PREPARED IN COOPERATION WITH THE
MARYLAND GEOLOGICAL SURVEY

GROUND-WATER YIELDS

AVAILABILITY

Fresh water in southern Maryland is available from precipitation, from streams, and as ground water occurring under water-table and confined conditions.

About 690 mgd (million gallons per day) is estimated to be available from streamflow, but the streams are subject to contamination and are limited in their accessibility. Furthermore, streamflow fluctuates greatly, and the local topography generally does not lend itself to large-scale impoundment of water by damming.

It is estimated that about 345 mgd (representing the average quantity of ground water discharging to the streams) is available as ground water under water-table conditions in shallow surficial deposits. These deposits, generally less than 100 feet thick, formerly supplied most of the domestic needs. However, the available drawdown generally is not sufficient to support large yields at specific locations, and seasonal fluctuations in storage are large. Also, in some places, contamination from the land surface or by salt water is a potential hazard. Nevertheless, through use of different well construction—collector types, for example—it may be feasible to develop large supplies from these deposits, particularly where their saturated thicknesses are greatest.

Underflow in the deeper artesian aquifers is much less than that in the shallow deposits, but the amount of water in storage is much greater. Underflow in the major artesian aquifers is estimated to be less than 28 mgd. Although the annual replenishment of water to the artesian aquifers is small, the large available drawdown, predictability of occurrence, relative freedom from contamination, and large amounts of water in storage favor dependence upon these aquifers as sources of water.

GROUND-WATER YIELDS

Yields, as discussed in this report are (1) short-term, (2) long-term, or (3) indefinitely sustainable. Short-term yields are those maintainable for several hours at a time, with longer intervening periods of no pumping. Long-term yields are those maintainable for a number of years, assuming withdrawal chiefly from storage and a gradually declining head. Indefinitely sustainable yields are those maintainable for an infinite number of years, assuming withdrawal is dependent only on normal and induced perennial ground-water underflow and vertical leakage.

SHORT-TERM YIELDS

Short-term yields are of significance primarily to those who are concerned with obtaining water on an intermittent rather than a sustained basis, and who plan to withdraw ground water during only a small fraction of the total time.

