Sedimentation of Loch Raven and Prettyboy Reservoirs Baltimore County, Md.

By John N. Holeman, Geologist

U. S. Department of Agriculture
Soil Conservation Service
SCS-TP-145
February 1965

CONTENTS

ACKNOWLEDGMENTS

The Soil Conservation Service provided transportation, aerial photographs, and sedimentation survey equipment. The field party was directed by J. L. Hunt, geologist, Engineering and Watershed Planning Unit, Upper Darby, Pa., assisted by John N. Holeman, geologist, Central Technical Unit. Other members of the field party were J. M. Zurlo, Jr., Engineering and Watershed Planning Unit, Upper Darby, Pa.; R. M. Amenta, Central Technical Unit; and N. M. Curtis, Jr., Maryland Watershed Work Plan Party. Information on soils in the watershed was supplied by Phil Walters, soil scientist, Harford County, Md., and M. F. Hershberger, Maryland State soil scientist.

Through Louis Ningard, superintendent of watersheds, Bureau of Water Supply, the city of Baltimore provided boats, fuel, and five men for the survey. Walter Sushko, watershed forester, Baltimore Bureau of Water Supply, was the leader of this group. The city also monumented the ranges with concrete markers.

SEDIMENTATION OF LOCH RAVEN AND PRETTYBOY RESERVOIRS, BALTIMORE COUNTY, MD.

by John N. Holeman, Geologist, Soil Conservation Service

This report presents information obtained from the 1961 sedimentation surveys of Loch Raven and Prettyboy Reservoirs in Baltimore County, Md.[1] These surveys, as well as the previous sedimentation surveys of 1943, were made by the Soil Conservation Service, U.S. Department of Agriculture.

Purpose of Surveys

The major objectives of these surveys were:

1. To evaluate the present rate of sediment production on the drainage area of the reservoirs and compare it with the rate before 1943. This comparison was expected to show the effect of land use changes and soil conservation measures installed on a large part of the drainage area between 1943 and 1961.
2. To measure the present capacity of Loch Raven and Prettyboy Reservoirs and to determine the probable future annual loss of capacity by sediment accumulation.
3. To provide a basis for estimating the long-term effects of land treatment on prolonging the life of a reservoir in the northern Piedmont physiographic province.

History

In 1873 the city of Baltimore began obtaining water from the Gunpowder Falls river with a temporary pumping station. Water was pumped as needed from the river. In 1881 a masonry dam was built across the river, creating a permanent reservoir called Loch Raven.

In 1912 a new dam was begun about 2,500 feet upstream from the old dam. The new dam had a spillway elevation of 188 feet above mean sea level. It was designed and built so that it could be raised when additional capacity would be needed. The structure was raised in 1922, and the new spillway elevation was 240 feet above mean sea level.

In 1933 another reservoir was created on Gunpowder Falls 12 miles upstream from the head of the Loch Raven backwater. This reservoir and dam were named Prettyboy after the small creek that flowed into the river just above the damsite.

Previous study.--L. C. Gottschalk, geologist, Soil Conservation Service, Washington, D.C., made reconnaissance sedimentation surveys of Loch Raven and Prettyboy Reservoirs October 4-9, 1943, to determine the extent of soil erosion in the Gunpowder Falls drainage area and its effect on these reservoirs. His report on that survey was issued in December 1943 as Special Report 5, Sedimentation Section, Office of Research, Soil Conservation Service (mimeographed). Information from his study has been used throughout this report.

General Information

Loch Raven Reservoir is in Baltimore County, 7 miles northeast of the Baltimore city limits and 5 miles northeast of Towson, Md. The dam is on Gunpowder Falls 9 miles above its mouth, an inlet of Chesapeake Bay. The inlet is called Gunpowder River. The total drainage area above the dam is 303 square miles and is referred to in this report as Gunpowder Falls Watershed. The part of Gunpowder Falls Watershed upstream from Loch Raven Dam but excluding the drainage area above Prettyboy Dam is referred to as Loch Raven Watershed. The 80 square miles of Gunpowder Falls Watershed behind Prettyboy Dam make up Prettyboy Watershed. Gunpowder Falls Watershed from Loch Raven Dam to the source of Gunpowder Falls in York County, Pa., is about 40 miles long. Loch Raven Reservoir is 10-1/2 miles long; Prettyboy Reservoir is 7-1/4 miles long. According to the Baltimore Bureau of Water Supply, the original area of Loch Raven Reservoir was 2,391 acres and of Prettyboy 1,498 acres.

Description of dams

Loch Raven Dam is a concrete dam 650 feet long and 75 feet above the streambed (fig. 1). The present elevation of the top of the dam is 246 feet above mean sea level, U.S. Geological Survey datum. The

Figure 1.--Loch Raven Dam.

[1] Loch Raven Reservoir was surveyed June 5-15, 1961, and Prettyboy Reservoir during the week of September 11, 1961.

Figure 2.--Prettyboy Dam.

spillway elevation when the dam was constructed in 1914 was 17 feet above the streambed. It was raised an additional 52 feet in 1922. The upstream face of the dam is vertical, and the downstream face has a slope of 1 foot vertical to 7-7/16 inches horizontal.

The spillway of Loch Raven Dam is an ogee section located near the center of the dam. It is 288 feet long and 69 feet above the streambed, and it has a capacity of 60 cubic feet per second per square mile of drainage area. There is a 10-foot steel conduit at elevation 173.5 feet in the dam. It extends 4,000 feet downstream and connects with a 12-foot concrete tunnel. This tunnel conveys water by gravity flow a distance of 6.5 miles to the Montebello filtration plant.

Prettyboy Dam is a concrete gravity overflow dam 845 feet long and 133 feet above the streambed (figs. 2 and 3). At the crest it is 25.5 feet thick and at the base 134 feet. The upstream face is vertical, and the downstream face has a slope of 1 foot vertical to 8.1 inches horizontal. The top of the dam is at elevation 540 feet above mean sea level, U.S. Geological Survey datum.

The spillway of Prettyboy Dam is a concrete overflow type 130 feet high and 274 feet long. A reinforced concrete arch bridge that has a road 20 feet wide and a footway on each side crosses the dam.

Figure 3.--Prettyboy Dam from reservoir side (winter 1957).

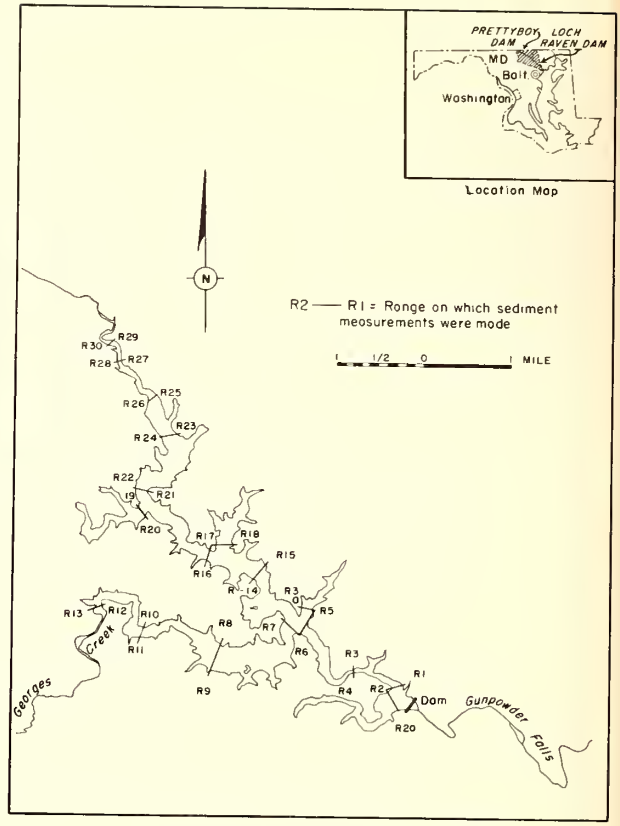

Figure 4.--Prettyboy Reservoir.

The elevation of the spillway is 520 feet above mean sea level. The spillway capacity is 210 cubic feet per second per square mile of drainage area. The dam contains two 36-inch needle-valve outlets at elevation 421.5 feet and eight 3- by 5-foot sluice gates near the bottom of the dam.

Reservoir basins

Prettyboy Reservoir is long and narrow and has an irregular shoreline formed by numerous coves at the entrances of small steep-gradient tributaries (fig. 4). The largest tributary, Georges Creek, forms a long and narrow arm in the lower part of the lake. Water is impounded in a narrow V-shaped valley that has steep walls. The residual soils of these valley walls are generally very thin or absent, and the sides and bottom of much of the reservoir are bedrock. On the more gentle slopes of the wider tributaries and along the reservoir itself, the old residual soil is sticky, micaceous, and buff colored. The gradient of Gunpowder Falls through Prettyboy Reservoir is 18.4 feet per mile. There are some small areas of prereservoir flood-plain deposits in the lower part of the reservoir and in the Georges Creek arm. The upper part of the reservoir, that above Range 28-27, covers an old milldam. The old

Figure 5.--View upstream from Prettyboy Dam at low water (1957). Shows crest of ridge that is usually submerged and narrow winding basin of the reservoir, as well as its rocky slopes thinly mantled by soil. Elevation of normal water crest is at tree line.

millpond deposits at the bottom of the reservoir are mostly gravel.

The greatest depth measured on Prettyboy was 123 feet below crest elevation on R2-2a. A submerged ridge 63 feet above the prereservoir channel was located on this range 800 to 1,000 feet from R2. Figures 5 and 6 are views of the dam and reservoir.

The shape of the basins of Prettyboy and Loch Raven Reservoirs is controlled by rock structure. Prettyboy Reservoir lies entirely within the Wissahickon formation of gneiss and schist, in which stream valleys are narrow and gorgelike. Loch Raven Reservoir, however, extends over a number of rock formations of differing resistance to erosion, and as a result it is characterized by both narrow reaches and broad open bays and by numerous irregular arms.

The lower quarter of Loch Raven Reservoir lies in the Wissahickon formation, which forms a narrow steep-walled basin (fig. 7) similar to that of Prettyboy Reservoir. Above this point, which is marked by the narrows just west of R5, to R22-23, Loch Raven Reservoir is underlain by the Cockeysville marble. The Cockeysville marble also underlies areas near the headwaters of the reservoir on both the main stream and the Western Run arm. These areas were once broad valleys or lowland meadows. Here the reservoir broadens out and the valley slopes are very gentle. Above R22-23 the Wissahickon schist and the Baltimore gneiss outcrop, forming narrow steep-walled channels. The narrow belt of the Cockeysville marble underlying the reservoir near its headwaters forms Paper Mill Pool on Gunpowder Falls and Ashland Pool on Western Run.

Figure 6.--View upstream from Prettyboy Dam near R16-17. Bridge is on Beckleysville Road. Elevation of normal water crest is at tree line.

According to the Bureau of Water Supply, the original maximum capacity of Loch Raven Reservoir was 72,733 acre-feet and that of Prettyboy Reservoir 60,979 acre-feet--23,700 and 19,870 million gallons respectively. The original length of the shoreline at crest elevation was 46 miles at Prettyboy and 50 miles at Loch Raven.

