water withdrawal from the Piney Point and Nanjemoy Formations at the Patuxent Naval Air Station. The net change of minus 10 feet in the concentric band several miles to the northwest and south is due in part to withdrawal from an increased number of domestic, small-scale public-supply, and commercial wells. However, it may be primarily a drawdown wave traveling outward in response to the large-scale ground-water withdrawals at the Naval Air Station during the several years immediately before 1951, and moving at an average but decreasing rate of 800 to 1,200 feet per year for the 15-year period. If the band represents a real wave more or less symmetrical east and west of the original center of propagation, its front may now be in the vicinity of the eastern shore of Chesapeake Bay. Decisive evidence as to the validity of this concept perhaps would require several years' record at a few observation wells near the leading and trailing edges of the "wave".

The well-defined area of negative change in the Aquia piezometric surface near Leonardtown owes its existence to continued withdrawal of ground water there for the public supply, at an estimated average rate of about 0.16 mgd. The negative change since 1951 implies that the water comes chiefly from storage and that annual ground-water underflow plays an unimportant role there. If the present rate of withdrawal is maintained, the cone of depression at Leonardtown probably will continue to expand and deepen, but at a decreasing rate.

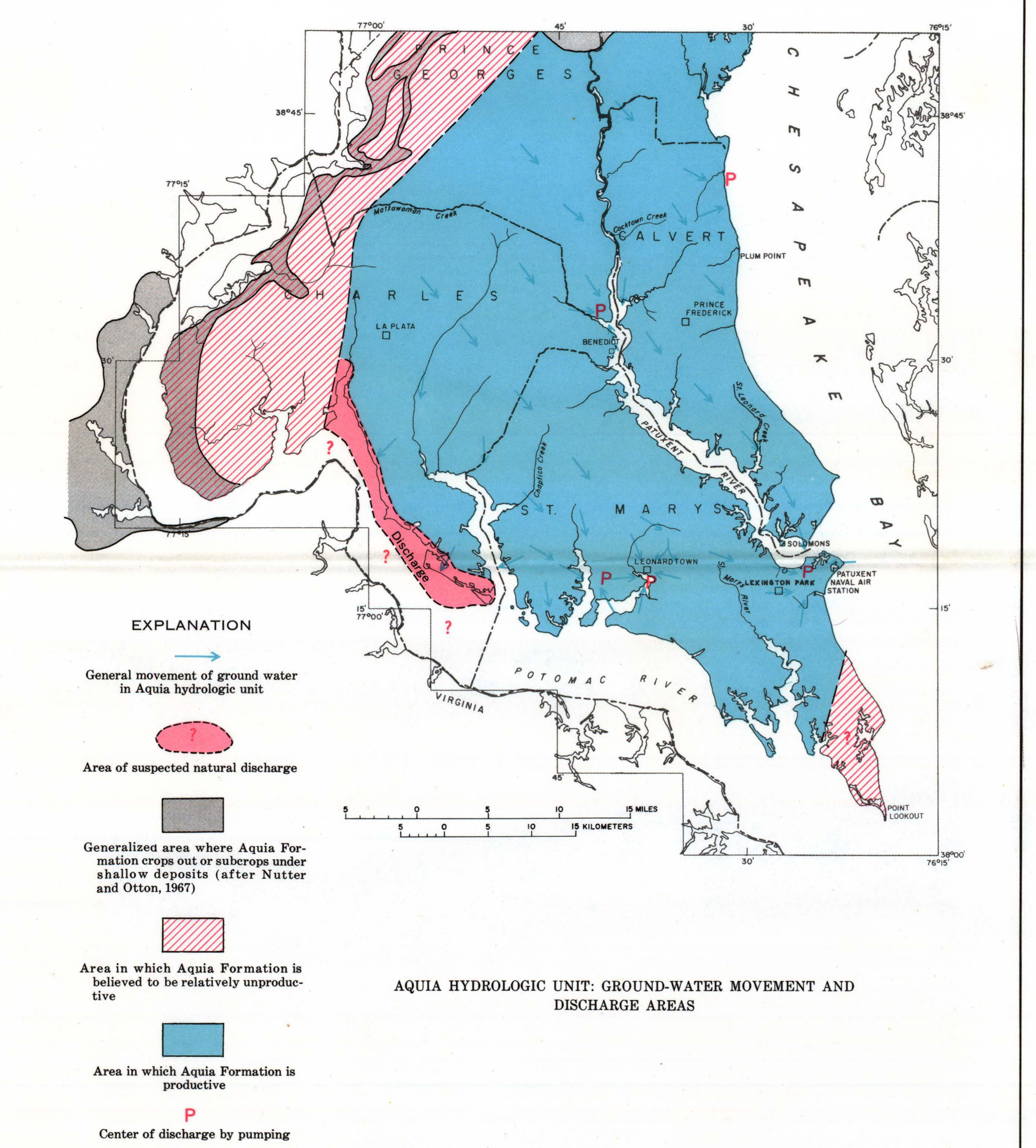
The area of negative change in the lower Patuxent Valley is believed to be at least in part a northwestward growth of the cone of depression centered near Lexington Park. Because large-scale withdrawals of water from the Aquia unit have continued since 1951 it would be expected that the cone of depression would have expanded in all sectors. In general it did not, suggesting the withdrawal is not from storage alone but may be supplied in large part by vertical leakage from above or below the Aquia unit.