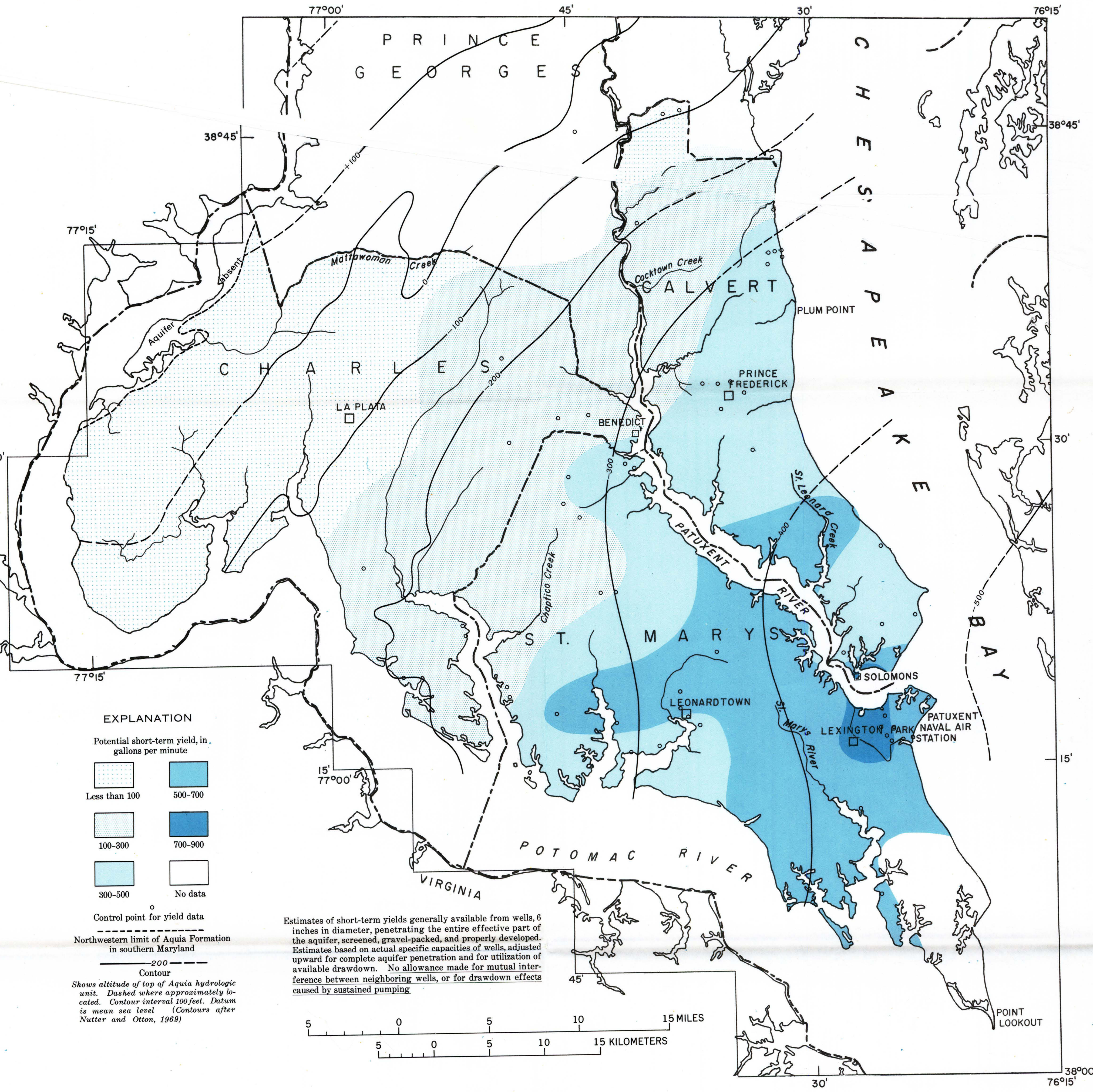
The yield maps indicate potential short-term yields from wells tapping the Aquia and Piney Point-Nanjemoy hydrologic units. These yields are not the theoretically attainable upper limits. Rather, they are believed to be generally obtainable from wells, 6 inches or more in diameter, that are screened, gravel-packed, properly developed, and penetrate the total effective part of the aquifer.

The yields indicated on the maps do not allow for possible interference from adjacent wells, or for slow cumulative drawdown effects during extended periods of pumping. Both factors can and do become important locally, and pose problems where withdrawals are sustained. The yields indicated are additive at any given point. That is, at a site where the potential short-term yields from the Aquia and Piney Point-Nanjemoy units are 300 gpm (gallons per minute) in each case, the total for wells screened in both units is 600 gpm. Comparable yields are available from the Magothy, Patapsco, Raritan, and Patuxent units where those units occur and are productive, but available information does not justify construction of "yield" maps.