Stratigraphy

The drainage area above Loch Raven Dam lies on the eastern edge of the northern part of the Piedmont province. Highly crystalline metamorphic formations of the Glenarm series of pre-Silurian age rest with a major unconformity on basement rocks known as the Baltimore gneiss of Precambrian age. The Glenarm series consists of three formations. At the bottom is

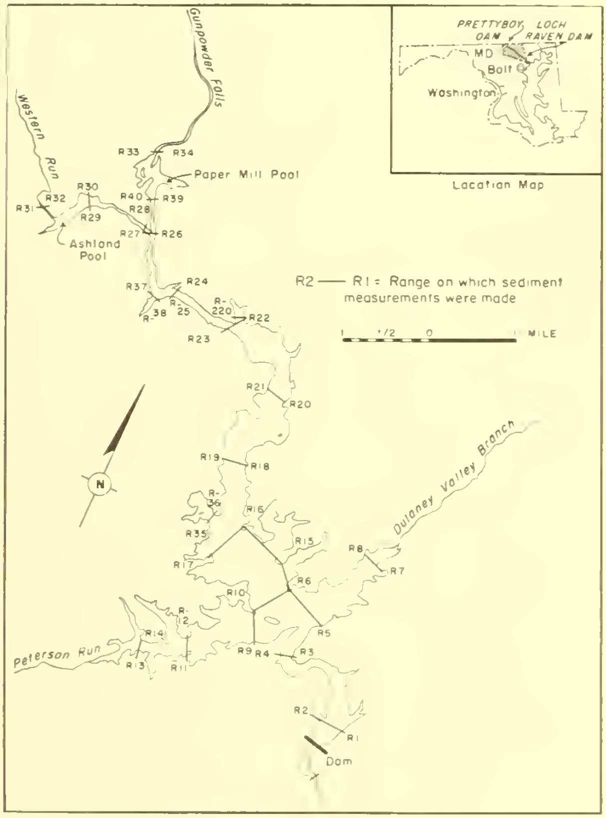

Figure 7.--Loch Raven Reservoir.

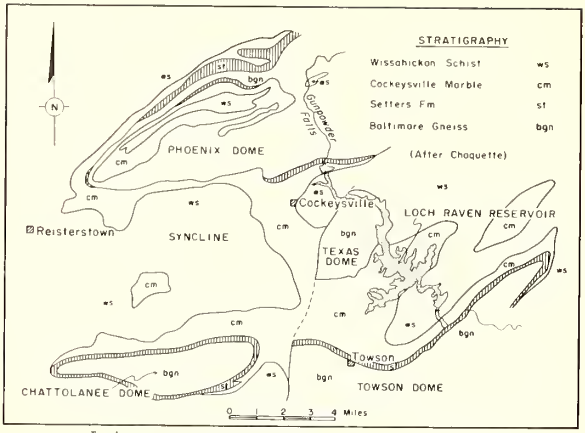

Figure 8.--Geologic map of the Loch Raven area.

the Setters formation, a peculiar schist composed mostly of quartz and divided into beds by parallel layers of muscovite. Overlying this is the Cockeysville marble, a medium- to coarse-grained white marble interbedded with dolomitic layers. The high degree of metamorphism of the marble has separated its original impurities into well-defined minerals. The youngest and uppermost formation of the Glenarm series outcropping in the area is the Wissahickon formation. It consists mostly of mica schist and mica gneiss interbedded with quartzite. The oligoclase-mica schist phase of the Wissahickon formation occurs in the southeastern part of the watershed near Loch Raven Reservoir. The drainage area of Prettyboy Reservoir lies entirely in the albite-chlorite schist phase of the Wissahickon. This phase is indicative of lower grade metamorphism. Post-Glenarm intrusions of dikes and sills are also present.

Structure

The Glenarm series underlies much of the Piedmont province from Virginia into southeastern Pennsylvania. The Glenarm series and the basement rocks were folded along northeast-trending axes and were metamorphosed and intruded by dikes and sills during Early Silurian or pre-Silurian time. A second period of intrusion that produced diabase dikes occurred more recently, probably during the Triassic period.

Choquette[2] and Broedel[3] recognize three northeast-trending major folds in this area (fig. 8)--(1) the Phoenix anticline with a core of the Baltimore gneiss just upstream from Loch Raven, (2) a discontinuous anticlinal fold along the southern boundary of the watershed consisting of the Chattolanee and Towson domes, and (3) a broad syncline of the Wissahickon and Cockeysville formations extending across Loch Raven Reservoir between the two anticlinal uplifts. The shallow flat-bottomed syncline is complicated by a steep-sided mass of the Baltimore gneiss straddling its inferred axis. This dome is called the Texas dome and is bounded on the west by a high-angle normal fault whose southern extension cuts off the western side of the Towson dome. The Texas dome produces the eastward curve in Loch Raven between R18-19 and R24-25. The origin of the Texas dome has been explained as an igneous intrusion of the Gunpowder granite, the uppermost part of the Baltimore gneiss complex.

The anticlines and syncline mentioned here are a part of the Westminster anticlinorium.[4] The axis of this large anticline extends generally in a northeasterly direction. The topographic expression of this structure determines in part the northwestern boundary of the watershed. The axis curves through central Maryland and southeastern Pennsylvania, passing through Westminster, Md., and about 10 miles southeast of York, Pa.

Topography and drainage

Loch Raven Watershed lies almost entirely within the Piedmont province. Loch Raven Dam is only a short distance upstream from the Fall Line to the Coastal Plain. The land rises to the west and northwest so that the drainage of Gunpowder Falls is southeastward into Chesapeake Bay. The elevation ranges from 171 feet, the streambed elevation at Loch Raven Dam, to 920 feet in the northwest, a difference of 749 feet.

Loch Raven Watershed can be divided into three types of topography: summit uplands, narrow gorgelike valleys, and wide meadow lowlands. The summit uplands are remnants of a succession of old peneplains or terrace levels stepping down from the higher elevations in the northwest to the lower elevations in the southeast. These resulted from a series of uplifts, each one starting a new cycle of geologic erosion. These upland slopes break off sharply where the larger streams have cut narrow gorgelike valleys, which are usually well wooded and are not cultivated. The wide gently rolling meadow lowlands are underlain by the Cockeysville marble and are generally 100 feet or more below the level of the summit uplands. They are intensively cultivated but occupy only a small area in the lower part of the watershed. They consist principally of Worthington Valley, Dulaney Valley, and the area from Cockeysville to Timonium.

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[2] Choquette, Philip W. Petrology and Structure of the Cockeysville Formation (pre-Silurian) near Baltimore, Maryland. Bull. Geol. Soc. Amer. 71: 1027-1052. 1960.

[3] Broedel, C. H. Structure of the Gneiss Domes near Baltimore, Maryland. Md. Geol. Survey Rpts. 13: 149-187. 1937.

[4] Campbell, M. R. Chambersburg (Harrisburg) Peneplain in the Piedmont of Maryland and Pennsylvania. Bull. Geol. Soc. Amer. 44: 553-573. 1933.

The drainage pattern is dendritic and well developed. The river has become entrenched in the crystalline rocks and has formed deep valleys. The tributaries have fairly steep gradients near Gunpowder Falls. Farther from the river the stream gradients decrease; as the streams become smaller, the relief decreases. Streams flowing through the calcareous strata are longer and have lower gradients than those in the more resistant crystalline areas.

Soils

The general pattern of soils is shown in figures 9 and 10. Six soil associations were mapped (tables 1 and 2). Each association contains a few major soils and several minor soils in a pattern that is characteristic although not uniform in every respect. Within any one association the soils differ from each other in some properties such as slope, depth, stoniness, and natural drainage. Each association is named for its major soil series, but it also includes other soils. Some of these soils also occur in other soil associations but in a different pattern.

The average annual sheet erosion for each soil association (table 3) was estimated by the Musgrave soil-loss formula, using an average degree and length of slope for each association; a 30-minute, 2-year-frequency rainfall of 1.17 inches; an average erosion rate for each association; and the particular cover and cropping practices on the land in 1940 and 1960.

TABLE 1.--Area and proportionate extent of soil associations

Soil association	Loch Raven Watershed		Prettyboy Watershed		Two watersheds	
	Acres	Percent	Acres	Percent	Acres	Percent
1. Conestoga-Hagerstown	20,490	14.4	0	0	20,490	10.5
2. Chester-Glenelg-Elioak............	49,960	35.0	32,900	64.3	82,860	42.7
3. Manor-Glenelg.......	56,410	39.5	6,910	13.5	63,320	32.7
4. Manor channery loam.	0	0	2,730	5.3	2,730	1.4
5. Sassafras...........	1,120	.8	0	0	1,120	.6
6. Stony steep land....	12,350	8.6	7,160	14.0	19,510	10.1
Reservoir surface......	2,390	1.7	1,500	2.9	3,890	2.0
Total area...........	142,720	100.0	51,200	100.0	193,920	100.0

TABLE 2.--Distribution of slope by soil association

Loch Raven Watershed (excluding Prettyboy)

Slope	Soil association						Total land area
	1	2	3	4	5	6	
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Nearly level (0-3 percent)...	13	5	5	0	0	37	9
Gentle (3-8 percent).........	72	61.5	22	0	37	11	42
Moderate (8-15 percent)......	15	30	35	0	61	2	27
Strong (15-25 percent).......	0	3	27	0	2	7	13
Steep (25-45 percent)........	0	0.5	11	0	0	35	8
Very steep (>45 percent).....	0	0	0	0	0	8	1
Total land area............	14.6	35.6	40.2	0	0.8	8.8	100
Prettyboy Watershed							
Nearly level (0-3 percent)...	0	11	10	0	0	3	9
Gentle (3-8 percent).........	0	48	12	15	0	2	35
Moderate (8-15 percent)......	0	32	28	33	0	0	27
Strong (15-25 percent).......	0	8	36	30	0	9	13
Steep (25-45 percent)........	0	1	14	22	0	73	14
Very steep (>45 percent).....	0	0	0	0	0	13	2
Total land area............	0	66.2	13.9	5.5	0	14.4	100

TABLE 3.--Estimated sheet erosion in 1940 and 1960 by soil association

Loch Raven Watershed

Soil association	Soil loss in 1940			Soil loss in 1960		
	Amount	Proportion of total loss	Annual rate	Amount	Proportion of total loss	Annual rate
	Tons	Percent	Tons per acre	Tons	Percent	Tons per acre
1......	124,580	7.1	6.08	45,900	6.6	2.24
2......	479,620	27.2	9.60	191,840	27.5	3.84
3......	1,119,170	63.5	19.84	433,230	62.3	7.68
5......	3,410	.2	3.04	1,790	.2	1.60
6......	35,570	2.0	2.88	23,710	3.4	1.92
Total	1,762,350	100.0	12.56	696,470	100.0	4.96
Prettyboy Watershed						
2......	263,200	52.0	8.00	126,340	47.2	3.34
3......	140,420	27.7	20.32	74,080	27.6	10.72
4......	64,640	12.8	23.68	29,700	11.1	10.88
6......	37,810	7.5	5.28	37,810	14.1	5.28
Total	506,070	100.0	9.98	267,930	100.0	5.28

SOIL ASSOCIATIONS IN LOCH RAVEN WATERSHED (excluding Prettyboy Watershed)

1. Conestoga-Hagerstown association.--This association occurs only in the south-central part of the watershed on the wide gently sloping basinlike areas underlain by the Cockeysville marble. These soils in the Conestoga and Hagerstown series formed in material weathered from marble, limestone, or calcareous schist--Hagerstown in material entirely from marble or limestone and Conestoga in material weathered from calcareous schist. There are also large areas of soils formed in schist alluvium or colluvium over marble. The soils are yellowish brown, brown, and reddish brown; they are deep, well drained, and medium textured. Water drains through them at a moderate rate, and they hold a large amount of moisture available to plants. They are inherently very fertile.

