Gunpowder Falls Maryland

USES OF A WATER RESOURCE TODAY AND TOMORROW

By DERIC O'BRYAN
and RUSSELL L. McAVOY

An analysis of the major demands on the Gunpowder Falls basin: living space, water supply, and recreation

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Introduction

The Maryland watercourse known as Gunpowder Falls is a lovely landscape and a sustaining and relaxing environment—a natural commodity for man to use and enjoy. The stream is not large, but as a water supply it is one of the most important in Maryland. More people depend on it for water than on any other water source within the State, and more money has been spent over a longer period to develop, treat, distribute, and protect its water than for any other Maryland stream. At 14 cents per thousand gallons, the water is one of the best bargains in Maryland, and a high-quality product, too, for the quality of Gunpowder Falls water is comparable with that of the best public supplies in the Nation. And it all belongs to Baltimore—the Baltimore Bureau of Water Supply holds rights to all surface or runoff water in the entire Gunpowder Falls basin.

Different people value Gunpowder Falls in different ways. To each of the 1.4 million water users the proportionate capital value share of the Metropolitan Baltimore water system is about $160. Each of Maryland's taxpayers is contributing about $5 towards the acquisition of a State park in the basin; development and maintenance of that park will cost more on a continuing basis. Every one of the approximately 1,000 families who settle annually (the number increases each year) in the expanding suburbs and diminishing rural corners of the basin invests several to many thousands of dollars on a home. Additional tens of thousands of people think of Gunpowder Falls in conjunction with a fishing license, a boating fee, an available picnic table.

The present overall conditions in the Gunpowder Falls basin are good. Much has been written about the basin, planned for it, and

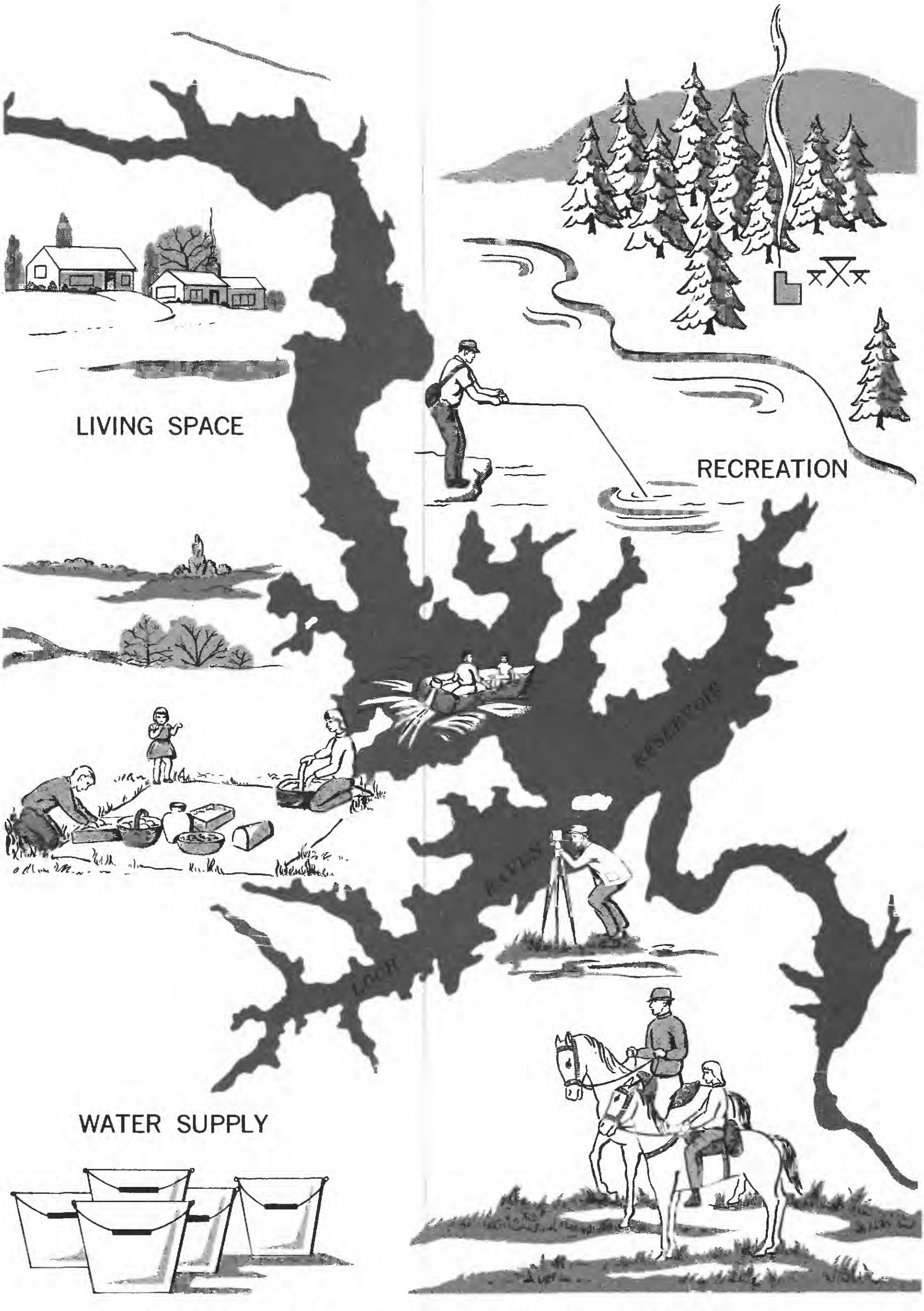

FIGURE 1.—The three major uses of the Gunpowder Falls basin.

done to it. The basin now provides (1) pleasant living space within easy commuting distance from Baltimore for a rapidly expanding population, (2) an excellent water supply, and (3) countrysides and reservoirs for limited recreation (fig. 1). These are the three major uses of the basin which bear upon the water resources, now and in the foreseeable future.

To date the basin has served admirably; it has met most of the demands placed upon it. Present actions, trends and forecasts, and universal human desires clearly indicate that its land and water will be used to an ever greater extent. Wise planning and development, based on a sound understanding of the basin's potential, will permit further equitable exploitation. If demands exceed the area's ability to meet them, the consequences will include "water problems."

We have analyzed the Gunpowder Falls basin as it is today, with emphasis on its water resource. We have considered the trends and plans and probabilities in store for it, and have attempted to predict the local condition of the water resource in years to come. The crux of our report is: How does the Gunpowder Falls water serve now, and how well will it serve 50 years hence?

WHAT THE BASIN PROVIDES TODAY

Living Space

Room for homes—living space—is one of the three major uses of the Gunpowder Falls basin; it is probably the most rapidly increasing use because more and more of Baltimore's residents look for suburban or country homes. Where he lives is of primary interest to everyone. Accessibility to means of livelihood and a pleasing environment are basic considerations in the selection of a permanent address. The attractive basin, on the margin of a thriving metropolitan area, inevitably will contain more and more people.

Location

The Gunpowder Falls basin is almost entirely within Baltimore County, Md., and the stream drains slightly more than half of the county. The 350-square-mile watershed is about 50 miles long; the maximum width is about 16 miles (fig. 2). It starts in Pennsylvania, a few miles north of the village of Lineboro, Carroll County, Md. The rolling to rugged country of the headwaters approaches 900 feet in elevation. The stream enters the northwestern corner of Chesapeake Bay near the old port of Joppa, where the fresh flowing water is "lost to salt."

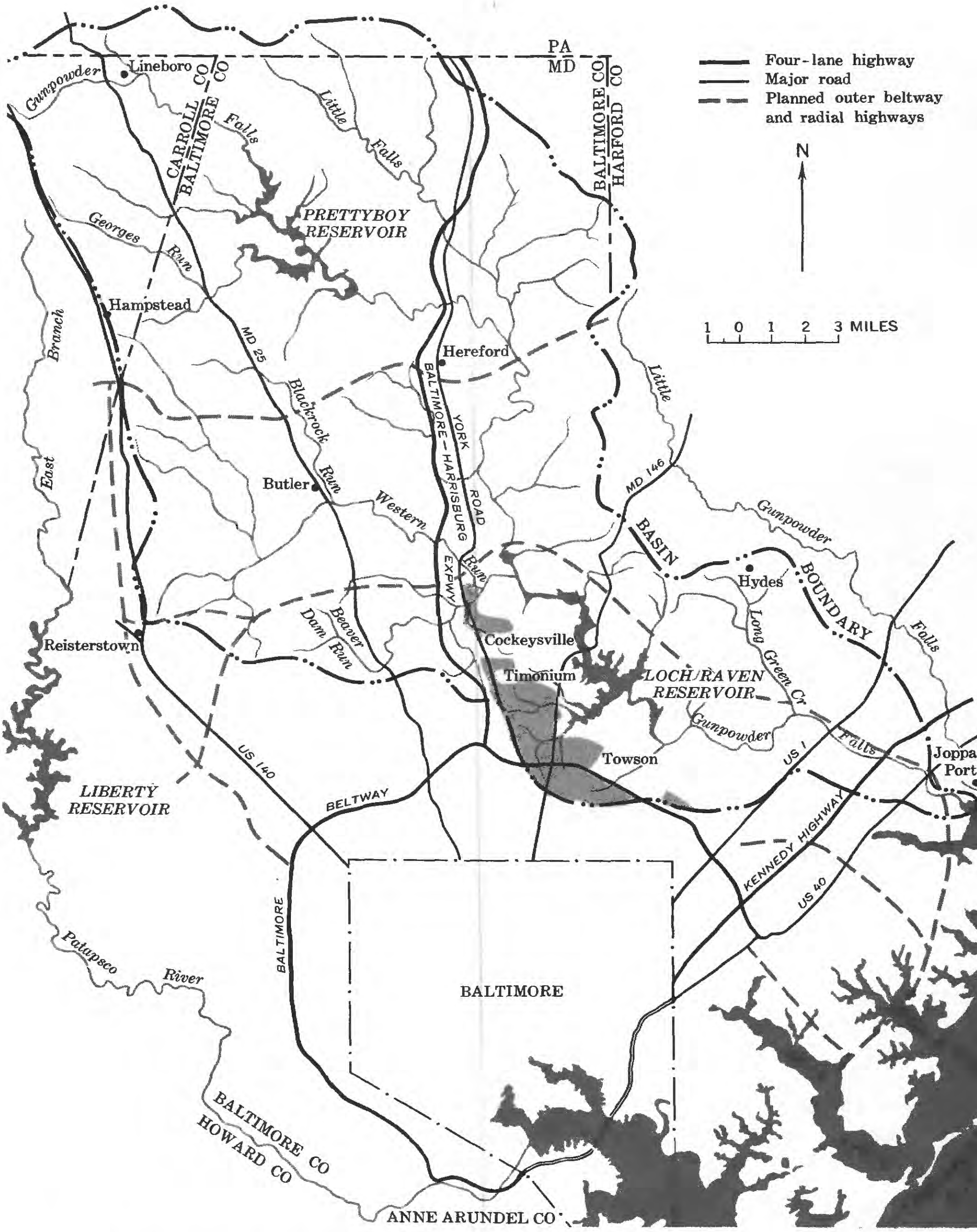

FIGURE 2.—Index map, showing main roads and highways in the basin, existing and planned (adapted from Maryland State Roads Comm., Plan. and Programming Div., 1961). Shaded areas are communities and industrial parks now in existence.

History

Captain John Smith may have entered the Gunpowder River estuary in 1608 on his second voyage of exploration in the Chesapeake Bay. Later, other ships sailed up the Gunpowder River as far as they could, to the last cascade of the stream before it enters the Coastal Plain. Above this so-called Fall Line, the stream was named the Gunpowder Falls to distinguish it from the downstream and tidal navigable part. The first white settlement in the region was established by 1627 southeast across the Bay on Kent Island, which is at the eastern end of the present Chesapeake Bay Bridge. The founder, Claiborne, soon after located a fur-trading station on Garrett Island (then called Palmer's Island) in the mouth of the Susquehanna River. Gunpowder Falls received its name about this time (Seitz, 1946, p. 9):

> Tradition relates that the * * * Indians * * * when first they became acquainted with gunpowder * * * supposed it to be a vegetable seed. They sowed it and expected a good crop, unsuspecting that this seed would produce bloodshed and violence instead of flowers and vegetables.

"Old" Baltimore, on the Bush River about 10 miles southwest of the Susquehanna's mouth, became the recognized seat of government by 1674 for the then-extensive Baltimore County. The seat was transferred to Joppa, at the head of the Gunpowder River, nominally in 1707 and entirely by 1712. Government business and a prospering tobacco trade were conducted there until the county seat was moved again in 1768 to present-day Baltimore. The Rumsey mansion (sketched on the cover), built in 1721, is the only surviving landmark of once-thriving Joppa.

Water has had an important role in the history of the Gunpowder Falls basin since 1775, when William Hoffman built the first papermill in Maryland. He determined that (Seitz, 1946, p. 10, 11):

> The land surrounding the Great Gunpowder Falls contained much limestone which was considered favorable for water near by, since it kept the water clear and pure. This was very important for papermaking. All paper was made by hand; cloudy or muddy water would discolor the paper. The location which Hoffman chose was near the source of the river, which again was an advantage, since upstream the water was clearer and would clear up quickly after heavy rains or flood. To be sure, it was a rather primitive wilderness around Gunpowder Falls, yet it was the abundance of water and its potential power that counted. Besides its natural features the place had some geographical advantages. Hoffman had been a papermaker in Pennsylvania. The new place was very close to the Pennsylvania-Maryland line, not more than sixteen miles from York.
>
> * * * Time and place seemed to favor Hoffman's undertaking. The year 1776 when he started to develop his business saw the beginning of the American Revolution. Shortly thereafter the Continental Congress moved from Philadelphia to York, Pennsylvania, a few miles north of Hoffman's mill.

According to Howard (1876, p. 818), Hoffman

> * * * espoused the cause of the Colonies and greatly facilitated the Government by furnishing it with paper. When it adopted currency, he manufactured the paper for nearly all the Continental money; an important historical fact, not generally known * * *

Throughout the 19th century the basin invited the construction of more papermills and other industries dependent on good water. Iron smelters—furnaces—had their day. Forests gave way to fields. The basin remained attractive, but many changes had taken place by 1881 (Scharf, 1881, p. 15):

> The Great Gunpowder has all its large affluents within the limits of the county. Several of these, such as the Little Falls, Western Run, Black Rock Creek, and Beaver Dam, are powerful streams which drain most of the northwestern half of the territory. The river itself is one of marked beauty and variety, and especially so in its upper divisions. Like all the rivers and creeks of the uplands, it plunges at one place over huge rocks in a heavy cascade, at the next it forms strong rapids among the boulders, and then placidly glides along for nearly a mile in a wider, deeper channel, through a bed of alluvial soil. Its course is very sinuous, and particularly so, on a grander scale, south of the great fork below Whitehall; while farther down it becomes a majestic stream, full of energy, and supplying power for very large mills factories, and furnaces at many points along its course. Yet it no longer fills the wide channel which it once occupied, nor can it be estimated to contain much more than one-fourth the volume of water that belonged to it about one hundred years ago. The drying up of springs which originally supplied its tributaries, and the decomposition of the rocks into soils along the banks, have changed the order of distribution of the water and placed it in new relations. Hillsides, once covered with trees, shrubs, and herbage, retained the rain-water near the surface or allowed it to flow in a gradual supply to the springs beneath, while a notable proportion entered the cracks in the rocks to trickle through and converge in the streams at lower levels. But now the hillsides, baked by the sun, allow the rains to run off by a single impulse, to be lost in swelling floods * * *

Careless use resulted in much erosion of the land in the 18th and 19th centuries. The port of Joppa, once able to accommodate ships of 8-foot draft, became choked with sediments. The head of the Gunpowder River now is a tidal marsh (Gottschalk, 1945, p. 223–225):

> A hydrographic chart of the Gunpowder estuary issued by the United States Coast and Geodetic Survey in 1846, a hundred years after the town (Joppa) had reached its peak of development, shows the above-tidewater delta surface to be a mile and a half long. By this date it had encroached within a quarter of a mile of the wharf. By 1897, when a second hydrographic chart was issued, the above-tidewater deposits had filled the entire estuary opposite the wharf and extended along a front three-fourths of a mile below the town. It was computed from data on these two charts that 7,900,000 cubic yards of sediment was deposited in the upper part of the Gunpowder estuary in the 51-year period between 1846 and 1897.

Today the above-tide deposits extend nearly to the Pennsylvania Railroad bridge, a mile and a half below the townsite. The scene at Joppa Town is one of desolation. Old foundations are still visible through the tangled growth of weeds and underbrush. At a distance of 20 or 30 feet out from the original shore line is a heap of stones, the remnants of the old wharf. A hundred feet beyond is tree-covered land where ships once rode at anchor.

The countryside today is much less erodable than it was 100 years ago. A third of the land has been permitted to revert to forest, and many tilled fields have been converted to pasture lands. Agriculture—and erosion resulting from it—has been on the wane, at least since the turn of the century.

Seitz (1946, p. 53–54) brings the history of the basin up to date and provides a thoughtful appraisal of the increasing value of the water resources:

The new dam whose waters now cover the greater part of the old Hoffman land was named Prettyboy Branch, a small tributary of the Great Gunpowder Falls. Prettyboy Branch derived its name from a riding horse of the same name that belonged to a farmer through whose property the creek ran. When the horse met an untimely death by drowning in the little stream, the farmer commemorated Prettyboy by giving the creek the name of the horse * * *

It was the water that brought the Hoffman mills into existence. It was the water that attracted old William Hoffman to this part of the state when he came south in 1775. It was the water that let him choose the valley of the Great Gunpowder Falls for his industry. Now it was the water again that caused his land to submerge. In William Hoffman's time the water had driven the wheels and had served the men who owned the land. Five generations later, the water had become more valuable than the land, and the land with all its mills and buildings, its trees and groves, its charming memories and old traditions had to yield before the necessities of a new, hard, forward-pushing time.

Population

Most of the half million people in Baltimore County live close to or within the metropolitan area, but less than 20 percent live in the Gunpowder Falls basin, which occupies half of the county's total area. Three-fourths of the residents of the basin live near the northern boundary of the city of Baltimore, in an arc of expanding communities on the west and south sides of Loch Raven Reservoir and extending down the southern rim of the basin to tidewater. The rest of the Gunpowder Falls basin is still rural. The basin's approximate 1960 population is listed in the caption of figure 3, by election districts.

Economics

Agriculture is waning in the Gunpowder Falls basin as population and land values increase (Hamilton, 1961, p. 8):

Suburbanization and industrial expansion, during the past 10 years, reduced by almost one-third the land in farms in Baltimore County. The number of

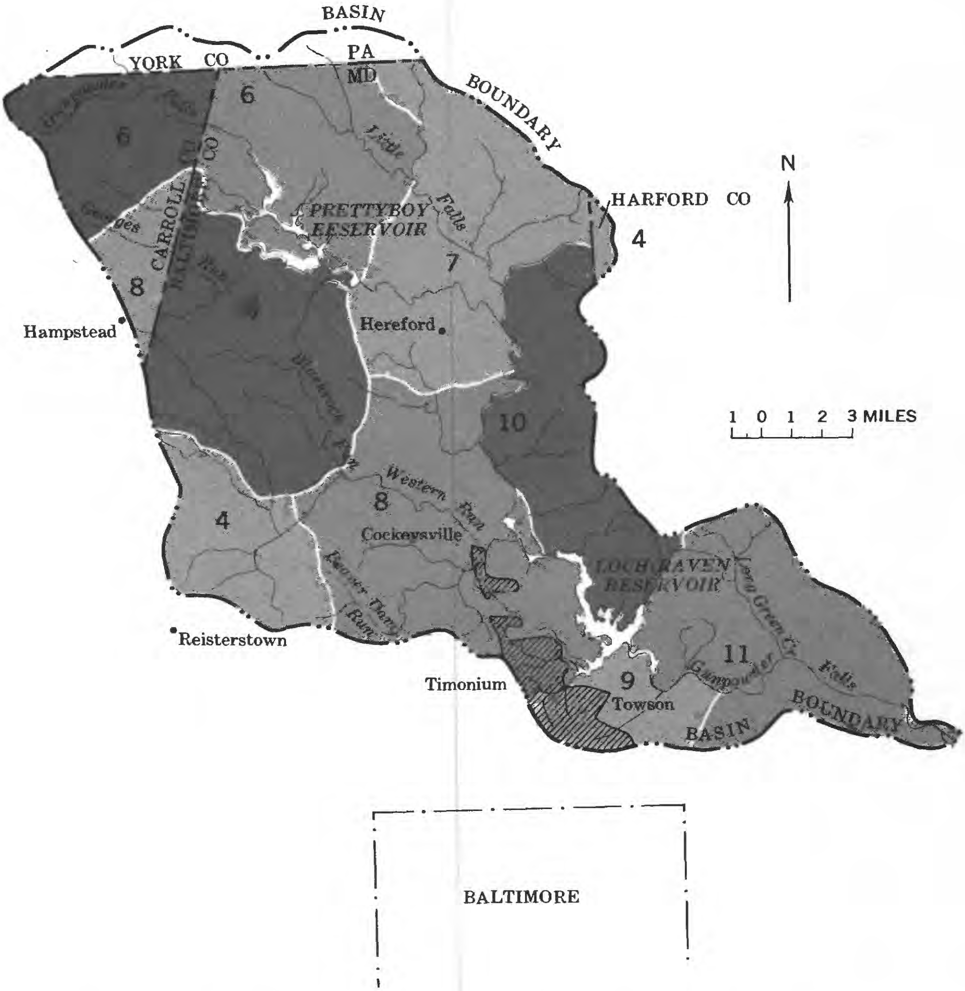

FIGURE 3.—Basin population, by election districts, based on the 1960 census (Maryland State Plan. Dept., 1961, p. 8–9; figures in parentheses in the following table show what part of the district is within the basin).

Area	*Population*
Baltimore County:	
District 4 (1/3)	5, 200
5 (all)	2, 550
6 (all)	1, 625
7 (7/8)	3, 650
8 (4/5)	17, 100
9 (1/3)	28, 700
10 (3/4)	2, 800
11 (4/5)	16, 500
Total	78, 125

Area	*Population*
Carroll County:	
District 6 (1/2)	2, 000
8 (1/4)	1, 000
Harford County:	
District 4 (few sq mi)	200
York County, Pa	2, 000
Total	5, 200

Total for the basin (rounded) 85, 000

farms declined by 51.7 percent. Baltimore County still ranks third in the number of farms, and the value of land and buildings per acre of $720 was the highest in the State.

Because of the heavy decline in the number of farms and land in farms, there was a corresponding drop in the acreage of all major crops and in the number of livestock * * *. The nearness to a large city and the heavy increase in housing projects has resulted in a good demand for nursery and greenhouse products.

The downtrend of farms and farming area from 1900 to 1960 is shown graphically in figure 4:

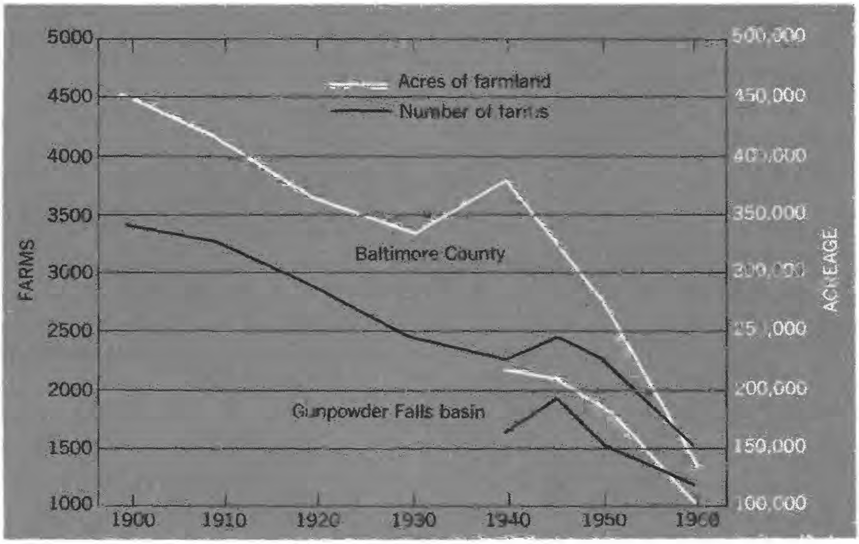

FIGURE 4.—Graph of land used for farming in Baltimore County and in the Gunpowder Falls basin, 1900–60.

The farm obviously is giving way to the suburb, though at a diminishing rate as the distance from Baltimore increases. Data for 1945 remind that a period of crisis, World War II in this case, can temporarily change a trend. In 1960, the land in the basin was used as follows:

Use	*Percent*	*Acres*
Farmland	58	130, 000
Forest	28	63, 000
Urban and residential	12	28, 000
Reservoirs	2	3, 900
Total (rounded)	100	224, 000

Small factories are along the railroad lines that follow the coast. A long-established metal-container-machinery plant and a metal-parts finishing company are located on a tributary of Long Green Creek. A dozen or more enterprises are on Beaver Dam Run, between Timonium and Cockeysville; they include air-armament and electrical-equipment factories, a precision-tool shop, a veneer mill, a large and active limestone quarry. An extensive industrial park is growing west of Cockeysville. Many water-filled pits are evidence of past quarrying of Cockeysville Marble—almost all the Washington Monument is faced with it.

The area contains no fuel resources and no minerals in quantities sufficient to warrant exploitation; it does provide building stone and crushed rock. Forests of the basin contain some trees of value, but lumbering of both hard and soft woods is sporadic; the borders of the two reservoirs are the only carefully planted and harvested forest tracts.

Roads

The Gunpowder Falls basin is crisscrossed more than 30 times by good, surfaced country roads, though the main stream valley, usually steep-sided and narrow, contains less than 5 miles of parallel roadways. A branch of the Pennsylvania Railroad winds up the central valley about 7 miles, from the head of Loch Raven Reservoir to the Little Falls tributary.

Several excellent highways traverse the basin. Interstate 83 (U.S. 111) is the parkway between Baltimore and Harrisburg, Pa. The John Kennedy Memorial Highway and U.S. 40 connect Baltimore with Philadelphia and other cities to the northeast. The Baltimore Beltway cuts across the south-central part of the basin south of Loch Raven Reservoir.

Loch Raven Dam is 12 miles from Baltimore's Pennsylvania Station; Prettyboy Dam is 26 miles away; Joppatowne, near the mouth of Gunpowder Falls and the head of the Gunpowder River (or estuary) is about 18 miles northeast. The center of the basin is roughly 60 miles from Washington and 80 miles from Philadelphia. The main roads and highways are shown on figure 2.

Water Resource

The Gunpowder Falls drainage basin and its landscape exist because of water action on land surface. The stream and its tributaries, in drought and in flood, have shaped the topography. Snow and rain have leached and weathered the surfaces of the bedrocks in varying degrees to form a smoothing and fertile cover of soil. The obvious water resource is the river in the valley bottom. Wells and occasional springs indicate the not-so-obvious wealth of water in the ground.