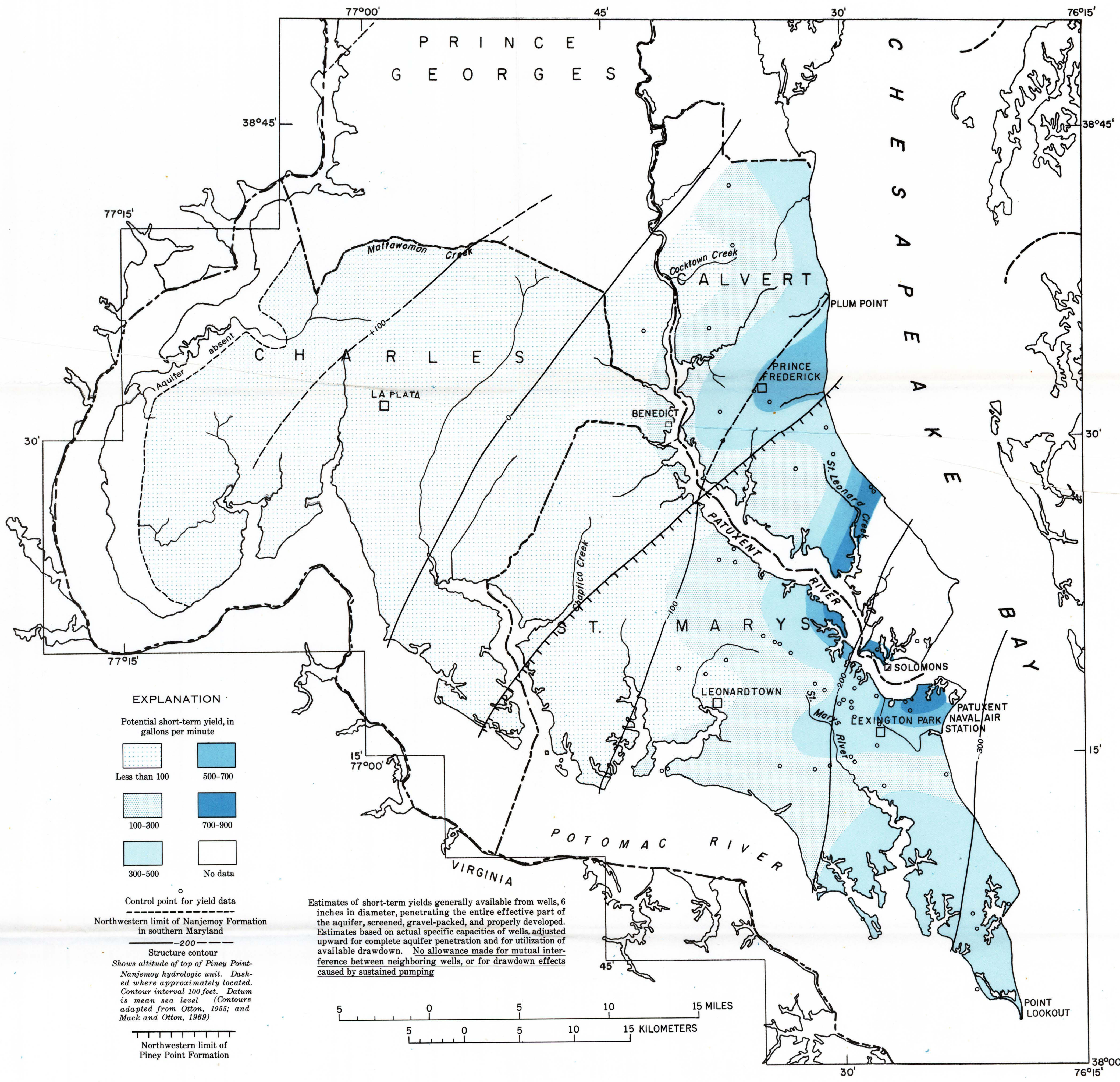
The maps are based on well specific capacities adjusted upward for complete penetration of the effective aquifer thickness and for utilization of available drawdown. Most of the specific capacities used in the study are based on data submitted by well drillers. Only half the drawdown available to the tops of the aquifers was used in computing the potential yields from the adjusted specific capacities. This was done to allow for decrease in well efficiency and specific capacity resulting from increased yield, for the variation in available drawdown caused by differences in land-surface elevation and the dip of the aquifer, and for the probably imprecise nature of some reported data. The potential yields indicated on the maps, therefore, are conservative.

Because the adjusted potential well yields incorporate permeability, total effective aquifer thickness, and available drawdown, the short-term yields maps also give relative indications of potential long-term yields.