About 9 percent of the acreage in this association consists of colluvial soils on the lower slopes near drainageways. These soils are moderately well drained to poorly drained. Soils on the flood plains of streams make up less than 7 percent of this association--about one-fourth are moderately well drained Lindside soils and three-fourths are dark-colored Dunning soils and grayish Melvin soils, which are poorly drained.

Because of the high productivity of the soils in this association and their gentle slopes, they have been cultivated intensively. They are only moderately erodible except for the Conestoga soils, which are highly erodible if mismanaged. Largely because of the gentle slopes, this association has not been a major source of sediment.

2. Chester-Glenelg-Elioak association.--This association consists of well-drained soils on the gently to moderately sloping uppermost parts of the uplands. They occur at high plateau levels and may have been the soils that formed the old peneplain surfaces before uplift and rejuvenation. They have been exposed to soil-forming processes for a long time and have thick, moderately fine textured subsoils.

These soils are yellowish brown, yellowish red, and red. They are deep and medium textured and formed in material weathered from micaceous schist. Water passes through them at a moderate rate, and they hold a large amount of moisture available to plants. They are moderately to highly productive. The upland soils--Chester, Glenelg, and Elioak--constitute more than 90 percent of the total acreage in this association.

About 5 percent of the acreage in this association consists of colluvial soils in the Glenville and Worsham series. Glenville soils are gently sloping and moderately well drained and are much more extensive than the poorly drained Worsham soils. Also included are alluvial soils--well drained soils in the Congaree series, moderately well drained soils in the Chewacla series, and poorly drained soils in the Wehadkee series. About three-fourths of the acreage of these bottom-land soils is in the Chewacla series.

These soils are only moderately erodible. Because they are mostly gently to moderately sloping and are productive, they have been cultivated intensively. Erosion is now moderate to moderately severe. Because this upland area has few well-defined channels, most of the sediment never reaches the reservoir but is deposited as colluvium on lower slopes.

3. Manor-Glenelg association.--This association is the most extensive in Loch Raven Watershed (table 1). In contrast to association 2, the old uplands on which these soils occur have been strongly dissected by geologic erosion and the slopes are moderate to strong and in some places steep. For the most part this association occupies whole interstream areas, but in places it occurs only on the strong slopes between the gently sloping uplands of association 2 and the steep stony land in association 6. It is principally in the central and southern parts of the watershed. In the south it surrounds the basinlike areas of association 1 or occurs on the stronger slopes within them.

Manor and Glenelg soils formed in material weathered from the underlying micaceous schist except in a small area north of Parkton where the underlying rock is a harder slatelike albite-chlorite schist. Here the soils are more shallow and contain more rock fragments. They are droughty and less productive than those underlain by micaceous schist.

Manor and Glenelg soils are shallow to moderately deep and yellowish brown to yellowish red. They contain mica flakes, which are numerous in the lower part of the soil and in the underlying loose weathered rock material. Because of these flakes, the soils are loamy and open, especially the shallow Manor soils, and water passes through them fairly rapidly. They retain only moderate amounts of moisture available to plants. During a long period without rain Manor soils are droughty.

The Manor soils are highly erodible, especially if sheet erosion has removed the original surface layer. The Glenelg soils are not quite so erodible. Because of this combination of strong slopes, highly erodible soils, and intensive cultivation, erosion is severe throughout this area, especially on the stronger slopes. This association is the major contributor of the sediment that eventually comes to rest in Loch Raven Reservoir. Since 1940 conservation measures and changes in land use have reduced the rate of erosion.

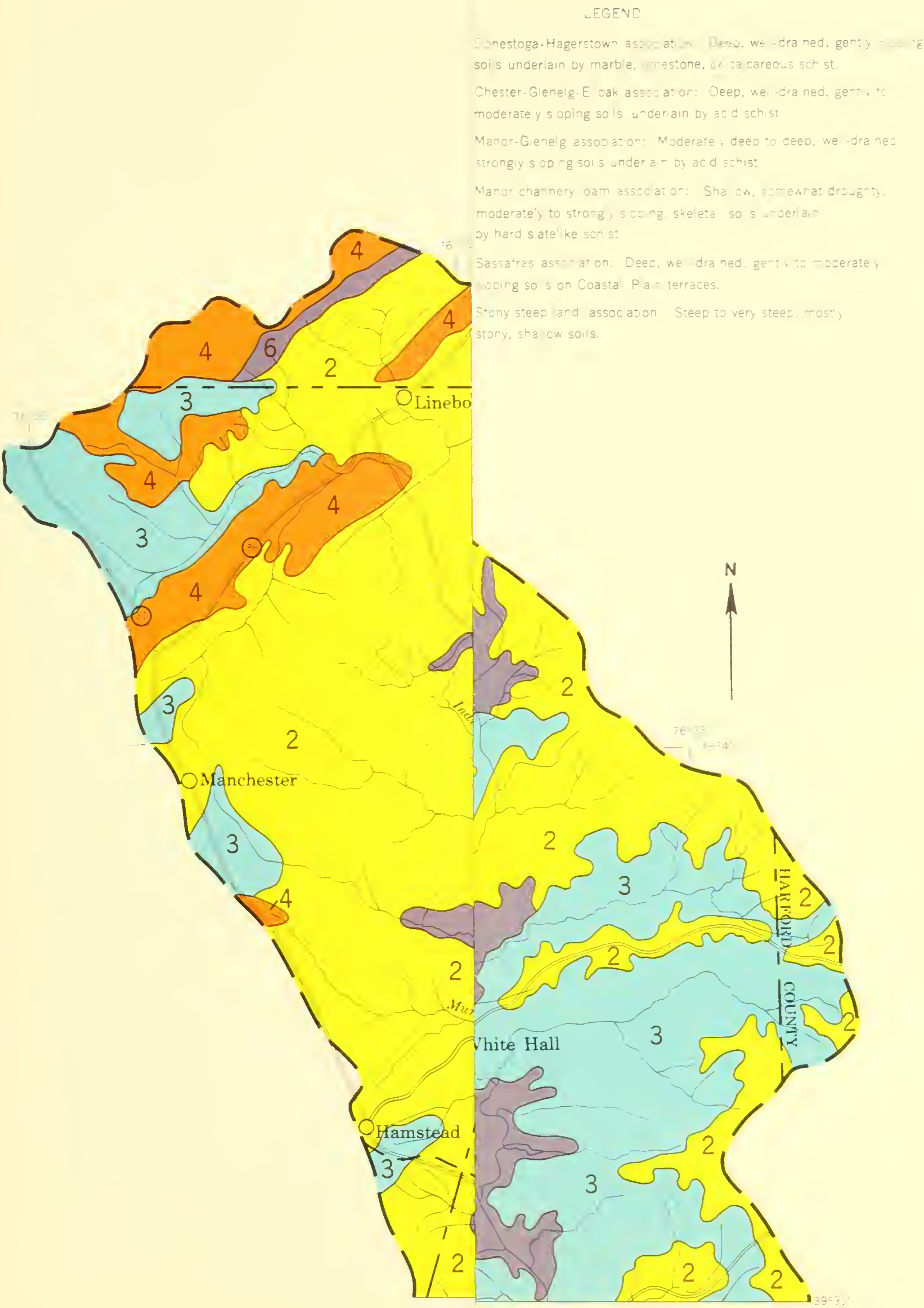
5. Sassafras association.--The Sassafras association is not extensive, occupying the less than 1 percent of Loch Raven Watershed that is in the Coastal Plain physiographic province. It lies on the fringe of the watershed just north of Towson. The Sassafras soils formed in unconsolidated gravelly, sandy, and loamy material deposited as Coastal Plain terraces over calcareous strata and in some places over marble. They are moderately to highly productive and moderately erodible.

This area has not been farmed intensively. As late as 1940 more than half the area remained in woods. Now the area is largely in urban, industrial, and similar uses. Erosion has been slight to moderate. While this area was being converted to these new uses, a large part of it was disturbed by construction operations and lay for a long time in an unstable condition. Much of the sediment produced during this period may have reached the reservoir.

6. Stony steep land association.--This association consists almost entirely of a miscellaneous land type on the steep valley walls that break sharply from the summit uplands to the stream bottoms below. This stony steep land consists mostly of large boulders or bedrock exposures that are surrounded by a shallow layer of soil. Because of this combination of steepness, stoniness, and shallowness, it is totally unsuited to cultivation or any farming enterprise other than woodland.

Included in the association are the relatively narrow bottom lands and colluvial soils that are flanked by the stony steep land.

Despite the steep slopes, there has not been much erosion since most of the area has never been farmed. Consequently, this association has not been an important source of sediment.


LEGEND
Conestoga-Hagerstown association: Deep, well-drained, gently sloping soils underlain by marble, limestone, or calcareous schist.
Chester-Glenelg-Elioak association: Deep, well-drained, gently to moderately sloping soils underlain by acid schist.
Manor-Glenelg association: Moderately deep to deep, well-drained strongly sloping soils underlain by acid schist.
Manor channery loam association: Shallow, somewhat droughty, moderately to strongly sloping, skeletal soils underlain by hard slatelike schist.
Sassafras association: Deep, well-drained, gently to moderately sloping soils on Coastal Plain terraces.
Stony steep land association: Steep to very steep, mostly stony, shallow soils.
N
Manchester
Hamstead
White Hall
HARFORD COUNTY