Water, a Variable Commodity

The quantity of water in a basin such as the Gunpowder Falls is as variable as the weather, and the two are closely related because the source of all fresh water is precipitation. The average yearly rainfall on the basin is approximately 46 inches; its distribution is quite uniform. Records for the Baltimore area for the last 140 years (see fig. 5) show a recent low of 22 inches of precipitation in 1930 and a high of 63 inches in 1889. The long record makes it possible

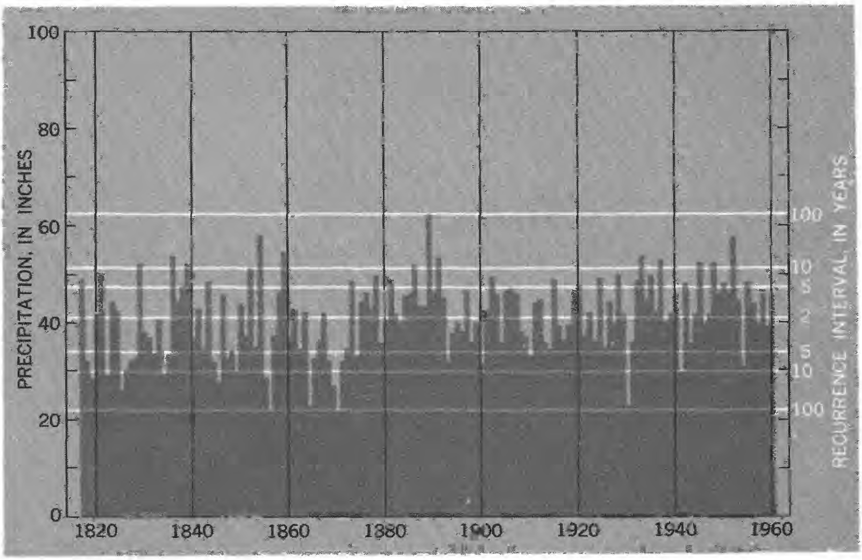

Figure 5.—Precipitation record for 140 years and probable rainfall expectancies 1817–1930, Baltimore, Md.; 1931–61, Towson, Md.

to determine about how often—but not when—a particular yearly precipitation value will occur. The additional ordinate scale at the right side of figure 5 shows that the drought of 1930 will be equaled or exceeded about once in a hundred years and that the high of 1889 may also be expected about once in a century. Figure 6 indicates that 90 percent of the time in years (or 9 years in 10) the annual rainfall will be between 29 and 55 inches. Sixty percent of the time (6 years in 10) the annual rainfall will be between 34 and 47 inches. The yearly occurrence of precipitation has no apparent order; it varies randomly between extreme values.

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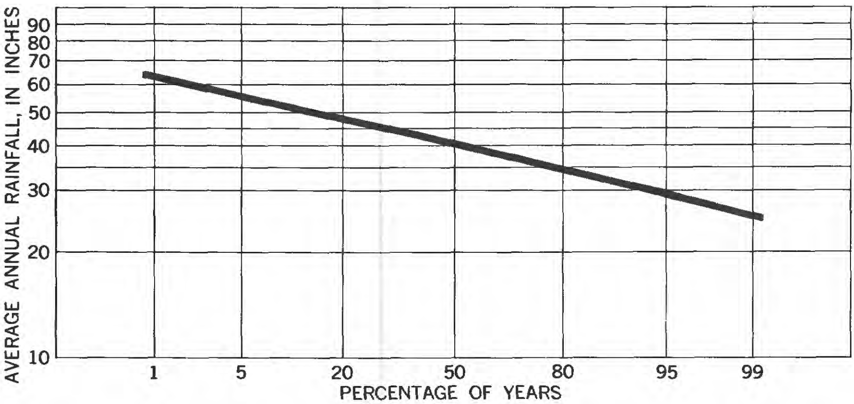


FIGURE 6.—Precipitation variability: Percentage of time when rainfall is more than the values shown in the left column. Example: 55 percent of the years have rainfall greater than 40 inches.

Precipitation also varies from month to month, the extremes being from 12 inches to less than 1 inch. These extremes usually occur during the summer and early fall. Average monthly precipitation records (water budget, table 1) for the period from 1884 to 1960 show August to have the highest rainfall, 4.8 inches. The lowest rainfall, 3.3 inches, occurs during November and February.

About 60 percent, or 28 inches, of the yearly precipitation returns to the atmosphere as evaporation or transpiration. This water, lost insofar as water supply and recreational uses are concerned, is nevertheless the water upon which plantlife depends. Table 1 shows the evapotranspiration loss (the moisture which evaporates plus the moisture which is used by plants) to be quite small, about 5 percent, during the colder parts of the year, October to March, in comparison to the warmer periods when more water is transpired and evaporated than is precipitated in any one month (Munson, 1962). When evapotranspiration is low, the precipitation is about twice the runoff. Much of the snow and rain soaks into the ground to replenish the water supply depleted during the previous growing season. As the water table rises, more water drains to the watercourses. Thus, streams have higher flows in the winter than in the summer even though rainfall is less.

Each square mile of the basin yields an average of about 860,000 gallons of water each day of the year, or about 1,360 gpd (gallons per day) for each acre. This yield varies from one-half of the average, or 450,000 gpd during a drought year, to about twice the average, or 1.4 mgd (million gallons per day) during a year of high

TABLE 1.—*Water budget, in inches by months, for the Gunpowder Falls basin 1884–1960*

[Precipitation=Runoff+evapotranspiration±gain-loss]

Month	Precipitation	Runoff	Evapotranspiration	Change in ground water	
				Gain(+)	Loss(−)
Jan	3.6	1.7	0.3	1.6	
Feb	3.3	1.9	.5	.9	
March	3.8	2.2	1.2	.4	
April	3.6	2.0	2.1		0.5
May	3.9	1.8	3.4		1.3
June	4.0	1.4	4.2		1.6
July	4.5	1.3	5.0		1.8
Aug	4.8	1.2	4.4		.8
Sept	4.0	1.0	3.1		.1
Oct	3.4	1.0	1.9	.5	
Nov	3.3	1.1	1.0	1.2	
Dec	3.5	1.3	.5	1.7	
Yearly average (rounded)	46	18	28	0	

runoff. These extreme values may be expected in 5 percent of the years or about 1 year in 20. The average daily flow of Gunpowder Falls from 1884 to 1960 is shown in figure 7; a comparison with the precipitation record in figure 5 shows the close relationship between the two. The average flow of the Gunpowder Falls at Loch Raven Dam, on the basis of the period of record from 1884 to 1960, is 264 mgd. The values on the right side of figure 7 show how often ex-

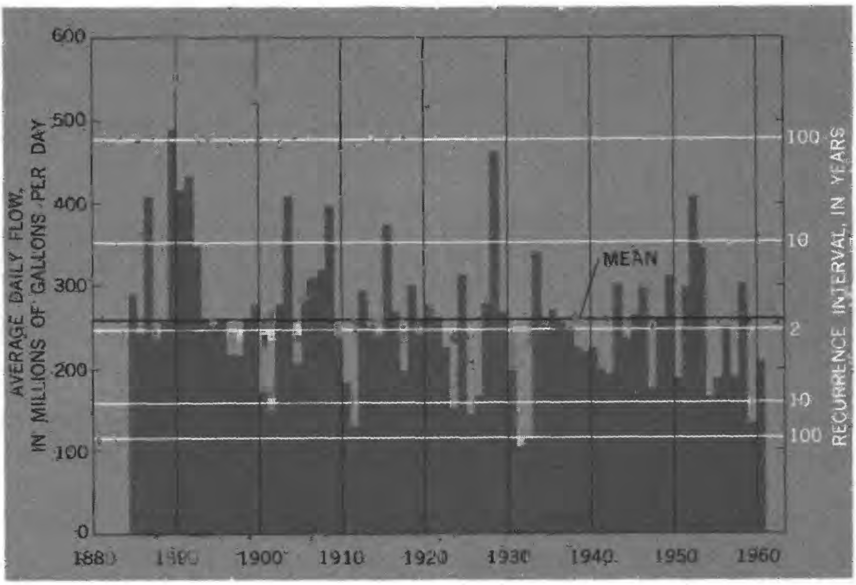


FIGURE 7.—Average daily flow and recurrence interval of Gunpowder Falls, 1884–1961.

treme conditions may occur. For example: the 1930 drought may be anticipated once in about 100 years.

The flow records of Loch Raven Reservoir between 1884 and 1960 show that streamflow which is average (860,000 gpd per sq mi) or greater will occur only about 4 years out of 10, or 40 percent of the time in years. The flow for 6 of the 10 years will be less than this amount. These and other probabilities of varying yearly flows from the basin are illustrated in figure 8.

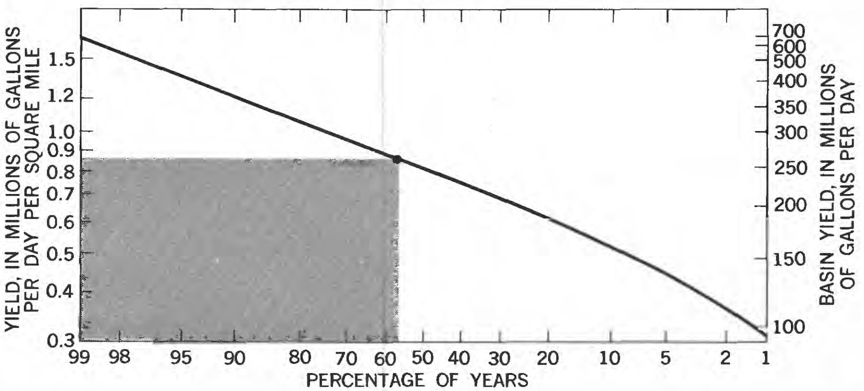
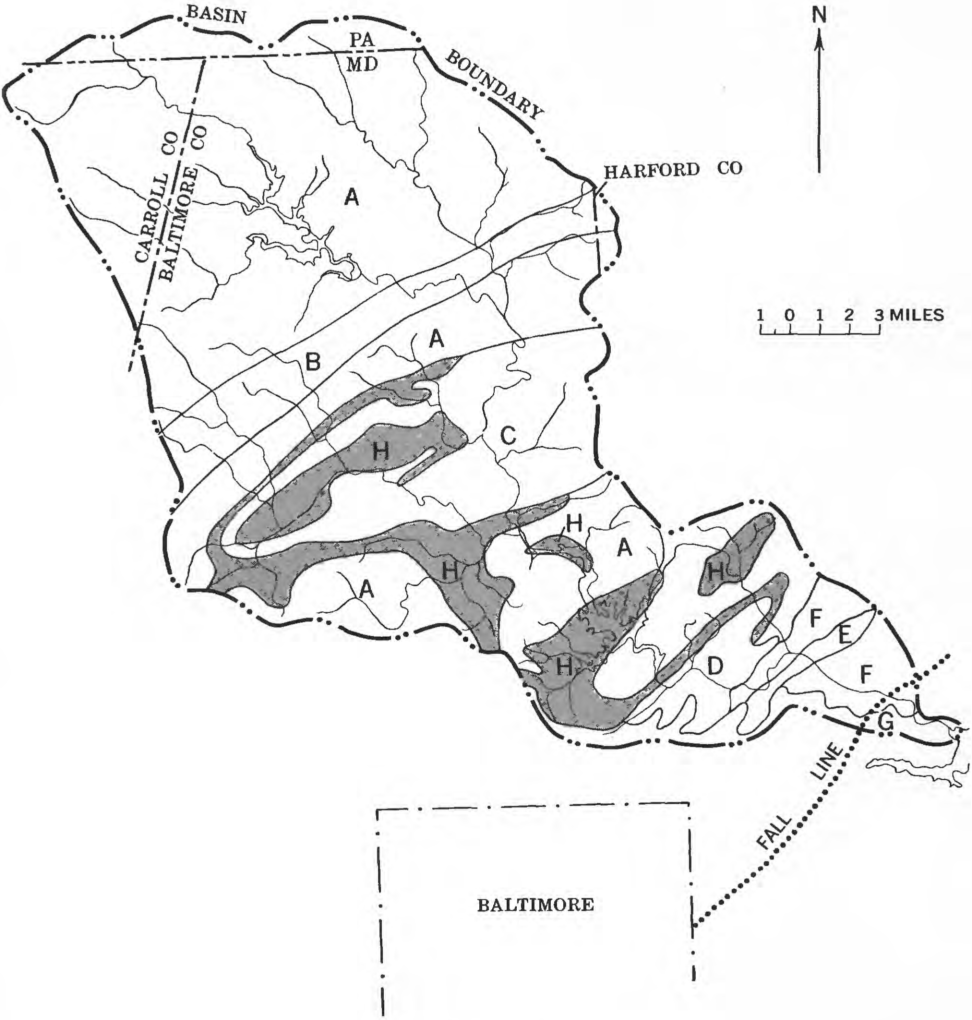


FIGURE 8.—Percentage of years when the flow of Gunpowder Falls is less than average. Example: About 60 percent of the years have streamflows less than the average yield of 860,000 gpd per sq mi.

Generally the flow of water in streams has a fairly uniform distribution except during low-flow periods. Then differences in geology become important, especially differences in the porosity of top soils and underlying rocks. The predominate rock formations in the basin occur in two distinct assemblages that delineate the two ground-water zones of the basin (fig. 9). The streams draining areas underlain by the weathered Cockeysville Marble (zone 2) have low flows markedly greater than those of streams draining areas of comparable size in zone 1. The weathered marble has a greater unit storage capacity than other rocks. The water is accumulated during periods of high flow, and released to sustain flow during dry periods. The stream low flows for zones 1 and 2 are shown in figures 10 and 11, in million gallons per day per sq mi; variations in the water yielded to streams within each zone are shown as a range of values for a given percent of time.

Averages and Probabilities

The water-cycle budget for the basin, based on hydrologic records extending back to 1884 (table 1), is portrayed graphically in figure 12. The table shows the average precipitation each month and the yearly



Zone 1
A, Wissahickon Formation
B, Peters Creek Quartzite
C, Baltimore Gneiss
D, Gunpowder Granite
E, Port Deposit Gneiss
F, Gabbro
G, Alluvium
Zone 2
H, Cockeysville Marble

FIGURE 9.—Generalized geologic map of the basin and ground-water zones.

average total of about 46 inches. Of this total, about 18 inches or about 40 percent drains from the area, some as overland runoff and the remainder by infiltration into the ground where it flows downgradient to discharge into surface streams at lower elevations. About 6 inches

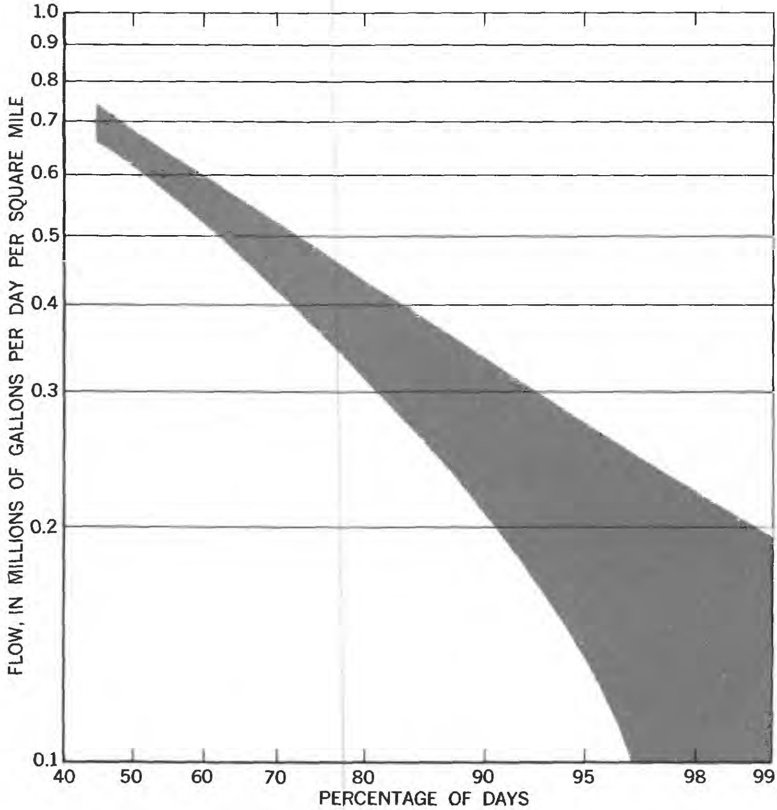


Figure 10.—Range of low streamflows from zone 1.

a year is direct surface runoff, and about 12 inches drains through the ground (Dingman and Ferguson, 1956, p. 52). The remaining 28 inches or 60 percent is lost through evapotranspiration. The runoff plus the evapotranspiration is equal to the precipitation received by the area on a yearly basis, but not on a monthly basis: From October through March the runoff plus evaporation is less than the precipitation; from April through September the reverse is true. These excesses and deficiencies express the additions to or depletions from the ground-water supply for the basin (fig. 12). The fluctuations in ground-water supply in a normal year are illustrated in figure 13. Levels are highest in March. Then the evapotranspiration increases so rapidly as to intercept most precipitation before it has a chance to reach the water table. Only during extremely wet summer seasons does the ground-water zone become recharged by rainwater in excess of the loss through evaporation and transpiration. However, when water

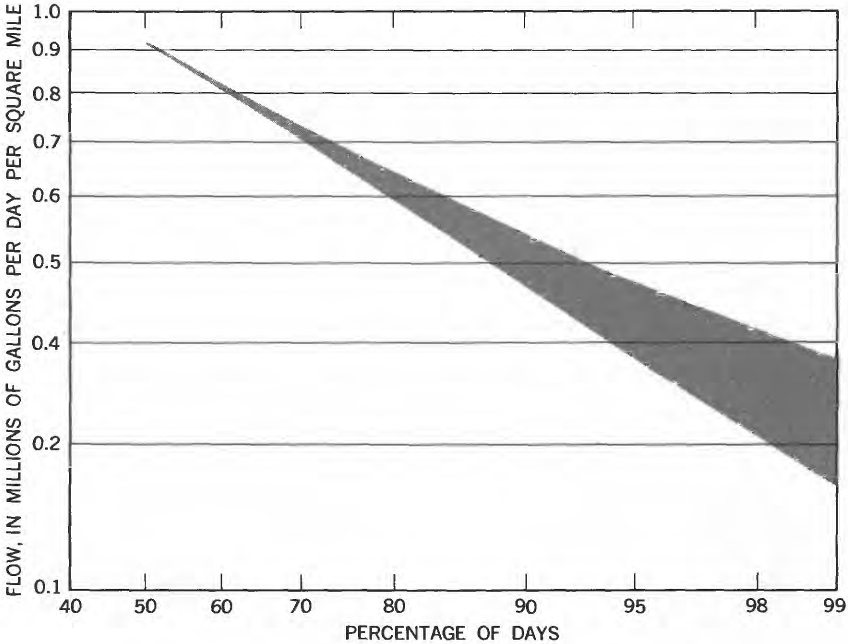


Figure 11.—Range of low streamflows from zone 2.

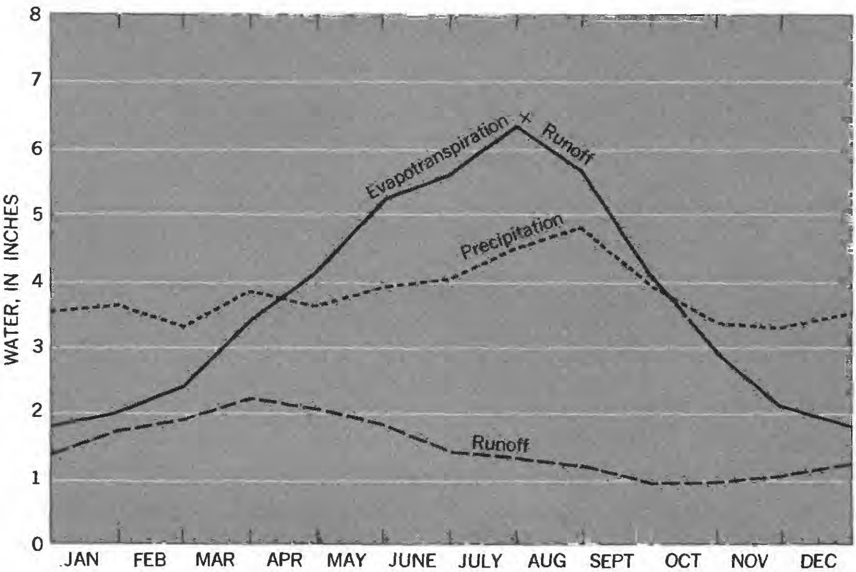


Figure 12.—The water-cycle budget, Gunpowder Falls basin. Annual precipitation (46 in.) = evapotranspiration (28 in.) + runoff (18 in.).

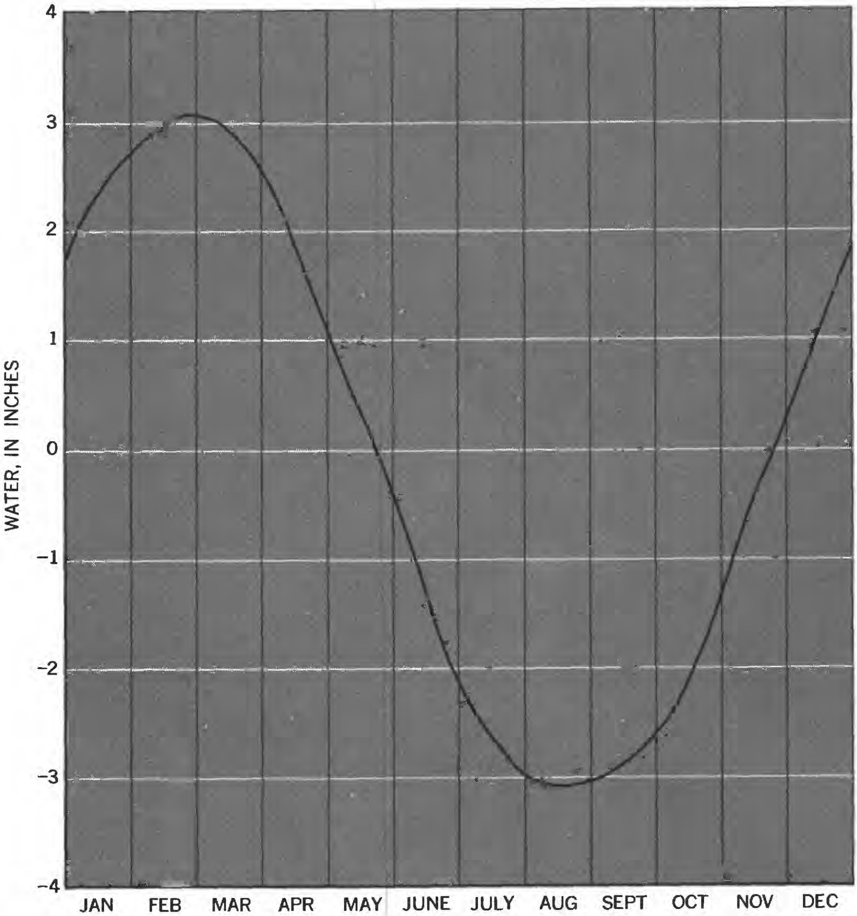


Figure 13.—Fluctuations in ground-water supply in a normal year, calculated from the water budget

is dispersed between soil particles, it will occupy a much greater area than when it is confined in a container such as a pail. In Long Green Valley, for example, which is an area of weathered Cockeysville Marble, the fluctuation in wells during a normal year is about 4 feet, that is, about 6 inches of water saturates about 4 feet of soil. During wet years, when precipitation contributes 8 to 10 inches of water to the water table, a fluctuation of about 5 to 6 feet may be expected. During drought periods the water table may drop as much as 8 feet. In the well at Hydes, near the center of Long Green Valley, the high and low water levels reflecting wet and dry periods since 1954 are 14.4 feet and 21.9 feet below the land surface—a variation of 7.5 feet. The actual monthly fluctuations of the water level of the Hydes well during 1961

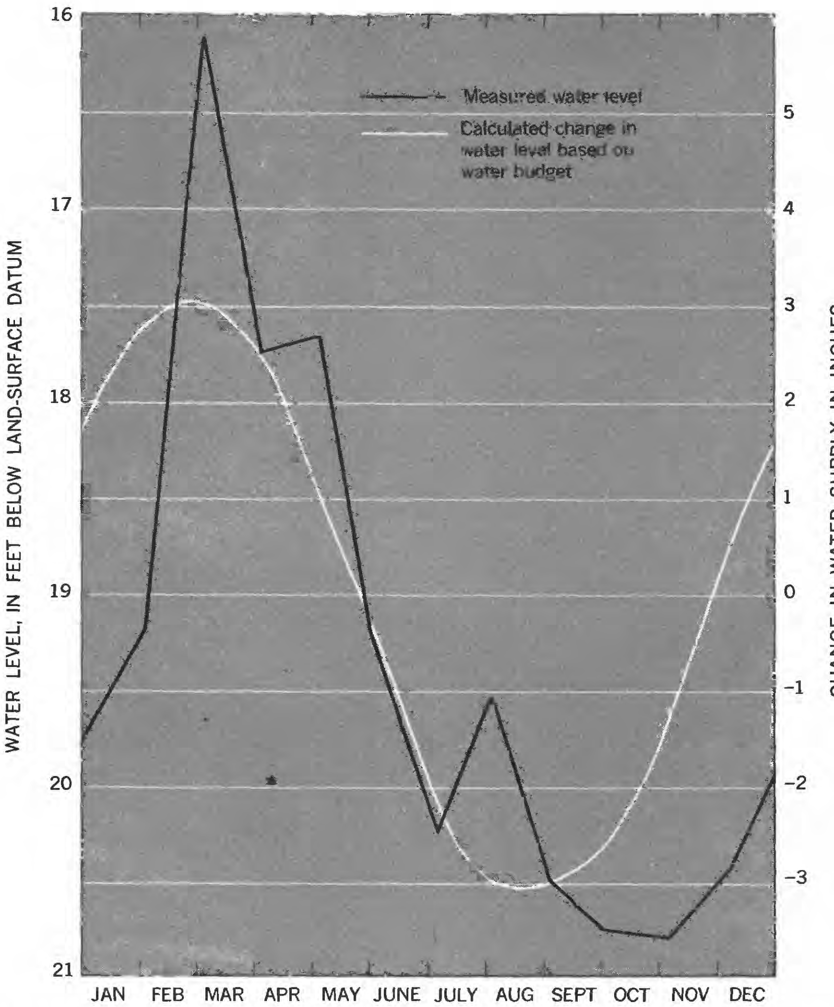


Figure 14.—Water-level changes in Hydes well for 1961 compared with changes in water supply calculated from water budget.

are plotted in figure 14 against the predicted changes in water supply calculated according to values in table 1 and in figure 12.

Public Supply for Metropolitan Baltimore

About 100 years ago, consultants for the city of Baltimore recognized the potential of the Gunpowder Falls as a source of water supply. Practical damsites are seldom found at the mouths of rivers, and the Gunpowder Falls is no exception; only about six-sevenths, therefore, of the total surface water available in the basin (from 303 of the 350 square miles) was considered for water-supply use.

The first dam was built in 1881 about 1,000 feet downstream from the present Loch Raven Dam; it is still intact. The capacity of the first reservoir was about 500 million gallons. In 1914 the big dam at Loch

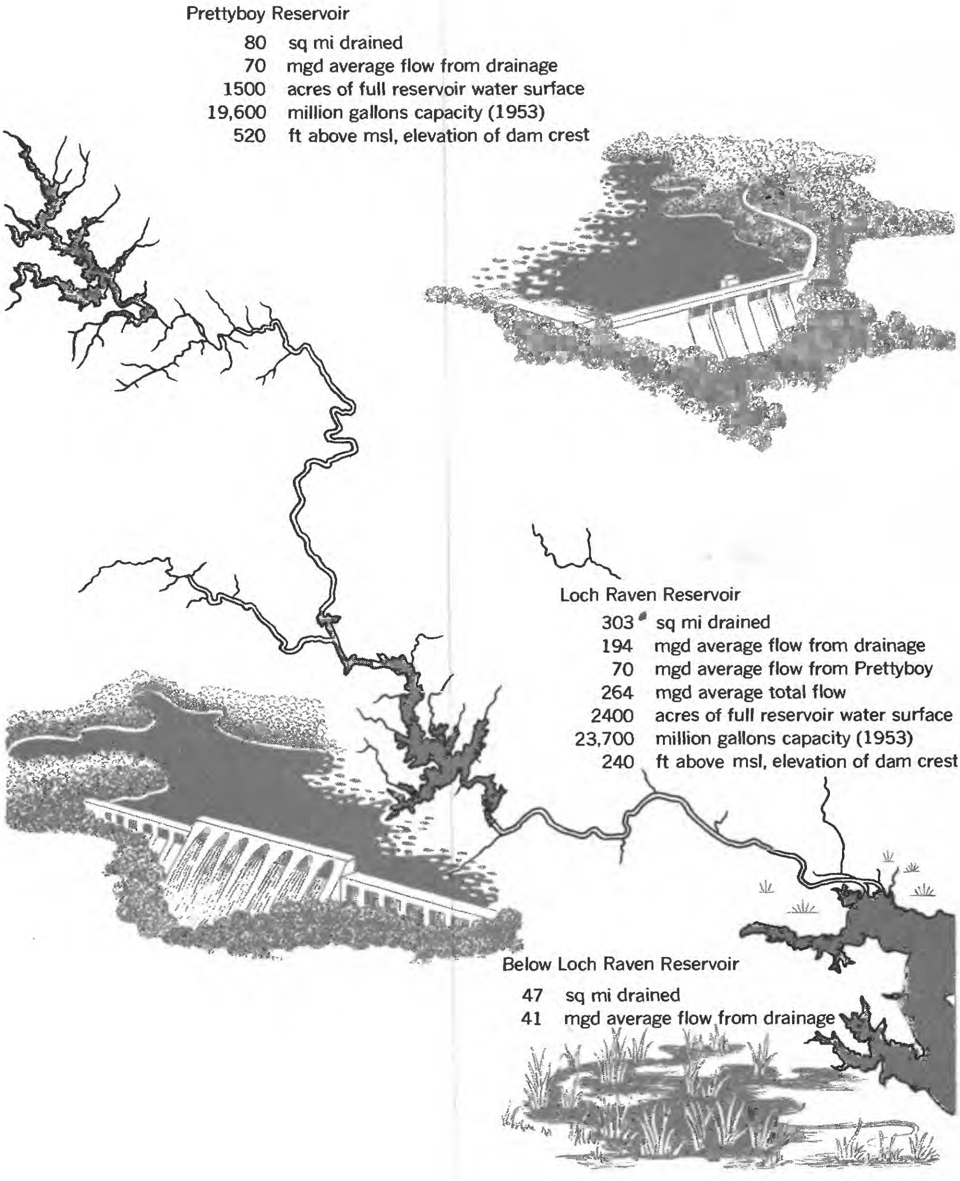


FIGURE 15.—Development of Gunpowder Falls as a water supply.

