Hydrology of Two Small River Basins in Pennsylvania Before Urbanization

GEOLOGICAL SURVEY PROFESSIONAL PAPER 701-A

Hydrology of Two Small River Basins in Pennsylvania Before Urbanization

By R. ADAM MILLER, JOHN TROXELL, *and* LUNA B. LEOPOLD

With a section on OBSERVATIONS OF STREAM FAUNA

By RUTH PATRICK and ROBERT R. GRANT, JR.

URBANIZATION AND WATER RESOURCES

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Data on various hydrologic parameters are given to facilitate discerning the effects of future urbanization

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By R. Adam Miller, John Troxell, and Luna B. Leopold

ABSTRACT

Basic data on water quantity, chemical quality, and suspended sediment are tabulated to record the conditions existing in two basins near Philadelphia, each about 32 square miles in area. The basins in 1970 are agricultural land for the most part, but urban and industrial development is imminent as the Philadelphia metropolitan area expands. Hopefully, as changes caused by urbanization occur in future years, data published herein will be useful as a base for comparison.

Pickering Creek basin has a higher population than the upper East Branch Brandywine Creek basin. The two are comparable in discharge characteristics and in shapes and sizes of channels, but the Pickering Creek basin is producing a considerably larger suspended-sediment load. Also the effects of urbanization are discernible in some chemical parameters.

During the study, a small subbasin, one-half square mile in area, was converted from agricultural use to an industrial park. This change resulted in a marked increase in sulfates, nitrates, chlorides, and dissolved solids in the streamflow.

INTRODUCTION

Urbanization is known to change certain hydrologic characteristics of a river basin. Owing to construction, protective vegetative cover is destroyed, soil is exposed, and some parts of the surface are rendered impermeable. Considering the availability of relevant theory and the massive alterations of basins now underway as population increases, it is surprising how little quantitative data on the details of hydrologic changes now occurring exist. A summary of data showing the dearth of material available at this time was recently published (Leopold, 1968). Particularly inadequate is the description of the relevant factors before the effects of roads, buildings, and other land alterations became appreciable.

This report is a basic-data compilation to record, in far more detail than is generally available, the hydrologic characteristics of a presently agricultural area, on the fringe of a rapidly expanding suburban and commercial zone. Urbanization is even now, in 1970, beginning in a few spots in the area discussed, and population studies related to land planning forecast a threefold increase by 1990 and a ninefold increase by 2020 (Chester County Water Resources Authority, 1968).

Hopefully, the data in this report will be used by planners and hydrologists in the coming decades to compare future conditions with present conditions and thus help spur the evolution of sound planning procedures, which will minimize the adverse effects of development. The report has a further purpose—to describe some morphological and streamflow characteristics of small basins in the Eastern United States. Basins of a few tens of square miles in area are too large to be intensively studied as controlled experimental watersheds but are smaller than the majority of those monitored by the Federal-State network of stream-gaging and water-quality-measuring stations.

THE BASINS AND URBANIZATION

THE BASINS

Two basins are discussed here, East Branch Brandywine Creek above Dorlan, Pa. (drainage area, 33 sq mi), and Pickering Creek above Phoenixville, Pa. (drainage area, 31 sq mi). The two are nearly adjacent but drain into different main stems; the East Branch Brandywine Creek basin empties into the Delaware River estuary and the Pickering Creek basin into the Schuylkill River, itself a tributary to the Delaware. As can be seen in figure 1, the basins are on the immediate western fringe of the expanding metropolitan area of Philadelphia.

At this time the area, predominantly agricultural, serves as a residence area for persons who work in towns and small cities in or near the basins. Few of the residents commute to jobs in Philadelphia.

The area, a rolling land in which many of the hillsides are covered with a mixed second growth of Appalachian hardwoods, consists of generally open flood plains used for pasture and, near the headwaters, some relatively flat uplands which have been under cultivation for

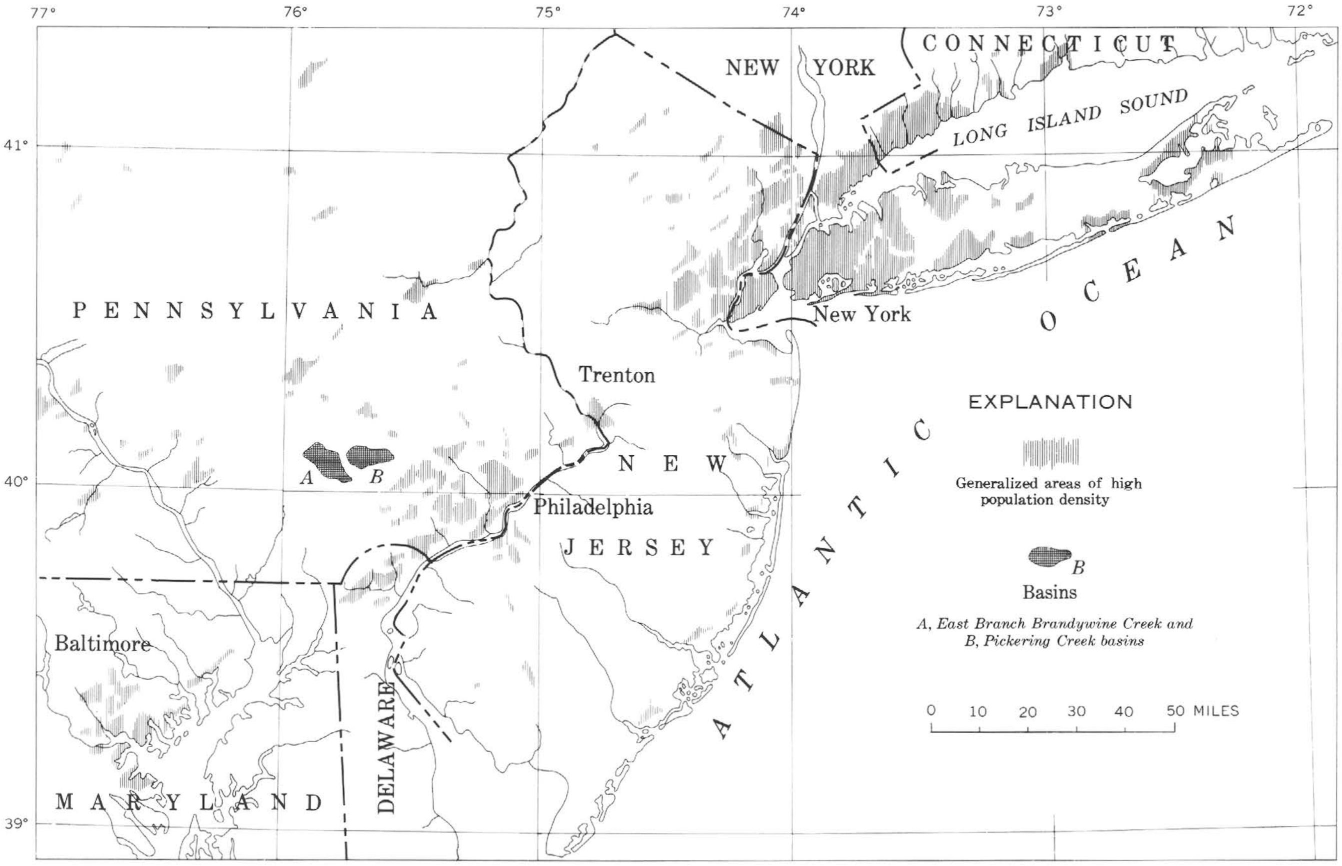

FIGURE 1.—Location of East Branch Brandywine Creek and Pickering Creek basins in relation to areas of high population density.

several generations. In the subbasins within the watersheds, forested land ranges from 7 to 40 percent, the median value being about 25 percent. Land in slopes equal to or greater than 10-percent gradient ranges from 8 to 48 percent, the median being about 25 percent. Drainage density, in miles per square mile, ranges from 0.96 to 2.82 and averages about 1.5.

The area is unglaciated, and the streams trend across a number of different rock types, mostly metamorphic and intrusive rocks but including Ordovician limestone and dolomite. These rocks tend to be weathered to some depth, but the regolith is nonuniform, and there is considerable variability in the depth of the wells serving individual homes. Because much of the land has been settled since colonial days, many of the wells are hand dug, although drilled wells having centrifugal pumps are becoming more common. There are no well-defined aquifers in the area; therefore, most of the wells tap the fissured bedrock or the local water table in the regolith and in the alluvium. The basins have an average annual precipitation of about 45 inches, and water surplus occurs throughout the period from November through May. Computations (Remson and others, 1968) by the Thornthwaite method show an average annual water surplus of about 16.7 inches. Under these conditions, typical of the humid eastern part of the United States, agriculture consists of raising beef and dairy cattle, corn grown primarily for feed, and wheat and barley for cash crops. In some places feed for fattening yearlings is imported from the West and is supplemented by the purchase of locally grown corn and silage.

THE STATE OF URBANIZATION

If the hydrologic data presented here are to be of use in defining hydrologic effects brought on by progressive urbanization, it is necessary to have as good a description as possible of the state of urbanization at the present time. This task is made difficult by the fact that, in the few studies of hydrologic effects of urbanization, no uniform method of defining the degree of urbanization has yet been evolved. Probably the best is that developed by D. Earl Jones and his associates of the Federal Housing Administration (FHA Land Planning Bull. 7) Unfortunately, their scale of land-use intensity is better adapted to describing degree of urbanization in city areas than in rural areas. On the basis of the average number of dwellings per acre, the preponderance of land in the East Branch Brandywine Creek and Pickering Creek basins has a land-use-intensity rating varying from 0.03 to 0.13, or, as given in the conversion table in figure 2, five to 20 houses per one-quarter square mile.

It is highly desirable to achieve a standard measure of land-use intensity as soon as possible so that different investigators can express such data on a common scale. Because the Federal Housing Administration's scale seems the most useful developed for urban areas at this time, we are expressing our data in the same terms, the translation being made through data on the number of houses per unit area. For the present report a picture of the areal distribution of population intensity, rather than a census, was needed and was obtained by counting the number of houses (the solid black squares) on topographic maps (U.S. Geological Survey, 1952, 1955a, b, 1956a, b, c). The density of houses counted from these topographic maps is given in figure 2. The figure, which was based on the scale of the Federal Housing Administration, also shows the geographic distribution of land-use intensity. This translation from number of houses per unit of area to the land-use-intensity scale is shown in tabular form as an insert in that figure. The general correspondence of the density of houses to the location of named villages can be seen in figure 2.

To obtain a generalized but quantitative characterization of the housing density and its variation, a grid system of lines between which the spaces represented one-quarter mile, was superimposed on the available topographic maps of the basins. The aerial photography for the maps used represents 1956 conditions. The number of houses (residences) was counted in each square a quarter square mile in area. The count showed 725 houses in the 33-square-mile upper East Branch Brandywine Creek basin, an average of five houses per quarter square mile and a standard deviation of 5. This density, one house per 32 acres, is equivalent to 0.03 on the FHA land-use-intensity scale. Interpreting the standard deviation, two-thirds of all the quarter-square-mile areas contained 5 ± 5, or zero to 10, houses. The 1956 maps of the nearby Pickering Creek basin show about 1,300 houses, an average of 8.8 per quarter square mile and a standard deviation of about 10. This density, one house per 18 acres, is equivalent to 0.05 on the FHA land-use-intensity scale. Two-thirds of all the quarter-square-mile areas contained 8.8 ± 10, or zero to 19, houses.

These density values mean that the Pickering Creek basin has an average density of houses 1.75 times that of the Brandywine, but the variation in density is larger by a factor of two. In other words, the Brandywine has a more uniform population distribution. The greater variance in the Pickering Creek basin is due, in part, to the fact that the basin includes a small part of the city of Phoenixville. The Pickering Creek basin appears to be feeling more pressure of urbanization at this time than the upper East Branch Brandywine Creek basin.

Although the number of small towns in each basin is about the same, comparison of the maps in figure 2 indicates that, generally, the Pickering Creek basin has a slightly higher density of houses. For example, excluding the areas immediately adjacent to Phoenixville, there were 1,000 residences counted in the Pickering Creek basin compared with 730 in the upper East Branch Brandywine Creek basin.

In a population study it was estimated that the upper East Branch Brandywine basin had 4,200 persons. The above data suggest then that the ratio of number of mappable houses in 1956 to the 1967 population was 1:5.8.

Some general data were obtained from landowners on the nature of agriculture. The sample, which was confined to the Pickering Creek basin, included about 5,000 of the 20,000 acres in the basin. It was, in other words, a 25-percent sample. The details are shown in table 7, near the end of the text.

The breakdown into uses of total land area in the Pickering Creek basin is approximately as follows:

	Acres	*Percentage of total*
Farms, active	8, 000	40
Estates, 5 acres or more	6, 000	30
Industries	300	1. 5
Homes, roads, villages, and other uses	5, 700	28. 5
Total	20, 000	100. 0

Of the 5,000 acres in the sample, the area used for woods, pasture, and cultivation accounted for 79 percent of the land area. These three uses accounted for 28 percent, 22 percent, and 50 percent, respectively. Thus, about 40 percent of the total land is used for cultivation and about 40 percent is woods and pasture.

In 1968 on the 5,000 acres were kept 1,555 cattle and horses—more cattle than horses—or an average of one animal per 3.3 acres in the area sampled.

The agricultural land is mostly fertilized with commercial fertilizers, varying in application from 250 to 400 pounds per acre. The incomplete tabulation shows that in 1968 a known 280 tons of fertilizer was applied. It is estimated that a total of at least 450 tons is used yearly in the Pickering Creek basin. The usual formula seems to be a 10–10–10 fertilizer. Manure is generally spread on the fields, in addition to the widespread use of commercial fertilizers.

The principal crops grown are corn, hay, and, to a lesser extent, wheat, barley, and oats. The limited data

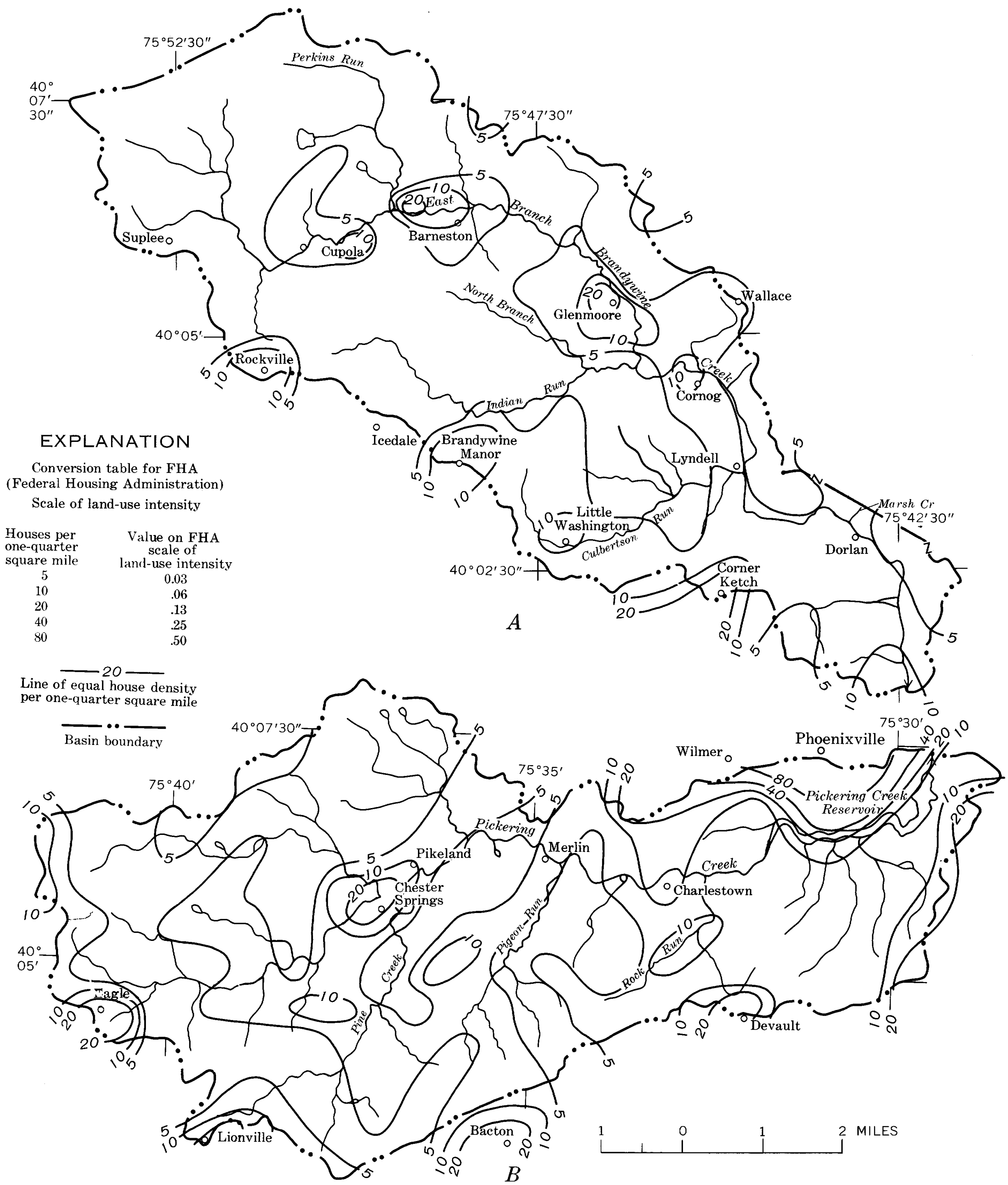

FIGURE 2.—Density of houses. *A*, Upper East Branch Brandywine Creek basin; *B*, Pickering Creek Basin. Number of houses counted per one-quarter-square-mile grid on topographic maps (U.S. Geological Survey, 1952, 1955a, b, 1956a, b, c).

suggest that 43 percent of the cultivated acreage is in corn, 49 percent in hay, and 8 percent in other crops. Much of the crops is used on the farm as food for stock.

