A. Air photo of the Bowie-Belair area in 1957 while it was still an agricultural area.

B. Air photo of the Bowie-Belair area in 1962 showing the new housing development about half completed.

Photos showing how the City of Bowie-Belair has changed from rural to urban during the period 1957 to 1962.

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GROUND WATER IN PRINCE GEORGES COUNTY

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ABSTRACT

This report is an appraisal of ground-water resources in a rapidly developing area of the Maryland Coastal Plain. It has been prepared to guide County and State planners in effectively supplying the water requirements of new industries, commercial establishments, and public water systems.

Bounded on the west by Washington, D. C., Fairfax County, Virginia, and Montgomery County, Maryland; on the east and north by the Patuxent River; and on the south by Charles County; Prince Georges County includes an area of 486 square miles of land. It is situated on a part of the Atlantic Coastal Plain adjacent to the Piedmont province. Altitudes of the land surface range from 0 to about 420 feet. About 75 per cent of the County lies between 100 and 200 feet above sea level and only about 1 per cent (5 square miles) is more than 300 feet above sea level. The climate is humid and temperate with a mean annual temperature of 55°F and an average annual precipitation of about 45 inches.

The County is underlain by a wedge-shaped mass of unconsolidated Coastal Plain sediments of Cretaceous, Tertiary, and Quaternary age which overlie much older crystalline rocks. The wedge of sediments is less than a foot thick in the northwestern part of the area but thickens to 2,500 to 3,000 feet in the southeastern part. The four major artesian aquifers—the Patuxent, Patapsco, Magothy, and Aquia Formations—dip gently toward the southeast.

An average of 44 mgd (million gallons per day) of water was used in the County in 1963. About 25 per cent of that quantity was from ground-water sources within the County and 75 per cent was from surface-water sources of the Washington Suburban Sanitary Commission—mainly the Patuxent River but including some water from the Potomac River. Ground water is used mainly to supply the many scattered rural homes but does supply a few public water systems.

Artesian aquifers of Prince Georges County function both as reservoirs capable of storing large quantities of water and as conduits capable of transmitting water from recharge areas. Quantities of water stored in the aquifers are adequate to supply water far into the future at the current rate of usage. Aquifer characteristics indicate that under optimum conditions, as much as

50 mgd of additional water may be available on a continuing basis through recharge from the outcrop areas. Shallow aquifers will undoubtedly receive an additional large increment of recharge water by infiltration of precipitation through the surface deposits.

A systematic appraisal of the ground water available from each of four localities in the County shows that the details of ground-water conditions vary from place to place. The thinness of the unconsolidated sediments in the northwestern part limits the amount of drawdown available and thus the amount of water available from individual wells. Geologic conditions will permit the withdrawal of large quantities of water from some aquifers in the eastern part of the County. Waterbearing properties of the major geologic formations, which seem to be most favorable in the northeastern part of the County, become progressively less favorable toward the southwestern part.

Piezometric maps show that the main area of recharge for most of the artesian aquifers is in the northwestern part of the County. The maps show that large cones of depression have formed in the area along the Potomac River south of Washington, D. C., as a result of heavy pumping from aquifers in both the Patuxent and Patapsco Formations. Water levels in many wells in that area are substantially below sea level. Concern about the possibility of salt-water contamination of aquifers by intrusion is justified only in the small portion of County adjacent to the lower Patuxent River.

Water from the western and southern part of the County requires little or no treatment before general use, whereas water from the northern part of the County generally needs treatment for high iron content and low pH.

INTRODUCTION

An extensive and rapidly expanding water distribution system has been developed in Prince Georges County by the Washington Suburban Sanitary Commission. Nearly all of the water used in this system in 1963 was obtained from the Patuxent River. Additional water was obtained from the Potomac River and a small amount was obtained from ground-water sources.

Ground-water aquifers supplied about 25 per cent of the water used in the County as a whole. This water was used mainly by individual residences located in rural areas which have not yet been reached by the distribution system. It also includes water used by the recently developed Bowie-Belair residential area.

The importance of ground-water supplies will increase as: (1) the limits of the capacities of the Potomac and Patuxent Rivers are approached and (2) as demands develop for large quantities of water in outlying areas many miles from the existing sources. In these situations it will be necessary to choose between development of well fields or construction of long pipe lines from existing water sources.

PURPOSE OF INVESTIGATION

It has been long known that ground water is available from certain aquifers underlying Prince Georges County (Darton, 1896, p. 134, 135, 151). Ground water supplied most of the residents when the area was mainly rural. Surface water from the Patuxent River now supplies many of the urban and suburban parts of the County but demands for ground water have increased in areas far removed from surface-water sources. In recent years, the increasing demands for water in some localities have not been met easily. County and State officials considering this fact and the fact that water demands probably will increase substantially in the next few decades realized that as much detailed ground-water information as possible should be made readily available in order to utilize this resource properly. This study was undertaken to appraise and evaluate the ground-water resources in order to furnish the County Planners with a guide in locating and designing new distribution systems and in generally assessing the ground-water resources of the County.

The study covered the entire area of the County, but was given greatest emphasis in two areas: (1) the tidewater Potomac area south of Washington, D. C., between the District line and the Charles County line, where the current need for water is most pressing and (2) the Bowie-Belair area in the northeastern part of the County, where it is desirable to measure the effects of recently completed well fields which may ultimately use most of the available ground water. Detailed studies were made also of the Chalk Point and Cheltenham areas. Figure 17 is a map showing locations of these areas.

METHODS OF INVESTIGATION

Much unpublished geologic and hydrologic information has become available in recent years as a result of (1) exploration for large supplies of ground water in the tidewater Potomac area by the Washington Suburban Sanitary Commission and in the Bowie-Belair area by Levitt & Sons, Inc.; (2) geologic exploration for underground gas storage in the Brandywine area by the Washington Gas Light Company, and (3) routine drilling of wells for small water supplies in outlying areas distant from the District of Columbia. Two earlier reports describing the ground-water resources of the County have been published (Meyer 1952 and Otton 1955).

This investigation has drawn heavily on information from the above sources, but has also entailed the collection of much additional data.

Data used in this report were obtained by: (1) collection of information on the location, depth, diameter, yield, and other pertinent features of approximately 870 wells and test holes; (2) field examination of outcrops of surficial deposits and laboratory examination of drill cuttings and well logs, to supplement existing geologic information; (3) collection and chemical analysis of 132 water samples from the aquifers; (4) measurements of water levels in 30 observation wells to determine the magnitude of fluctuations due to both natural causes and pumping; (5) collection and analysis of samples of waterbearing formations to determine their physical properties such as porosity, grain size, and permeability; (6) test pumping of wells at more than 30 sites to determine the coefficients of transmissibility and storage of the aquifers.

The basic data used in the preparation of this report are on file in the Maryland district office of the U. S. Geological Survey.

ACKNOWLEDGMENTS

The author acknowledges the assistance rendered by the well drillers, well owners, and Federal, State, County, and City agencies. The Layne-Atlantic Co., Shannahan Artesian Well Co., Sydnor Pump & Well Co., Columbia Pump & Well Co., and H. H. Bunker and Sons, Inc., were especially helpful in providing well-construction data and other well information. The Washington Suburban Sanitary Commission, the Potomac Electric Power Company, and Levitt and Sons, Inc., provided assistance in tests at their well fields. The Washington Gas Light Company furnished information obtained during its studies for the underground storage of gas in the Brandywine area. Appreciation is expressed for information on ground-water conditions at Bowie-Belair provided by Leggette, Brashears, and Graham, Inc. W. J. Moyer, State Climatologist for Maryland (U. S. Weather Bureau), wrote much of the section describing the climate. The project was carried out under the immediate supervision of E. G. Otton of the U. S. Geological Survey.

LOCATION AND EXTENT OF AREA

Prince Georges County is in the western part of southern Maryland (fig. 1). Its western boundary is adjacent to the State of Virginia and envelops the eastern half of Washington, D. C. The northern boundary of the County is within 15 miles of Baltimore, Maryland. The Patuxent River forms the entire eastern boundary of the County. The County extends 43 miles in the north-south direction and about 20 miles in an east-west direction. It includes an area of 486 square miles.

PHYSICAL FEATURES

The physical features of the County have been described by Gerald Meyer (1952, p. 88). The following is quoted from that source:

"Maryland contains parts of five physiographic provinces, which are, from west to east, the Appalachian Plateaus, the Valley and Ridge, the Blue Ridge, the Piedmont Plateau, and the Coastal Plain. Prince Georges County is almost entirely within the Coastal Plain province, its boundary with Montgomery County nearly coinciding with the Fall Line, the boundary between the Piedmont Plateau and the Coastal Plain.

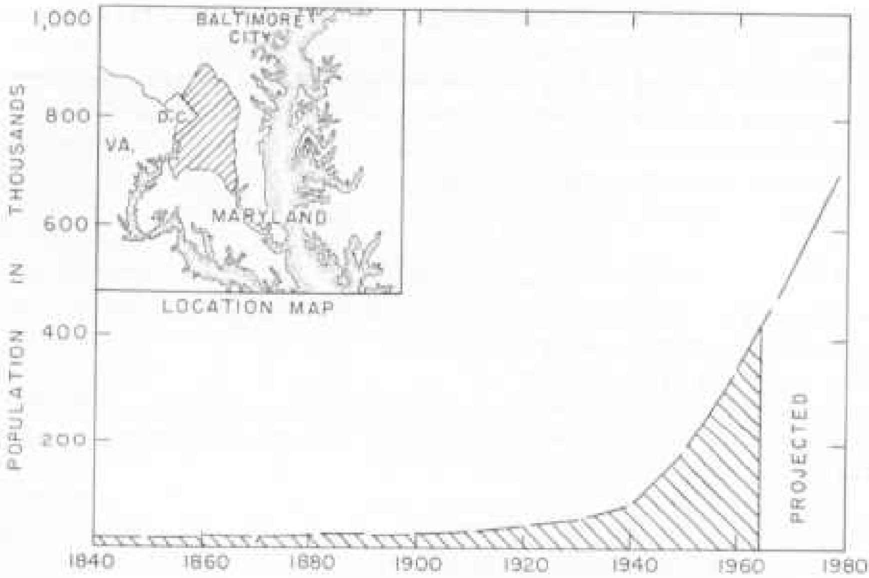


FIGURE 1. Graph showing population trends.

"The Piedmont Plateau, which is underlain by hard crystalline rocks, is moderately dissected and well drained, and accordingly the plateau generally is characterized by a hilly, rolling terrain. In general, the valleys are broad and shallow, but in some places near the Fall Line streams have incised the plateau more deeply and the valleys are relatively narrow. The land surface slopes gently eastward to the Coastal Plain, where, with an increase in slope, the rock surface passes beneath unconsolidated sediments that make up the Coastal Plain.

"In Prince Georges County the Coastal Plain is characterized by a gently rolling land surface in the northern part of the county, and by a partly dissected upland plateau in the southern part. The upland plateau extends southward into Charles, Calvert, and St. Marys Counties. Near the Fall Line and along the edges of the upland plateau in the southern part of the county stream erosion has been rapid, and the relief is greater than in other parts of the county. Headward erosion by Piscataway Creek has almost completely transected the upland plateau.

"The Patuxent and Potomac Rivers, in this area largely estuaries of Chesapeake Bay, form respectively, the eastern and part of the western boundaries of the county. In contrast to the streams in the Piedmont Plateau the major streams flowing into these estuaries are typically sluggish and have broad valleys. The western part of the county is drained by the Anacostia River, Oxon Run, and Henson, Piscataway, and Mattawoman Creeks which flow westward to the Potomac River, and the eastern part by Western Branch, Rock, Black Swamp, and Swanson Creeks which flow eastward to the Patuxent River."

The highest part of the area lies along the northwestern boundary just south and west of Laurel. In this vicinity lies the only part of the County which is more than 300 feet above sea level (about 5 square miles) and the highest point which is about 420 feet above sea level.

POPULATION

The population of Prince Georges County began to increase rapidly in the decade between 1940 and 1950 (fig. 1). The upward trend established in those years has continued to the present resulting in a population at the end of 1963 of 457,000. The rapid population increase is expected to continue at least until 1980. The increase, however, is not expected to be uniformly distributed throughout the area. Most of the increase has been and will continue to be in the localities surrounding the District of Columbia.

The increase in population is attributed mainly to the movement of governmental and commercial establishments into the County with accompanying needs for workers and the development of suburban residential areas for workers employed in Washington.

CLIMATE[1]

The climate of Prince Georges County strongly influences the availability of ground water. The relatively large amount of precipitation which occurs in the northeastern part of the United States favors the recharge of formations. Shallow water-table aquifers are recharged by direct downward percolation. Deep artesian aquifers are recharged both by movement downdip from outcrop areas and by leakage through less permeable confining beds. Temperature variations influence the viscosity of water and the rate of evaporation. Warm water can percolate into the soil much faster than cold water. A large proportion of water from summer rains is returned to the atmosphere almost immediately by evaporation. The growth of heavy vegetation during periods of warm weather also results in the return to the atmosphere of large quantities of water before it can move downward to the water table, thus reducing the amount and rate of recharge to the aquifers.

Prince Georges County has a humid, semi-continental climate. Winters are generally mild and summers are warm and moist. Spring and fall are the most pleasant seasons of the year.

Because of its location in the middle latitudes where the general flow of the atmosphere is from west to east, most weather systems move in this direction though the summers are dominated by warm, moist air moving northward from the Gulf of Mexico. The winters are dominated by cold dry air from

[1] This section of the report adapted from W. J. Moyer, Climatologist for Maryland, U. S. Weather Bureau.

Central Canada which has been somewhat modified by its passage over the Appalachian Mountains. The influence of the nearby Atlantic Ocean is felt in the summer when occasional easterly winds bring cooler air over the hot land and in the cooler seasons when on-shore winds (Northeasters) develop ahead of low pressure areas moving northward along the Coast to bring raw uncomfortable weather and much of the winter's precipitation.

Temperature and precipitation data for a long-period climatological station at Cheltenham in the southern part of the County are shown on figure 2. Conditions throughout the County are similar to those shown on the graph.

The mean temperature is about 55° or 56°F. While the annual mean maximum temperature of 65° to 67°F is nearly the same over the County, the annual mean minimum temperature does vary 3 to 4 degrees from 43° to 47°F.

The annual precipitation is between 44 and 45 inches and is fairly evenly distributed through the year. About 3 to 3½ inches fall during most months except for the period May through August when it is slightly higher. August is the month with the greatest precipitation. While measurable precipitation falls on about one-third of the days in the year, useful amounts of rain occur much less frequently. On only 74 to 80 days is 0.1 inch or more reported.

Heavy precipitation may occur in any month but its variability is greatest in summer. In a hurricane such as CONNIE in August 1955, rainfall of 9.54 inches was recorded at Cheltenham, 6.98 inches at Glenn Dale and 7.86 inches at Greenbelt. Although the storm set many precipitation records, much higher rainfall intensities for shorter periods of time may occur in summer thunderstorms. More commonly, the local summer thundershowers will bring 1 to 3 inches in one storm with much of it running off, while a few miles away only a sprinkle may fall. In winter, precipitation occurs from general storms that cover large areas.

Serious droughts are most likely in summer. Generally, the rainfall plus the stored soil moisture are adequate for good crop yields. However, the unequal distribution of summer showers, the occasional dry spells at critical stages of plant growth and the high summertime evaporation create emergencies in which irrigation would be of great value in securing maximum crop yields. The driest year on record was 1930 when only 17.98 inches of precipitation fell at Glenn Dale and 22.58 inches fell at Cheltenham.

The annual snowfall is 19 to 20 inches. The amount varies considerably from year to year, ranging for a 55-year period at Cheltenham from 2.0 inches in the 1949–1950 winter to 48.3 inches in 1939–1940. During the 42-year period at Glenn Dale it ranged from 2.0 inches in the 1949–1950 winter to 52.8 inches in 1957–1958.

WELL NUMBERING SYSTEMS

Two well numbering systems were used in the preparation of this report, these are:

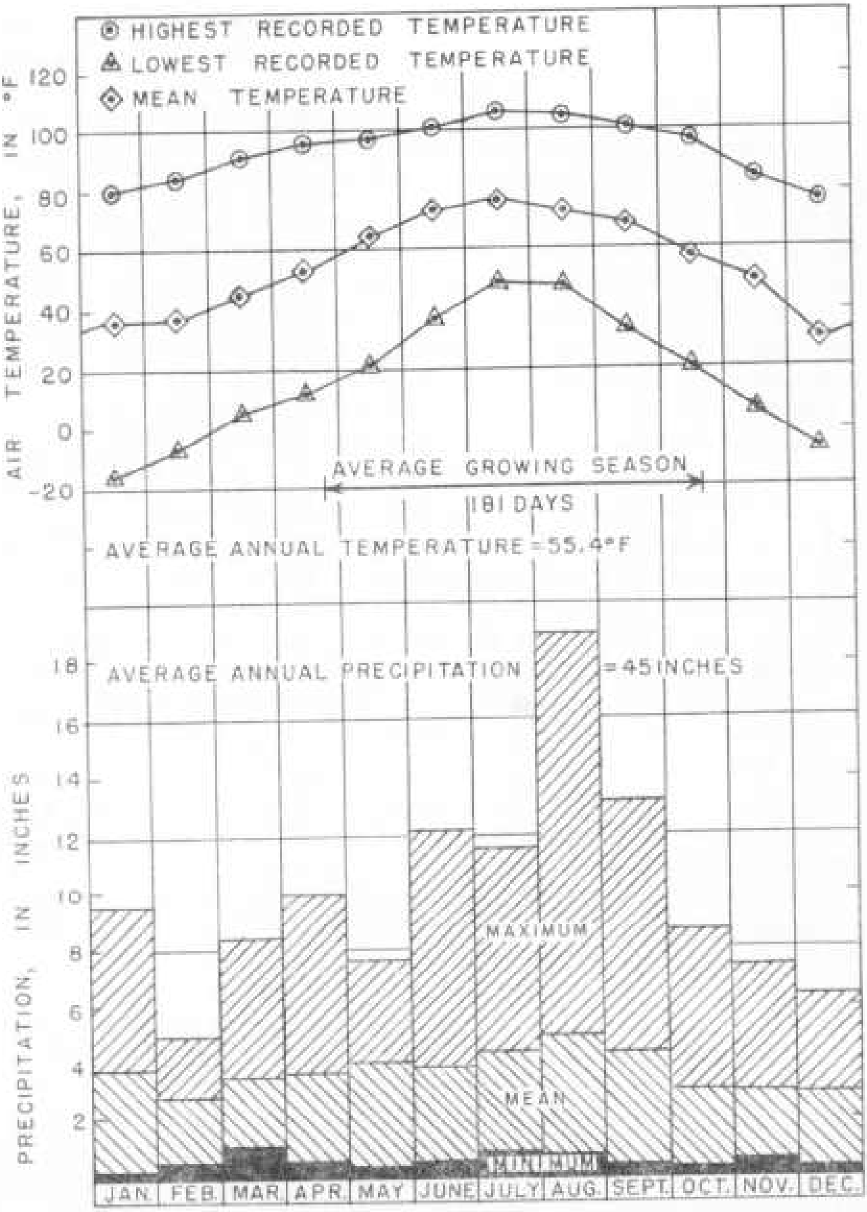


FIGURE 2. Graphs showing monthly air temperatures and precipitation at Cheltenham.

1) Maryland system, used for all wells in Maryland.
2) District of Columbia-Virginia system, used for all wells mentioned in the report which are in these political units.

Briefly, the two systems are:

The Maryland well-numbering system groups all wells outside of Baltimore City by counties. A two-letter symbol, derived from the county name, is used as a prefix for each well number. Thus, in this report, PG is the prefix for wells in Prince Georges County, AA is for Anne Arundel County, and Ch is for Charles County. Each county is divided into 5-minute quadrangles. Each quadrangle from north to south is designated by uppercase letters and from west to east by lowercase letters (see margins of figure 3). The wells are numbered in each 5-minute quadrangle in the order in which they were inventoried. For example: PG-Hf 1 indicates the first well numbered in the southeasternmost 5-minute quadrangle in Prince Georges County.

The District of Columbia-Virginia system groups wells by standard 7½-minute topographic maps of the U. S. Geological Survey. A two letter symbol, derived from the name of the topographic quadrangle is used as a prefix for each well number Thus AX is the prefix for numbers in the Alexandria quadrangle, BV for the Belvoir Quadrangle and WW for the Washington West Quadrangle.

Each quadrangle is divided into nine rectangles by lines drawn through the 2½-minute grid lines. The rectangles thus formed are lettered A, B, C, from north to south and a, b, and c from west to east. The wells are numbered consecutively in each quadrangle, the pair of uppercase and lowercase letters indicating the rectangle in the quadrangle and the double uppercase letter the quadrangle. For example: AX-Bb-1 indicates the first well numbered in the central rectangle of the Alexandria quadrangle.

WATER USE

Water-supply systems in Prince Georges County, excluding farm ponds, supplied an average of about 44 mgd in 1963 (see table 1). About 25 per cent of this quantity was derived from ground-water sources within the County and the other 75 per cent was from surface-water sources, mainly the Patuxent River but including some water from the Potomac River.

Of the 11 mgd of ground water used, only about 0.5 mgd was used by industries or commerical establishments—much of it for air conditioning. Approximately 7.0 mgd were supplied for domestic and farm use. An average of a little more than 1 mgd was used by military and governmental institutions.

Meyer (1952, p. 110) estimated that ground-water use during 1949 and 1950 averaged approximately 4 to 5 mgd, which was roughly one-half the quantity used in 1963. The increase is due mainly to the increase in population in outlying areas of the County which are not served by public supplies using surface-water sources.

Maps included in annual reports of the Washington Suburban Sanitary Commission show that much of the area north of U. S. Highway 50 and practically all of the thickly populated part of the County bordering the District of Columbia is served by the water and sewerage facilities of the Washington

TABLE 1

USE OF WATER IN PRINCE GEORGES COUNTY IN 1963 BY SOURCE AND TYPE OF USE

CATEGORY	SOURCE	TYPE OF USE	AVERAGE QUANTITY USED (MGD)
Ground water	Wells and springs	Public supply	2.4
		Industrial and commercial	.5
		Domestic and farm	7.0
		Military	.2
		Institutional	.9
	Total ground water		11.0
Surface water	Patuxent River	Public supply (Washington Suburban Sanitary Commission)	30.0
	Potomac River	Public supply	1.0
		Military (Andrews Air Force Base)	1.5
	Total surface water		32.5
Total water used			43.5
Water use per capita			95 (gpd)

Suburban Sanitary Commission. It is estimated that approximately 80 per cent of the population of the County is served by these facilities. Prior to the formation of the Sanitary Commission in 1918, most towns bordering the District of Columbia were supplied with water by their own municipal wells and those living in the more rural areas were supplied by private wells. The water was derived principally from the waterbearing sands in the Patuxent Formation. Most of the ground-water supplies within the service area of the Sanitary Commission gradually were abandoned and were replaced by the surface-water supply of the Commission. The boundaries of the Sanitary District have been extended from time to time to include additional populated areas in the County, and as the boundaries of the District increased, many wells within the newly annexed areas were abandoned. Consequently, ground-water pumping has decreased in some parts of the County and a large part of the present pumping is in the area outside the Sanitary District.

Relatively large quantities of water are also being pumped from areas adjacent to Prince Georges County. As may be seen in figure 3, an average of about 1.4 mgd is pumped in Washington, D. C., and an average of about 2 mgd is

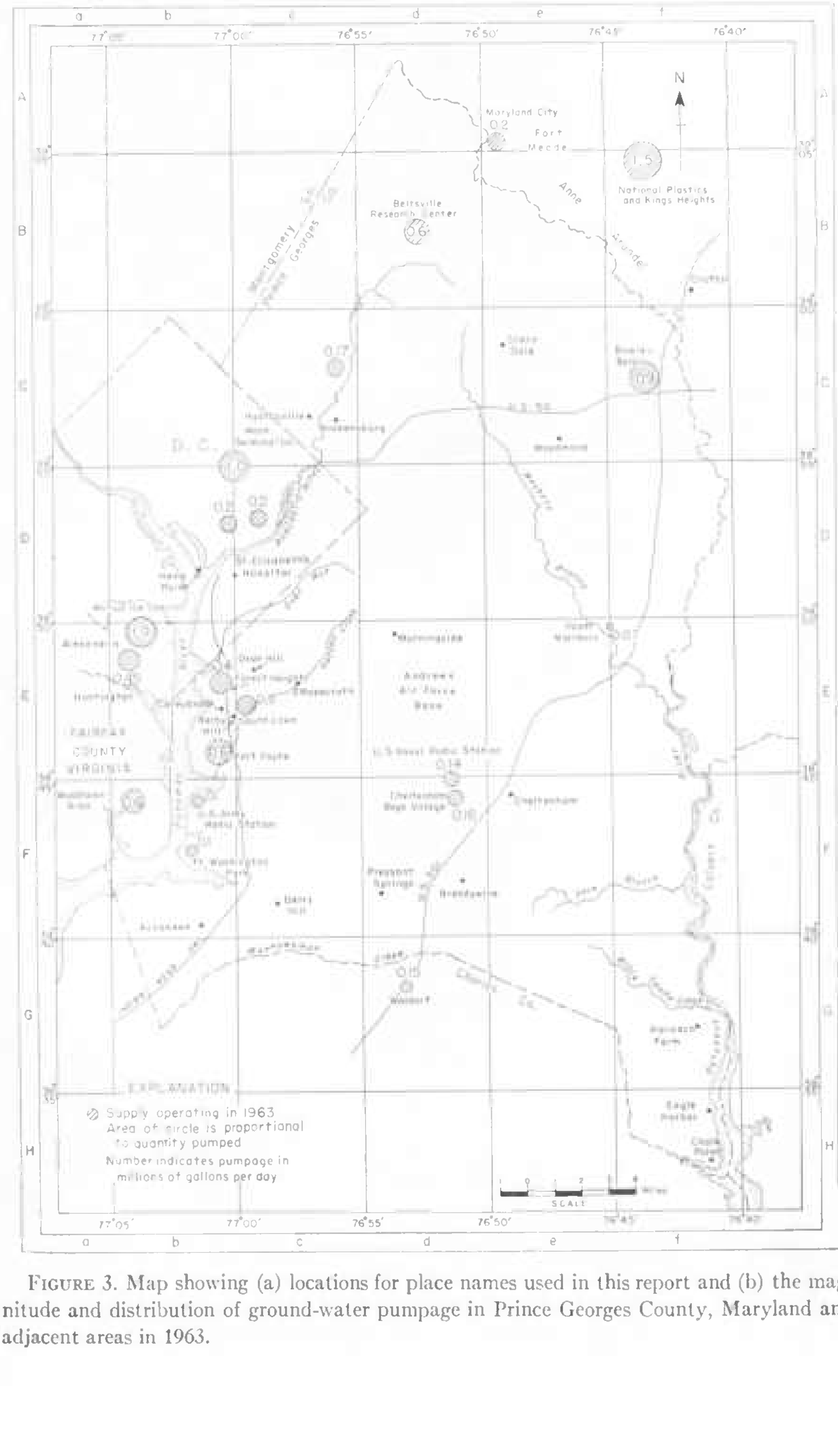


Figure 3. Map showing (a) locations for place names used in this report and (b) the magnitude and distribution of ground-water pumpage in Prince Georges County, Maryland and adjacent areas in 1963.

pumped from wells in the Virginia coastal plain on the west side of the Potomac River.

GEOLOGY

The availability of ground water in Prince Georges County is dependent on the local geology and the precipitation. Geologic conditions, to a large extent, control the amount of water that can be taken from a particular formation, the rate at which individual wells can be pumped, and the depth to which wells must be drilled.

Prince Georges County is underlain by a wedge-shaped mass of unconsolidated sedimentary deposits which overlie older rocks of Precambrian or Early Paleozoic age and some arkosic rocks of Triassic age. The unconsolidated deposits are stratified layers of sand, gravel, silt, and clay. The sand and gravel strata comprise the major water-bearing sediments.

The ancient crystalline basement consists of igneous and metamorphic rocks. The Triassic rocks are primarily shales and arkosic sandstones. The surface of the crystalline rocks dips gently (from 60 feet to 110 feet per mile) toward the southeast as far as Salisbury (70 miles southeast of Prince Georges County) where the dip steepens greatly (Vokes, 1957, fig. 12, p. 46). In Washington, D. C., and just north of the Montgomery County line these rocks crop out at the land surface at an altitude of 200 to 400 feet above sea level. At Belair, in the northeastern part of Prince Georges County, they lie at a depth of about 1,050 feet below sea level and in the area near Brandywine, they are at a depth of 1,400 to 1,500 feet below sea level (fig. 4). Near Chalk Point, in the southeastern part of the County, they may be 2,500 to 3,000 feet below sea level. Because the crystalline rocks are buried at great depth throughout most of the County, they are seldom penetrated by drilling. Almost no information is available regarding their character. They commonly grade upward from fresh hard rock into a layer of clayey, rotted rock. Few wells yield water from the crystalline rocks where they lie buried beneath the sediments. Locally, near the fall line in the northwestern part of the County, a few gallons per minute may be obtained from wells which tap a crevice or fracture.

The unconsolidated deposits are usually easy to drill and, where exposed, are generally soft enough to be worked with a shovel. The wedge-shaped mass of unconsolidated deposits thins to less than 1 foot in the northwest and is probably 2,500 to 3,000 feet thick in the southeast. The layers of clay, silt, sand, and gravel composing most of these deposits crop out at the surface. They have been studied extensively (Miller, 1911 and Cooke, 1952), described in detail, and geologic names have been given to several distinct units in the County.

Plate 1, three geologic sections across the County, shows that: (1) the depth to crystalline rock increases progressively toward the southeast; (2) the unconsolidated layers lie upon one another and the youngest (uppermost) formations

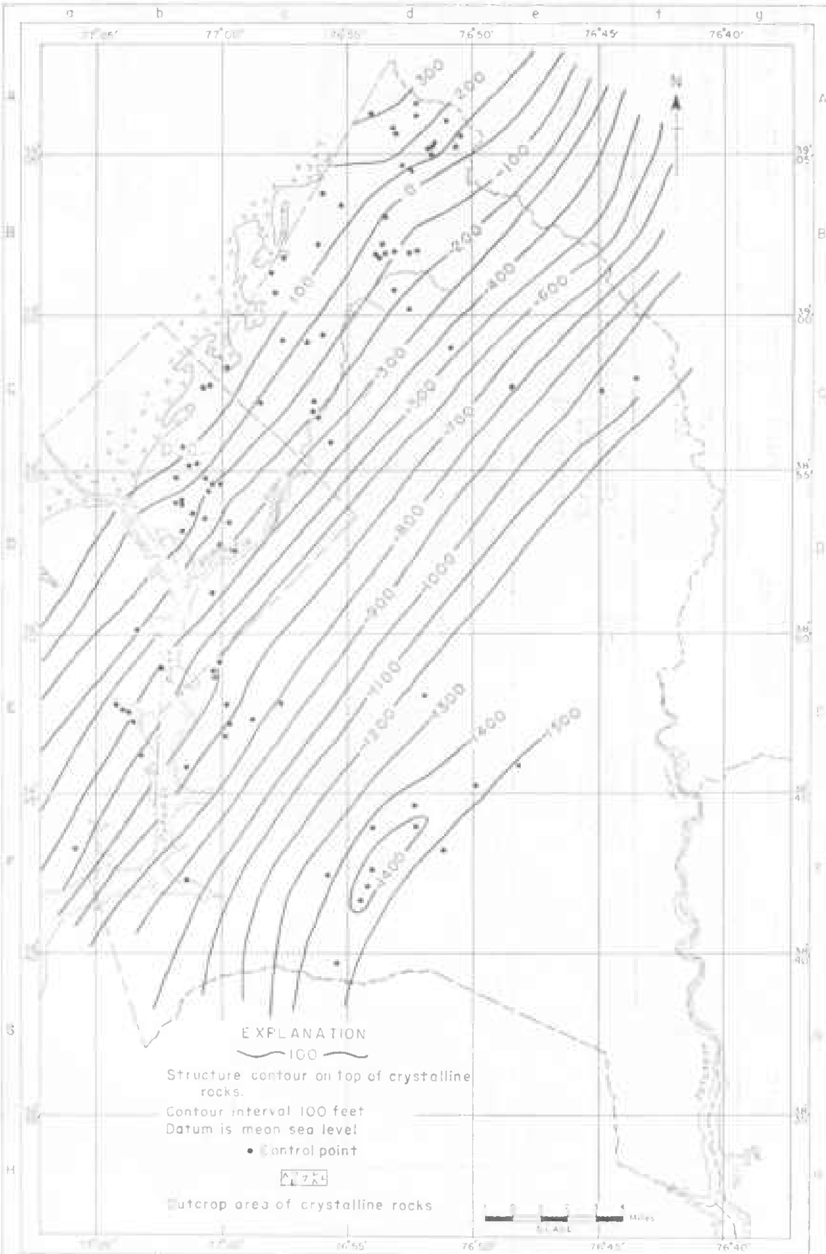


FIGURE 4. Map showing outcrop area and altitude of top of crystalline rocks.

TABLE 2

GEOLOGIC FORMATIONS IN PRINCE GEORGES COUNTY[1]

SYSTEM	SERIES	GROUP	FORMATION	APPROXIMATE THICKNESS (FEET)	GENERAL CHARACTER	WATERBEARING PROPERTIES
QUATERNARY	Recent and Pleistocene		Lowland deposits	0–50±	Irregularly bedded sand, gravel, and clay.	Yields adequate supplies for domestic purposes to shallow wells.
TERTIARY(?)	Pliocene(?)		Upland deposits	10–50	Irregularly bedded cobbles, gravel, and fine sand, intermixed with silt or clay.	Yields generally adequate supplies for domestic purposes to dug wells in southern part of county.
TERTIARY	Miocene	Chesapeake Group	Choptank Formation	50	Fine sand, sandy clay, and clay.	Generally not an aquifer but supplies a few dug wells.
			Calvert Formation	20–200	Gray and greenish-gray clay and sandy clay; generally contains diatoms.	Yields small supplies of water to domestic and farm dug wells.
	Eocene	Pamunkey Group	Nanjemoy Formation	0–225	Gray to dark-gray glauconitic silt and clay; 20–40 feet of dense and tough clay at base (Marlboro Clay Member).	Not an important aquifer.
			Aquia Greensand	0–140	Greenish-gray glauconitic sand and sandy clay; contains indurated layers, with fossil shells.	Yields moderate supplies of water to dug wells in the east-central part of the county; an important aquifer in the southeastern part of the county.
	Paleocene		Brightseat Formation	0–70(?)	Gray to dark-gray micaceous silty and sandy clay.	Not an important aquifer.