The extensive area of negative change centered in northern Calvert County may be slightly illusory but in part is due to widespread increased withdrawal of ground water from domestic, commercial, and public-supply wells, especially in the vicinity of the junction of the four counties. Also, it may be due in part to the contributory drawdown effects of free-flowing old wells along the shores of the Patuxent River in Charles County and northward.

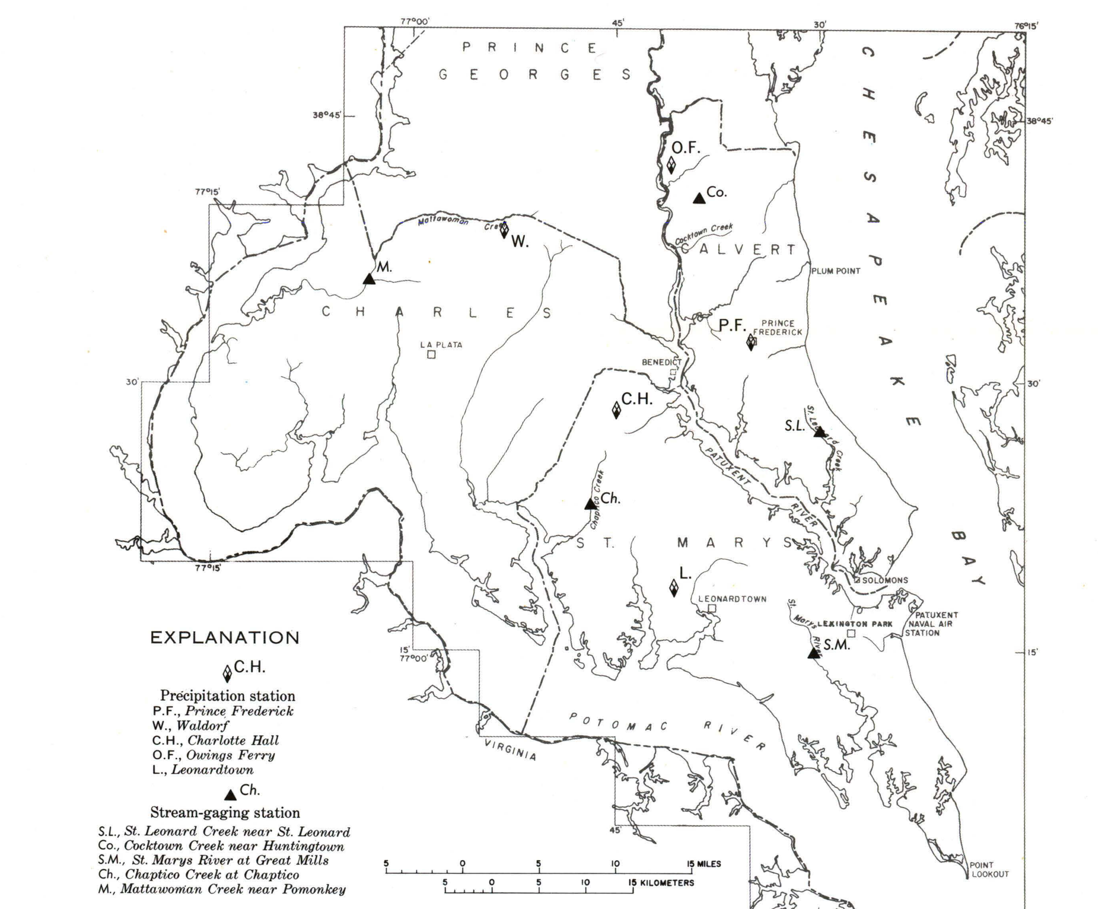
It is believed that the ridge-shaped area of positive change in St. Marys County is illusory, associated with interpretation of more data available for 1966–67 than for 1951.