PRETTYBOY - LOCH RAVEN RESERVOIR WATERSHEDS
GENERAL SOIL MAP
NORTH SECTION

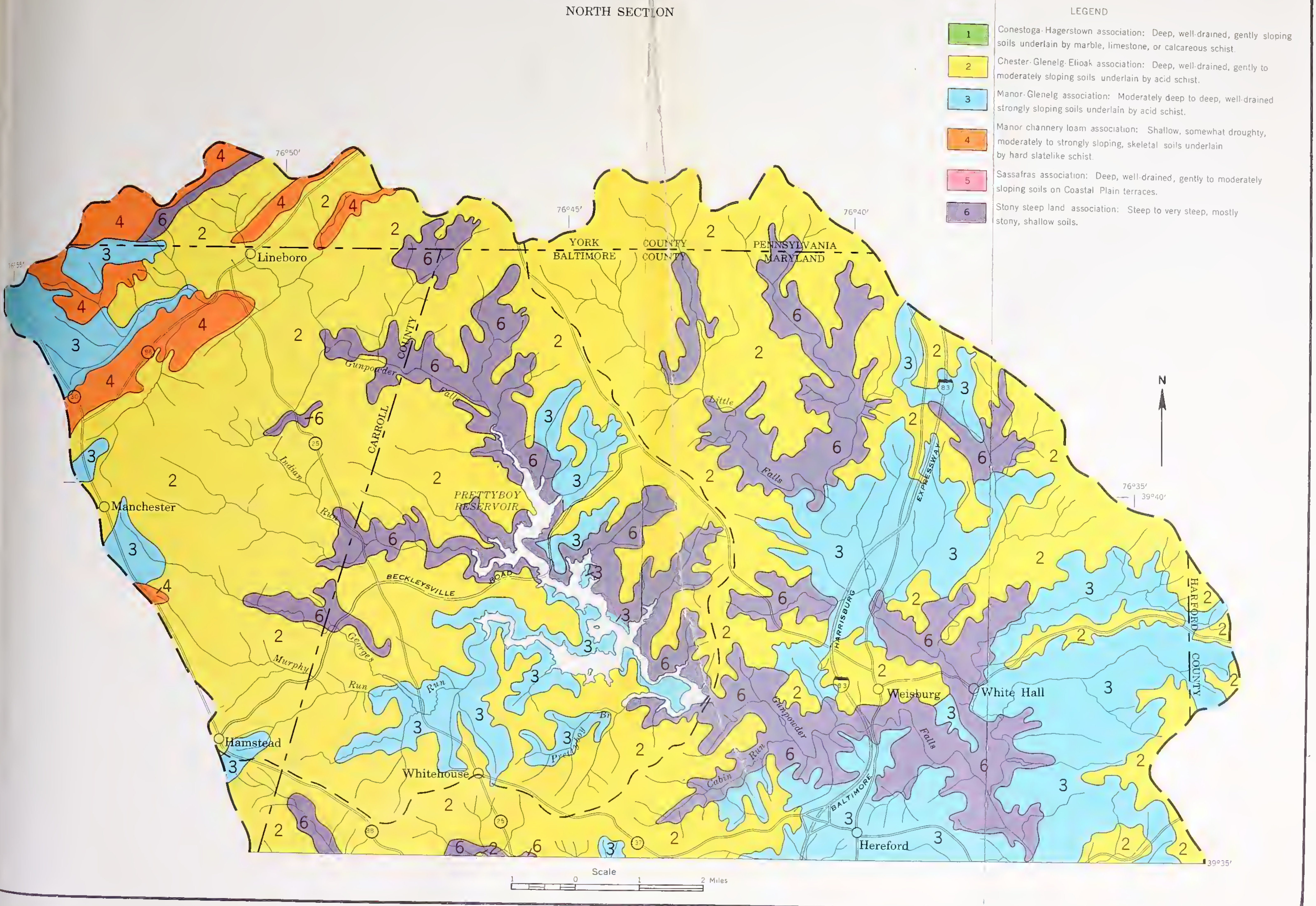
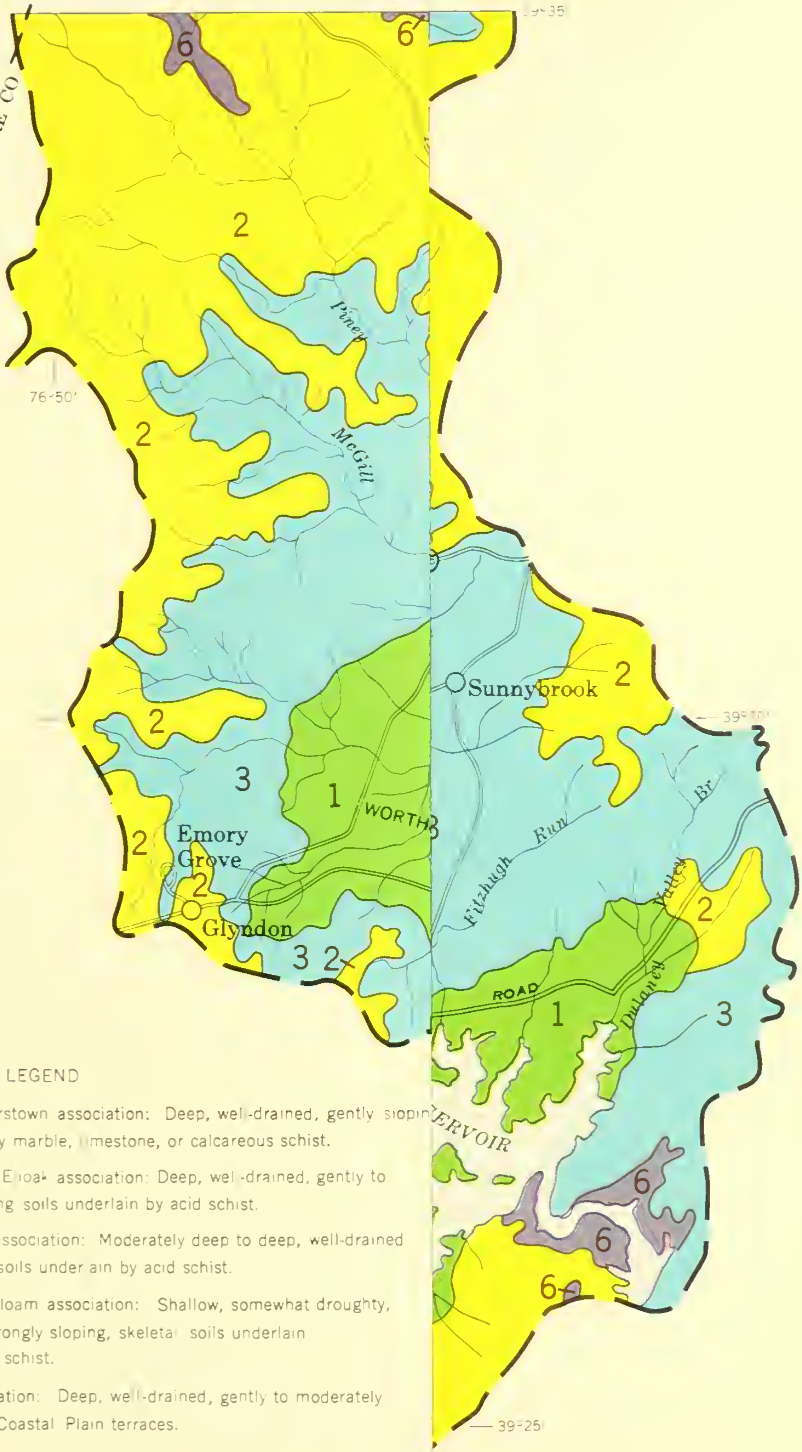


Figure 9



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6	Stony steep land association: Steep to very steep, mostly stony, shallow soils.

PRETTYBOY - LOCH RAVEN RESERVOIR WATERSHEDS

GENERAL SOIL MAP

SOUTH SECTION

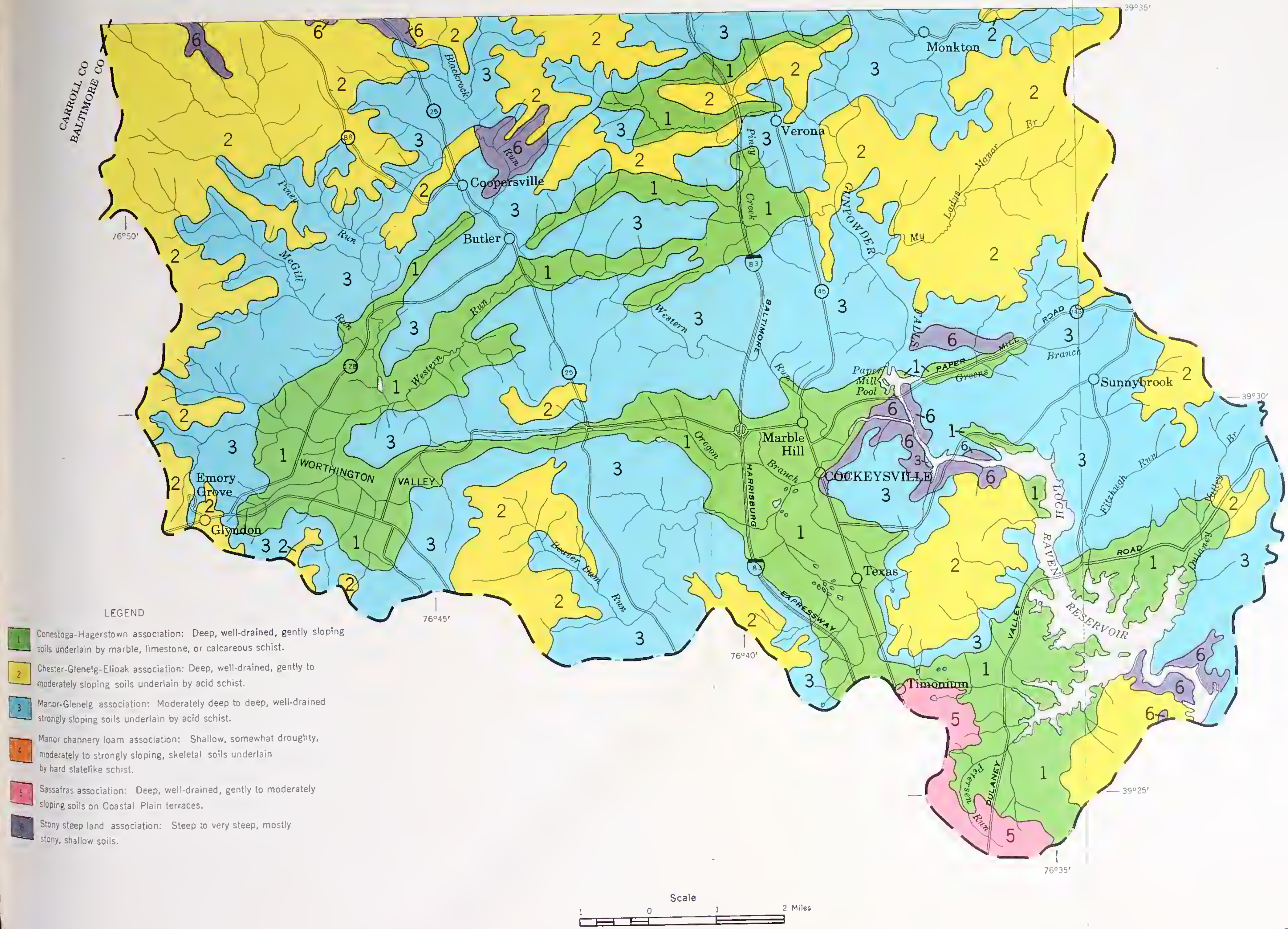

Figure 10

SOIL ASSOCIATIONS IN PRETTYBOY WATERSHED

The entire drainage basin of Prettyboy Reservoir is underlain by hard schists and quartzites. The schists appear to become progressively harder from Baltimore County northeastward into Carroll County, Md., and York County, Pa., where some slatelike phyllite underlies the soils. This harder rock is the source of the soils in association 4, mostly Manor channery loam. In general, the soils in Prettyboy Watershed are not quite so deep nor so productive as those in Loch Raven Watershed and the area is more rolling. Four of the six soil associations occur in Prettyboy Watershed.

2. Chester-Glenelg Elioak association.--This association, by far the most productive in the watershed, is also the most extensive, covering nearly two-thirds of the watershed. Sheet erosion has been moderate on these soils, which are moderately erodible and mostly gently sloping, but some of the stronger slopes have been severely eroded and gullied. A large part of this association is still being cultivated. It is estimated that almost half of the sediment deposited in Prettyboy Reservoir has come from these soils. The area is still producing sediment but at about one-third the previous rate.