The contours of the tops of the Aquia and Piney Point-Nanjemoy hydrologic units are presented for use in determining depths of those units below land surface. At a given point, depth from land surface to the top of a unit is the difference in altitudes of the land surface and the top of the unit.



MAP SHOWING SHORT-TERM GROUND-WATER YIELDS AVAILABLE FROM AND TOP OF THE AQUIA HYDROLOGIC UNIT



MAP SHOWING SHORT-TERM GROUND-WATER YIELDS AVAILABLE FROM AND TOP OF THE PINEY POINT-NANJEMOY HYDROLOGIC UNIT

The map of potential short-term yields from the Aquia unit indicates a general increase southeastward in southern Maryland, from less than 100 gpm to more than 600 gpm, reflecting a general southeastward increase in transmissibility of the Aquia unit.

The map of potential short-term yields from the Piney Point-Nanjemoy unit indicates a general increase eastward, from less than 100 gpm in the western two-thirds of the report area to more than 300 gpm in eastern Calvert County and most of eastern St. Marys County, and more than 500 gpm east of Prince Frederick and in the lower Patuxent River valley. These changes reflect a corresponding eastward increase in transmissibility of the Piney Point-Nanjemoy unit.

LONG-TERM YIELDS

The maps of short-term yields do not take into account the possible effects of nearby wells that might tap the same aquifer. If wells were to be pumped for extended periods, local cones of depression would develop in the piezometric surfaces of the corresponding aquifers, and would expand if pumping were maintained. In time (depending on their proximity) the cones of depression would merge, and the drawdown effect would be compounded with resulting rapid decrease in yields. Therefore, for long-term yields resulting from sustained withdrawals, well spacing is a critical factor.

In addition to well spacing, long-term yields from wells are affected by vertical inter-aquifer leakage, proximity to permeability barriers, and perennial ground-water underflow within the individual aquifers. The extent and significance of vertical leakage in southern Maryland are virtually unknown at present. The presence of permeability barriers is known only imperfectly. Perennial underflow, computed on the basis of transmissibility and hydraulic gradient, is discussed under "Indefinitely Sustainable Yields".

Evaluation of the individual factors and determination of potential long-term ground-water yields throughout southern Maryland are beyond the scope of this report. Two examples of hypothetical aquifer development are discussed below to indicate the type of quantitative analyses needed to determine long-term yields.

Line A–A′ on the map showing hypothetical wells was located so as to place it beyond the effects of the Lexington Park cone of depression and reasonably far from any known permeability barrier in the Aquia unit. Its orientation is such that the transmissibility coefficient of the Aquia unit is fairly constant along the line, and underflow as of 1951 was normal to the line.

Assuming 500 gpm (0.72 mgd) of water were withdrawn continuously from the Aquia unit at an isolated well (No. 5) midway on line A–A′, the drawdown at the end of 1,000 days (2.73 years) would be about 276 feet, or 77 percent of the 360 feet of drawdown available to the top of the aquifer. After 10,000 days (27 years) of continuous withdrawal, the drawdown would be about 328 feet, or 91 percent of the total available. Drawdown would continue, but at a constantly decreasing rate.

If a second well (No. 4) were to tap the Aquia unit 3 miles to the southwest and both wells (Nos. 4 and 5) were pumped continuously at 500 gpm, the drawdown at each after 2.73 years would be 276 feet plus 40 feet caused by the well 3 miles away—a total of 316 feet at each well.

If a third well (No. 6) were located 3 miles to the northeast of well No. 5 and all three wells were pumped at 500 gpm for 2.73 years, the drawdown in the middle well (No. 5) would be 276+40+40, or 356 feet. Theoretically, at the end of 10,000 days of pumping the drawdown at the middle well would be 328+65+65, or 458 feet; this drawdown would be more than that available, and the yield from the middle well would have decreased considerably long before the end of 10,000 days.