CRETACEOUS	Upper Cretaceous		Monmouth Formation	0–50±	Gray to dark-gray glauconitic, micaceous silty and sandy clay.	Not an important aquifer.
			Magothy Formation	0–50	Light-gray sand and gravel and interbedded light-colored clay; contains lignite, pyrite, and glauconite.	Important aquifer in southeastern half of county; yields more than 250 gpm.
		Potomac Group	Patapsco Formation	200–500+	Interbedded sand, clay, and sandy clay; in places upper part consists of 200 feet of pink clay.	Important aquifer in north-central and northwestern parts of county; yields more than 1000 gpm.
			Arundel Clay	0–200	Red and brown clay.	Generally not an aquifer.
	Lower Cretaceous		Patuxent Formation	140–300+ Individual sands range from 8 to 110 feet in thickness	White, yellow, gray, and brown sand, and interbedded clay; contains kaolinized feldspar, lignite and pyrite.	Important aquifer in northwestern part of county; yields as much as 1500 gpm to drilled wells.
TRIASSIC		Newark Group		0–200+	Shales, sandstones and conglomerates; red, brown and green.	Not an important aquifer because of its low permeability and because it is too deeply buried to be accessible; penetrated by a few deep test holes.
PRECAMBRIAN OR CAMBRIAN					Chiefly schist, granite, gabbro, and gneiss.	Yields small supplies of water, generally less than 10 gpm to wells in northwestern part of county.

[1] Modified from Meyer 1952, p. 90.

are exposed progressively to the east; and (3) the formations thicken to the east. Little information is available regarding the unconsolidated deposits at depths greater than 700 feet in the southeastern parts of the County.

Studies of the structural geology of southern Prince Georges County by the Washington Gas Light Company showed that the surface of the bedrock and some of the overlying Coastal Plain formations are dome shaped (see fig. 4). This necessitated a departure from the earlier concept, based on sidely scattered data, that the surface of the basement rocks and most of the overlying formations dip uniformly toward the east or southeast. Future detailed studies may prove that the bedrock surface throughout the County is characterized by localized reversals of slope and that uniformly sloping surfaces are more the exception than the rule. However, when reviewed on a broad scale, the general slope of the rock surface as well as the overlying formations is toward the southeast.

Table 2 summarizes the thickness and character of the geologic units in the County.

Several contour maps showing the altitudes of the tops of the major water-bearing formations in the County are enclosed in later sections of this report. These maps predict the approximate depth at which an aquifer may be encountered. For example, if one wishes to drill to the Patuxent Formation at a location transected by the -800-foot contour, one need only add 800 feet to the altitude of the land surface at the proposed well site to predict the depth of drilling required to penetrate to the top of the formation. The slope or dip of the aquifers varies; the deepest aquifer, the Patuxent Formation, has dips up to 110 feet per mile throughout the area (see fig. 6), whereas the Aquia Greensand, one of the overlying aquifers, dips southeastward 15 to 25 feet per mile (see fig. 15).

More detailed geologic descriptions of specific parts of the County are given in those sections of this report dealing with the individual formations and individual areas.

Several earlier publications deal with the general geology of Prince Georges County. Outstanding among these are Miller (1911); Miller, Bibbins, and Keith (1911); Cooke and Cloos (1951); and Cooke (1952).

HYDROLOGY

Water evaporated from the sea and land surface and water transpired by plants rises into the atmosphere as water vapor. This water vapor is carried by the winds to other areas. Under the right conditions the vapor forms clouds and eventually returns to the earth as precipitation. Some of the precipitation infiltrates the land surface and percolates to the saturated zone to become ground water. The continuous circulation of water from the land and sea to the atmosphere and from the atmosphere to the land and sea is known as the "hydrologic cycle." It explains in a general way the source and movement of water in the streams and in the ground. Thus the water available from the aquifers in Prince Georges County is derived from precipitation. The distribution of precipitation may be expressed quantitatively by the hydrologic budget. The hydrologic budget may be expressed by the equation:

$$P = R_s + R_g + \Delta S + E$$

In which:
P = precipitation
R_s = stream runoff
R_g = ground-water discharge or underflow (to the sea)
ΔS = change in ground-water storage
E = evapotranspiration

Precipitation and stream runoff are the factors in the hydrologic budget that can be determined most accurately. Ground-water discharge to the sea is difficult to evaluate, but may be on the order of only a few per cent of the precipitation. Changes in ground-water storage may be evaluated to some degree where adequate ground-water level records are available. Evapotranspiration is the most difficult to measure accurately. It is usually computed as a residual after all the other factors have been determined.

Over a period of several years, the changes in ground-water storage (S) will tend to be zero, although for one 2-year period Rasmussen and Andreasen (1959, p. 98) report that the change in ground-water storage in Beaverdam Creek basin near Salisbury, Maryland, was about 2 per cent of the total precipitation. An average rate of evapotranspiration (E) for Prince Georges County has not been determined, but the value of about 60 per cent of the precipitation used by Rasmussen and Andreasen probably is in the right order of magnitude.

The values assigned to the general hydrologic equation for Prince Georges County are:

	SYMBOL	PER CENT OF TOTAL PRECIPITATION	INCHES OF WATER PER YEAR	MILLION GAL. PER SQ. MI. PER YEAR	MILLION GAL. PER DAY AVERAGE	
					Per sq. mi.	Entire county
Stream runoff	R_s	35	15	260	0.7	340
Ground-water discharged to the sea	R_g	5[1]	2	30	.1	49
Change in ground-water storage	ΔS	0	0	0	.0[2]	0[2]
Evapotranspiration	E	60	27	470	1.3	632
Precipitation	P	100	44	760	2.1	1,021

[1] Assumed.
[2] Varies from month to month, but tends to average zero over long periods.

The quantity of water stored in an aquifer depends on the *porosity* or percentage of the total volume that is occupied by pores and other openings. The rate at which water moves in aquifers and the readiness with which it may be withdrawn through wells or discharged by springs is controlled by the *permeability*.

The major sources of water in the aquifers of Prince Georges County are: (1) precipitation within the County which directly recharges the aquifers; (2) subsurface flow into the County, derived from precipitation in other counties, chiefly adjacent Anne Arundel, Charles, and Calvert; and (3) infiltration into the aquifers from streams whose flow originates chiefly in the Piedmont. Such infiltration is possible only when normal ground-water gradients are reversed as a result of pumping. At present the quantity of water entering the aquifers from surface streamflow is negligible.

Precipitation within the County is the source of most of the ground water currently used. However, heavy pumping of the artesian aquifers near the County boundaries will cause water to move into the area from adjacent areas. Most of the waterbearing formations crop out in the County. Some of the water arriving as precipitation at the outcrop area of each of these formations percolates into the ground and moves toward points of discharge which are always points of lower hydraulic head. As Maryland is in the humid climatic belt, most of the aquifers are brim full and water is continually being discharged from them to supply the flow of the streams during periods of no overland runoff.

Much of the water in the deeper parts of the waterbearing formations may have originally entered the ground in adjacent counties. Some of this water has been in transit a long time because its rate of movement through the sands and gravels is slow under the low natural head differentials which prevail.

Water is discharged from the aquifers by seepage in low-lying areas, by evapotranspiration, and by pumpage from wells. Seepage from the ground furnishes the water flowing from springs and surface streams during prolonged periods of no rainfall. Ground-water runoff in the Beaverdam Creek basin reportedly amounted to about 11 inches per year, or about 26 per cent of the precipitation (Rasmussen and Andreason, 1959, p. 98). This rate is believed to be relatively high, but is in accord with the high rate of ground-water recharge. Of course, over a period of time, ground-water discharge must equal recharge unless appreciable changes in storage occur.

Pumpage from wells, a form of ground-water discharge which was insignificant in the ground-water regimen of the County in the year 1900, is now a factor of importance and will be a more important form of discharge by the year 1980. Maps of the piezometric surfaces in the Patuxent and Patapsco Formations (figs. 7 and 10) show areas of piezometric depression which are the result of heavy ground-water discharge from wells ending in those formations in the southwestern part of the County and in the adjacent Virginia area. Discharge from the Patuxent Formation in the Virginia area has caused lowering of water levels in this aquifer for several miles along the western boundary of Prince Georges County.

SOURCE AND MOVEMENT OF GROUND WATER

About 60 per cent of the precipitation in Prince Georges County returns to the atmosphere through evaporation and transpiration. Perhaps 40 to 50 per cent infiltrates through the soil zone and reaches the zone of saturation. This water, temporarily at least, increases the ΔS, or ground-water storage component, of the hydrologic cycle. Among the factors determining the amount of water that is absorbed by the ground are the porosity and permeability of the surficial materials, the slope of the land, the amount and kind of vegetal cover, and the intensity and amount of precipitation. Rain falling at a slow, steady rate on dry, permeable, flat ground infiltrates more readily than rain falling at a rapid rate on a moist, steep, relatively impermeable ground.

An average of about 2.1 mgd of precipitation falls per square mile in the area. Studies of the hydrologic budget by Rasmussen and Andreasen (1959, p. 98) indicate that approximately 50 per cent of the precipitation, or about 1 mgd per square mile, eventually reaches the water table and that about 45 per cent of the water reaching the water table is returned to the atmosphere by evapotranspiration. Thus, roughly about 0.5 mgd of water is theoretically available for withdrawal from the ground-water reservoirs for each square mile of outcrop of the waterbearing formations.

Once water reaches the zone of saturation it begins to move laterally under the influence of gravity toward points of discharge, such as springs, wells, streams, or topographically low areas. Water thus in transit is under either water-table or artesian conditions. Where water only partially fills a permeable bed, its surface is free to rise and fall. Such water is unconfined and is said to be under water-table conditions. Where the water completely fills a permeable bed that is overlain by a relatively impermeable bed, its surface is not free to rise and fall and the water is said to be under artesian conditions. Water under artesian conditions is under sufficient pressure to rise above the top of the bed in which it occurs, though not necessarily above the land surface.

A formation in the zone of saturation that is permeable enough to transmit water in usable quantities to wells or springs is called an *aquifer*. Areas in which water is gained by infiltration into the aquifers are called recharge areas. Areas in which water is lost by natural seepage from aquifers are called discharge areas. Water may also be discharged from aquifers by means of slow leakage or movement upward or downward through semipervious or relatively impervious confining beds. Such beds or layers are called *aquicludes*.

FACTORS CONTROLLING THE AVAILABILITY OF GROUND WATER

The geologic and climatic conditions in Prince Georges County favor the availability of ground water. Ground water, if properly developed and protected from contamination will continue to be a valuable natural resource in the County. In most cases, water removed from the ground at a reasonable rate will be replaced by water from precipitation. If pumping is carried out at too high a rate in a small area in the southeastern part of the County, however, some of the water pumped may be replaced by brackish water from the Patuxent River.

The availability of ground water in Prince Georges County has been estimated on the basis of the limited data available in 1964. The availability is described in terms of (1) types of sources, (2) rates of withdrawal, (3) specific aquifers, and (4) specific areas.

SOURCES

The total amount of ground water developed in Prince Georges County in future years will be derived from two sources: (1) water stored in the ground-water reservoirs which would be available for a time even if there were never again any precipitation, and (2) recharge water from precipitation which replenishes the ground-water reservoirs on a continuing basis. Therefore, to estimate the amount of water available from the aquifers of the County, estimates were made of the amount of water in storage and the rate at which recharge to the aquifers can be expected to occur under average conditions. Estimates were also made of the rates at which water can be transmitted through the aquifers to centers of actual or potential pumping.

WATER STORED IN GROUND-WATER RESERVOIRS

Large quantities of water are stored in the coastal plain deposits underlying Prince Georges County. A rough estimate indicates that the sands in the coastal plain wedge contain in storage about 3 trillion (3×10^{12}) gallons of water, a large percentage of which occurs in relatively thin sand layers capable of supplying comparatively few gallons per minute to individual wells. A very large number of expensive, low-yielding wells would be needed to remove a significant portion of this total from the ground.

However, even though much of the "free" water is isolated in thin sand layers and therefore is relatively inaccessible, there may be as much as one trillion gallons available from sands thick enough to yield water at high rates. It would take about 250 years of pumping at 11 mgd (the average total rate of pumping in Prince Georges County in 1963) to produce one trillion gallons. Obviously, this figure for water in storage seems very high, and it would be very misleading if it were considered to represent the amount which could be obtained with the ease and low cost per gallon of water pumped in 1963. To exploit a significant percentage of the large total would require construction of many new wells, significant increases in power costs for lifting the water from greater depths, and some possible hazards such as land subsidence and water contamination. It might also require the development of new well construction techniques.

RECHARGE BY PRECIPITATION

Recharge to aquifers by means of precipitation in the outcrop area or by leakage from adjacent formations greatly increases the quantities of water available from waterbearing sands. It is the factor which will make the ground-water reservoirs of Prince Georges County a continuous, although limited, source of water. Factors which must be considered in estimating the rate at which water from precipitation can safely recharge the aquifers are: frequency and amount of precipitation, infiltration capacity of the soils, transmissibility of aquifers, and hydraulic heads and gradients.

Parts of later discussions of individual aquifers deal with the rates at which the aquifers can be recharged.

Precipitation and Infiltration Capacity

The rate at which an aquifer can be recharged depends in large part on the amount of water available from precipitation and on the infiltration capacity of soils. One inch of precipitation on an area of 1 square mile provides 17.4 mg (million gallons) of water. With an average annual precipitation of about 44 inches the total precipitation on the 486 square miles of Prince Georges County is about 380 billion gallons per year or an average of about 1 billion gallons per day. Probably less than half of this amount reaches the zone of saturation to become ground water, and only a part of this ground water is readily available for use by man.

Infiltration rates for the soils of Prince Georges County are not available. In the Beaverdam Creek basin near Salisbury, Rasmussen and Andreason (1959, p. 98) estimated that approximately 50 per cent of the precipitation arriving at the land surface reached the zone of saturation. However, the soils of that area have high infiltration capacities. Doubtless, many of the soils of Prince Georges County have infiltration capacities equal to those of the Beaverdam Creek basin, but much of the County has more clayey soils which have lower infiltration capacities. Probably over the entire area of the County the soils are capable of absorbing somewhat less than half the precipitation.

Permeability, Transmissibility, and Storage

Hydraulic permeability is the capacity of a material to transmit water. The coefficient of permeability (P_f) is defined as the rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at the prevailing temperature. The coefficient of transmissibility (T) is the rate of flow of water in gallons per day through a vertical section of the aquifer 1 foot wide extending the full saturated thickness of the aquifer under a hydraulic gradient of 1 foot per foot. The thickness of the aquifer in feet is commonly designated by the symbol (m). Thus, the coefficient of transmissibility may be written:

$$T = P_f m$$

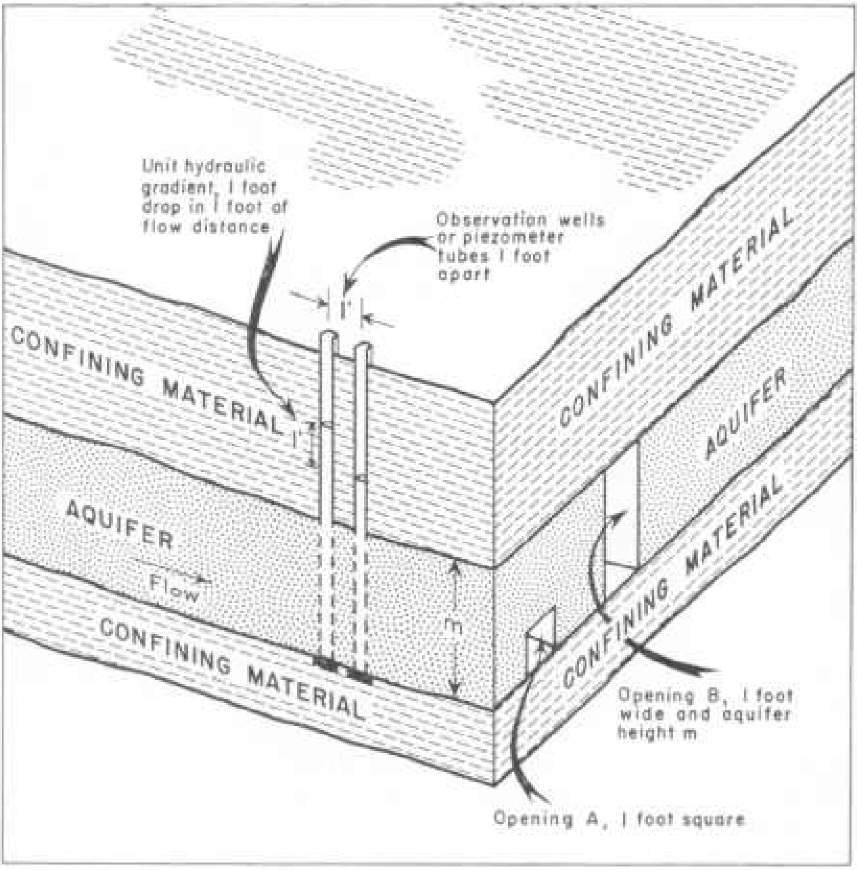


FIGURE 5. Diagram explaining the coefficients of permeability and transmissibility.

The coefficients of transmissibility, permeability, and storage for aquifers may be determined from pumping tests, laboratory analyses of earth materials, and by approximate means using specific-capacity data from wells. Figure 5 explains graphically the concepts involved in the coefficients of permeability and transmissibility. Because the transmissibility of a waterbearing formation directly affects the water levels in the formation, tests to determine coefficients of transmissibility were made by pumping selected wells for known periods of time at known rates of discharge and, where possible, observing the following effects: (1) the hydraulic interference occurring in the aquifer determined by measuring water levels in one or more observation wells; (2) the rate at which the water level in the pumped well recovered when pumping was stopped; (3) the drawdown in the pumping well. Data obtained from these tests were analyzed by methods developed by Theis (1935) and Cooper and Jacob (1946). The methods of analysis of aquifer tests make use of the Theis nonequilibrium formula and modifications of it. The use of the formula implies certain idealized assumptions which are never realized in nature. Nevertheless, the Theis equation has been found to be a useful device in quantitative ground-water studies.

Where pumping tests cannot be made, coefficients of transmissibility can be estimated by a system devised by E. C. Reed (Keech and Dreeszen, 1959, p. 37–38). In this method each lens or layer of the aquifer, as shown by well logs or drill-cutting descriptions, is assigned a coefficient of permeability within a range as follows:

MATERIAL	RANGE OF COEFFICIENT OF PERMEABILITY (GPD/SQ FT)
Clay and silt	0–100
Sand, very fine, silty	100–300
Sand, fine to medium	300–400
Sand, medium	400–600
Sand, medium to coarse	600–800
Sand, coarse	800–900
Sand, very coarse	900–1000
Sand and gravel	1000–2000

Layers of material of similar physical characteristics in an aquifer are assigned a coefficient of permeability, which multiplied by the thickness in feet of that material, provides a rough estimate of their coefficient of transmissibility. The sum of the coefficients of transmissibility of the various materials in the aquifer is considered to approximate the coefficient of transmissibility for the entire aquifer or geologic unit.

Aquifers, in addition to functioning as conduits through which water can move from areas of recharge to areas of discharge, function also as reservoirs which store large quantities of water. The coefficient of storage (S) is a term devised to characterize this hydraulic property of an aquifer. It is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of hydraulic head normal to that surface. It is dimensionless. By using the coefficients of storage and transmissibility, it is possible to predict the amount of drawdown that will occur at a given distance from a well pumping at a known rate for a given period of time. Such information is useful in planning the spacing of wells because it facilitates the prediction of the degree of hydraulic interference between wells and aids in computing the length of time a well can be pumped under various geohydrologic conditions.

Hydraulic Head and Gradient

The rate of flow through permeable sand or gravel-sized earth materials is proportional to the hydraulic gradient. This fact was observed and demonstrated by Darcy in 1856 and is sometimes expressed by the formula $Q = PIA$ (Ferris, 1949, p. 226) where:

Q = the quantity of water discharged per unit time
P = permeability of the material
I = the hydraulic gradient
A = the cross-sectional area through which the water must move

Hydraulic head may differ from one aquifer to another at the same place. It usually varies from place to place even in the same aquifer. Water moves, in response to differences in hydraulic head, from points of high head to points of lower head. Hydraulic head in an aquifer is usually determined by measuring the water level in a well. Where these measurements are available from several wells ending in the same aquifer, a piezometric (or hydraulic head) map may be constructed. Such a map can be used to show the direction of movement of gound water and to determine recharge and discharge areas of the water.

In sloping or dipping aquifers of uniform transmissibility greater drawdown in wells is available in the downdip direction, as the water in a given aquifer occurs under greater head. The increased available drawdown permits significantly greater yields per well.

SALT-WATER INTRUSION

The proximity of a large body of saline or brackish water generally poses a hazard to adjacent land areas because heavy pumping may draw the saline water into the aquifers and cause contamination of water supplies. Because the lower Patuxent River is the only large body of brackish water adjacent to the County, the only land area in which the hazard of salt-water contamination poses a serious threat is the southern 10 or 12 miles of the County adjacent to the Patuxent River. This hazard must be considered before steps are taken to develop fully the ground-water capacity of the Chalk Point area. However, the silts on the bottom of the Patuxent River may form an effective seal to prevent the leakage of brackish water into producing aquifers. No significant instances of salt-water intrusion have been reported to date within Prince Georges County, but salt-water contamination of aquifers in the Baltimore industrial area, an area geologically similar in several respects to the Chalk Point area has been extensive (Bennett, and Meyer, 1952, p. 124–171).

The section of the Potomac River along the western boundary of Prince Georges County becomes somewhat brackish at times. However, such occurrences are infrequent and concentrations of salts are generally too low to present a serious hazard.

RATES OF WITHDRAWAL

Although large quantities of water are stored in the ground and large additional quantities are available from recharge, ground water is often obtained only with difficulty because aquifers release water to wells at rates which depend on aquifer transmissibility, hydraulic gradients, and methods of well construction. In some situations, water can be pumped from the ground at rates greater than the rate of recharge. In other situations, water can recharge the aquifers at rates equal to or greater than the rate at which the water can be released by the aquifers to wells.

Water can be pumped from individual wells at rates which are dependent on: (1) the amount of drawdown available in the well and (2) the specific capacity of the well. The drawdown available in wells in Coastal Plain aquifers is generally considered to be the number of feet of head between static water level and the top of the waterbearing formation. Thus, in an area where the static water level stands 60 feet above sea level and the top of the formation is 40 feet below sea level, there are about 100 feet of drawdown available in a well. The *specific capacity* of a well is the number of gallons per minute of water that may be obtained for each foot of drawdown. For example, some of the better wells in Prince Georges County yield 10 gallons per minute of water for every foot of drawdown.

The theoretical maximum rate of withdrawal (Q_w) from a single well, therefore, is the number of feet of drawdown available times the specific capacity. For example:

Maximum rate
of withdrawal Q_w = ft of drawdown available $\times$ specific capacity
$Q_w = 100 \text{ ft} \times 10 \text{ gpm per ft} = 1000 \text{ gpm}$

It must be remembered in using this formula that it gives a maximum figure for a fixed period of pumping which will be reduced in actual practice by factors such as well screen losses and slow declines in drawdown during extended periods of pumping.

Tables of wells and of hydrologic, geologic, and chemical data prepared for specific areas of Prince Georges County, and presented in this report include both specific capacity and available drawdown data that assist in making rough theoretical estimates of well potentials.

Well fields are designed generally to obtain a specific quantity of water by the most economical method. Hydrologic and geologic data for the proposed sites are essential to the proper design of such fields. Consideration must be given to factors such as: (1) the available drawdown and specific capacity of individual wells in each sand; (2) proper spacing required between wells screened in the same aquifer in order to reduce the interference between wells; and (3) the possibility of constructing some wells in one aquifer and some in another.

Where waterbearing sands are relatively shallow, the available drawdown is often quite limited and much more water can be obtained from several properly spaced wells than could be obtained from a single well. On the other hand, the available drawdown is great enough in deep sands to increase the yield per well and thus to reduce the number of wells per field.

The construction of some of the wells in one aquifer and the remainder in a different aquifer has the advantage of eliminating interference effects between wells. This type of design minimizes the need for well spacing and reduces the cost of transmission lines required to carry water from wells to a central point for treatment or storage.

Drawdown of water levels due to heavy pumping at individual well fields tends to reduce the quantity of water available at adjacent sites in the County because it reduces the amount of available drawdown. Scalapino (1963, p. 26–32) has described interference effects which have occurred in a somewhat similar area due to the pumping of large quantities of water from the Carrizo Sand in Texas. Graphs of water levels in subsequent parts of this report show that current (1964) pumping from the Patapsco Formation is lowering water levels in wells several miles away from pumping sites. Water-level declines in distant observation wells have been on the order of a few tens of feet or less. In Prince Georges County serious consideration must be given to the impact proposed wells will have on existing wells.

AVAILABILITY OF GROUND WATER FROM GEOLOGIC UNITS

This investigation of the ground-water resources was devoted primarily to the major waterbearing units in the County. These are the Patuxent, Patapsco, Magothy, and Aquia Formations and the deposits of Pliocene(?) and Pleistocene age. In addition, small ground-water supplies are obtained at a few places from the Monmouth and Calvert Formations. Detailed information concerning the waterbearing properties of the minor aquifers is not available.

Study of the geologic data available for Prince Georges County shows that the waterbearing sands are rather unpredictable in their occurrence and distribution. Although each of the major aquifers has somewhat distinctive waterbearing characteristics, the sands themselves often vary considerably from one place in the County to another with respect to thickness, mineral content, and permeability.

In places some of the aquifers in the County are separated from one another by aquicludes. In other places the sands are separated by partial aquicludes and are, therefore, hydraulically connected. In such places, water may leak from one aquifer to another, when differences in hydrostatic pressures exist between them. Thus, the geology of the County is such that some aquifers function as relatively separate, simple, and individual systems, whereas other aquifers are interconnected and form very complex systems.

POTOMAC GROUP

In Prince Georges County, the Patuxent, Arundel, and Patapsco Formations comprise the Potomac Group. In the northern part of Prince Georges County, the lithologic character of the Arundel Clay is distinctive enough to simplify the problem of differentiating the three formations of the group. In the southern part of the County, however, and in the coastal plain portion of Fairfax County, Virginia, sands of the Patapsco and Patuxent Formations are much less abundant and the feasibility of differentiating the formations on the basis of lithology is greatly reduced. However, in order to simplify the discussions in this report, an effort was made to extend use of the names Patapsco and Patuxent Formations from the northern part of the County into the area south of the District of Columbia where justification for use of the names is admittedly weak. The structure map, figure 6, showing the top of the Patuxent Formation, is based on a somewhat arbitrary definition of the top of the formation. In some instances, such decisions were based on little more than the depth to the first good sand in the zone approximately 250 feet thick immediately overlying bedrock.

Patuxent Formation

The Patuxent Formation is a valuable source of ground water in the northern part of the County. It lacks good waterbearing sands in parts of the tidewater Potomac area and its water-yielding properties are poor in the Cheltenham area. However, the formation has not been explored in the southeastern part of the County and it is conceivable that fair waterbearing sands may occur there.

The Patuxent Formation is the source of water for most wells in the northwestern part of the County because it is the only Coastal Plain aquifer in that area. Preliminary tests indicate that downdip it can supply large quantities of water (up to 1500 gpm) to new residential developments in the Bowie-Belair area. The water supply at the Beltsville Agricultural Research Center which pumped an average of 0.6 mgd in 1963 has been obtained from the Patuxent Formation for many years. An average of approximately 3 mgd is obtained from the Patuxent Formation in the District of Columbia and Virginia areas west of Prince Georges County. The use of the formation as a source of water in the southeastern part of the area is limited by two factors: (1) relatively great depth to the formation—greater than 1100 feet below sea level, and (2) the apparent low transmissibilities of the sands. These two factors combine to increase the cost per gallon of water from the formation in this area and thus limit its potential as a source of water supply.

The outcrop area of the Patuxent Formation forms a somewhat irregular band approximately 4 to 5 miles wide east of the Fall line. It extends northeastward from Fort Belvoir in Fairfax County, Virginia, through Washington, D. C., to Baltimore. The total area of outcrop along a 34-mile reach between Fort Belvoir and Laurel (fig. 6) is about 110 square miles, of which about 40 square miles is in Prince Georges County. Thus, water in the form of precipitation is a source of much of the ground water available from the aquifer in Prince Georges County. Assuming that precipitation on the outcrop area recharges the aquifer at roughly 0.5 mgd per square mile, then the total potential ground-water recharge along the 110-square mile belt of outcrop is on the order of 55 mgd.

The Patuxent Formation is the oldest of the unconsolidated Coastal Plain

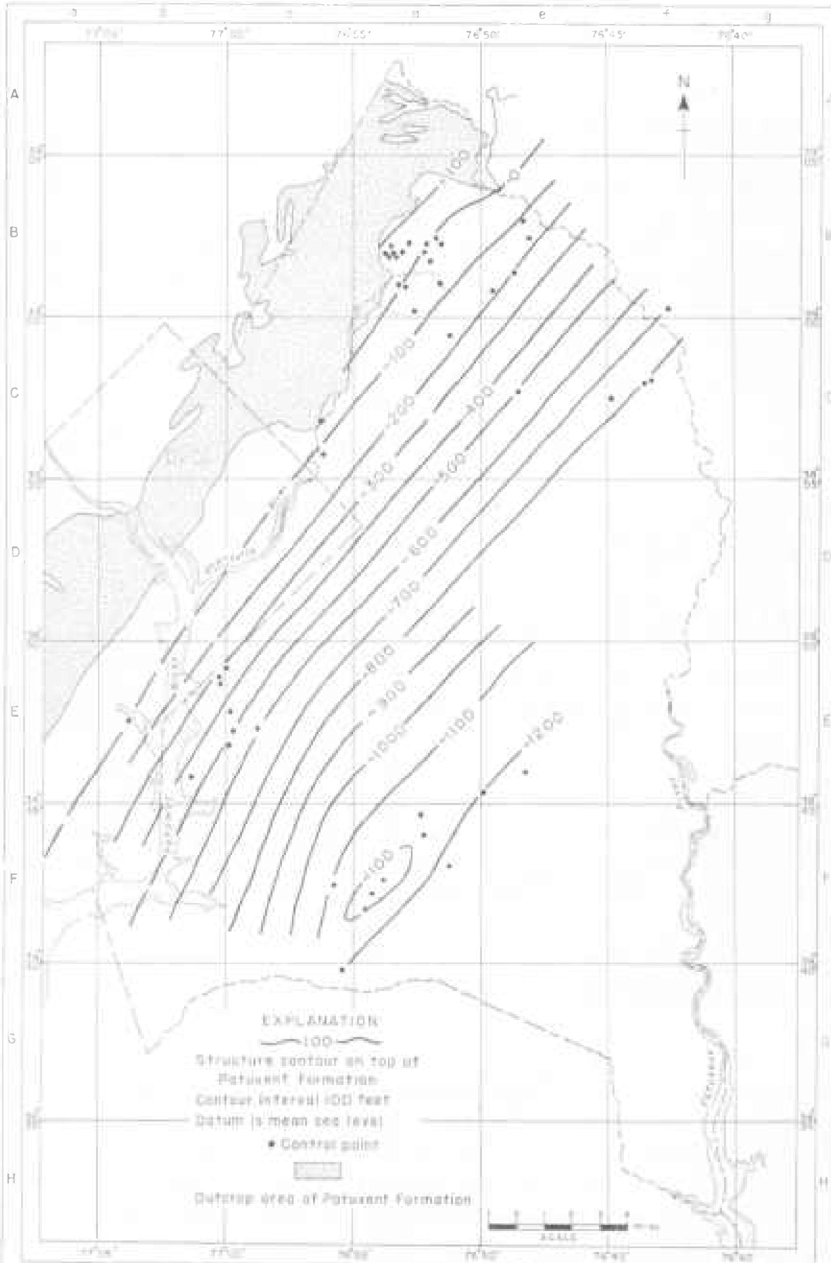


FIGURE 6. Map showing outcrop area and altitude of top of Patuxent Formation.

deposits in the County. It consists of layers of sand, sand and gravel, sandy clay, and clay. The sand and gravel commonly occur in one or two wide-spread sheet-like units which constitute the waterbearing part of the formation. Geologic sections show the nature of the Patuxent Formation as it occurs in the tidewater Potomac (D-D′ and E-E′, Plate 2), Bowie-Belair (F-F′, fig. 23), and Cheltenham (G-G′, fig. 30) areas. These sections reveal that individual sands in the Patuxent Formation are much thicker (about 100 feet) in the Bowie-Belair area than they are in the northern part of tidewater Potomac area or the Cheltenham area, where they are only 20 to 30 feet thick.

Evidence of the lateral extent and continuity of the sands from place to place is found in water-level data from several wells in the Patuxent Formation. In the Cheltenham area, large quantities of inert gases injected into a well tapping a sand in the Patuxent Formation caused water levels to rise as much as 109 feet in a well nearly 1 mile distant and 9 feet in a well 4.3 miles distant. In a well at Rosecroft Raceway, south of the District of Columbia line, water levels have been affected as much as 20 feet by changes in pumping at South Lawn almost 2 miles to the west.

Recharge to most waterbearing formations in the County occurs in two ways: (1) by leakage of water downward or upward into the formation through overlying or underlying formations; and (2) by movement downdip from topographically higher parts of the outcrop area of the formation. Some water may leak into the Patuxent Formation from overlying younger formations but the quantity received is probably relatively insignificant and is much smaller than the quantity being removed by pumping at the present time (1963). Recharge by downward leakage is greatly retarded in the case of the Patuxent Formation by the thick overlying Arundel Clay which tends to seal it hydrologically from downward percolating water.

Recharge by the second means, movement from areas of high hydraulic head in the outcrop belt, will probably be the most reliable source of replenishment of water pumped from the formation in future years.

The piezometric map of the Patuxent Formation (fig. 7) shows that hydraulic heads in the formation are as much as 150 feet above sea level in the outcrop area in the northern part of the County but that they are as low as 50 feet below sea level near the tidewater Potomac and more than 100 feet below sea level in the Virginia area just across the Potomac River from the Indian Head Highway. These data indicate that the direction of movement of water is from the recharge area where the outcrop is topographically high, north of the District of Columbia, to the area of heavy pumpage just south of the District boundary.