THE STUDY

ORIGIN OF THE INVESTIGATION

The basic data in this report were collected as part of a project in urban planning, conceived and directed by the Institute for Environmental Studies of the University of Pennsylvania under the leadership of Ann Louise Strong. The planning project involved the development of a land-use plan for the upper East Branch of Brandywine Creek, subsequently published by the Chester County Water Resources Authority (1968). The plan was premised on the delineation of areas within the basin which would be protected from further development, though these protected areas would remain in private ownership and present land uses and occupancy would continue as in 1968. The lands visualized as needing protection from further housing or commercial development are of three types: (a) flood plains, (b) a buffer strip extending 300 feet on either side of all major and minor stream channels, and (c) areas of steep slopes and woods. These three types of land would constitute a Water Resources Protection District, comprising a total of 46 percent of the basin area. On the remaining 54 percent of the area, development would be permitted but only under the zoning regulations established by local government bodies.

To preserve the esthetic character of the countryside, the plan envisioned that the protected area would form a network of green space or open space fingering through the basin along the stream network. It was reasoned that concentration of development in the area outside the Water Resources Protection District would bring higher land values, owing to the existence of nearby undeveloped and protected land. It was hoped that the result would be no net loss but perhaps a net gain in property values and income in the county.

The principal legal means of achieving the planned protection was the purchase of easements from landowners, based on a realistic appraisal of the effects of the restrictions on land values. The sale of such easements by landowners was to be voluntary, but the easements were to be permanent and attached to the property deed.

The establishment of the Water Resources Protection District, premised on scientific principles insofar as they are presently known, was aimed at maintaining the quality of the water resources, the natural hydrologic functioning of the watershed, and the esthetic amenities.

Meetings, lectures, field trips, conferences, and personal visits attempted not only to acquaint the landowners with the proposals but to explain the details of the easements and the principles on which the plan was constructed. The final plan was printed and distributed. However, the majority of landowners declined, and the project was therefore abandoned.

The hydrologic studies instituted at the beginning of the planning effort were designed to establish the principal hydrologic characteristics of the basin in its present condition and to furnish basic data against which changes with time could be compared. Because the land-use plan was to apply only to the upper East Branch of Brandywine Creek, the nearby Pickering Creek basin was studied as a control .The present report presents the basic data and, in addition, provides an opportunity to discuss certain morphological features of the stream channels and the water resources.

The program of hydrologic-data collection was financed jointly by the Ford Foundation and the U.S. Geological Survey. The Ford Foundation and the Pennsylvania Department of Forest and Waters supported the other parts of the planning effort.

PLAN OF THE HYDROLOGIC STUDY

At each of several stream points representing a range of drainage area in both the upper East Branch Brandywine and Pickering Creeks, observations were made of discharge or water stage and suspended sediment, and samples of water were taken periodically for quality analysis. At two of the points in each basin, a water-stage recorder was installed. At the other points, a staff gage was installed. Each station having either a recorder or a staff gage installed was rated by current-meter measurements made at a variety of discharges. The location of all measuring points is shown in figure 3, and their names and drainage areas appear in table 1.

The water samples for chemical-quality analysis were taken at each station periodically to obtain a picture of seasonal variation. Several samples were obtained during one storm to indicate short-term changes with discharge. The same methods governed the sampling of suspended sediment.

Two channel cross sections were surveyed in the Pickering Creek basin, and 14 were surveyed in the Brandywine Creek basin. No resurveys were made. Copies of these data will be filed in the International Repositories for Vigil Network Data in Washington, D.C., and Uppsala, Sweden. These repositories preserve original survey data, so that many years hence different investigators can find the original bench marks and resurvey the sections.

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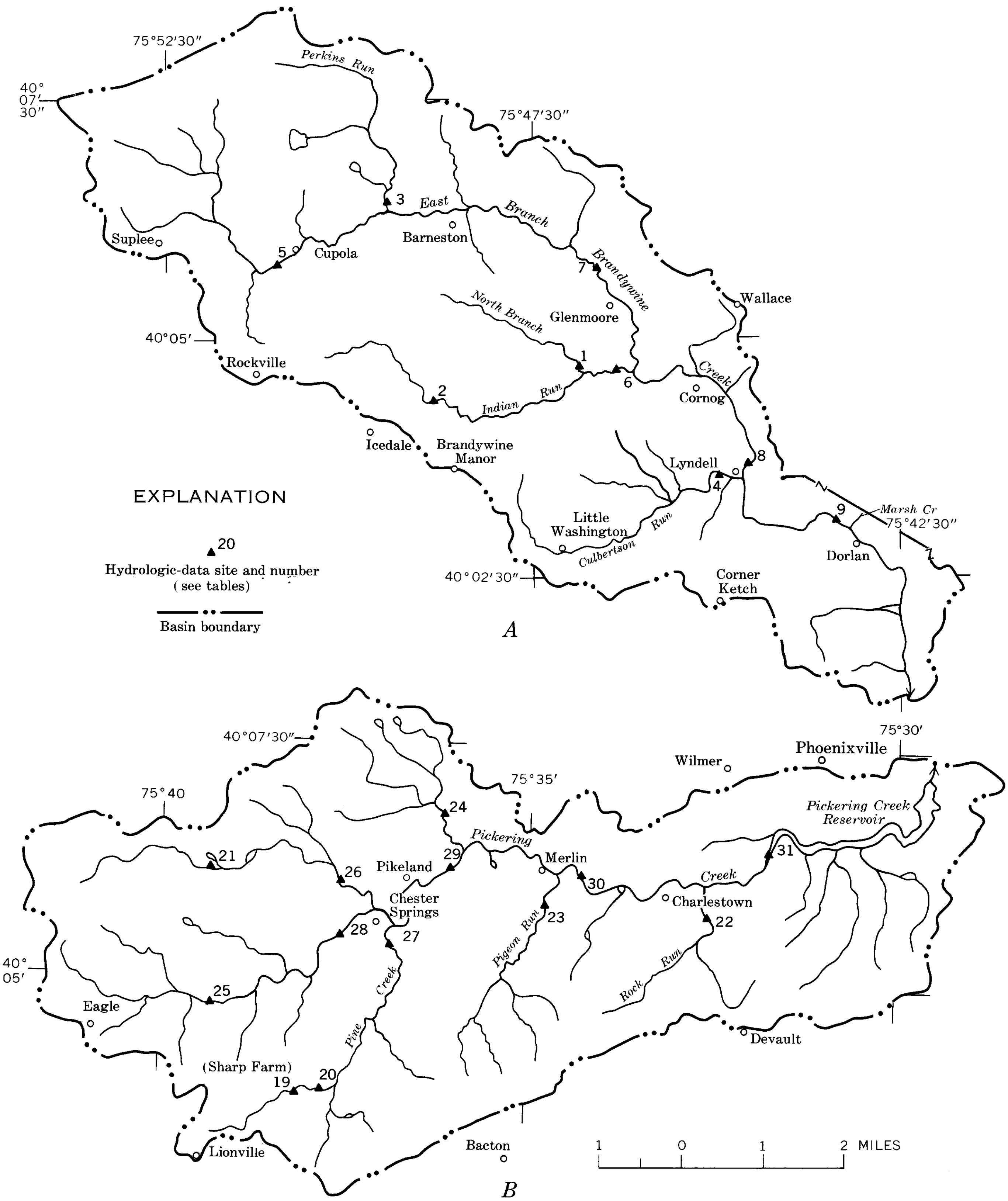
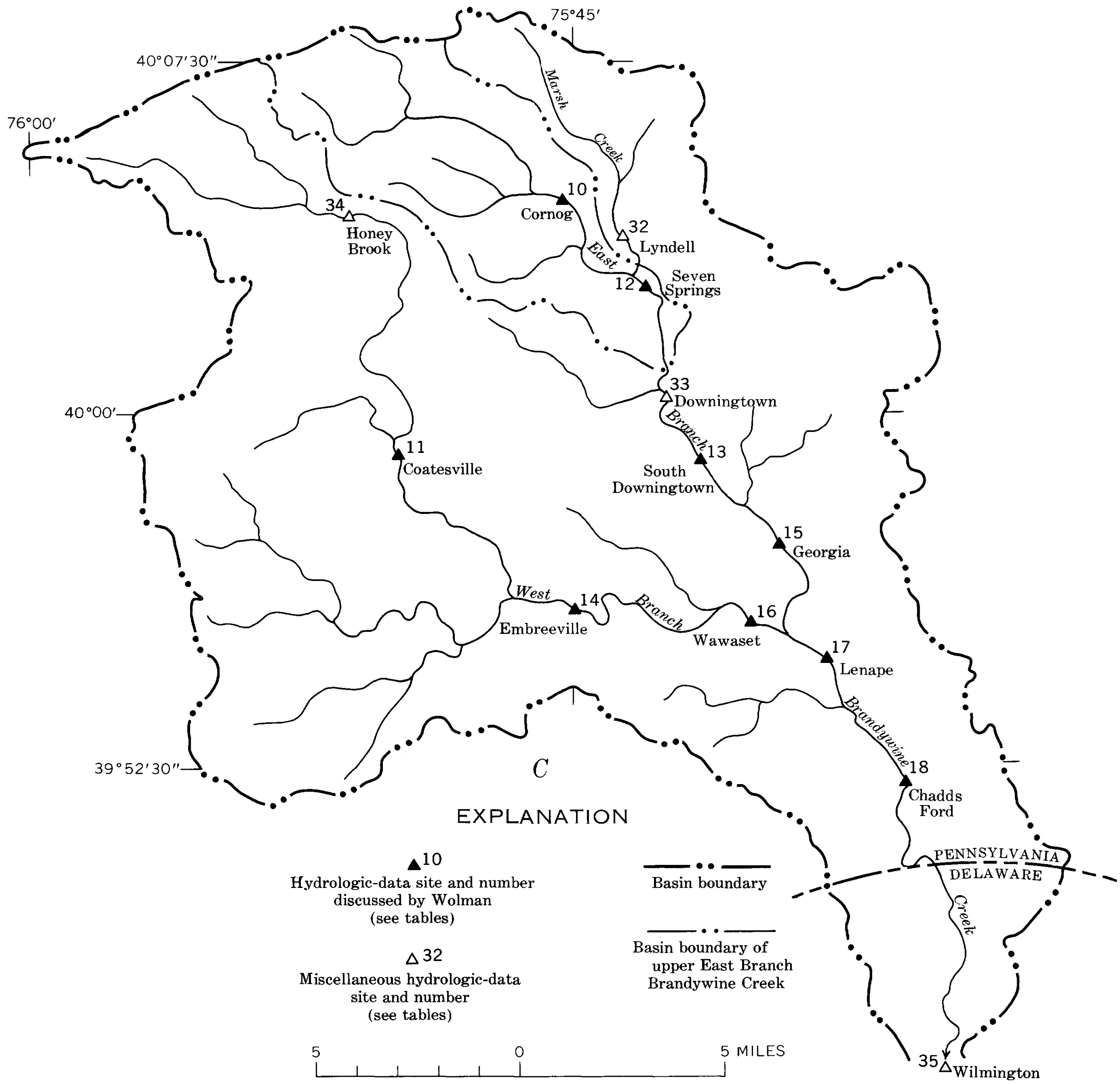


FIGURE 3.—Location of hydrologic-data sites. *A*, Upper East Branch Brandywine Creek basin; *B*, Pickering Creek basin; *C* (facing page), Brandywine Creek basin.



The approach to the ground-water problem was dictated by the short period of investigation, 2 years. In such a short timespan, observation of water level in wells would have little interpretive value. Therefore, we chose a nonstorm period of low flow, when the streamflow consisted entirely of ground water feeding the channel, and obtained discharge measurements and water-quality samples for each unit area of about 1 square mile. These data indicate the areal variation of quantity of the overflow of the ground-water reservoir and the associated water quality.

The stream biota was sampled at several places, not necessarily at each gaging location. A discussion of the results is near the end of the text, and the data are tabulated in table 11.

ORGANIZATION OF THE REPORT

The discussion of each hydrologic parameter includes not only the data from individual measuring points but also the interrelation within the basins. For example, the flow characteristics are discussed first for individual stations and then for the basins as a whole. A later

TABLE 1.—*Measuring points in Brandywine Creek and Pickering Creek basins and the associated average annual flow and estimated bankfull characteristics*

[Average annual discharge: Estimated from fig. 4 except for stations having a continuous-stage recorder]

No. in fig. 3	Station	Drainage area (sq mi)	Average annual discharge (cfs)	Estimated bankfull Q 1.5-yr recurrence interval (cfs)	Hydraulic values at 1.5-yr recurrence interval			
					Width (ft)	Depth (ft)	Velocity (fps)	Slope (ft per ft)
	Upper East Branch Brandywine Creek basin (fig. 3*A*)							
1	North Branch at Glenmoore	1.6	1.4	78				0.0176
2	Indian Run at Germany Hollow Road	2.0	1.8	92	22	1.5	2.6	.0095
3	Perkins Run at Rose Cottage	3.7	3.4	156	19	2.5	3.3	.020
4	Culbertson Run at Lyndell	3.9	3.8	163	39	2.8	2.5	.0148
5	East Branch Brandywine at Cupola [1]	6.2	5.8	230	43	2.5	2.1	.00625
6	Indian Run at Glenmoore	6.3	5.8	230	31	2.1	4.0	.0143
7	East Branch Brandywine at Glenmoore	16.5	17.0	510				.004
8	East Branch Brandywine at Lyndell	27.1	28.0	740	52	3.2	4.0	.00456
9	East Branch Brandywine at Dorlan [1]	33.4	35.0	890	61	2.7	5.6	.00267
	Brandywine Creek basin (fig. 3*C*), Wolman's data (1955)							
10	East Branch Brandywine at Cornog	25.7		720	50	2.6	6.0	0.0034
11	West Branch Brandywine at Coatesville [1]	45.8		1,150	120	2.2	4.0	.0018
12	East Branch Brandywine at Seven Springs	54.2		1,300	80	3.8	4.6	.0026
13	East Branch Brandywine at South Downingtown	86.0		2,000	60	4.4	7.5	.0008
14	West Branch Brandywine at Embreeville	117.0		2,500	85	4.4	6.2	.0005
15	East Branch Brandywine at Georgia	118.0		2,500	90	4.8	4.8	.0006
16	West Branch Brandywine at Wawaset	134.0		2,900	70	4.8	7.5	.001
17	Brandywine at Lenape	259.0		5,100	130	7.0	6.0	.00075
18	Brandywine at Chadds Ford [1]	287.0	375.0	5,600	170	5.5	6.0	.00066
	Pickering Creek basin (fig. 3*B*)							
19	Pine Creek at Sharp Farm	0.5	0.4	35	13	1.5	1.5	0.0143
20	Pine Creek near Lionville	1.1	1.0	63	5.7	.6	1.8	.0167
21	Tributary Pickering at Art School Road	1.9	1.7	93	12	2.2	3.4	.0100
22	Rock Run at Charlestown	2.6	2.4	120	26	1.6	2.8	.0235
23	Pigeon Run at Merlin	2.8	2.7	130	24	2.0	2.9	.0050
24	Tributary Pickering near Kimberton	3.1	2.8	140				.0118
25	Pickering near Eagle	3.1	2.8	140				.005
26	Tributary Pickering at Chester Springs	4.3	4.0	180				.0077
27	Pine Creek at Chester Springs	5.1	4.8	210	19	2.2	4.6	.0182
28	Pickering near Chester Springs [1]	6.0	5.7	260	17	3.8	4.2	.0038
29	Pickering at Pikeland	17.7	18.0	550				.0021
30	Pickering at Charlestown	26.0	28.0	730				.0037
31	Pickering near Phoenixville [1]	31.4	34.0	840	90	1.7	5.4	.0033
	Other locations							
32	Marsh Creek near Lyndell [1]	17.8	19.6					
33	East Branch Brandywine Creek at Downingtown [1]	81.6	85.0					
34	West Branch Brandywine Creek near Honey Brook [1]	18.7	19.4					
35	Brandywine Creek at Wilmington [1]	314.0	435.0					

[1] Site of continuous-stage recorder.

section (p. A11) contains a discussion of sediment characteristics at individual stations and for the basins as a whole. However, the basic data in tables 7, 8, and 11 are grouped by individual stations—all observations of flow, sediment, chemical quality, and others compiled for each station location. In the interpretive sections near the end of the report, some generalizations are made and our impressions are summarized.