Hypothetical wells tapping the Aquia unit have been indicated along line A–A′ at intervals of 3 miles. The wells are assumed to be 12 inches in diameter and 100 percent efficient. Sustainable yields have been calculated for periods of 1,000 days and 10,000 days, based on available drawdown to the top of the aquifer ranging from 260 feet at A to 425 feet at A′; a transmissibility value of 5,000 gpd per ft; a storage coefficient of 0.0002; and on the assumption that virtually all the water comes from storage. The results are shown in the table of long-term sustainable yields.

The increase in sustainable yields from A to A′ is related to a general eastward increase in available drawdown. For the Aquia unit, potential long-term sustainable yields increase toward the east and southeast, because available drawdown and transmissibility increase in those directions. A similar analysis for the Piney Point-Nanjemoy unit would show that the potential long-term sustainable yields also increase generally—though less regularly—toward the east.

A total of at least 5.25 mgd for 2.73 years, or 3.48 mgd for 27 years could be withdrawn from the Aquia unit from wells spaced as shown on line A–A′ if all the water came from storage and no water were withdrawn from nearby wells in the same unit. In reality, some additional water is available from perennial ground-water underflow, lateral underflow induced from adjoining areas, and vertical leakage from other aquifers. (In reality, by 1966–67 the increasing Leonardtown cone of depression had reduced the available drawdown by 10 to 20 feet along the central part of line A–A′.)

For the purpose of mining as much water as possible and as rapidly as possible from ground-water storage under an area, a grid network would be much more efficient than a line of wells. In a grid arrangement the yield from each well would be smaller but the combined yield from all the wells would be greater. Also, interference effects would be more complex (see example of hypothetical-well spacing under *Leonardtown Area*).

The perennial ground-water underflow in the Aquia unit at line A–A′ can be estimated using the modified Darcy formula $Q = TIL$, where:

Q = ground-water flow, in gallons per day
T = coefficient of transmissibility, in gallons per day per foot of aquifer
I = hydraulic gradient, in feet per mile, and
L = length of the vertical plane through which the flow occurs, in miles

Here, it is assumed that $T = 5{,}000$ gpd per ft and $L = 24$ miles. The underflow is only 0.15 mgd, assuming a hydraulic gradient (L) of 1 1/4 feet per mile (the estimated slope of the piezometric surface under natural conditions). On a long-term basis the estimated total potential sustainable yield from wells 1 through 9 along line A–A′ would be increased by only 0.15 mgd by perennial underflow in the Aquia unit.

The amounts of water inducible by lateral underflow from adjoining areas and vertical leakage from other aquifers are unknown factors. However, the quantities from these sources probably would increase as the drawdown produced by withdrawal along line A–A′ increased, because of increased head differences.

Leonardtown Area.—Combined withdrawal from three wells (I, II, and III) in the Aquia unit, spaced 3 miles apart around Leonardtown and assuming no other local withdrawal from that unit, could be maintained at 1,500 gpm (2.16 mgd) for 2.73 years or 1,200 gpm (1.73 mgd) for 27 years, from storage alone. Some additional yield would accrue from perennial underflow, underflow induced from adjoining areas, and vertical leakage. The present rate of withdrawal from the Aquia unit at Leonardtown is estimated to be about 0.17 mgd, or about one-tenth the computed 1.73 mgd available from storage on a 27-year basis.

If a fourth well were added to the three-well network—say well No. 4 in line A–A′ or a well 3 miles southwest of well No. III—the four wells would have to be pumped at lower individual rates, but the combined rate of withdrawal on a 27-year basis would be greater than for the three wells.

If water were withdrawn simultaneously from hypothetical wells 1 through 9 along line A–A′ and from hypothetical wells I, II, and III, mutual interference would be increased, and the total rate of withdrawal possible from storage on a long-term basis would be less than the sum of the totals indicated for the two groups of wells. Also, withdrawal from the wells along line A–A′ would remove part of the small perennial underflow in the Aquia unit that might otherwise benefit the well field in the Leonardtown area.