Observation well PG-Ad 8 at Laurel is a dug well in the outcrop area of the Patuxent Formation. It is 35 feet deep and its record of water levels shows a normal annual fluctuation and no noticeable net drawdown in the 15 years of record. The water levels in this well indicate that annual recharge to the Patuxent Formation is equal to the rate of discharge from the formation and that

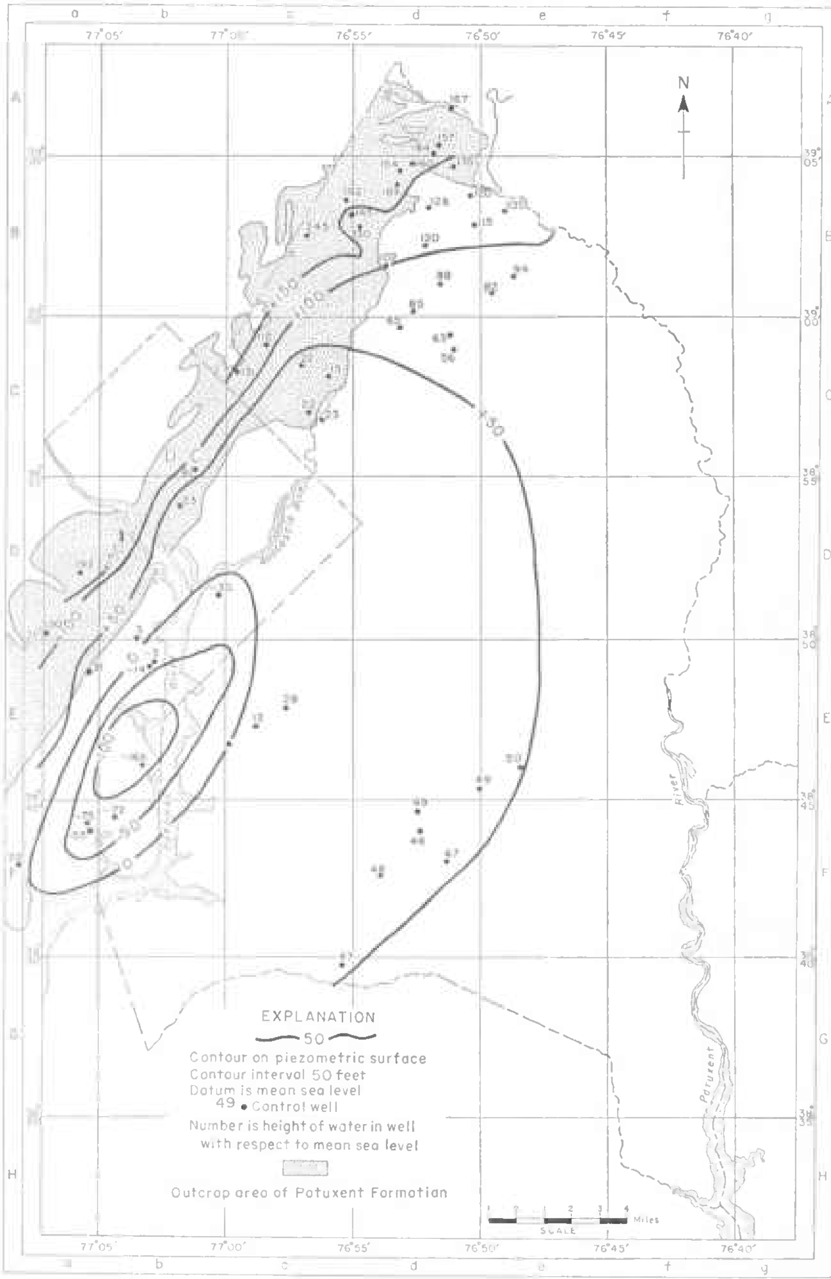


FIGURE 7. Map showing outcrop area and piezometric surface of Patuxent Formation.

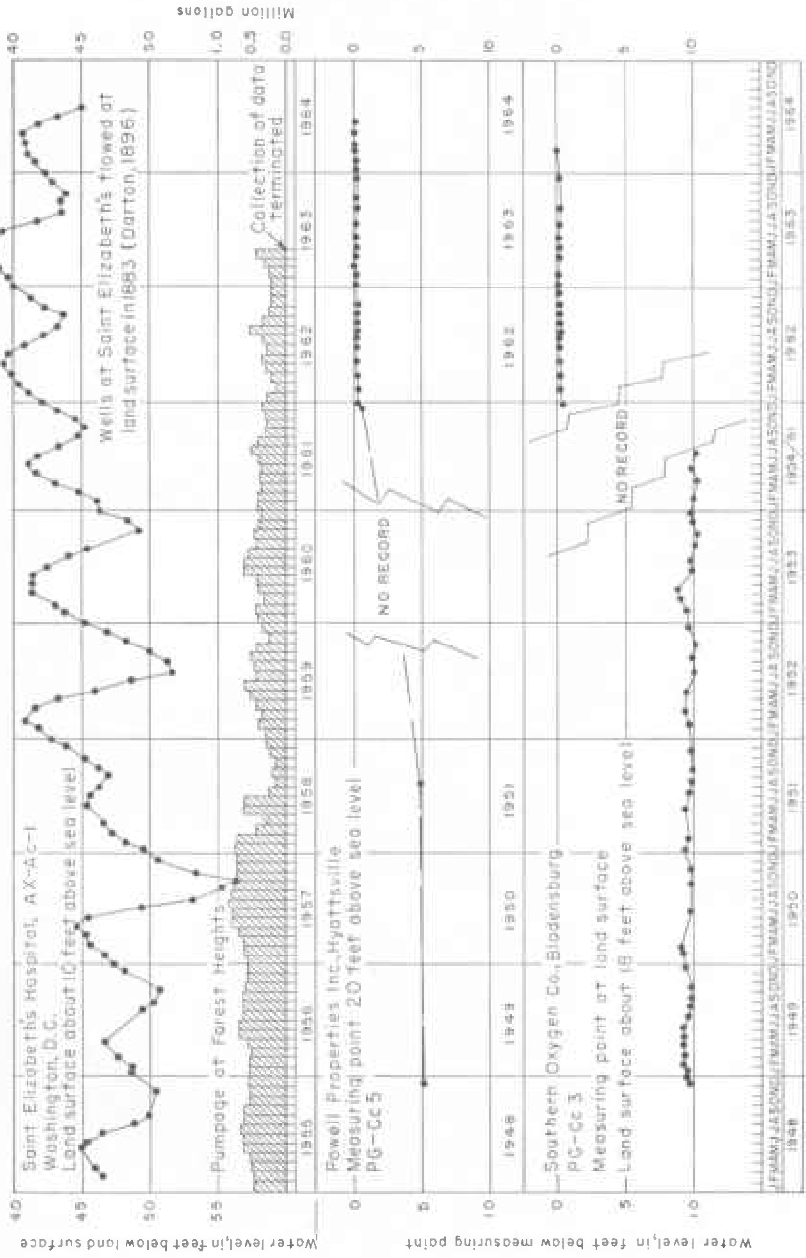


FIGURE 8. Hydrographs showing how water levels in the Patuxent Formation near Washington, D. C., have risen as a result of decreases in the rate of pumping.

TABLE 3

Transmissibility, Permeability, and Storage Coefficients of the Patuxent Formation

Location	Coefficient of Transmissibility (gpd/ft) T	Effective Sand Thickness (ft) M	Field Coefficient of Permeability (gpd/ft²) P_f	Coefficient of Storage S	Length of Drawdown Phase of Test (minutes)	Screen Position Referred to Sea Level (ft)	U.S.G.S. Well Number
Muirkirk-Mineral Pigments Corp.	600	12	50	0.0001	139	108 to 101	PG-Bd 33
						89 to 81	
Patuxent Wildlife Research Center	7,000	42	167	—	480	−140 to −150	PG-Be 22
Bladensburg-Southern Oxygen Co.	600	8+[1]	70	—	271	−139 to −147	PG-Cc 3
Bladensburg-Powell Properties Inc.	10,000	27	370	—	303	−102 to −132	PG-Cc 5
Engineering Research Co.	5,000[2]	15	330	—	—	−116 to −131	PG-Cc 31
Forest Heights	7,000	88	80	—	—	−255 to −260	PG-Eb 2
						−325 to −330	
						−499 to −504	
						−528 to −538	
						−578 to −583	
South Lawn	10,000	35	285	—	360	−446 to −476	PG-Ec 41
Kerby Hill	4,000	28	140	—	480	−506 to −526	PG-Ec 46
Brandywine-Moore #2	847	30	30	—	9,060	−1109 to −1139	PG-Fd 59
Bowie-Belair	9,000	125	80	—	4,320	−810 to −1052[3]	PG-Cf 64
	11,000	75	130	—	4,320	−763 to −838	PG-Cf 66
Kings Heights (Anne Arundel Co.)	15,000	40	380	—	1,110	−527 to −547	AA-Cc 78
	50,000	125	400		960	−674 to −694	
Crofton (Anne Arundel Co.)	20,000	110	180	—	5,810	−800 to −910	AA-Cc 86
Washington, D. C.	7,000	25	280	0.006	1,440	18 to −10	WW-Cc-37

Hains Point, D. C.	3,000	25	120	—	1,452	−88 to −113	WW-Cc-40
St. Elizabeth's Hospital, D. C.	15,000[2]	40	375	—	—	−345 to −387	AX-Ac-1
Virginia-Alexandria Mutual Ice Co.	20,000	40	500	—	6,000	−218 to −239	AX-Bb-2
Fairfax County, Va. Huntington Field	9,000	68	130	.0004	1,630	−171 to −176 −186 to −200 −271 to −286 −296 to −311	AX-Bb-9
Fort Belvoir, Va.	5,000	100	50	—	580	casing perforated from +90 to −80	BV-Ac-4

[1] Well did not reach bottom of aquifer but penetrated only the thickness shown.
[2] Determined from specific capacity.
[3] Twelve individual screens having a total length of 142 feet are positioned between these altitudes.

no net decrease in stored water has occurred, at least in the vicinity of the well. Thus, water has always been readily available in the outcrop area for recharge to the deeper artesian segments of the formation. Water levels in PG-Bd 17, a drilled well screened in the Patuxent Formation at the Beltsville Agricultural Research Center, show some decline in recent years. The decline is probably due to increased pumping at the Research Center.

Hydrographs in figure 8 show that water levels have risen in recent years in some parts of the Patuxent Formation. For example, water levels in the St. Elizabeth's Hospital well have risen as much as 5 feet in the past 10 years but they are still about 30 feet below sea level and well below the original static level. Water levels in well PG-Cc 5 at Bladensburg were about 5 feet below measuring point from 1948 to 1951, but in recent years have stabilized at about the measuring point. The measuring point in this well is about 20 feet above sea level. Water levels in PG-Cc 3 were about 10 feet below measuring point between 1948 and 1954 but have held at about the measuring point from 1962 to 1964. The rise in the levels is attributed to decreases in pumping from the Patuxent Formation in the Washington, D. C. and nearby areas where some well supplies have been abandoned in favor of water from public supplies derived from surface water sources.

The results of aquifer tests show that the coefficients of transmissibility of sands in the Patuxent Formation are generally low in Prince Georges County, ranging from 600 gpd per foot near Muirkirk to 10,000 gpd per foot near Bladensburg (table 3). Coefficients of storage range from 0.0001 to 0.006 and are in the range of artesian values. West of the Potomac River the maximum coefficient of transmissibility, 20,000 gpd per foot, was determined from a test on a well at the Mutual Ice Company in Alexandria, Virginia.

Figure 9 shows that the Patuxent Formation dips beneath the land surface toward the southeast from its outcrop belt in the northwestern part of the County. The formation is believed to function as a conduit capable of transmitting water downdip from its area of outcrop. As the quantity of water percolating through a given cross section of an aquifer is proportional to the hydraulic gradient and the coefficient of transmissibility, the quantity of water capable of moving through the aquifer can be computed for any segment of it using the following modified form of the Darcy equation (Ferris, 1949, p. 226):

$$Q = TIL$$

where:

Q = discharge or flow, in gallons per day

T = coefficient of transmissibility in gallons per day per foot

I = the hydraulic gradient, in feet per mile, assumed on the basis of water levels (hydraulic heads) lowered to the top of the formation

L = the length, in miles, of cross section through which the flow would occur.

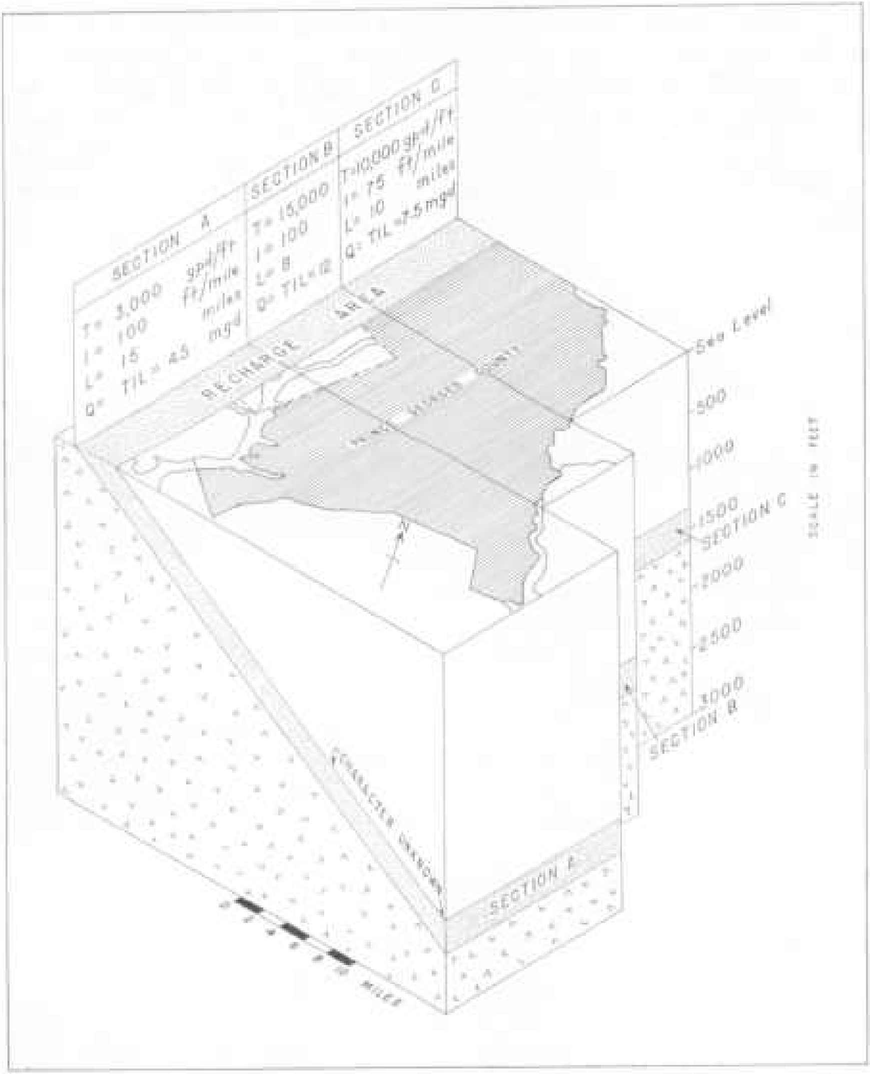


FIGURE 9. Block diagram showing how the Patuxent Formation functions as a conduit to transmit water southeastward from its recharge area.

Data obtained from aquifer tests in Prince Georges County and adjacent areas show that the coefficients of transmissibility of the sands in the Patuxent Formation range from less than 1,000 to more than 50,000 gpd per foot (table 3). The total length of 33 miles of recharge area in the County was divided arbitrarily into three segments, sections A, B, and C (fig. 9). The figure shows that the most permeable segment, section B, is in the central part of the County.

To use the formula $Q = TIL$ as a means of approximating the maximum possible theoretical flow through the aquifer, it is necessary to assume that it would be possible to lower water levels in the artesian part of the aquifer to the top of the aquifer. Such lowering is assumed to take place across a strip along the southeastern boundary of the County, parallel to the outcrop belt. Then the maximum theoretical rate of flow through each segment of the aquifer across the County would be:

$$Q = TIL$$

Section A: Q =	3,000 ×	100 ×	15 =	4.5 mgd
Section B: Q =	15,000 ×	100 ×	8 =	12.0 mgd
Section C: Q =	10,000 ×	75 ×	10 ×	7.5 mgd
Total Q			=	24 mgd

The preceding analysis, which would allow a maximum theoretical flow of 24 mgd through the Patuxent Formation, assumes: (1) the sands in the aquifer are hydraulically interconnected; (2) their transmissibility is essentially constant along the designated aquifer strip; and (3) water levels in the deeper portions of the aquifer can be lowered to a level sufficient to cause hydraulic gradients approximating those assumed. It is doubtful if any of the above assumptions can be completely or even partially fulfilled. Therefore the quantity of 24 mgd of water capable of being transmitted through the Patuxent Formation is an approximate theoretical limit. The actual quantity available from the aquifer in the County may be somewhat more or less than 24 mgd, depending in part on the extent to which the aquifer is pumped in adjacent areas and in part on the correctness of the estimated coefficients.

PATAPSCO FORMATION

The Patapsco Formation is lithologically similar to, but generally thicker than, the Patuxent Formation. More than 100 feet of waterbearing sands occur within the Patapsco Formation in the northeastern part of the area. However, these sands become progressively thinner and more clayey toward the southwestern part of the area. Geological data obtained by the Washington Gas Light Company in the Cheltenham area indicate that the Patapsco Formation includes some excellent waterbearing sands.

The outcrop area of the Patapsco Formation covers a belt which is approximately 7 miles wide in the northern part of the County and becomes progressively narrower southwestward toward Virginia (fig. 10). The maximum length of the formation across the recharge area parallel to the strike is about 34 miles. On an assumed recharge rate of 0.5 mgd per square mile, the total quantity of recharge on the outcrop area is on the order of 42 mgd.

Figure 10 shows that the water levels (piezometric surface) in the Patapsco Formation are highest in the northern part of the County and become pro-

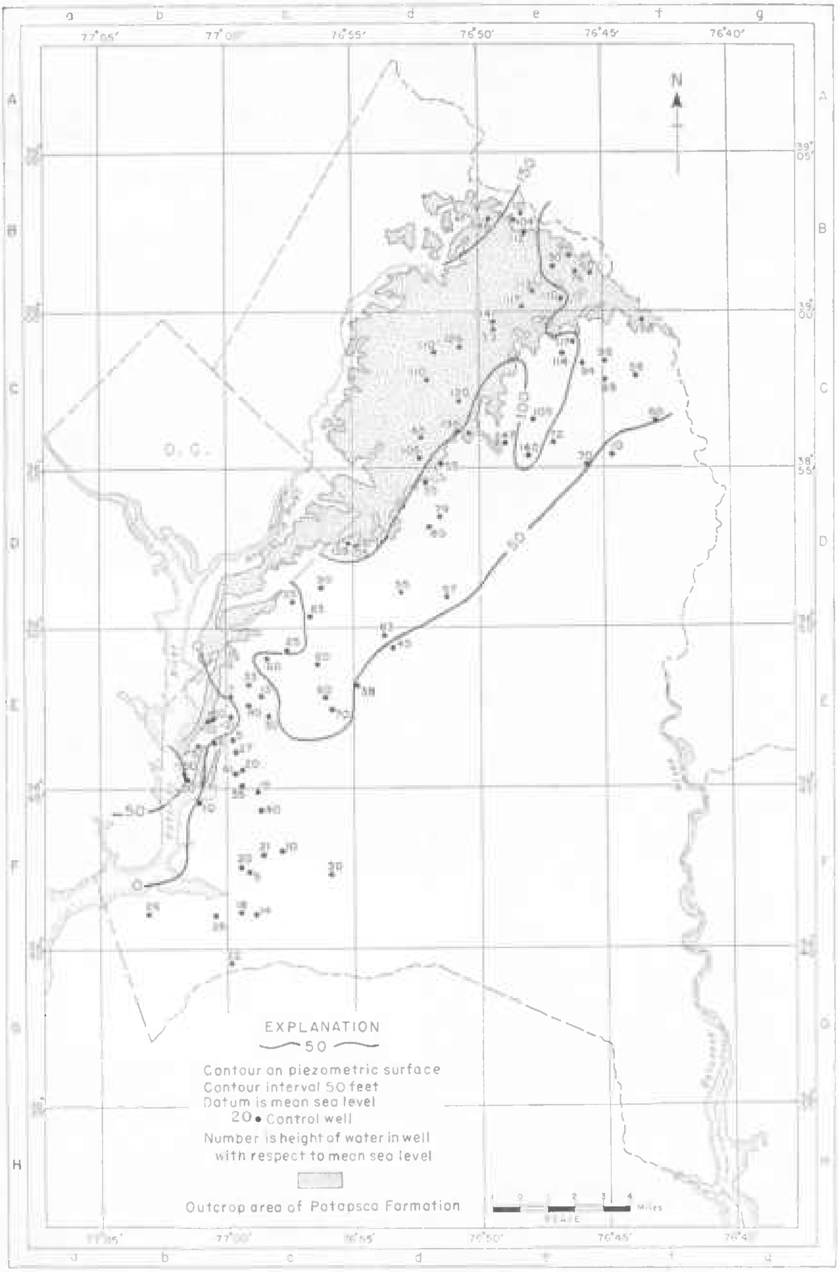


FIGURE 10. Map showing outcrop area and piezometric surface of Patapsco Formation.

TABLE 4

Transmissibility, Permeability, and Storage Coefficients of Sands in the Patapsco Formation

Location	Coefficient of transmissibility (gpd/ft) T	Effective sand thickness (ft) M	Field coefficient of permeability (gpd/ft²) P_f	Coefficient of storage S	Length of drawdown phase of test (minutes)	Screen position referred to sea level (ft)	U.S.G.S. well number
Woodmore School	300	10	30	—	720	−388 to −398	PG-Ce 39
Bowie-Belair	16,000	100	160	0.0003	13,680	−342 to −357	PG-Cf 32
					(9.5 days)	−383 to −398	
						−540 to −585	
Careybrook	1,300	>9	<144	—	480	−131 to −140	PG-Eb 7
Fort Foote	2,000[1]	20	100	—	120	−41 to −61	PG-Eb 20
Individual sands	2,000[1]	22	90	—	(not pumped)	−88 to −110	Do.
	4,000[1]	28	143	—	120	−196 to −221	Do.
	4,000[1]	40	100	—	120	−406 to −426	Do.
Permanent well	12,000	88	137	—	5,760	−88 to −108	PG-Eb 26
						−196 to −221	
						−397 to −427	
Accokeek School	1,500	>14	<107	—	300	—	PG-Fb 21
Berry Hill School	6,500	25	260	—	730	—	PG-Fc 31
Kings Heights	5,000	65	77	.00003	480	+31 to +16	AA-Cc 78
(Anne Arundel Co.)	30,000	80	—	—	1,080	−100 to −120	Do.
	20,000	40	500	—	1,080	−260 to −280	Do.
South Lawn	4,000	38	375	—	360	−64 to −89	PG-Ec 41
	2,000[2]	35	570	—	none	−182 to −197	PG-Ec 41
Oxon Hill Junior High School	1,200	31	40	—	420	−222 to −242	PG-Ec 43
Morningside	4,000[1]						

[1] Estimated from specific capacity data.

[2] Estimated on basis of driller's remarks.

gressively lower toward the south. Water levels are as much as 188 feet above sea level in the northern part and are about 50 feet below sea level in the southern part along the Potomac River near Fort Foote in the tidewater Potomac area. The low water levels along the Potomac River are due chiefly to the effect of pumping from the Patapsco Formation in the tidewater Potomac area and the Fairfax County area of Virginia.

Table 4 shows the coefficients of transmissibility, permeability, and storage of the sands in the Patapsco Formation. The coefficients of transmissibility range from 300 gpd per foot for a thin sand in the formation about 3.5 miles southwest of the Bowie-Belair area to 30,000 gpd per foot for a sand at Kings Heights in Anne Arundel County (4 miles northeast of the Prince Georges County line).

An estimate of the maximum amount of water the sands in the Patapsco Formation may be capable of transmitting downdip from their outcrop area was made by treating the formation as a conduit and using the average hydrologic properties determined by tests. The concept of the formation functioning as a conduit is shown graphically in figure 11. Using the modified form of the Darcy equation $Q = TIL$, and the assumptions used in the analysis of the Patuxent Formation, about 14 mgd of water could theoretically be transmitted downdip from the recharge area. The computations are:

$$Q = TIL$$

$$\begin{aligned}
\text{Section A: } Q &= 5{,}000 \times 65 \times 14 = 4.6 \text{ mgd} \\
\text{Section B: } Q &= 3{,}000 \times 60 \times 8 = 1.4 \text{ mgd} \\
\text{Section C: } Q &= 15{,}000 \times 50 \times 10 = 7.5 \text{ mgd} \\
\hline
\text{Total } Q &= 13.5 \text{ mgd} \\
&\quad \text{(approx. 14)}
\end{aligned}$$

It is unlikely that uniform gradients of a magnitude adequate to transmit this quantity of water could be created by wells pumping along the southern boundary of the County. Nevertheless, the quantity of 14 mgd is a theoretical upper limit of the rate of withdrawal of ground water from the formation on a sustained basis across the Country.

MAGOTHY FORMATION

The Magothy Formation is the source of water for several of the larger water supplies in the eastern and southeastern parts of the area. Sands within the formation are thickest and most permeable in the adjacent Annapolis area. They become progressively thinner toward the southwest, and they pinch out completely to the south in Charles County between Waldorf and LaPlata. Until recently, wells drilled only as deep as the Mathothy Formation have been capable of supplying the needs of users, and drilling to deeper aquifers was not necessary.

Figure 12 shows the altitude of the uppermost sand in the Magothy Forma-

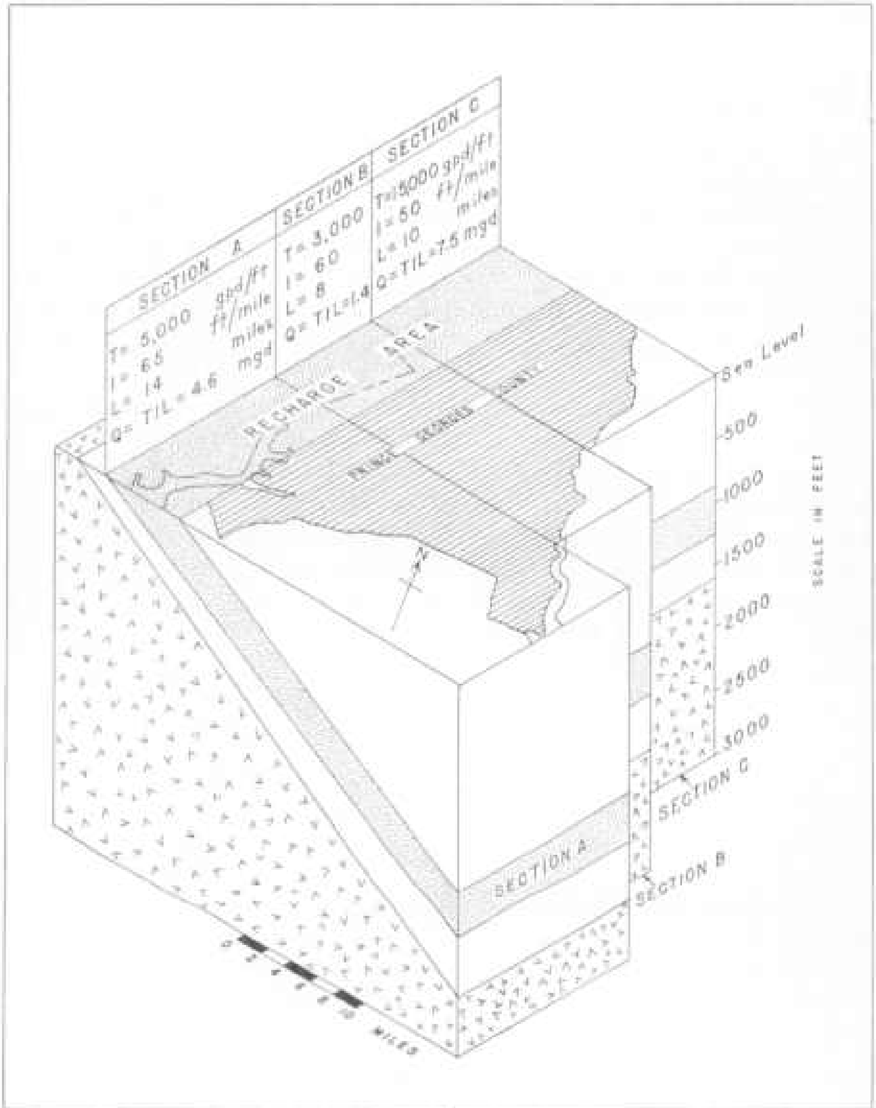


FIGURE 11. Block diagram showing how the Patapsco Formation functions as a conduit to transmit water southeastward from its recharge area.

tion, which crops out at the land surface only in the central and northeastern areas of the County. Younger formations overlap the Magothy in the southwestern area, thus covering the formation where it would otherwise outcrop. The area of the exposed part of the formation is about 22 square miles. Assuming an average rate of ground water recharge of 0.5 mgd per square mile, the

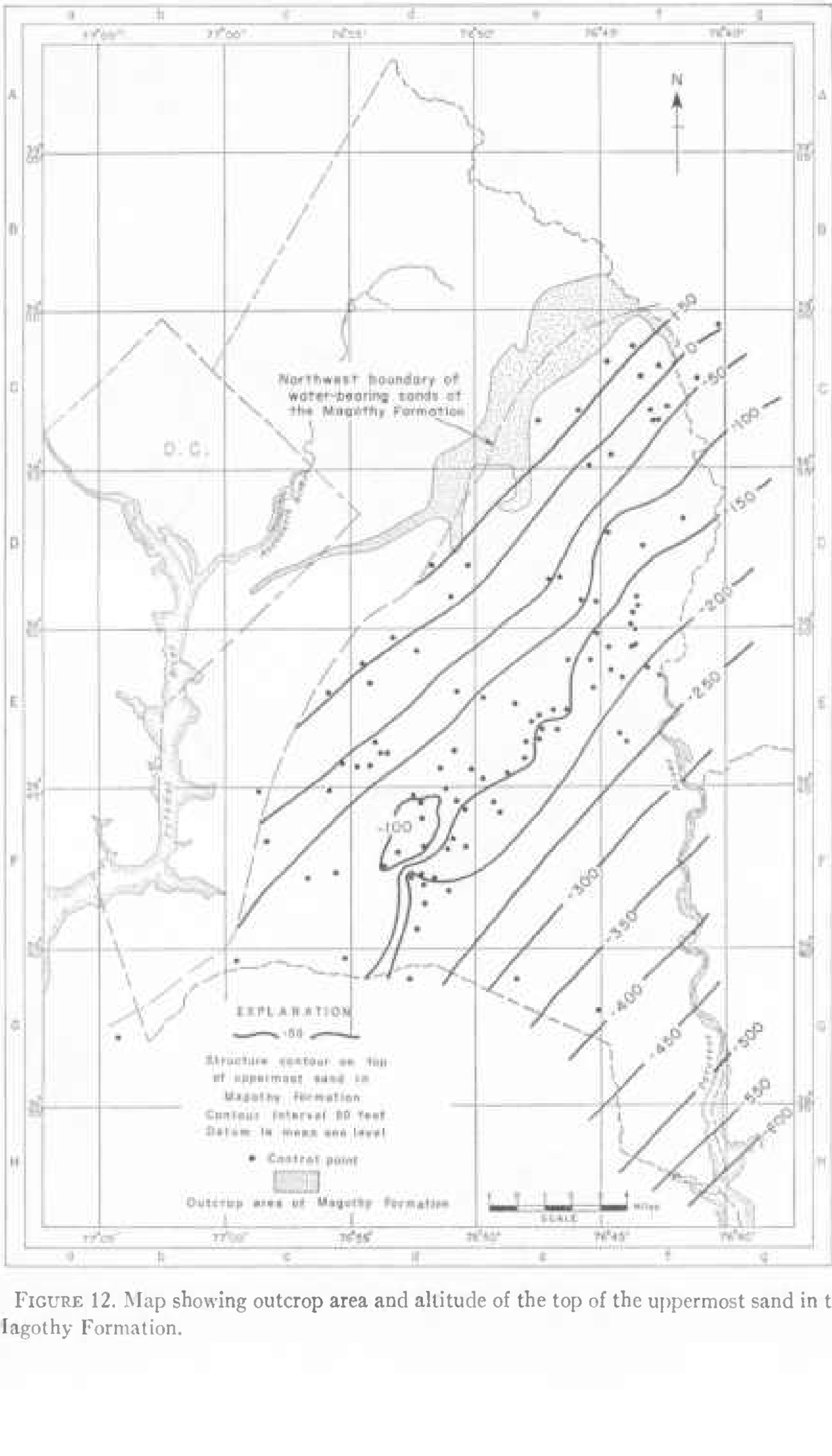


FIGURE 12. Map showing outcrop area and altitude of the top of the uppermost sand in the Magothy Formation.