SURFACE-WATER HYDROLOGY

DRAINAGE AREA–DISCHARGE RELATIONSHIPS

Gaging stations at Wilmington and upstream locations in the Brandywine Creek basin have varying lengths of records; one record covers nearly 50 years. The mean annual discharge computed from the long-term records is plotted against the respective drainage areas in figure 4 (solid line). Generally, for natural basins, this plot is linear on log-log paper and has a slope of approximately 1.0; in the plot of figure 4, the graph is linear and has a slope of 1.1, an agreement which is satisfactory considering the fact that only five long-term gaging stations are available for constructing the relationship. Two stations, 5 and 32, each having about 9 months of record, have been added to the plot to demonstrate the relationship even at small drainage areas.

Generally in the Middle Atlantic States the mean annual flow is on the order of 1 cfs (cubic foot per second) per square mile of basin area in basins of the magnitude of 100 square miles. Reading off the curve in figure 4, one notes a discharge of 1.2 cfs per square mile for basins of 100-square-mile area.

The upper dashed curve of figure 4 represents flow having a recurrence interval of 1.5 years as a function

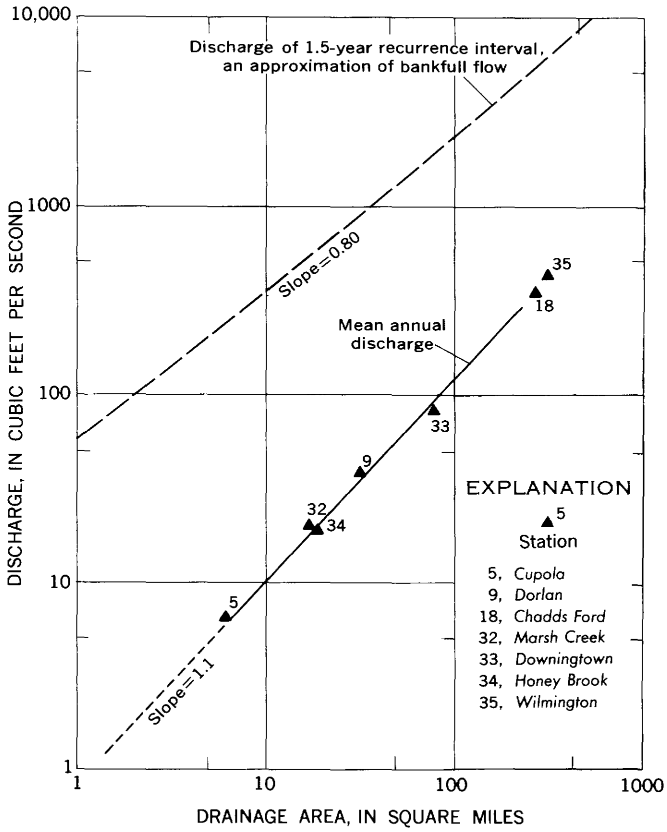


FIGURE 4.—Discharge as a function of drainage area, for mean annual flow and for flow having a recurrence interval of 1.5 years.

of drainage area. Flow of this frequency of occurrence is considered an approximation of bankfull condition. Data for this graph are from published curves for the State of Pennsylvania (Busch and Shaw, 1960). Generally such lines representing the relation of flow of a given recurrence interval to drainage area are linear on log-log paper and have a slope between 0.7 and 0.8. In figure 4 the dashed line has a slope of 0.80 as expected. The discharges represented by this dashed line are those equaled or exceeded on the average of once every 1.5 years or 2 out of 3 years in the annual maximum series.

From these curves can be read estimates of the mean annual flow and the bankfall discharge for the project locations; these estimates are in table 1. That the flood which fills the channel to bankfull stage has a recurrence interval of 1 to 2 years, or an average of 1.5 years, has been demonstrated by previous analyses (Leopold and others, 1964, p. 320–321).

For the record, data are tabulated below from which the curves relating mean annual flood, drainage area, and recurrence interval may be reproduced. These data were obtained by extrapolation from the published curves of Busch and Shaw (1960), which differ slightly from the regional flood-frequency curves for Pennsylvania of Tice (1968).

Ratio to mean annual flood	Recurrence interval (yr)	Drainage area (sq mi)	Mean annual flood (cfs)
0.45	1.1	0.5	44
.71	1.5	1.0	75
.91	2.0	10.0	480
1.00	2.3	100.0	2,900
1.45	5.0		
1.89	10.0		

AT-A-STATION HYDRAULIC GEOMETRY

What has proven to be a useful way to organize a mass of hydraulic data from a drainage system is to plot channel and flow parameters against different discharges to observe how the channel at one location accommodates the rise and fall of flow during a storm. This relationship is called the hydraulic geometry of the stream at a station, or at a given cross section. In simplified form the geometry is described by the relation of width, depth, and mean velocity to various discharges. These relations are developed from individual current-meter measurements at the location (Leopold and others, 1964, p. 215–219). A single station, Indian Run at Glenmoore, is presented in figure 5 as an example.

The curves show the expected power-function relation of discharge to the three variables—that is, a straight-line relation on log-log paper. As flow at the station increases from the mean annual value, 5.8 cfs, to the bankfull condition, 230 cfs, the width of the flowing water increases from 16 to 31 feet. Simultaneously the depth goes from 0.7 to 2.1 feet, and the velocity from 0.53 to 3.9 fps (feet per second).

To satisfy continuity, the product of width, depth, and velocity must equal the discharge. Thus, the sums of the slopes of the three graph lines must equal unity. The respective slopes are 0.19, 0.29, and 0.54, the sum of which is 1.02, having 2-percent error for the lines drawn through the points by eye. Experience has shown this to be satisfactory agreement.

To compare these relations with others, we can turn to the previous detailed study of the Brandywine Creek basin (Wolman, 1955) and compare the slope values of the at-a-station curves. Values from this study, values derived from theory, and average values for basins studied in the United States (Leopold and Maddock, 1953) are shown below. It can be seen that the values found in the present project are of the expected order of magnitude.

Source of data	At-a-station curve exponents		
	Width, b (ft)	Depth, f (ft)	Velocity, m (fps)
This study, 15 stations from groups A and C, table 2	0.23	0.34	0.43
Main stem of Brandywine Creek, Wolman (1955) data, seven stations (revised)	.04	.41	.55
Average values for the United States (Leopold and Maddock, 1953)	.26	.40	.34
Values from theory (Langbein, 1966)	.23	.42	.35

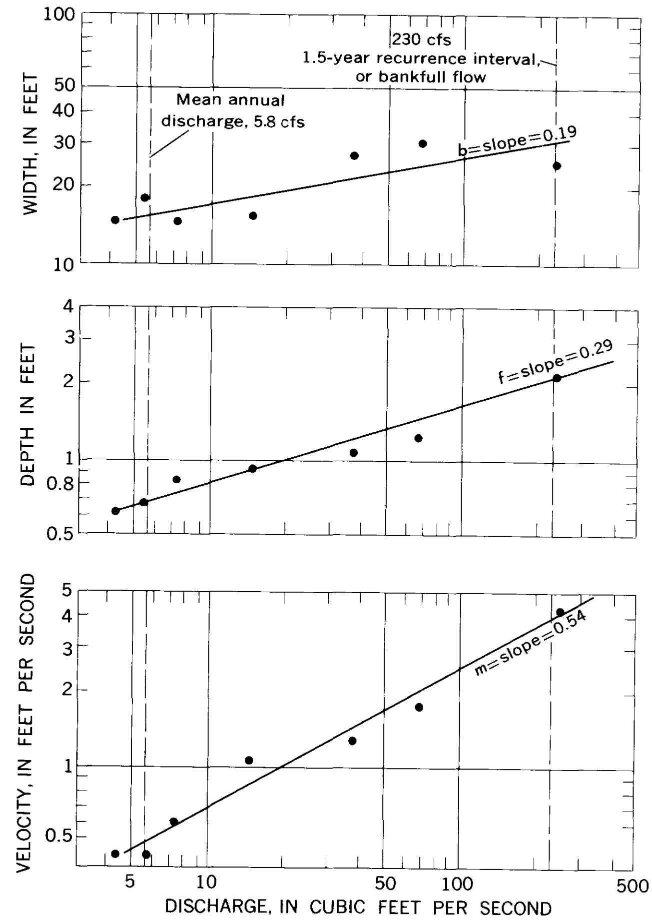


FIGURE 5.—At-a-station hydraulic geometry, Indian Run at Glenmoore.

The slopes of the regression lines in the plots of width, depth, and velocity as functions of discharge at the individual stations are shown in table 2.

THE DOWNSTREAM HYDRAULIC GEOMETRY

Of special interest to the student of river channels is the change downstream along a river system, because there are so few basins in the world within which a series of measurements have been made along the channel system. The present project data added to the observations made in the Wolman study of 1955 make the Brandywine an especially well-documented small basin in the number of comparable hydraulic measurements along the channel network.

The downstream analysis can be made for flows of any chosen recurrence interval (frequency). One of the flow-frequency values of interest is that corresponding to bankfull condition, approximated in this study by the recurrence-interval value of 1.5 years. The values of discharge at this frequency were read from figure 4 and are tabulated in table 1.

In a manner similar to the at-a-station relations, the downstream changes of width, depth, and velocity as discharge increases owing to the addition of tribu-

TABLE 2.—*At-a-station data for the Brandywine Creek and Pickering Creek basins*

		At-a-station curve exponents		
No.	Station	Width, *b* (ft)	Depth, *f* (ft)	Velocity, *m* (fps)
	A. Upper East Branch Brandywine Creek basin			
1	North Branch at Glenmoore			
2	Indian Run at Germany Hollow Road	0.16	0.30	0.52
3	Perkins Run at Rose Cottage	.18	.34	.46
4	Culbertson Run at Lyndell	.38	.44	.20
5	East Branch Brandywine at Cupola [1]	.24	.34	.41
6	Indian Run at Glenmoore	.19	.29	.54
7	East Branch Brandywine at Glenmoore			
8	East Branch Brandywine at Lyndell	.12	.36	.52
9	East Branch Brandywine at Dorlan [1]	.15	.32	.52
	Average, group A	.20	.34	.45
	B. Brandywine Creek basin, Wolman (1955) data			
10	East Branch Brandywine at Cornog	0.04	0.40	0.52
11	West Branch Brandywine at Coatesville [1]	.22	.30	.48
12	East Branch Brandywine at Seven Springs	.05	.45	.48
13	East Branch Brandywine at South Downingtown	.04	.36	.61
14	West Branch Brandywine at Embreeville	.02	.39	.59
15	East Branch Brandywine at Georgia	.02	.29	.69
16	West Branch Brandywine at Wawaset	.05	.42	.53
17	Brandywine at Lenape	.08	.46	.46
18	Brandywine at Chadds Ford [1]	.16	.45	.42
	Average, group B	.08	.39	.53
	C. Pickering Creek basin			
19	Pine Creek at Sharp Farm	0.55	0.38	0.08
20	Pine Creek near Lionville	.36	.48	.16
21	Tributary Pickering at Art School Road	.18	.45	.37
22	Rock Run at Charlestown	.13	.22	.66
23	Pigeon Run at Merlin	.36	.35	.30
24	Tributary Pickering near Kimberton			
25	Pickering near Eagle			
26	Tributary Pickering at Chester Springs			
27	Pine Creek at Chester Springs	.11	.30	.60
28	Pickering near Chester Springs [1]	.09	.44	.47
29	Pickering at Pikeland			
30	Pickering at Charlestown			
31	Pickering near Phoenixville [1]	.22	.09	.69
	Average, group C	.25	.34	.42
	Average, groups A, B, and C	.17	.36	.47
	Average, groups A and C	.23	.34	.43

[1] Site of continuous-stage recorder.

taries can be plotted from the data in table 1 and are presented in figure 6. The same relation of slopes of the lines is required for the downstream as for the at-a-station relations, which is that the sum must equal unity. The respective slopes of the lines are 0.47, 0.27, and 0.26.

The average channel slope as measured on topographic maps was determined for each station and tabulated in table 1. These slope values were plotted against bankfull discharge (fig. 7). The resulting plot has a slope of −0.87.

The following table enables the comparison of the values of the Brandywine downstream hydraulic geometry with values of other river systems and with theoretical values.

River systems	Downstream hydraulic-geometry exponents			
	Width, b (ft)	Depth, f (ft)	Velocity, m (fps)	Slope, z (ft per ft)
Average value, Midwestern United States [1]	0.5	0.4	0.1	−0.49
Brandywine Creek, Pa., Wolman's report [1]	.42	.45	.05	−1.07
Ephemeral streams in semiarid United States [1]	.5	.3	.2	−.95
Appalachian streams [1]	.55	.36	.09	
Theoretical value [2]	.50	.38	.12	−.55
Present Brandywine study	.47	.27	.26	−.87
18 Illinois basins, mean [3]	.48	.36	.16	

[1] Leopold, Wolman, and Miller (1964).
[2] Langbein (1966).
[3] Stall and Fok (1968).

The width exponent for the present study is fairly close both to the width exponents derived from other studies and to the theoretical value of 0.50. The depth exponent is smaller and the velocity exponent is significantly larger than in most of the other river systems.

SUSPENDED-SEDIMENT DATA

There are few basins where the density of stations for collecting suspended-sediment samples is greater than in the project area. The individual samples must be organized in some uniform manner which

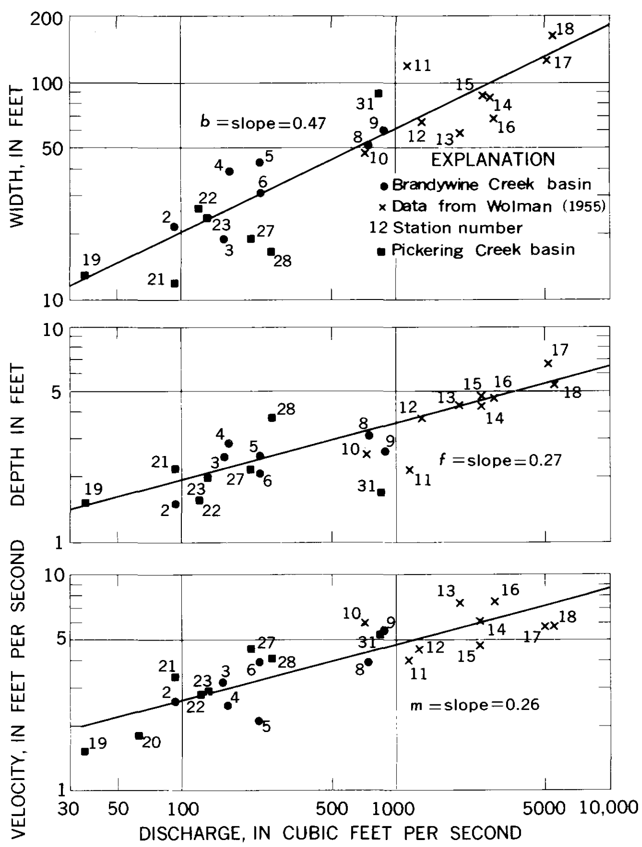


FIGURE 6.—Downstream hydraulic geometry for the Brandywine Creek and Pickering Creek basins. Recurrence interval of 1.5 years, approximate bankfull discharge.

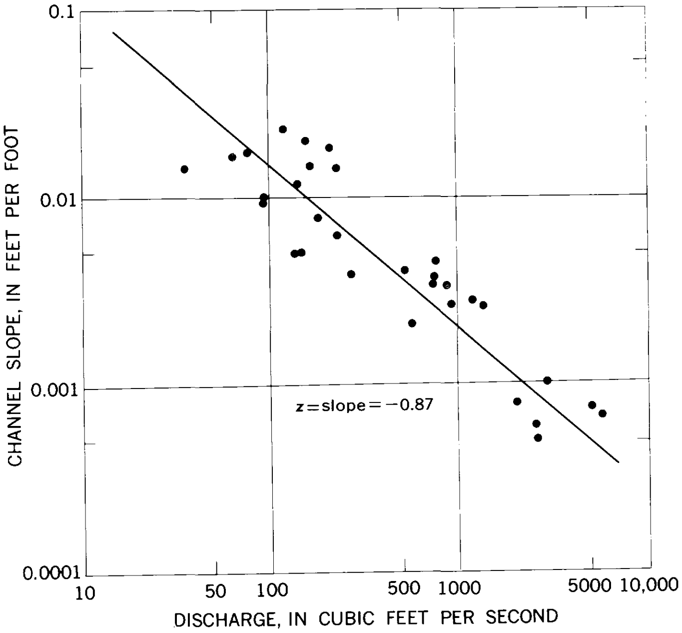


FIGURE 7.—Relation of channel slope to discharge of 1.5-year recurrence interval for upper East Branch Brandywine Creek and Pickering Creek basins.

generally takes the form of a relation of sediment load to discharge at a given station. The instantaneous sediment concentration represented in the water-sample bottle is ordinarily expressed as a rate per day though the sample was a momentary condition. The concentration in the bottle, in milligrams per liter by weight, is multiplied by the discharge, in cubic feet per second, and by a constant to yield sediment flow rate, in tons per day. The constant used here is for deposited sediment of 80 pounds per cubic foot, and thus 1,000 mg/l (milligrams per liter) in a discharge of 1.0 cfs yields 3.46 tons per day. In equation form, $L=KCQ$, where L is sediment flow rate, in tons per day, K is a constant equal to 0.00346, C is sediment concentration, in milligrams per liter, and Q is water discharge, in cubic feet per second.