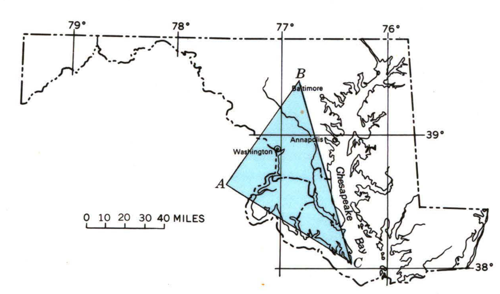
PINEY POINT-NANJEMOY HYDROLOGIC UNIT: GROUND-WATER MOVEMENT AND DISCHARGE AREAS

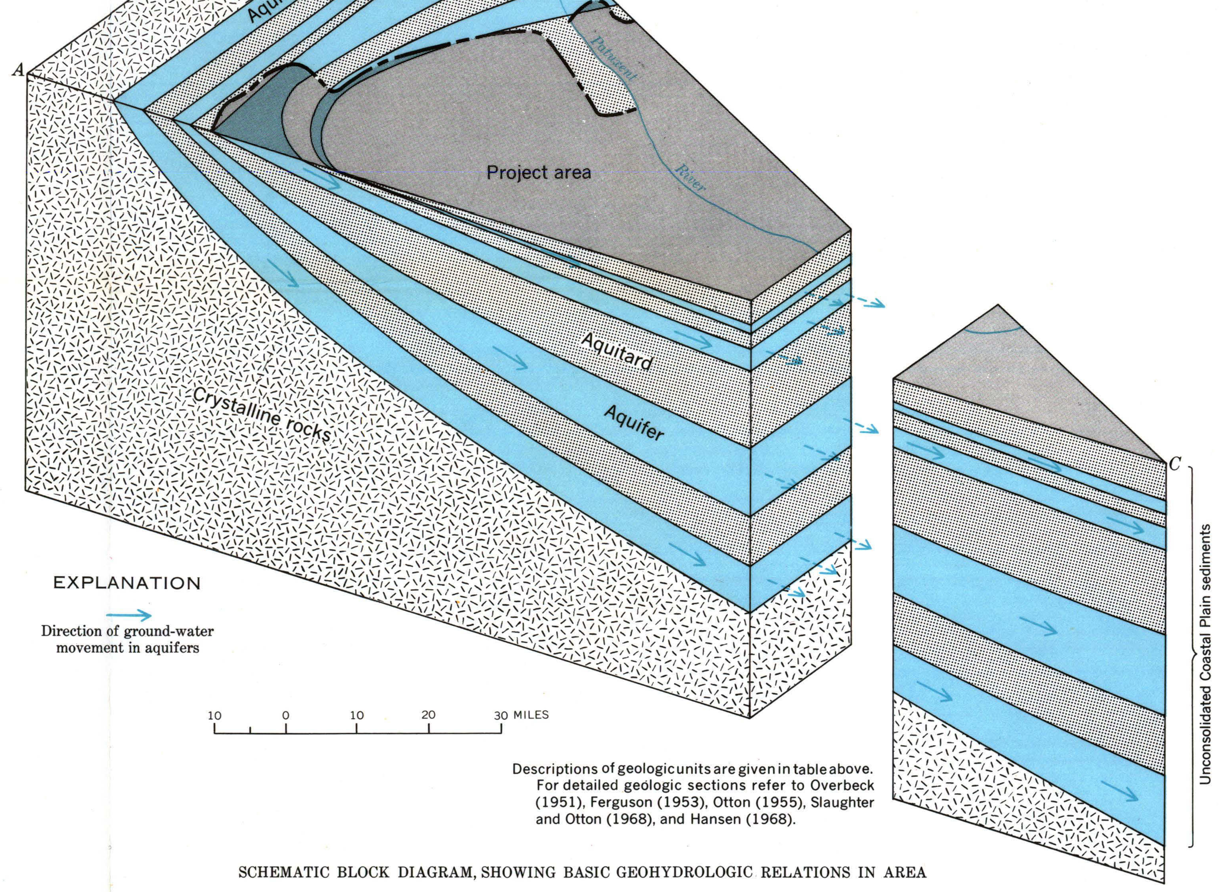