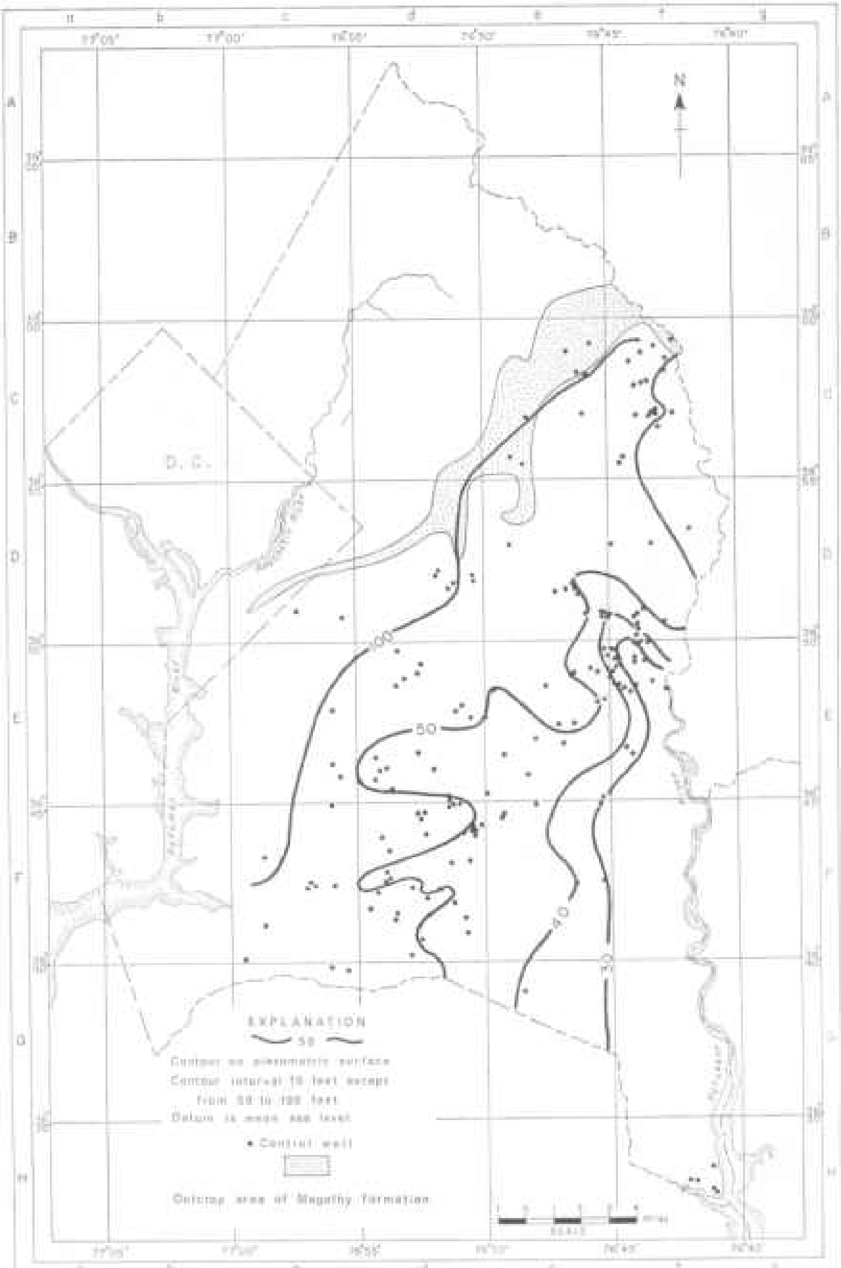


FIGURE 13. Map showing outcrop area and piezometric surface of Magothy Formation.

TABLE 5

Transmissibility, Permeability, and Storage Coefficients of Sands in the Magothy Formation

Location	Coefficient of transmissibility (gpd/ft) T	Effective sand thickness (ft) M	Field coefficient of permeability (gpd/ft²) P_f	Coefficient of storage S	Length of drawdown phase of test (minutes)	Screen position referred to sea level (ft)	U.S.G.S. well number
Bowie-Belair	18,000	90	200	0.0002	8640	−22 to −28 −82 to −88 −202 to −208	PG-Cf 33
Fairgrounds at Upper Marlboro	20,000	30+[1]	670	—	360	−195 to −203	PG-Ef 1
Brookwood	15,000	40	375	—	480	−157 to −167	PG-Ee 51
U. S. Naval Radio Sta. Cheltenham	11,000	50	220	.00014	775	−162 to −208	PG-Fd 11
Boys Village of Maryland	17,000	23+[1]	740	.00015	210	−180 to −201	PG-Fd 5
Brandwine Receiver Station	10,000	—	—	—	360	−130±	PG-Fd 63
Chalk Point PW 2	4,000	35	115	.0001	1440	−591 to −621	PG-Hf 26
Do. PW 3	6,000	40	150	—	1440	−595 to −617	PG-Hf 27
Do. PW 1	3,500	33	106	.00003	1440	−589 to −616	PG-Hf 28
Mattawoman; Charles County	17,000	66	258	—	—	−242 to −275 −281 to −307	Ch-Bf 127
Morningside Elementary School	7,000[2]	20+[1]	350	—	240	77 to 45	PG-Ed 41

[1] Well did not reach bottom of aquifer but penetrated only the thickness shown.
[2] Estimated from specific capacity data.

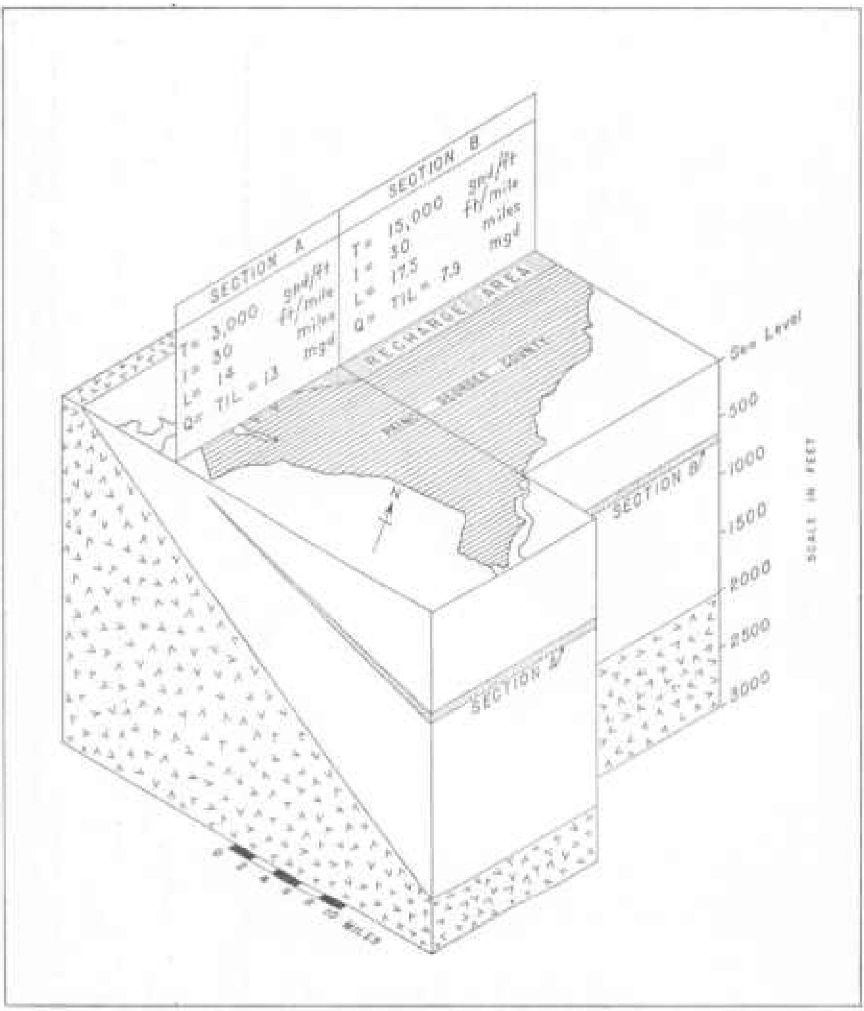


FIGURE 14. Block diagram showing how the Magothy Formation functions as a conduit to transmit water southeastward from its recharge area.

total quantity of water recharging the aquifer across the 18-mile outcrop belt is on the order of 11 mgd.

Figure 13 shows the piezometric surface in the sands in the Magothy Formation. Highest water levels are in the areas of outcrop which are highest topographically. The low water levels (artesian heads) in the vicinity of Upper Marlboro reflect in part the low topography in that area. The valley in which Upper Marlboro is located is a natural discharge area for ground water, where the water is leaking upward through overlying confining layers. Many Magothy

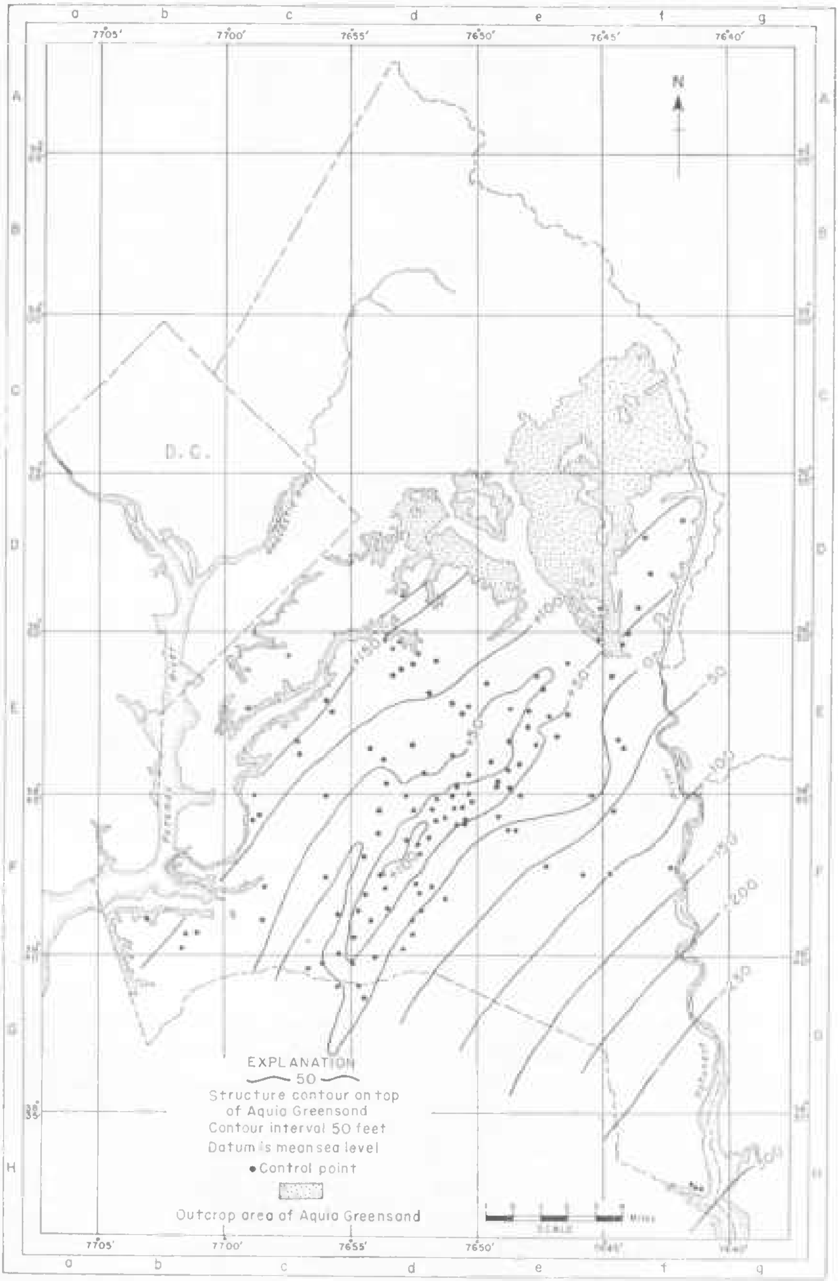


FIGURE 15. Map showing outcrop area and altitude of top of Aquia Greensand.

wells flow free in the area because the piezometric surface of the Magothy Formation is higher than the land surface.

Hydrologic coefficients for the sands in the Magothy have been determined by aquifer tests, which show that the coefficients of transmissibility range from 3,500 gpd per foot in the Chalk Point area to 20,000 gpd per foot in the Upper Marlboro area (table 5). Coefficients of storage, based on aquifer tests, range from 0.00003 to 0.0002.

Using the concept of the aquifer functioning as a conduit transmitting water downdip from its recharge area, the theoretical maximum rate of flow across a section of the aquifer normal to its outcrop area is about 9 mgd (fig. 14):

$$Q = TIL$$

Section A: $Q =$	$3{,}000 \times 30 \times 14$	$= 1.3$ mgd
Section B: $Q =$	$15{,}000 \times 30 \times 17.5$	$= 7.9$ mgd
Total Q		$= 9.2$ mgd

The practical limit of withdrawal from the sands in the Magothy Formation may be somewhat less than the theoretical limit, because of the difficulty inherent in creating the maximum hydraulic gradients and because the conduit analysis assumes that all the water moves downdip from the outcrop area. The conduit analysis does not take into account the water which would move laterally into the County from adjacent areas if heavy pumping were to occur along the County boundaries.

AQUIA GREENSAND

No large wells in the area were producing water from the Aquia Greensand in 1964. Data from test wells of the Potomac Electric Power Company at Chalk Point indicate that wells capable of yielding several hundred gallons per minute could be developed. Dug wells in the area of outcrop of the Aquia Greensand supply the needs of individual home owners. Records are available of only a few artesian wells in the Aquia Greensand. Geologic logs of some of these wells show the Aquia to be too clayey to be an aquifer in places.

Figure 15 shows the outcrop area and the altitude of the top of the Aquia Greensand. Detailed test drilling by the Washington Gas Light Company in the Brandywine area in the south-central part of the County revealed a domal structure with a closure of more than 50 feet.

A coefficient of transmissibility for the Aquia Greensand has been determined at only one site in the County, Chalk Point (table 6). Here the greensand is about 100 feet thick and has a transmissibility of about 4,000 gpd per foot. Therefore, the average permeability is about 40 gpd per square foot.

Water levels in the outcrop areas of the greensand are as high as 200 feet above sea level. The water levels become progressively lower toward the southeast. They are 19 to 20 feet above sea level at Chalk Point.

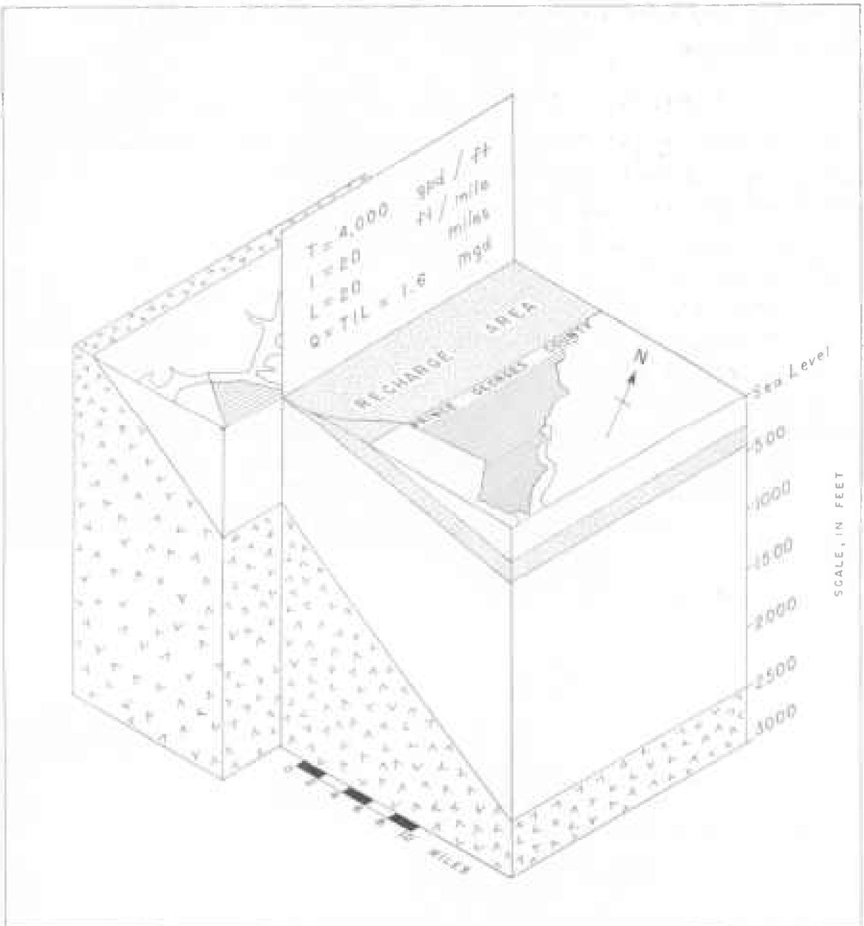


FIGURE 16. Block diagram showing how the Aquia Greensand functions as a conduit to transmit water southeastward from its recharge area.

Based on the concept of the Aquia Greensand functioning as a conduit transmitting water downdip from its recharge area, the theoretical maximum rate of flow across the section of the aquifer normal to its outcrop is about 1.6 mgd (fig. 16). However, this is based on a simplified and generalized analysis of the flow system of the aquifer.

NANJEMOY FORMATION

The Nanjemoy Formation is an important aquifer in Calvert and St. Marys Counties but it supplies water to only a few homes in the southern part of Prince Georges County. One estimate of the transmissibility of the Nanjemoy at the site of one of these wells was 800 gpd per foot. The formation has been tapped by wells at only a few places and is, at best, a poor or unreliable aquifer in the area of this report.

DEPOSITS OF PLIOCENE (?) AND PLEISTOCENE AGE

The Pliocene (?) and Pleistocene deposits are the most important source of domestic ground-water supplies in the County. Although the quantity of water withdrawn from each dug or driven well is relatively small, the total pumped from wells tapping these deposits is estimated to be about 3.5 mgd.

The deposits of Pleistocene and older (?) age have been classified (Bennett and Meyer, 1952, p. 68) into upland and lowland deposits. The upland deposits have been mapped in the Brandywine quadrangle by Hack (1955, plate 2). The extent of lowland deposits is shown on the geologic map of Prince Georges County (Cooke and Cloos, 1951). The upland deposits blanket much of the southern part of the County but where they are sufficiently permeable to yield large quantities of water, they are usually too well drained to store much water. Their saturated thickness ranges from 0 to perhaps 20 or more feet. Where only a few feet of the material is saturated the drawdown available to pumping wells is limited and yields are seldom large.

Lowland deposits occur along several streams and valleys. During the early phases of this study, it was thought that some permeable lowland deposits might occur along the upper Patuxent River at positions which would permit induced recharge of water from the river. To induce recharge from the river, it is

TABLE 6

TRANSMISSIBILITY, PERMEABILITY, AND STORAGE COEFFICIENTS OF THE AQUIA AND NANJEMOY FORMATIONS AND OF DEPOSITS OF PLIOCENE(?) AND PLEISTOCENE AGE

LOCATION AND AQUIFER	COEFFICIENT OF TRANSMISSIBILITY (GPD/FT) T	EFFECTIVE SAND THICKNESS (FT) M	FIELD COEFFICIENT OF PERMEABILITY (GPD/FT^2) P_f	COEFFICIENT OF STORAGE S	LENGTH OF DRAWDOWN PHASE OF TEST (MINUTES)	SCREEN POSITION REFERRED TO SEA LEVEL (FT)	U.S.G.S. WELL NUMBER
Chalk Point, Aquia Greensand	4,000	100	40	—	60	−404 to −409	PG-Hf 24
Eagle Harbor Nanjemoy Formation	800	—	—	—	[1]	—	PG-Hf 3
Aquasco Deposits of Pliocene(?) and Pleistocene age	30,000	20±	1,500	0.08	447	—	PG-Gf 24

[1] Test consisted of observing rate of recovery after stopping flow of water for 22 minutes.

FIGURE 17. Map showing location of geologic sections and areas of special interest in this report.

necessary that the permeable deposits occur at a significant depth below normal river stage. Wells in such circumstances might draw a large proportion of their water from the river if heavily pumped.

Several test holes were augered along the banks of the Patuxent River to delineate the lowland deposits. At all sites tested the base of the lowland deposits was near or a few feet above the water level in the river.

Lowland deposits are tapped effectively by wells at Aquasco Farm in the southeastern part of the County. There the deposits consist of permeable sands and gravels. Aquifer tests were carried out in these deposits and transmissibilities of the sands range from 13,000 to 70,000 gpd per foot. A value of 30,000 gpd per foot is used in table 6 as it is considered to be the most representative of the deposits as a whole.

AVAILABILITY OF GROUND WATER IN SELECTED AREAS

Ground-water conditions differ from one part of the County to another because the geology and hydrology differ. Four subareas, shown in figure 17, were designated for special study because demands for water are, or may become, critical in these areas. The accuracy of the estimates of the quantity of ground water available from each of the subareas depends on the amount and type of available data. In the Chalk Point area and the southern part of the tidewater Potomac area, estimates can be made of water available only from the thickness of sediments explored as of 1964. Few hydrologic data are available for aquifers below the Magothy in the Cheltenham area. Future drilling and testing will undoubtedly show that the quantity of water available in some areas is larger than the estimated quantities because additional waterbearing strata will be found at greater depths.

Hydraulic interference must be expected where wells in adjacent areas tap the same aquifer to the extent that the cones of depression or interference spread beyond the area.

The estimates of the quantities of water available from a specific area are based on water levels in 1963. The quantities will be less if and when water levels in the aquifers are lowered below the 1963 level. Because of uncertainties as to which areas will be developed first, no attempt is made to predict the amount of water that will be available in each area at the time it is developed.

One of the areas, Chalk Point, is sufficiently near a salt-water body to warrant concern about the intrusion of salt water from the Patuxent River. The availability of ground water in the tidewater part of this area may be limited more by the hazared of aquifer contamination than by the ability of the formations to transmit water. Generally, existing data are inadequate to evaluate properly the hazard of salt-water contamination.

TIDEWATER POTOMAC AREA

The tidewater Potomac area includes about 25 square miles of land within a rectangle about 3 miles wide along the east side of the Potomac River between Washington, D. C., and the southern boundary of Prince Georges County (fig. 17). The top of crystalline bedrock is relatively deep, and the unconsolidated Coastal Plain deposits range from 500 to 1,200 feet in thickness. Table 7 and figure 18 show that wells yielding up to 650 gpm have been constructed in the

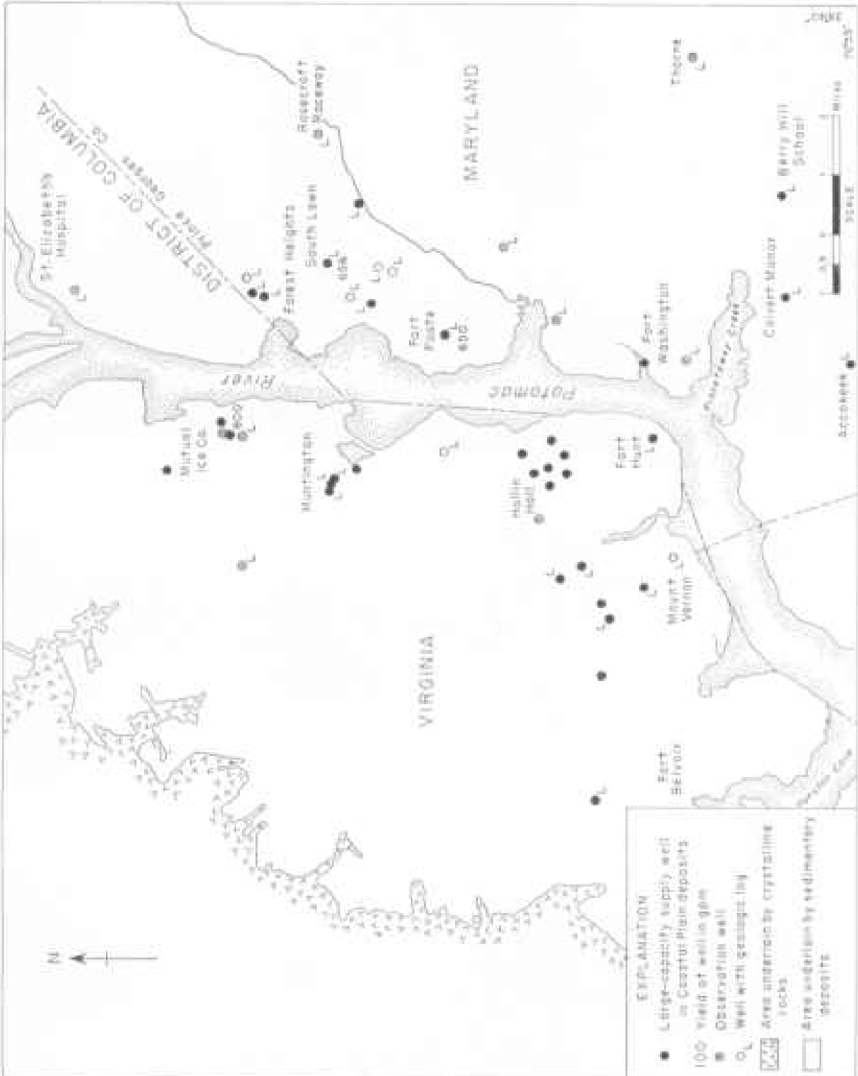


FIGURE 18. Map showing locations of selected high-capacity and observation wells in the tidewater Potomac area.

TABLE 7

DATA FOR HIGH-CAPACITY WELLS IN OR NEAR THE TIDEWATER POTOMAC AREA

U.S.G.S. WELL NUMBER	OWNER'S NAME AND DESIGNATION	ALTITUDE OF LAND SURFACE (FT)	DEPTH OF WELL (FT)	ALTITUDE OF SCREEN (FT)	ALTITUDE OF WATER LEVEL AND DATE OF MEAS. (FT)		YIELD (GPM)	SPECIFIC CAPACITY (GPM/FT OF DRAWDOWN)	AQUIFER
					Static	Pumping			
PG-Eb 1	Washington Suburban Sanitary Commission (Forest Heights—Prod. well no. 1, Oneida Way)	20	603	−337 to −357 −548 to −588	−69.12 (12/6/48)	−267 (9/—/47)	439 (9/—/47)	2.4	Potomac Group
PG-Eb 2	Washington Suburban Sanitary Commission (Forest Heights—Prod. well no. 2, Huron St)	20	630	−255 to −260 −325 to −330 −499 to −504 −528 to −538 −578 to −583	−82.00 (9/10/46) −83.20 (1/7/49)	−236 (9/10/46)	540 (9/10/46) 520[1] (4/—/60)	3.5	Do.
PG-Ec 42	Washington Suburban Sanitary Commission (South Lawn well)	179.5	656	−64 to −89 −182 to −197 −446 to −476	6.5 (10/17/60) −1.63 (4/3/62) −20 (10/10/63) 22.46 (5/4/64)	−72.5 (10/17/60) −80 (10/10/63)	760 (10/17/60) 305 (10/10/63)	10 4	Do.
PG-Eb 26	Washington Suburban Sanitary Commission (Fort Foote)	151	578	−88 to −108 −196 to −221 −397 to −427	9 (10/22/57)	−102 (10/22/57)	650 (10/22/57)	5.8	Do.
PG-Fb13	National Park Service (Fort Washington Park—Prod. well no. 7)	176	653	−399 to −442	21 (11/28/42) −16 (3/31/64)	−111 (11/28/42)	342 (11/28/42)	2.6	Do.[2]

PG-Fc 31	Prince Georges Co. Board of Education (Berry Hill Elementary School)	100	710	−576 to −581 −589 to −599	3.32 (10/11/62)	−23.63 (10/10/62)	120 (10/10/62)	4.5	Patapsco Fm.
AX-Ac-1	St. Elizabeths Hospital (Prod. well no. 1)	10	398	−345 to −365 −368 to −388	−35.06 (7/21/64)		1200 (5/21/36)	7[3]	Patuxent Fm.

[1] With free discharge.
[2] Sand is 42 feet thick.
[3] Estimated.

northern part of the area. These wells are part of the public supply system of the Washington Suburban Sanitary Commission. The highest specific capacity in the area was reported to be 10 gpm per foot of drawdown at the South Lawn well. The bottom of the deepest well screen is 607 feet below sea level in a sand in the Patuxent Formation. Most of the high-yielding wells are screened in more than one sand.

In 1963, an average of 2 mgd of ground water was pumped from the Patuxent and Patapsco Formations, the major aquifers in the area. This quantity is only a fraction of the total water used during that year, the remaining quantity being derived from surface water supplies of the Sanitary Commission. This study indicates that a few more million gallons per day may be available from ground-water sources but that the area probably could never economically supply its total water requirements with ground water.

Important considerations in estimating the availability of ground water in the tidewater Potomac area are: (1) yield capability of wells (well construction), (2) the character of the waterbearing sands with regard to their thickness, extent, and permeability and (3) the hydrostatic head of water in the sands.

The geologic and hydrologic conditions in the northern part of the area have been more thoroughly explored than those in the southern part. Test drilling and electric logging of the complete section of Coastal Plain deposits have been carried out at several sites north of Fort Foote by the Washington Suburban Sanitary Commission. In addition, short-term pumping tests have been carried out on individual waterbearing sands at several other sites.

The best information for the southern part of the area is from wells which penetrated only about half the total thickness of Coastal Plain sediments. One of these was a well drilled at Fort Washington Park for the U. S. Army during World War II. Table 7 shows that this well was drilled to 477 feet below sea level, screened in a sand from 399 to 442 feet, and had a specific capacity of 2.6 gpm per foot of drawdown at the end of a 49-hour test. Additional information is available from a well drilled for the Prince Georges County Board of Education at the Berry Hill Elementary School. Sands were tested here to depths as great as 618 feet below sea level; the well was screened in two sands, one from 548 to 589 feet below sea level and the other from 597 to 607 feet below sea level. The specific capacity obtained was 4.5 gpm per foot of drawdown after a 12-hour test.

CHARACTERISTICS OF SANDS

Sands capable of supplying the quantities of water needed by large water users are not abundant in the tidewater Potomac area. At some sites, the full thickness of Coastal Plain sediments contains no sand aquifers worthy of development for large supplies. At the best locality, three or four fair sands have been found in the combined Patuxent and Patapsco Formations. It is a common practice in this area to screen several sands of limited productivity in the same

TABLE 8

Summary of Data from Pumping Tests of Aquifers in the Tidewater Potomac Area

U.S.G.S. Well Number	Owner and Location	Altitude of Land Surface (ft)	Date of Test	Total Depth Drilled (ft)	Test No.	Altitude of Sand Tested (ft)	Altitude of Water Level (ft)			Yield (gpm)	Specific Capacity (gpm/ft of drawdown)
							Static	Pumping	Hours pumped		
PG-Eb 29	Washington Suburban Sanitary Commission (Forest Heights)	43	7/19/56	697	1	−101 to −121	−14	Approx. −93	7.5	200	2.8
			7/27/56		2	−225 to −245	−202[1]	−265	6	26	1.3
PG-Eb 20	Washington Suburban Sanitary Commission (Fort Foote)	151	10/3/56	828	1	−41 to −61	16	−39	2	50	.9
			—		—	−88 to −110	—	—	0	100 to 150[2]	—
			10/11/56		2	−194 to −227	−2		2	300	2
			10/24/56		3	−386 to −427	41	−169	2	230[3]	.7
PG-Ec 46	Washington Suburban Sanitary Commission (Kerby Hill Road)	71	9/20/60	804	1	−506 to −526	25	−139	8	285	1.7
PG-Eb 28	Washington Suburban Sanitary Commission (Oxon Hill Manor)	170	7/31/56	727	—	[4]	—	—	—	[4]	—
PG-Ec 43	Washington Suburban Sanitary Commission (Oxon Hill School)	109	3/24/60	843	1	−222 to −242	−21	−151	6	210	1.6
PG-Ec 41	Washington Suburban Sanitary Commission (South Lawn)	179.5	6/24/60	875	1	−48 to −86	30	−45	6	320	4.2
			7/27/60		2	−440 to −475	33	−20	6	275	5.2
PG-Ec 45	Fort Washington Estates, Inc.; well no. 2 (Friendly)	89	6/4/55	400	1	−286 to −301	14 −0.42 (5/6/64)	−94	?	300	2.4

[1] This static level apparently resulted from heavy pumping of wells PG-Eb 1 and Eb 2.
[2] Estimated by driller on basis of drill cuttings.
[3] Driller suggested that the screen may have been partially clogged, thus preventing the determination of the full capacity of the sand.
[4] No pumping test was run at this well because the driller's log showed no sand capable of yielding the required amount of water.

well with the hope that combined they will yield as much water as a single sand of high productivity.

Geologic section D-D′ (Plate 2) shows that the Coastal Plain deposits thin toward the west and that waterbearing sands cropping out on the west side of the Potomac River in Virginia are thin and few in number. Some of the sands are too clayey or too fine-grained to be aquifers. Where productive sands occur on the west side of the River they are heavily pumped. Therefore, the effect of such pumpage is to create a hydraulic boundary which limits the transmittal of ground water eastward across the Potomac River to Prince Georges County.

Geologic section E-E′ (Plate 2), extending from St. Elizabeth's Hospital in the District of Columbia southward to Accokeek in Prince Georges County, shows that several wells in the northern part of the area penetrated to bedrock. Wells in the northern part of the area also provide reliable data concerning the waterbearing properties of the Patuxent Formation. In the Fort Washington area and southward the well data for the Patuxent are less reliable. It is possible that deep test drilling might reveal the existence of productive waterbearing sands in the Patuxent Formation at Fort Washington.

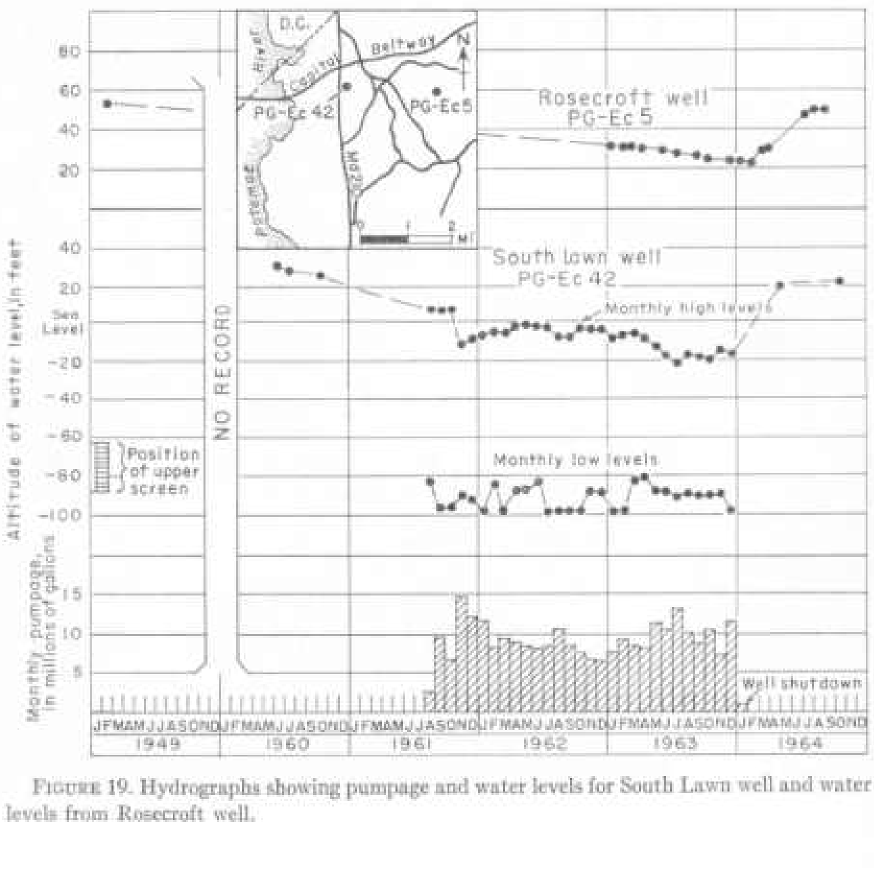


FIGURE 19. Hydrographs showing pumpage and water levels for South Lawn well and water levels from Rosecroft well.