A typical sediment transport curve is presented in figure 8 for Pickering Creek near Phoenixville. Each point on the graph represents a single sample, and the suspended-sediment discharge, in tons per day, is plotted against the instantaneous discharge of water. The slope of this line is an element in the hydraulic geometry of stream channels. The slope of the line in figure 8, represented by the exponent j in the relation

$$L \sim Q^j,$$

where L is load, in tons per day, $\sim$ is a proportionality constant, and Q is discharge, has a value of 2.7 and is recorded in table 3. The usual range of values for this

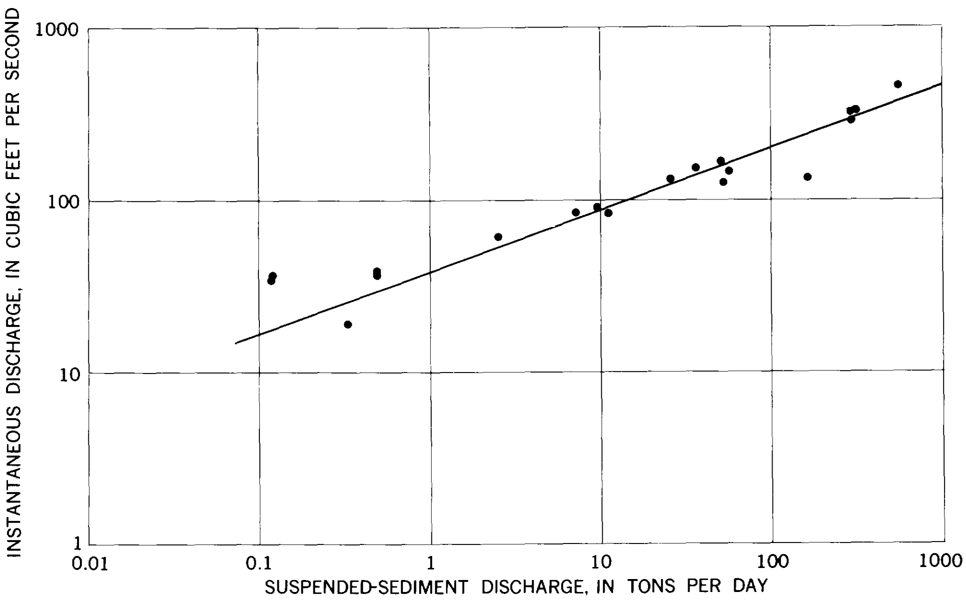


FIGURE 8.—Transport curve for suspended-sediment load at Pickering Creek near Phoenixville.

exponent (slope) is 1.5–3.0. The graph shown is therefore typical of many river data.

TABLE 3.—*Slope of the sediment transport curve for various stations*

No.	Station	Slope of sediment transport curve, *j*
2	Indian Run at Germany Hollow Road	1.8
3	Perkins Run at Rose Cottage	2.0
4	Culbertson Run at Lyndell	3.1
5	East Branch Brandywine Creek at Cupola	2.3
6	Indian Run t Glenmoore	1.8
9	East Branch Brandywine Creek at Dorlan	2.4
19	Pine Creek at Sharp Farm	2.7
21	Tributary Pickering Creek at Art School Road	2.8
22	Rock Run at Charlestown	2.8
23	Pigeon Run at Merlin	3.0
24	Tributary Pickering Creek near Kimberton	2.0
26	Tributary Pickering Creek at Chester Springs	3.1
27	Pine Creek at Chester Springs	2.7
28	Pickering Creek near Chester Springs	2.7
31	Pickering Creek near Phoenixville	2.7

The several sediment transport curves for locations in the project area are shown in figure 9, including the curve for the long-term record at Wilmington.

The slopes of respective sediment transport curves are very similar. Only stations 2 and 6 have a low slope—that is, a less than usual rise of suspended load to increased discharge. As shown in figure 9, the quantitative comparison among stations is difficult with superimposed sediment transport curves because as drainage area increases, so does the expected discharge for any given frequency. Thus, if one reads the sediment load at a given discharge, the large drainage areas show a lower value than the small areas because the given discharge may be a low flow for the large areas and a floodflow for the small areas.

A valid mode of comparison is to read the sediment load from each transport curve at a discharge of a given frequency or recurrence interval. This has been done for discharges approximating bankfull (1.5-year recurrence interval) listed in table 1. Figure 10 is a plot of sediment load for each station at bankfull. If the points alined along a 45° slope, the sediment concentration would remain the same as you travel downstream in the basin. Instead the points scatter considerably. However, it can be seen that points showing high sediment loads include stations 19, 22, and 23 of the Pickering Creek basin and only station 4 of the Brandywine. Points showing less than average sediment loads include stations 2, 3, 5, 6, and 9, all in the East Branch Brandywine and none in the Pickering. The area on Pine Creek at Sharp Farm which, in 1968, was changed from agricultural use to industrial use, is shown by station 19, an especially high sediment load for its discharge. Culbertson Run at Lyndell (station 4) is also high, probably because of housing construction near Little Washington. Generally, it appears that Pickering Creek is producing more suspended sediment than comparable places in upper East Branch Brandywine.

FLOOD PLAINS AND TERRACES

As previously mentioned, several cross sections were established and surveyed in hopes of determining at a later date what effect urbanization would have on the geometry of the channel. As a further step we wished

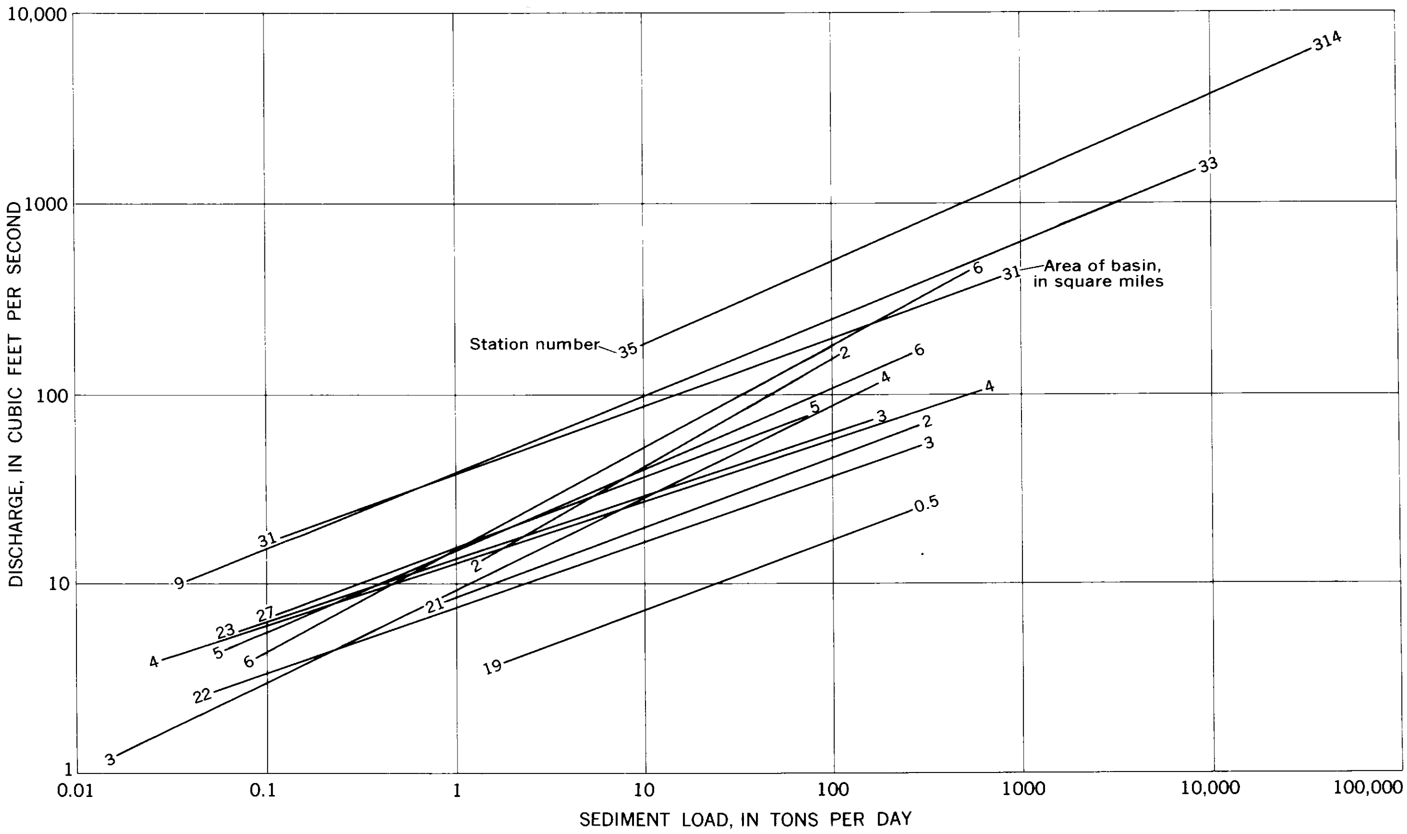


FIGURE 9.—Transport curves for suspended-sediment load at hydrologic-data sites in upper East Branch Brandywine Creek and Pickering Creek basins.

to determine the meaning of the several berms at various places along the channels.

A valley cross section includes two principal elements—the valley flat and the channel. The valley flat often consists of more than one level, the level presently being built by the river, which is called the flood plain, and levels constructed during former stream regimens. The latter, called berms, are abandoned flood plains or terraces. They may be broad and conspicuous level areas, or merely small and obscure features.

The flood plain, a product of the riverflow and sediment load, is considered to be intimately related to bankfull discharge, which is believed to be the discharge effective in channel formation. Basically, the flood plain is constructed by two processes—deposition on the inside of the river curves and, to a lesser degree, overbank deposition (Wolman and Leopold, 1957). Thus, as a stream migrates across a valley floor, it leaves behind a flat bench, the flood plain.

A change in stream regimen and channel-forming discharge can result from several causes, including tectonic, climatic, and man-induced changes. Among the man-induced changes is alteration of the basin by urbanization. When the dominant (channel-forming) discharge is increased, entrenchment or incision of the river may occur. Once again, as the stream migrates across the valley floor, a new valley flat is formed. Since the new valley flat is related to the new dominant discharge and new channel, it is at a lower level than the previous valley flat. Meanwhile, the old valley flat

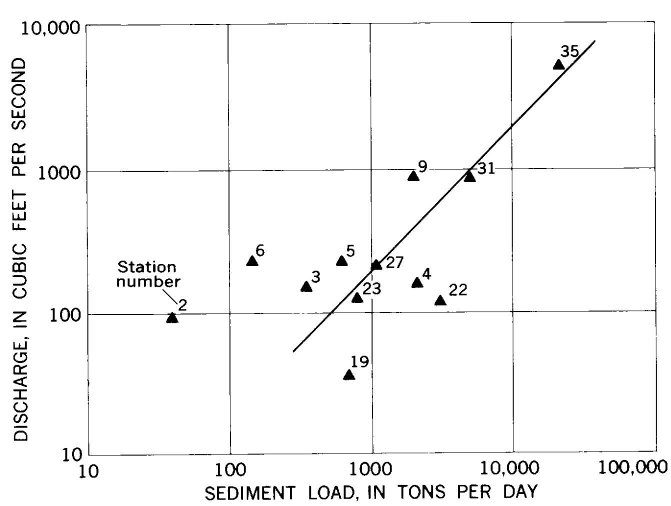


FIGURE 10.—Sediment load at each station for a discharge of 1.5-year recurrence interval.

may or may not be left as a terrace or a berm, depending on the limits of the lateral migration of the stream during its latest regimen.

Close inspection of the immediate area of the small channels in the Brandywine area shows that berms or level zones appear fairly close to the channel. Depending on location, these berms may be difficult to recognize, or they may not appear at all. If the berms are a part of the present channel, then the width and depth of water whose surface is coincident with the berm level should be correlative with other channel characteristics, such as dominant discharge and downstream hydraulic geometry. The problem discussed here is the identification of the true flood plain and its relation to abandoned flood plains or terraces.

Photographs in figure 11 show the berms or local flat levels near the channel in the study area. These berms are subtle rather than pronounced, but many of them can be traced rather consistently along considerable distances.

The berms also show up on some of the cross sections which were surveyed and documented. The upper graph in figure 12 shows the channel and valley cross section for Indian Run at Germany Hollow Road. In the cross section, the berm that appears at an elevation of 98 feet and a distance of 60 feet is the low berm. The high berm appears at elevation 98.7 feet and distance 35 feet.

At each field location inspected, the extant levels or berms were identified, and some simple measurements were made. At most locations two levels were usually apparent, a valley floor reaching to adjoining colluvial slopes and an inner level confined to narrow commonly discontinuous segments near the stream channel. For present purposes, these two are called the high and low berms. It is believed that one of these two is the flood plain being constructed by the present stream regimen. The narrowness of the low berm suggests that it may be a transient and perhaps unimportant feature, in which case the main valley flat (high berm) is the flood plain. On the other hand, the valley flat could be a terrace and the present flood plain could still have formed to only a slight degree below the abandoned level and is therefore just a narrow band along the channel. As an approach to the identification of the present flood plain, cross-sectional data are used below to estimate discharge at the level of each berm, and the recurrence interval of the discharges is estimated. The objective is that the level of the flood plain should be such that the recurrence interval of discharge would approximate 1.5 years.

Table 4 shows channel width and depth for the water level even with the surfaces of the high and low berms. From these basic data, cross-sectional area is estimated for each berm level. The velocity was ascertained by combining two previously presented relationships: (1) the velocity-discharge correlation, shown in the downstream hydraulic geometry, and (2) the discharge–drainage-area relationship. The resulting velocity–drainage-area relationship was then used to determine the velocity at each station. Multiplying the cross-sectional areas times the velocity gave an estimate of the discharge at each of the two berm levels.

The results of the computations are plotted on the lower graph in figure 12. The low berm is denoted by an "x", and the high berm is denoted by a circle. Superimposed are the regional curves for floods of recurrence intervals of 1.5, 2.33, and 10 years. It is easily seen that the calculated discharges of most of the low berms have regional recurrence intervals varying between 1.5 and 2.33 years. The high berm has a variable recurrence interval, from about 10 years at 1 sq mi to 2.33 years somewhere between 100 and 300 sq mi.

Although the estimates are only rough, the recurrence-interval data suggest that in the upper East Branch Brandywine Creek basin the channels have abandoned the level of the main valley flat, leaving it as a terrace, and are constructing a new flood plain at the level of the low berm.

As the drainage area increases in size, the two berms converge hydraulically—that is, the discharges calculated for the berms converge in the downstream direction. As was observed in the field and as can be seen in table 4, there is no obvious converging of the berms in terms of either depth or width. The hydraulic convergence must be due to either channel slope or roughness.

The above estimates are derived from basic data on the channel cross section at the levels of observed

FIGURE 11.—Typical reaches of streams in upper East Branch Brandywine Creek and Pickering Creek basins; the subtle character of two berms or levels of the valley floor is seen in some photographs. *A*, East Branch Brandywine Creek at Downingtown, downstream from the main study area; near the far streambank a narrow flat area can be seen that is a few feet lower than the more extensive valley flat on which are the houses in the background. The narrow bench near the stream is the low berm, and the higher more extensive flat is the high berm. *B* and *C*, East Branch Brandywine Creek at Dorlan; the high berm is the more extensive wooded valley flat, and near the stream is a lower narrow flat area, the low berm. *D*, Pigeon Run near Merlin; typical land use in the agricultural areas of the Pickering Creek basin. In the right foreground, at the most visible downstream part of the channel, is the low berm. *E*, Pickering Creek near Phoenixville; nonurban use; pasture near the stream and crop-producing field on the far right. *F*, East Branch Brandywine Creek at Glenmoore; nonproducing land on the upper East Branch Brandywine. Nearby flat lands are used for farming.