Raven was completed to a spillway height of 188 feet above mean sea level (msl). In 1923 the crest was raised to 240 feet to increase the capacity to 23.7 billion gallons. About 125 days of average flow, not considering drainage from the area above Prettyboy Dam, is required to fill Loch Raven Reservoir.

Prettyboy Dam, completed in 1932, created an additional 19.6 billion gallons of storage on the Gunpowder Falls. The drainage area above Prettyboy Dam is 80 square miles. About 280 days of average flow is required to fill the Prettyboy Reservoir. By the release of water through valves in the dam, this reservoir is used to maintain a high water level in Loch Raven Reservoir. Some reference figures for the developed water supply, as well as for the lower part of the basin, are given in figure 15.

The amount of water that can be taken from the Gunpowder Falls safely—without exceeding the supply—has been computed as 148 mgd (Gregory, Requardt, and Wolman, 1934, p. 81). This safe-yield estimate equals the capacities of the reservoirs minus 10 percent reserved for emergency purposes; it is based upon the 1930 drought period, which is considered the most severe on record. Figure 16 shows the amount of water used each year by Metropolitan Baltimore since 1910. Between 1881 and 1952, all the public water was supplied by the Gunpowder Falls. During this interval, the amount of water required for the peak year was 196 mgd in 1952 but from 1942 to 1956 the demand on the system exceeded the safe yield.

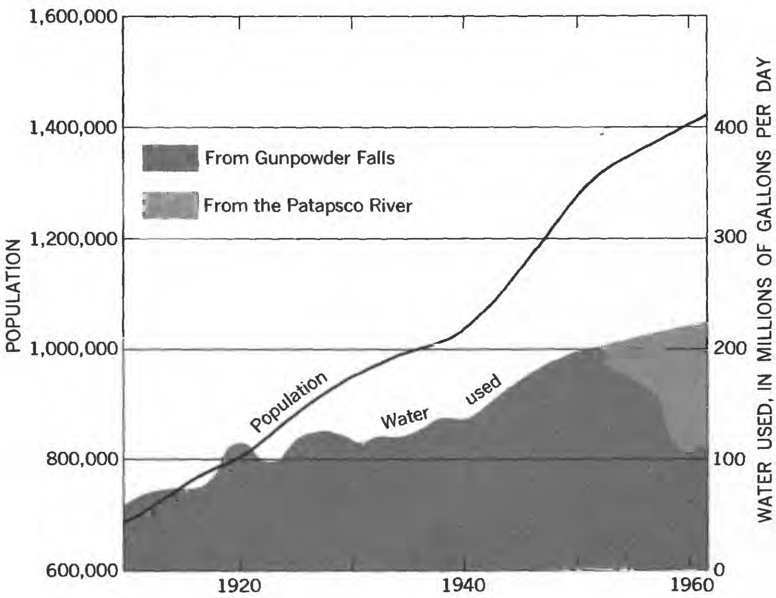


FIGURE 16.—Water used and population in Metropolitan Baltimore, 1910–63.

In 1952, as an emergency measure, the city began pumping water from a temporary station at Avalon on the Patapsco River (fig. 2) while the dam for Liberty Reservoir was under construction. In 1955 the first water from Liberty Reservoir was delivered to the metropolitan area.

Because of its elevation (the dam's crest is 420 feet above msl), Liberty Reservoir water is distributed by gravity flow to the Ashburton Filtration Plant (elevation 353 feet) and to most parts of the higher north and west sections of the metropolitan area (fig. 17). The water from Gunpowder Falls supplies the lower east and south sections. This redistribution in the supply system reduced the demand on the Gunpowder Falls water supply from a high of 196 mgd in 1952 to about 104 mgd in 1958.

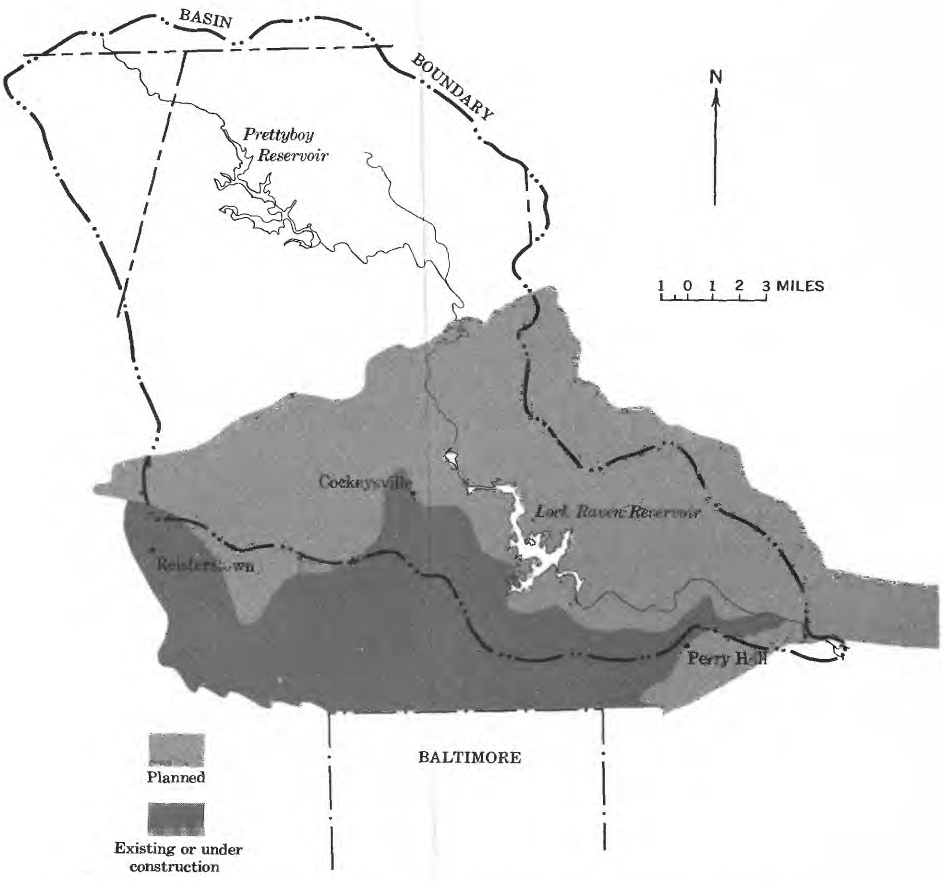


FIGURE 17.—Water-service area for northern Metropolitan Baltimore (1964) and planned extensions (Geyer, 1959).

In 1960 the City of Baltimore Bureau of Water Supply provided for a population of 1,386,500 living on 199 square miles composed of the entire city and adjoining parts of Anne Arundel, Howard, and Baltimore Counties (fig. 2). The average amount of water used was 202 mgd; 250 million gallons was needed in a peak day.

The shifting of about one-half of the water-distribution system to the Liberty Reservoir Patapsco River source, plus a rapidly increasing demand for water in expanding suburbia, had raised the draft rate on the Liberty Reservoir to about 105 mgd by 1964, about the maximum that can be taken from this source.

The probability that water in a reservoir will reach any given level, regardless of the exact sequence of precipitation events, can be expressed by Langbein's (1958) theory of queues. A preliminary analysis of the effects of various draft rates on Liberty Reservoir, adapted from a more intensive study of the adjacent and similar Gunpowder Falls watershed, shows that, at the present rate of withdrawal, the reservoir may be emptied about 9 percent of the years or roughly once in 11 years (fig. 18). When increased percentages of the reservoir's content are withdrawn (noted on the left of fig. 18), the reservoir's water level is lowered accordingly (noted on the right margin). The computed safe yield of the reservoir, 95 mgd, would cause a deficiency in 2 percent of the years or about once in 50 years.

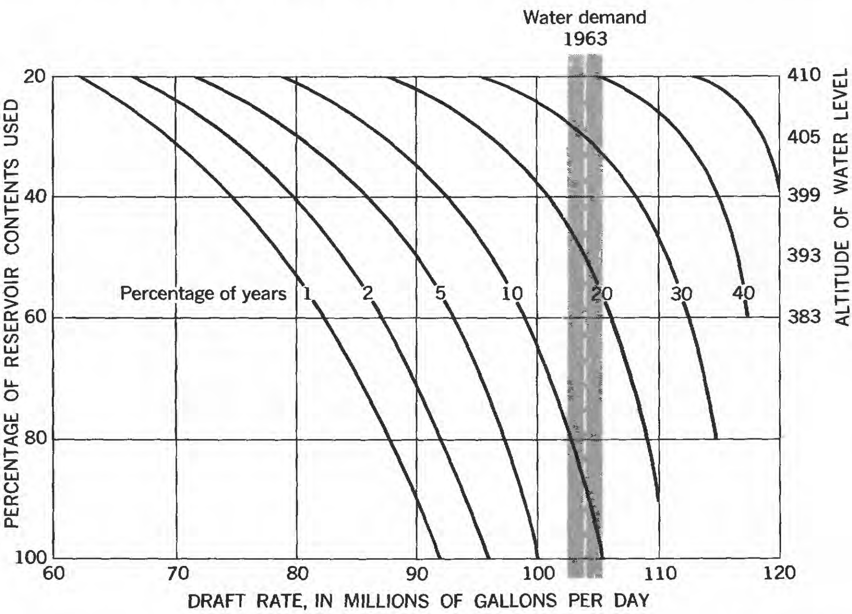


Figure 18.—Probability, in percentage of years and with varying draft rates, of decreasing Liberty Reservoir contents below designated levels.

If the 1964 draft rate of 105 mgd is increased to 110 mgd, the reservoir may be expected to fail once in 5 years, or sometime in a year during 20 percent of the years; to increase draft another 6 million to about 116 mgd will cause it to fail on an average of once in 3 years. Consequently, further increases in the demand for public water for the metropolitan area will have to be met from the Gunpowder Falls until the projected Susquehanna River supplement becomes available. (See p. 58.) In all further computations, we assume that use of the Patapsco system will be stabilized at an average annual draft rate of 105 mgd.

Figure 19 shows the probabilities of Gunpowder Falls Reservoir failure calculated for various draft rates.

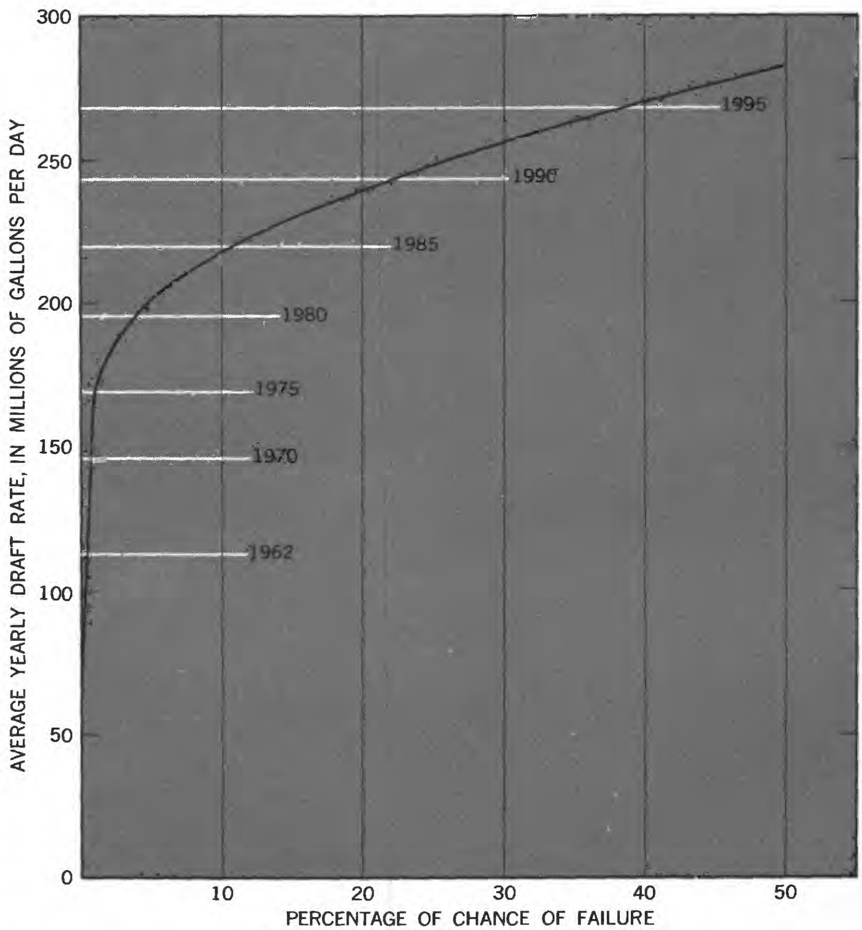


Figure 19.—Chance of failure of Gunpowder Falls water-supply system for various draft rates and years in which increased draft rates may be imposed.

A statistical analysis of the Gunpowder Falls water supply shows that the draft on it can be substantially increased. The computed safe-yield figure of 148 mgd is quite conservative. A rate of 148 mgd would cause the system to be deficient about once in well over 100 years; in fact, the draft rate would have to be increased to about 175 mgd in order to anticipate a shortage once in a 100-year period. This computation does not mean that in every 100-year period there would be one year of shortage; it means only that, on the basis of the variability and quantity of past flows and the capacity of present impoundments, a shortage could be anticipated during 1 year in a 100-year period.

Draft rates higher than 148 mgd from Loch Raven Reservoir would cause deficiencies to occur at more frequent intervals:

Draft rate (mgd)	*Probability of deficiency*	
	Percent	*Year(s)*
175	1	1 in 100
185	2	1 in 50
195	4	1 in 25
202	5	1 in 20
218	10	1 in 10
240	20	1 in 5
257	30	1 in 3
270	40	2 in 5

The demand on Gunpowder Falls obviously can be increased considerably above the present rate of 110–115 mgd without much risk.

Prettyboy Reservoir has been full and overflowing since 1955, when it was drained to the bottom. This drawdown was during the moderately severe drought in 1954 when Gunpowder Falls streamflow was only 142 mgd and the demand on the system was 184 mgd; the Patapsco system had not then been completed. No releases were made from Prettyboy Reservoir until 1963, even though the flow of the Gunpowder Falls averaged only 139 mgd in 1959; the draft rate that year was 115 mgd and Loch Raven was able to meet the demand without water from Prettyboy.

The lowest level of the water surface in Loch Raven Reservoir in the last 23 years was about 6.5 feet below the dam crest; this level occurred in 1941 and again in 1955. The next lowest level was about 5.5 feet in 1944 and 1959. The total area of the full reservoir is approximately 2,400 acres, and a drop in the reservoir level of 5–6 feet exposes about 600 acres of shoreland, which is one-fourth of the surface area of the full reservoir.

Loch Raven Reservoir water levels will fluctuate more widely during years of low water demand, such as the present demand of 110 mgd, than during years when the demand is moderately high, about 175 to 190 mgd. The water in Loch Raven Reservoir can be lowered 8 to 10 feet below the dam crest and still supply the present demand by gravity flow. At high draft rates the level of the reservoir must be kept within the top foot of the pool in order to provide sufficient pressure to force the needed quantity of additional water through Montebello Tunnel to the Montebello Filtration Plant, if reliance is on gravity. Pumps have been installed to draw water below the 230-foot mark of the reservoir should the need ever be sufficiently critical to warrant the additional expense.

During the 6-year period from 1957 to 1962, the average flow of the river was 190 mgd, of which 115 mgd or 60 percent was diverted for metropolitan use. During the same period, Loch Raven Reservoir spilled in 51 of the 72 months or about 65 percent of the time in months. The amount of water spilled by the reservoir from 1953 through 1962, the time of spills by months, and the months when no water spilled are shown in figure 20. During these 10 years the reservoir spilled some water during 60 percent of the months. The spills during the first 5 years were much less frequent than during the next 5 years, although the streamflow during the two 5-year sequences was comparable. The longest period of no spills was 14 months.

Retentions of water by Loch Raven Reservoir lessens the flow below the dam during periods of little or no spill. On its way to the Fall Line, this part of the stream cuts through rugged Piedmont terrain in a channel that was designed by nature to accommodate an average flow of about 260 mgd. The present average flow is only about one-half that amount. Fifty percent of the days the flow is less than 6 mgd, equivalent to a stream 10 feet wide, 1 foot deep, flowing with a velocity of 1 foot per second. Daily flows as low as one-fifth of this value (1.2 mgd) occur about 2 percent of the time.

Supplemental Supplies for Industry

During a peak period Metropolitan Baltimore needs as much as 250 mgd, exclusive of industrial needs which alone are almost twice that amount. The huge Sparrows Point Plant of the Bethlehem Steel Corp. uses 400 mgd; other industries use about 50 mgd. Although few large industries are supplied directly by the metropolitan water system, Gunpowder Falls and Patapsco water are indirectly involved in a rather unusual way in the industrial use of water, as briefly described in the following paragraph.

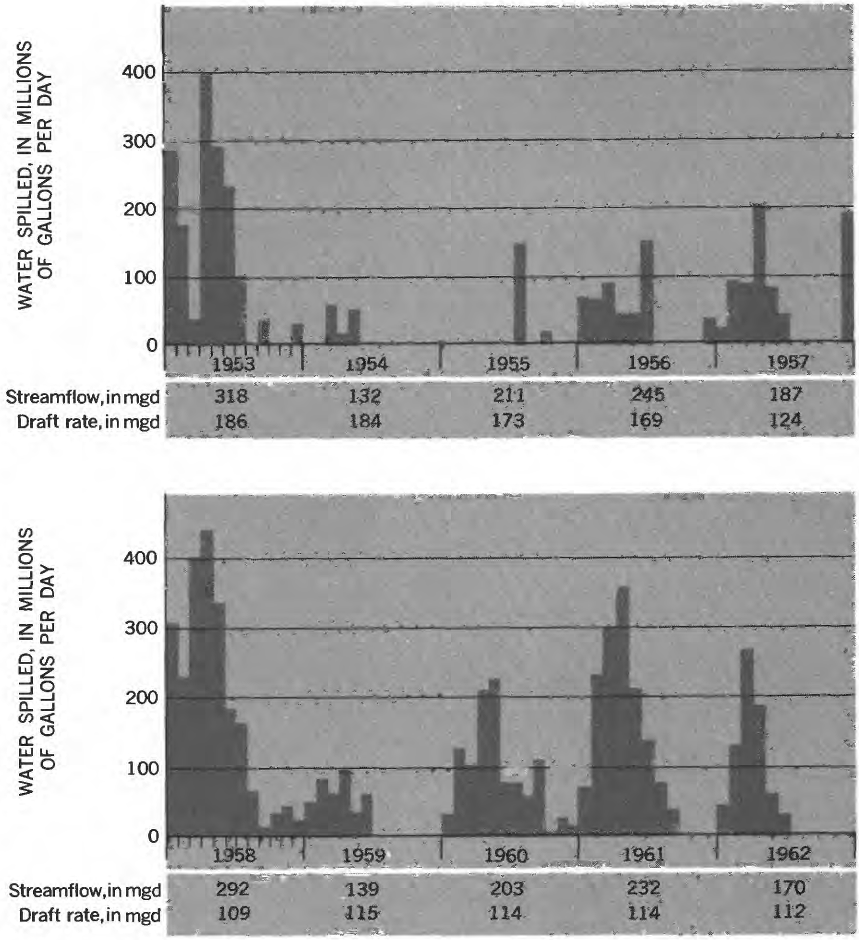


FIGURE 20.—Average daily flow of water, by months, over Loch Raven Dam, 1953–62.

Water pumped from wells supplied as much as 50 mgd to industrial users in the years before World War II, an important contribution to the overall water supply at that time (1940) because the Bureau of Water Supply could not deliver more than 200 mgd and the average use was 161 mgd. Lack of pollution control and salt-water contamination as the result of over-pumping, however, is forcing a steadily increasing number of industries to buy water from the city's system. Only 100 wells remained in industrial use in 1958; they yielded about 24 mgd. Engineers at the Sparrows Point Plant worked out an equilibrium between continued use of water from wells, brackish water from Chesapeake Bay, and effluent from Baltimore's Back River Sewerage Treatment Plant in order to secure the supply of cooling liquid needed. In 1942 the company constructed, at its own expense, pipelines to convey the effluent from Baltimore's sewerage-treatment plant. In 1943 the company purchased about half the effluent available, 23.5 mgd, and it has continued to the present to use about half of the effluent available, even though the total amount has more than quadrupled. All parties are satisfied; the city is paid for its waste water, and the company finds treated effluent less corrosive than brackish water.

Rural Dependence on Wells

For most residents of Metropolitan Baltimore, their only water-supply concern is the periodic nominal bill, but people living outside of the metropolitan area, north or east of the water-service area (fig. 17), are entirely dependent upon water from wells or springs, for the Baltimore Bureau of Water Supply holds the rights to all surface or runoff water in the Gunpowder Falls basin. Their water supplies cannot be secured directly from small impoundments, although such ponds are permissible for stock watering and for fishing, as is evident in the almost 500 ponds in the basin. The individual homeowner may use all the subsurface or ground water desired and available, but he must rely on wells or springs. Actually, all the water pumped from the wells in the basin totals no more than 3 to 4 mgd. Furthermore, this use only interrupts the natural passage of the water to the stream; most of the used water goes back into the ground via septic tanks.

About 40 percent of the precipitation on the basin becomes available as surface water and ground water (table 1). The amount of water in the ground may be estimated from measurements of annual precipitation and of runoff volumes, inasmuch as the water lost by runoff is replenished with more precipitation and recharge of the water table: the estimated ground-water runoff is 0.5 mgd per square mile (Dingman and Ferguson, 1956, p. 52), the approximate ground-water runoff from the 350-square-mile basin is 171 mgd, and ultimate practical recovery from this ground-water reservoir would be about one-third of the total (Otton, Martin and Durum, 1964, p. 96), about 57 mgd. These gross figures mean that sufficient water might be pumped from the ground to supply 1,000 people per square mile at 150 gpd per capita, or 1,500 people per square mile at 100 gpd per capita. This conclusion applies only to the hypothetical "average" square mile. Geology is an important factor in water availability and in well yields (p. 14); much more water may be expected from the sedimentary strata of the Coastal Plain, for instance, than from the crystalline rocks of the Piedmont, and Cockeysville Marble formations yield the most water in the Piedmont.

Ground Water in the Piedmont

The surface or near-surface occurrences of the rock formations in the Gunpowder Falls basin are shown in figure 9. These contorted rocks form the rolling to rugged country—the Piedmont—and comprise all formations but the flat shoreland along Chesapeake Bay which is part of the Coastal Plain.

In the Piedmont, most of the available ground water is contained in the various "mantle" soils, seldom more than 100 feet thick, that overlie the bedrock, though some water is also found in the fractures in the bedrock. Some bedrock formations are more jointed and fractured than others, but fractures are not common at great depths. Cockeysville Marble is an exception; the undecomposed rock contains scattered solution channels capable of yielding moderate quantities of water to drilled wells; yields average 20 gpm (gallons per minute), and the maximum known yield in the basin from this formation is 90 gpm.

Ground Water in the Coastal Plain

The Coastal Plain part of the Gunpowder Falls basin comprises less than 10 square miles between the Fall Line and Chesapeake Bay. We were able to estimate the ground-water supply expectancy of this area from well tests conducted at nearby Joppatowne. This residential development is within a mile of the southeastern boundary of the basin and within the Little Gunpowder Falls drainage; local geology, topography, and width of the Coastal Plain are almost identical in the two areas. The following evaluation of the ground-water resource at Joppatowne is highly indicative of the ground-water potential in the Coastal Plain part of the basin.

The Coastal Plain part of the Gunpowder Falls basin and the adjoining Joppatowne area are mapped in figure 21. The Joppatowne subdivision was started during the summer of 1962, and at completion will contain about 3,000 individual homes—perhaps 10,000 residents, plus churches, schools, and shopping and recreational facilities.

The geologic formations underlying the area consist of sand, silt, and clay beds 50–250 feet thick. These Coastal Plain sedimentary strata thin to the northwest and are not present northwest of U.S. Highway 40, which follows the Fall Line; they thicken as they extend to the southeast. Underneath these sand and gravel beds are the crystalline rocks characteristic of the Piedmont; because these

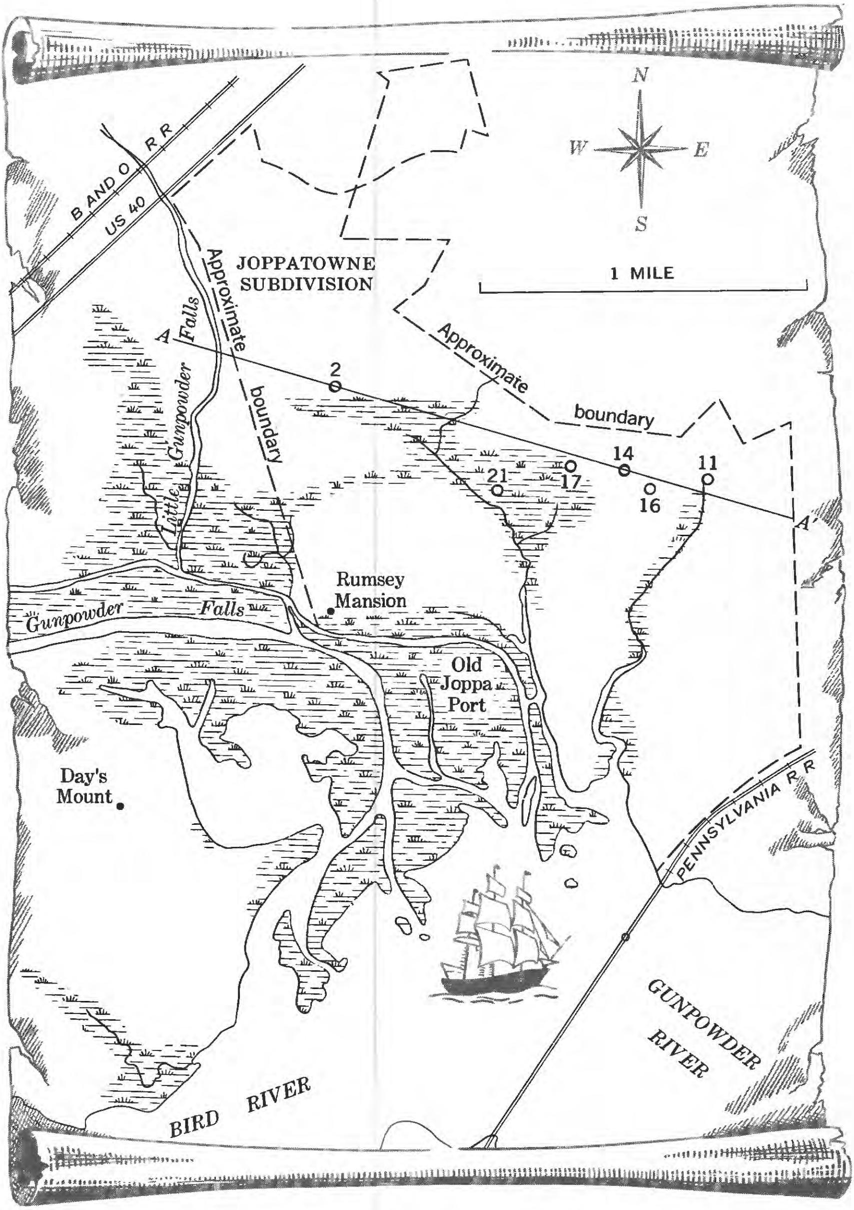


FIGURE 21.—The Coastal Plain section of the Gunpowder Falls basin and the Joppatowne well field. (Line *A–A'* is line of wells and test borings shown in fig. 22.)

rocks store and transmit very little water, they are not considered in the estimate of the potential water yield.