Plate 2 also shows that individual sands within the Coastal Plain deposits are irregular in thickness, permeability, and extent. Table 8 presents data obtained during pumping tests on several of these sands. These data indicate that the highest specific capacity for a well in an individual sand is 5 and the average is around 2 gpm per foot of drawdown. The sands range in thickness from a few to about 50 feet and average 20 to 25 feet. They commonly pinch out completely in short distances. One of the problems which this study attempted to solve was the correlation of sands from well to well. Correlation of a particular sand in one well with a sand in another nearby well is often difficult. Data from the Fort Foote well indicate that there is no good waterbearing sand in the Patuxent Formation at that locality. However, productive sands are present in the Patuxent Formation in some nearby wells. Correlation of sands between wells has been made chiefly on the basis of water-level fluctuations caused by hydraulic interference between wells. For example, the sand screened in the well at Rosecroft Raceway (PG-Ec 5) has been correlated with the deepest sand screened in the South Lawn well (PG-Ec 42) by the way water levels in the Rosecroft well responded to the shutdown of the South Lawn well.

Figure 19 shows monthly high and low water-level readings and pumpage data for the South Lawn well. This well was pumped at a rate of about 0.3 mgd from late 1961 to early 1964, and then was shut down completely. Water levels which had been declining slowly in the Rosecroft well began to recover at a fairly rapid rate shortly after the South Lawn well was shut down. Other correlations of this type are mentioned in the following discussion of water levels.

WATER LEVELS

Piezometric maps for the Patuxent and Patapsco Formations (figs. 7 and 10) show that the water levels in these formations have been lowered substantially by pumping.

It is reasonable to assume that water levels in all the aquifers were above sea level prior to the start of heavy pumping several decades ago. In places in the tidewater Potomac area ground-water levels were several tens of feet below sea level in 1963 and 1964.

The extensive cone of depression in the piezometric surface of the Patuxent Formation (fig. 7) has resulted from heavy pumpage from at least four large well fields in the area; these are—Forest Heights, Maryland; St. Elizabeth's Hospital, District of Columbia; Mutual Ice Company, Alexandria, Virginia; and the Huntington field of the Fairfax County Water Authority, Virginia. The cone probably has been in existence since 1883 when St. Elizabeth's Hospital drilled its first well. According to Darton (1896, p. 157) the first well at St. Elizabeth's Hospital was sunk in 1883 to a depth of 350 feet. Water from the well flowed at the land surface at that time. All pumpage from wells at St. Elizabeth's was terminated about 1944 when the hospital began to obtain its water from the public water system of the District of Columbia. Figure 8 shows that the water level in one of the former production wells is now (1964) from 30 to 35 feet below sea level.

The shape of the cone changes as large production wells are turned on and off. For example, during summer months, when pumpage is high, water levels in observation wells near the main production wells of the Mutual Ice Company in Alexandria, Virginia, are as much as 105 feet below sea level, whereas water levels in the winter are as much as 20 feet above sea level.

Records of the Mutual Ice Company at Alexandria, Virginia, show that an 8-inch diameter well drilled there in 1913 yielded 800 gpm. Another well with a capacity of 300 gpm was drilled for the concern about 1922. Water from these wells is used extensively during the summer months for making ice. Figure 20 shows the hydrographs for two additional observation wells, Mutual Ice Company number 2 and Space Avionics number 1; the water levels in these wells show the effect of pumping from the Mutual Ice Company wells.

Three wells drilled in the period between 1947 and 1949 along the south side of Hunting Creek are supplying a large part of the ground water currently used by the Fairfax County Water Authority. Water levels in one of these wells AX-Bb-9, ranged from about 138 feet to 152 feet below sea level, depending on whether or not nearby wells were pumping.

Two wells drilled in 1945 and 1946 for the Washington Suburban Sanitary Commission at Forest Heights also take relatively large quantities of water from the basal sand in the Patuxent Formation. A cutback in the production from these wells in 1958 may account for the rise of about 5 feet seen on the hydrograph for the St. Elizabeth's well (fig. 8).

Hydrographs of the Thorne, Friendly Village, and Fort Washington wells (PG-Fc 17, -Ec 45, and -Fb 13) show progressively declining water levels since measurement of the water levels began (fig. 21). These wells are all completed in the Patapsco Formation and it seems probable that water levels in them are declining in response to the general increase in the rate of pumping from that formation in areas several miles distant. Water-level data from these wells also show that some sands are separate and hydrologically independent of other sands, as the water levels continued to decline in them even though the South Lawn well stopped pumping. This sustained decline must be due to pumping from some other source.

QUANTITATIVE ESTIMATES

Figure 22 summarizes the geologic, hydrologic, and chemical quality data for the strata in the northern part of the tidewater Potomac area (fig. 18). Geologic data for the southern part of the area are inadequate to use for a quantitative estimate of the ground-water potential of this segment. It is believed that the southern part may be less productive than the northern part.

Data for the geologic section in figure 22 were obtained from the test hole

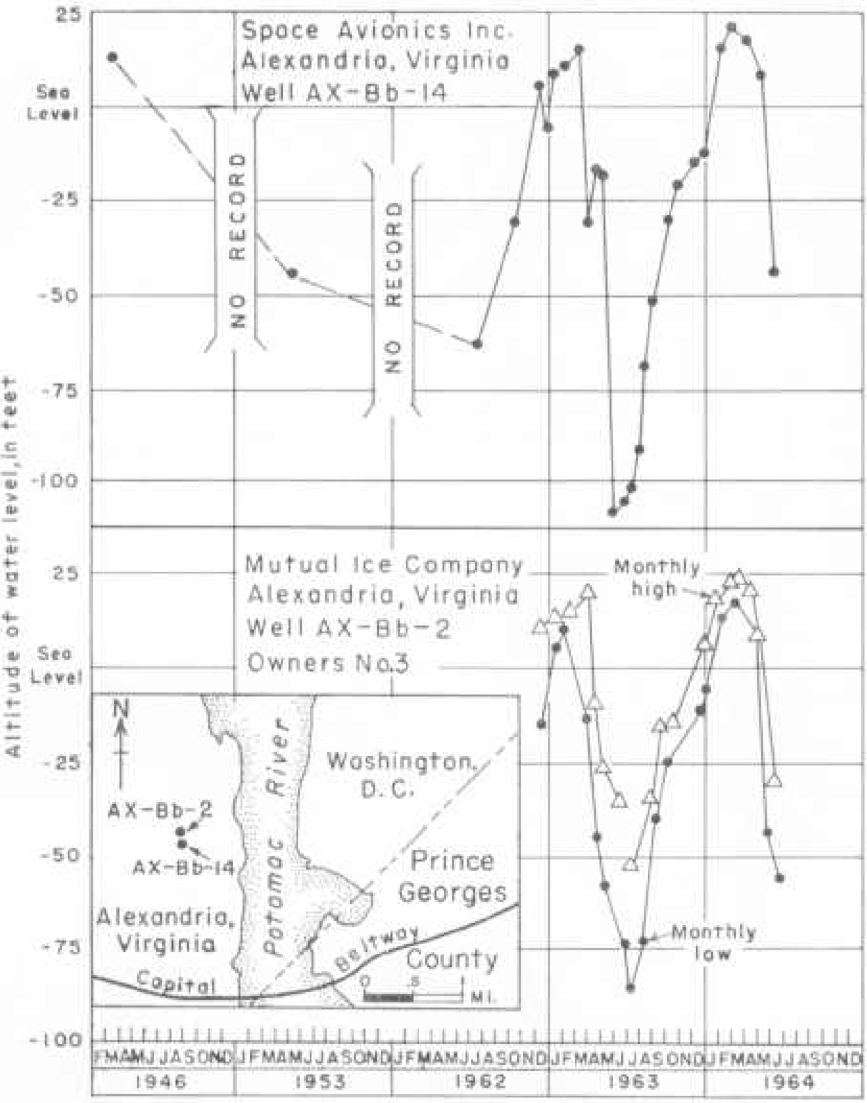


Figure 20. Hydrographs for two wells tapping the Patuxent Formation in the Alexandria, Virginia, area.

drilled at South Lawn by the Washington Suburban Sanitary Commission. Although the lithology changes somewhat from one well to another, the section indicates, in general, typical geologic conditions in the area. Figure 22 shows that ground water can be obtained from three sands in the area; two of these are in the Patapsco Formation at altitudes above −300 feet; the third sand is at the top of the Patuxent Formation at altitudes of −400 to −500 feet. A

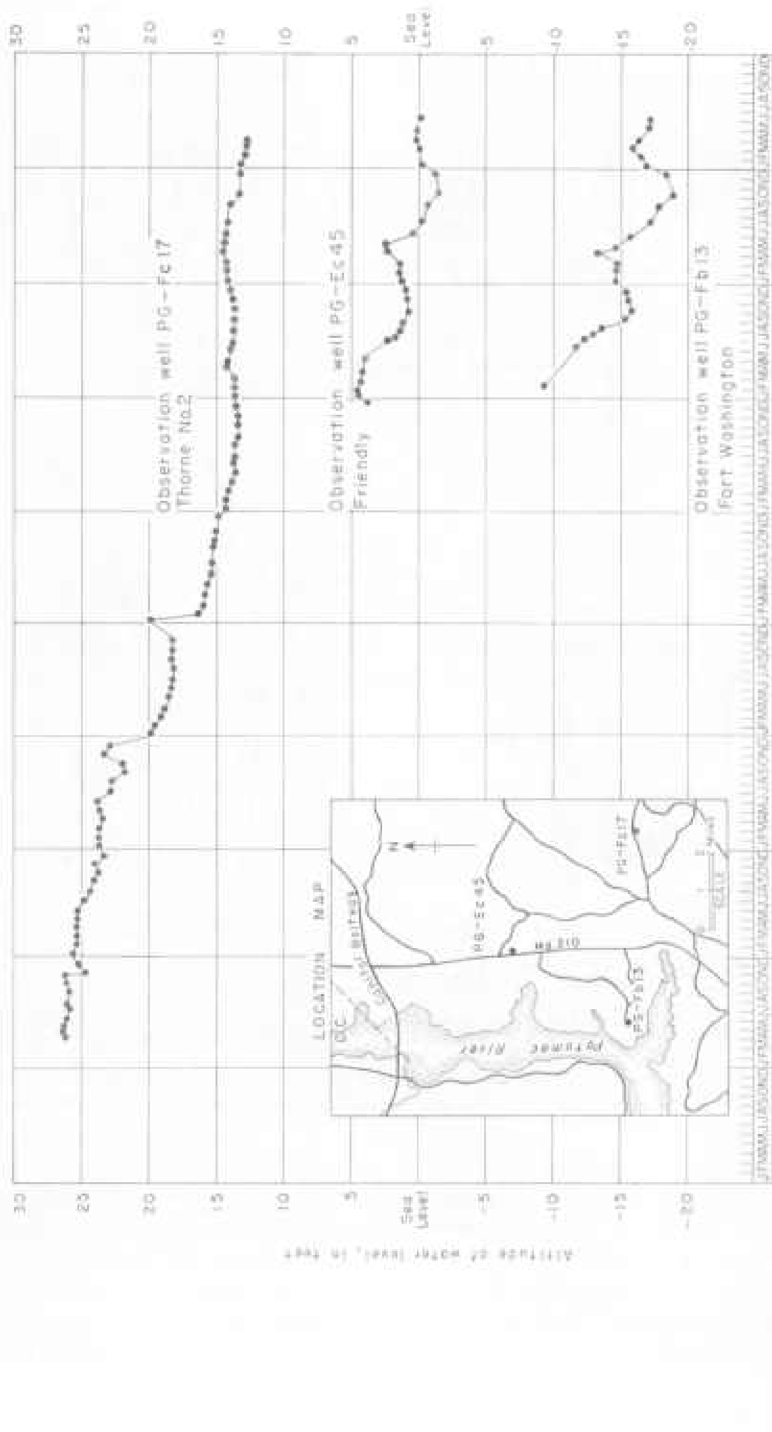
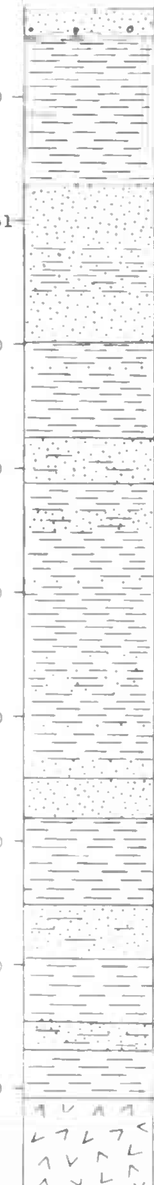
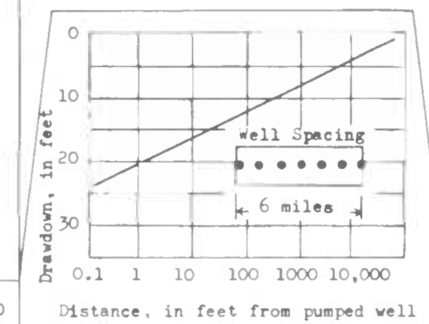
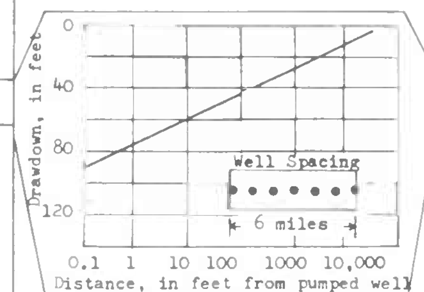
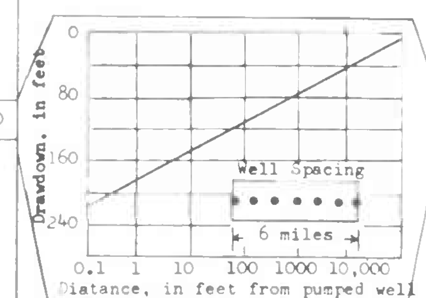


FIGURE 21. Hydrographs showing water levels in three wells in the Patapsco Formation in the tidewater Potomac area.

GEOHYDROLOGY				QUALITY OF WATER		QUANTITY OF WATER							
						DATA USED IN COMPUTATIONS							
						AQUIFER PROPERTIES		HYPOTHETICAL WELL FIELD					
Geologic unit	Position relative to sea level (ft)	Composite geologic section 1/	Aquifer or aquiclude	Number of analyses	Range in chemical constituents and properties of ground water (in ppm except for pH)	Transmissibility (gpd/ft)	Storage coefficient (S)	Available drawdown (ft)	Number of wells	Spacing between wells (ft)	Pumping rate per well (gpm)	Distance - drawdown graph for 1,000 days of pumping	Estimated quantity of water available (mgd)
Quaternary deposits													
Monmouth Formation	+100		Aquiclude										
Patapsco Formation and Arundel Clay	Sea level		Aquifer 2/	2 1 1 1	Iron (Fe) 0.38 - 0.8 Chloride (Cl) 2 Hardness as $CaCO_3$ 10 pH 7.8	4000	0.0001	50	7	5280	30	 	0.3
	-100		Aquiclude										
	-200		Aquifer	0	No data	2000	.0001	160	7	5280	55	 	0.7
	-300		Aquiclude										
Patuxent Formation	-400		Aquifer	2 1 1 1	Iron (Fe) 0.3 - 0.48 Chloride (Cl) 4.5 Hardness as $CaCO_3$ 2.0 pH 8.4	10,000	.0001	450	7	5280	640	 	4.5
	-500		Aquiclude										
			Aquifer 2/	1 1 1 1	Iron (Fe) 0.2 Chloride (Cl) 7.5 Hardness as $CaCO_3$) 1.0 pH 8.4								
	-600		Aquiclude										
			Aquifer 3/										
	-700		Aquiclude										
Crystalline rocks			Aquiclude										

1/ Based on log of well at South Lawn
2/ Untested
3/ No quantitative data available

FIGURE 22. Geologic, hydrologic, and chemical data used in estimating the availability and quality of ground water in the northern tidewater Potomac area.

fourth sand is present at some localities near the base of the Patuxent Formation; although a chemical analysis of the water is available, the sand is relatively thin at South Lawn and is not considered to be an important source of ground water.

An analysis was made of the quantity of ground water available in the northern tidewater Potomac area by assuming that a line of wells is located along the arbitrarily defined 6-mile extent of the area. The spacing of these wells would be at reasonable distances so that when pumping simultaneously (from the same aquifer) the resultant drawdown would be the limiting drawdown, or the drawdown of the water level approximately to the upper surface of the aquifer. A pumping period of 1,000 days was selected as it can be shown that by this time at least 95 percent of the drawdown in the aquifers will have occurred. The analysis is based on the preparation of a distance-drawdown graph for each aquifer, the selection of a realistic rate of pumping (640 gpm for the Patuxent Formation) and the computation of the mutual hydraulic interference of each well on the other wells in the aquifer system. For example, the self-drawdown of a single well tapping the upper sand in the Patuxent Formation would be about 190 feet. To this must be added 51 feet of additional drawdown caused by each adjacent well located 1 mile away; a well located 2 miles away will cause approximately 40 feet of additional drawdown in the first well and a well 3 miles away will cause 36 feet additional. Thus, by summing the drawdowns obtained and by using the distance-drawdown graph, it is possible to estimate the quantity of water which can be pumped by stabilizing the drawdown in the center well or wells at or just above the upper surface of the aquifer. The resulting total yield of the wells at the indicated spacing is considered to be the limit of withdrawal from that aquifer based on the hydrologic coefficients used. A similar analysis is applied to each of the aquifers. Of course, the well configuration used may be less efficient from the standpoint of costs of pipeline and pumping to a central treatment or storage facility.

The following is a summary of the quantities shown on the right side of figure 22:

AQUIFER	TOTAL THEORETICAL YIELD (MGD)
Patapsco Formation	
(sand from −50 to −90 feet)	0.3
(sand from −170 to −210)	.7
Patuxent Formation	
(upper sand)	4.5
Total (all aquifers)	5.5

The analysis above is based on certain assumptions concerning the geohydrology of the area; these are that the transmissibility of the aquifers is reasonably uniform and constant and the aquifers are of infinite extent—that the sands do not occur as isolated lenses of local extent in an impervious clay matrix. There is no evidence to show that such conditions do occur in the area. If a waterbearing sand did occur as an isolated lens and it were to be pumped heavily for a long period of time (for example—1,000 days), drawdowns in excess of those predicted would occur in the pumping wells and ultimately the yield of the wells would decline substantially.

BOWIE-BELAIR AREA

The Bowie-Belair area incudes about 8 square miles which are being developed from an agricultural area into a residential area by Levitt & Sons, Inc. The area is located in the northeastern part of the County near the Patuxent River (fig. 17).

Ground-water supplies have been developed to furnish the water requirements of the community. Extensive exploration in the form of test drilling, electric logging, and test pumping was carried out by the developer to be sure the required amount of water would be available. Four holes were drilled to bedrock to determine the complete thickness of Coastal Plain sediments and to determine the depth and character of the waterbearing sands (table 9). Three zones were found to be worthy of development. As a result production wells and observation wells were constructed in the two uppermost zones and pumping tests were carried out in them. The deepest zone is currently being tested and developed.

Geologic and hydrologic data from the tests were used to prepare the geologic section in fig. 23. The well data are summarized in table 9. Figure 23 shows that bedrock was encountered at about 1050 feet below sea level; that

TABLE 9

DATA FROM DEEP TEST HOLES IN BOWIE-BELAIR AREA[1]

U.S.G.S. WELL NUMBER	OWNER'S NAME AND DESIGNATION	DATE DRILLED	ALTITUDE OF LAND SURFACE (FT)	DEPTH DRILLED	ALTITUDE OF BASEMENT ROCK (FT)
PG-Cf 28	Levitt & Sons, Inc.; probe hole no. 2	7/31/58	114.4	1178	−1064
PG-Cf 29	Levitt & Sons, Inc.; probe hole no. 1	9/3/58	142.2	1165	−1023
PG-Cf 53	Levitt & Sons, Inc.; probe hole no. 3	8/22/62	114.4	1172	−1048
PG-Cf 65	Levitt & Sons, Inc.; probe hole no. 4	3/16/65	129	1176	−1047
AA-Cc 85	Crofton Corporation probe hole no. 1[2]	12/7/63	51	1069	−1013

[1] Electric logs, drillers' logs, and well cuttings were obtained from these tests.
[2] Gamma-ray log available.

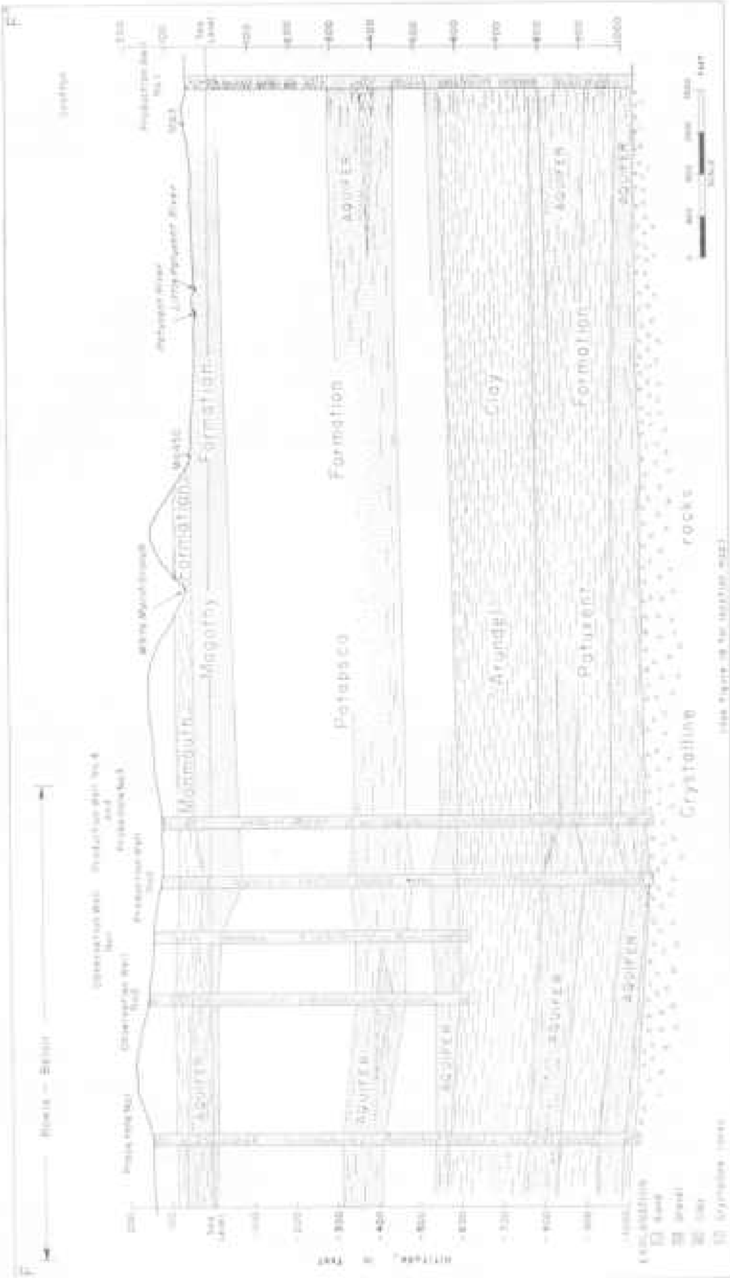


FIGURE 23. Geologic section (F-F') based on test drilling in the Bowie-Belair and Crofton areas.

the total thickness of the Coastal Plain sediments is about 1150 feet; and that three major waterbearing zones are present. These occur as: (1) a deep zone within the Patuxent Formation at altitudes ranging from −750 to −1050 feet, (2) a middle zone within the Patapsco Formation at altitudes of −300 to −600 feet, and (3) an upper zone within the Magothy Formation at altitudes ranging from 45 to −80 feet.

The Patuxent Formation ranges from 250 to 300 feet in thickness and the sands in it vary in thickness from one locality to another. An aquifer test in 1965 of a new production well, PG-Cf 64, tapping the Patuxent Formation shows the transmissibility to be 10,000 gpd per foot. When put into operation, this well will be pumped at a rate of 1500 gpm. The static water level in the well is about 65 feet above sea level and its specific capacity is about 5 gallons per minute per foot of drawdown. A second well to the Patuxent Formation was planned for a site approximately 0.5 mile west of this well. However, core samples and electric logs from the probe hole at the second location, PG-Cf 65, indicated that geologic conditions were not favorable for the development of large quantities of water. The site was therefore abandoned and current plans (1965) call for the completion of a production well at the location of probe hole number 1, well PG-Cf 29.

The transmissibility of the Patuxent Formation at Crofton, 3 miles to the northeast, is 20,000 gpd. A well, AA-Cc 86, developed in the Patuxent at Crofton has been tested at 2,000 gpm for brief periods of time. In 1964 this well had a static water level of 65 feet above sea level, and a specific capacity of about 12 gallons per minute per foot of drawdown.

Water levels are declining in the Patuxent Formation in this area. Hydrographs for the nearest observation wells in the formation are shown in figure 24. The Fort Meade and Kings Heights wells are about 6 and 7 miles respectively north of the Bowie-Belair field. Declines in the water levels in these wells prior to 1964 may be due to increased pumpage at Maryland City or Beltsville Agricultural Research Center. Declines after June 1964 may be due in part to pumpage at Crofton.

The Patapsco Formation is about 500 feet thick in the Bowie-Belair area. Nearly half of its total thickness consists of clay occurring in layers from a few inches to over a hundred feet thick. Three of the four deepest sands in the formation were tested in 1959 by Leggette, Brashears & Graham, consulting ground-water geologists for Levitt and Sons, Inc. The testing consisted of observing the drawdown in wells located 1,100 feet and 2,000 feet respectively, from Production well 2 (PG-Cf 32) while Production well 2 was pumped for $9\frac{1}{2}$ days at 1,230 gpm. The coefficients of transmissibility obtained from this test range from 14,000 to 17,000 gpd per foot and the storage coefficients range from 0.0003 to 0.0005.

Aquifer tests were made also on sands in the Magothy Formation and a transmissibility of 18,000 gpd per foot was determined. The storage coefficient

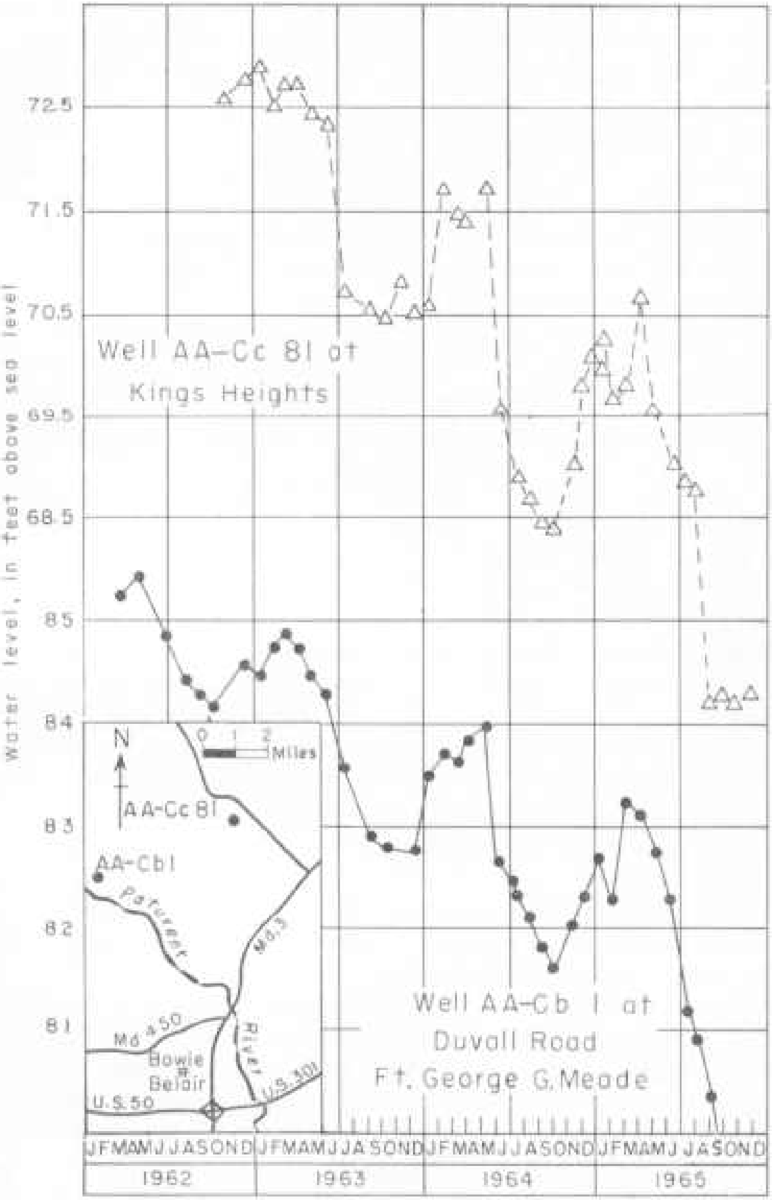


FIGURE 24. Hydrographs showing water level changes in observation wells in the Patuxent Formation near the Bowie-Belair area.

was 0.0002. Although the transmissibility of the Magothy Formation is greater than that of the Patapsco, the limited drawdown available in it—about 60 feet in the Bowie-Belair area, severely limits the amount of water available from the aquifer.

During the aquifer tests in 1959, a test was made to determine whether or not the Magothy Formation had any hydrologic connection with the sands in the Patapsco Formation. The test consisted of observing water levels in well PW2 (PG-Cf 32) while well PW 1 (PG-Cf 33) was being pumped, and observing PW 1 while PW 2 was being pumped. No evidence of a hydrologic connection was found as a result of this short-term testing.

Three wells capable of a combined yield of about 5 mgd are currently (1964) supplying the Bowie-Belair area. Table 10 summarizes the data for these wells. About 80 per cent of the total water is pumped from the two wells in the Patapsco Formation and the other 20 percent is from well (PG-Cf 33) in the Magothy Formation.

Wells PW 2 and PW 3 yield water from the Patapsco Formation. PW 2 is equipped with two submersible pumps, each with a 1,100 gpm capacity. Well PW 3 produces about 1,200 gpm using a single submersible pump. During a test in May 1963, these two wells were pumped simultaneously for 48 hours at a combined rate of 4.15 mgd.

One of the primary objectives of this study was to verify the reliability of the aquifers as sources of water for Bowie-Belair by observing the ground water systems in operation. Under ideal conditions, the water levels in the aquifers should stabilize when the pumping rate becomes constant and the cone of depression reaches an adequate source of recharge. Once this condition is established, no more water would have to be taken from storage and the water pumped would be replaced by water from precipitation at the recharge area. Under the worst conditions, where a sand aquifer occurs as a lense surrounded by clay, the cone of depression would reach barriers in all directions after a period of extended pumping. The water levels would continue to fall until all water was removed from storage.

Knowledge of the ground-water system in operation is based on the collection and analysis of water-level and pumpage records for wells tapping both the Magothy and the Patapsco Formations. The earliest data were obtained in 1959 at Bowie-Belair. These data show the continual increase in pumpage resulting from the increase in population. Seasonal variations in water use from winter to summer are noticeable. Observations of water-level fluctuations in the Patapsco Formation were made in wells PG-Cf 32, PG-Cf 35, and PG-Cf 44. Observations of water levels in the Magothy Formation were made in PG-Cf 33, PG-Cf 30, and PG-Cf 6.

Water levels in the Patapsco Formation are shown in figure 25, a hydrograph correlating pumpage from PG-Cf 32 and PG-Cf 35 with recovering water levels in PG-Cf 32 and monthly low water levels in PG-Cf 44. Well PG-Cf 44 is lo-

TABLE 10

Data for High-Capacity Wells in or Near the Bowie-Belair Area

U.S.G.S. Well Number	Owner's Name and Designation	Altitude of Land Surface (ft)	Depth (ft)	Altitude of Screen (ft)	Altitude of Water Level and Date of Measurement (ft)		Yield (gpm)	Specific Capacity (gpm/ft of drawdown)	Aquifer
					Static	Pumping			
PG-Cf 32	Levitt & Sons, Inc. Prod. well no. 2 (1959)	115.7	700	−342 to −357 −383 to −398 −540 to −585	62.99 (7/26/61)	−133.3[1] (4/12/62)	2160 (4/12/62)	11	Patapsco Fm.
PG-Cf 33	Levitt & Sons, Inc. Prod. well no. 1 (1959)	115.7	192	5 to −75	60.30 (7/26/61)	9.7[1]	600 (4/12/62)	12	Magothy Fm.
PG-Cf 35	Levitt & Sons, Inc. Prod. well no. 3 (1961)	147.5	733	−356 to −391 −443 to −469 −501 to −509 −559 to −586	59.21 (3/9/62)	−221.05[2]	988 (5/24/63)	3.4	Patapsco Fm.
PG-Cf 64	Levitt & Sons, Inc. Prod. well no. 4 (1965)	114	1169	−810 to −1052[3]	60 (11/27/64)	−112.5[2]	1104	6.4	Patuxent Fm.
PG-Cf 66	Levitt & Sons, Inc. Prod. well no. 5	142	980	−763 to −838	54.02 (11/1/65)	−82.30[2] (11/4/65)	1040	7.6	Patuxent Fm.
AA-Cc 86	Crofton Corp. Prod. well no. 1 (1964)	51	960	−800 to −910	65 (7/24/64)	−2 (6/2/64)	825	12	Patuxent Fm.

[1] After pumping 52 hours.
[2] After pumping 72 hours.
[3] Twelve individual screens having a total length of 142 feet were placed between these altitudes.

cated at the Bowie-Belair sewage treatment plant, about 10,000 feet north of the well field.

Figure 26 is a hydrograph showing the effect which pumping from the shallow production well in the Magothy Formation had on water levels in well PG-Cf 6, a well screened in the same sand at a distance of 7,000 feet. Examination of this hydrograph shows that water level declines can be matched with pumpage increases. For example, increased pumping during the period May 3 to May 13, 1963, caused a significant decline in water levels. Furthermore, the water level rose about 0.75 foot during the period April 1 to April 12, 1963, during a period when there was virtually no pumpage from the shallow well.