A

B

C

D

E

F

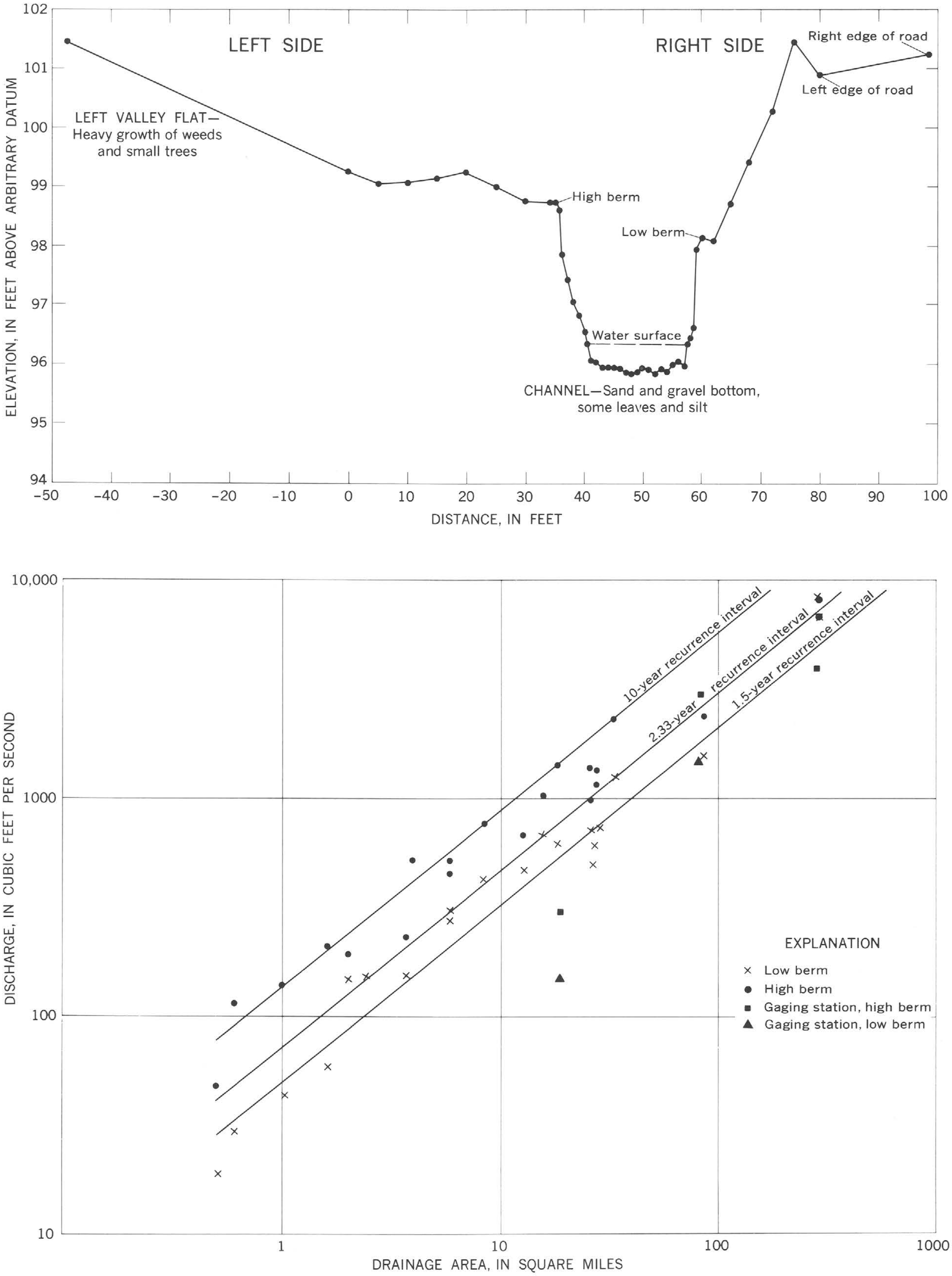


FIGURE 12.—*Upper,* Cross section of channel and valley flat, Indian Run at Germany Hollow Road; *Lower,* Discharge values computed for levels of the high and low berms at locations where berm heights were measured in the field.

TABLE 4.—*Physical properties of channel cross sections in and near Brandywine Creek*

[Cross-sectional area at berm level, high berm, computed as channel area below low berm plus the product of channel width at high berm and depth. Velocity of 1.5-year recurrence-interval flow from velocity–drainage-area relationship. Remarks: C, from cross sections; S, from survey of berms; T, more than two berms noted, but the two recorded in table give best agreement (areas computed on basis of three berms); W, from Wolman (1955)]

No.	Station (listed in order of increasing drainage area)	Drainage area (sq mi)	Low berm		High berm		Cross-sectional area at berm level (sq ft)		Velocity of 1.5-year-recurrence-interval flow (fps)	Estimated discharge—water at berm level (cfs)		Remarks
			Height above bed (ft)	Channel width at berm level (ft)	Height above bed (ft)	Channel width at berm level (ft)	Low berm	High berm		Low berm	High berm	
19	Pine Creek at Sharp Farm	0.5	1.1	9	2.2	14	9.9	25	1.9	19	48	C
-----	East Branch Brandywine Creek at Cretchmer Farms, State Route 82	~.6	1.5	10	3.5	22	15	59	2.0	30	118	C
-----	Culbertson Run at U.S. Route 322	~1	--------	--------	3.2	20	--------	64	2.2	--------	141	C
-----	East Branch Brandywine Creek at McConnel Farm, Legislative Route 15146	~1	2.0	10	--------	--------	20	--------	2.2	44	--------	C
1	North Branch at Glenmoore	1.6	2.3	11	4.3	32	25	89	2.4	60	214	C
2	Indian Run at Germany Hollow Road	2.0	2.1	24	3.0	30	50	77	2.5	150	192	C
-----	Culbertson Run at Special School Road	~2.4	3.0	20	--------	--------	60	--------	2.6	156	--------	C
3	Perkins Run at Rose Cottage	3.7	3.0	19	4.0	25	57	82	2.8	160	230	C
4	Culbertson Run at Lyndell	3.9	--------	--------	4.2	44	--------	185	2.8	--------	518	C
-----	East Branch Brandywine Creek upstream of Cupola	5.8	3.7	26	5.4	39	96	163	3.2	307	521	S
-----	East Branch Brandywine Creek on Cupola Road	~5.8	3.0	29	4.0	53	87	140	3.2	278	448	C
-----	East Branch Brandywine Creek downstream of Cupola	8.3	3.7	46	5.1	71	130	230	3.3	430	760	S,T
-----	East Branch Brandywine Creek downstream of Barneston Bridge	12.6	4.1	32	5.2	52	131	188	3.6	472	677	S
-----	East Branch Brandywine Creek upstream of Glenmoore	15.5	4.6	39	6.0	63	180	268	3.8	685	1,020	S
-----	East Branch Brandywine Creek upstream of Indian Run	18.0	3.6	44	6.6	69	158	365	3.9	616	1,420	S
-----	East Branch Brandywine Creek at Cornog	25.9	4.3	40	6.3	80	172	332	4.2	722	1,390	S,T
10	East Branch Brandywine Creek at Cornog	~26	3.0	40	4.6	70	120	232	4.2	504	976	C
8	East Branch Brandywine Creek at Lyndell	27.1	3.5	48	5.5	70	168	308	4.3	723	1,320	C
-----	East Branch Brandywine Creek at Lyndell	27.1	4.5	50	5.4	56	222	272	4.3	605	1,170	S
9	East Branch Brandywine Creek at Dorlan	33.4	4.8	60	7.6	83	288	232	4.4	1,267	2,300	C
13	East Branch Brandywine Creek at South Downingtown	86.0	5.0	59	7.0	75	296	446	5.4	1,600	2,410	W
18	Brandywine Creek at Chadds Ford	287	--------	--------	9.0	130	--------	1,170	7.0	--------	8,190	W
-----	Brandywine Creek at Chadds Ford	287	--------	--------	7.7	130	--------	1,000	7.0	--------	7,000	S

berms. Data on mean annual flood, on recurrence interval, and on discharge at berm height came from generalizations drawn from regional analyses. There are, however, three gaging stations in and near the study area from which measurements can be used for obtaining recurrence interval of flow at berm level. Such a situation eliminates the necessity of extrapolation from regional relations. The berm levels at the three stations were identified in the field in the manner described in connection with table 4. The discharges applicable to berm elevations and the resulting recurrence intervals are summarized below.

No.	Station	Record period (yr)	Drainage area (sq mi)	Quantities at level of each berm			
				Discharge (cfs)		Recurrence interval (yr)	
				Low berm	High berm	Low berm	High berm
34	West Branch Brandywine Creek near Honey Brook	1961–67	18.7	150	300	1.1	1.5
33	East Branch Brandywine Creek at Downingtown	1959–67	81.6	1500	3000	1.2	1.2
18	Brandywine Creek at Chadds Ford	1914–57	287.0	--------	3800	--------	1.12

These results can be shown another way, by superimposing them in figure 12. The three station values are very similar to the calculated discharge of the berms, varying in recurrence interval from slightly under 1.5 years to slightly above 2.33 years on the regional analysis.

To summarize, the valley flat that borders the Brandywine Creek is the flood plain of streams draining at least 100 sq mi of area. However, it appears that changes in the relations between rainfall, runoff, and sediment load occurred in postglacial and recent times. These changes were probably associated with the advent of agriculture in colonial days and, no doubt, complicated by the well-known climatic change of the last century. Whatever the exact cause, the data suggest that for small basins, the flood plain was abandoned and became a terrace and, after downcutting, the streams began anew to form a flood plain at a lower level.

In the smaller drainage areas, housing or other development could take place on the valley flat, which is flooded about 1 out of every 10 years. But for a drainage area of at least 100 sq mi, development on the valley flat would be flooded an average of every 2 or 3 years.

CHEMICAL QUALITY OF THE STREAMFLOW

It is generally thought that urbanization tends to degrade water quality, not merely in terms of a changing sediment load, but also in amounts of dissolved load. Surprisingly, data available to document this logical postulate are meager and commonly apply only to large rivers where a great variety of influences other than urbanization have been operative. In the present investigation many chemical analyses have been made within the confines of two small river basins. In the 33-sq mi basin of the upper East Branch Brandywine Creek, 89 chemical analyses of water samples were made during the 2-year investigation. In the 31-sq-mi basin of Pickering Creek, 62 chemical analyses were made.

PLAN FOR DATA COLLECTION

The water samples for chemical analysis were taken principally at the sites where discharge and sediment measurements were made. The observation network was designed to sample a variety of subbasins varying in size from about 1 to 30 sq mi. Because flexibility is necessary in a program whose aim is to measure the progressive changes in water quality resulting from land development, the locations of measuring points were subject to change, except for the places where water-stage recorders were installed. It was also planned that water-quality samples from each location be obtained under a variety of flow conditions, from low flow to stormflow. In addition special chemical determinations were made at particular sites.

CHEMICAL QUALITY AT A GIVEN LOCATION

In a study of urbanization there is no assurance at the present time that the chemical parameters which we measure are the important ones. Although the fact that the amount of nitrate and phosphate dissolved in water exercises an important control over the stream biota is well known, the situation may, in fact, be much more complicated, for there may be trace elements which have a subtle and, at present, unknown effect of even greater importance. The decision that the water samples taken during the present investigation would be analyzed in the manner generally considered standard was made with the understanding that, as more is learned about the effects of urbanization, it may be necessary to discard some of the currently analyzed chemical factors and substitute other factors.

Two principal kinds of chemical variations should be considered—variance in time and in space. In a stream system the changes of flow with respect to time are marked and can vary through nearly two orders of magnitude in small drainage basins. This flow variance progressively decreases as the size of the contributing basin increases. It may be expected that, as streamflow increases during storm runoff, concentrations of some chemical parameters would tend to decrease as a result of dilution by rainwater. The second type of variation which can be expected is a variation in geographic space that would reflect the local occurrence of different rock types and their associated soil materials.

In making comparisons in space and in time, certain standards must be adopted to form the basis for comparison. For example, at what particular flow or discharge rate should one compare different locations within a given river basin, knowing that, at any one time, there is more flow at the downstream location than at the upstream one? Also, during stormflow, two points that are geographically close can actually be simultaneously experiencing very different degrees of discharge. To avoid confusion, then, it is mandatory that certain rules be established for making these comparisons.

In figure 13 several chemical factors are presented as functions of stream discharge at a particular location. The example chosen is Indian Run at Glenmoore, which has a drainage area of 6.3 sq mi. There are separate graphs for the concentrations of dissolved solids, chlorides, sulfates, phosphates, and nitrates as functions of discharge. Along the discharge scale for this location, two points, representing the mean annual discharge and the approximation of bankfull discharge, have been chosen as standard for the present discussion. As discussed earlier, the discharge having a 1.5-year recurrence interval is used in this report as an approximation of the bankfull discharge.

The dissolved-solids concentration does not change significantly from low flow to high. At the station the solids vary generally from 60 to 70 mg/l. There seems to be a slight increase in chloride concentration, from 4 to about 8 mg/l, as flow increases from low to high values. The sulfate concentration also tends to increase somewhat, changing from about 10 to 17 mg/l from low to high flow. The nitrate level remains fairly constant at 4 mg/l throughout the range of flows. The phosphate concentration, a somewhat unique parameter, shows a large increase as discharge increases, although the actual phosphate concentration is small; as the graph shows, phosphate concentration at this station changes from about 0.01 to 0.15 mg/l as discharge increases from mean annual to bankfull stage. In addition, there is a much larger scatter of points about the main regression line for phosphate than for the other parameters.

Based on the same types of graphs as those in figure 13, a listing is presented in table 5 for each stream location where chemical-quality samples were obtained in both the upper East Branch Brandywine Creek and the Pickering Creek basins. For each of the five chemical parameters, the concentration is shown for two standard discharges, mean annual flow, or mean Q, and approximate bankfull flow, that flow having a 1.5-year recurrence interval. Many of the blanks in the table exist because of an insufficient number of observations.

There is considerable similarity among the locations studied. With the exception of station 19, Pine Creek at Sharp Farm, the concentrations of each of the five factors remain in the same order of magnitude regardless of location. For example, with the exception noted above, the total dissolved solids at mean annual flow vary

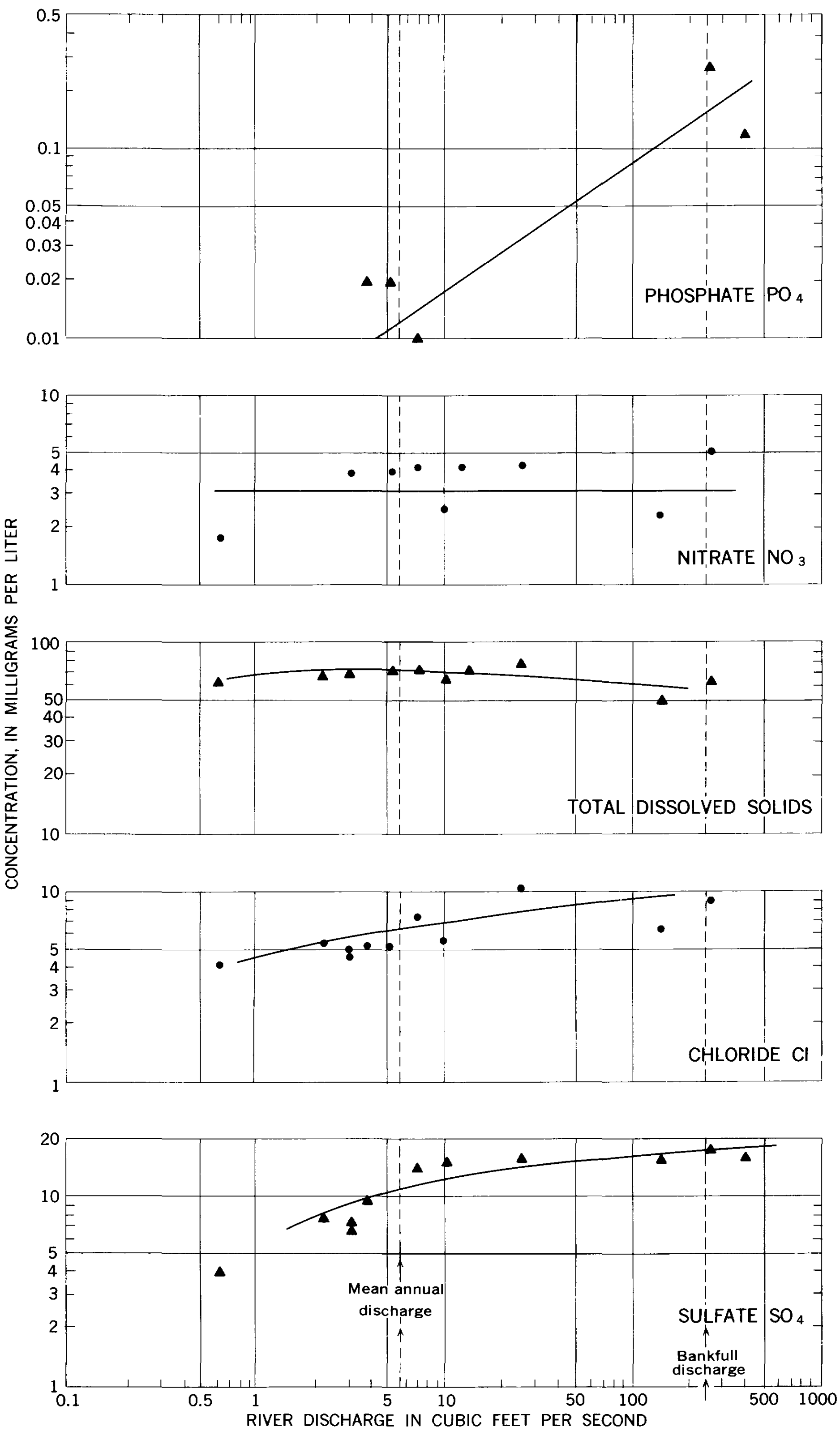


FIGURE 13.—Water-quality factors as functions of river discharge, Indian Run at Glenmoore.