3. Manor-Glenelg association.--This association is not nearly so extensive in Prettyboy Watershed as in Loch Raven Watershed. About two-thirds flanks Georges Run in Baltimore County; one-third is in Carroll County.

The upland soils--Glenelg and Manor loams and gravelly loams--formed in material weathered from the underlying albite-chlorite schist and are not nearly so micaceous as the soils in the same series in Loch Raven Watershed. These soils are highly erodible, particularly the steeper areas where most of the original surface layer has been removed. Erosion has been rapid. Because of their small extent, however, these soils have not yielded as much sediment to Prettyboy Reservoir as the soils in association 2. But because the most rapidly eroding slopes are close to the main streams, a large part of the sediment produced has been deposited in the reservoir.

4. Manor channery loam association.--About two-thirds of this association is in Carroll County, Md., and one-third in York County, Pa. It occurs principally at the higher elevations. Manor channery loam formed in material weathered from hard slatelike schists and phyllites. It is a shallow skeletal soil about 18 inches deep and contains many slatelike flat fragments that are as much as 6 inches long. The soil is called "channery" because of these fragments, which increase in number with depth until at 3 feet there is almost nothing but a mass of broken schist fragments. The soil is acid and the least productive in the watershed. Water passes through it at a fairly rapid rate, and only a small amount of moisture is available to plants. Moderate, strong, and steep slopes prevail, and there are only small areas of colluvial soils and bottom land.

Erosion has been only moderate on this soil, partly because the many schist fragments on the surface impede the flow of water over the soil and stop soil-particle detachment. Because of this and the small acreage, only a small amount of sediment has come from this association.

6. Stony steep land association.--Except for the comparatively narrow bottom land extending from the head of the reservoir, in Prettyboy Watershed this association consists only of stony steep land on the steep valley walls that flank the flood plains. Most of the original bottom land and colluvial soils on the lower slopes has been flooded by Prettyboy Reservoir.

This land is being eroded slowly but, because of the steeper slopes, at a slightly higher rate than the same kind of land in Loch Raven Watershed to the southeast.

Land-capability classes

The approximate acreage and proportionate extent of each land-capability class in Loch Raven and Prettyboy Watersheds is shown in table 4. The capability classification is a grouping of soils that shows in a general way how suitable they are for farming. It is a practical grouping based on limitations of the soils, the risk of damage when they are used, and how they respond to treatment. In this system all the kinds of soil are grouped in eight classes designated by Roman numerals 1 through VIII. In class I are the soils that have few limitations, the widest range of use, and the least risk of damage when they are used. In the other classes the soils have progressively greater natural limitations such as risk of erosion, poor drainage, shallowness, droughtiness, or stoniness. In class VIII are soils and landforms so rough, shallow, or otherwise limited that they do not produce worthwhile yields of crops, grazing, or wood products.

Method of Survey

The surveys were based on the maps and ranges established in the 1943 survey and aerial photographs made in 1957. Just before the survey, concrete monuments were set at above-crest elevation on each range end. An additional range was established at Loch Raven 129 feet downstream from and parallel to Paper Mill Bridge. Five new ranges were added to those laid out on Prettyboy in 1943. They were added to obtain greater accuracy in calculating sediment accumulation in segments containing contributing streams.

Each range was measured by securing a reel of steel airplane cable near one concrete marker and

TABLE 4.--Area and proportionate extent of land-capability classes

Land-capability class	Loch Raven Watershed		Prettyboy Watershed	
	Acres	Per-cent	Acres	Per-cent
Land suitable for cultivation and other uses:				
Class I--These soils have few or no conditions that limit their use. They can be safely cultivated without special conservation treatment.	420	0.3	15	0.1
Class II--These soils have some natural condition that limits the kinds of plants they can produce or that calls for some easily applied conservation practice when they are cultivated.	52,480	37.4	16,350	32.9
Class III--These soils have more serious or more numerous limitations than those in Class II. The limitations may be natural ones--such as steep slope, sandy or shallow soil, or too little or too much water. Or the limitations may be erosion brought on by the way the land has been used. Thus they are more restricted in the crops they can produce or, when cultivated, call for conservation practices more difficult to install or keep working efficiently.	37,330	26.6	13,760	27.7
Land suitable for occasional cultivation and other uses:				
Class IV--These soils have very severe limitations that restrict the kind of plants they can grow. If cultivated, they require very careful management. In humid areas, they are suitable for occasional but not regular cultivation; in subhumid and semi-arid areas, crops fail in years of low rainfall.	11,230	8.0	6,410	12.9
Land generally not suitable for cultivation but suitable for other uses:				
Class V--These soils have little or no erosion hazard but have some condition impractical to remove that limits their use largely to pasture, range, woodland, recreation, or wildlife food and cover.	0	0	0	0
Class VI--These soils have very severe limitations that make them generally unsuited to cultivation and restrict their use largely to pasture, range, woodland, recreation, or wildlife food and cover.	27,790	19.8	8,000	16.1
Class VII--These soils have very severe limitations that make them unsuited to cultivation and that restrict their use to pasture, range, woodland, recreation, or wildlife food and cover with careful management.	9,960	7.1	4,720	9.5
Class VIII--These soils and landforms have limitations that prevent their use for commercial plant production and that restrict their use to recreation, water supply, or wildlife food and cover with careful protection.	1,120	.8	445	.9
Total..	140,330	100.0	49,700	100.0

stretching the cable across the range on line with the concrete markers to the opposite shore. A linemeter attached to the boat and the cable measured the horizontal distance on the range. Water depth was measured with a sounding bell and line, a 14-foot sounding pole, and an automatic recording fathometer. Where used, hand soundings were made every 10 or 20 feet. Continuous water-depth recordings were made with the fathometer. "Marks" (solid vertical lines on the graph) indicated each 10-foot interval of distance from the monument along the range.

Sediment thickness was measured with the sounding pole where the prereservoir surface was less than 14 feet below the present surface. In deeper water sediment thickness was sampled by throwing in a 9-foot sampling spud attached to a bronze-core line and retrieving it. Measurements of sediment accumulation and water depth were made on 24 ranges at Loch Raven and on 23 ranges at Prettyboy. Additional measurements were made in Paper Mill Pool at Loch Raven.

Sediment samples were taken on seven ranges at each reservoir to obtain representative examples of the specific weight of the sediment. These are listed in tables 5 and 6. An 8-foot-long, 1.5-inch inside diameter, brass, piston-type sediment sampler was used.

Calculations

The original capacity and sediment volume were calculated by the general formula:

$$V = \frac{A'}{3}\left(\frac{E_1 + E_2}{W_1 + W_2}\right) + \frac{A}{3}\left(\frac{E_1}{W_1} + \frac{E_2}{W_2}\right) + \frac{h_3E_3 + h_4E_4 + \cdots}{130{,}680}$$

where

- V = original capacity or sediment volume of a segment in acre-feet
- A' = calculated quadrilateral surface area in acres
- A = planimetered surface area of the segment in acres
- E = cross-sectional area of the range in square feet
- W = length of the range at crest elevation in feet
- h = perpendicular distance from the range on a tributary to:
  - (1) the junction of the tributary with the main stream or
  - (2) the point where the thalweg of the tributary intersects the downstream range in feet.

The original capacity of Loch Raven Reservoir was also calculated by the contour method. Volumes at various (10-foot or less) contour levels were calculated by the modified prismoidal formula:

$$V = L/3 \quad (A + \sqrt{AB} + B)$$

where

- V = original or remaining capacity in acre-feet
- L = contour interval in feet
- A = area at the lower contour in acres
- B = area at the upper contour in acres.

These calculations were based on a contour map of the reservoir prepared before the dam was raised in 1922. Because of a 5.6-acre island in one segment and the highly irregular shoreline, this second method was presumed to be the more accurate. The results adopted as final for Loch Raven Reservoir were obtained by a combination of the range and contour methods. At several places either it was not possible to penetrate the sediment or complete penetration to the old surface was questionable. At these places the water-depth measurements were compared with the cross sections from 1943 and the earlier contour maps to get good approximations of sediment thickness.

Sediment in the Reservoirs

Character of sediment

The deposits in Prettyboy Reservoir were distinguished from the old channel deposits and residual soils on the basis of color, texture, and cohesiveness. In the lower part of the reservoir the bottom is rocky. In other parts the old bottom could be recognized by the yellow-brown, highly cohesive, gritty clay that contains particles of rotten schist. The lacustrine sediments were micaceous, light grayish-brown silty clays, and they were generally less dense than the old deposits. As might be expected, fine to medium quartz sand appeared in the sediment deposits in the headwaters. Organic material that included leaves, wood, and charcoal fragments occurred throughout the sediment.

Recognizing the contact between the sediment and the old bottom was more difficult in Loch Raven Reservoir. The old bottom consists of more diverse materials than at Prettyboy Reservoir. There are two sets of submerged deltaic deposits. The first is in the lower part of the reservoir and formed in the old reservoir between 1881 and 1914. The second set formed in the 1914-22 headwaters when the spillway crest was at 188 feet. Evidence of the latter set is on R5-6 in the sandy bottom material that was probably carried in by Dulaney Valley Branch. More evidence is in the thick (9 feet or more) sediment deposits along the thalweg on R18-19, which would have been near the 1914-22 headwaters of the reservoir. Where the reservoir is underlain by the Cockeysville marble, the old bottom is a dense, orange, gritty, sticky clay. In some places the old bottom consists of sandy channel and flood-plain deposits and in other places of rock.

In general the saturated sediment in Loch Raven Reservoir is a light grayish-brown clay. After drying and oxidizing, it is tan and very hard. It contains very fine flecks of mica and some organic matter. Samples recovered on R5-6 and R6-10 showed the upper 0.8 to 1.2 feet of sediment to be banded. Very thin layers of grayish-brown silty clay alternated with darker layers. These contrasting laminae probably represent seasonal sedimentation.

Sediment in Loch Raven Reservoir above the junction of Western Run and in the headwaters of Prettyboy Reservoir contains gas. This is believed to be the product of decomposing organic material. Large bubbles were seen to rise to the surface from time to time. When a spud was thrown into the sediment, a stream of bubbles emerged at the surface. No odor was discernible. Gas was noted particularly on R26-27 at Loch Raven and on R29-30 at Prettyboy.

Distribution of sediment

Some sediment was found on every range in Loch Raven Reservoir. The average sediment depth was 1.3 feet on R1-2 and 8.7 feet on R33-34. The amount of sediment increases generally with distance from the dam (fig. 11).

In Ashland Pool a 3-inch layer of medium-grained sand was found from 12 to 15 inches below the sediment-water interface. It is overlain and underlain by buff-colored clay and silt. A thin layer of finer textured sand was found in the sediment sampled at

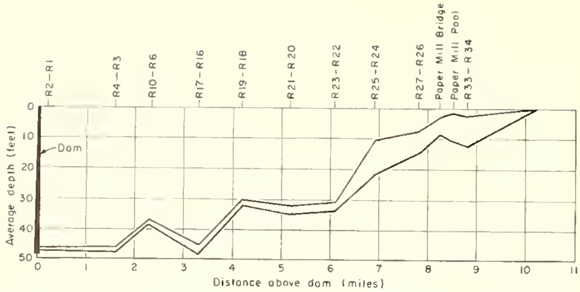

Figure 11.--Distribution of sediment in Loch Raven Reservoir.