Figure 27 shows water levels since 1961 in three wells screened in the Magothy Formation. An earlier measurement of 60 feet above sea level, made in well PG-Cf 6, was made in 1949 during a previous study (Meyer 1952). During the 12-year period between the 1949 measurement and 1961 the water level apparently declined about 5 feet due to pumping of the aquifer by nearby wells of small capacity. The hydrograph for well PG-Cf 30 (also in fig. 27) was prepared from records of a continuous water-level recorder installed on that well. Monthly high and low readings shown on the graph indicate a range of 7 to 10 feet between highest water levels and lowest levels measured when well PW 1 was operating. The hydrograph for AA-Dc 13 (fig. 27 also) shows water levels in a well 2.2 miles to the east, separated from well PW 1 by the Patuxent River. The altitude of the water level in well AA-Dc 13 is about 25 feet lower than the level in PG-Cf 6.

Figure 28 presents geologic, hydrologic, and chemical quality data used to evaluate the ground-water resources of the Bowie-Belair area. In order to appraise the quantity of ground water available, a distance-drawdown graph was prepared, based on computations using the Theis equation, for each of the three aquifers, the Magothy, Patapsco, and Patuxent Formations. The analysis is based on the use of a reasonable spacing of a line of wells tapping each aquifer and an optimum pumping rate wherein the resultant drawdown in all the wells in the aquifer, pumping continually at the specified rate, will not exceed the limiting pumping level (potential drawdown) at the upper surface of the aquifer. For example, at the end of 1,000 days of pumping at a rate of 1,650 gpm, a single well in the Patapsco Formation having a radius of 1 foot will have a self-drawdown of 250 feet. If this well were the middle well of three wells spaced 6,000 feet apart, it would be affected by an additional increment of drawdown of about 55 feet from each of two adjacent wells. Thus, the ultimate drawdown in the well would be 360 feet or about at the top of the aquifer. The three wells, pumping continuously, would yield 4,950 gpm, or 7.1 mgd. This quantity is, therefore, shown in the right-hand column of Figure 28.

The analysis above assumes that no vertical leakage will occur between formations, that the hydraulic coefficients are correct, and that the geohydrologic conditions in the aquifer are reasonably uniform. The analysis of the Patuxent

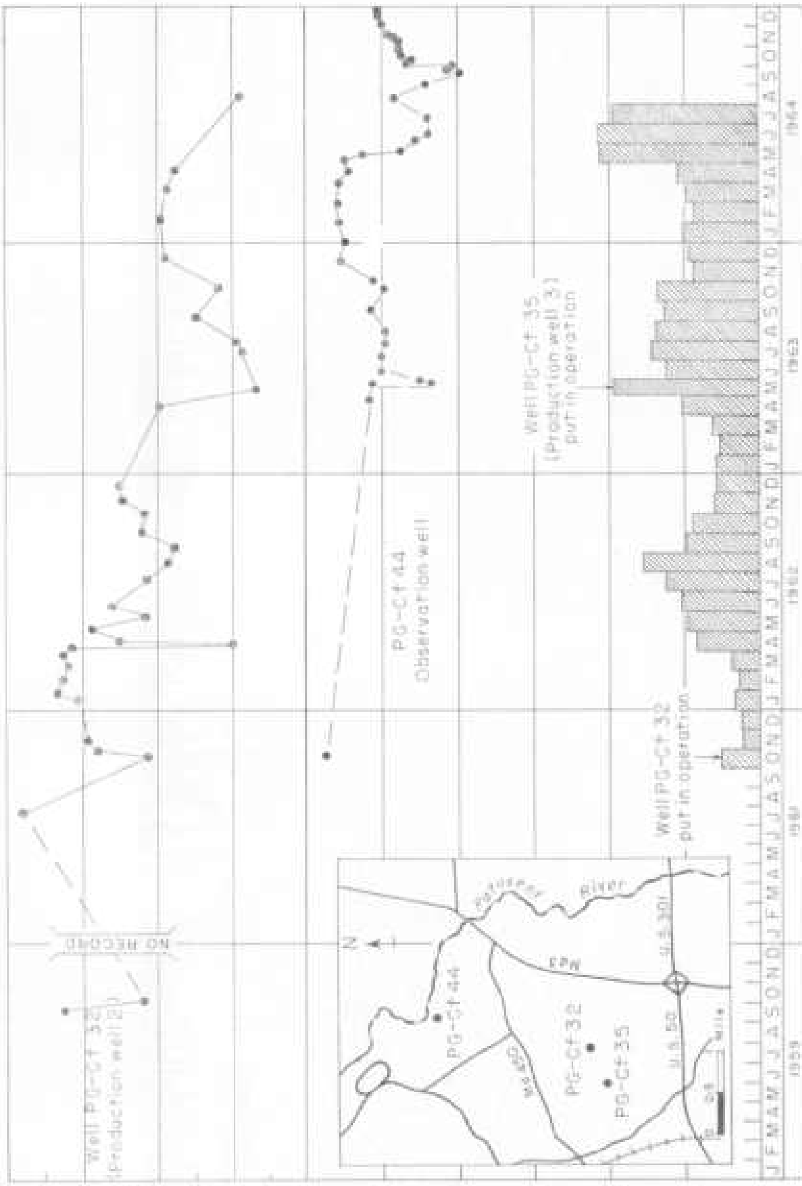


FIGURE 25. Water levels and pumpage from the Patapsco Formation in the Bowie-Belair area from 1959 through 1964.

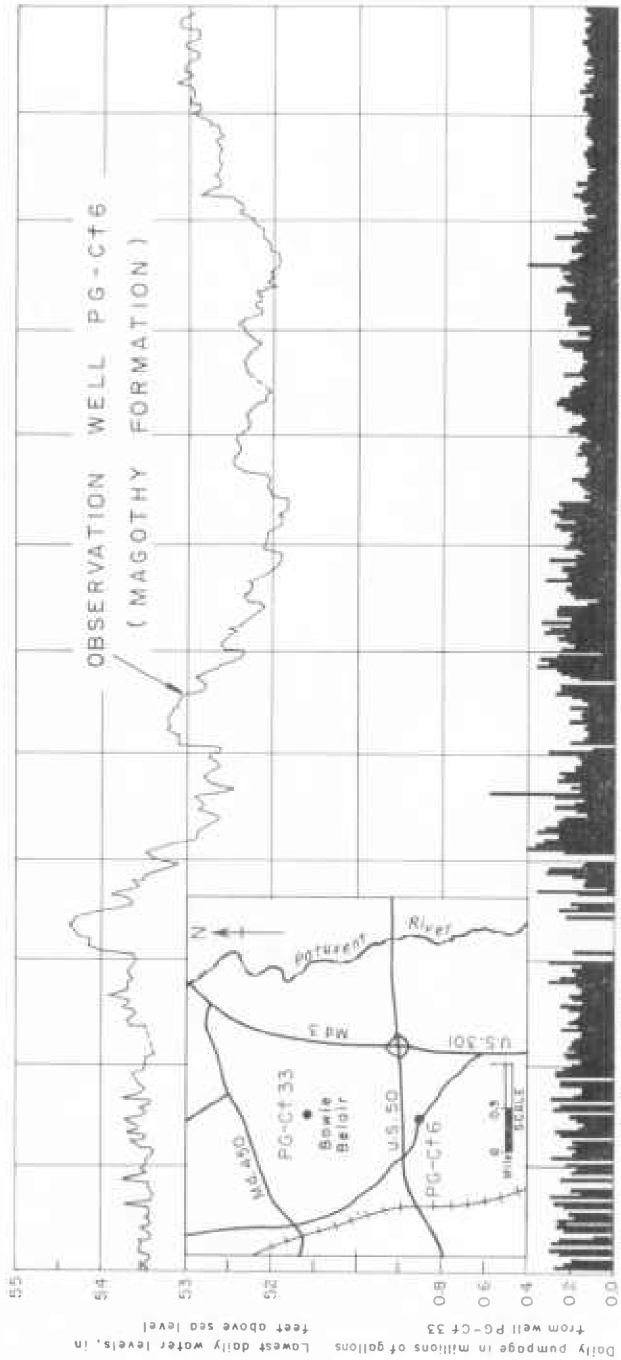


FIGURE 26. Daily water levels in an observation well and pumpage from the Magothy Formation in the Bowie-Belair area during 1963.

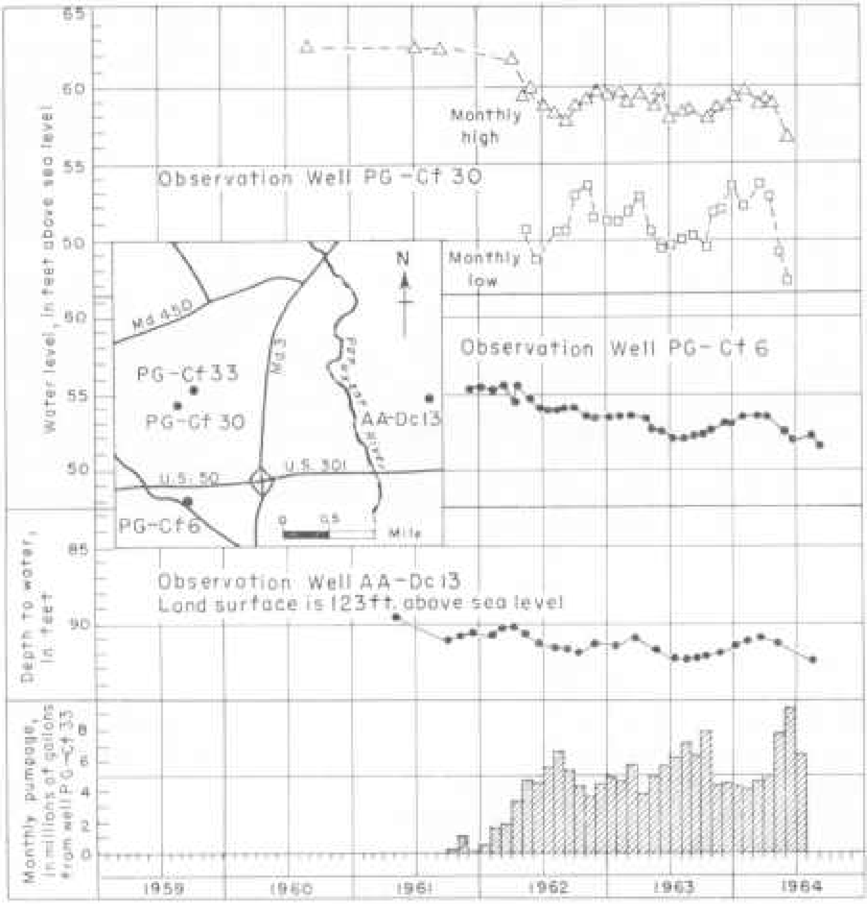


FIGURE 27. Graph showing monthly pumpage from the Magothy Formation since the beginning of pumping at Bowie-Belair and water levels in nearby observation wells.

Formation assumes the outcrop area to be too far away to be a significant recharging boundary. The analyses of the Patapsco and Magothy Formations assume that their recharging boundaries are at a distance of 5 miles and 1 mile, respectively.

The following summarizes these estimates:

AQUIFER	TOTAL THEORETICAL YIELD (MGD)
Magothy Formation	3.4
Patapsco Formation	7.1
Patuxent Formation	8.5
Total	19.0

Thus, about 19 mgd is the theoretical limit of ground water which could be withdrawn from the aquifers in the Bowie-Belair area when they are pumped at rates close to their limits. The quantity actually available may be somewhat more or less than this amount. Leakage from overlying formations would tend to raise the value above 19 mgd. Hydraulic interference caused by pumping from aquifers at points outside the area would reduce the quantity below 19 mgd.

Water levels in wells near the Bowie-Belair well field are affected to a noticeable degree by the heavy pumping from both the Patapsco and Magothy Formations. Stabilization of water levels has not yet occurred in the observation wells, and cannot be expected to occur as long as pumping rates increase. Water levels recover rapidly in all wells when the large production wells are turned off. The limited effect to date (1964) at distances of 1 mile or more from Bowie-Belair suggests that the 1964 rate of pumpage could be continued almost indefinitely. Collection of water-level and pumpage data should continue, however, because pumping rates from these aquifers continue to increase, both at Bowie-Belair and in nearby areas.

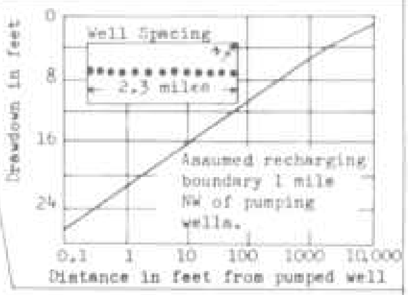
CHALK POINT AREA

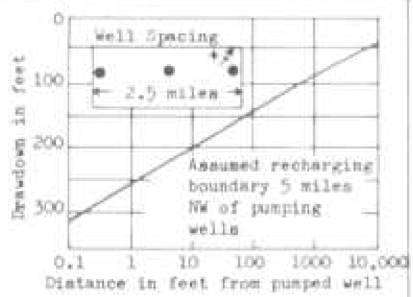
The Chalk Point area consists of about 0.5 square mile of land in the extreme southeastern part of the County (fig. 17). It is bordered on the east by the Patuxent River and on the south by Swanson Creek. Interest in the area has been intensified by the construction of an electric-generating station by the Potomac Electric Power Company. Most of the water used by the plant, for cooling the turbines, is taken from the Patuxent River which is brackish. However, the design of the plant calls for about 400 gpm of relatively pure water for boiler make-up.

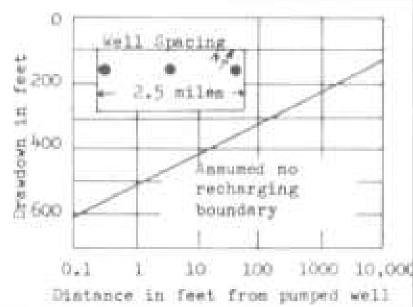
Because very few ground-water data were available, a detailed test program was carried out by the owner to determine whether or not the required amount of water of satisfactory quality was available. Three test holes were drilled, logged electrically, screened and cased, and water from them was tested for its chemical quality. Data from the test holes were used to design a well field of three production wells screened in the Magothy Formation. The deepest hole in the area was drilled to 675 feet, although the sediments may be as thick as 2,500 to 3,000 feet there. This indicates that about 70 percent of the Coastal Plain sediments in this area are still unexplored. However, test drilling indicated that the required amount of water could be obtained within the upper 600 feet of sediments and that deeper drilling was not necessary.

Two good waterbearing sands occur in the zone tested. The deeper of the two is in the Magothy Formation and the shallower is in the Aquia Greensand. Three production wells were screened in the Magothy Formation. The thickness of the Magothy at Chalk Point ranges from 35 to 60 feet. Pumping tests were run to determine the hydraulic characteristics of the aquifers. The transmissi-

GEOHYDROLOGY				QUALITY OF WATER		QUANTITY OF WATER							
						DATA USED IN COMPUTATIONS							
						AQUIFER PROPERTIES		HYPOTHETICAL WELL FIELD					
Geologic Unit	Position relative to sea level (ft)	Composite geologic section 1/	Aquifer or aquiclude	Number of analyses	Range in chemical constituents and properties of ground water (in ppm except for pH)	Transmissibility (gpd/ft)	Storage coefficient (S)	Available drawdown (ft)	Number of wells	Spacing between wells (ft)	Pumping rate per well (gpm)	Distance - drawdown graph for 1,000 days of pumping	Estimated quantity of water available (mgd)
Aquia Greensand	+100	Land surface	Aquifer 3/	1 1 1 1	Iron (Fe) 0.01 Chloride (Cl) 14 Hardness as $CaCO_3$ 25 pH 7.0	1,000 2/		10-20					
Monmouth Formation			Aquiclude										
Magothy Formation	Sea level		Aquifer	1 1 1 1	Iron (Fe) 5.3 Chloride (Cl) 1.5 Hardness as $CaCO_3$ 10 pH 4.8	18,000	0.0002	60	13	1,000	180		3.4
Patapsco Formation	-100		Aquiclude										
	-200		Aquifer 4/										
	-300		Aquiclude										
	-400 -500		Aquifer	1 1 1 1	Iron (Fe) 9.6 Chloride (Cl) 1.4 Hardness as $CaCO_3$ 13 pH 6.0	16,000	0.0003	375	3	6,000	1,650		7.1
Arundel Clay	-600 -700		Aquiclude										
Patuxent Formation	-800 -900 -1000		Aquifer	2 1 1 1	Iron (Fe) 0.14-3.6 Chloride (Cl) 2.2 Hardness as $CaCO_3$ 10 pH 5.7	11,000	0.0001 2/	860	3	6,000	2,000		8.5
Crystalline rocks			Aquiclude										







1/ Based on data from PG-Cf 28, test hole for Production well No. 2
2/ Estimated
3/ Water-table aquifer; only limited supplies available from shallow wells
4/ Untested

FIGURE 28. Geologic, hydrologic, and chemical quality data used in estimating the availability and quality of ground water in the Bowie-Belair area.

72 b

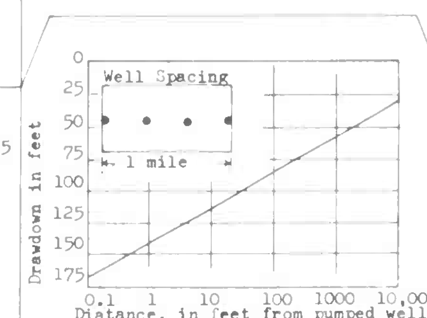
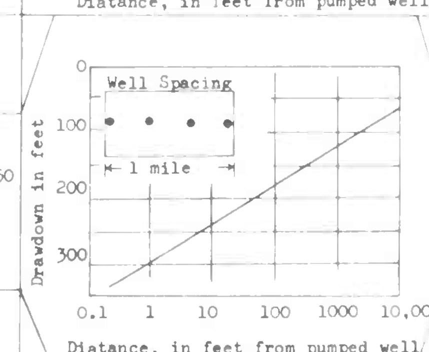
GEOHYDROLOGY				QUALITY OF WATER		QUANTITY OF WATER							
						DATA USED IN COMPUTATIONS							Estimated quantity of water available (mgd)
						AQUIFER PROPERTIES		HYPOTHETICAL WELL FIELD					
Geologic Unit	Position relative to sea level (ft)	Composite geologic section	Aquifer or aquiclude	Number of analyses	Range in chemical constituenta and propertiea of ground water (in ppm except for pH)	Transmissibility (gpd/ft)	Storage coefficient (S)	Available drawdown (ft)	Number of wells	Spacing between wells (ft)	Pumping rate per well (gpm)	Distance - drawdown graph for 1,000 days of pumping	
Fleistocene deposits	Sea level												
Calvert and Nanjemoy Formations	-100 -200												
Marlboro Clay			Aquiclude										
Aquia Greensand	-300 -400		Aquifer	2 2 2 2	Iron (Fe) 0.18 - 0.38 Chloride (Cl) .3 - 8.8 Hardness as $CaCO_3$ 118 - 126 pH 7.6 - 7.9	4000	0.0001	300	4	1700	215		1.2
Monmouth Formation	-500		Aquiclude										
Magothy Formation	-600		Aquifer	3 3 3 3	Iron (Fe) 0.46 - 0.7 Chloride (Cl) .3 - 2.0 Hardness as $CaCO_3$ 108 - 125 pH 7.2 - 8.2	4000	0.0001	620	4	1700	450		2.5
Fatapsco Formation	-700		Aquiclude										

FIGURE 29. Geologic, hydrologic, and chemical data used in estimating the availability and quality of ground water in the Chalk Point area.

bility of the Magothy is about 3,500 gpd per foot (at the west part of the area) and is about 6,000 gpd per foot (at the east). The coefficients of storage range from 0.00003 to 0.0001 (table 5).

Altitude of the land surface in the vicinity of the well at Chalk Point is between 10 and 17 feet. The piezometric surface in the Magothy Formation is about 27 feet above sea level in the area so Magothy wells will flow when water levels are not affected by pumping. The well data in the Chalk Point area are summarized in Table 11. The data show that static water levels in the Magothy were about 10 feet higher than levels in the Aquia Greensand before pumping began. This difference in head between the two formations indicates that water will move upward from the Magothy to the Aquia under natural conditions. On the other hand the direction of movement has been reversed locally to move from the Aquia to the Magothy because of heavy pumping from the Magothy.

Figure 29 summarizes the geologic, hydrologic, and chemical quality data for the upper 700 feet of strata in the Chalk Point area. The figure indicates that at Chalk Point four properly-spaced wells pumping from the Magothy Formation at a rate of 450 gpm per well could be expected to yield a total of about 2.5 mgd. The figure also shows that four properly-spaced wells in the Aquia Greensand could be expected to yield a total of about 1.2 mgd. Examination of the distance-drawdown graph for the Aquia Greensand (right side of Fig. 29) shows that at a distance of 1,700 feet (0.3 mile) each well will cause a drawdown of the water level in the nearest well of about 52 feet, based on pumping 215 gpm for 1,000 days. Each well, of course, causes some increment of drawdown in water levels in all other wells in the same aquifer in the area. By use of a method of summation of drawdowns, the distance-drawdown graph and an optimum pumping rate, the quantity available from the formation was determined. Optimum pumping rate is that rate which will cause the water levels to decline only to a position slightly above the top of the aquifer.

AQUIFER	TOTAL THEORETICAL YIELD (MGD)
Aquia Greensand	1.2
Magothy Formation	2.5
Total, both aquifers	3.7

Thus, based on drawdown computations using the Theis nonequilibrium equation, about 3.7 mgd could be withdrawn from these two aquifers during a 1,000-day period of continuous pumping. The method of analysis assumes that all water withdrawn would be taken from storage and that no recharge would be obtained by leakage from above or below each aquifer or by movement from the recharge area. Since it is likely that heavy pumpage in the area will cause

TABLE 11

SUMMARY OF DATA FROM WELLS AND TEST HOLES IN THE CHALK POINT AREA[1]

U.S.G.S. WELL NUMBER	OWNER'S NAME AND DESIGNATION	ALTITUDE OF LAND SURFACE (FT)	DEPTH OF WELL FT	ALTITUDE OF SCREEN (FT)	ALTITUDE OF WATER LEVEL (FT)		YIELD (GPM)	SPECIFIC CAPACITY (GPM/FT OF DRAWDOWN)	AQUIFER
					Static	Pumping			
PG-Hf 23	Potomac Electric Power Co. (test hole no. 1)	7	613[2]	−601 to −606	28 (5/16/62)	—	—	—	Magothy Fm.
PG-Hf 24	Potomac Electric Power Co. (test hole no. 2)	8.24	417[3]	−404 to −409	18.79 (5/16/62)	—	—	—	Aquia Green-sand
PG-Hf 25	Potomac Electric Power Co. (test hole no. 3)	13.57	454	−351 to −357	18.52 (5/18/62)	—	6.3 flow (5/18/62)	—	Do.
PG-Hf 26	Potomac Electric Power Co. (Prod. well no. 2)	14	635	−591 to −621	flows (2/8/63)	214.6 (2/8/63)	385 (2/8/63)	1.6	Magothy Fm.
PG-Hf 27	Potomac Electric Power Co. (Prod. well no. 3)	16	633[4]	−595 to −617	25.7 (6/9/63)	165.7 (4/5/63)	400 (4/5/63)	2.1	Do.
PG-Hf 28	Potomac Electric Power Co. (Prod. well no. 1)	6.8	623[5]	−589 to −616	flows (5/10/63)	222 (5/17/63)	421 (5/17/63)	1.7	Do.
PG-Hf 29	Potomac Electric Power Co. (domestic well)	12±	14.5	none	0.5 (4/4/63)	—	—	—	Quaternary deposits

[1] All wells except PG-Hf 29 drilled during period 1962–63.

[2] Tested to 675; [3] tested to 454; [4] tested to 650; [5] tested to 640.

water to leak vertically into these aquifers the amount of water actually available may be somewhat more than the total of 3.7 mgd.

Because of the proximity of the brackish Patuxent River and Swanson Creek, salt-water contamination might be caused by large scale development of these aquifers.

CHELTENHAM AREA

The Cheltenham area includes about 16 square miles along the northwest side of U. S. Highway 301 (fig. 17). Because the area is mainly rural, most homes obtain their water supply from individual dug or drilled wells. The town of Upper Marlboro, the Boys Village of Maryland, and the U. S. Naval Radio Station at Cheltenham are the largest users of ground water in or near the area, using a combined average of about 0.4 mgd. The area is located about 17 miles southeast of the Fall Line and land surface elevation ranges from 10 to 250 feet above sea level. Bedrock lies at a depth of about 1,400 feet below sea level. The geologic units comprising the Coastal Plain deposits range from Early Cretaceous to Recent in age. The major waterbearing sands occur in the Patuxent, Patapsco, and Magothy Formations.

Extensive studies of the geology of the area were made for the Washington Gas Light Company by the consulting firm of Ball and Associates of Denver, Colorado. The study was made to determine the feasibility of storing natural gas underground for use in the Washington metropolitan area during periods of peak demand. The study by the consultants included a review of existing geologic data, preliminary magnetometer and gravity-meter surveys, the drilling and electric logging of 78 test holes into relatively shallow strata, less than 400 feet deep, the drilling and casing of 12 test holes ranging in depth from about 1,260 to more than 1,800 feet, collection and analysis of well cuttings and cores, geophysical logging, hydrologic and gas injection testing, and preparation of detailed reports.

Most of the data from these studies have not been published and the unpublished information was made available for this study by the Washington Gas Light Company. Geologic section G-G′ (figs. 17 and 30) was prepared from geologic and geophysical logs collected as part of that study.

Four of the deep test wells penetrated the complete thickness of the Coastal Plain sediments to reach the crystalline basement. Six of them penetrated arkosic-type rocks, both consolidated and unconsolidated, of Triassic age. One well, Mudd No. 3, penetrated 233 feet of consolidated arkosic rocks but did not reach the underlying crystalline rocks. Table 12 summarizes the data available from the 12 deep test wells.

Mudd No. 3 and Thorne No. 2, the first deep test wells drilled, were studied most intensively with respect to the total thickness of Coastal Plain deposits because they were the first wells in the area to penetrate below 700 feet. Because data from these wells indicated that a deep sand in the Patuxent Forma-

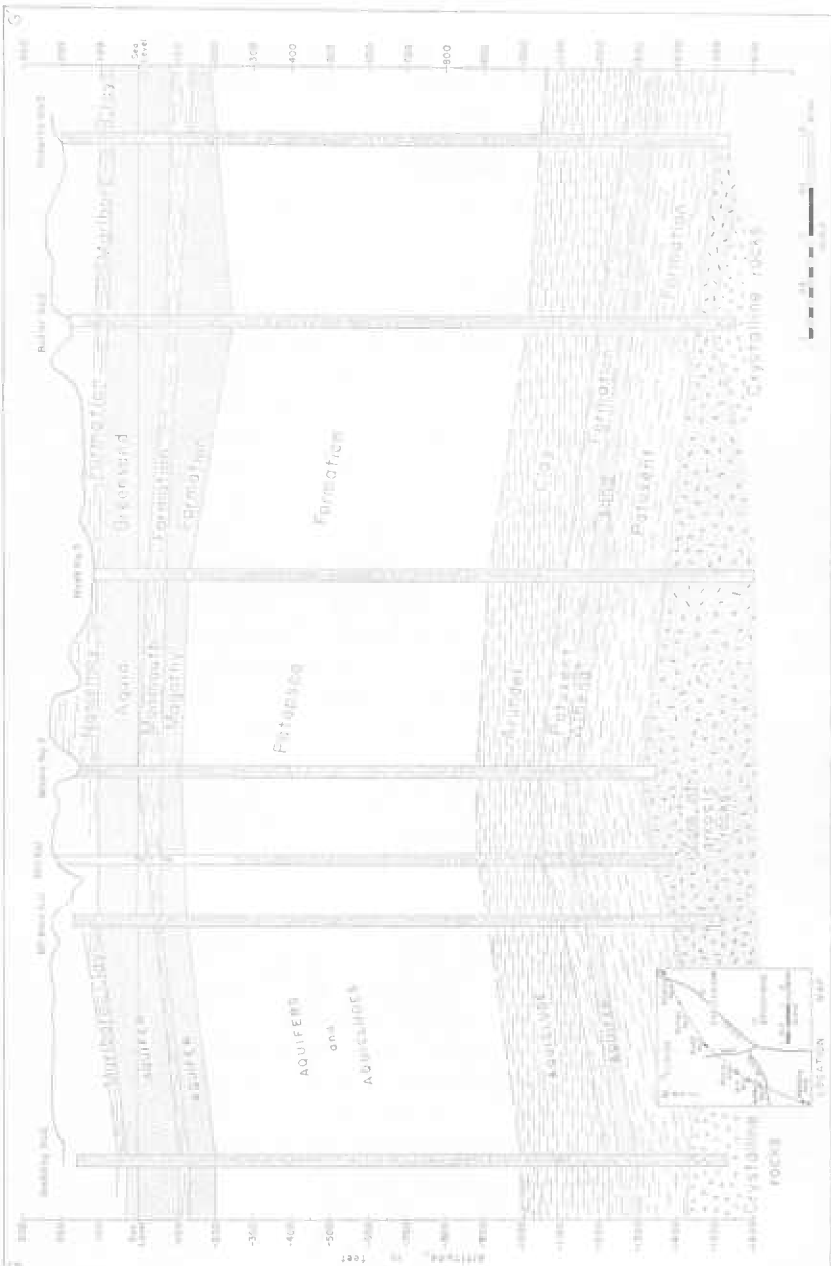


FIGURE 30. Geologic section (G-G') in the Cheltenham area.

tion, designated the Athena sand by the gas company consultants, was best suited for gas storage, only the lower parts of wells drilled subsequently were studied intensively. Cores and cuttings from the Athena sand were tested for porosity, grain size, and permeability. Each of the 12 deep holes was cased and with the exception of one hole, hydrologic connection was established with selected sands by means of screens or casing perforations.

Data from the following sources are available to indicate the transmissibility of the Athena sand: a 6-day drawdown test, slug tests, particle-size analyses, electric logs, and gas injection tests.

In 1955 an aquifer test was run by pumping the Moore No. 2 well screened in the Athena sand, at a rate of 67 gpm for 6 days. Results of the test were somewhat uncertain because of a possible leak in the airline. Values obtained for transmissibility from this test range from 45 gpd per foot to 850 gpd per foot.

The gas injection test was made in 1958 primarily to determine the rate at which the formation could accept gas for storage and the rate at which gas could be withdrawn when needed. It consisted of pumping of large quantities of inert gas into the Athena sand at the Moore No. 2 well over a period of several weeks and observing the effect of the gas injection on the hydraulic head in other Athena wells. The effect was similar to that of an aquifer test in reverse. Raising the pressure on the water in the Athena sand in the vicinity of Moore No. 2 caused water levels to rise 98 feet in the Hill well about 1 mile to the south. Hydrologic information from this test is a by-product of the gas test and was obtained by converting volumes of injected gas at given temperatures

TABLE 12

DATA FROM TEST WELLS DRILLED FOR GAS STORAGE PROJECT NEAR BRANDYWINE, MARYLAND

U.S.G.S. WELL NUMBER	PROPERTY OWNER'S NAME AND WELL NUMBER	ALTITUDE OF LAND SURFACE (FT)	DEPTH OF WELL BELOW LAND SURFACE (FT)	ALTITUDE OF BOTTOM OF WELL (FT)	ALTITUDE OF TOP OF CRYSTALLINE ROCK (FT)	ALTITUDE OF TOP OF ARKOSIC ROCK (FT)
PG-Fd 58	Buckler no. 2	96	1541	−1445	—	—
PG-Ee 50	Butler no. 2	165	1715	−1550	−1495	−1452
PG-Fd 56	Dennison no. 3	233	1737	−1504	−1484	—
PG-Fd 57	Hill no. 1	219	1605	−1386	—	−1336
PG-Fd 43	McMain no. 1	219	1735	−1516	—	−1378
PG-Fd 59	Moore no. 2	172	1517	−1345	—	−1312
PG-Fd 60	Moore no. 3	173	1262	−1089	—	—
PG-Fd 61	Mudd no. 3	118	1719	−1601	—	−1368
PG-Ee 49	Roberts no. 2	211	1746	−1535	—	−1503
PG-Fd 62	Robinson no. 2	230	1812	−1582	—	−1577
PG-Fc 17	Thorne no. 2	59	1470	−1411	−1335	—
PG-Gc 5	Wedding no. 2	196	1723	−1527	−1430[1]	−1430[1]

[1] Character of this rock uncertain; may be crystalline or arkosic.

TABLE 13

HYDROLOGIC PROPERTIES DETERMINED FROM LABORATORY AND FIELD TESTS ON THE ATHENA SAND IN THE PATUXENT FORMATION

WELL NAME	RANGE IN LABORATORY COEFFICIENT OF PERMEABILITY Pf (GPD/FT²)	WELL SPECIFIC CAPACITY (GPM/FT OF DRAWDOWN)	ESTIMATED COEFFICIENT OF TRANSMISSIBILITY (GPD/FT)
Butler no. 2	—	0.03	60
Dennison no. 3	0.08–32	.09	180
Moore no. 2	.03–3.0	.21	410
Mudd no. 3	2–15	.1	200
Thorne no. 2	.5–1.0	—	—
Wedding no. 2	1–4	—	—

to gallons of water to determine the value of Q for the pumping rate. This procedure is a reasonable approximation of an aquifer test.

Pumping water-level changes at the Hill, McMain, and Wedding observation wells were plotted on semi-logarithmic paper according to their distances from the Moore No. 2 well. The Thiem equation was then used to obtain a value for the transmissibility of the sand. The value obtained was 847 gpd per foot, which is very similar to the maximum value of 850 gpd per foot obtained from an analysis of the 6-day aquifer test.

Laboratory permeability determinations were made of several samples of the Athena sand from five of the gas-storage wells. The results are given in table 13.

The tabled values of laboratory permeability are quite low when compared with the field permeability values for the better aquifers in the area (see tables 4, 5, and 6). Based on specific capacity measurements obtained from bailer tests on five of the gas storage test wells, the transmissibility of the Athena sand ranges from 60 to 540 gpd per foot. These values are in the same low range as those obtained from the 6-day aquifer test on the Moore No. 2 well.

The geologic section in figure 30 (G-G′) summarizes most of the information available concerning the Patapsco Formation in the area. Only meager hydrologic data are available for the Patapsco Formation because the water requirements of the past have been easily satisfied by wells tapping the overlying Magothy Formation. Figure 30 shows that several good sands exist in the Patapsco Formation. The transmissibilities of these sands, based on estimated permeabilities and measured thicknesses, range from 6,000 to 24,000 gpd per foot. When water requirements are greater, it is probable that these sands will be tested by pumping and more precise data will be obtained regarding their hydrologic character.