TABLE 5.—*Dissolved load at measurement stations, in milligrams per liter, for two discharge values, mean annual discharge (mean Q) and bankfull discharge*

[Dissolved-load quantities interpolated on graphs showing load–discharge relation]

No.	Station	Drainage area (sq mi)	Dissolved solids at—		Phosphate (PO_4) at—		Nitrate (NO_3) at—		Sulfate (SO_4) at—		Chloride (Cl) at—	
			Mean Q	Bankfull	Mean Q	Bankfull	Mean Q	Bankfull	Mean Q	Bankfull	Mean Q	Bankfull
	Upper East Branch Brandywine Creek basin:											
2	Indian Run at Germany Hollow Road	2.0	84	60	0.02	0.17	8	4.2	--	--	6.6	4.4
3	Perkins Run at Rose Cottage	3.7	78	70	.06	.35	6	6	12	21	7	8.5
4	Culbertson Run at Lyndell	3.9	95	60	.05	--	9	4	24	22	9.5	6.5
5	East Branch Brandywine at Cupola	6.2	90	75	.07	--	5.5	4.1	17	18	9	6
6	Indian Run at Glenmoore	6.3	70	60	.01	.15	3.1	3.1	11	17	6	8
8	East Branch Brandywine at Lyndell	27.1	82	80	--	.19	3	8	11	--	7	9
9	East Branch Brandywine at Dorlan	33.4	88	70	.06	.31	6	5	18	18	9	9
	Pickering Creek basin:											
19	Pine Creek at Sharp Farm	.5	160	160	.03	.30	24	5	40	17	22	40
21	Tributary Pickering at Art School	1.9	80	80	--	--	--	--	--	--	--	--
22	Rock Run at Charlestown	2.6	130	90	--	--	--	--	--	--	--	--
23	Pigeon Run at Merlin	2.8	96	--	--	--	3.5	--	20	--	14	--
24	Tributary Pickering near Kimberton	3.1	100	--	--	--	5	--	23	--	7	--
26	Tributary Pickering at Chester Springs	4.3	72	--	--	--	2.6	--	15	--	6	--
27	Pine Creek at Chester Springs	5.1	100	--	--	--	4	--	20	--	15	--
28	Pickering near Chester Springs	6.0	95	95	.01	.40	6	9	16	20	9	14
31	Pickering near Phoenixville	31.4	100	80	.06	.40	3.5	5.3	22	24	9.5	8.2

from 70 to 130 mg/l. The geographic organization of the variances is discussed separately.

The second generalization which can be drawn from table 5 is that, as discharge increases from mean annual to bankfull, four of the five parameters keep a fairly constant concentration instead of showing a tendency for dilution. The fifth parameter, phosphate, has a marked concentration increase, varying from tenfold to fortyfold, as discharge increases. All the phosphate data tend to be scattered about the regression line, as mentioned previously. Experience elsewhere indicates that the amount of phosphate available as solute is sensitive to the redox potential. Perhaps slight changes in acidity of the water when diluted by rain make the phosphate available for solution.

Station 19, Pine Creek at Sharp Farm, is an exception. It had been hoped at the beginning of the investigation that, during the life of the project, at least several and hopefully many, small areas would actually undergo the transition from agricultural to industrial or housing use. The plan was to establish one or more observation sites downstream from any new construction project as soon as it started. The half-square-mile area above Sharp Farm was the only one in which such a change took place in the 2 years of the project. In this small headwater area, what had formerly been agricultural land is being converted into an industrial park. In 1968 two large one-story buildings were completed. Up to the time of this writing (early 1969), sewage was disposed of in septic systems, though the industrial complex will probably have to install a disposal plant before any further expansion is allowed under existing local governmental regulations.

The data show that this area is unique because of the high dissolved-solids, nitrate, and sulfate values at low flow and high chloride values at all flows. As shown in table 5, station 19 had 160 mg/l dissolved solids compared with a median value of less than 100 mg/l for all other sites. Both the level and rate of phosphate increase were approximately the same as those at other sites. The nitrate value at low flow was more than double that of any other area, but apparently this concentration was diluted as discharge increased. At low flow, the sulfate value was almost double that at any other site; at high flows, there was a tendency for dilution. Chloride concentration at low flow, also nearly twice the value at any other site, increased with discharge to a value of 40 mg/l at bankfull flow, approximately four times that of any other measuring station.

SOME OBSERVATIONS ON THE GROUND-WATER HYDROLOGY

GROUND-WATER DISCHARGE

Measurements of the quantity of streamflow during nonstorm or low-flow periods were made to determine the characteristics of the local ground water. Simultaneously, water samples were analyzed to show the geographic distribution of dissolved material in this same ground water.

The location of measuring points during the low-flow period of late summer 1967 is shown in figure 14*A* and *B*. The basins were divided into subbasins of approximately 1-sq mi area and, along main streams, at increments of about 1-sq mi drainage area. The actual discharge-measurement data and the chemical analyses appear in table 6.

The total ground-water contribution is surprisingly varied geographically over the two basins, as can be seen in figure 15*A* and *B*. The maps present lines of equal low-flow stream discharge. Inspection of the maps shows that the overflow of the ground-water reservoirs varies geographically through the two basins by a factor of about 5. The lowest values, approximating 0.25 cfs per square mile, occur in three zones; namely, the headwaters of Indian Run near Icedale, the tributary to Pickering Creek near Kimberton, and the head of Pine Creek near Lionville. Relatively high values of ground-water discharge occur in the Pickering Creek basin at the headwaters of Pigeon Run and Rock Run, in the vicinity of West Pikeland, in the downstream part of the upper East Branch Brandywine Creek basin, especially near Dowlin Industrial School and Caln and in the upstream part of the basin near Suplee.

CHEMICAL QUALITY OF GROUND WATER

In regard to the quality of the ground-water discharge, dissolved solids are especially high in the headwaters of Rock Run in the Pickering Creek basin and near Suplee in the upper East Branch Brandywine Creek basin. With the exception of these two areas, the two basins are more or less uniform. Maps of dissolved solids at low flow are shown in figure 16*A* and *B*. The dissolved-solids concentration was computed as 65 percent of the conductance (micromhos).

The sulfate concentrations and chloride concentrations can best be shown by taking into consideration the geology and physical development of the basins. Figures 17*A* and *B* are generalized geologic maps of the Brandywine Creek and Pickering Creek basins, respectively (Bascom and Stose, 1938). Of the features which have been generalized, the most conspicuous one is in the southeastern part of the Brandywine Creek basin near Dorlan where the Pickering Gneiss and granodiorite are shown as gneiss. In the Pickering Creek basin this differentiation was made. Numerous small intrusions and dikes in both basins are not shown.

Superimposed on the geologic maps are all the subbasins which drain an area wholly, or almost wholly, within one rock type. If geology is an important factor in the ground-water quality, there should be only a small range of concentration values within each rock type.

In addition to the 1967 measurements and samples, an initial quality sampling had been carried out during September 1966. The data for this survey appear at the end of the report, generally as the first chemical sample for each station. The 1966 data are included in the pertinent illustrations as point values. The 1967 data are plotted at the center of the subbasin even though they were collected at the point of outflow from the basin.

The sulfate concentrations for the two basins are shown in figure 18*A* and *B*. The average concentrations are as follows:

Basin	*Average sulfate concentration (mg /l)*
Brandywine Creek:	
Gneiss, northwest corner of basin	15
Gneiss, southeast corner of basin	22
Anorthosite	5.9
Pickering Creek:	
Pickering Gneiss	11
Granodiorite (excluding subbasin 29)	18

As seen from the table, the sulfate concentrations within the anorthosite are much lower than the concentrations in the gneiss-granodiorite family. The larger values within the gneiss in the Brandywine Creek basin could be due to longer residence time because of a smaller relief. Deep circulation patterns or nonhomogeneous rock types underlying the subbasins could also be credible explanations.

There was no apparent correlation between the dissolved-load values from low-flow stream water and from well analyses.

The chloride concentrations for the two basins are shown in figure 19*A* and B. The averages are as follows:

Basin	*Average chloride concentration (mg/l)*
Brandywine Creek:	
Gneiss, northwest corner of basin	9.4
Gneiss, southeast corner of basin	9.2
Anorthosite	5.9
Pickering Creek:	
Pickering Gneiss	5.3
Granodiorite	13.9

For the chloride, correlation is successful between the anorthosite of the Brandywine Creek basin and the Pickering Gneiss of the Pickering Creek basin, but the remaining three groups show outliers and probably indicate sources of contamination. The source of the high values of the outliers cannot be pinpointed except in the southern section of the Pickering Creek basin, which is traversed by the Pennsylvania Turnpike. These subbasins show much higher chloride concentrations than those subbasins which are not traversed by the turnpike. In all probability, this high chloride concentration is due to highway salt treatment to combat snow and ice conditions.

There does not seem to be any particular correlation between the amount of streamflow produced by ground-water runoff and the chemical characteristics of the same water. Variability of all parameters seems to be somewhat greater geographically in the Pickering Creek basin than in the Brandywine. The only area which seems to deviate consistently from the average is

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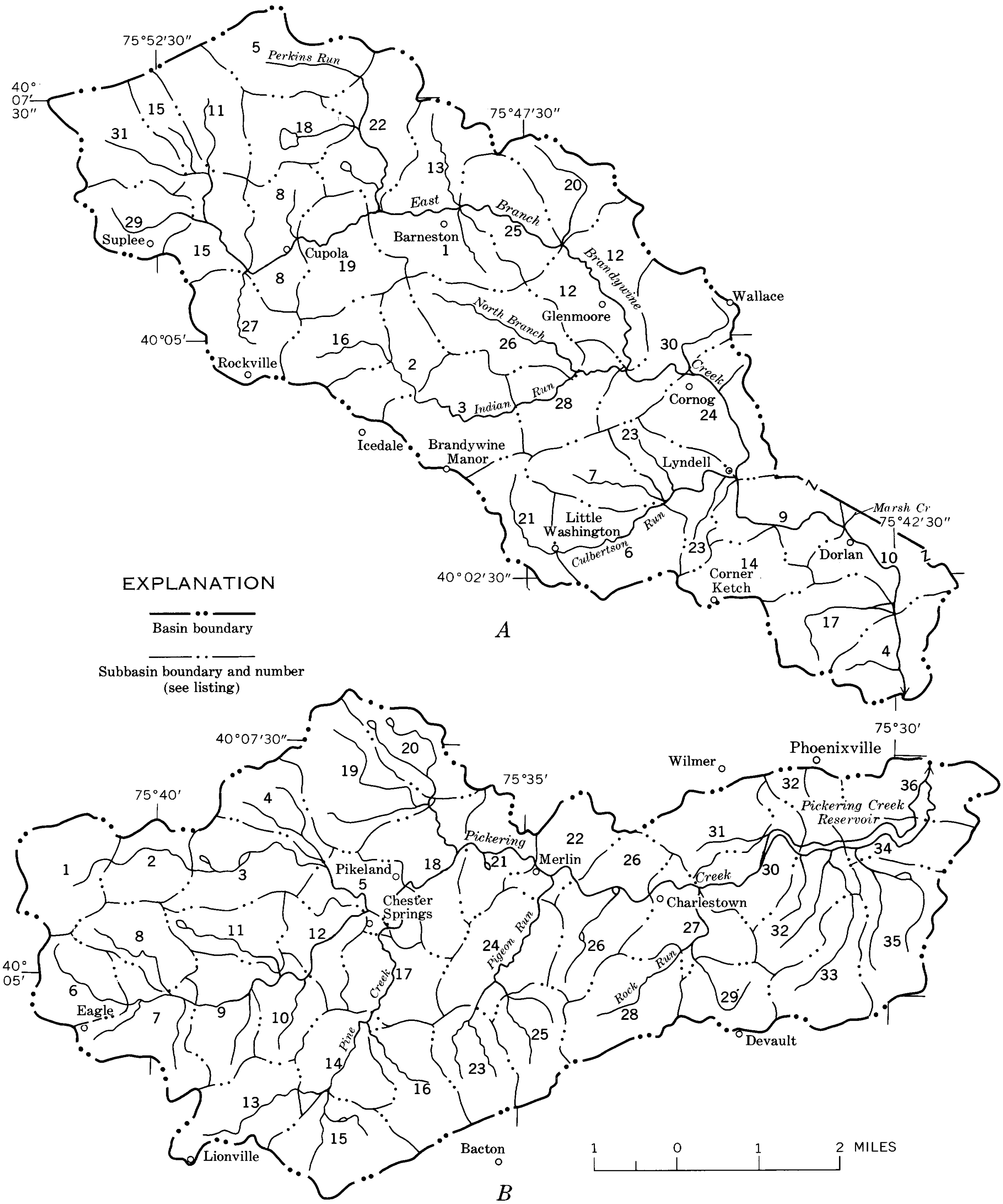


75°52'30"
40°
07'
30"
Perkins Run
75°47'30"
East
Branch
Brandywine
Barneston
Suplee
Cupola
Wallace
Glenmoore
North Branch
40°05'
Rockville
Indian
Run
Cornog
Creek
Icedale
Brandywine
Manor
Lyndell
Little
Washington
Culbertson
Run
Marsh Cr
75°42'30"
Dorlan
Corner
Ketch
40°02'30"
EXPLANATION
Basin boundary
Subbasin boundary and number
(see listing)
A
40°07'30"
75°40'
75°35'
Wilmer
Phoenixville
75°30'
Pickering Creek
Reservoir
Pickering
Pikeland
Merlin
Chester
Springs
Charlestown
Creek
40°
05'
Eagle
Pigeon
Run
Rock
Run
Pine
Creek
Devault
Lionville
Bacton
1
0
1
2 MILES
B

the headwaters of Rock Run near Devault, where total discharge, sulfate, and solids are high, but chloride is average.

GENERAL DISCUSSION OF THE HYDROLOGY

The present report, a basic-data document, is intended to find its maximum usefulness some years hence when a similar investigation might provide new data to compare with those presented here. Though it was hoped that even during the 2-year data-collection effort there would be several areas which would change from agricultural to urban, this did not, in fact, occur except in one half-square-mile headwater tributary, Pine Creek in the southwestern part of the Pickering Creek basin.

The data show that the quantities of streamflow are very consistent geographically, being primarily a function of drainage area. Though the streamflow characteristics are quite uniform, there is considerable variability in the shape and size of channels, even among sites of the same drainage area. Because preurbanization conditions are so inherently variable, only fairly large changes in channel shape and size which occur as a result of urbanization will be recognized and attributed to urbanization.

For basins not larger than 10 sq mi, the channel data show that the most obvious valley flat is not a feature constructed by the stream in its present regimen but is attributable to previous streamflow conditions. The obvious valley flats for small drainage basins are terraces rather than presently forming flood plains. Abandonment of the former flood plain and initiation of a new flood plain, still very narrow and often difficult to recognize in the field, might be attributed to the effect of land clearing incident to early 19th century agricultural development. Though a reasonable conjecture, this attribution is, as yet, unproven.

The effects of changes in stream regimen which caused the incision of small headwater tributaries and the consequent initiation of a new flood-plain system are restricted to small headwater tributaries. This has a particular significance in prognosticating that which might be observed in the future as urbanization becomes more complete. The larger channels—that is, channels draining basins of 10 sq mi or more—will probably show little, if any, alteration in channel shape and size as a result of urbanization. It can be expected that any change in channels which is caused by urbanization will be restricted to relatively small headwater areas.

The basic data show a surprising variability in the production of nonstorm streamflow attributable to overflow of the ground-water reservoirs. Also the chemical-quality characteristics of this ground water tend to have considerable geographic homogeneity in some chemical parameters, but rather large inhomogeneities in other chemical parameters. In this respect, one of the purposes of the present report has been achieved—that is, to ascertain, at least in a reconnaissance manner, the natural or preurbanization variability of chemical factors.

The one small area which was actually undergoing change from agricultural to industrial use during the life of the project showed marked changes in chemical content of the water, a fact which indicates that urbanization does indeed cause significant alterations in water quality. But the data suggest that such alterations

FIGURE 14.—Outlines of subbasins. Discharge measurements that are given in this report were made at downstream end of subbasins.