Limited amounts of water are also available at Leonardtown from the Piney Point-Nanjemoy hydrologic unit despite fairly low transmissibility locally (estimated to be about 2,500 gpd per ft, and less to the northwest). Withdrawal of water from storage in this unit probably could be maintained for 3 years at 100 gpm each for three hypothetical wells (a total of 0.43 mgd) 3 miles apart and centered about Leonardtown. If the wells had no source of water other than storage in the Piney Point-Nanjemoy unit, the piezometric surface probably would be drawn down to the top of the aquifer locally in a very few years and the well yields would then decline rapidly.

Some additional water might be obtained from lateral recharge from the northwest, but because the unit has lower transmissibility in that direction recharge by underflow would be limited. Some water also might be derived from vertical leakage, especially from the overlying materials, but the amount is unknown.

Fresh water occurs in the Patapsco, Raritan, and Patuxent units at greater depths. The potential sustainable yields from these units are not known, but they are believed to be comparable with those available from the Aquia unit.

INDEFINITELY SUSTAINABLE YIELDS

Indefinitely sustainable yields involve no reduction in ground-water storage. They depend only on utilization of the perennial underflow, or ground water that normally would discharge elsewhere.

One method of approximating the upper limit for indefinitely sustainable yields from an aquifer under a large area is by the conduit analogy. This approach assumes that the aquifer conducts ground water directly from the intake area to its discharge area, and gives an estimate of the maximum amount of water that theoretically could be withdrawn from an aquifer on a perennial basis. The total amount of ground-water flow possible through an imaginary vertical plane located in the intervening area, and oriented normal to the direction of flow, is computed by using the equation $Q = TIL$. In using this method one assumes an average transmissibility for the entire area and a hydraulic gradient equal to the slope of the piezometric surface if it were drawn down to the top of the aquifer. Both assumptions admittedly are unrealistic, but are useful.

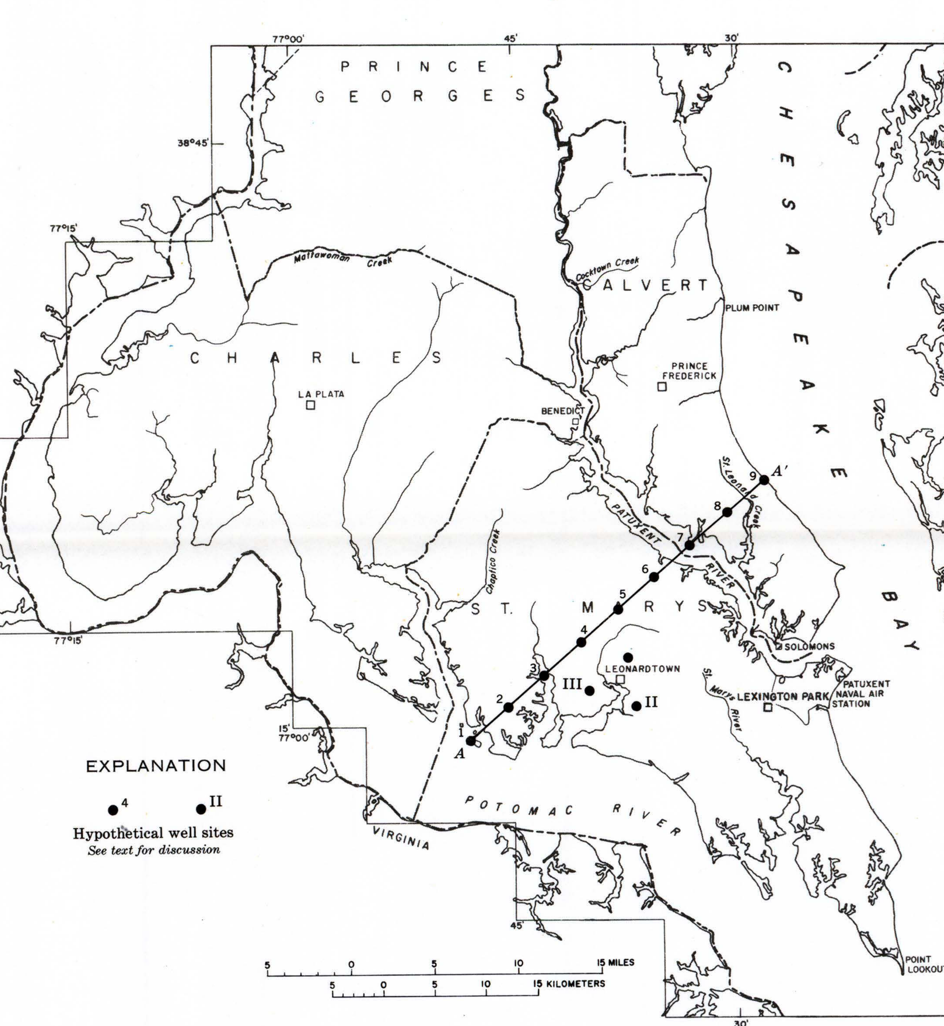
The totals for the three counties (see table of indefinitely sustainable yields) are only partially additive, because perennial underflow intercepted in one county cannot be recaptured in another county farther along in the direction of the underflow.