A cross section along line *A–A′* of figure 21 shows the general nature of the deposits penetrated in the Joppatowne wells (fig. 22). Clean sand or gravel alternate irregularly with clay or sandy clay; the former are aquifers, strata producing water, and the latter are aquicludes, strata that yield little or no water. Individual deposits thicken or thin or pinch out entirely over a few tens or hundreds of feet. The pumping-test results indicate that most or all of the deep sand beds are connected with surface sand beds. The water table in the vicinity varies from about a foot to as much as 20 feet below land surface, depending on topography.

Though the strata both above and below the sand aquifers yield less water than the sand, they do transmit water to the sand when its water pressure is reduced by pumping. Hence, water in the sand aquifer may be replenished from one or both of two sources: (1) dewatering of the overlying clay and sandy clay, which in turn will be recharged by rainfall, and (2) recharge from streams or from the estuary when the water table is lowered sufficiently by pumping to cause water to flow from surface sources into the aquifer and toward the pumped wells. The ability of the aquifer to sustain large withdrawals over long periods of time will depend on these two sources.

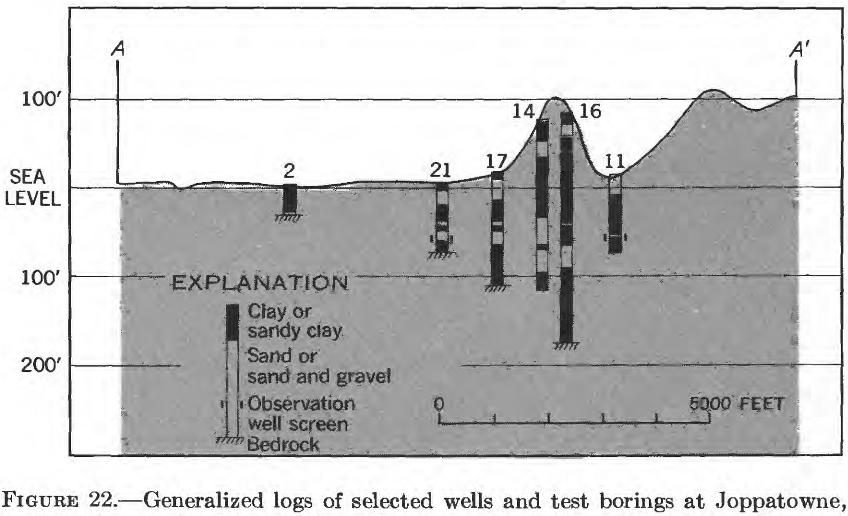


FIGURE 22.—Generalized logs of selected wells and test borings at Joppatowne, along line *A–A′* of figure 21. All wells are in the Ec section of the standard location grid for Harford County, Md.

The following conclusions based on tests of the local ground-water supply for Joppatowne may be applied to the adjoining strip of Coastal Plain within the Gunpowder Falls basin:

1. The water-yielding characteristics of the aquifer at Joppatowne are comparable to those of aquifers in the Baltimore area.
2. The sand aquifer is replenished with water from adjoining strata as pumping proceeds. However, the data are insufficient to distinguish between water that comes from storage in the aquifer and water that may be derived from nearby streams and from the estuary.
3. The short-term pumping tests indicated that replenishment by local rainfall or stream infiltration is sufficient to sustain a continuous pumpage of 1.0 mgd or more from the sand aquifer. Some water pumped from the aquifer may be replenished with water from the estuary, and in late summer and early fall this estuarine water may become brackish. In the Baltimore area, similar formations were contaminated by brackish water as much as a mile inland from the nearest estuarine water (Bennett and Meyer, 1952, pl. 16). Salt-water infiltration could be detected by monitoring one or more observation wells situated near the estuary for increase in chloride content. Early warning of infiltration of brackish water into the aquifer should provide time for corrective procedures, because ground-water velocity usually is quite slow and decreases with distance from the center of pumping.

Waste Disposal

The inevitable companion of a water-supply system is a system or systems for the disposal of sanitary wastes and storm-water runoff—whether for an isolated residence or for a metropolitan area. The basic problem is to keep the water supply clean and isolated from the wastes, particularly from untreated wastes.

Scattered rural homeowners have been able, and will continue, to get by with water wells and septic tanks. But these do not suffice when communities and suburbs expand beyond the 50-house unit figure which is defined in Maryland as the limit of a small subdivision (Geyer, 1959, p. 40):

* * * It has been customary to require large lot sizes wherever septic tank systems are used. This may reduce the nuisance when the system fails but it will increase the per capita cost of sewers when they are built later on. It may also result in population densities that are much lower than are desirable for a given area.

The customary sequence of events for a householder on the fringe of a metropolitan area is first to pay for a septic tank and then to pay again, this time for sewer services.

Much thought is devoted to methods of waste disposal which will accommodate population growth and keep surface and ground waters reasonably clean. When population expansion results in contiguous communities, interceptors connect local sewerage networks to conduct wastes to large regional treatment plants. Figure 23 shows the present areas served by the metropolitan sewer systems, as well as extensions under construction or planned.

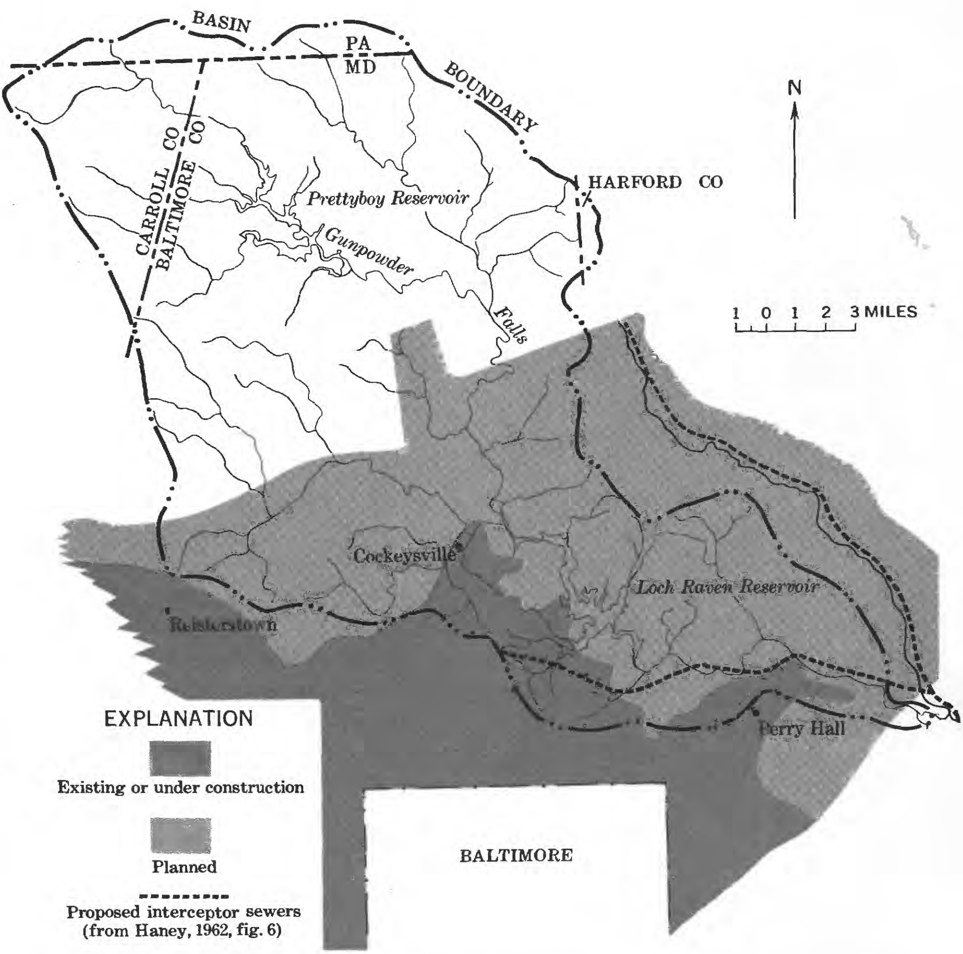


FIGURE 23.—Present (1964) and planned sewered areas of northern Metropolitan Baltimore. (Adapted from Geyer, 1959, and from Haney, 1962.)

Metropolitan Baltimore's waste-disposal systems have kept pace reasonably well with its water-supply development (Geyer, 1959, p. 26):

> * * * Unlike most other large cities, Baltimore has separate systems for collecting sanitary wastes and for collecting storm water runoff. This dual system makes it relatively easy to carry away and treat sanitary sewage while permitting storm runoff to discharge into natural water courses within the city. It avoids the periodic overflow, throughout the city, of mixtures of sanitary sewage and storm water. Such overflows inevitably accompany heavy rainfall, where a combined or single system of sewers is used to carry both storm water and sanitary wastes.

Runoff water is not comparable to raw sewage but it does contain pollutants. Streets and parking areas contribute snow-melting compounds, grease and gasoline, in addition to such trash as chewing gum, bits of tobacco, and rotting paper. Parks and lawns contribute insecticides and fertilizers; pets contribute wastes indiscriminately. Surface waters inevitably are degraded as urbanization takes place, as is discussed in the following section.

Water Quality

Water quality is determined basically by three major factors: geology, climate, and living organisms. The geology (and topography) governs the rate at which water moves over and through a mantle soil, the extent to which different minerals and different types of soils dissolve and the erodibility of the different soils. The climate governs the amount of water available for solution and subsequent dilution of dissolved matter, the fragmentation of rocks and soils by freezing and thawing, and the movement of dissolved and suspended materials in the water.

Plants incorporate dissolved minerals into organic substances by utilizing them as food; when the plants die and decay, the minerals are returned to the earth. Bacteria, molds, and other minute organism aid in the breaking down of mineral matter to form organic substances during their life processes, and also in the reduction of organic matter to mineral matter. Larger plants protect the soil from erosion; their roots work into the earth at the same time, loosening the soil and dividing rocks and cohesive particles.

Many effects of man are obvious and well known, and no part of the Gunpowder Falls has escaped them. The early settlers were quite ruthless with the natural resources. At one time or another, practically the entire basin was "burned over" to provide "new" ground for farming. The soil was tilled until it could no longer produce acceptable harvests; then new areas were burned over and farmed, and the exhausted land was left to erode. Eventually a new cover of trees and other vegetation would grow on the depleted soil, revive it, and then the farmers would move back again.

Today, happily, most of the basin is covered with forests or well-tended farms (see p. 9). The few industries release little waste; sources of industrial pollution now are less serious than in the heyday of the papermills in the 18th and 19th centuries. Present water quality reflects primarily the influences of geology, but some of the effects of the accelerated growth of local communities on water quality are becoming apparent (see p. 37).

Effects of the Geology

The chemical quality of the water reflects the soluble properties of the formations in the two generalized geologic areas. The first, zone 1 (fig. 9), is composed of schist, gneiss, and granite; it yields water that is soft and dilute and that contains comparatively little mineral matter, usually fewer than 65 parts to every million parts of water. The dominant minerals are calcium and bicarbonate. The highest concentrations occur during low-flow periods; lower concentrations result from dilution by rainfall and occur at higher flows. Chemical analyses for selected streams in the basin and the probable range of concentrations are presented in table 2.

TABLE 2.—*Chemical analysis of water from selected streams in zone 1*

[Concentrations in parts per million]

Substance	Sample					Most probable range
	1	2	3	4	5	
Calcium	12	9.0	6.0	6.5	6.0	3–10
Magnesium	2.4	2.5	1.9	5.4	1.9	1–4
Sodium and potassium	3.9	----------	5.5	2.1	4.4	2–5
Bicarbonate	36	22	26	22	25	15–50
Sulfate	4.0	4.1	5.0	3.6	5.0	2–15
Chloride	5.7	----------	6.2	8.9	6.2	3–8
Nitrate	8.6	----------	4.2	6.3	4.2	3–8
Total dissolved matter	63	[1] 57	48	58	48	20–65
Detergent (ABS [2])	.03	----------	.06	.05	.06	----------

[1] Calculated.
[2] Alkyl benzene sulfonate.

1. Gunpowder Falls at Lineboro, Md., Oct. 24, 1962.
2. Gunpowder Falls at Lineboro, Md., Mar. 26, 1963.
3. Little Falls at Blue Mount, Md., Oct. 24, 1962.
4. Overshot Run near Sunnybrook, Md., Oct. 24, 1962.
5. Lower East Fork Dulaney Valley Branch near Long Green, Md., Oct. 24, 1962.

Zone 2 is composed of Cockeysville Marble, which weathers into fine loose particles. Marble consists of calcium carbonate and minor amounts of other minerals; it is more soluble than the rock formations of zone 1. Water draining from the marble can be quite hard, objectionable for some uses. For example, calcium carbonate precipitates and forms a scale on containers in which the water is heated. Except for its hardness, the water of zone 2 is of excellent chemical quality. (See table 3.)

TABLE 3.—*Chemical analysis of water from selected streams in zone 2*

[Concentrations in parts per million]

Substance	Sample 1	Sample 2	Most probable range
Calcium	35	45	30-60
Magnesium	15	13	10-20
Sodium and potassium	5.8		2-8
Bicarbonate	122	170	120-250
Sulfate	14		2-10
Chloride	25	9.4	2-8
Nitrate	5.6		2-10
Total dissolved matter	196	[1] 204	120-250
Detergent (ABS [2])	.03		

[1] Calculated.
[2] Alkyl benzene sulfonate.

1. Beaver Dam Creek at Cockeysville, Md., Oct. 24, 1962.
2. Goodwin Run at Padonia, Md., Mar. 26, 1962.

Most of the streams in zone 2 have their headwaters in zone 1; the marble has weathered to form basins and valleys but the more resistant materials of zone 1 form the ridges and uplands. Consequently the water seeping from the hillsides reflects the chemical character of zone 1. The water in the basin and valley streams actually is a mixture. The highest concentration of mineral matter in water of zone 2 occurs during low-flow periods and is about 250 ppm (parts per million).

Except for Long Green Creek and some other small tributaries, surface water below Loch Raven Dam cannot be classified according to geologic locale because it flows across many different geologic formations characteristic of both zones (fig. 9). At times the lower Gunpowder Falls receives most of its water directly from reservoir spill; at other times practically all its water comes from downstream ground-water seepage into the channel. This ground-water seepage locally contains calcium bicarbonate concentrations sufficiently high to make it moderately hard to hard.

The chemical quality of the water in the two reservoirs remains almost constant throughout the year because of their large capacities in relation to inflow. Prettyboy Reservoir reflects the quality of zone 1; there is no marble in the upper 80 square miles of the drainage. Chemical concentrations in Loch Raven are slightly higher than those in Prettyboy Reservoir because it receives water from both zones.

Total dissolved-mineral concentrations in Loch Raven range from 70 to 100 ppm. The water is soft to slightly hard.

Effects of Man's Activities

At present, man's activities in the basin have only a slight effect on the chemical quality of the water. The Baltimore Bureau of Water Supply has done an excellent job of guarding the water's purity. However, a few man-caused factors are worth mentioning.

Analysis of water samples collected during low streamflow at eight scattered locations proved that detergents are present at many places in both ground and surface water, in concentrations ranging from about 0.03 to 0.06 ppm. These concentrations are very low, well below the foaming level. Ground water receives detergents primarily from septic tanks or similar disposal systems; streams receive some in runoff from automobile-service stations, small laundries, and dairy milking parlors and processing plants. Wells at some houses in developments in the basin have detergent concentrations high enough to produce quite a head of foam on a glass of water—an indication of pollution from cesspools. The detergent concentration in Loch Raven Reservoir is about 0.03 ppm.

Nitrate and chloride concentrations are other possible indications of man's effect on the basin's water supply. Concentrations of nitrates much in excess of 5 ppm should be viewed with suspicion. Nitrates are a product of the final decomposition of organic matter, which is primarily protein in nature. A concentration as high as was found in sample 1 of table 2 indicates the breakdown of more than normal amounts of organic matter.

A concentration of chloride occurring naturally in water in a basin such as Gunpowder Falls probably will not exceed 10 ppm. Much of the chloride found in sample 1 of table 3 probably came from man-contributed wastes in or near Cockeysville. Chemical analysis of runoff in the urban areas of Baltimore County and city indicate that use of salt for melting snow and ice on roads may contribute 50 to 75 ppm of chloride to the streams during winter and early spring.

With the assistance of personnel of the Baltimore Bureau of Water Supply, reconnaissance surveys were made of Loch Raven Reservoir on June 5 and October 6, 1963, to note the effect of the Towson, Timonium, Texas, and Cockeysville populations on the quality of the reservoir water, as opposed to the contributions from the opposite or northeast side which is much more sparsely populated and little developed. Most observations in the tributary inlets to the reservoir were made within a few hundred yards of the stream inflowing from the contributing area. The first survey was planned to follow a rainstorm so that the observation at the sampling stations (see fig. 24) would reflect a recent washing of the land surface. Heavy rains, totaling about 3 inches, fell on June 3 and 4.

Most of the reservoir inlets were turbid for a distance of one-fourth to one-half mile. Observations were taken for temperature, dissolved-mineral concentrations, dissolved oxygen, and coliform bacteria (any of a number of bacilli that live in the intestines of vertebrates; the coliform count is used as a measure of the purity of water).

Dissolved solids were somewhat higher in samples from the Long Quarter Branch Cove of the reservoir (closest to Towson) than from the opposite side. This difference was explainable by the slightly different geologic terrain which contributes a harder type of water. One sample from a cove at station K had a much greater concentration than samples from any of the other stations, probably resulting from house-construction activities.

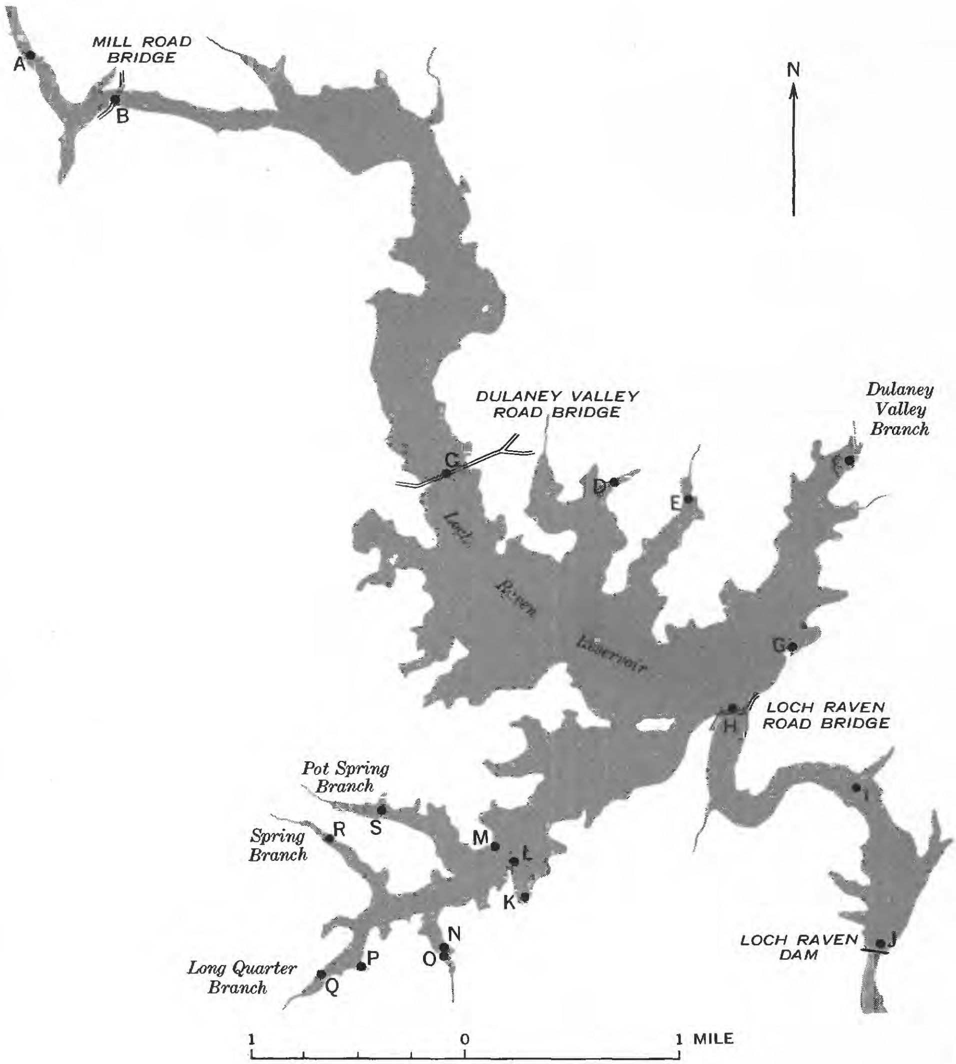
Farms and dairies are numerous to the northeast of Loch Raven Reservoir, especially in Dulaney Valley; higher counts of coliform bacteria might be expected in the adjoining water of the reservoir inasmuch as the bacteria live in the intestines of warm-blooded animals. Actually the reverse was true; the highest count was from the Long Quarter Branch arm. A fairly high count of coliform bacteria was expected and found in the headwaters of the reservoir because the drainage above is heavily farmed and the Beaver Dam Run tributary contains a large population in the towns of Timonium, Texas, and Cockeysville.

FIGURE 24 (opposite page).—Map of reconnaissance surveys of Loch Raven Reservoir, June 5 and October 6, 1963:

Station shown on fig. 24	Dissolved solids (ppm)		Coliform bacteria count per liter		Dissolved-oxygen concentration, Oct. 6	
	June 5	Oct. 6	June 5	Oct. 6	Percent saturation	Ppm
A	48	--	70,000	--	--	--
B	69	68	95,000	50	69	8.4
C	71	76	2,800	100	60	7.4
D	74	--	13,000	--	--	--
E	76	87	8,000	350	59	7.5
F	81	88	12,000	100	61	7.8
G	81	80	5,000	200	55	7.0
H	68	87	10	0	64	7.8
I	--	--	--	50	--	--
J	--	83	--	--	49	6.5
K	220	81	11,000	0	69	8.5
L	160	--	--	--	--	--
M	81	--	--	--	--	--
N	93	--	--	--	--	--
O	81	88	60,000	0	61	7.4
P	93	--	--	--	--	--
Q	92	102	54,000	50,000	69	8.4
R	87	88	31,000	25,000	--	--
S	81	90	8,000	500	--	--

The low counts of coliform bacteria found at Dulaney Valley Road (2,800 per liter) and at Loch Raven Road (10 per liter) strongly indicate that the detention time of the water moving through the reservoir is sufficient to permit oxygenation of most of the bacterial load.

The fact that dissolved-oxygen concentrations in surface samples taken at all sampling stations had satisfactory saturation percentages indicates that oxygen-consuming organic pollution was not present in appreciable amounts. Some samples were highly saturated because



of the photosynthetic activity of oxygen-producing microvegetation such as algae.

The second survey of Loch Raven Reservoir, October 6, 1964, was made to determine reservoir conditions after a long drought. Streamflow was quite low, and rains sufficient to cause runoff had not occurred in many weeks. However, on the day of the survey it rained steadily and affected the results obtained at the sampling sites in Long Quarter Branch, Spring Branch, and Pot Spring Branch. The coliform concentrations were fairly low at all other sampling stations (fig. 24). The influent streams to Loch Raven appear to carry relatively low counts of coliform bacteria during low-flow periods, and the major counts of coliforms are washed into the lake during times when rainfall is sufficient to produce surface runoff. The second survey confirmed the ability of the lake to assimilate bacteria; the counts of coliforms were again low at the bridges on Dulaney Valley and Loch Raven Roads, as well as at the midpoint between the dam and Loch Raven Road.

The dissolved-oxygen concentrations in samples taken about 3 feet below the surface ranged from 6.5 to 8.5 ppm. These concentrations are about two-thirds that of water saturated with oxygen.

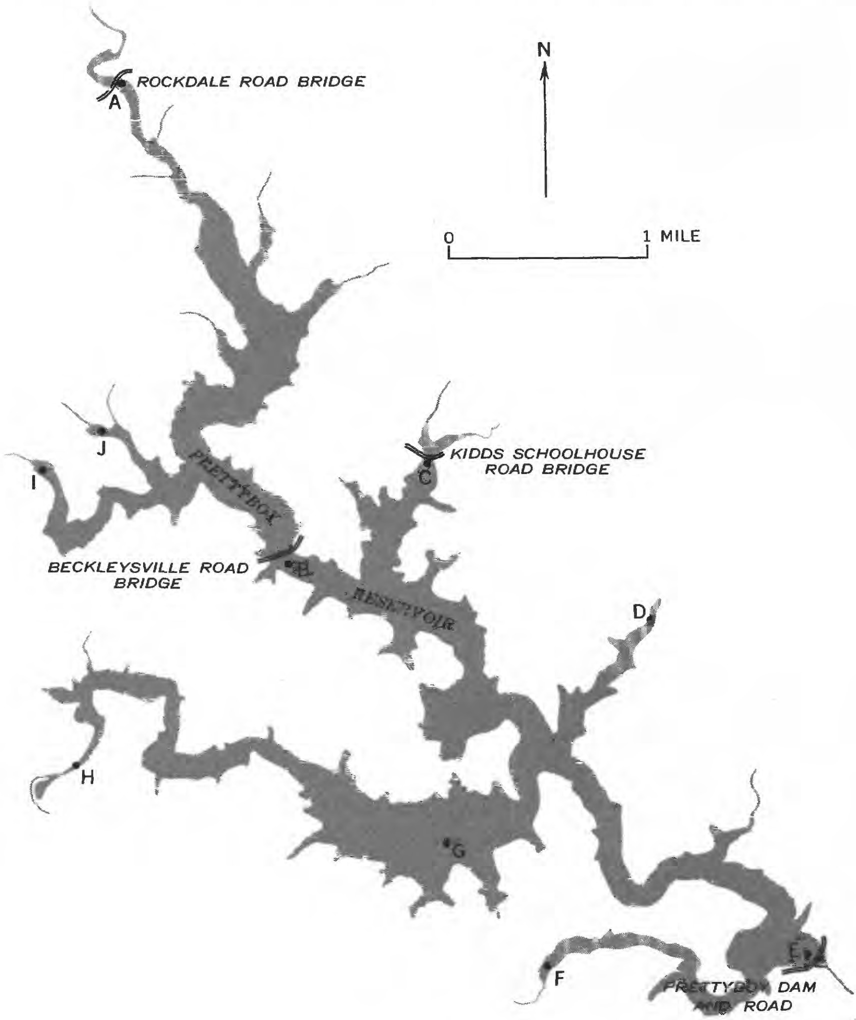
Dissolved-solids concentrations averaged about 85 ppm and were about 10 percent higher than during the June 5 survey. The dissolved solids in Long Quarter Branch Cove were appreciably higher, probably from effluents from the shopping center in that small drainage basin.

Prettyboy Reservoir was surveyed on October 5, 1963, and results are shown on figure 25. The flow of streams into the reservoir was very low. The data indicate that Prettyboy has higher coliform bacteria counts, lower dissolved-solids concentrations, and higher dissolved-oxygen values than Loch Raven Reservoir.