R24-25 near Warren Bridge. It appears that this sand was brought in by a major storm. It is doubtful that a continuous layer of sand extends the 2 miles from Ashland Pool to Warren Bridge. The tributary above R37-38 could well have supplied the fine sand noted at R24-25.

On R3-4 a sand layer was found at the bottom of the 27.5 inches of sediment recovered. This most likely is a deltaic deposit formed before the dam was raised to its present height.

Only a small amount of the sediment in Loch Raven Reservoir appears to result from wave erosion. Except in the basins overlying the Cockeysville marble, the reservoir is rock-rimmed and there is virtually no erosion from wave action. But along the shore northeast of monument 5 and adjacent to the Dulaney Valley road, several hundred feet of shoreline have receded. This area lies to the west of the largest expanse of open water in the lake and attests to the power of waves produced by the prevailing westerly winds. The soil being eroded is in the Hagerstown series, which formed in material weathered from this marble, and now the orange cohesive subsoil is exposed.

The shape of Loch Raven Reservoir has played an important part in the distribution of sediment. Near its head and in the Western Run arm, the reservoir widens appreciably from narrow confined channels to form Paper Mill Pool and Ashland Pool. These broad pools form natural settling basins.

In 1944 Gottschalk proposed a plan for trapping additional sediment and controlling its distribution in Paper Mill Pool. This was to be accomplished first by a brush diversion structure in the main channel to deflect the incoming flow into the deeper eastern section of the pool. Vegetative screens would be established on the sediment deposits in the shallow western section and along the natural levee of the central main channel. After the eastern section entrapped sediment to crest level, flow would be diverted to the western side of the pool and vegetative screens would be established to encourage deposition of sediment above the crest elevation of the reservoir. Subsequently flow would be diverted to first one side and then the other until eventually sediment would be stored for an average thickness of at least 2 feet above crest over the entire pool area of 100 acres. Altogether the pool could store some 660 acre-feet of sediment. The unsightly marshy condition would be eliminated, and the pool area would become a fertile, productive, and esthetically pleasing woodland.

A pilot channel was excavated with dynamite in 1945 to carry the main flow into the eastern section. Numerous plantings were made of cypress, willow, and other desirable trees, shrubs, and aquatic vegetation. No diversion structure was installed, however, and the plan was never completed. Since the current was not diverted into the pilot channel, it filled up over the years with brush and sediment.

By 1948 all the introduced plants and cuttings had disappeared, apparently having been crowded out by nettle, polkberry, cattail, and natural willow growth. Now there is dense natural vegetation on the levee and in the western section of the pool. Because of the levee, no sediment gets into the eastern section except during flood flows. The eastern section is relatively sediment free and contains 4 and 5 feet of water except where Green Branch empties into the eastern arm near Paper Mill Road (fig. 14).

In 1961 the amount of sediment in Paper Mill Pool was equivalent to about 90 percent of its below-crest capacity. Ashland Pool has lost about 85 percent of its original capacity. The deposits in both pools have built up in places to 1.5 feet and more above crest elevation, especially on the natural levees that have formed adjacent to their main channels.

The vegetation that has taken over on the levees, the above-crest islands, and the shallows helps prevent the scouring of sediment during flood flows. The sediment in both pools is compacted from repeated aeration. Most flows currently pass on through the pools within the main channels, carrying sediment farther into the reservoir before deposition. Figures 12, 13, and 14 are aerial views of Paper Mill Pool illustrating the accumulation and distribution of sediment from 1938 to 1957.

Figure 12.--Paper Mill Pool in 1938.

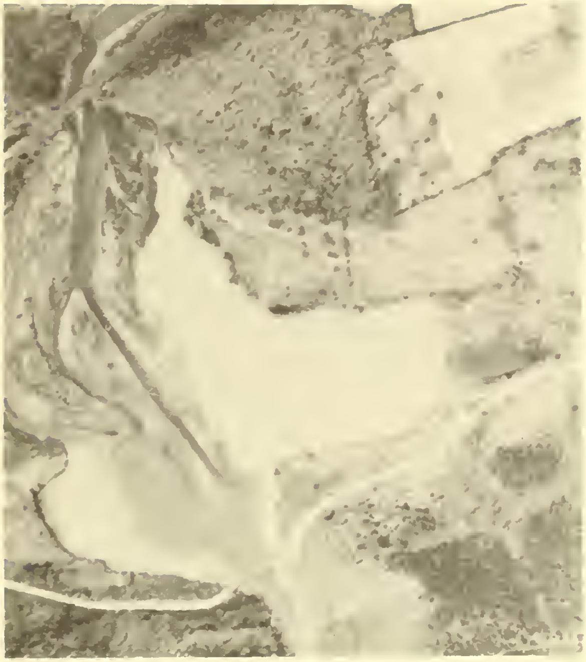

Figure 13.--Paper Mill Pool in 1943.

In Prettyboy Reservoir no sediment was found on the four ranges on Gunpowder Falls immediately upstream from the dam. Above R14-15 the sediment thickness generally increased up to the head of the reservoir. On R29-30 sediment thickness of 5 feet and slightly more was measured--the average was 2.4 feet.

Figure 14.--Paper Mill Pool in 1957.

The principal tributary emptying into Prettyboy Reservoir is Georges Creek, which forms an arm about 3 miles long to the west of the main body of the reservoir. On R12-13, near the headwaters of this arm, the greatest sediment thickness measured was 4.6 feet, but the average sediment thickness of 3 feet exceeded the average on R29-30 (fig. 15).

Several times since 1943 Prettyboy Reservoir has experienced drawdowns that have caused redistribution of sediment (figs. 3, 4, and 5). During these periods sediment deposited near the head of the reservoir has been eroded and flushed on down toward the dam. This may explain the finding of an average of 0.7 foot less sediment on R29-30 in 1961 than in 1943.

During dry seasons water is released through Prettyboy Dam to maintain the supply at Loch Raven Reservoir. At such times there is opportunity for aeration and compaction of the exposed sediment as well as for erosion and redeposition. This is shown by the fact that the average dry weight of sediment sampled in Prettyboy Reservoir was 7.8 pounds per cubic foot more than that from Loch Raven Reservoir (tables 5 and 6).

There is only a small amount of shore erosion in the reservoir. At low water a series of steplike

TABLE 5.--Physical data for sediment samples from Loch Raven Reservoir

Range[1]	Depth from top of sediment	Length of sample	Dry weight per cubic foot	Moisture content
	Inches	Inches	Pounds	Percent of dry weight
3-4	5-12	7	39.1	114.2
3-4	21-27	6	48.9	7 .6
13-14	1-7	6	35.8	122.7
13-14	8-14	6	48.9	93.3
13-14	15-22	7	81.1	41.3
24-25	5-11	6	47.3	103.4
24-25	14-17	3	48.9	86.6
Ashland Pool	7-12	5	50.8	100.0
Ashland Pool	[2] 12-15	3	94.5	41.3
Ashland Pool	18-25	5	52.8	81.4
Paper Mill Pool	--	5	56.7	68.9
Total	--	--	604.8	--
Average	--	--	55.0	--
18-19	(3)	4	91.4	29.7

[1] Sediment on R7-8 was too soupy for sampling.
[2] Sand layer.
[3] Old bottom.

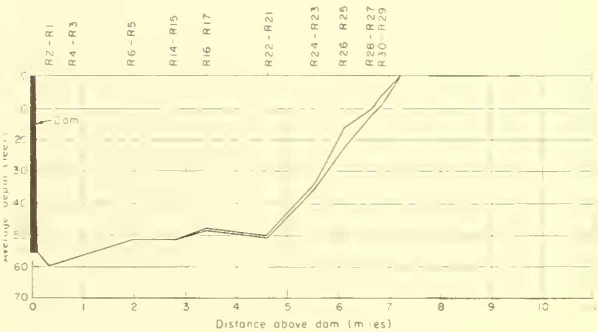

Figure 15.--Distribution of sediment in Prettyboy Reservoir.

TABLE 6.--Physical data for sediment samples from Prettyboy Reservoir

Range	Depth from top of sediment	Length of sample	Dry weight per cubic foot	Moisture content
	Inches	Inches	Pounds	Percent of dry weight
8-9	2-6	4.0	44.5	88.9
12-13	3-8	5.0	44.9	100.0
27-28	4-8.3	4.3	54.6	66.6
27-28	[1] 12.5-15	2.5	82.3	28.5
27-28	18-23.5	5.5	60.0	60.0
31-32	0-7.5	7.5	62.6	60.4
31-32	7.5-12	4.5	82.6	36.8
33-34	0-5.5	5.5	78.3	38.6
33-34	0-6	6.0	52.2	87.5
33-34	6.0-13.5	7.5	65.2	50.0
35-36	0-14.75	14.75	43.1	95.4
37-38	0-3.5	3.5	69.8	40.0
37-38	3.5-20.5	17.0	55.2	70.8
37-38	20.5-24	3.5	83.7	33.3
Total	--	--	879.0	--
Average	--	--	62.8	--
33-34	[2] 5.5-8.25	2.75	89.0	24.0

[1] Sand layer.
[2] Old bottom.

benches in the thin soil mantle is visible on some of the steep banks along the shore. These narrow benches are the result of wave action at various water levels. The sediment produced from this erosion does not represent a storage loss. The erosion occurs below crest elevation and thus is merely a redistribution of the soil material. Most of the shore is resistant metamorphosed rock that is partly covered by shallow residual soil.

Results of the Surveys

Data from both surveys indicate a decreased rate of sediment accumulation during the 1943-61 period from that in the earlier period (figs. 16 and 17). The sediment accumulation in the reservoirs is thought to be equivalent to the sediment yield of the watersheds because the trap efficiency of each reservoir approaches 100 percent. It is very unusual for turbid water to invade either reservoir to within a mile of the dam.

The new rate of sediment accumulation in Loch Raven Reservoir is less than a third of the old rate. The annual rate of sediment accumulation per square mile of drainage area before 1943 was 0.618 acre-feet. For 1943-61 the annual rate was 0.187 acre-feet. This is equivalent to an average of 185 acre-feet of sediment deposited in the reservoir each year before 1943 and of 41 acre-feet each year since 1943.

From measurements and from a contour map, the original capacity of Loch Raven Reservoir was calculated to be 70,169 acre-feet and the present capacity 64,072 feet. The surface area of the lake, as measured on aerial photos by a planimeter, decreased 5 acres in the past 18 years. The original area was 2,391 acres. It decreased to 2,337 acres in 1943 and to 2,332 acres in 1961. Because of inherent errors in the measurement of aerial photos on a scale of 1:20,000, these figures are not to be considered exact, but it is apparent that the reservoir area has decreased with sediment deposition.

Loch Raven Reservoir has a large capacity-watershed ratio--now 211 acre-feet per square mile of watershed. The current average annual storage loss (to 1961) is 0.18 percent (table 7). The total capacity loss is 8.7 percent.

The quantity of sediment deposited annually in Prettyboy Reservoir since 1943 is 56 percent of the quantity deposited annually between 1933 and 1943. For 1933-43 the rate of sediment accumulation was 0.699 acre-feet per square mile of drainage area per year. For 1943-61 the rate was 0.391 acre-feet per square mile per year. This amounts to about 54 acre-feet per year for the first period and about 30 for the second period.