The Magothy Formation has supplied the water requirements of the Cheltenham area for many years. Nearly all the wells in the area to date (1964) have been completed in the Magothy Formation. Table 14 lists some of the high

TABLE 14

DATA FOR HIGH-CAPACITY WELLS IN THE CHELTENHAM AREA

U.S.G.S. WELL NUMBER	OWNER'S NAME AND DESIGNATION	ALTITUDE OF LAND SURFACE (FT)	DEPTH OF WELL (FT)	ALTITUDE OF SCREEN (FT)	ALTITUDE OF WATER LEVEL (FT)		YIELD (GPM)	SPECIFIC CAPACITY (GPM/FT OF DRAWDOWN)	AQUIFER
					Static	Pumping			
PG-Ee 6	Town of Upper Marlboro	64	262	−183 to −198	41 (9/20/49)	−46[1] (7/15/46)	180 (7/15/46)	2.1	Magothy Fm.
PG-Ef 5	do.	25	226	probably between −170 and −200	flows (1964)	—	58 (when flowing—1940) 45 (when flowing—1949)	—	Do.
PG-Fd 11	U. S. Naval Radio Station (GSK well)	230	438	−162 to −208	46.07 (7/19/49) 38.43 (3/13/63)	—	239 (5/12/49)	—	Do.
PG-Fd 64	U. S. Naval Radio Station (White City well)	230	—	—	—	—	250 (3/13/64)	—	Do.
PG-Fd 39	Boys' Village of Maryland (no. 3)	230	451	−206 to −221	44 (2/—/52) 40.12 (3/10/64)	−40 (2/—/52)	240 (2/—/52)	3.4	Do.
PG-Fd 55	Boys' Village of Maryland (Boiler house well)	215	439	−173 to −184 −196 to −224	44.53 (4/3/64)	5[1] (7/27/56)	303 (7/27/56)	8.1	Do.
PG-Fd 40	Brandywood Estates, Inc. (8-inch well)	201	374	−143 to −173	52 (6/9/55) 47.27 (3/31/64)	−20[2] (6/14/55)	225 (6/9/55)	3.0	Do.
PG-Fd 45	Washington Gas Light Co.	172	289	−81 to −94 −108 to −117	47 (11/22/57)	−32[1] (11/27/57)	200 (11/27/57)	2.5	Do.

[1] Based on 24-hour test. [2] Based on 49-hour test.

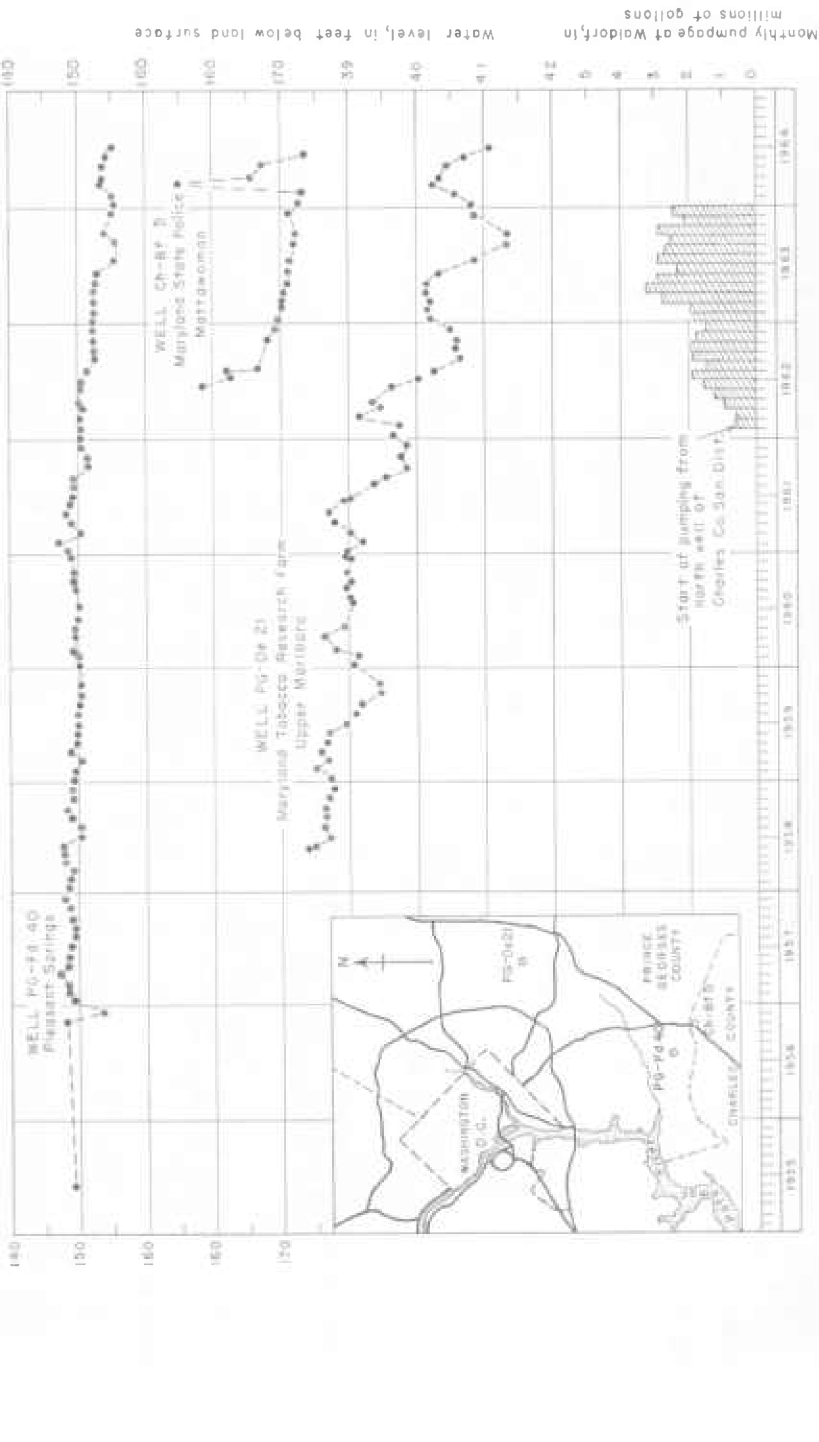


FIGURE 31. Hydrographs showing water levels in wells tapping the Magothy Formation in or near the Cheltenham area.

capacity wells in the area. The transmissibility of the Magothy ranges from 10,000 to 20,000 gpd per foot. This aquifer is probably the most consistent lithologically of any of the four major aquifers in the County. Water-yielding sands seem to be present at all sites tested in the area and the altitudes of the top of the sand can generally be predicted with a fair degree of accuracy.

Figure 31 shows water levels in three observation wells tapping the Magothy Formation. Wells PG-Fd 40 and Ch-Bf 5 (in Charles County) are located in or near the southern part of the area.

Water-level declines in well Ch-Bf 5 are due to pumpage from the northernmost public-supply well of the Charles County Sanitary District. Pumping began in this well in February 1962. Water-level declines shown in the hydrograph for PG-Fd 40, located 3 miles north of the Sanitary District north well, are probably due to the same pumpage.

Water levels in PG-Dc 21, located 3 miles northwest of Upper Marlboro, have shown a steady decline since 1958. It is probable that most of the decline in this well is due to increased pumpage from the Magothy Formation in the vicinity of Upper Marlboro.

Few data are available for wells ending in the Aquia Greensand. Some small-capacity domestic wells have been completed in the Aquia, but most of them pass through it to tap the underlying Magothy Formation.

A blanket of relatively permeable deposits of sand, gravel, and clay, ranging up to 50 feet in thickness, covers most of the upland parts of the Cheltenham area. These deposits, comprising part of the Columbia Group, are the source of water for several domestic dug wells. The water table is generally within 10 to 20 feet of the land surface, and in the undissected uplands, suction pumps are commonly used in the water-table wells. The ground-water potential of these deposits is limited but they furnish some recharge to the deeper artesian aquifers by means of vertical leakage through the underlying semipervious beds.

The quantity of ground water available in the Cheltenham area was estimated by preparing a geo-mathematical model of an idealized well field (or fields) tapping all of the major aquifers. This method is based on (a) study of the geologic and hydrologic data available for the area, (b) and the use of the Theis non-equilibrium equation. This equation was used to compute drawdowns in the aquifers under the idealized conditions required for a mathematical analysis. Where transmissibilities could not be obtained from aquifer tests, they were estimated by multiplying assumed aquifer permeabilities by known thicknesses of the aquifers. The required storage coefficients were assumed where no aquifer test data were available. Distance-drawdown graphs, assuming the aquifers to be infinite in lateral extent, were prepared for each aquifer. A period of pumping of 1,000 days (2.7 years) was used as it can be shown that in an ideal infinite aquifer more than 95 percent of the drawdown will have occurred by the end of this period of time. The spacing of wells was arbitrary and the rate of pumping was adjusted so that the total drawdown in the center well was a little less than the available drawdown. The available drawdown used in the analysis is the drawdown in the center well or wells along a line which will not be below the upper surface of each aquifer. The results of the analysis are shown in figure 32.

As an example of the method used, the distance-drawdown graph for the Patuxent Formation in the lower right-hand corner of figure 32 shows that a 12-inch diameter well pumping from the aquifer at a rate of 215 gpm will have a self-drawdown of approximately 550 feet and will cause a lowering of the water level in the aquifer of 112 feet at a distance of 5,280 feet (1 mile). Thus, if 9 wells were to tap the aquifer along the 8-mile width of the area the drawdown in the central well would stabilize slightly above the upper surface of the aquifer at a altitude of 1180 feet below sea level.

However, the combined yield of the 9 wells tapping this aquifer would be only 2.8 mgd, and this quantity of water could only be obtained by relatively high lifting and pumping costs, at least for the central wells in the configuration.

The quantity of water available from the Patapsco Formation is difficult to predict because no water wells have been completed in the formation in this area. It has been estimated that the sands in the Patapsco Formation have a combined transmissibility of 39,000 gpd per foot. Estimates made in figure 32 indicate that about 32 mgd could be obtained from these sands for long periods of pumping if their transmissibilities remained constant for distances of several miles. However, geologic data indicate the sands become much thinner and their transmissibilities decrease toward the northwest. Data from wells in Charles County also indicate that the waterbearing sands pinch out toward the southwest. Thus, the estimate of 32 mgd for the Patapsco is probably valid for a relatively short period of time only. In order to obtain an estimate of the quantity of water available from the Patapsco Formation for a longer period of time (several years), it was assumed that the transmissibility of the Patapsco Formation is 6,000 gpd per foot over a wide area, a much more reasonable assumption. Estimates based on this assumption indicate that about 4.5 mgd are available from the Patapsco Formation. This value is probably on the conservative side because the transmissibility is greater than 6,000 gpd per foot in the Cheltenham area.

Extensive aquifer tests should be made in the Cheltenham area in order to predict accurately the quantity of water available from the Patapsco Formation. The preceding discussion indicates that: (1) the area is worthy of testing, (2) that large quantities of water could be obtai[illegible] during short periods of pumping, and (3) that some quantity greate[illegible] gd could probably be obtained on a sustained basis. These a[illegible] are summarized here:

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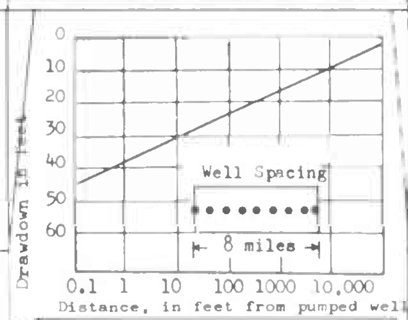
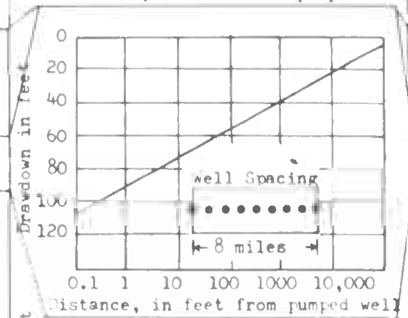
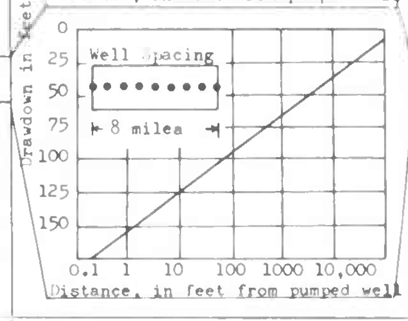
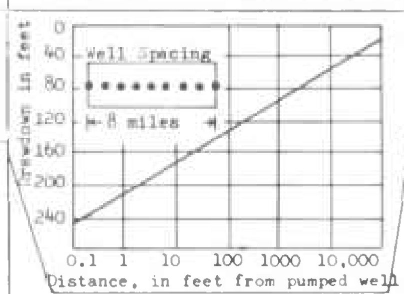
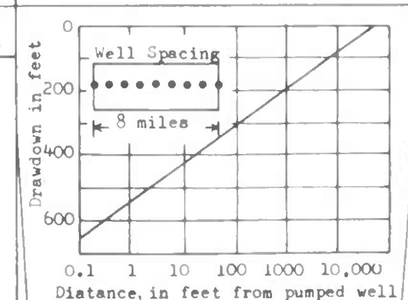
GEOHYDROLOGY				QUALITY OF WATER		QUANTITY OF WATER							
						DATA USED IN COMPUTATIONS							
						AQUIFER PROPERTIES		HYPOTHETICAL WELL FIELD					
Geologic Unit	Position relative to sea level (ft)	Composite geologic section 1/	Aquifer or aquiclude	Number of analyses	Range in chemical constituents and properties of ground water (in ppm except for pH)	Transmissibility (gpd/ft)	Storage coefficient (S)	Available drawdown (ft)	Number of wells	Spacing between wells (ft)	Pumping rate per well (gpm)	Distance - drawdown graph for 1,000 days of pumping	Estimated quantity of water available (mgd)
Aquia Greensand	+100 to Sea level		Aquifer	2 2 2 2	Iron (Fe) 0.12 Chloride (Cl) .7 - 1.6 Hardness as $CaCO_3$ 106 - 234 pH 7.8 - 8.0								
Monmouth Formation			Aquiclude	11 11 11 11	Iron (Fe) 0.08 - 0.83 Chloride (Cl) 1.1 - 9.5 Hardness as $CaCO_3$ 117 - 178 pH 7.3 - 7.8								
Magothy Formation	-100		Aquifer			15,000 2/	.0001 3/	120	9	5280	200		2.6
Patapsco Formation			Aquiclude										
	-200		Aquifer			6,000 2/	.0001 3/	260	9	5280	200		2.6
	-300		Aquiclude										
	-400		Aquifer			9,000 2/	.0001 3/	450	9	5280	510		6.6
	-500		Aquiclude										
	-600 to -700		Aquifer			24,000 2/	.0001 3/	650	9	5280	1740		22.5 4/
Arundel Clay	-900 to -1100												
Patuxent Formation	-1200		Aquifer 5/	3 3 8 4	Iron (Fe) 0.03 - 0.4 Chloride (Cl) 10 - 33 Hardness as $CaCO_3$ 8 - 28 pH 7 - 9.9	1,000	.0001	1200	9	5280	215		2.8
Bedrock (arkosic)	-1400 to -1600		Aquiclude										

1/ Based on data from Mudd No. 3, PG-Fd 61
2/ Estimated by assuming a value for permeability and multiplying by the thickness of the sand
3/ Assumed
4/ See text for discussion of the significance of this value
5/ Athena sand; poor aquifer

FIGURE 32. Geologic, hydrologic and chemical data used in estimating the availability and quality of ground waters in the Cheltenham area.

FORMATION	TOTAL THEORETICAL YIELD (MGD)	
	High value—short term	Limiting value—long term
Magothy	2.6	2.6
Patapsco		
sand at −220 to −250	2.6	
sand at −400 to −440	6.6	4.5
sand at −600 to −700	22.5	
Patuxent	2.8	2.8
Total	37.1	9.9

CHEMICAL CHARACTER OF WATER

The chemical character of ground water in Prince Georges County is variable from place to place and from aquifer to aquifer. The water requires no treatment before general use in some areas, but requires rather extensive treatment in others. High concentrations of iron and low pH are troublesome characteristics of water from the major aquifers in the Bowie-Belair area. Water from the Fort Foote and Forest Heights wells in the tidewater Potomac area contains few troublesome constituents. Table 15 lists some of the common chemical constituents in ground water and indicates their significance. Discussion of the important properties and constituents in ground water in the area follows.

OCCURRENCE OF IMPORTANT CONSTITUENTS

All values for constituents are expressed in ppm (parts per million by weight). One part per million is a unit weight of a constituent in a million unit weights of water.

Silica: The silica content of 91 samples of ground water from Prince Georges County ranges from 3.1 to 59 ppm. The median silica content of 91 samples is 13 ppm. Most natural waters contain less than 30 ppm of silica and only 6 analyses from the area of this report show greater concentrations than this. The silica content of ground water in the County should not be troublesome for most uses.

Aluminum: The aluminum content of 63 samples ranges from 0.0 to 4.5 ppm. The median value is 0.0 and only 2 samples show concentrations greater than 1.0 ppm. The concentration of 4.5 ppm is for water from the Magothy Formation at Cheltenham Boys Village.

TABLE 15

ELEMENTS AND COMPOUNDS COMMONLY FOUND IN GROUND WATER (FROM WALKER, 1956)

CONSTITUENT	SOURCE	SIGNIFICANCE
Silica (SiO_2)	Siliceous minerals present in essentially all formations.	Forms hard scale in pipes and boilers.
Iron (Fe)	The common iron-bearing minerals present in many formations, such as hematite, limonite, pyrite and magnetite.	Oxidizes to a reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown and is objectionable for food processing and beverages. Larger quantities impart taste and favor the growth of iron bacteria.
Manganese (Mn)	Manganese-bearing minerals, such as psilomelane and pyrolusite	Rarer than iron; in general has same objectionable features; brown to black stain.
Calcium (Ca) and magnesium (Mg)	Minerals that form limestone and dolomite and occur in some amount in almost all formations. Gypsum also a common source of calcium.	Cause most of the hardness and scale-forming properties of water; soap consuming.
Sodium (Na) and potassium (K)	Feldspars and other common minerals; ancient brines, sea water.	In large amounts, cause foaming in boilers, and other difficulties in certain specialized water uses.
Bicarbonate (HCO_3) carbonate (CO_3)	Action of carbon dioxide in water on carbonate minerals.	In combination with calcium and magnesium forms carbonate hardness; decomposes on application of heat with attendant formation of scale and release of corrosive carbon dioxide gas.
Sulfate (SO_4)	Gypsum, iron sulfides, and other rarer minerals; common in waters from coal-mining operations and many industrial wastes.	Sulfates of calcium and magnesium form hard scale.
Chloride (Cl)	Found in small to large amounts in all soils and rocks; natural and artificial brines, sea water, sewage.	Objectionable for various specialized industrial uses of water.

TABLE 15—*Continued*

CONSTITUENT	SOURCE	SIGNIFICANCE
Fluoride (F)	Various minerals of widespread occurrence, in minute amounts.	In water consumed by children about 1.5 ppm and more may cause mottling of the enamel of teeth, and as much as 1.5 ppm reduces incidence of tooth decay.
Nitrate (NO_3)	Decayed organic matter, sewage, nitrate fertilizers, nitrates in soil.	Values higher than the local average may suggest pollution. More than about 45 ppm NO_3 may cause methemoglobinemia (infant cyanosis), which is sometimes fatal. Waters of high nitrate content should not be used for baby feeding.

Fluoride: Excessively high concentrations of fluoride in drinking water cause mottling of teeth and changes in bone structure. The safe limit is not universally agreed upon, but the Public Health Service recommends control limits between 0.8 and 1.7 ppm (1961, p. 943). Some fluoride in drinking water is a deterrent to tooth decay. Fluoride has been added to the drinking-water supplies of some municipalities in order to combat dental caries. Most ground waters in Prince Georges County contain far less fluoride than the recommended maximum concentration. The fluoride content of 78 ground-water samples from the County ranges from 0.0 to 2 ppm. The median value is 0.1 ppm. Only 5 samples showed a concentration higher than 0.4 ppm.

Iron: The U. S. Public Health Service recommends that drinking water contain no more than 0.3 ppm of iron (1961, p. 941). Although water containing large quantities of iron has no toxic effect, concentrations above 0.3 ppm are likely to cause a red coloration of the water which in turn causes staining of laundry. In Prince Georges County, high iron concentrations are one of the chief problems relating to the quality of ground water. Studies of iron concentrations in ground water are subject to several possible pitfalls resulting in inaccurate determinations due to improper sampling procedures. It is probable that some such errors were not eliminated from the data used in this report, but the overall view of the iron problem is discernible. The iron content of 98 samples of ground water ranges from 0.0 to 58 ppm.

Figure 33 is a map showing the location of wells from which the water was analyzed for iron content. Forty-four percent of the waters had 0.3 ppm or less of iron. Highest iron concentrations are in ground water found in the northeastern part of the County. The aquifers in the Patapsco and Magothy Formations in the vicinity of Bowie-Belair contain water which must be treated because of its high content.

However, water from the Magothy Formation in the vicinity of Upper Marlboro, about 10 miles to the south, and from the Patapsco Formation in some parts of the tidewater Potomac area contains such low concentrations of iron it does not have to be treated.

Chloride: Figures 34 and 35 show that the chloride content in most wells in the County is below 10 ppm. Water from several wells in the south-central part of the County has a chloride content of more than 10 ppm. Water from these wells is from the Patuxent Formation, which is more than 1,200 feet below sea level in that area. Water from these depths may be expected to have higher concentrations of chemical constituents because the water has had to travel further and has had greater exposure to earth materials than the water from shallower depths.

Analyses of water from public-supply wells at Forest Heights show a chloride content above 100 ppm at various times. It is possible that such concentrations may result from movement of brackish water from the Potomac River into the aquifers. This is unlikely because the chloride content of the River water at this point is seldom great.

Salt-water contamination on a minor scale has taken place in a dug well at Chalk Point. Analyses show that chloride concentration in water from the well has been as great as 2,580 ppm. The well is in very permeable material and is located about 120 feet from the shoreline of the Patuxent River. At this place the chloride content of the river water ranges from 3,000 to 8,000 ppm. Proximity of the brackish river water and increased pumping of the well for use in the construction of a generating plant may explain why the shallow well became salty.

Total dissolved solids: The total concentration of dissolved solids in water is useful in interpreting chemical analyses. The U. S. Public Health Service (1961) recommends a limit of 500 ppm for water of good chemical quality. However, if such water is not available, a total solids content of 1,000 ppm may be permitted.

The dissolved solids content of 98 ground-water samples ranges from 20 to 950 ppm. The ranges and median values for the major aquifers are shown in figure 35. High concentrations for samples from the Patuxent Formation were obtained from water from the deep test wells drilled for gas storage in the Brandywine area. Twelve samples from 8 of the deep wells contained over 300 ppm, including the maximum for the County of 950 ppm.

Figure 36 is a map showing wells from which analyses of dissolved solids are available, the values obtained, and the source aquifer. The map shows that

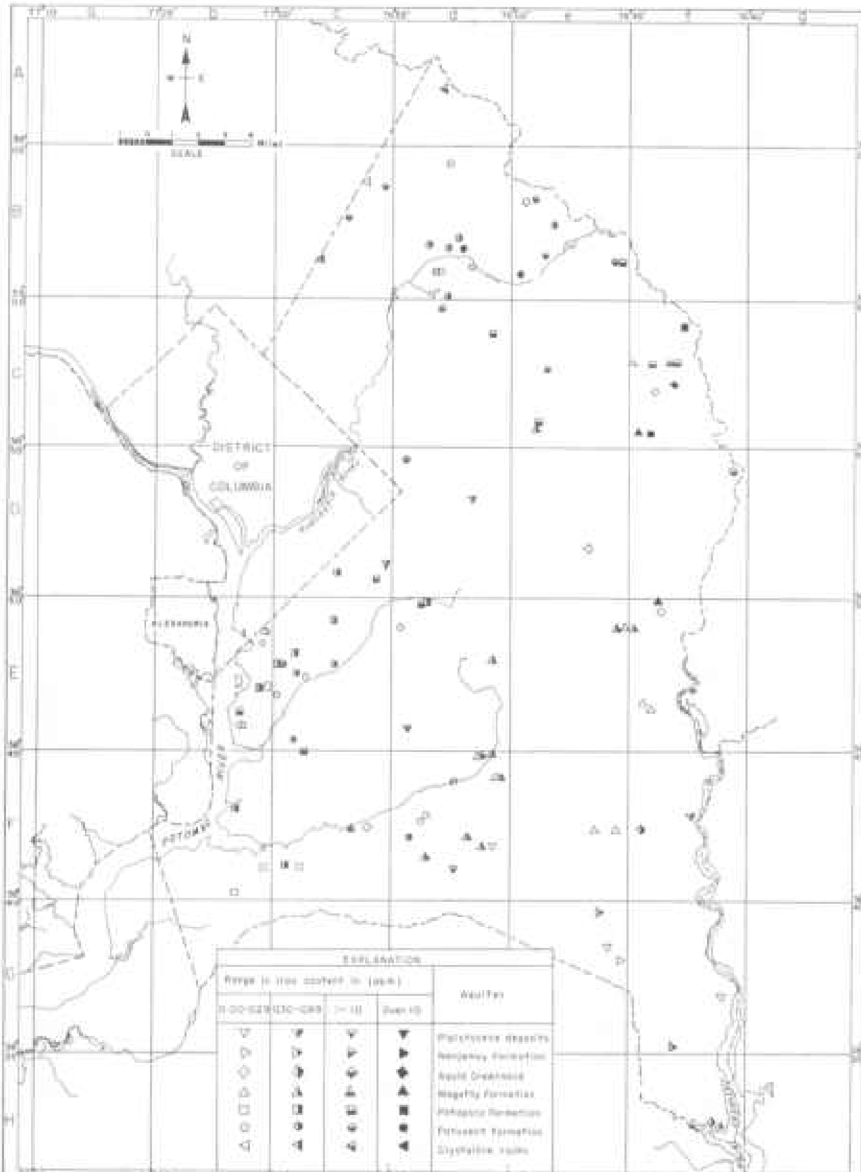


FIGURE 33. Map showing range in iron content in ground waters in Prince Georges County.

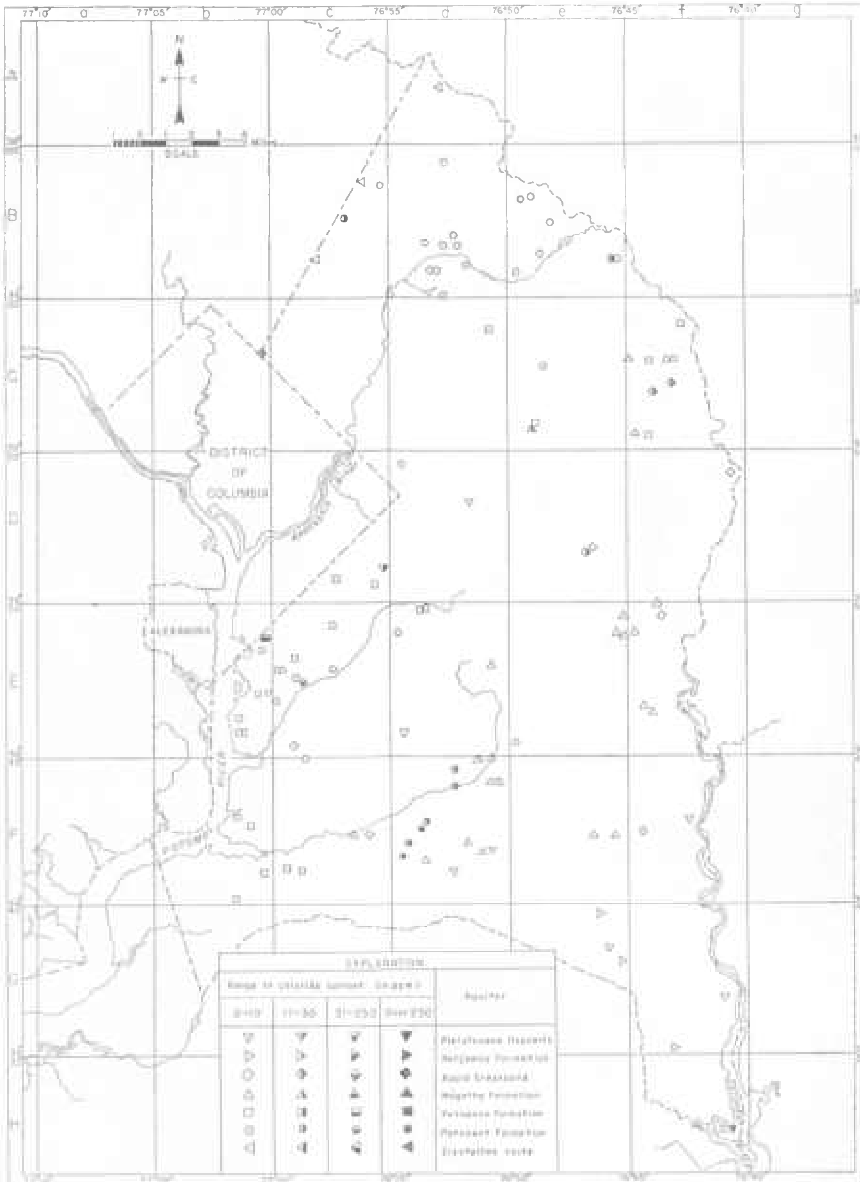


FIGURE 34. Map showing range in chloride content in ground waters in Prince Georges County.

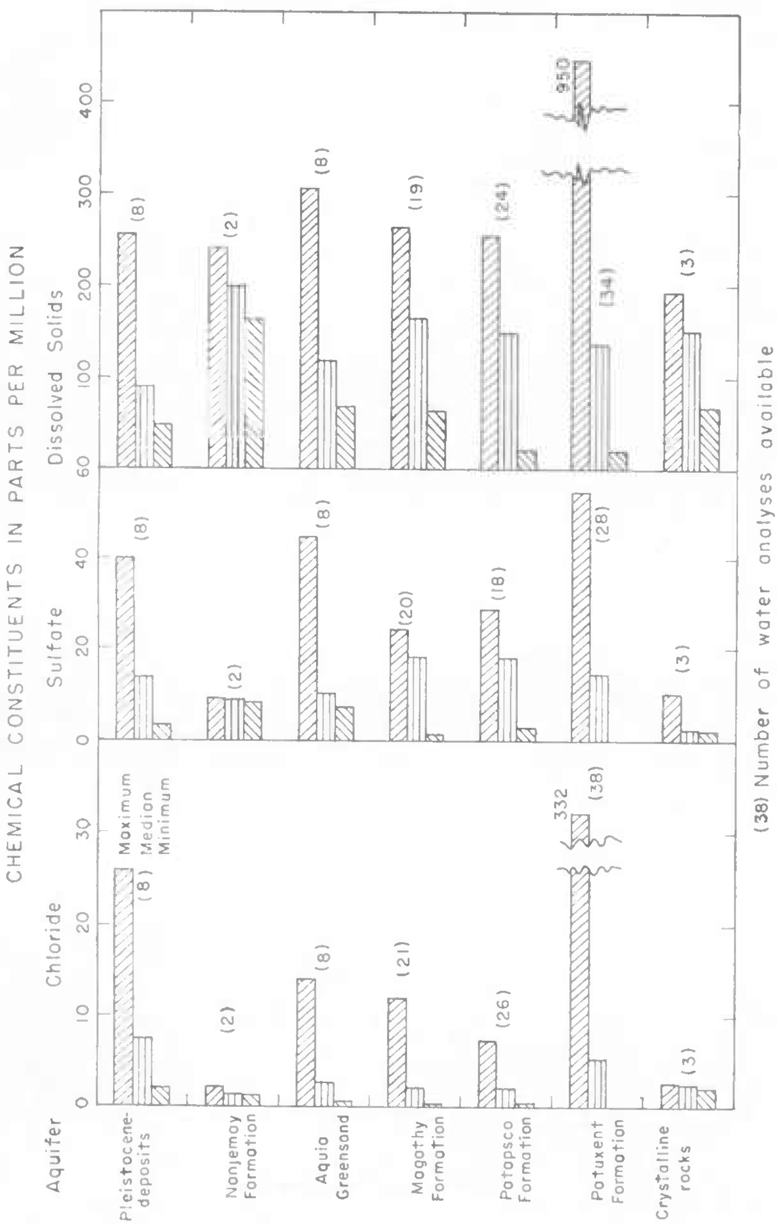


FIGURE 35. Graph showing concentrations of chloride, sulfate, and dissolved solids in ground waters in Prince Georges County.

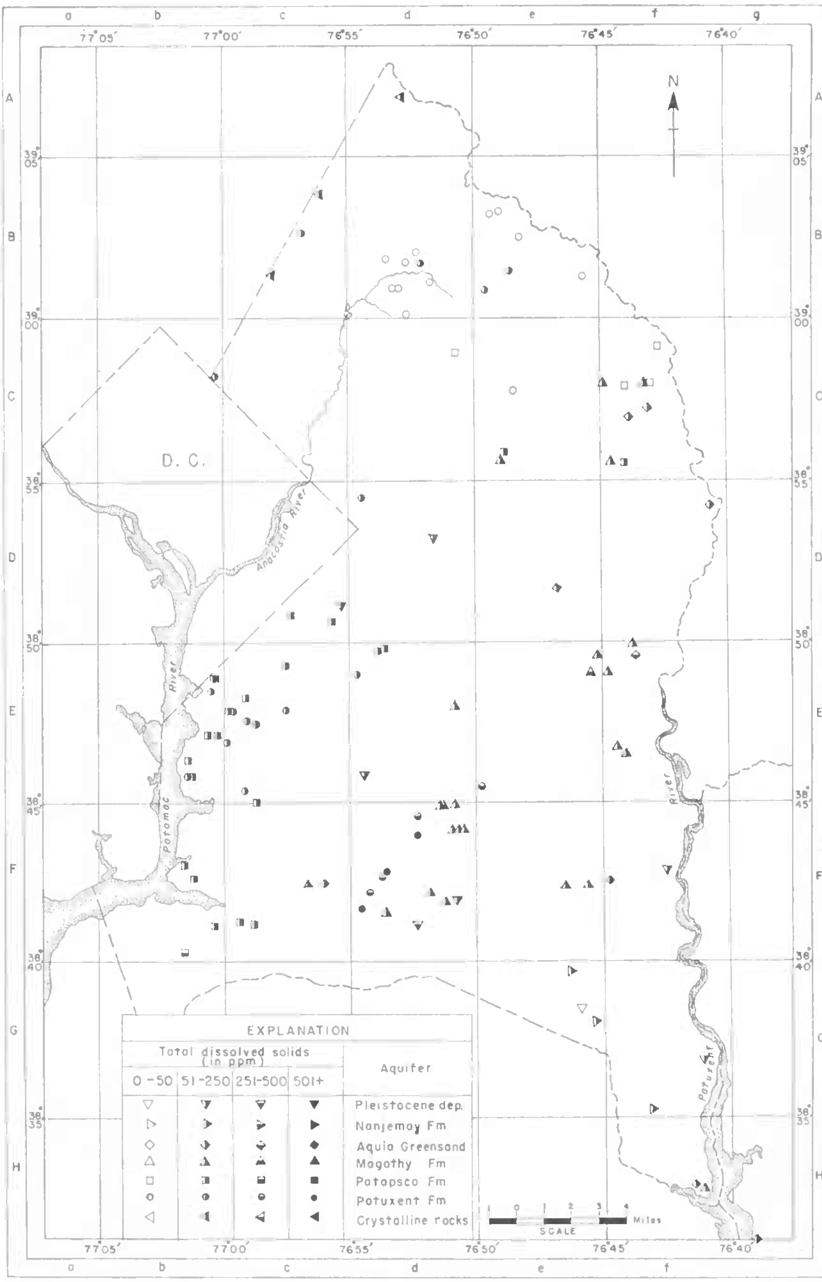


FIGURE 36. Map showing total dissolved solids in ground waters in Prince Georges County.

throughout most of the County the total dissolved solids content is below 250 ppm, that in the northern part of the County, much of the water contains less than 50 ppm, and that in the Brandywine area several waters contained more than 500 ppm.