FIGURE 25 (opposite page).—Map of reconnaissance survey of Prettyboy Reservoir, October 5, 1963:

Station shown on fig. 25	Dissolved solids (ppm)	Coliform bacteria count per liter	Dissolved-oxygen concentration	
			Percent saturation	Ppm
A	45	5,000	77	8.5
B	48	1,400	74	7.4
C	42	2,500	61	7.8
D	47	1,000	75	7.0
E	46	2,000	73	7.7
F	47	7,000	82	7.7
G	48	1,800	73	7.3
H	47	4,000	77	8.5
I	42	2,800	72	8.5
J	45	4,000	77	9.0

For these surveys, all samples were taken at the midpoint across the channel where the water shallowed to 5 feet. The coves in Prettyboy Reservoir are narrow and deep, and there samples can be obtained quite close to the influent streams; however, the shallow, broad silt-filled coves of Loch Raven Reservoir did not permit sampling close to the influent streams. This difference in depth, together with the fact that water remains longer in Loch Raven, explains, in part, the higher coliform counts in Prettyboy Reservoir. There is, however, strong indication that streams influent to Prettyboy Reservoir carry higher counts of coliforms at low flow than do the streams flowing into Loch Raven, that is, that more polluting sub-



stances are being introduced directly to the streams in the Prettyboy area. The surface area of Loch Raven Reservoir is 50 percent greater than Prettyboy Reservoir; hence the chance for oxygenation of its water is greater by that amount.

Effects of Storm-Water Runoff

When rain falls, part of it soon enters the watercourses as storm-water runoff. This runoff usually brings with it a myriad of things —dissolved chemicals, bits of trash, oils and tars from roads, decaying organic matter, and so on—that acculumate in the watercourses and decrease the purity of the water in the drainage basin. To determine about how much contamination the runoff from the planned urbanized areas will add to the Gunpowder Falls basin, two areas in the City of Baltimore were selected for study. Although these areas are outside the basin, they were chosen because their hydrological environments are like those of the urbanized areas that are now growing in the basin.

Area A is a 100-percent residential section containing detached and semidetached homes on lots of about 2,000 to 3,000 square feet; it has been developed within the last 10 years. The total area is 47 acres, and 44 percent of it is covered with impervious surfaces such as streets, sidewalks, and roofs. It has a population of about 1,600 people. Sanitary sewers carry all domestic sewage from the area, and storm sewers carry away excess water from rain, lawn-sprinkler runoff, automobile wash water, and the like. The storm sewer discharges into a tributary of Herring Run.

Area B is a mixed residential area containing row houses and a highly developed shopping center. Sixty-eight percent of its total area of 47.4 acres is imperviously surfaced. The residential area contains about 800 people. The shopping center occupies about 17 acres and consists of a large department store, two supermarkets, one theatre, and about 25 smaller businesses. Area B has separate sewer systems for sanitary wastes and for storm runoff. The storm water also drains into a small tributary of Herring Run.

Areas A and B are almost identical in size, shape, and slope of the land surface; they are part of the same drainage basin, were developed at the same time, and are about 1 mile apart. Consequently, any difference in the quality of the water draining from the areas must be due to differences in man's activities. Figure 26 is a record of the amount of dissolved mineral matter contained in the water draining from area A for a 4-day period. Little change in water quality takes place from 8:00 p.m. to 8:00 a.m., but from 8:00 a.m. to 8:00 p.m. the changes are frequent and extensive. These changes

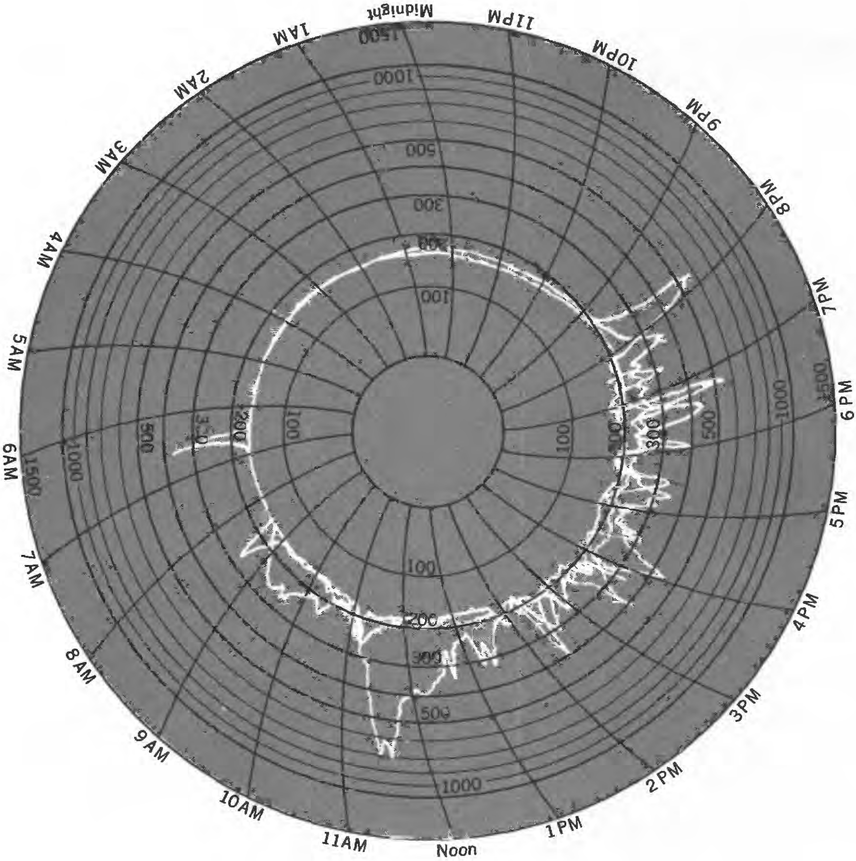


FIGURE 26.—Recorder chart of runoff record from area A for a 4-day period. The continuous record lines show conductivity values; dissolved-solids concentrations are approximately 60 percent of the conductivity values.

are directly attributable to the dumping and flushing of liquid and other wastes into the storm sewers. Some of the larger flushings of polluted water, such as the one between 11:00 a.m. and noon, are due to street washes. The smooth record obtained at night shows that the normal mineralization of water in the area is about 100 to 110 ppm; because of the indiscriminate dumping, flushing, washing, and watering that takes place during the daytime, however, the mineralization of water fluctuates from about 110 ppm to more than 500 ppm of dissolved solids. This diurnal change was observed over a 2-month period.

During the warmer weather in April and May, the small stream channel which received the water from the storm sewer of area A had a luxuriant growth of algae, slimes, and molds which were quite

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odoriferous. The nitrates (10–15 ppm) and phosphates (2–3 ppm) in the water were nutrients for the streambed growth.

During and after storms, high runoff scours these organisms from the streambed and washes them to a settling area, in this case the Back River. Oxidation of these materials uses the oxygen in the water and can result in an environment which will not support aquatic life. Such water in a settling area can create taste and odor problems, and even health hazards, and it is generally unfit from an aesthetic point of view.

The record of the dissolved-mineral matter in water draining from area B (fig. 27) is much more uniform than that from area A. The small increases (caused by increase of calcium chloride) which occur hourly are of undetermined origin; they may be caused by automatic

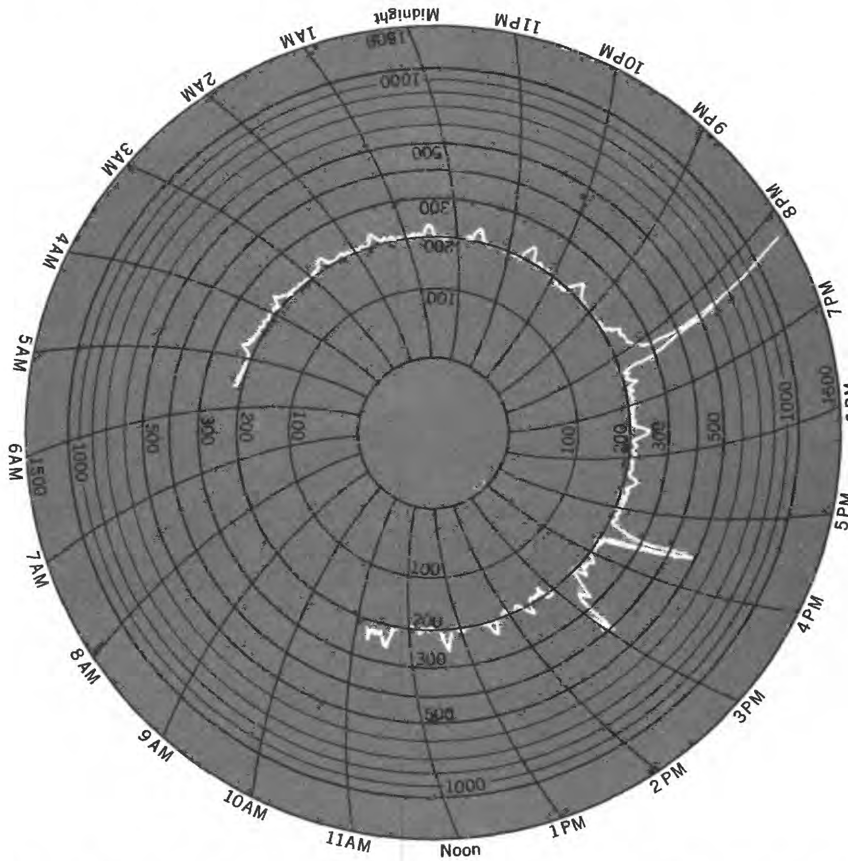


FIGURE 27.—Recorder chart of runoff record from area B, 11 a.m. to 5 a.m. The continuous record line shows conductivity values; dissolved-solids concentrations are approximately 60 percent of the conductivity values.

defrosting refrigeration equipment used by the large supermarkets. Several large increases in dissolved solids occurred during the day. A single gasoline station was the main source of pollutants from area B; it contributed foamy car washings, gasoline, motor oils, greases, and radiator flushings.

The stream channel below the storm-sewer outfall of area B did not have as much algae and slime as area A, probably because of the inhibiting effect of the petroleum products in the runoff. Observed nitrate, phosphate, and chloride concentrations were as much as 4, 10, and 80 ppm, respectively. Besides dissolved materials in the water, both areas contributed notable quantities of newspapers, cardboard boxes, tin cans, rags, broken glass, sand and gravel, wire, children's toys, and so on, to the storm drains.

During low flow, coliform bacteria counts were quite low, generally less than 100 per liter. It is doubtful that storm runoff in area B would have as high a coliform bacteria count as the water in most arms of Loch Raven Reservoir because the high density of the development and the local laws tend to keep to a minimum the number of animals in such an area.

During periods of no precipitation, or runoff due only to melting snow and ice, the flow from the area was only a fraction of that occurring during a storm. The late winter and early spring runoff was about 25 to 40 gpm. In April and May, when evapotranspiration demands increased considerably, the flow diminished to 5 to 10 gpm.

Runoff from both areas was quite rapid during a storm. Within a few minutes after a rain began, the flow increased noticeably and then varied almost as the rainfall. Within 30 to 60 minutes after a storm the flow was almost back to the prestorm amount.

Runoff from the storm of April 29–30, 1963, from area A was analyzed to determine the amount of dissolved matter. Figures 28 and 29 show the sequence of events for this storm. Rain began to fall at 6:00 p.m. on April 29; during the next 10 hours about 1 million gallons of water fell on the area of which an estimated 450,000 gallons ran off. The 5 weeks preceding April 29 and 30 were very dry and consequently runoff from pervious areas was negligible, the runoff coming primarily from the impervious surfaces which constitute 44 percent of area A. The calculated amount of dissolved-mineral matter in the runoff resulting from man-made causes was about 350 pounds; the average concentrations for the storm water was about 95 ppm. This concentration can be interpreted to mean (1) that the impervious surfaces resulting from urbanization permit

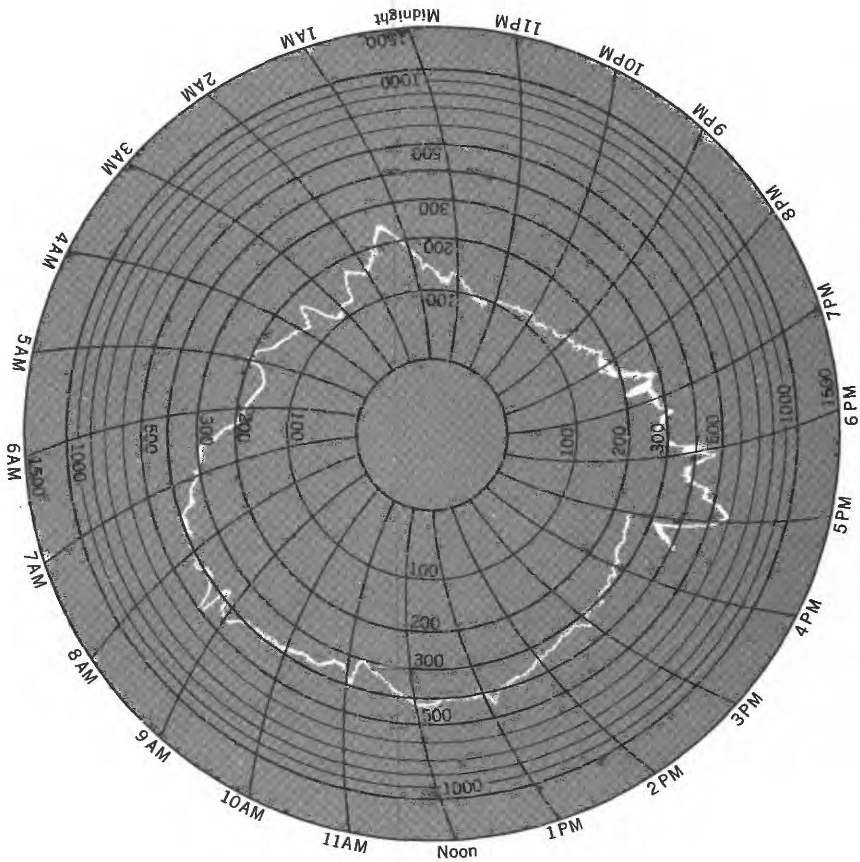


FIGURE 28.—Recorder chart of storm-runoff record from area A, Apr. 29–30, 1963. The continuous record line shows conductivity values; dissolved-solids concentrations are approximately 60 percent of the conductivity values.

a 40 to 50 percent greater runoff and (2) that the amounts of dissolved solids are 30 to 50 percent greater because of urbanization.

Effects of Sedimentation

The Gunpowder Falls basin has long been a notoriuos producer of sediment. The area was heavily farmed during the 18th and 19th centuries. Where forests were not burned to make way for fields, they were cut heavily to feed papermills and satisfy lumber needs. The harbor of old Joppa was used only about 100 years before it became choked with silt (see p. 6). The first municipal water-supply reservoir in the basin, built in 1881, lost 85 percent of its capacity to sediment by 1900. Only by the dredging of 1.8 million tons

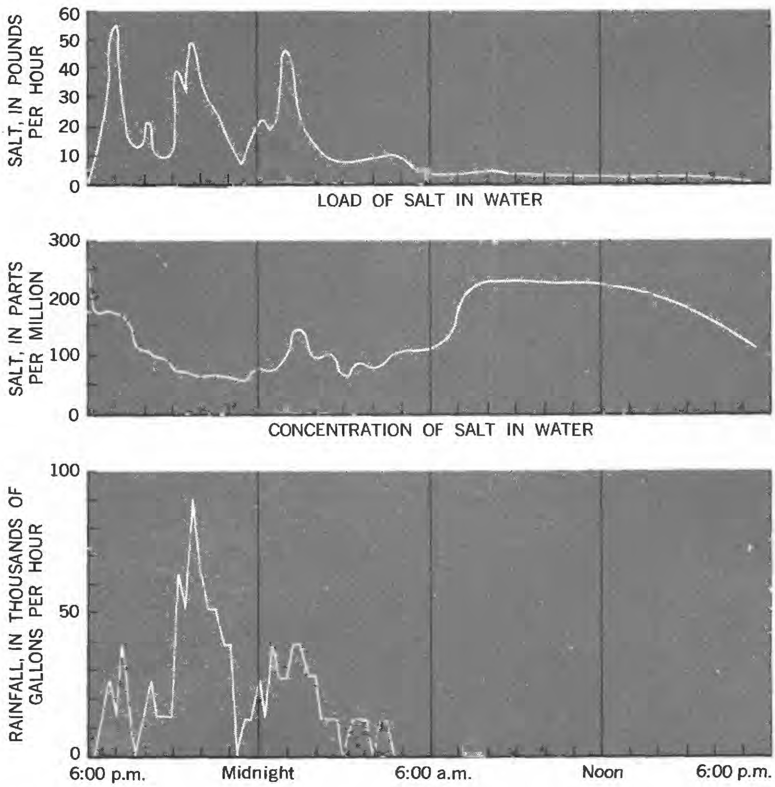


FIGURE 29.—Relationships of dissolved substances to rainfall in area A during the storm, April 29–30, 1963.

of sediment was it made to last until the present larger Loch Raven Dam was constructed in 1914.

Land use is the dominant factor in sediment production within the basin, geology and climate playing lesser roles. Land use at the present time is about 60 percent farm and pasture, 30 percent forest, and 10 percent urban or suburban (see p. 9). The basin has changed a great deal since the coming of the white man more than 300 years ago. Before the advent of Europeans, forests almost certainly covered at least 80 percent of the area, the remainder being forest-fire glades and small fields tilled by Indians, but by 1900 an overwhelming 90 percent of the land was in farms (fig. 30).

The usual sequence of erosion and sedimentation has been summarized by Guy and Ferguson (1962, p. 27):

> Sediment derived from natural and agricultural erosion has always given varying degrees of concern to those who plan, finance, or manage water reservoirs. A third source of sediment threatens to reduce further the useful life

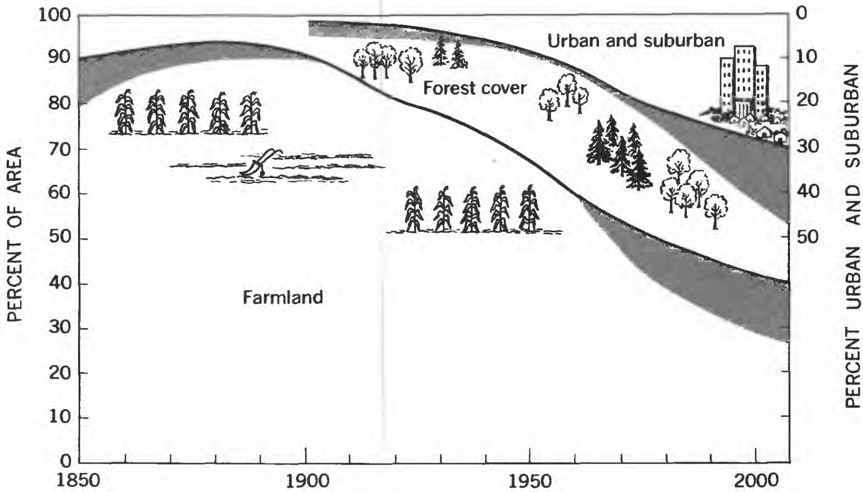


FIGURE 30.—Land use in the basin, 1850–2010. Gray area shows the most probable ranges of values for periods for which records are incomplete and for the forecasts.

of many reservoirs downstream from urban centers. This newly recognized source is the result of the increasing quantity of soil material exposed or reshaped by modern earth moving equipment during the construction phases of urban development. The inevitable widening of stream channels after urbanization is an additional source of sediment.

Sediment yield from forested land is quite small, averaging about 50 tons per square mile per year from a basin such as the Gunpowder Falls. Before the area was settled, the 350 square miles of the basin probably yielded about 15,000 to 20,000 tons per year to the Gunpowder River estuary.

Agricultural use of land accelerates erosion because the land must be ploughed and broken up before planting. While the earth is loosened and exposed, rainfall and runoff carry away some of the topsoil. Then, as the sediment-carrying waters enter lakes and estuaries downstream, the topsoil is redeposited. Row crops, such as corn, permit more erosion than cover crops, such as clover, because a large percentage of the soil surface in a field of corn remains bare throughout the growing season. Obviously, it is difficult to estimate annual erosion from an "average" square mile of farmland in the Piedmont.

Gottschalk (1945, p. 224) determined that about 6.5 million tons of sediment was deposited in the upper part of the Gunpowder River estuary between 1846 and 1897, assuming that no sediment was lost to the lower part of the estuary or to the Chesapeake Bay. This total resulted from about 340 tons per square mile per year, as shown in the lower left block of figure 31. During the last 20 years of this period, the original Loch Raven Reservoir was intercepting about 30 percent of the sediment from the basin. If allowances are made for this interception and it is estimated that the 340 tons per square mile per year deposited in the estuary constitute 40 to 50 percent of the total yield per year for the 1846–97 period, the annual yield appears to have been about 900 to 1,100 tons per square mile per year.

From 1881 to 1900, the original Loch Raven Reservoir trapped about 2.5 million tons of sediment. The reservoir caught 25 to 35 percent of the sediment inflow; consequently, the basin's yield probably was within the range of 1,000 to 1,200 tons per square mile per year. (See fig. 31.) At that time the basin was 90 percent farmed (fig. 30), and farming practices generally were not in keeping with soil conservation.

The 1943 survey of Loch Raven Reservoir (Gottschalk, 1943, p. 16–17) showed that the sediment yield per square mile was 800 tons per year for the preceding 29-year period. This yield totaled 7.9 million tons and reduced the capacity of the impoundment about 8 percent. A survey of Prettyboy Reservoir the same year revealed that it had accumulated about three-fourths of a million tons of sediment during its 11-year span, or about 900 tons per square mile

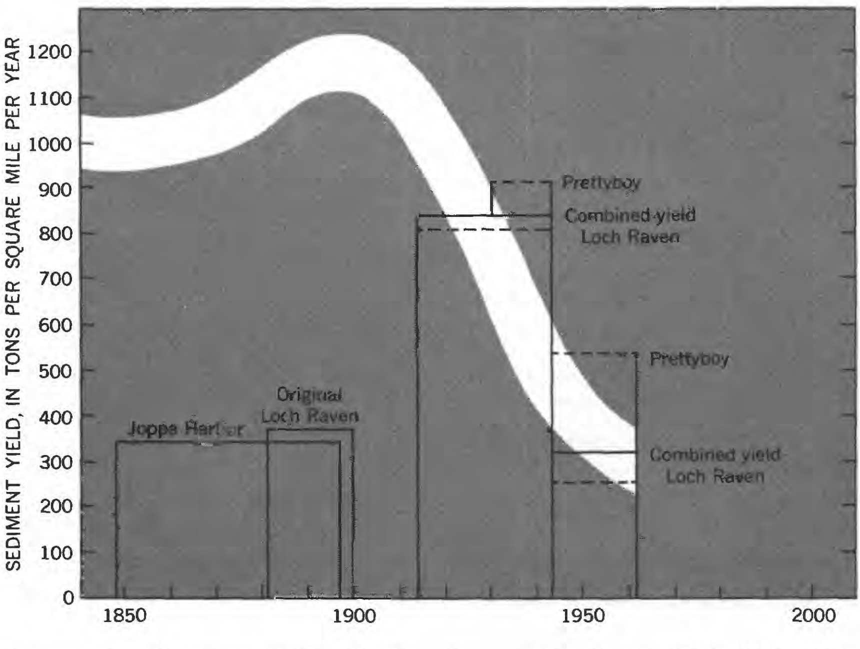


Figure 31.—Sediment yield reflecting change in land use, 1850–1963. (For a fuller explanation, see p. 51.)

per year. These sediment yields are shown as the center block of figure 31.

Analysis of Loch Raven Reservoir survey data (Holeman, written commun., 1963) for the Dulaney Valley and Long Quarter Branch arms indicate that the average annual yield of sediment for the 1914–62 period was about 3,000 and 1,300 tons per square mile, respectively, from those tributaries. The estimated yield from Dulaney Valley Branch may be too high, although about 60 to 70 percent of the drainage was intensively farmed during the period. Much of the Long Quarter Branch drainage was farmed prior to World War II; since then, fields have been replaced by residential developments.

Surveys of both reservoirs in 1961 (Holeman, written commun., 1963) showed that the sediment yield had declined markedly. For the 1943–61 period, the yield of Loch Raven Reservoir was only 233 tons per square mile per year, almost 70 percent less than the 800-ton figure of the earlier survey. The drop in yield is attributed to the decline in the amount of land farmed and to conservation practices. At the present rate of sedimentation, Loch Raven Reservoir is expected to last well over 1,000 years. The yield to Prettyboy Reservoir remained fairly high at 550 tons per square mile per year for the 1943–61 period, about 40 percent less than the 900-ton figure estimated from the earlier survey. This reservoir also appears to have a life expectancy of more than 1,000 years. The estimated annual sediment yield per square mile of the Gunpowder Falls basin for the past 100 years is shown by the curve in figure 31.

Erosion resulting from urban growth is now recognized as a serious problem. After a strip of agricultural or wooded land is earmarked for a residence, an industrial park, or an expressway, bulldozers, earth scoops, and graders remove the cover of vegetation. The earth is thus exposed, in cuts and fills, to rain and storm runoff. Weathering and erosion of the soil continue throughout the period of construction until the ground is again covered with grass and other plants or sealed with impervious roofs and pavements. A house plot may be stripped, the home built, and the yard replanted all in a few months but sections of an industrial park, a superhighway, even of a large residential development may remain bare for several years.

Holeman and Geiger (1959) made a sedimentation resurvey of Lake Barcroft, Fairfax County, Va., to determine the change after two-thirds of the watershed had been urbanized. Guy and Ferguson (1962, p. 30) concluded from the Lake Barcroft resurvey:

> * * * that each square mile passing through the construction cycle processes of clearing, grading, building, and seeding results in an accumulation of approximately * * * 25,000 tons of sediment per square mile.

The similarities between the Lake Barcroft and Loch Raven areas include geology, topography, climate, and the complexity of construction methods; therefore the sedimentation estimate of 25,000 tons per square mile for the period of development for Lake Barcroft probably is applicable to sections of Gunpowder Falls slated for urbanization.

Sediment yield from an urbanized area, after construction is completed, is 50 to 100 tons per square mile per year, or about one-third of the present yield of the Gunpowder Falls basin excluding the part above Prettyboy Reservoir where the yield is about 550 tons per square mile per year.

A major source of sediment from an urban area is the erosion of stream channels. Storm water leaves an urban area in greater quantities and at faster rates than from "natural" or rural lands. The impervious surfaces of a city do not permit the water to soak into the ground; instead it is routed into gutters, lined ditches, and sewer pipes. Carter (1961, p. 9) found that the maximum flood discharge expected in a 2-year period is about twice as great from a suburb as from a countryside. This additional flow has increased energy which results in the rapid widening and downcutting of channels to undermine retaining walls, bridge abutments, and culverts, until the stream bed is sufficiently enlarged to accommodate the excess water. Thus, man-made earthfills may be washed away, and streamside structures are threatened or destroyed.

In summary, the sediment yields that can be expected from the basin according to the use of the land are:

	Tons per square mile per year
Forested land	About 50
Farmland	1,000 to 5,000
Land stripped for construction	25,000 to 50,000
Urban and suburban land	50 to 100

Recreation

The influence of an expanding metropolis and its inhabitants on adjoining green spaces, watersheds, and countrysides suitable for recreational purposes is an increasingly important problem.

In August, 1958, a working committee of the Baltimore Regional Planning Council recommended that 10 acres of State or regional park land and 33 acres of open spaces should be available per 1,000 people for recreational purposes. The committee noted that water-supply reservoirs had a maximum permissible recreational use below that of reservoirs for which the maintenance of water quality was not of first importance. The committee determined a 1958 deficiency of about 30 percent in local recreational areas, and it forecast a 58-

percent deficiency by 1980 if no new areas are acquired. This conclusion was the impetus for the present acquisition of land for the Gunpowder Falls State Park (Allen, 1958, p. 3).

Much of the Gunpowder Falls basin possesses attractive open spaces: forests interspersed with fields and pastures, a rolling to rugged topography, and a generally clear stream. Many stretches of valley remain sparsely settled and well timbered by second-growth trees. Most of the valley is inaccessible by car, but roads border and, in places, cross it.