The Baltimore Bureau of Water Supply previously had determined from surveys and from a contour map with 5-foot contour intervals that the original capacity of Prettyboy Reservoir was 60,979 acre-feet. From hand-sounding measurements, fathograms, and comparisons with the original contour map, the present capacity was determined to be 59,864 acre-feet. This is a total loss of 1.83 percent of original capacity because of sedimentation. The current average annual rate of storage loss is 0.06 percent (table 7).

TABLE 7.--Rate of sediment accumulation in 16 reservoirs in northern part of Piedmont province

Reservoir	Location	Age at date of survey	Original capacity	Total drainage area	Latest capacity-watershed ratio	Annual storage loss	Annual sediment-accumulation rate
		Years	Acre-feet	Square miles	Acre-feet per square mile	Percent	Acre-feet per square mile
Greenbelt	Greenbelt, Md.	21.1	196	0.83	182	1.09	2.57
Palington	Spring Grove, Pa.	1.6	63	2.91	21	3.09	.669
Loch Raven	Towson, Md.	47	70,169	303	211	.18	.593
New Glatfelter	York, Pa.	2	62	3.0	21	2.85	.592
Prettyboy	Hereford, Md.	28.5	60,979	80	748	.06	.504
Barcroft	Alexandria, Va.	42.6	1,847	14.5	144	.38	.473
Burnt Mills	Silver Spring, Md.	7.8	181	27.0	3.5	6.08	.408
Williams	York, Pa.	27	2,686	42.9	52	.63	.394
Atkisson	Bel Air, Md.	12	896	45.46	16	1.78	.351
Coatesville	Coatesville, Pa.	35	1,019	5.0	194	.14	.28
Triadelphia	Ashton, Md.	16.2	20,222	81.4	241	.08	.20
Jackson	Manassas, Va.	7.2	4,500	337.0	12.3	1.06	.141
Pedlar	Oronoco, Va.	31	1,860	33.21	52	.24	.134
Old Glatfelter	York, Pa.	55	147	74.3	0.1	1.69	.033
Icedale	Chester Co., Pa.	51	137	20.0	5.3	.04	.03
Fishing Creek	Frederick, Md.	12	236	8.5	28	.03	.007

RESERVOIR SEDIMENT DATA SUMMARY
SCS-34 Rev. 6-62

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

NAME OF RESERVOIR: Loch Raven Reservoir

DATA SHEET NO.: 4 - 1

DAM	1. OWNER Dept. Public Works, Baltimore	2. STREAM Gunpowder Falls	3. STATE Maryland
	4. SEC. TWP. RANGE	5. NEAREST TOWN Towson	6. COUNTY Baltimore
	7. STREAM BED ELEVATION 171	8. TOP OF DAM ELEVATION 246	9. SPILLWAY CREST ELEV. 240

RESERVOIR 10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA ACRES	13. ORIGINAL CAPACITY ACRE-FEET	14. GROSS STORAGE ACRE-FEET	15. DATE STORAGE BEGAN
a. MULTIPLE USE					
b. FLOOD CONTROL					1914
c. POWER					
d. WATER SUPPLY	240	2.391	70,169 1/ 2/	70,169 1/ 2/	16. DATE NORMAL OPER. BEGAN
e. IRRIGATION					
f. CONSERVATION					
g. SEDIMENT					1914
h. INACTIVE					

17. LENGTH OF RESERVOIR 10.5 MILES | AV. WIDTH OF RESERVOIR .3 MILES

WATERSHED		
18. TOTAL DRAINAGE AREA 303 SQ. MI.		22. MEAN ANNUAL PRECIPITATION 42.53 INCHES
19. NET SEDIMENT CONTRIBUTING AREA 219.4 3/ SQ. MI.		23. MEAN ANNUAL RUNOFF INCHES
20. LENGTH 50 MILES	AV. WIDTH 6 MILES	24. MEAN ANNUAL RUNOFF AC.-FT.
21. MAX. ELEV. 920	MIN. ELEV. 171	25. CLIMATIC CLASSIFICATION Humid

SURVEY DATA

26. DATE OF SURVEY	27. PERIOD YEARS	28. ACCL. YEARS	29. TYPE OF SURVEY	30. NO. OF RANGES OR CONTOUR INT.	31. SURFACE AREA ACRES	32. CAPACITY ACRE-FEET	33. C/W RATIO AC.-FT. PER SQ. MI.
1914	-	-	-	-	2,391	70,169 1/, 2/	231 1/ 2/
Oct. 1943	29	29	Range Recon.	18	2,337	64,813 2/	214 2/
June 1961	18	47	Range Detail	24	2,332	64,072	211

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW ACRE-FEET a. MEAN ANNUAL	b. MAX. ANNUAL	c. PERIOD TOTAL	36. WATER INFL. TO DATE AC.-FT. a. MEAN ANNUAL	b. TOTAL TO DATE

26. DATE OF SURVEY	37. PERIOD SEDIMENT DEPOSITS ACRE-FEET a. PERIOD TOTAL	b. AV. ANNUAL	c. PER SQ. MI.-YEAR	38. TOTAL SED. DEPOSITS TO DATE ACRE-FEET. a. TOTAL TO DATE	b. AV. ANNUAL	c. PER SQ. MI.-YEAR
Oct. 1943	5,356	185	.618 3/	5,356	185	.618 3/
June 1961	741	41	.187	6,097	130	.593

26. DATE OF SURVEY	39. AV. DRY WGT. LBS. PER CU. FT.	40. SED. DEP. TONS PER SQ. MI.-YR. a. PERIOD	b. TOTAL TO DATE	41. STORAGE LOSS PCT. a. AV. AN.	b. TOT. TO DATE	42. SED. INFLOW PPM a. PERIOD	b. TOT. TO DATE
Oct. 1943	60 4/	808 2/	808 2/	.26 2/	7.63 2/		
June 1961	55.0 (11)	233	740	.18	8.69		

1/ Based on original potential capacity to 240' elevation

2/ Revised after 1961 survey

3/ Net sediment contributing area was 299.4 sq.mi. until 1933 when Prettyboy dam was completed. This area was used in 1943 calculations.

4/ Assumed

Figure 16.--Summary of sedimentation data for Loch Raven Reservoir.

RESERVOIR SEDIMENT DATA SUMMARY
SCS-34 Rev. 6-62

Prettyboy Reservoir
NAME OF RESERVOIR

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

4 - 2
DATA SHEET NO.

DAM

1. OWNER Dept. Public Works Baltimore	2. STREAM Gunpowder Falls	3. STATE Maryland
4. SEC. TWP. RANGE	5. NEAREST TOWN Hereford	6. COUNTY Baltimore
7. STREAM BED ELEVATION 387	8. TOP OF DAM ELEVATION 540	9. SPILLWAY CREST ELEV. 520

RESERVOIR

10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA ACRES	13. ORIGINAL CAPACITY ACRE-FEET	14. GROSS STORAGE ACRE-FEET	15. DATE STORAGE BEGAN / 16. DATE NORMAL OPER. BEGAN
a. MULTIPLE USE					15. April 10 1933
b. FLOOD CONTROL					
c. POWER					
d. WATER SUPPLY	520	1,498	60,979 1/	60,979 1/	
e. IRRIGATION					16. October 1933
f. CONSERVATION					
g. SEDIMENT					
h. INACTIVE					

17. LENGTH OF RESERVOIR 7.25 MILES | AV. WIDTH OF RESERVOIR .32 MILES

WATERSHED

18. TOTAL DRAINAGE AREA 80 SQ. MI.	22. MEAN ANNUAL PRECIPITATION 42.53 INCHES
19. NET SEDIMENT CONTRIBUTING AREA 77.5 SQ. MI.	23. MEAN ANNUAL RUNOFF INCHES
20. LENGTH 12 MILES; AV. WIDTH 6.67 MILES	24. MEAN ANNUAL RUNOFF AC.-FT.
21. MAX. ELEV. 920; MIN. ELEV. 387	25. CLIMATIC CLASSIFICATION Humid

SURVEY DATA

26. DATE OF SURVEY	27. PERIOD YEARS	28. ACCL. YEARS	29. TYPE OF SURVEY	30. NO. OF RANGES OR CONTOUR INT.	31. SURFACE AREA ACRES	32. CAPACITY ACRE-FEET	33. C/W RATIO AC.-FT. PER SQ. MI.
April 1933	-	-	-	-	1498	60,979 1/	762 1/
Oct. 1943	10.5	10.5	Range Recon.	14	1498	60,410 1/	755 1/
Sept. 1961	18	28.5	Range Detail	23	1467	59,864	748

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW ACRE-FEET a. MEAN ANNUAL	35. b. MAX. ANNUAL	35. c. PERIOD TOTAL	36. WATER INFL. TO DATE AC.-FT. a. MEAN ANNUAL	36. b. TOTAL TO DATE

26. DATE OF SURVEY	37. PERIOD SEDIMENT DEPOSITS ACRE-FEET a. PERIOD TOTAL	37. b. AV. ANNUAL	37. c. PER SQ. MI.-YEAR	38. TOTAL SED. DEPOSITS TO DATE ACRE-FEET. a. TOTAL TO DATE	38. b. AV. ANNUAL	38. c. PER SQ. MI.-YEAR
Oct. 1943	569	54.2	.699	569	54.2	.699
Sept. 1961	546	30.3	.391	1115	39.1	.504

26. DATE OF SURVEY	39. AV. DRY WGT. LBS. PER CU. FT.	40. SED. DEP. TONS PER SQ. MI.-YR. a. PERIOD	40. b. TOTAL TO DATE	41. STORAGE LOSS PCT. a. AV. AN.	41. b. TOT. TO DATE	42. SED. INFLOW PPM a. PERIOD	42. b. TOT. TO DATE
Oct. 1943	60 2/	913	913	0.09	0.93		
Sept. 1961	62.8(14)	547	705	0.06	1.83		

1/ Revised after 1961 survey
2/ Assumed

Figure 17.--Summary of sedimentation data for Prettyboy Reservoir.

Factors Affecting Reduced Sediment Yield

Precipitation and runoff

Precipitation and runoff for the two periods were compared to explore the possible causes of the reduced sediment yield in the second period (1943-1961). Records of the nearby Weather Bureau station at Baltimore show that the average annual precipitation was 41.83 inches in 1914-43 and 44.40 inches in 1944-60, an increase of 6 percent for the second period. The average annual amounts of rain falling in storms exceeding 2, 3, and 4 inches in 24 hours were all larger for this second period.

The computation of direct runoff indicated that under normal conditions in these watersheds a rainfall exceeding 1 inch in 24 hours is required to produce surface runoff. The computed average annual surface runoff was 3.07 inches in 1914-43 and 3.53 inches in 1944-60, an increase of 15 percent for the latter period. If only the runoff during the growing season (April-October) is considered, the increase for the second period was even greater--43 percent.

The city of Baltimore has maintained records of the flow of Gunpowder Falls at Loch Raven Dam since 1883. The measured average daily flow in million gallons per square mile was 0.809 in 1914-43 and 0.828 in 1944-1959, an increase of 2.3 percent.