AQUIA HYDROLOGIC UNIT: GROUND-WATER MOVEMENT AND DISCHARGE AREAS



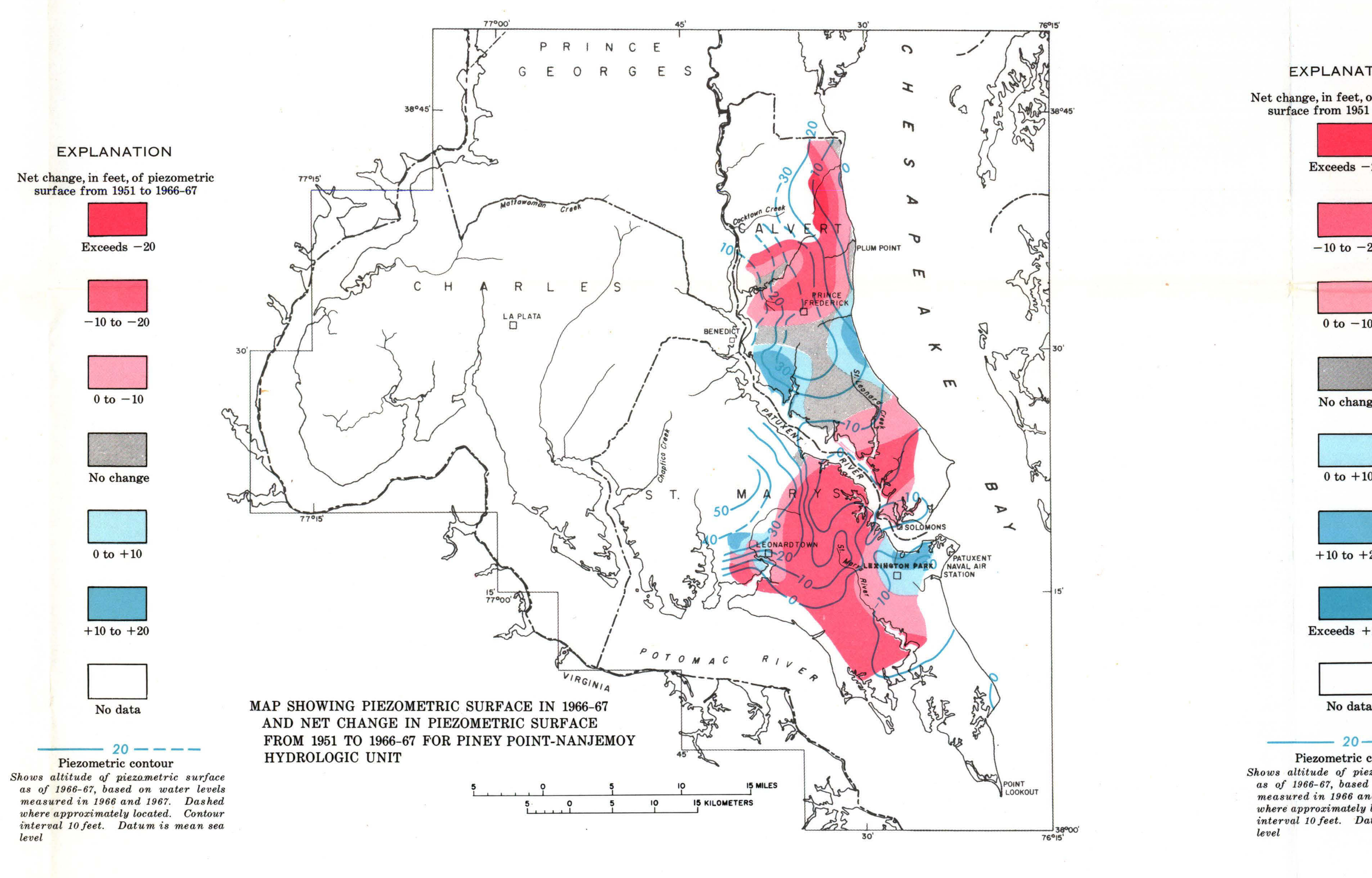
MAP SHOWING LOCATION OF COLLECTION SITES FOR DATA USED IN PRECIPITATION-RUNOFF GRAPH