A, Upper East Branch Brandywine Creek basin:

1	Barneston	9	Reeds Road	17	Industrial School	25	Nantmeal
2	Baron	10	Dowlin	18	Isabella	26	North Branch
3	Brandywine Manor	11	Fontaine	19	Lewis Mills	27	Rockville
4	Caln	12	Glenmoore	20	Lincoln	28	Springton
5	Conestoga	13	Goodwill	21	Little Washington	29	Suplee
6	Guthriesville	14	Corner Ketch	22	Loag	30	Wallace
7	Culbertson	15	Honey Brook	23	Lyndell	31	White School
8	Cupola	16	Icedale	24	Milford Mills		

B, Pickering Creek basin:

1	Tank Farm	10	Oppermans Corner	19	Birchrunville	28	Hollow
2	St. Matthews	11	West Pikeland	20	Kimberton	29	Devault
3	Vincent Church	12	Trail	21	Hallman	30	Pickering
4	Birch	13	Lionville	22	Merlin	31	Wilmer
5	Chester Springs	14	Pine	23	Pigeon	32	Meadowbrook
6	Eagle	15	St. Pauls	24	Rapps Corner	33	Diamond Rock
7	Interchange	16	Bacton	25	Yellow Springs	34	Williams Corner
8	Missing Road	17	Horseshoe	26	Charlestown	35	Britons Corner
9	Anselma	18	Pikeland	27	Aldham	36	Bull Tavern

TABLE 6.—*Low-flow discharge measurements and chemical analyses, upper East Branch Brandywine Creek and Pickering Creek basins*

Subbasin	Measured discharge (cfs)	Drainage area of subbasin (sq mi)	Incremental discharge (cfs)	Incremental unit discharge (cfs per sq mi)	SO_4 (mg/l)	Cl (mg/l)	Conductance (micromhos)
Upper East Branch Brandywine Creek basin, Aug. 29–Sept. 7, 1967							
Fontaine	0.46	0.995	0.46	0.46	14	6.7	132
White School	.49	1.183	.489	.41	17	14	142
Suplee	.71	.903	.710	.79	15	7.5	209
Rockville	.60	1.165	.600	.52	8.4	4.2	123
Honey Brook	3.08	1.500	.821	.55	15	12	159
Cupola	3.18	1.100	.100	.09	13	9.5	153
Lewis Mills	2.76	1.340	−.42	−.31	14	9.5	151
Loag, Conestoga, and Isabella	1.80	3.760	1.80	.48	9.6	9.6	126
Goodwill	.44	1.030	1.62	.73	10	8.6	121
Barneston	6.18	1.180			11	8.6	138
Lincoln	.63	.93	.63	.68	10	4.6	89
Nantmeal	5.29	1.15	−.89	−.77	10	8.0	135
Icedale	.14	.96	.14	.15	6.1	6.2	137
Baron	.49	1.01	.35	.35	5.3	7.1	146
Brandywine Manor	1.61	1.65	1.12	.68	6.5	5.1	107
North Branch	.54	1.57	.54	.34	6.9	5.9	102
Springton	3.70	1.15	1.55	1.35			
Glenmoore	7.30	1.70	1.38	.81	9.6	9.0	132
Wallace	9.22	1.54	−1.78	−1.16	8.8	7.7	123
Little Washington	.62	.95	.62	.65	24	7.7	142
Guthriesville	1.23	1.42	.61	.43	23	12	168
Culbertson	.56	.96	.56	.58	21	7.7	136
Lyndell	2.73	1.13	.94	.83	24	9.9	149
Milford Mills	11.30	1.45	−.65	−.45	12	7.5	131
Corner Ketch	.72	.87	.72	.83	25	10	128
Reeds Road	18.0	1.09					
Industrial School	.96	1.18	.96	.81	18	8.1	133
Dowlin	27.0	1.02					
Pickering Creek basin, Sept. 26–28 and Oct. 1–6, 1967							
Tank Farm	0.35	1.21	0.35	0.29	11	5.6	128
St. Matthews	.83	.80	.48	.60	11	5.6	120
Vincent Church	1.23	1.33	.40	.30	10	5.7	120
Birch	.35	.85	.35	.41	11	4.4	95
Chester Springs	9.82	.97	.99	1.02	15	10	149
Eagle	.43	.86	.43	.50	10	7.5	169
Interchange	1.43	1.26	1.00	.79	13	9.5	144
Missing Road	.30	.95	.30	.32	13	4.7	102
Anselma	1.53	1.06	.10	.09	14	9.0	146
Oppermans Corner	3.07	.78	.71	.91	13.1	8.0	149
West Pikeland	.93	.80	.93	1.16	9.2	5.6	140
Trail	3.80	.72	.73	1.01	13	8.5	154
Lionville	.63	1.10	.63	.57	25	25	219
Pine	2.78	.96	.84	.88	18	16	152
St. Pauls	.71	1.18	.71	.60	14	7.5	108
Bacton	.60	1.19	.60	.50	15	16	129
Horseshoe	3.45	1.10	.07	.06	16	14	147
Pikeland	10.6	1.33	.37	.28	15	10	146
Birchrunville	.34	1.57	.34	.22	13	7.1	148
Kimberton	.07	1.00	.07	.07	8.8	3.8	152
Hallman	9.71	.87	−.89	−1.02	16	8.5	146
Merlin	12.9	.90	1.64	1.82	14	8.5	146
Pigeon	.75	.96	.75	.78	16	23	160
Rapps Corner	1.55	1.46	.35	.24	18	13.0	147
Yellow Springs	.45	.87	.45	.52	22	8.5	147
Charlestown	14.5	1.52	.12	.05	17	8.5	148
Aldham		1.13					
Hollow	.66	1.27	.66	.52	13	9.5	131
Devault	.82	.85	.82	.96	49	8.5	304
Pickering	14.7	1.09	−.27	−.25	17	10	157
Wilmer	.47	1.03	.47	.46	24	7.5	183
Meadowbrook		1.34					
Diamond Rock	.50	1.03	.50	.49	30	6.0	155
Williams Corner		1.17					
Britons Corner	.76	1.34	.76	.57	18	6.2	139
Bull Tavern		.97					

are more observable at low flow than at high. Also the effect of industrialization on this one tributary was a marked increase in sediment movement, measurable in terms of both suspended-sediment concentration and sediment deposited in stream channels.

All the significant data obtained during the investigation appear in tabular form at the end of the report as well as in generalized form in the text. A similar data-collection program will be needed at an appropriate time to establish quantitatively the effect of urbanization on various hydrologic parameters.

OBSERVATIONS OF STREAM FAUNA

By RUTH PATRICK and ROBERT R. GRANT, JR.

On May 23 and 24, June 15 and 16, July 5 and 6, and September 16 and 17, 1967, the Limnology Department of the Academy of Natural Sciences of Philadelphia carried out four cursory surveys of six areas, each on Brandywine and Pickering Creeks and their tributaries. On October 12 and 13 and November 14 and 15, 1967, two additional surveys were carried out on 11 other areas in the two watersheds. The fieldwork was done by Ruth Patrick and Robert Grant of the

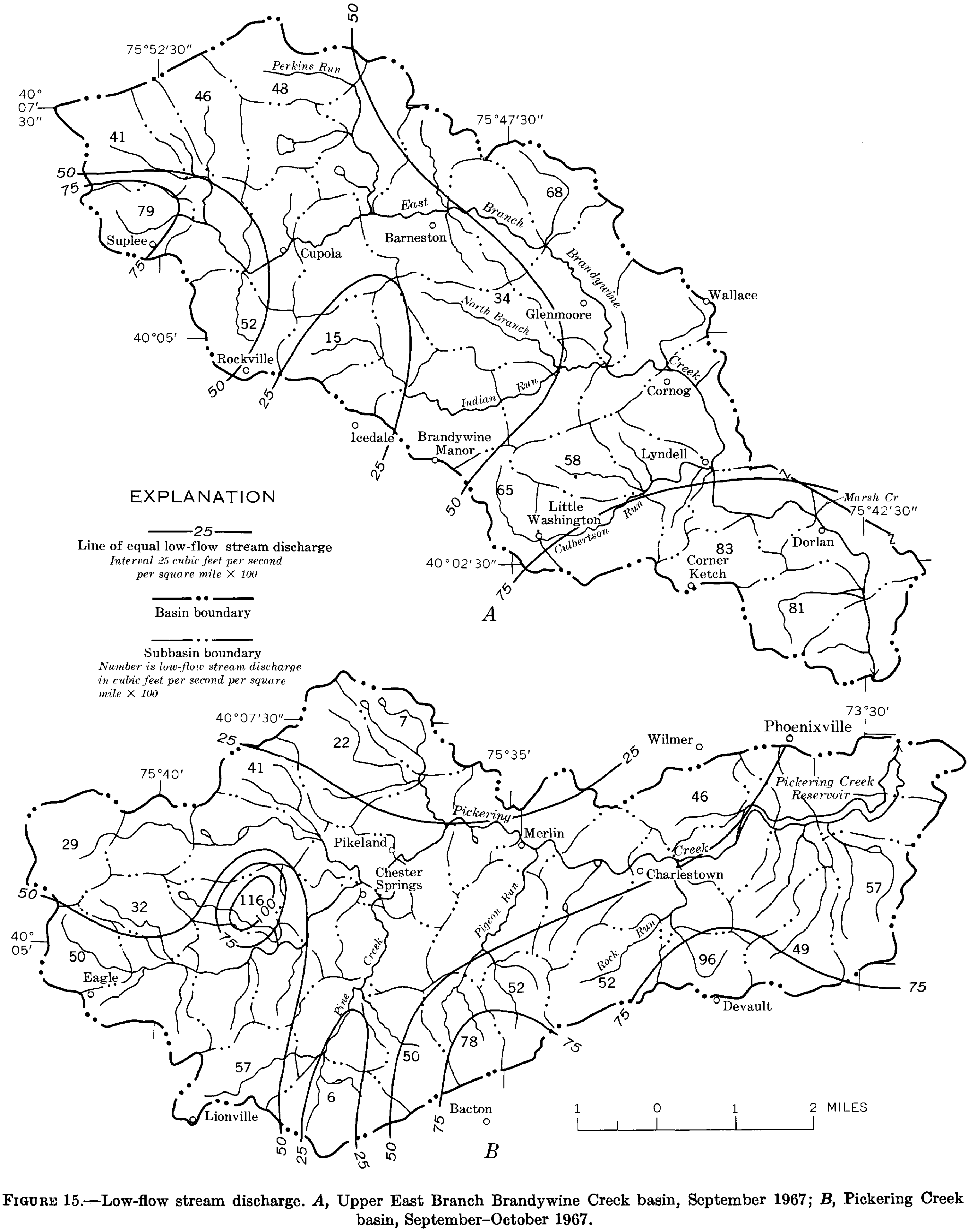


Figure 15.—Low-flow stream discharge. *A*, Upper East Branch Brandywine Creek basin, September 1967; *B*, Pickering Creek basin, September–October 1967.

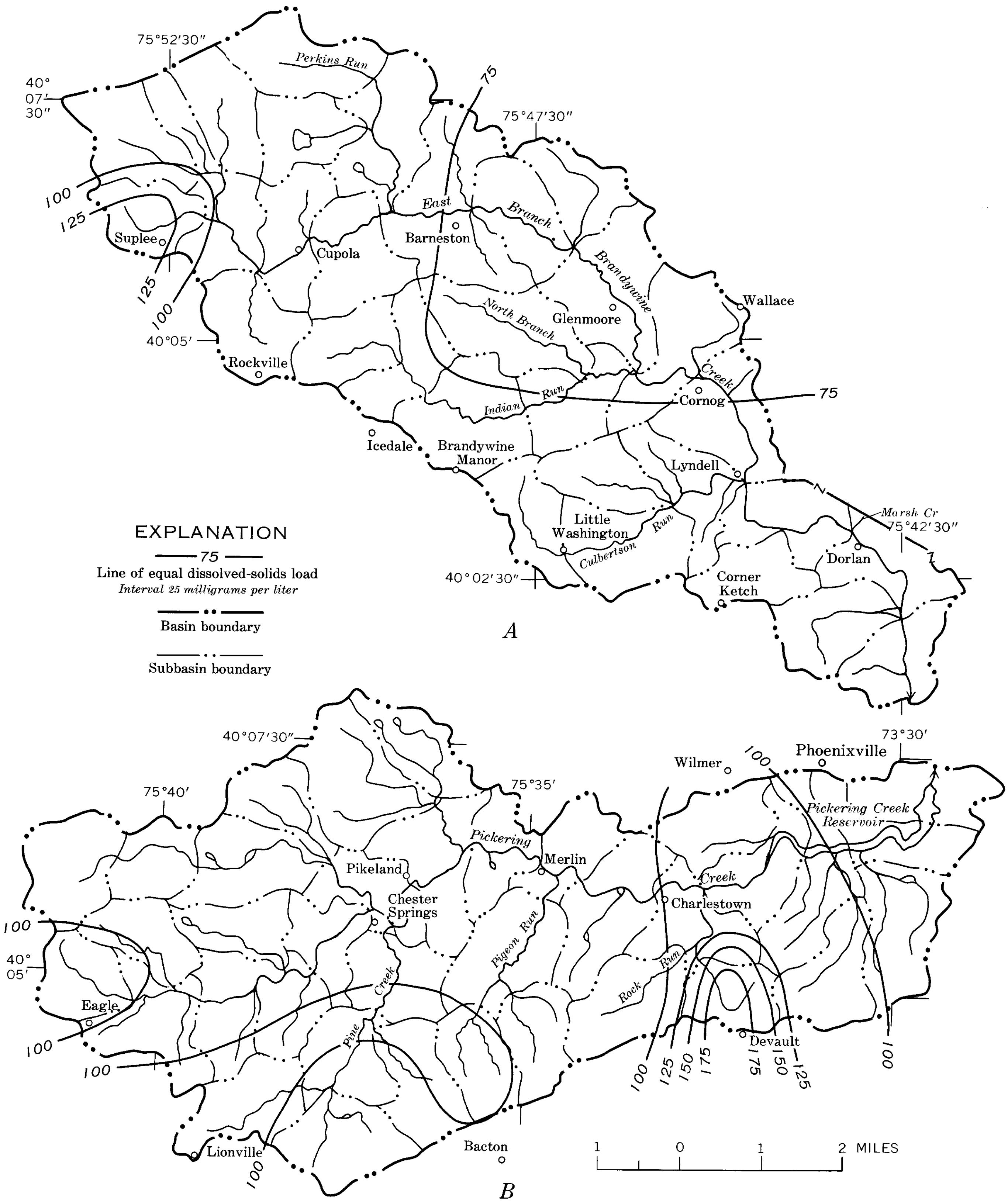


Figure 16.—Dissolved-solids loads of streams at low flow during nonstorm period, August–September 1967. *A*, Upper East Branch Brandywine Creek basin; *B*, Pickering Creek basin.

Academy of Natural Sciences and William Dawson of the U.S. Geological Survey.

The purpose of these surveys was to ascertain the basic forms of aquatic life at the stations and to note any condition in the aquatic life that reflected a change in water quality. The major groups of macroscopic aquatic organisms were studied at each station, as well as any obvious concentrations of microscopic life. Station locations are shown in figure 20*A* and *B* and described in table 9; tables 10 and 11 (at end of report) give chemical data and frequency of faunal forms.

In this type of study the condition or health of the river is indicated by the relative population sizes of the three major groups of organisms: namely, algae, invertebrates, and insects. In natural, healthy streams a large number of species is present. Typically, there are a great many more species of diatoms than species of invertebrates, other than insects. In large part our conclusions are drawn from the kinds and numbers of species which form the majority of the biota.

Under healthy conditions where nutrient levels are low, there is generally a large number of diatom species, a fine assortment of insect species, and several invertebrate species such as snails, crustacea, and often worms, though their populations are very small. Under healthy conditions where low-level streams flow through farmlands, a large variety of diatoms, insects and lower invertebrates occur in fairly large populations. The large insect populations consist mainly of mayflies and caddisflies, and the algae populations, of diatoms.

Among the first signs of overenrichment are patches of blue-green algae and *Spirogyra* and common occurrences of rooted aquatics, such as *Anacharis* or *Potamogeton*, and of the alga *Oedogonium*. However, the growth of *Oedogonium*, *Spirogyra*, and blue-green algae, as well as the rooted aquatics, should be moderate. Under such conditions there are generally fairly large populations of crayfish, and *Physa* snails and *Planaria* become more common.

When the healthy condition of the river has been definitely damaged by organic pollution, diatoms become somewhat less common, or, if common, are largely composed of species such as *Nitzschia palea* and *Gomphonema parvulum*. Also common under such conditions are *Oedogonium*, which often becomes an established part of the flora, and certain species of the genus *Synedra*. *Spirogyra* occur in shallow pools in fairly large quantities, and patches of blue-greens are frequently seen over the surface of the mud. Under organically polluted conditions flatworms sometimes become very common as do *Physa* snails, and crayfish often increase in abundance.