LONG-TERM SUSTAINABLE YIELDS FROM HYPOTHETICAL AQUIA WELLS 1-9

Well no.	1	2	3	4	5	6	7	8	9	Total
Yield (2.73 yrs) gpm (mgd)	350 (.50)	300 (.43)	325 (.47)	350 (.50)	400 (.58)	400 (.58)	450 (.65)	475 (.68)	600 (.86)	3,650 (5.25)
Yield (27 yrs) gpm (mgd)	200 (.29)	175 (.25)	200 (.29)	200 (.29)	265 (.38)	275 (.40)	300 (.43)	350 (.50)	450 (.65)	2,415 (3.48)

It is assumed that the water is withdrawn only from storage, and that there is no other nearby withdrawal from the Aquia unit. It is assumed, also, that the wells are 12 inches in diameter and 100 percent efficient.

The total yields along line A-A′ could be increased slightly by juggling the pumping rates at the nine wells, and could be increased more by spacing wells closer together and decreasing the individual pumping rates.



LOCATIONS OF HYPOTHETICAL WELLS DISCUSSED UNDER "LONG-TERM YIELDS"

COMPUTATION AND SUMMARY OF INDEFINITELY SUSTAINABLE YIELDS FROM MAJOR AQUIFERS IN SOUTHERN MARYLAND, BY COUNTY

	Calvert County								St. Marys County								Charles County[1]
Hydrologic unit	T (gpd per ft)	×	I (ft per mile)	×	L (miles)	=	Q (mgd)		T (gpd per ft)	×	I (ft per mile)	×	L (miles)	=	Q (mgd)		Q (mgd)
Piney Point-Nanjemoy	6,000	×	9.5	×	11.5	=	0.7		6,000	×	8	×	15	=	0.7		—
Aquia	7,000	×	8	×	7	=	0.4		10,000	×	12	×	18	=	2.2		1.6
Magothy	10,000	×	22	×	12.5	=	2.8		3,000	×	16	×	6.5	=	0.3		2.5
Patapsco-Raritan[2]	7,000	×	19	×	19	=	2.5		7,000	×	11	×	16	=	1.2		6.2
Patuxent[2]	4,000	×	19	×	13.5	=	1.0		4,000	×	19	×	17	=	1.3		4.7
Total							7.4								5.7		15.0

[1] Yields for Charles County after Slaughter and Otton (1968)
[2] Transmissibility values extrapolated from Charles County and elsewhere; "I" is estimated.

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WATER RESOURCES OF SOUTHERN MARYLAND

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