The City of Baltimore Bureau of Water Supply owns and controls the Prettyboy and Loch Raven Reservoirs and the acreages around them. The diligent and careful supervision of these areas is aimed at maintaining the high quality of the water and keeping the watershed clean, but the reservoirs are open to the public. The pleasing waterscapes and stalwart dams are photogenic and aesthetically satisfying in themselves. Well-tended forests encircle the shores, and they have provided the city with about a million dollars worth of lumber—more than half a million from November 1955 through June 1959 (Reigner and Sushko, 1960, p. 3)—from controlled logging around Loch Raven. This planting and thinning has improved the appearance of the area and resulted in healthier trees. Thus, areas set aside for conservation or recreation may provide additional uses.

The following recreational pursuits are permitted at both reservoirs:

1. Fishing from designated shores and from boats equipped with electric motors in waters a mile or more above the dams. The boat center at Loch Raven Reservoir is exceptionally well equipped and maintained.
2. Picnicking in prescribed areas; about 200 rustic tables have been installed at Loch Raven Reservoir and 75 at Prettyboy Reservoir. More are being added each year.
3. Horseback riding and hiking on well-maintained logging tracks and trails.
4. Miscellaneous activities. Additional attractions at Loch Raven are a clubhouse, golf course, and skeet range. Deer hunting with bow and arrow in season is allowed at Prettyboy Reservoir.

Some of the specific prohibitions are:

1. No wading, swimming, sailing, or canoeing.
2. No cottages may be constructed, nor is camping condoned.
3. No fires may be built, even in the picnic areas.

4. No fuel-powered motorboats (other than official patrols) are allowed on the lakes.

Approximately 200,000 people annually fish the lake and stream waters; many times that number frequent the dams to gaze at the lolling carp and schools of bluegill. The stream above Loch Raven is stocked with trout. In the spring, runs of salt water fish swim up the channel as far as Loch Raven Dam; Gunpowder Falls has been listed as one of the eight best shad streams on the Atlantic Coast.

Other recreational facilities in the basin include:

1. The Valley Ranch near Roller, Carroll County, which keeps a stable of horses and is a convenient headquarters for fishing and hiking parties.
2. The Gunpowder Youth Camps, Inc.—Puhtok Boys Camp and Alkor in the valley east of Hereford.
3. The 100-acre Cone Boy Scout Reservation, between the confluence of Long Green Creek and Gunpowder Falls, which is used for camping and other scouting activities.
4. The Gunpowder Rifle Range, one-half mile north of Notchcliff Road, which is used periodically by the Maryland National Guard for high-caliber rifle practice (it will be discontinued when the State park is opened).
5. An area reserved for winter sports—ice-skating, sledding, skiing—near the old County Alms House east of Texas.
6. Several restaurants, periodically attended by civic groups from the Baltimore area, tourists, and local residents.
7. Several private clubs.

The Gunpowder Falls basin has the requisite attractions for many recreational uses which involve the natural and developed parts of the water resource. Adjacency to Metropolitan Baltimore has resulted in the many recreational facilities now available. More will be needed to satisfy increasing pressure from those seeking pleasure and relaxation. Satisfaction of this need, with minimal effect on the important water supply, is considered in the following section on "Water Supply versus Recreation."

LOOKING AHEAD

Urban Growth and Zoning

The word "megalopolis" is self-explanatory, if you can imagine a city composed of cities. Jean Gottman popularized the term in a provocative article (1957, p. 189–200) considering the urbanization of the northeastern seaboard. He envisioned megalopolis as an urban colossus reaching from Boston to Richmond. The Gunpowder Falls is within this area.

Growth by urban sprawl is being criticized more and more, and zoning—planning—for the future is the order of the day. Planning "wedges and corridors," (open spaces between strips reserved for tomorrow's industrial and residential growth) and "metrotowns," (peripheral cities of the future, each to accommodate one to two hundred thousand people) is a publicized pursuit, although some of the specific forecasts and recommendations apparently are debatable, impractical, and even unacceptable, in whole or in part, to many groups.

The Gunpowder Falls basin today is a focus of attention for zoning and planning. Part of it is being acquired for a State park by the Maryland Department of Forests and Parks, a "wedge" for the future. Land has been zoned for industrial parks and residential areas, and some areas are in the process of development as "corridors." Here and there is an area whose population is rapidly increasing and which merits consideration as a "metrotown" by the Baltimore Regional Planning Council. Most planners envision northern Baltimore County, above the latitude of Prettyboy Dam, as remaining more or less rural for the next 50 years, with an average of 5 acres per household.

Population Forecasts

Population forecasts are the usual base for predicting future demands on the resources of an area, water very much included. Several estimates have been based on the 1950 and 1960 censuses. The 1950 estimates consider but do not reflect the trend, although already apparent in 1950, of accelerated growth of the suburbs at the expense of the city. The 1960 estimates do reflect the trend, but vary as to when it will be reversed to show population increases for the city of Baltimore.

Actual 1950 and 1960 census totals for the city of Baltimore and three forecasts which vary markedly are shown in figure 32. The estimates based on the 1950 census are much higher than the ones based on the 1960 census, when the continuing downward trend in the city's population became more apparent. The estimate by the Baltimore Bureau of Water Supply of slightly over a million people in the city by the year 2010 has been accepted as the most realistic figure for Baltimore.

The three forecasts shown in figure 33 for Baltimore County are quite uniform, primarily because all three were based on the 1960 census. If the 1970 and 1980 estimates of the Maryland State Plan-

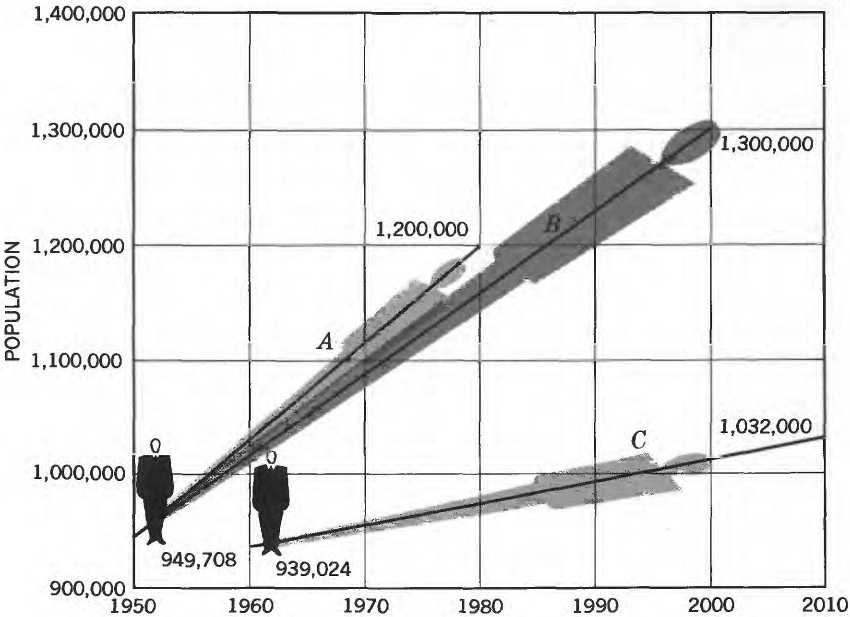


FIGURE 32.—Population forecasts for Baltimore City to 2010. *A*, From the Maryland State Planning Commission (1959). *B*, From Requardt, Shaw, and Wolman (1953); estimated increase from 1950 to 2000 is 36.9 percent. *C*, From the Baltimore City Bureau of Water Supply (1962); estimated increase from 1960 to 2010 is 9.9 percent.

ning Department are extended in a straight line to the year 2010, the forecast is only 40,000 higher than the lowest estimate, which was computed by the Baltimore City Bureau of Water Supply. The population of the county by the year 2010 will probably be nearly 1.1 million.

Two forecasts for the Baltimore metropolitan area (fig. 34) differ by little more than 100,000 for the year 2010, even though they were computed on census figures for different decades. In general, they anticipate that the population of the metropolitan area will be about 2.3 million in the year 2010. Domestic water needs will average 230 mgd, and commercial and industrial demands for fresh water will be about the same, a total water need of 450 million gallons on an average day.

To forecast the population in the Gunpowder Falls basin of the year 2010 (fig. 35), the Baltimore County Office of Planning and Zoning estimates of election-district populations in 1980 were adapted to apply only to the election-district areas lying within the basin (the same method used in computing the 1960 total in fig. 3).

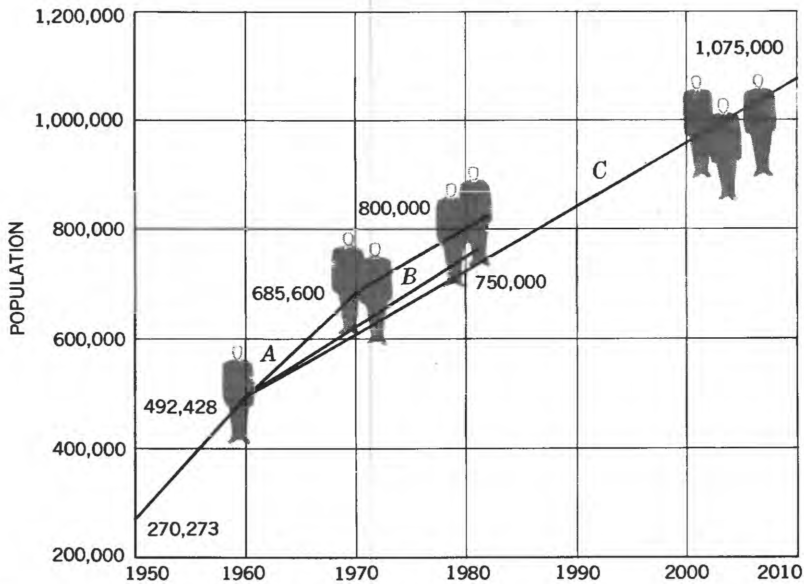


FIGURE 33.—Population forecasts for Baltimore County to 2010. *A*, From the Maryland State Planning Commission (1959). *B*, From the Baltimore County Office of Planning and Zoning (1962). *C*, From the Baltimore City Bureau of Water Supply (1962); estimated increase from 1960 to 2010 is 118.3 percent.

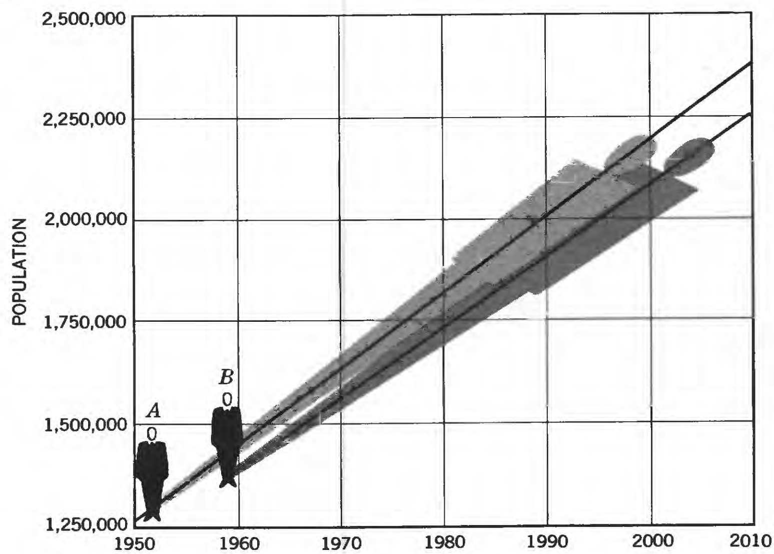


FIGURE 34.—Population forecasts for Metropolitan Baltimore to the year 2010. *A*, From Requardt, Shaw, and Wolman (1953); estimated increase from 1950 to 2000 is 72.8 percent. *B*, From Baltimore City Bureau of Water Supply (1962); estimated increase from 1960 to 2010 is 63.2 percent.

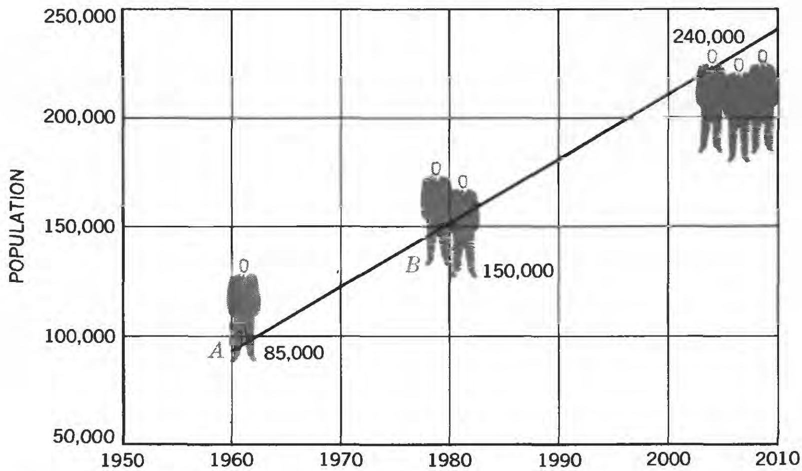


FIGURE 35.—Population forecasts for the Gunpowder Falls basin to the year 2010. *A*, Election-district census count (fig. 3). *B*, Election-district count from estimates of the Baltimore County Office of Planning and Zoning (1962); estimated increase from 1960 to 2010, is 182.4 percent.

The next step was to extrapolate in a straight line the 1960 computation and the 1980 estimate to 2010. A reasonable prediction is that nearly a quarter of a million people will live in the basin 50 years hence. This figure may even be too conservative if the planned metrotowns prosper. Population predictions for the four areas considered are:

Area	Population		
	1960	1980	2010
Baltimore City	940,000	950,000-1,000,000	1,000,000-1,375,000
Baltimore County	500,000	750,000- 800,000	1,000,000-1,075,000
Metropolitan area	1,400,000	1,800,000-1,900,000	2,250,000-2,400,000
Gunpowder Falls basin	85,000	150,000	240,000

Projects and Plans

Increasing population means increasing demands on water by "people at work, at play and at home" (Requardt, Shaw, and Wolman, 1953, p. 7) and increasing difficulties in the maintenance of a high-quality water supply. Many of the major demands and difficulties have been anticipated, as is shown in the following discussions of projects and plans which have either been activated or approved in principle. There are inevitable interrelationships and counterinfluences among the different plans involving water supply, the Gunpowder Falls State Park, traffic arteries, and zoning. This report does not go into the detail needed in an engineering plan; however, the engineering plan for a single-purpose project (such as a water supply or a State park) usually considers other planning objectives only in a collateral way. We have tried to present the overall aspects of the diversified subjects as useful preliminaries to future considerations by others.

Water for the Metropolis from the Susquehanna River

Projections indicate that the metropolitan population will increase from the present level of 1.4 million persons to 1.8–1.9 million in 1985 and 2.2–2.4 million by the year 2010—a 50 to 60 percent increase in the next 50 years.

Water needs for the metropolitan area will double or triple by 2010. The predicted demands range from 460 to 525 million gallons in an average day. The present demand is 210 mgd. The most conservative prediction by the Bureau of Water Supply assumes a rate of increase in demand for the next 50 years of 4.8 mgd per year. The increase for the 50-year period 1910–1960 was about 2.8 mgd per year. The maximum decade of growth was 1938–48 when the demand increased about 6 mgd per year. When the population increased only about one quarter of a million, from 1950 to 1962, the demand increased about 2.5 mgd per year, about one-half the predicted rate for the next 50 years (fig. 36). The Bureau of Water

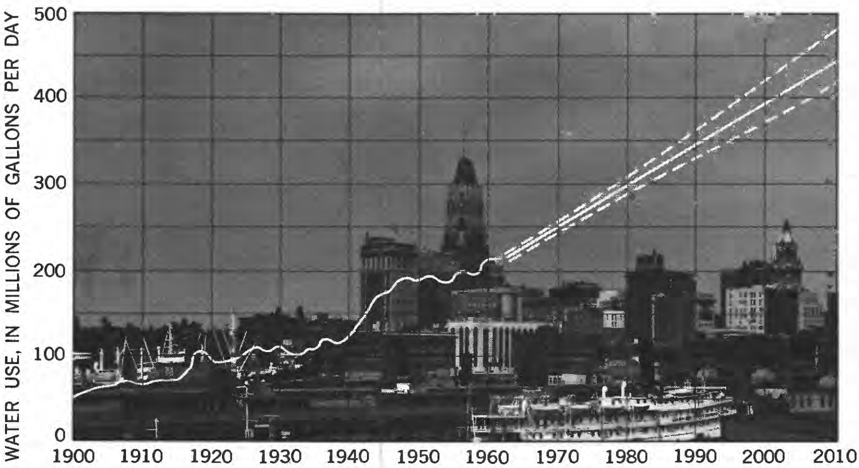


FIGURE 36.—Water used by Metropolitan Baltimore from 1900 to 1962 and projected to 2010. Photograph by the Maryland Port Authority, Baltimore, Md.

Supply foresees either an increase in the per capita use of water or an increase in demands for water from industry.

To meet this anticipated demand the metropolitan area will be using water from three sources: The Patapsco River, the Gunpowder Falls, and the Susquehanna River. The Patapsco and Gunpowder Falls potentials for water supply have already been considered (p. 19).

Susquehanna River water will be available to Metropolitan Baltimore by 1966. The Baltimore Bureau of Water Supply has secured rights for 250 mgd through a pipeline now under construction, with an option to double the amount by the end of the century.

Plans have been made to provide for all the water the city will need, both the metropolis and the surrounding and expanding service-area neighborhoods, until well past the turn of the century (table 4). The Susquehanna water will be made available by withdrawal from the Conowingo Reservoir upstream from the west end of the Conowingo Dam, 33 miles northeast of Baltimore and about 10 miles from the north end of Chesapeake Bay. An aqueduct 144 inches in diameter will conduct it to a diversion point below the dam. From there the first pipeline, 108 inches in diameter, has been extended south and southwest to follow the Fall Line to Baltimore. The pumps being installed will be capable of forcing 240 mgd through the main. The amount delivered to Metropolitan Baltimore will probably be about 220 mgd, 20 mgd being allowed for leakage. maintenance interruptions, and the Harford County taps.

TABLE 4.—*Water supply needed for Metropolitan Baltimore, in million gallons per day*

	[1] 1950	[1] 1960	1970	1980	1985	1990	2000	2010
Source of data:								
Bureau of Water Supply	187	211			321			460
Requardt, Shaw and Wolman (1953			285	340		400	460	
Geyer (1959)							463	
Authors' projection			250	300		350	400	450
Source of water:								
Gunpowder Falls (Loch Raven Dam)	148	148	220	220		220	220	220
Patapsco River (Avalon-pump expedient)	50							
Patapsco River (Liberty Dam)		95	105	105		105	105	105
Susquehanna River			220	220		440	440	440
Total water available	198	243	549	549		769	769	769
Peak-day need		250			483			738

[1] Actual.

The Susquehanna water will be more expensive than water from the Patapsco River and Gunpowder Falls. It is acquired 33 miles away and must be pumped from the 45-foot elevation at the source to the Montebello Filtration Plant at a 215-foot elevation. Pumping is not the only additional expense. The costs of the pipeline, the pumps, and their maintenance are important considerations. Another expense, difficult to compute at this time, involves the purchase of needed water from the Philadelphia Electric Power Co., which constructed the Conowingo Dam, when the maintained flow over the dam is less than the minimum needed by the hydroelectric plant. The city will attempt to draw water only during high-flow periods or when the plant is not operating. Fortunately, the Susquehanna is a large river; the lowest weekly flow expected in a 30-year period is 1.1 billion gallons per day.

Demands of industry may hasten the construction of a second pipeline to the Susquehanna. Present industries will expand and new industries will be located along the Fall Line, all needing water. Some consideration is being given to placing the second aqueduct farther inland where it can provide raw water to the existing and planned communities in the northern parts of Baltimore and Harford Counties.

Five taps are being made in the pipeline under construction to augment or replace local water supplies along the Fall Line in Harford County; 10 mgd is the agreed-upon total maximum draw from the five taps.

Susquehanna water will be a fine reserve, an addition to the present supply for the expanding urban area. The City of Baltimore Bureau of Water Supply plans to extend existing mains to serve a larger area (fig 17). This extension will permit a more concentrated population west and south of Loch Raven Reservoir and along the south side of the lower Gunpowder Falls. The Bureau of Water Supply plans to draw as much water as possible from the Gunpowder Falls and Patapsco River before using the Susquehanna line. The practical intent of the Bureau is to use all the available cheaper and better water before drawing from the Susquehanna, and the Bureau makes no allowances for other interests in the basin. Possible compromises are discussed on pages 75–80.

The Gunpowder Falls State Park

Another firm plan is to create a State park in the valley-bottom parts of the Gunpowder Falls and Little Gunpowder Falls basins. The State government has appropriated funds for the purchase of more than 10,000 acres of desired properties. Figure 37 shows the locations of the disconnected sections on the estuary, Little Gunpowder Falls, Loch Raven Dam to the Fall Line of Gunpowder Falls, and the stretches on each end of Prettyboy Reservoir. The

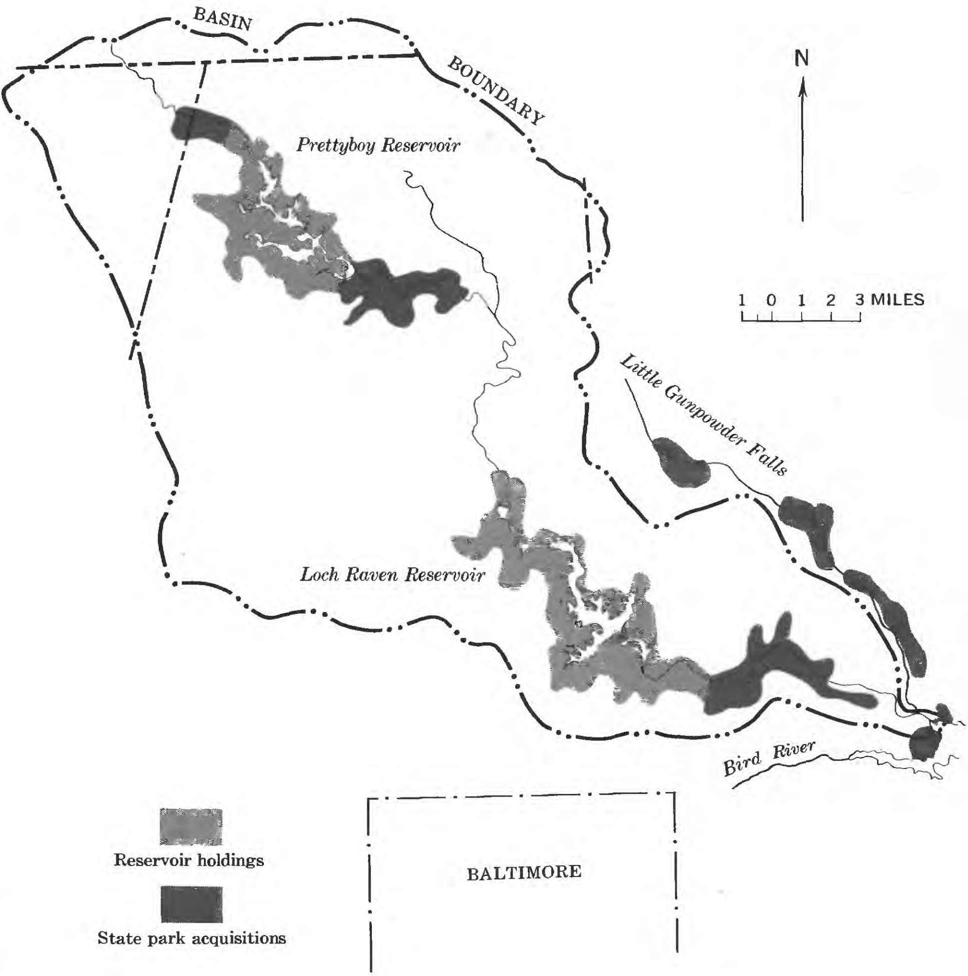


FIGURE 37.—Present and proposed recreational areas in the basin and in the adjoining Little Gunpowder Falls basin. (Adapted from Allen, 1958.)

existing publicly owned acreages around the reservoirs controlled by the Bureau of Water Supply, total an additional 11,400 acres and are a fine supplement to the proposed park, but they have a more limited recreational use because of restrictions enforced to maintain the quality of water in the reservoirs.

Not every rural area is suitable for a State park. City dwellers want easy access to a pleasing countryside which is not fenced and posted against trespassing. It should have a stream or lake or bay, one or more good viewpoints, a fine stand of trees, some wildlife.

"The general environment must be such as to promote a feeling of completely informal, relaxed, outdoor living" (Allen, 1958, p. 5).

The proposed park possesses a fair share of the desired attractions. Plans call for a network of approach roads (but no new valley roads) and convenient trails to many picnic and a few camping areas. Hiking, riding, and fishing will be encouraged, and several public swimming pools may be built. A beach and boating facilities will be developed on the estuary.

The park may be divided into two sections: the part above Loch Raven Dam where recreational activities must be restricted in order to protect the water supply, and the part below the dam where the demands of the water supply will lessen seasonally many of the recreational facilities for which the State park is being designed.

This State park is now in the process of being created, but present thinking varies on how much recreation can take place in it. Water-supply authorities emphasize the need for protection of a vital resource; they regret the pending drawdown of the reservoirs and the lack of water in the lower Gunpowder Falls, the limitations to recreation—but they do not want to yield on their requirements and restrictions.

Public officials and community leaders who realize that Metropolitan Baltimore now has a deficiency of open space and recreational areas want to see the Gunpowder Falls park lands reserved and protected. Some believe it sufficient now merely to acquire the properties, which they think may be developed, or resuscitated, in the future when demands are greater and improved technological knowledge may be applied. Others would go so far as to advocate extensive recreational development now, even to swimming in the reservoirs.

Zoning and Related Legislation

All Baltimore County has been zoned into areas reserved for industrial, commercial, residential, rural or agricultural, and recreational or open-space purposes. This zoning is based on what exists in specific locations today and on trends. It is guided by population records and forecasts, present traffic lines and plans for extensions or changes, existing and planned public services such as water and sewer mains, and economic considerations such as land values and land use and accessibility to offices and markets.

Planners realistically make allowances for special interests and for the ingrained tendency, known as urban sprawl, to expand along lines of opportunism, convenience, and least resistance. However, more and more legislation is being enacted to reenforce zoning. Some measures are palliative and interim, and are recognized as such; practicality discourages close approximation to an ideal, even if an ideal condition is comprehensible at this time. Proposed legislation, currently receiving serious study, stipulates a minimum of 1 acre, 2 acres, or even 5 acres, in some localities, before granting permission to build a house dependent on well water and a septic tank. This legislation would lessen the chance of pollution of the ground-water resource and thus protect health. In time, however, it may become more a restriction than a safeguard: it could prohibit the growth of a population dense enough to finance the ultimately needed public water and waste-disposal systems for a community. As pointed out by Geyer (1959, p. 37), one family per acre is not economically sound now if pressures exist which will result in rezoning.

Present plans involving zoning, the future water supply, the traffic network, and so on, also consider waste disposal—interim sewage-treatment plants and an ultimate network of interceptor sewers. These plans will obviate reliance on the questionably efficient individual septic tanks for most of Baltimore County south of the Loch Raven Dam by 1975 at the earliest, or more probably by 1985; estimated annual costs per customer range from $61 in 1975 to $45 in 1985 (Haney, 1962, p. 41). Figure 23 shows the existing sewer system as well as planned extensions.

Highways, Byways, and a Bridge

Another complex of reasonably firm plans is illustrated by figure 2 which indicates in a general way the highways and throughways, the byways and bypasses planned by 1985 when an estimated 850,000 cars will be driven in the metropolitan area.

Highways are the avenues of probable population growth, and the site of consequent problems of water supply and demand. They pose erosion and sedimentation problems; thousands of tons of mud and silt may be washed into existing reservoirs and ponds during the period of construction, which may last a year or more. They may permit water pollution inadvertently; for example, a truck carrying oil or chemicals may be wrecked in a tributary draining to a reservoir. They may even deter population growth locally, as well as be conducive to it. The Planning Commission of Kent County, on the Eastern Shore, is recommending the construction of a bridge across the northern Chesapeake Bay to provide more rapid access to Baltimore. If this bridge is built, possibly by the year 1985, it would provide access to a new and attractive Eastern Shore residential area less than an hour's commuting time away for workers in Metropolitan Baltimore. Opening this area would lessen pressure on the expansion of suburbia in the counties encircling the city.