All these figures show a greater amount of total precipitation and runoff in the watershed during the period of reduced sediment yield, strongly indicating that some other factor (or factors) is the cause of this reduction.

Land use

In 1939 about three-fourths of the land in the watersheds was in farms; in 1959 only about a third of the land was in farms. The number of farms decreased to about a third of the number in 1939, but the average size increased from 82 acres to 106 acres. No survey of land use was made at the time of this sedimentation survey, but unpublished data from the Division of Agriculture, U.S. Bureau of the Census, for the six election districts wholly or mostly within Loch Raven watershed (Nos. 5, 6, 7, 8, and 10 in Baltimore County) and Prettyboy Watershed (No. 6 in Carroll County) are representative (table 8).

TABLE 8.--Land use changes in Loch Raven and Prettyboy Watersheds

Land use	Loch Raven		Prettyboy	
	1939	1959	1939	1959
	Percent	Percent	Percent	Percent
Cropland	41.5	18.4	58.1	15.3
Plowable pasture	8.5	6.0	4.0	5.8
Woodland	15.8	6.6	16.2	2.1
Other land in farms	9.3	2.4	12.1	1.0
Land not in farms	24.9	66.6	9.6	75.8

Data for Baltimore County are also indicative of land use changes. Almost 90 percent of the drainage area above Loch Raven Dam lies within Baltimore County and constitutes 45 percent of its total area. There are 390,400 acres (610 square miles) in Baltimore County of which 154,000 acres (39.5 percent) are classified as agricultural land. The 79.4 square miles of the city of Baltimore are not a part of the county.

Table 9 shows a steady decline in cultivated land, pasture, and woodland in Baltimore County except during World War II. The biggest change has been the reduction of land in farms. Much of this land has been converted to residential areas, especially near Baltimore, and to industrial use.

In some reservoirs, sediment from road banks is an important part of the sediment accumulation. This has not been true of either Prettyboy or Loch Raven. Even where roadbanks have been eroded, as during construction of the Baltimore-Harrisburg Expressway, very little sediment reached the reservoirs, and now roadbanks throughout the watershed are sloped and covered with grass to prevent erosion.

The city of Baltimore owns about 11,500 acres adjacent to Loch Raven and Prettyboy Reservoirs, about 6 percent of the watershed. Much of this land is in natural forest, and most of the previously cultivated land has been planted to conifers. Since 1943 the forested area has been increased at Loch Raven Reservoir by 266 acres and at Prettyboy by 552 acres. The total amount of reforested land is 1,038 acres at Loch Raven and 581 acres at Prettyboy. Most of it has been planted with loblolly pine and white pine.[5] The city's management program for watershed land is based on the principle of multiple use. Erosion is controlled and water quality protected, and the land is used for growing timber, improvement and utilization of timber resources, and recreation. There are now only 912 acres of nonforested city-owned land in the two watersheds, and these areas are in grass and other plant cover.

Conservation measures

In the 1943 report on Loch Raven and Prettyboy Reservoirs, Gottschalk pointed out "the main source

[5] Reigner, Irwin C., and Walter C. Sushko. The Baltimore Watershed: An Example of Good Management. Public Works 91(4): 85-88. 1960.

TABLE 9.--Land use in Baltimore County, Md.

Land use	1940	1945	1950	1955	1960
	Percent	Percent	Percent	Percent	Percent
Cropland	32.0	36.3	32.1	25.5	18.1
Pasture	8.2	10.7	8.0	8.2	6.2
Woodland	14.2	16.1	12.7	1[illegible].3	7.2
Other	45.6	36.9	47.2	56.0	68.5
Total	100.0	100.0	100.0	100.0	100.0

Figure 18.--Sheet erosion near Cockeysville, Md., in 1943.

of sediment deposited in Loch Raven and Prettyboy Reservoirs is sheet erosion (figs. 18 and 19) of cultivated land.... In the case of the Gunpowder Falls watershed there is no doubt but that approved conservation measures would greatly improve crop production as well as reduce the rate of sediment inflow to Prettyboy and Loch Raven Reservoirs. Such a program is urgently needed, would unquestionably pay for itself, and would be of mutual benefit to the City of Baltimore and the landowners."

In the 18 years since Gottschalk's report many conservation measures have been installed, as shown in the following list. Statistics for Baltimore County are assumed to be representative of Gunpowder Falls Watershed. In 1961, 85 percent of the agricultural land in Loch Raven Watershed was operated by soil conservation district cooperators and basic conservation plans had been made for 47 percent of the agricultural land.

	Percent of agricultural land
On cropland:	
Conservation crop rotations	22
Contour farming	22
Cover cropping	2
Strip cropping	17
On grassland:	
Hayland planting	7
Pasture improvement	7
Pasture planting	7
Rotation grazing	20
On farm woodland:	
Tree planting	2
Woodland improvement	4
Woodland protection	5

Though these conservation measures (figs. 20 and 21) do not cover a large area in terms of the total watershed, they have an important effect on the sedimentation rate because they have been applied to the

Figure 19.--Gullying near Cockeysville, Md., in 1943.

areas that are a major source of sediment. The fact that the sedimentation rate has dropped substantially--to less than one-third the previous rate at Loch Raven and to about one-half the previous rate at Prettyboy--confirms Gottschalk's expectation.

Interpretations and Conclusions

The primary reason for the drop in the sedimentation rate since 1943 appears to be the large acreage that went out of agricultural use into residential and other nonfarm uses. Another important reason is the installation of conservation measures on much of the remaining farmland.

This conclusion appears at first glance to be inconsistent with the conclusion of a similar study of Lake Barcroft in the suburbs of Washington, D.C. [6] During the period of change from farm to nonfarm land in Lake Barcroft Watershed, the sedimentation rate increased rather than decreased. The main reason for this difference is that urbanization at Lake Barcroft was more abrupt and large areas had no plant cover from 3 months (single dwelling) to 2 or 3 years (major construction projects). Also, much of the construction at Lake Barcroft was concentrated near the reservoir, so that almost all the eroded soil became sediment. In Loch Raven and Prettyboy Watersheds, the land use change was scattered, was farther away from the reservoirs, and did not include extensive removal of plant cover. Many farms, for example, were converted to suburban homes with very little disturbance of soil and grass. Forests owned by the city of Baltimore border the reservoirs and trap some sediment before it reaches the reservoirs.

By comparing the average annual rate of sediment accumulation in Loch Raven Reservoir for the two periods on a per-square-mile basis--0.618 acre-feet before 1943 versus 0.187 since--it can be seen that

[6] Holeman, John N., and A. F. Geiger. Sedimentation of Lake Barcroft, Fairfax County, Va. SCS-TP-136. 1959.

Figure 20.--Land use in Prettyboy Watershed in 1943.

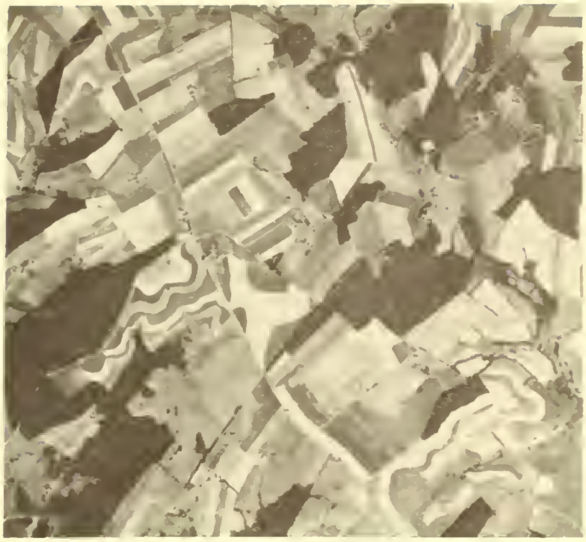

Figure 21.--Land use in Prettyboy Watershed in 1957.

not only has the total amount of sediment been reduced but also the rate per square mile is only 30 percent of that of the earlier period. Although since 1933 Prettyboy Dam has reduced the original area contributing sediment to Loch Raven Reservoir by 80 square miles, it could not have caused the drop in rate on a per-square-mile basis. This fact suggests that the major reduction was caused by land use changes and soil conservation measures, which have kept more of the sediment at its source. In Prettyboy Watershed, where the sediment-contributing area has remained constant, the reduced sediment yield can be attributed to better land use and management.

It is not unreasonable to use the data from these two surveys as a basis for estimating the long-term effects of proper land management in the northern part of the Piedmont province. From this study it appears that erosion has been reduced 56 percent in Prettyboy Watershed and 70 percent in Loch Raven Watershed by using the land within its capability and with recommended conservation practices. Because of these changes, there has been a tremendous reduction in sediment damage to the two reservoirs and the effective life has been greatly extended.

These surveys tend to verify that which has been found many times before. The sediment yield of a watershed can be reduced to tolerable limits by applying approved conservation measures and using the land within its capability. Keeping the soil in place not only maintains and enhances soil productivity but is also the most economical way to reduce sediment damage downstream.

Appendix

A survey to determine the ground elevation above mean sea level at each of the concrete range markers at Loch Raven Reservoir was made May 9 and 10, 1961, by W. C. Sushko and aids. The water-surface elevation measured near the markers ranged from 240.58 to 240.60 feet over the reservoir. The elevation shown below is the elevation in feet of the station monument at ground surface.

Marker	Elevation	Marker	Elevation
R1	246.05	R21	241.42
R2	241.71	R22	242.04
R3	241.85	R22a	243.44
R4	244.17	R23	245.48
R5	251.75	R24	249.32
R6	241.59	R25	242.00
R7	241.53	R26	244.82
R8	241.41	R27	244.76
R9	245.40	R28	246.54
R10	241.34	R29	241.94
R11	240.84	R30	244.72
R12	241.94	R31	246.22
R13	242.38	R32	244.38
R14	241.34	R33	246.78
R15	241.67	R34	245.26
R16	241.55	R35	245.64
R17	249.14	R36	241.26
R18	242.45	R37	244.26
R19	247.06	R38	243.68
R20	241.79	R39[1]	247.02
		R40[1]	242.48

[1] Range X_1 to X_2, subsequently designated R39-40, was added 129 feet downstream from Paper Mill Bridge.

The survey measuring ground elevation at the base of the concrete range markers at Prettyboy Reservoir was made June 1, 1961. The water-surface elevation was 520.24 feet at all locations during the survey. The elevation of the 10 additional markers installed during the sedimentation survey was determined September 19, 1961, at which time the water-surface elevation near each marker was 520.10 feet.

Marker	Elevation	Marker	Elevation
R1	526.82	R20	523.26
R2	521.42	R21	522.76
R2a	526.74	R22	523.70
R3	526.04	R23	525.66
R4	522.26	R24	526.20
R5	524.90	R25	523.74
R6	523.18	R26	522.80
R7	523.38	R27	524.58
R8	520.90	R28	521.90
R8a	521.98	R29	524.96
R9	522.02	R30	523.62
R10	521.80	R31	526.72
R11	523.22	R32	522.86
R12	523.40	R33	522.10
R13	522.74	R34	523.62
R14	523.10	R35	523.36
R15	525.40	R36	523.16
R16	522.32	R37	521.60
R17	524.92	R38	523.02
R18	521.74	R39	523.14
R19	521.70	R40	524.48

USDA-SCS-HYATTSVILLE, MD. 1965