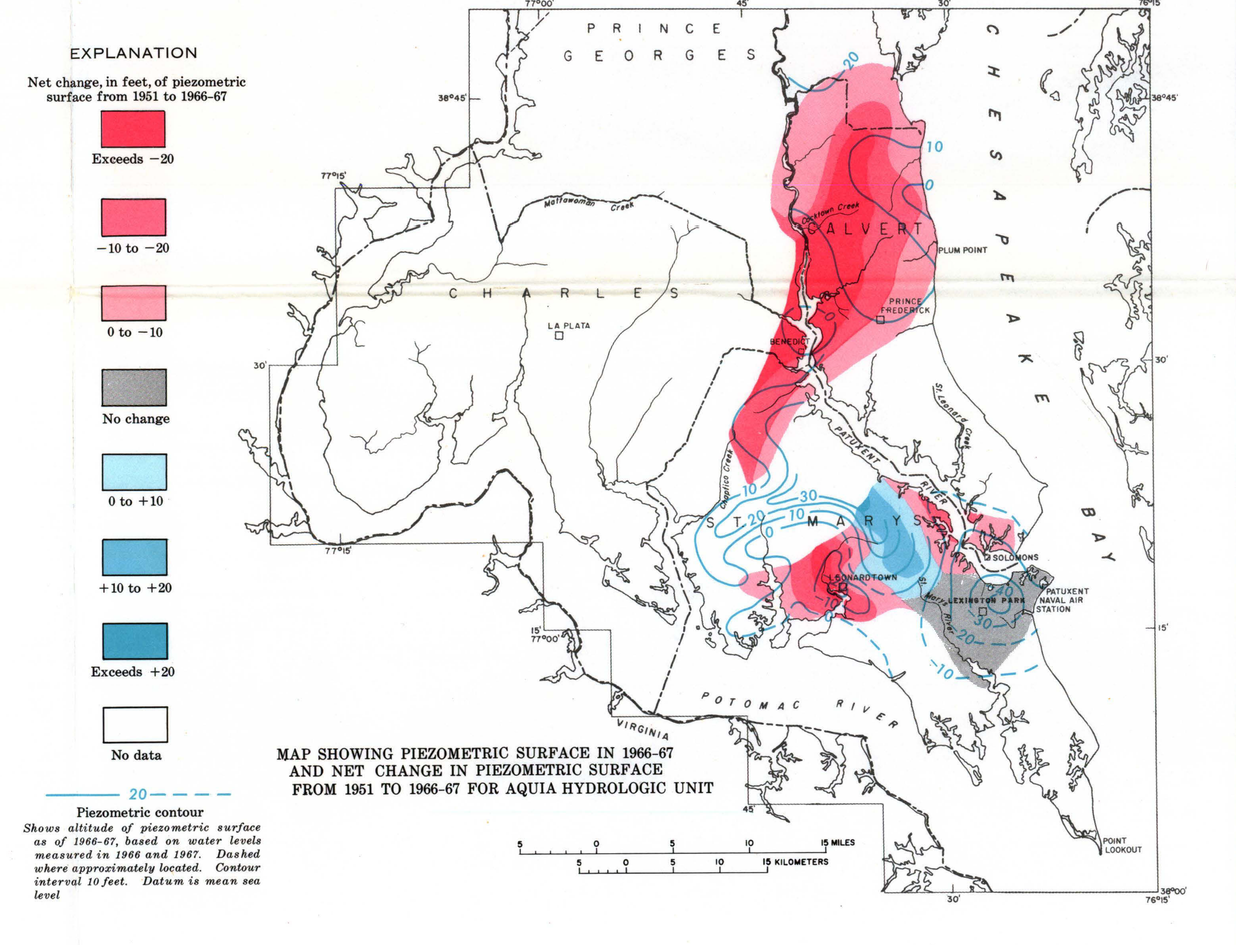


Descriptions of geologic units are given in table above. For detailed geologic sections refer to Overbeck (1951), Ferguson (1953), Otton (1955), Slaughter and Otton (1968), and Hansen (1968).

SCHEMATIC BLOCK DIAGRAM, SHOWING BASIC GEOHYDROLOGIC RELATIONS IN AREA



MAP SHOWING PIEZOMETRIC SURFACE IN 1966-67 AND NET CHANGE IN PIEZOMETRIC SURFACE FROM 1951 TO 1966-67 FOR PINEY POINT-NANJEMOY HYDROLOGIC UNIT



MAP SHOWING PIEZOMETRIC SURFACE IN 1966-67 AND NET CHANGE IN PIEZOMETRIC SURFACE FROM 1951 TO 1966-67 FOR AQUIA HYDROLOGIC UNIT

WATER RESOURCES OF SOUTHERN MARYLAND

By
James M. Weigle, Wayne E. Webb, and Richard A. Gardner
1970

For sale by U.S. Geological Survey, price $1.75 per set