Suburbs and Metrotowns

Metrotowns are visualized as "cohesive urban developments, larger than traditional towns and smaller than modern cities * * * deployed radially and in a series of rings around the city of Baltimore * * * Metrotowns would contain concentrations of population—100,000 to 200,000 persons each—at higher densities than now found in suburban communities" (Baltimore Regional Planning Council, 1962, p. 2–3).

Urban development has been taking place along the western and southern sides of Loch Raven Reservoir, in the Gunpowder Falls basin, at an accelerating rate during the last 20 years. Existing communities, population expansion, proximity to the extending public services of Metropolitan Baltimore, a steadily improving road network—all are conducive to the local growth of suburbs and small cities. By 1985, if present forecasts are accurate, the basin will contain one growing metrotown, half or more of two others, and a small fraction of a fourth. Planners and public officials know all too well that zones can be rezoned and frequently are. They also know that if they have been realistic and thorough, their forecasts and plans will serve as guides, and will materialize as a generalized whole rather than in particulars. Thus, figure 38 depicts the thinking, as of February 1963, of the Baltimore Regional Planning Council and the Maryland State Planning Department concerning probable urbanization of the Gunpowder Falls basin by 2010. A quarter of a million people will be living in the basin by 2010 and at least half of them will look to Metropolitan Baltimore for their water supply.

Brief appraisals of proposed metrotowns are necessary preliminaries to forecasting effects on the basin's total water resources. The Baltimore Regional Planning Council visualizes various metrotown areas as probable sites for planned urbanization. Planners should know the amounts of water available and needed locally, the prospects of erosion and of accelerated sedimentation of the reservoirs, the probability of increasing pollution (and supply) from stormwater runoff from impervious surfaces. Some aspects of four of these possible metrotown areas are discussed below; some advantages and disadvantages of each are listed in table 5.

Reisterstown

Reisterstown and vicinity is considered by the Baltimore Regional Planning Council as the center of a metrotown which will extend in all directions from the height of land between the Patapsco, Gwynns Falls, and Gunpowder Falls basins (fig. 38). The metrotown will be contained more or less within election district 4. Early growth is

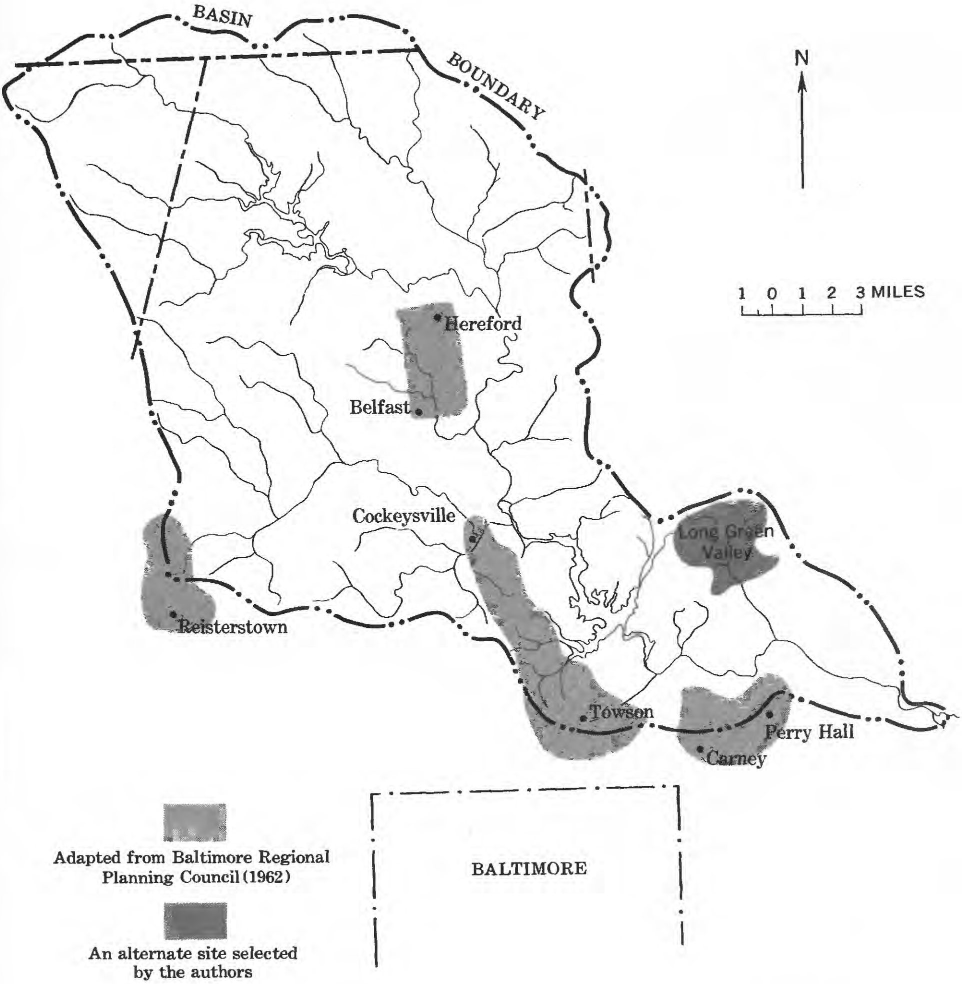


FIGURE 38.—Possible metrotown sites within the Gunpowder Falls basin.

already extending northwest from Baltimore along U.S. Highway 140. Growth probably will be more rapid after completion of a paralleling expressway and a second circumferential beltway (see fig. 2) which will speed up transportation.

Only a tenth to a fifth of the Reisterstown metrotown will be within the Gunpowder Falls basin. Topography, and the present and planned arterial highways, suggests that this fraction will be primarily residential—there will be some shopping centers but no industries. This fraction will be composed of some 20,000 people on approximately 4,000 acres by the year 2010.

TABLE 5.—*Suitability or readiness of metrotown sites for urbanization*

Item	Reisterstown	Carney-Perry Hall	Towson-Cockeysville	Hereford-Belfast	Long Green Valley
Accessibility to downtown Baltimore (mileages from Union Station).	17 miles (to junction of U.S. 140 and Md. 30). Present roads to be supplemented by Expressways and the 2d circumferential highway.	11.5 miles (to Perry Hall). The John Kennedy Memorial Highway, recently completed, now supplements U.S.1 and U.S. 40. Harford Road serves the Carney section.	11 miles (to Texas). Served by the York Road and the Baltimore-Harrisburg Expressway. The 2d circumferential highway will skirt Cockeysville.	20 miles (to Hereford). Served by the York Road and the Baltimore-Harrisburg Expressway. The 2d circumferential will skirt the south boundary.	15.5 miles (to Hydes). Present 2-lane roads will connect with the 2d circumferential highway near Glenarm.
Topography and elevation (feet above msl).	Gently rolling highland, 490 to 635.	Rolling upland ridge, 250 to 485.	Valley bottom and uplands, 270 to 500.	Rolling uplands; varied, 320 to 690.	2 valleys and uplands, 275 to 575.
Present economy (in order of importance).	Residential, industrial, farms.	Residential, farms, industrial.	Residential, industrial, farms.	Farms, residential.	Farms, residential, industrial.
Existing development.	Towns. Scattered industries. Water main. Sewage treatment plant.	Towns. Beltway. Some water mains. Sewer line under construction.	Towns. Expressway. Industrial Park. Water main. Sewer line.	Hamlets. Expressway.	Hamlets. 2 industries.
Planned development, other than urban.	Industrial park; metropolitan sewerage service.	Metropolitan water and sewerage networks.	Expanded industrial park.	Circumferential highway along south boundary. East-west Expressway through center.	Circumferential highway through the southwest part.
Water supply	Metropolitan network.	Partly served by city mains; extensions are planned.	Metropolitan network; extension of city main to Ashland is planned.	Wells; extension of city main from Ashland is planned.	Wells; extension of city mains from Cub Hill or Perry Hall are possible.
Sewage disposal	Local treatment plant; gravity main to city's network planned by 1970.	Septic tanks. Pumping station connection with city's network under construction for part of area; local treatment plants for other parts planned by 1970. Gunpowder Falls gravity main by 2010.	Many septic tanks north of Timonium. Force main to city's network serves most of the community.	Septic Tanks. Extension of force main from Cockeysville after 1970.	Septic tanks. Gunpowder Falls gravity main by 2010.
Probable effects on watershed.	Some sedimentation and runoff pollution of Loch Raven Reservoir.	None	Accelerated sedimentation of Loch Raven Reservoir. Storm-runoff pollution.	Accelerated sedimentation of Loch Raven Reservoir. Storm-runoff pollution.	None.
Probable effects on State park.	None	Sedimentation and runoff pollution.	None	None	Sedimentation and runoff pollution.
Recreational potential	Easy access to Liberty Reservoir and the State park.	Easy access to Loch Raven Reservoir and to lower sections of the State park, including the estuary.	Easy access to Loch Raven and Prettyboy Reservoirs and to the State park.	Easy access to both reservoirs and to upper section of the State park.	Easy access to Loch Raven Reservoir and to lower sections of the State park, including the estuary.

Carney-Perry Hall

The Carney-Perry Hall area, northeast of Baltimore City, is a scene of present suburban development. The scattered residential areas and small communities eventually may be consolidated into a metrotown (according to the Baltimore Regional Planning Council), much of which will be south and outside of the Gunpowder Falls basin. Approximately 40,000 people will be living in residential subdivisions on about 8,000 acres within the basin by 2010. Accommodating shopping centers will be constructed; few if any industries are anticipated.

Towson-Cockeysville

A metrotown already is being centered on Towson. Northern Towson and small but growing communities extending north along the ridge between Loch Raven Reservoir and Beaver Dam Run, along the York Road and the Harrisburg Expressway, are within the Gunpowder Falls basin (fig. 2). The area is growing rapidly; it already includes more than 20 named residential sections either established or being developed, a large quarry, and a cluster of light industries that form the core of what will be an extensive industrial park. At least 100,000 people will probably be living on the approximately 20,000-acre part of the metrotown within the basin by the year 2010. Some of these people today have homes less than 200 yards from the shore of Loch Raven Reservoir. The growth of this metrotown merits careful attention if the Gunpowder Falls water for the metropolitan supply is not to suffer in quality.

Hereford-Belfast Road

Another metrotown has been planned for the Hereford-Belfast Road area, which is between Prettyboy and Loch Raven Reservoirs and west of the Gunpowder Falls stream and is bisected by the Harrisburg Expressway. The second circumferential highway around Baltimore, and Western Run valley, will separate this small city from the larger Towson-Cockeysville metrotown to the south. About 60,000 people will live in the community by the year 2010, on approximately 12,000 acres of the Gunpowder Falls basin.

PROBLEMS, CHOICES, AND COMPROMISES

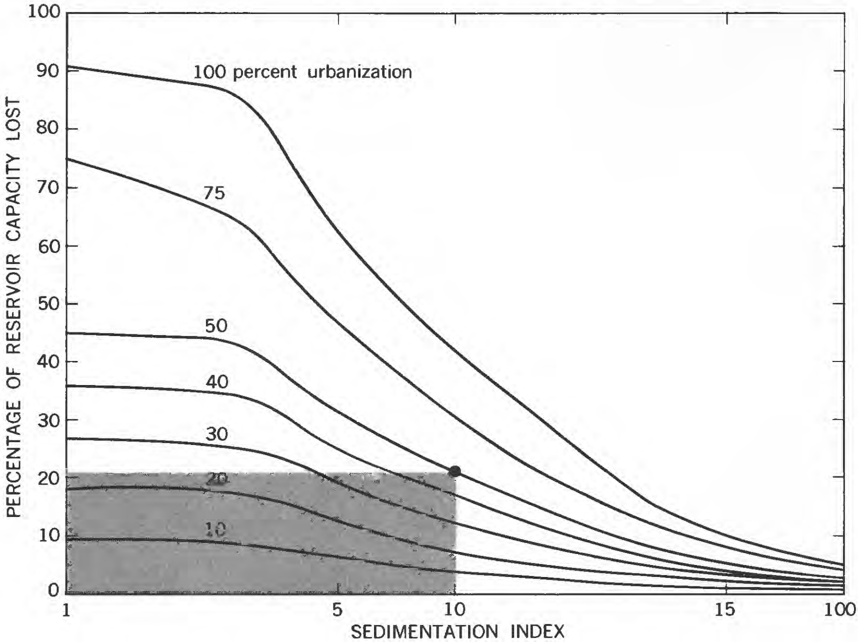
The Gunpowder Falls basin, as visualized in the year 2010, will provide (1) much of the water supply for almost 2.5 million people in Metropolitan Baltimore, (2) nearly 100,000 homesites, and (3) approximately 25,000 acres of out-of-doors for recreational purposes. Plans (table 4) call for the distribution of roughly four-fifths or more of the basin's streamflow in the Metropolitan Baltimore area. A quarter of a million people will be living in the basin, 80 to 90 percent of them in metrotowns. The largest open spaces, aside from the rural northern third of the basin, will be the reservoir reservations, totaling 15,300 acres, and the 10,000-acre State park. Water supply, living space, and recreational facilities are interrelated; people require all three, and competition among them results as demands or pressures increase.

Living Space Versus Water Supply

Urban development and maintenance will undoubtedly affect the quality of the Gunpowder Falls water resources, and to a lesser extent, the quantity of the water. The pollutants (other than sewage) that storm-water runoff carry into the streams and the tests that were made to determine the kinds and locations of pollutants already present in Loch Raven and Prettyboy Reservoirs have been discussed (p. 37). As local communities grow, the amount of pollutants that enter the streams and reservoirs will increase. Erosion and sedimentation in the area have been discussed also (p. 46); although the situation today has improved, further urbanization of the basin may introduce a potential sediment problem that could be detrimental to the water supply. As an alternative, the possibility of constructing a metrotown in the Long Green Valley subbasin, which drains into Gunpowder Falls below the Loch Raven Reservoir, deserves consideration because urbanization there would not contribute pollutants and sediments to that part of the Gunpowder Falls basin used for Metropolitan Baltimore's water supply.

The Potential Sediment Problem

The Gunpowder Falls basin has a high sediment-yield potential when the land is subjected to certain uses. Yields at present are modest. The water-supply reservoirs have large capacities, and they will remain efficient far into the future (see fig. 31). Not so the small watershed impoundments, which provide water for irrigation, storage for flood control, sediment detention, stock, fishing, and other recreational pursuits. Brune (1953) has shown that the percentage of sediment trapped in a reservoir is closely related to the impoundment's capacity and the annual inflow, that is, on any given stream, small reservoirs will fill with sediment faster than large ones, even though the former retain smaller percentages of the sediment flowing into them. The amount of loss in reservoir capacity that may be expected when various percentages of the basin change in character from rural to urban, assuming a yield of 25,000 tons of sediment from each square mile that undergoes urbanization, is indicated in figure 39; sediment retentions for normal ponded reservoirs of



$$\frac{\text{Capacity of reservoir (million gallons)}}{\text{Drainage area (square miles)}} = \text{Sedimentation index}$$

$$\text{Example: } \frac{\text{100 million gallons}}{\text{10 square miles}} = 10 \text{ (sedimentation index)}$$

FIGURE 39.—Chart of capacity loss to sediment in small impoundments because of urbanization.

Example: Percentage of drainage area to be urbanized equals 50. Find sedimentation index of 10 on figure; follow line up to 50-percent urbanization curve; follow left on a horizontal line to the left margin. Approximate loss of reservoir capacity is about 20 percent.

different sizes were taken from Brune (1953, p. 414). For example, reservoirs with capacities of less than 5 million gallons per square mile of drainage area (sediment index equals 5) may lose 30 percent of their capacities when 50-percent urbanization takes place upstream.

Large amounts of sediment affect the aquatic-life balance of a reservoir, particularly if the sediment includes a high percentage of fine clay which may stay suspended for several weeks and give the water a cloudy appearance. Turbidity prevents sunlight from penetrating the water, oxygen levels are reduced, feeding and spawning habits of varieties of fish are disturbed, and undersirable species become dominant. Thus the ecology of a reservoir may change for the worse, and many years may be required for the reservoir to

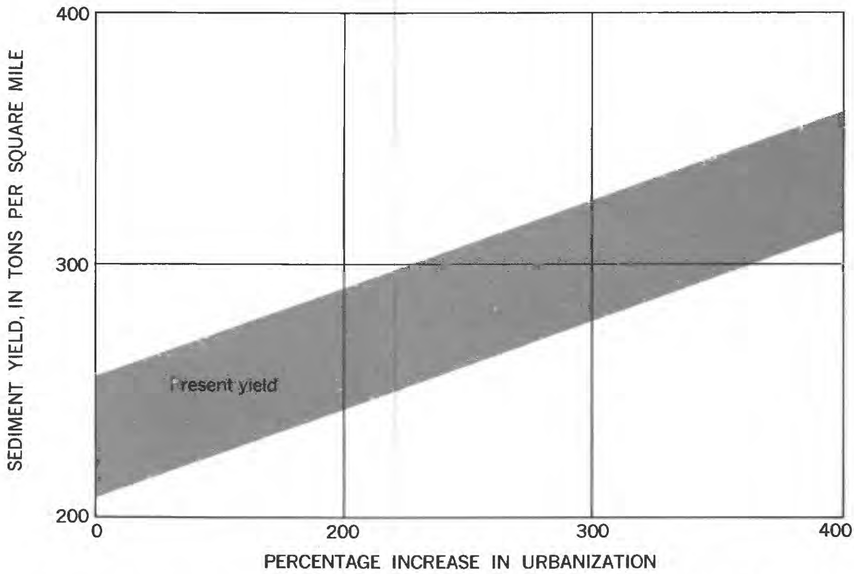


FIGURE 40.—Projected annual sediment yield for the basin below Prettyboy Dam for 1960–2010 as urbanization increases.

return to the former healthy condition—if it has not lost most of its capacity during the period of urban development.

The anticipated threefold increase in population by the year 2010, and resultant urbanization, will increase the basin's sediment yield about 30 percent. If population growth were not a factor, the present yield of about 235 tons of sediment per square mile per year from the area below Prettyboy Dam would remain constant, or more probably diminish. As new construction keeps pace with the population growth, the sediment yield will average between 275 and 325 tons per square mile per year. Sediment yield for the doubling and quadrupling of the population is estimated in figure 40. This figure is drawn on the basic assumption that during the period of urbanization a decrease of about one-third in sediment yield from rural sections will be more than compensated by an increase from the urbanized areas to give a new sediment rate about a third greater than the present rate. Sedimentation will not be a basinwide problem, but it will create local problems, particularly where small reservoirs and ponds are adjacent to the several planned metrotowns.

An Alternate Metrotown Site

Sedimentation and storm-water runoff may or may not become important factors in the water supply in the coming 50 years, but urbanization does change the hydrologic environment. The adverse consequences are sufficiently serious to warrant discussion of the hydrologic effects of alternative possibilities, even some which may not presently be under definite consideration. The effects of additional large communities—metrotowns—in the Gunpowder Falls basin upstream from Loch Raven dam should be compared with those of alternative areas.

A hydrologic evaluation of Long Green Valley, east of Loch Raven Reservoir and draining below the dam, indicates that it is one alternate site for a metrotown which holds to a minimum the conflict between urbanization and water supply. An appraisal of this site for urban development focuses attention on the hydrologic factors that city planners should consider—assuming that urban growth can be guided.

Long Green Valley, in its upper reaches, is an oval basin resulting from the weathering of a pocket of Cockeysville Marble; it is rimmed by hills and ridges composed of the more resistant Wissahickon Schist. Hydes Post Office is a convenient central point of reference (see fig. 2). A similar but narrower valley to the south, centered on the community of Glenarm, parallels the Hydes basin and also overlies deposits of marble. Long Green Creek drains both valleys as it flows southeast, through an increasingly steep ravine, to join the main Gunpowder Falls about 5 miles below the Loch Raven Dam. The combined Hydes and Glenarm areas, and the slopes rimming and separating them, total about 20 square miles—13,000 acres which could accommodate as many as 60,000 people (fig. 41).

Farms now occupy most of the bottom lands. A metal-container machinery factory and a metal-parts finishing company are located at Glenarm. Extensive estates and several residential developments (along the western and northern rims of the Hydes basin) dot the deforested highlands. The bed of an abandoned railroad traverses the two basins in a north-south direction; it crosses the Gunpowder Falls approximately 1.5 miles below Loch Raven Dam.

Neither sedimentation during construction nor storm-water runoff would affect the metropolitan water supply because the entire area drains below Loch Raven Reservoir. They could pose problems in the lower reach of the planned Gunpowder Falls State Park.

The Long Green population would be dependent upon water from wells during the initial growth period, until 1985 or 1990, when the expectancy of 25,000 residents would have a water requirement of 2.5 mgd.

The low base flow of a stream represents the safe long-term ground-water yield of an area if this water can be pumped from wells instead of being allowed to flow away overland. The low flow

FIGURE 41.—Long Green Valley, a possible alternate metrotown site.

of streams draining areas underlain by the weathered Cockeysville Marble is greater than streams of comparable size that drain areas of different geology (p. 14).

The low-flow part of a duration curve applicable to Long Green Creek (fig. 42) shows that the flow exceeds 2.0 mgd and may be as high as 2.5 mgd for 95 percent of the days during the year. Estimated on the basis of a 95-percent flow, the ground-water yield from properly sized, spaced, and developed wells in the area would be as much as 2.5 mgd. The wells should be located along the stream, in the downstream end of Long Green Valley, to capture the maximum amount of water. An estimated 10 to 15 wells should deliver the needed amount of water (see p. 74).

In determining the flow that is exceeded 95 percent of the time, the 5 percent of the time when the flow is less than the 2.0 to 2.5 mgd must also be considered. Low flows usually occur during dry periods in late summer.

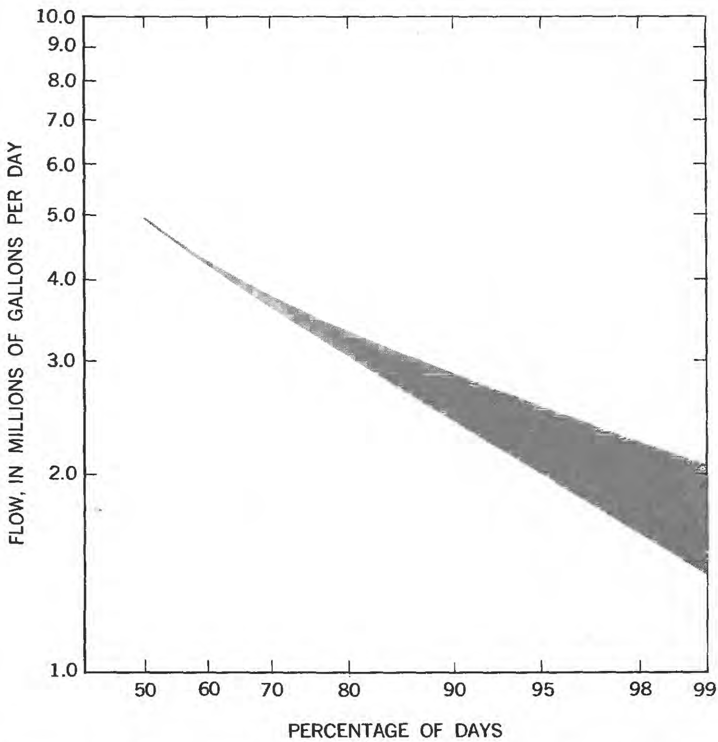


FIGURE 42.—Low streamflow from Long Green Valley at Gittings, showing percentage of days when flow exceeds the amounts in the left column.

A 6-inch-diameter test well at Hydes, drilled to a depth of 165 feet, produced 85,000 gpd (60 gpm) with 43 feet of drawdown. A 12-inch well properly constructed and developed at the Hydes site should produce more than twice this quantity. The soil mantle at this location is 127 feet thick; from 127 to 165 feet the well is drilled in solid marble. The records on the Hydes well, coupled with sparse data on other local wells, indicate that the valley sediments may average about 100 feet in thickness over an area of approximately 6 square miles. The top 50 feet of this aquifer contains from 3 to 6 billion gallons of water. This amount of water in storage is more than adequate to sustain 2.5 mgd yields through occasional dry periods.

These estimates are preliminary. In order to determine the yield more precisely, additional study should include:

1. A better definition of the low flow of Long Green Creek. A gaging station operated near the Gittings bridge for a minimum of 1 year would provide this information.
2. Test drilling to find out the thickness and extent of the mantle of decomposed marble in the valleys, to permit a closer estimate of the ground water in storage, and well-yield expectancies.
3. Determination of the permeability of the sediments in different parts of the valley, to compare with the records of the Hydes well.
4. Determination of the induced recharge potential along Long Green Creek, particularly at the lower end of the valley—near the Gittings bridge.

At present the Hydes Post Office is 5 miles from the nearest water mains of the Baltimore system (Perry Hall or Cub Hill). If water is provided through extension of the metropolitan network by the end of the century, the old railroad line might provide a once-defined right-of-way for a water main to the Glenarm and Hydes area; or a tap from the second Susquehanna pipeline, if the line is routed inland, might serve the area.

Waste disposal from Long Green Valley should not be dependent upon septic tanks if population growth is encouraged and if well fields are used. A local waste-treatment plant might suffice for the next 20 to 25 years, but there would be objections to the disposal of the effluent in the waters of the State park. An interceptor connection with the Perry Hall pumping station (fig. 23) which would be connected to the Back River sewage-treatment plant of the metropolitan system is a possible solution. At some later date, if the proposed Gunpowder Falls interceptor to a treatment plant on the Gunpoyder River estuary becomes a reality (p. 33), the Long Green metrotown would be served by a system functioning entirely by gravity flow.

Water Supply Versus Recreation

The increasing pressure for more recreational space and facilities raises problems that concern the best interest of the water supply which requires keeping water as pure and as cheap as possible. Increased recreational use of the water supply would result in increased pollution which would necessitate additional treatment of the water at more cost. Recreational and aesthetic pressures might also result in lessening the amount of water available for the mains of metropolitan Baltimore if low drawdown of the reservoir water levels was strongly criticized. When Susquehanna water is available, compromises will be possible—if the public is willing to pay for them.

Draft Rates and Water Levels

The draft from Liberty Reservoir on the Patapsco River is approaching its upper limit (p. 23, fig. 18). The present draft rate of 105 mgd will result in a deficiency about once in 10 years, a draft of 110 mgd would cause a shortage about once in 5 years, and a 117-mgd draft about once in 3 years. Frequent deficiencies would mean increased costs and problems in distribution-system operation and maintenance. The draft on the Patapsco probably will be stabilized at about 105 mgd, which has a 1 year in 10 chance of deficiency.

In other words, the Gunpowder Falls will supply additional water to meet the demands of the growing metropolis; it is capable of a much higher draft rate (p. 25, fig. 19). Figure 36 shows the predicted water demand for Metropolitan Baltimore from 1960 to 2010. The middle years of the forecast zone were used for the following calculations:

1. Loch Raven Reservoir is capable of supplying the present (1964) demand without reliance on water released from Prettyboy Reservoir. In fact, there is only a 1-in-20 chance that Loch Raven will not be able to supply this demand when using only the top two-tenths of the reservoir's capacity, which is equal to the top 6 feet of the pool.
2. The demand from the Gunpowder Falls water-supply system will be about 150 to 170 mgd in 1970–75, and release of water from Prettyboy Reservoir will become increasingly essential to the Gunpowder Falls water-supply system. During this transitional period of increasing demand, the water-supply engineer will have to decide how much the

Loch Raven water level should fluctuate; maintenance of a fairly stable water level will mean an increased use of water from Prettyboy Reservoir.