Hardness: Hardness was determined for 102 samples of ground water. The hardness ranges from 1.0 to 234 ppm. The ranges and median values for the major aquifers are shown in figure 37. The median values from aquifers of Patapsco age or older indicate that the water is soft. Median values for formations of Magothy age or younger indicate the water is harder. The median value for the Aquia Greensand probably would be much higher if more of the samples had been taken from deep drilled wells. Most of the analyses used to obtain the value given in figure 37 were from shallow wells in the outcrop area where calcium carbonate shells have been leached away.

Figure 38 is a map showing the range in hardness of ground waters in the area. In general, the ground water in the northern and western part of the County is soft and water in the remainder of the County is moderately hard to hard. The greater hardness in the southeastern part is attributed to the abundance of calcium carbonate shells in some of the aquifers. The hardness of water in the Magothy Formation may be the result of downward leakage from the overlying formations which are so rich in calcium carbonate.

Sulfate: The sulfate (SO_4) content of 87 samples of ground water ranges from 0.0 to 55 ppm. The range and median concentrations from each of the major aquifers are shown graphically in figure 37. All concentrations are well below the recommended limit of 250 ppm set by the U.S. Public Health Service (1961).

pH: The term "pH" is used to express the acidity or alkalinity of water and represents the hydrogen-ion concentration. A pH of 7.0 is neutral. Water having a pH less than 7.0 indicates increasing acidity; that having a pH greater than 7.0 indicates alkalinity. Acid water is objectionable chiefly for its corrosive attack on metal.

The pH of 100 ground-water samples from Prince Georges County ranges from 4.5 to 9.9. The ranges and median values for water from the principal aquifers are given in figure 37. The wide spread in range of pH values for individual formations results from geographically widespread distribution of samples. Figure 39 shows the locations of wells for which pH determinations were made. It shows that much of the water in the northeastern part of the County has a pH below 5.5 and most of the water is below 7.0. Values of pH in the southern part of the County are nearly all above 7.0 (that is, on the alkaline side).

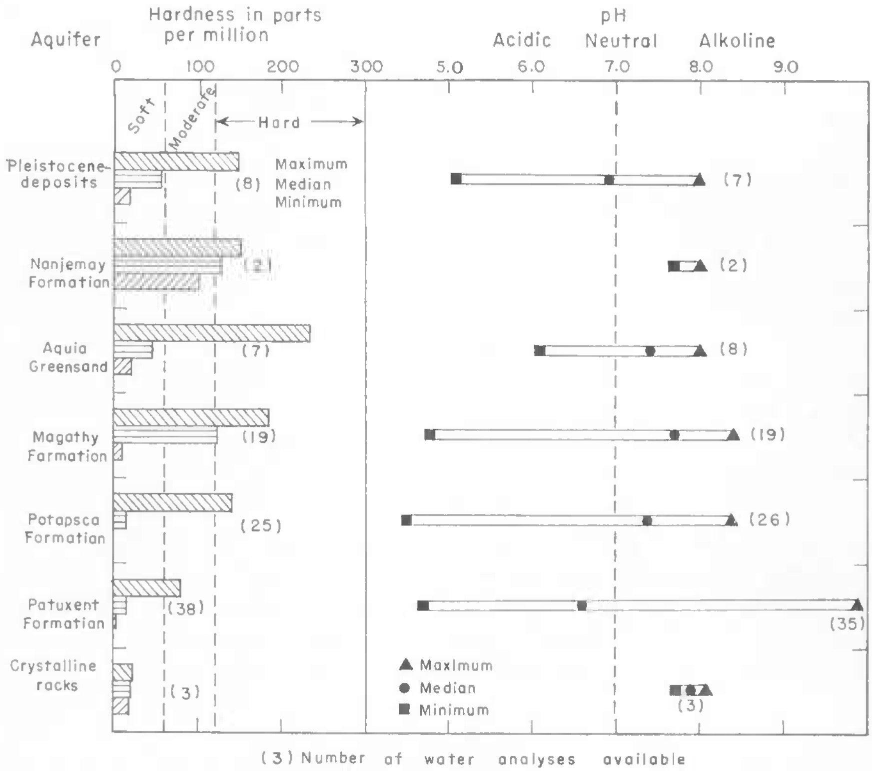


FIGURE 37. Graph showing hardness and pH of ground waters in Prince Georges County.

CLASSIFICATION BY MAJOR CONSTITUENTS

Waters are commonly classified according to their major constituent anions and cations as measured in equivalents per million. Most water from the Magothy Formation or overlying units is of the calcium bicarbonate type whereas water from underlying aquifers is generally of the sodium bicarbonate type. Other types of water are found in some of these aquifers but data regarding them are too scarce to permit generalizations regarding their occurrence. Back (1960) has described the chemical character of ground water from Prince Georges County in his paper entitled: "The origin of hydrochemical facies of ground water in the Atlantic Coastal Plain."

SPECIAL CASES

IRON PROBLEM IN WATER AT SOUTH LAWN

Because of excessive iron in water from the South Lawn well, (PG-Ec 42) the Washington Suburban Sanitary Commission discontinued use of the well in 1964. Water samples collected during exploratory testing of the site showed that the iron content of water from two of the three sands screened in the permanent well was well below the recommended limit of 0.3 ppm. After pumping

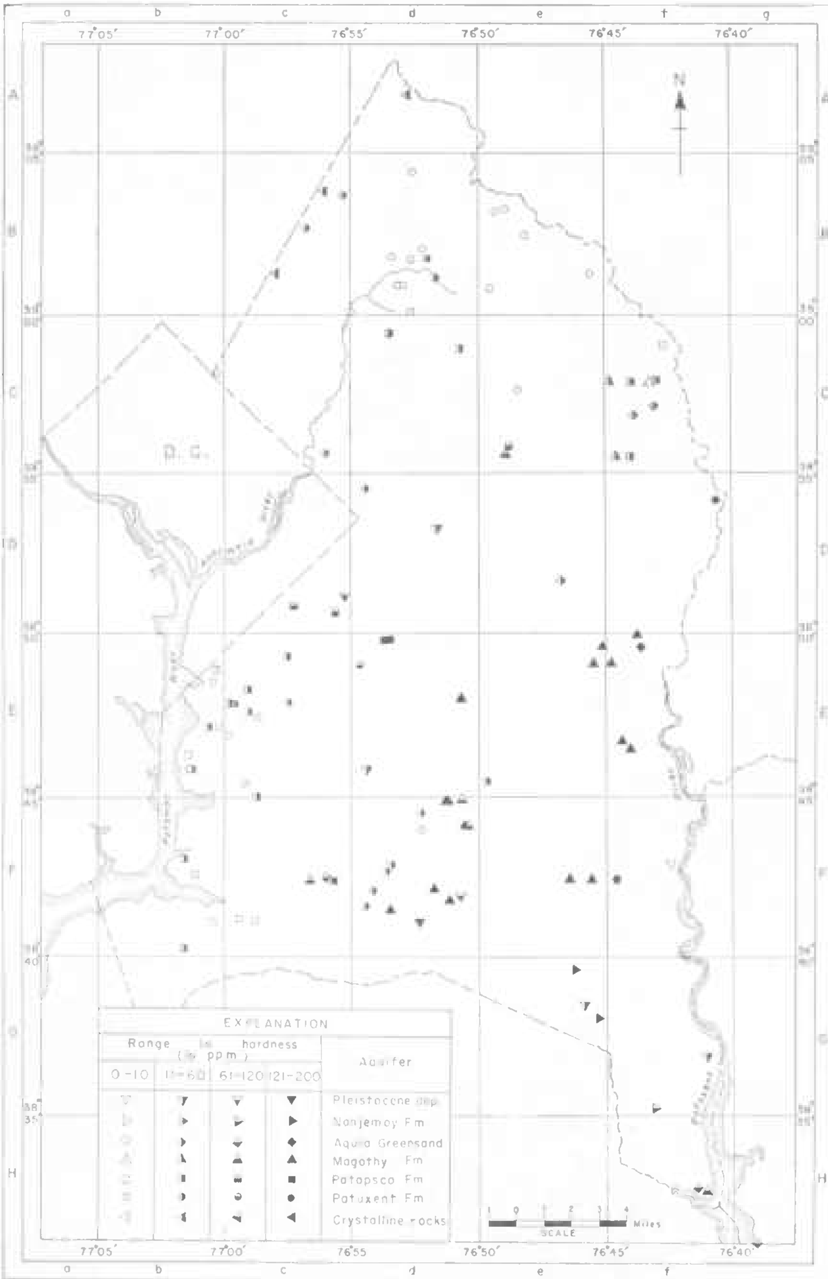


FIGURE 38. Map showing hardness of ground waters in Prince Georges County.

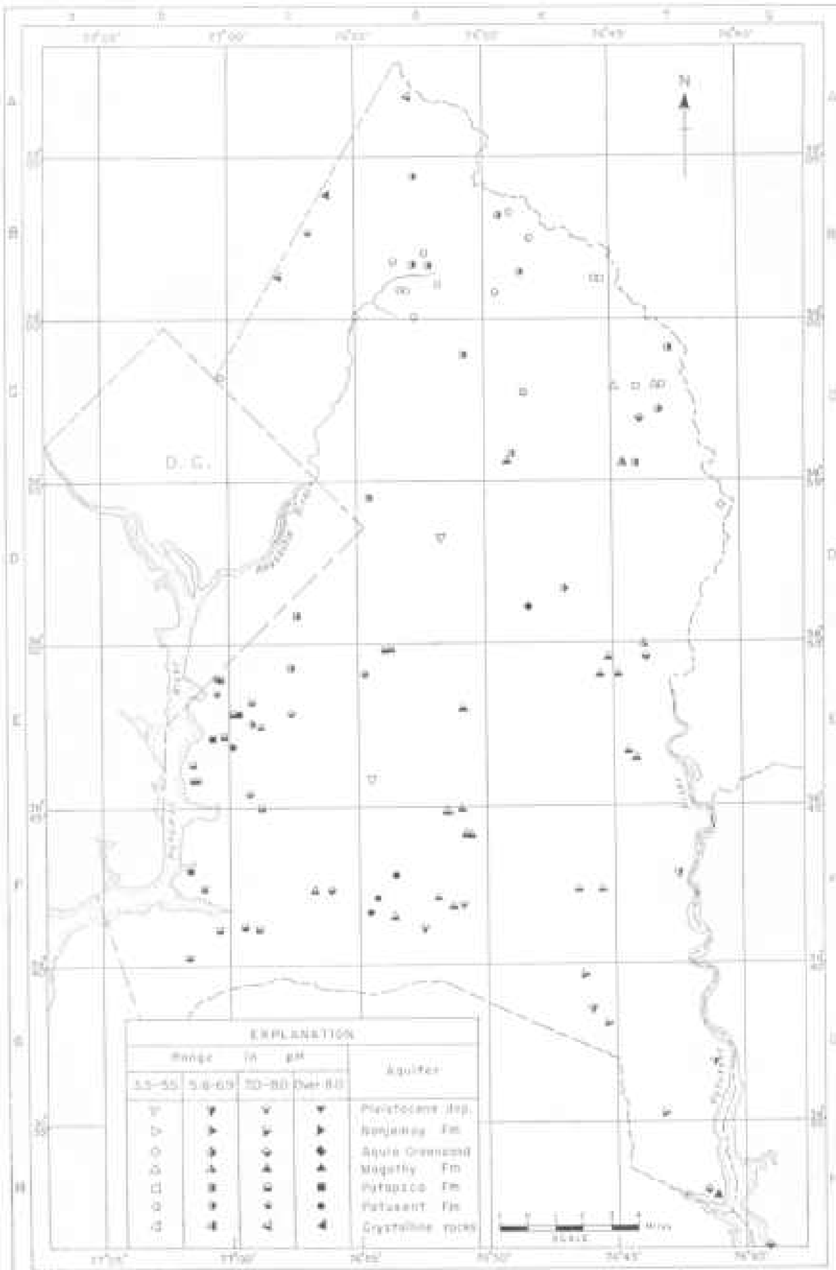


FIGURE 39. Map showing the range in pH of ground waters in Prince Georges County.

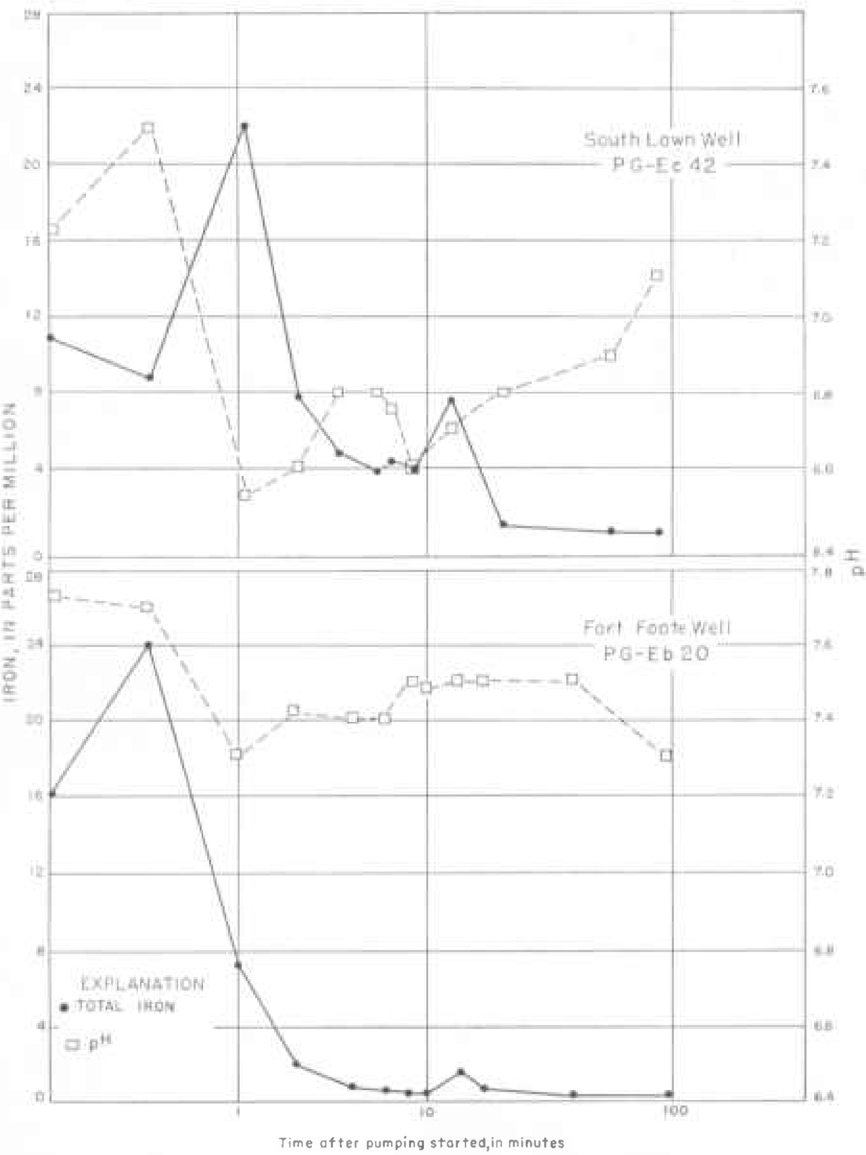


FIGURE 40. Graph showing change in concentrations of iron and pH in water from the Fort Foote and South Lawn wells during the first 2 hours of pumping.

the permanent well for a few months, however, it was found that each time the pump was turned on, the well yielded concentrations of iron up to 22 ppm during the first few minutes, but that the iron concentration dropped to about 0.7 ppm after a few hours of pumping.

William Back, research geologist with the U. S. Geological Survey, made tests to determine the rate of change of the iron concentration at both the South Lawn well and the Fort Foote well (PG-Eb 26). The test consisted of taking 12 samples in a 3-hour period, the first of which were taken at 30-second intervals and the subsequent samples taken at progressively longer intervals. The samples were analyzed for iron and pH and the results plotted as semi-logarithmic graphs in figure 40.

Comparison of the two graphs shows that water from the Fort Foote well had a fairly constant pH throughout the test and that although the iron concentration was as high as 24 ppm at 0.33 minute, the concentration dropped rapidly to about 2 ppm at 2 minutes. After 10 minutes of pumping, the iron concentration was down to 0.5 ppm. The graph for water from the South Lawn well shows that both the pH and the iron content fluctuate sharply and inversely to one another. This graph also shows that the rate of decline from the initial high iron concentration is much slower in this well, with the iron remaining at 1.1 ppm after 15 minutes of pumping.

The high iron concentration in the first water pumped from these wells probably comes from the well casing. Large areas of the casing which are submerged when the well is shut down are exposed during periods of pumping and thus are subject to corrosion.

QUALITY OF WATER FROM SANDS PENETRATED BY THE THORNE NO. 2 WELL, (PG-FC 17)

Determinations of the quality of water in six of the sands penetrated by the Thorne No. 2 well (PG-Fc 17) were made by the Washington Gas Light Company as part of the study to determine the feasibility of underground storage of gas. The water samples were collected by perforating the casing at the desired depths, placing a magnesium plug at a slightly greater depth, and then bailing or swabbing the well to obtain water samples representative of the water in the formation. Once a satisfactory sample was obtained, another packer was placed above the zone previously sampled, the casing opposite the next higher sand perforated, and the water sampled in the same manner. Except for the water from a depth of 1,343 feet below sea level, concentrations of constituents in the water were below the limits recommended by the U. S. Public Health Service for potable water supplies. Chloride content of water from the so-called "Terminus"[2] sand of the Gas Light Company was reported to be 332 ppm. Total dissolved solids of water from this aquifer was reported to be 844 ppm.

[2] The name "Terminus" was assigned by Ball and Associates to a sand which is deeper than the Athena sand of the Patuxent Formation.

SUMMARY

The known ground-water resources of Prince Georges County are not large for an area underlain by extensive Coastal Plain deposits. Geologic data show that the ratio of aquifers to non-aquifers is rather small. Two sources for the total quantity of ground water available from Prince Georges County are: (1) water in storage within the geologic formations which act as reservoirs—sources which would eventually be depleted if pumped at too high a rate, and (2) water from precipitation which recharges the ground-water reservoirs on a limited but continuing basis.

A rough estimate of the amount of water stored in the sedimentary deposits underlying Prince Georges County indicates that about one trillion (1×10^{12}) gallons of water are in relatively productive aquifers. This is enough water to supply the County for 250 years at the average rate of 11 mgd, which is the estimated total ground-water use in 1963. This figure would be misleading if it were considered to represent the amount which could be obtained with the ease and the low cost per gallon of water pumped in 1963. To exploit a significant portion of the one trillion gallons would require construction of many new wells, large increases in power costs for lifting the water from greater depths, and some possible hazards such as land subsidence and water contamination.

The Patuxent, Patapsco, and Magothy Formations, the Aquia Greensand, and deposits of Pliocene(?) and Pleistocene age contain waterbearing sands capable of supplying ground water in quantities sufficient for industrial, municipal, or irrigation supplies.

To estimate the rate at which artesian ground-water reservoirs can be recharged by water from the outcrop areas, the sands were considered to function as conduits and it was assumed that quantities of water available in the recharge area are more than adequate to keep them full. Computations were made of the quantities of water that might be transmitted downdip through them under hydraulic gradients which would prevail if water levels in them could be lowered to their upper surfaces along a line parallel to their strike. These quantities are:

FORMATION	LENGTH IN MILES	QUANTITY (MGD)
Aquia Greensand	20	1.5
Magothy	32	9.2
Patapsco	32	14.0
Patuxent	33	24
Total	—	48.7 (approx. 50)

The quantity of 50 mgd of ground water which could be conducted through the artesian strata must be considered only an approximation. The analysis used to compute this quantity assumes a relatively high degree of uniformity of the hydrologic properties of the aquifers and aquicludes. It further assumes an approximate 100 percent recovery of ground water by means of wells. In some places, actual conditions no doubt deviate substantially from the idealized assumptions used in the analysis.

In addition to the above quantity available from the artesian aquifers, a substantial quantity of water is available from the aquifers where they occur under water-table conditions. Water-table conditions prevail throughout most of the County and the total outcrop area of the aquifers is substantial. In the outcrop areas, the artesian aquifers are brim full and the ground-water recharge in excess of that which moves downdip through them maintains the flow of surface streams.

Piezometric maps for the Patuxent and Patapsco Formations show that the present recharge area for these formations is in the northwestern part of the County, which is topographically high and that much of their discharge area is along the Potomac River, an area which is topographically low and from which relatively large quantities of water are being pumped.

Concern about the possibility of contamination of fresh-water aquifers by water induced from nearby bodies of salt water is justified only in the 10 or 12 square miles of the southeastern part of the County adjacent to the Patuxent River.

The complete thickness of the Coastal Plain deposits has been tested by several test holes in the northern section of the tidewater Potomac area. The sediments are as thick as 900 feet in that area and contain relatively few good water-producing sands. Water-level data indicate these sands generally extend throughout the area but drilling data indicate some sands are absent at certain sites.

Quantities of ground water available from the northern part of the tidewater Potomac area are quite limited. About 5½ mgd might be available from it if all aquifers were completely exploited. However, the cost of such exploitation might exceed the value of the water. Reliable hydrologic and geologic data from deeper than 500 feet below sea level have not been obtained in the southern part of the tidewater Potomac area. Future testing to basement may reveal the presence of significant water-bearing sands at depth.

The total thickness of the Coastal Plain deposits in the Bowie-Belair-Crofton area has been tested by five test holes which reached basement. The Patuxent, Patapsco, and Magothy Formations underlie the area. Each contains sands capable of yielding large quantities of water. Combined they should be capable of supplying water at the 1964 rates of use for many years. Water-level data show that although pumping at high rates has a significant effect on the artesian head in the aquifers a few miles distant, water levels recover substantially during periods of reduced pumping. Pumping rates will continue to increase during the next few years because of increased growth and urbanization. Potential rates of withdrawal from this area are estimated to be as high as 19 mgd.

Estimates indicate that about 4 mgd could be obtained from the Magothy and Aquia Formations in the Chalk Point area. Geologic exploration to date (1964) in the area has reached a depth of only 675 feet, which is probably only the upper 30 percent of the total thickness of the Coastal Plain deposits in the area. The geologic and hydrologic characteristics of deposits deeper than 675 feet are unknown. Reasonable estimates of the total quantity of water available from the area will be possible only by drilling to the basement rock and hydrologically testing usable aquifers which may be discovered.

Data from the gas-storage study indicates that sands worthy of testing occur in the Cheltenham area. In some places aquifers may have transmissibilities greater than 25,000 gpd per foot. Rough estimates indicate that the combined waterbearing sands in the area may be capable of yielding up to 37 mgd for short periods of time (a few months) and probably as much as 10 mgd on a continuing basis. However, as in the tidewater Potomac area, the cost of obtaining these quantities may exceed the value of the water.

A review of the estimated total quantity of ground water available from each of the four areas described in detail is:

AREA	QUANTITY[1] AVAILABLE (MGD)
Tidewater Potomac (North)	5.5
Bowie-Belair	19.0
Chalk Point	3.7
Cheltenham	9.9[2]

[1] The reader is cautioned against adding these values to obtain a combined total because development of one area will reduce the quantity available in other areas.

[2] Long-term sustained yield.

It should be noted that the estimated quantities available from three of the above areas (tidewater Potomac, Bowie-Belair and Cheltenham) include substantial amounts of water obtainable from two or more major aquifers common to each area. If and when large-scale withdrawals of water occur simultaneously in these aquifers, some hydraulic interference must be expected between areas. For example, the sustained (long term) pumping rate from three sands in the Patapsco Formation in the Cheltenham area is computed to be about 4.5 mgd, or about 3,130 gpm (fig. 32). Based on computations using an average transmissibility of 27,500 gpd per foot, it is estimated that the 4.5 mgd rate of pumping at Cheltenham would produce declines in the water level in the aquifer at Bowie-Belair, about 16 miles distant, of from 20 to 30 feet at the end of 2.7 years of continuous pumping. Similarly, the same rate of withdrawal for the same period of time would cause a decline of water level of 40 to 50 feet in the aquifer at the tidewater Potomac area, 10 miles distant. Of course, pumping of equal quantities of water from one of the other areas would produce similar declines in the Cheltenham area. The above analysis is predicated on an assumption that hydraulic boundaries are absent and on an assumed widespread uniformity of aquifer characteristics. Thus, it appears that concurrent development of the aquifer potentials at all three sites is not feasible and an order of priority should be established. This is a problem of water-resources management and control.

The quality of water from the southern part of the County is generally good for most purposes without treatment. Water from the northern part of the County is generally high in iron and rather acidic. Most water from the Patuxent Formation in the Cheltenham area is of good quality but a sample of water from a deep sand lying below 1,300 feet had dissolved solids as high as 844 ppm.

Proper management of the aquifers in the County will assure continuous supplies of many millions of gallons a day. Such management will entail: (1) the detailed monitoring of water levels and pumpage from individual aquifers, (2) the development of new well fields only after studies of the hydraulic effects they will have on other areas, and (3) guarding against aquifer contamination from any source.

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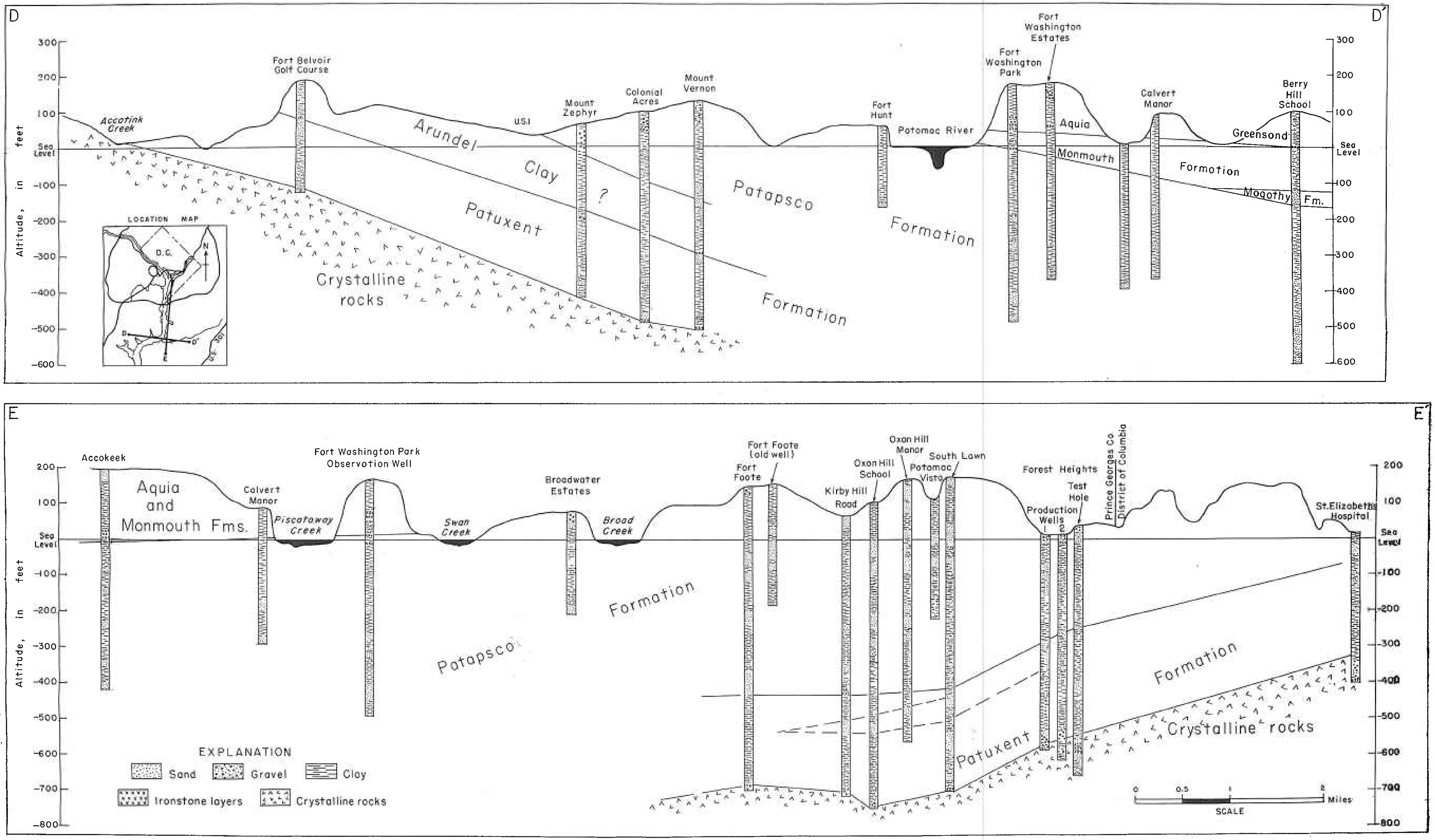

Plate 2. Geologic sections in the tidewater Potomac area: D-D′ based on wells from Accotink Creek, Virginia, to Berry Hill School, Prince Georges County, and E-E′ based on wells from Accokeek, Maryland, to St. Elizabeth's Hospital in the District of Columbia.

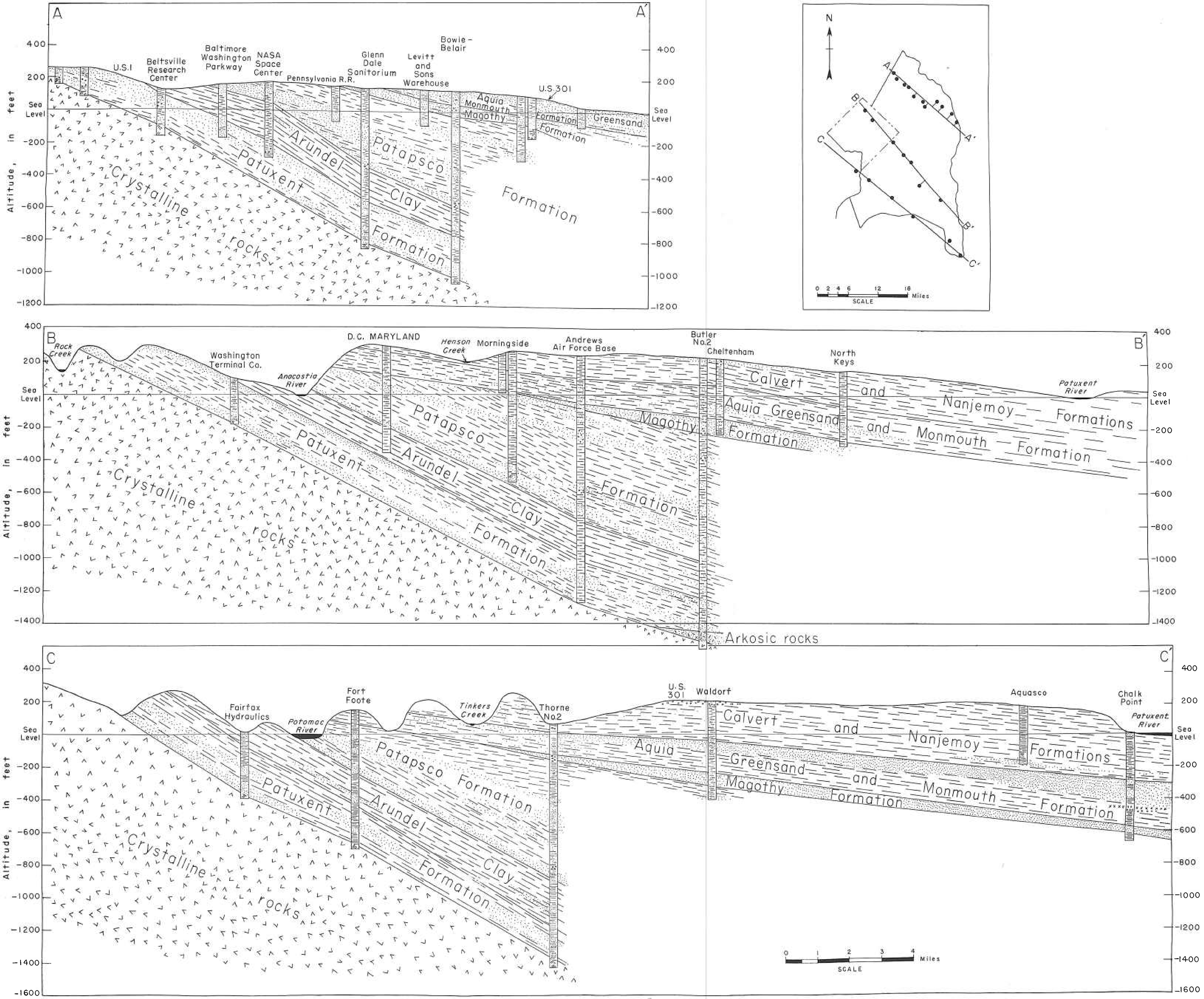

PLATE 1. Geologic sections A-A′, B-B′, and C-C′ across Prince Georges County.