3. By 1980 the demand on Gunpowder Falls will be about 200 mgd. This rate will require maintenance of the water level in Loch Raven Reservoir within the top few feet of the pool in order to have sufficient pressure in the Montebello Tunnel to supply the required 200 mgd to the filtration plant. If the drawdown of Loch Raven Reservoir is limited to 3 feet, releases from Prettyboy Reservoir will be needed 60 to 70 percent of the year. About 1 year in 6, all the water in Prettyboy Reservoir and also the top 3 feet in Loch Raven Reservoir would be needed to meet the demand on the Gunpowder system. The total capacity of Prettyboy Reservoir plus the top 3 feet of the water in Loch Raven Reservoir equals 22 billion gallons (see fig. 15).
4. The chance of a failure—of using all the water in both Gunpowder Falls and Prettyboy Reservoirs during a drought—would occur about once in 25 years (fig. 43). There is a 1-in-20 chance that all the water in Prettyboy Reservoir and eight-tenths of the volume in Loch Raven Reservoir would be required, and a 1-in-10 chance that more than three-tenths of the volume in Loch Raven Reservoir would be required.
5. By 1990–95 the demand on Gunpowder Falls could be 240 to 270 mgd. The probability that the reservoirs will not be able to deliver this amount increases significantly. The expectancy of failure of both reservoirs with a draft of 240 mgd is about once in 5 years, and the 270 mgd rate would result in failure once in 2 to 3 years. There is some question whether the Montebello Tunnel could deliver water at the higher rate. Probably 240 to 250 mgd could be realized, but with a deficiency once in about 5 years. During periods of deficiency, Susquehanna River water would have to be used to augment the supply needed by Metropolitan Baltimore.

The water levels in both Gunpowder Falls reservoirs probably will fluctuate widely after about 1985. Complete drainage of Prettyboy Reservoir can be expected once in 3 to 4 years. Loch Raven Reservoir can be expected to be 10 feet below dam crest about once in 5 years, and 20 feet below dam crest about once in 6 years. A water level 10 feet below dam crest would expose about 550 acres of shoreline, which is equal to about 20 percent of the reservoir surface. A water level 20

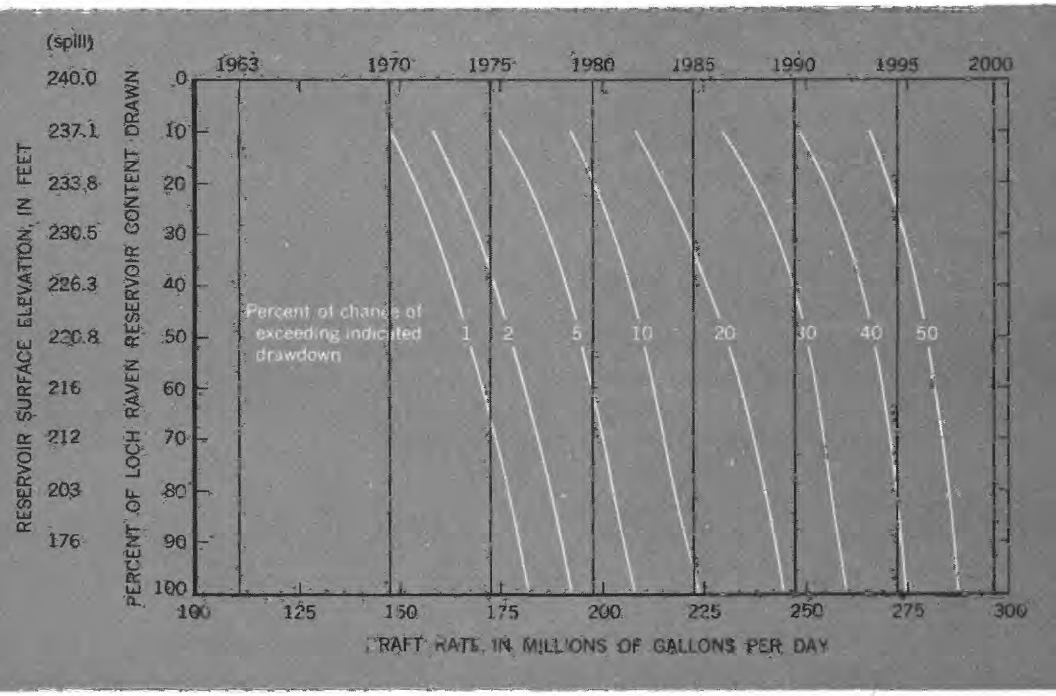


Figure 43.—Relations between draft on the Gunpowder Falls water supply and probability that Loch Raven Reservoir contents will fall below indicated amounts. Loch Raven Reservoir drawdown values include full use of Prettyboy Reservoir contents. The projected draft rates (bottom scale) are for the Gunpowder Falls water-supply system only.

feet below dam crest would expose about 950 acres constituting about 38 percent of the full-reservoir area:

Loch Raven Reservoir water-surface elevation (feet)	*Acres covered with water*	*Land surface exposed (percent)*
240 (full)	2, 400	---------
235	2, 200	8
232. 5	2, 000	17
230	1, 850	23
227. 5	1, 750	27
225	1, 700	33
222. 5	1, 550	35
220	1, 450	38

Rights to all surface water in the basin and to the construction of reservoirs on the Gunpowder Falls were secured many years ago. The sole purpose was to provide water for the metropolitan area.

Since World War II, however, recreational pursuits have become an increasingly important part of the American way of life; land and water resources provide the setting. The conservative guardians of the Gunpowder Falls water supply have yielded somewhat in recent years to allow increased fishing privileges, boat marinas, and picnic areas (see p. 52). The public, in search of recreation, on the other hand, has sought many privileges which were not granted. Recreational demands will become more intense in the coming 20 to 30 years, when the population doubles. Compromises will be increasingly in order.

Optimum reservoir conditions for recreation would be those in which the water level would not be drawn down to expose great expanses of bare shoreline. Mudflats are not pleasing sights, and they hinder access to the water. In addition, greatly fluctuating water levels are particularly undesirable during the spawning periods of fish which lay eggs in shallow water. Frequent or prolonged changes in reservoir content also can cause changes in the biological and physical environments which have undesirable effects on aquatic life and water quality.

The conflict between recreational use of Loch Raven and Prettyboy Reservoirs and water demand for the metropolitan area will begin to be critical about 1980, when the draft rate is expected to be about 200 mgd. Before then the chance of lowering the Loch Raven lake level below the dam's crest will occur in about 10 percent of the years.

Hydrologic analysis suggests that, for recreational purposes, the Loch Raven Reservoir water surface should be held above the 233.8-foot mark (see fig. 43) which is about 6 feet below the top of the dam. For adequate water supply at this level, recreation would have to be restricted 1 year in 10. To achieve this level, the draft rate must be held to 195 mgd. If the water level were held at the same elevation and recreation restricted 1 year in 5, the draft rate could be raised to about 212 mgd. (See fig. 43.)

The table below notes that water-surface elevations of 3, 6, and 10 feet below the dam crest would provide draft rates from 190 to 240 mgd, depending upon the chance the decision-maker is willing to accept in allowing the water level to drop below a selected level.

Chance (percent; years) water will fall below indicated level	Level (feet below top of dam)		
	3	6	10
	Maximum draft rate permissible to maintain level (mgd)		
10; 1 in 10	190	195	200
20; 1 in 5	205	212	217
30; 1 in 3	225	235	240

Augmenting the Flow Below Loch Raven Dam

The amount of water flowing in the Gunpowder Falls below Loch Raven Reservoir has been greatly reduced by diversion to the metropolitan system. About half the time, mostly during the summer and fall, the streamflow is below 10 cfs (cubic feet per second) and the water movement is sluggish. During warm summer periods, large amounts of algae and slime tend to accumulate in the channel. This growth is caused by two major factors: (1) a buildup of the dissolved chemical substances in the water, which are nutrients to plant growth, and (2) the amount of water flowing in the stream is insufficient to create enough turbulence to keep the channel flushed. From an aesthetic standpoint, this condition is undesirable in a public park. On the basis of the runoff record for 1950–60 and the present rate of withdrawal from Loch Raven Reservoir for water supply, maintaining minimum flows year round at 20, 15, and 10 cfs could be done by releasing about 4.7, 3.0, and 1.4 mgd, respectively. However, it would be necessary to augment low flows only during the periods of deficiency that occur during the warm months when oxygen levels are low, not during other periods. Consequently, only about half the above amounts would be needed, that is, 2.4 mgd for a flow of 20 cfs, 1.5 mgd for 15 cfs, and 0.7 mgd for 10 cfs. Though the amount of water involved is small, releases would have to be made during critical periods of the year. In future years, water probably will seldom be permitted to spill over the dam. Dilution of downstream water by releases from Loch Raven would lower dissolved-chemical concentrations and provide a more acceptable quality of water through the lower parts of the State park.

Additional Impoundments

The recreational facilities available and planned in the Gunpowder Falls basin have been listed (p. 52), as well as the recreational pursuits allowed and the restrictions enforced by the Bureau of Water Supply. The water-supply demand on Gunpowder Falls may eventually be as much as 240 mgd. The average annual flow at Loch Raven is about 260 mgd. The water basin, as presently developed, will continue to lose some water to the Chesapeake Bay when high water spills over Loch Raven Dam.

Thirty years ago, attention (Gregory, Requardt and Wolman, 1934, p. 103) was directed to the construction of a water-supply reservoir on Western Run at Butler (see upper right of center, fig. 2); the consideration ended primarily because of economic reasons. This reservoir would have been equal to Prettyboy in capacity (20 billion gallons) and would have yielded about 18 mgd. Perhaps a new look at the Gunpowder Falls is in order, to equate resource potential with resource demand through additional impoundments. If economic and low-yield considerations ruled out large reservoirs for water supply 30 years ago, then certainly the same would hold true today. However, inasmuch as recreation, low-flow supplementation, flood control, and soil conservation have been receiving more attention in recent years, the appraisals of the water resource should be expanded accordingly. Topographic and streamflow conditions are suitable for the construction of small impoundments, particularly on the Western Run and Little Falls tributaries and on the main stream above Prettyboy Reservoir. They would:

1. Expand recreational facilities for picknicking, fishing, boating, and other out-of-door sports and amusements. Camping might be permitted around some reservoirs. Sailboats and canoes might be allowed on one or more of the lakes. Even swimming might be permitted in an upstream impoundment, where the water would have plenty of opportunity to aerate, filter, settle, and purify in streambeds and lower reservoirs in its course downstream.

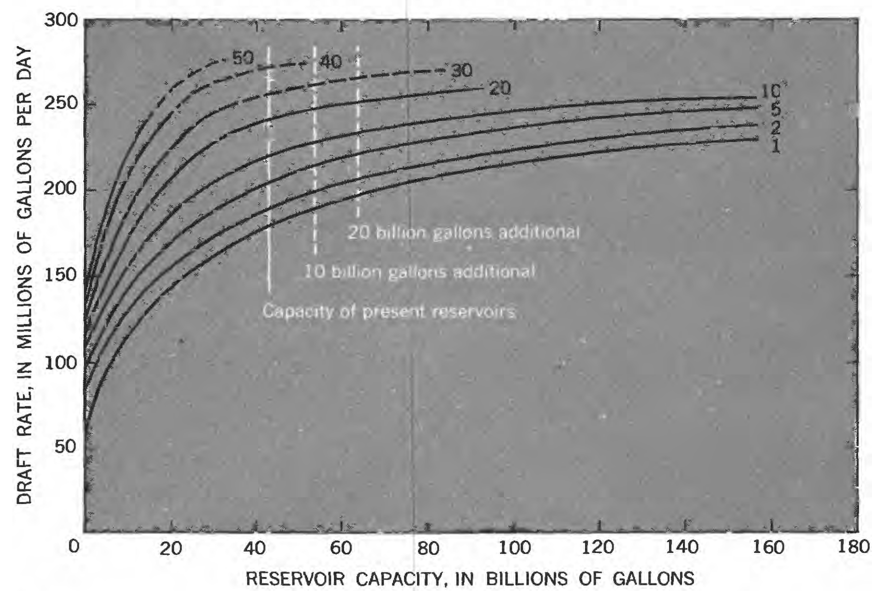


Figure 44.—Amounts that draft rate from reservoirs on Gunpowder Falls can be increased with additional reservoir capacities. The curves show the chance, in percent, of occurrence of deficiencies; the curves were computed by combining the probability of carryover-storage requirements which are based on probability routing of the annual discharge (see Hardison and Furness, 1963) with the probability of seasonal requirements.

2. Increase the storage capacity of the water-supply system. This increase would assist the Bureau of Water Supply in maintaining a high draft rate during extreme drought-period emergencies (fig. 44).
3. Assist in maintaining an acceptable minimum flow below Loch Raven Dam by releasing water into and through Loch Raven Reservoir when necessary.
4. Supplement Prettyboy Reservoir in keeping the water level in Loch Raven Reservoir at or above the 233-foot elevation mark needed to permit gravity flow to the Metropolitan Baltimore water-supply system.

Increasing the Patapsco Water Supply

Liberty Reservoir has a high enough water level (the dam crest is 420 feet above msl) to permit gravity flow to the Ashburton Filtration Plant (353 msl) and to the higher parts of Metropolitan Baltimore. At present the system can supply 105 mgd with a chance of deficiency 1 year in 10. When available supply does not meet the needs in the higher metropolitan areas, Gunpowder Falls water must be pumped into the high-altitude mains at additional expense.

Prettyboy Reservoir captures 70 mgd on an average day throughout the year (fig. 15). A pipeline about 10 miles in length could deliver any desired fraction of that amount to the Patapsco drainage and thus augment the Liberty Reservoir supply (fig. 45). Releases from Prettyboy Reservoir would have to be calculated on the respective needs of the Loch Raven and Liberty water-supply systems; however, the draft rate on Liberty could be raised 30 to 40 mgd if desired. The water would have to be pumped over the divide, at least for the initial lift, until syphoning became effective; this pumping would have to be done each time water was released from Prettyboy to Liberty because elevations of gaps in the divide approach 640 feet. Cost probably would prohibit extensive tunneling and an extension of 2 to 3 miles of pipeline to achieve inexpensive gravity flow (the crest of Prettyboy Dam is 520 feet above msl). Half of the Prettyboy Reservoir average daily yield (35 mgd) would permit that amount of increase of the draft rate on Liberty Reservoir. Half the storage capacity of Prettyboy would increase the present storage volume of Liberty (43,000 million gallons) almost 23 percent—to a total of 52,800 million gallons.

This project would lessen the attractiveness of Prettyboy Lake for recreation because the water level in Prettyboy at times would be unattractively low. A compromise would be the maintenance of

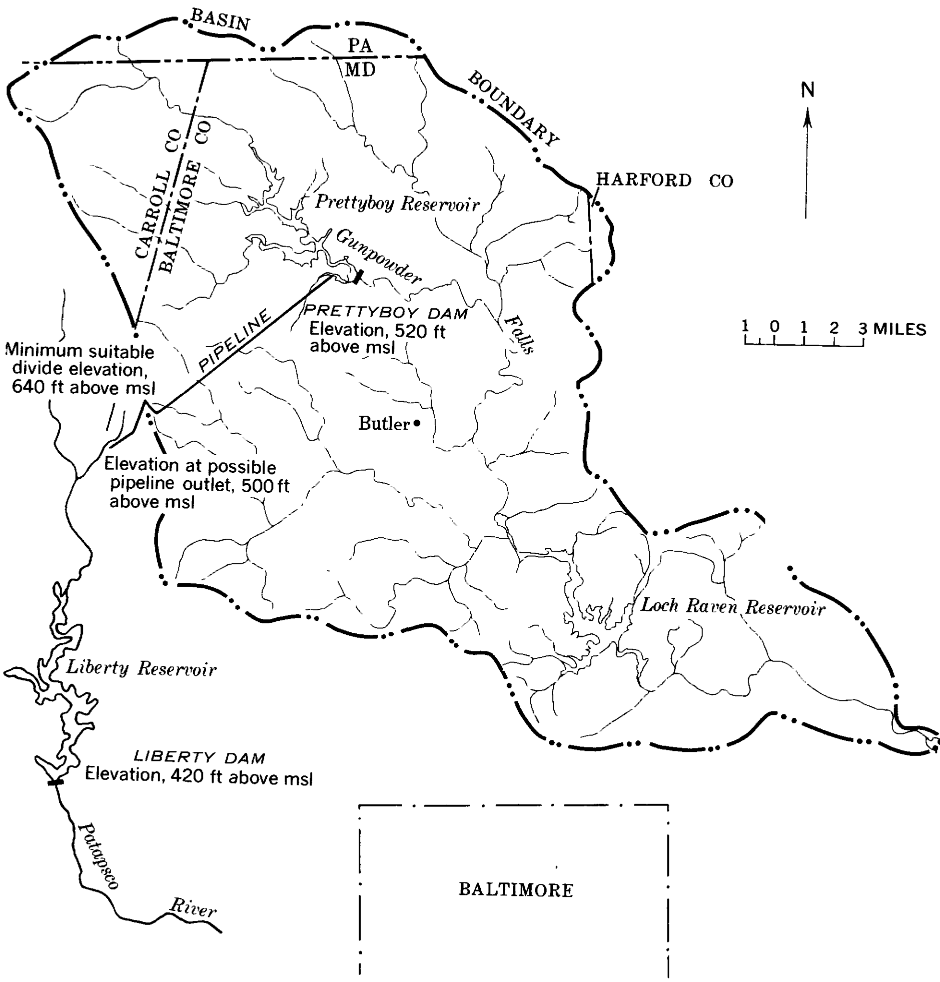


Figure 45.—Map showing possible route of pipeline that could be built to divert water from Gunpowder Falls basin to Patapsco River basin.

attractive high water levels, insofar as possible, in Loch Raven and Liberty.

Recreation Versus Living Space

As yet, there is little competition between urban growth and the need for open spaces. Good roads, speedy cars, and increasing amounts of free time permit the city dwellers to drive to the countryside or to recreational areas in a fraction of an hour from downtown Baltimore. Only the ubiquitous "No Trespassing" and "Posted" signs are reminders that the city dwellers' activities in the country are limited, for the most part, to the roads and the few public lands. The growth of suburbia, however, is pushing the countryside farther and farther away. New housing developments are springing up and greatly changing the attractive roadside landscapes. The increasingly common practice of local farmers to sell "front-acre lots"—the strips of land bordering a road or highway—as residence sites satisfies the city-worker purchasers who want homes in the country, but this practice greatly alters the aesthetically pleasing open-space appearance of a rural landscape.

The State Planning Commission and the Department of Forests and Parks have recognized the advisability of reserving land now to meet expanding future needs for parks and open spaces. One result is the planned Gunpowder Falls State Park, which will supplement and increase facilities now provided by the reservoir areas. These agencies know (see p. 51) that by 1980 there will be a deficiency of some 30,000 acres of recreational land—94 square miles—and twice that by 2010, unless more land is acquired soon, before housing developments preempt all the choice sites and before land values increase to figures too exorbitant for large-scale purchase. This situation applies to all the five counties adjoining the metropolitan area.

The Baltimore County Office of Planning and Zoning, also aware of the need for acquiring open space now to meet future needs, has a study underway of the actual and potential recreational areas within the county. Perhaps this study will result in the setting aside of a few thousand additional acres as extensions of the present reservoir and planned State park tracts.

It is expected that in 2010 the northern third of the basin will still be rural—one household per 5 acres, although most farmers probably will have disposed of many of their front-acre lots for home sites. The State park will be an attractive and popular entity, but further recreational space will be needed. The questions are Where and How.

Publicly Owned Additional Impoundments

The construction of more dams in the basin would convert land to water-surface area—a loss of living space. As the years go by and land values increase, the social and economic cost may preclude inundating 1,000 to 3,000 more acres in the drainage area, in addition to the 3,900 acres already covered by the water in Loch Raven and Prettyboy Reservoirs (fig. 15). Planners of the Gunpowder Falls State Park may therefore consider the construction of additional impoundments soon, accessible to the public, on suitable rural sites on both Gunpowder Falls and Little Gunpowder Falls. Most reservoirs in the larger basin would provide the benefits already mentioned (p. 80–81). A dam on Little Gunpowder Falls would provide a lake where swimming and other water sports would have no tangible effect on the Metropolitan Baltimore water-supply system.

An alternative course of action would be to encourage and aid builders in the construction of additional impoundments, in conjunction with the expansion of the suburbs and the growth of metrotowns.

Possibilities on the Estuary

The State park as planned will include the head of Gunpowder River—the head of the estuary—from the east bank of the mouth of Gunpowder Falls west to a point about half way up the Bird River arm. This east-west airline distance is just under 3 miles; the shoreline mileage is several times greater. Present plans calls for a marina and a swimming beach on this park land.

Keeping the water clean should not be too difficult. No pollution of consequence is expected from the military installation, which includes the entire eastern shore of the estuary and two of the western shore promontories. The two Gunpowder Falls streams will flow through a State park, and it can be expected that their water will be kept at acceptable State park standards; sanitary conditions in the State park holdings on the estuary itself will be controlled. Possible sources of pollutants which may merit watching are (1) the primary-sewage-treatment plant at growing Joppatowne, (2) the effluent-discharge point from the large sewage-treatment plant, which is recommended for construction by the end of the century, to handle the waste from the two proposed Gunpowder Falls interceptors (fig. 23), and (3) the growth of industrial and residential developments along the western side of the Gunpowder River estuary, especially including the northwestern arm of Bird River.

CONCLUSIONS

The Gunpowder Falls drainage basin, north of Baltimore, is about 50 miles long, has a maximum width of 16 miles and contains almost 350 square miles. The headwaters are just inside Pennsylvania, and the watercourse drains about half of Baltimore County as it meanders southeast to the Chesapeake Bay. The basin provides water and space for living, working, and playing. As the population increases in the coming decades, the demand for these water and land resources will increase as the needs intensify.

More than 85,000 people now (1964) live in the basin—three-fourths of them occupy an arc of villages and expanding suburbs to the south and west of Loch Raven Reservoir, which forms the northeastern fringe of Metropolitan Baltimore. The basin is now predominantly rural: 60 percent farmland, 30 percent forest covered, and 10 percent urbanized. The comparatively few local industries are mostly between Towson and Cockeysville.

The basin receives an average of about 46 inches of precipitation per year; about 28 inches are lost through evapotranspiration; the remaining 18 inches are available as surface and ground water for man's use. Thus, the water available amounts to 300 mgd, and to 264 mgd for the watershed above Loch Raven Dam. The yield varies seasonally, being greater in winter when evapotranspiration is less. It also varies regionally, although to a much lesser extent, with the geology; the areas where marble is prevalent retain and release ground water at a more constant rate to maintain flow in associated streams than do the areas where igneous and metamorphosed rocks predominate.

The upper 80 percent of the basin has been developed almost fully as a water supply for Metropolitan Baltimore. No more water will be obtained from this area, and the present and future concerns of management are protection and regulation. The safe yield has been computed at 148 mgd—an admittedly conservative figure. The present system could supply 200 mgd with a probable deficiency in only 1 year out of 20. This higher draft rate would cause greater fluctuations in the water levels of the two reservoirs, particularly in upstream Prettyboy Reservoir, which is used to regulate Loch Raven, but it would lessen the amount of water presently lost by spill over Loch Raven Dam. The lower valley, between Loch Raven and the estuary, is outside the present water-supply development.

Ground water is available in moderate amounts from wells throughout the basin; about 3 mgd are pumped to supply small communities and scattered households. In the part of the basin in the Piedmont, wells drilled into the weathered marble provide the largest and most consistent yields, averaging about 20 gpm per small well. In the narrow part of the basin in the Coastal Plain, the sandy aquifer apparently can provide about 250 gpm per large well, but sustained heavy pumping might result in intrusion of brackish water into the aquifer from the bordering estuary.

Water secured from marble formations is moderately to very hard. Soft water may be expected from the igneous and metamorphosed bedrocks and their overlying mantles. Some man-caused pollutants are discernible in most surface water and in some local supplies of ground water; detergents are widespread although usually in low concentrations. Storm-water runoff from developed areas contains many pollutants which vary in amount diurnally and seasonally; the most noticeable are traceable to week-day activities associated with gas stations, stores, and households in general, and to the practice of salting slippery roads in winter.

Waste is disposed of through sanitary sewers in many sections of the basin adjacent to Baltimore; storm-water runoff is conducted through a separate system. Joppatowne has a primary treatment plant. In the rest of the area, settlements and isolated homes are dependent upon septic tanks.

Erosion and sedimentation within the basin was a problem in the 18th and 19th centuries; the silting of the port of Joppa is attributable to intensive farming upstream. At present (1964) the sediment erosion rate is low, except during the months or years when tracts of land are stripped for development; the two reservoirs have a life expectancy of almost 1,000 years.

Recreational facilities in the basin are now centered on Loch Raven and Prettyboy Reservoirs. The Baltimore City Bureau of Water Supply permits fishing from shores and from electric motorboats in areas well above the dams and maintains attractive picnic grounds and horseback and hiking trails.

Trends affecting the basin and plans concerning it indicate that more and more land will be used for housing developments, particularly in the sections below Prettyboy Dam. More water will be diverted to metropolitan mains. More roads and highways will traverse the drainage basin. An increasing number of motorists will seek recreation in the valley. The basin's population is expected to triple by the year 2010, at which time a quarter of a million people will live there. The intent of the Baltimore Regional Planning Council is to cluster most families in several planned communities—small cities or metrotowns. Water from Gunpowder Falls will be drawn at a rate of 220 mgd, if officials of the Bureau of Water Supply decide to risk a deficiency in 1 year out of 10. The bureau now plans to use as much of the local purer and cheaper supply as possible before tapping water from the Susquehanna River through the pipeline now being constructed.

The entire basin has been zoned for industrial, commercial, residential, agricultural, and recreational sections or for open-space development, and extensions of the present road network have been planned for the coming 20 years. About 20,000 acres of valley-bottom land (some of it in the Little Gunpowder Falls drainage basin to the east) and estuary shoreland are being acquired for a State park.

Increasing demands on the local resources are inevitable. Equitable adjustments among the competing interests will require an understanding of the hydrologic system and the effects of alternative actions. This report has outlined some of the hydrologic effects of some alternatives that are presently under consideration by the community and some that are not.

The need for living space can affect the maintenance of a drainage basin which has been developed for water supply. The principal effects of urbanization are (1) pollution of the storm-water runoff, and (2) temporary increases in sedimentation. Runoff from residential and commercial sections contains varying amounts of undesirable dissolved solids, seldom enough to cause alarm but enough to suggest that a planned community should not be placed upstream from a water-supply reservoir. Erosion from land surfaces that are being stripped during development will result in an increased rate of sedimentation in impoundments farther downstream in the absence of corrective action such as the construction of settling ponds

The competition between the uses of the basin for water and for recreation can be resolved by compromise and additional development:

1. In Loch Raven Reservoir—if the water level could be maintained within 3 feet or less of the top of the dam, water-supply management could count on 190 mgd with a probable deficiency in 1 year out of 10, and recreation seekers would be confronted only rarely with wide expanses of bare shoreline.
2. In the channel below Loch Raven Dam—if 0.8 to 2.4 mgd could be released from the water supply during the warm dry periods of the year to assure a flow of 10 to 20 cfs downstream, the lower valley would be much more attractive, healthy, and useful for recreational purposes.
3. At Liberty Reservoir (Baltimore's source of water on the Patapsco River)—a higher water level could be maintained, for aesthetic and practical purposes, if water should be diverted as needed from Prettyboy Reservoir on the Gunpowder Falls. Apparently Prettyboy Reservoir will be subjected to increasingly frequent drawdowns to keep the water level in Loch Raven within 10 feet of the dam crest; some of its water could be diverted to augment the Liberty supply—on the basis of management needs.
4. In the basin above Loch Raven Reservoir—the construction of several relatively small impoundments on tributaries of the Gunpowder Falls above Loch Raven Reservoir would capture more water as well as provide more centers for fishermen, picnickers, and the like.

Although impounded water covers land that could be used for living space, the increasing need for recreation facilities utilizing bodies of water suggests that more small dams be constructed and lakes be made available within the Gunpowder Falls basin. Besides these lakes, a reservoir on State park land, in the adjacent Little Gunpowder Falls drainage basin but outside of the Metropolitan Baltimore water-supply basin, could be used for swimming, water skiing, and other sports not now permitted at the Bureau of Water Supply impoundments. Another way of alleviating future friction between living-space and recreation needs in the basin would be to expand present plans for the development of the tidal section of the State park land. Maryland has little public shoreline land, but more and more people will want to use local beaches and marinas. By locating facilities where they can be expanded and by securing permission to use some of the shoreline belonging to the nearby military base, development might keep pace with need for many years to come.

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