Mildly toxic conditions cause the total number of species to decrease. When this occurs, mayflies are

TABLE 9.—*Station locations for faunal observations*

[Stations do not correspond to those in tables 1-8]

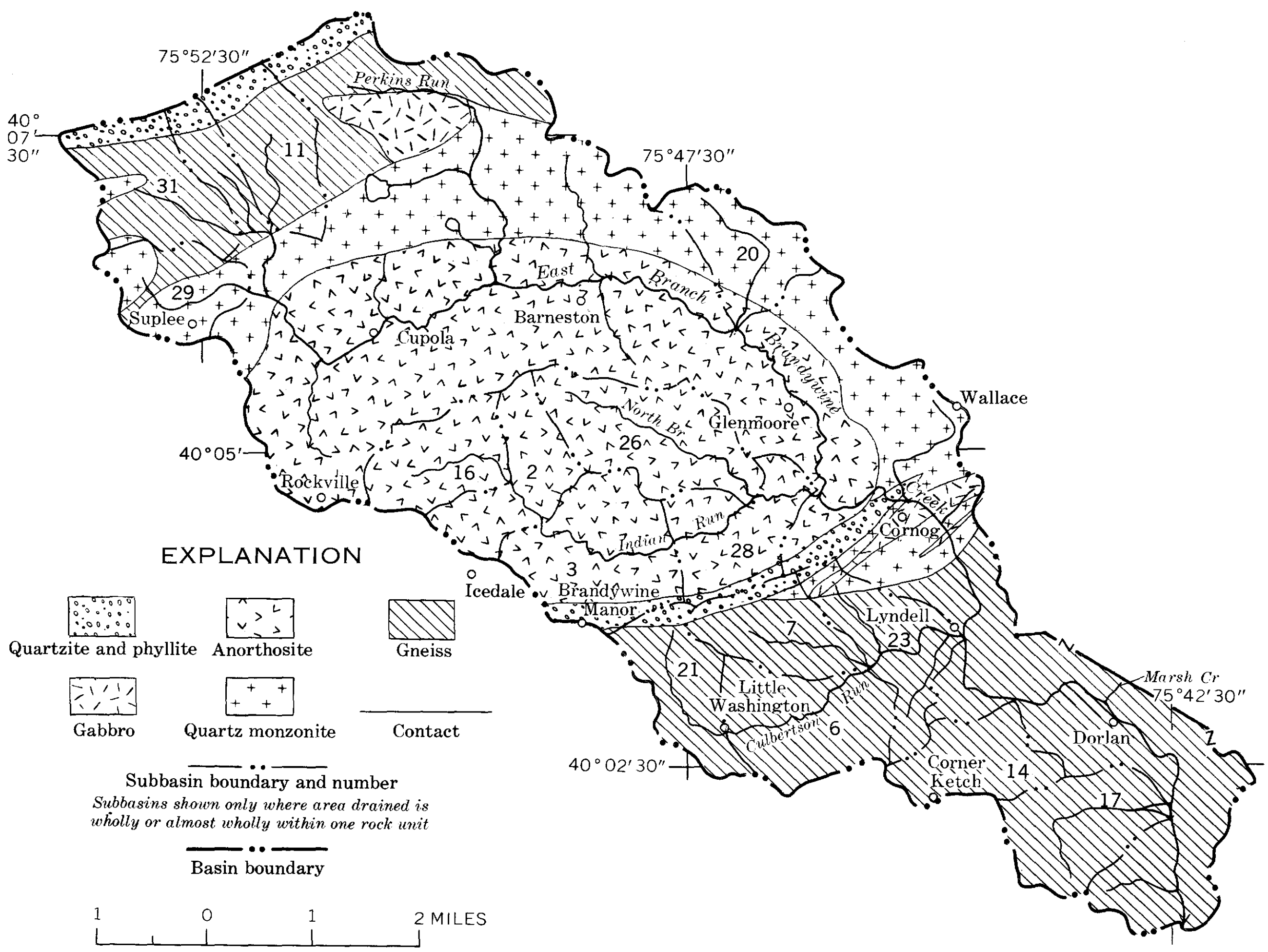
Station	Location		Description
	Latitude North	Longitude West	
May-September, 1967			
B-1	40°06′07″	75°50′00″	East Branch Brandywine Creek near Lewis Mills, approximately 1,100 ft downstream from junction of State Routes 15149 and 15148.
B-2	40°05′48″	75°46′44″	East Branch Brandywine Creek near Glenmoore, just upstream from Route 282 bridge.
B-3	40°04′38″	75°45′40″	East Branch Brandywine Creek near Cornog, just upstream from Devereux School Road bridge.
B-4	40°03′04″	75°43′22″	East Branch Brandywine Creek near Dorlan, approximately 2,000 ft upstream from Dorlan Road bridge.
B-7	40°04′41″	75°46′18″	Indian Run near Springton, both sides of Route 282 bridge.
B-9	40°03′32″	75°44′46″	Culbertson Run near Lyndell, just upstream from Route 282 bridge.
P-2	40°05′46″	75°37′09″	Pickering Creek near Chester Springs, approximately 150 ft downstream from Route 15216 bridge (just below rock dam).
P-3	40°06′23″	75°35′29″	Pickering Creek near Merlin, approximately 4,000 ft downstream from Route 113 bridge.
P-4	40°06′03″	75°32′54″	Pickering Creek below Charlestown, off Route 15034 approximately 2,700 ft upstream from Route 29 bridge.
P-5	40°06′32″	75°31′41″	Pickering Creek near Williams Corner, approximately 3,300 ft downstream from Route 29 bridge.
P-6	40°06′53″	75°36′20″	Tributary to Pickering Creek near Kimberton, approximately 1,300 ft upstream from Route 15192 bridge.
P-7	40°05′36″	75°34′52″	Pigeon Run near Merlin, just downstream from Route 15050 bridge.
October-November, 1967			
1	40°04′33″	75°46′55″	Indian Run near Springton, just downstream from the Route 15154 bridge.
2	40°05′55″	75°50′44″	East Branch Brandywine Creek near Cupola, both sides of Route 15145 bridge.
3	40°05′41″	75°51′18″	Tributary to East Branch Brandywine Creek near Cupola, entering East Branch Brandywine Creek at lower limit of station 4.
4	40°05′43″	75°51′18″	East Branch Brandywine Creek near Cupola, approximately 300 ft upstream from Route 15148 bridge.
5	40°06′16″	75°52′01″	East Branch Brandywine Creek near Cupola, along Route 15146 approximately 2,500 ft upstream of the junction of Suplee and Forrest Roads.
6	40°06′22″	75°49′31″	Perkins Run near Cupola, just upstream from confluence of Perkins Run and East Branch Brandywine Creek.
7	40°06′20″	75°49′36″	East Branch Brandywine Creek near Cupola, just upstream from Wyebrook Road bridge.
8	40°42′46″	75°47′03″	Culbertson Run near Little Washington, upstream from the most downstream of the two bridges on U.S. Route 322.
9	40°04′42″	75°40′22″	Pickering Creek near Byers, off Route 15142, approximately 4,000 ft down Route 15142 from Route 100.
November-December, 1966			
10	40°05′48″	75°37′10″	Tributary to Pickering Creek near Chester Springs, just upstream from confluence of tributary and Pickering Creek which is at lower limit of station 11.
11	40°05′46″	75°37′12″	Pickering Creek near Chester Springs, both sides of Route 15216 bridge.
12	40°04′23″	75°48′47″	Indian Run near Brandywine Manor, just downstream from bridge on Route 82.
13	40°06′09″	75°34′44″	Pickering Creek near Oppermans Corner, at Nantmeal Road.
14	40°06′10″	75°34′38″	Pigeon Run at Merlin, at bridge on Pickering Road.

absent, the number of damselflies may increase, and the kinds of caddisfly species sometimes shift. Under severely toxic conditions there is a reduction in the number of diatoms, and *Stigeoclonium* often becomes very common. The total number of species is greatly reduced in all groups. *Physa* snails, tubificids, and flatworms, which are tolerant of organic loads, are very sensitive to toxic conditions.

METHODS

In order to obtain the maximum amount of data in the limited time and with a limited number of personnel available, survey work is concentrated in areas containing the greatest proportion of species. Rocks, logs, and debris from shallow water habitats are examined for algae, insects, and other invertebrates. Mud and sand from shallow water are sifted to obtain worms, mollusks, and insect larvae. Mud flats are examined for algal mats and snails. Rocks are removed from riffles and systematically searched for fast-water species such as mayflies, caddisflies, stoneflies and hellgrammites. Beds of aquatic plants and root tangles are worked with a dip net to obtain the species, like beetles and damselflies, that favor such habitats. Accumulations of leaves and trash in backwaters are collected and placed in a light pan, so that the dragonflies, midge larvae, leeches, and other specimens may be picked out. Any fish observed are tabulated, but actual fish collections are not made. Finally, notes are made on the presence and relative abundance of the various species.

For this report, the following procedures were followed. Shallow water areas were waded. For a wadable stream less than 75 feet wide, at least half an hour was spent examining rocks and vegetation in riffles and pools. One hour was required for a wadable stream from 75 to 150 feet wide, and, for any stream broader than 150 feet, half an hour was spent on each bank, the stream being waded as far out to the center as possible. In nonwadable streams, a boat was used to collect floating debris, particularly deadwood, for examination.



Geology from Bascom and Stose (1938)

A

RESULTS (MAY THRU SEPTEMBER)

These studies, carried out between May and September 1967, were made once each month, except August.

STATION B-1

Diatoms, the most common algae found, were very abundant during May and July and common during June and September. Of the green algae, *Oedogonium* was present all 4 months and was common in September, *Spirogyra* was present each month except July, *Cladophora* was present in July, and *Hydrodictyon* was present in September. Blue-green algae were also present all 4 months. Rooted aquatic plants were seen in July and September.

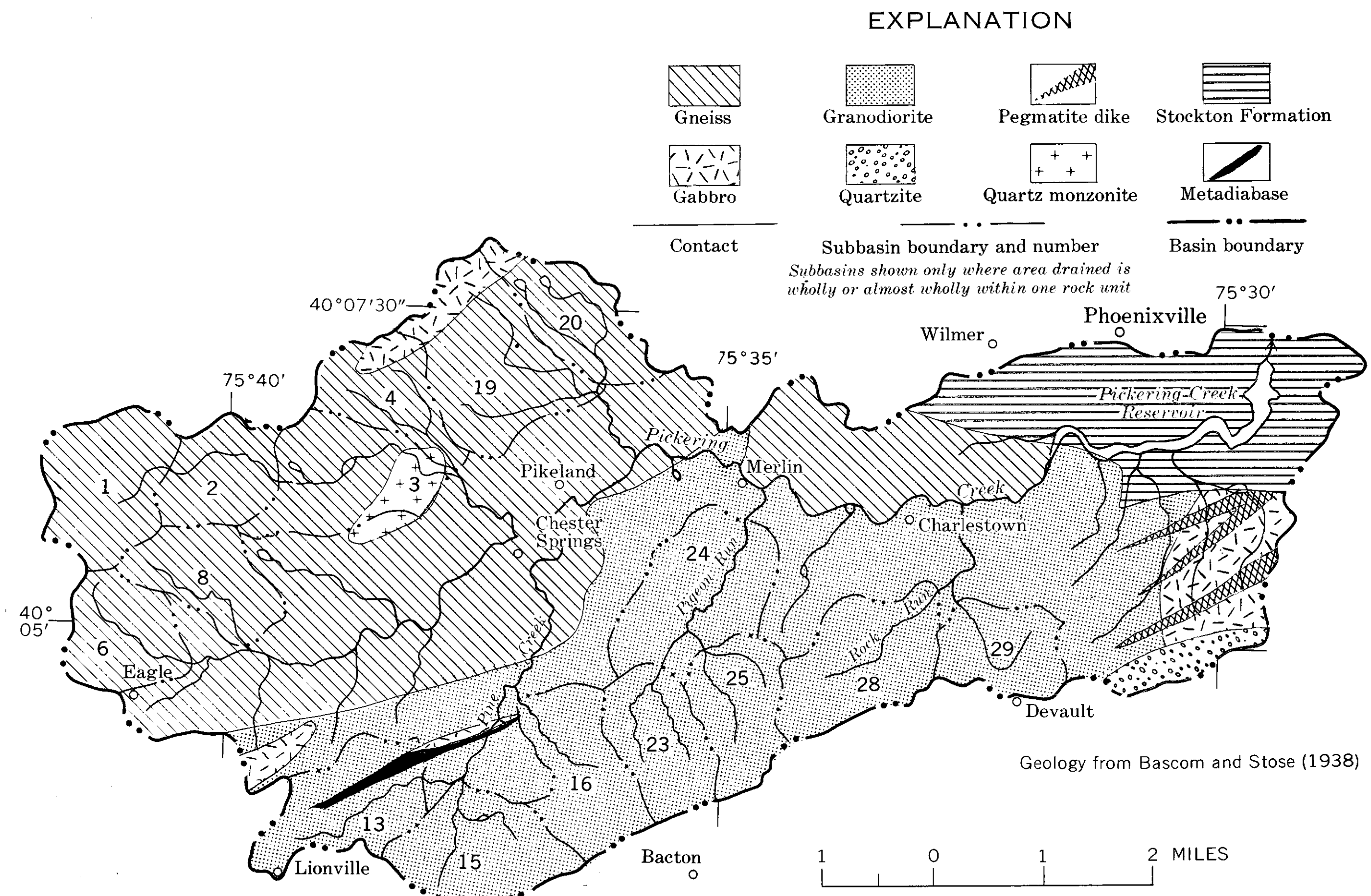
Mayflies were abundant and damselflies, stoneflies, and caddisflies were present all 4 months. Stoneflies and caddisflies were common in May and September. Because stoneflies are typically cool-water forms, they would be expected to be more common in the spring and fall months. Hellgrammites were observed in June and September; midge larvae, blackfly larvae, and gilled snails were found in September. Crayfish were present in each month, and *Physa* snails were found in July and September. Fish seen during each survey included minnows, darters, and sunfish.

Station B-1 seemed to be healthy; however, in addition to the large diatom and mayfly populations, sporadic increases in *Oedogonium* and caddisfly populations indicated the presence of some enrichment. This station did not show any significant change in water condition during the months of May, June, July, and September. (See table 10.)

STATION B-2

Diatoms, very abundant in May and July, were the dominant algae all 4 months. *Cladophora* and *Oedogonium* were present in each survey, as were the blue-green algae; *Vaucheria*, a yellow-green algae, was present in May, July, and September. Rooted aquatics were common all 4 months.

Mayflies were common each month. Stoneflies and caddisflies were present each month and were common in May. In September, caddisflies were common, and some midge larvae were found. Fingernail clams were



B

FIGURE 17.—Generalized geologic maps. *A* (facing page), Upper East Branch Brandywine Creek basin; *B*, Pickering Creek basin.

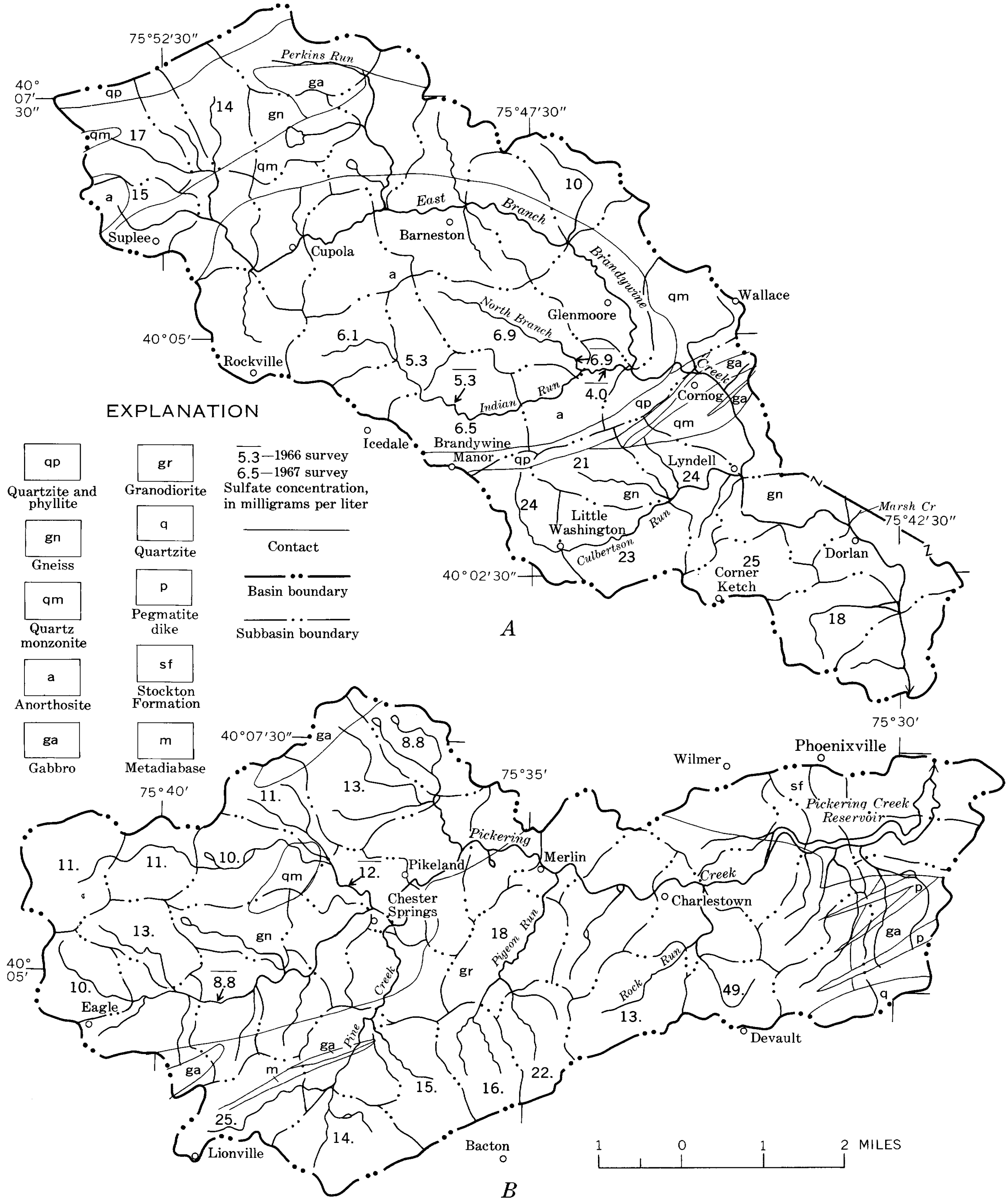


Figure 18.—Sulfate (SO_4) concentrations of streams at low flow during nonstorm period, August–September 1967. *A*, Upper East Branch Brandywine Creek basin; *B*, Pickering Creek basin.

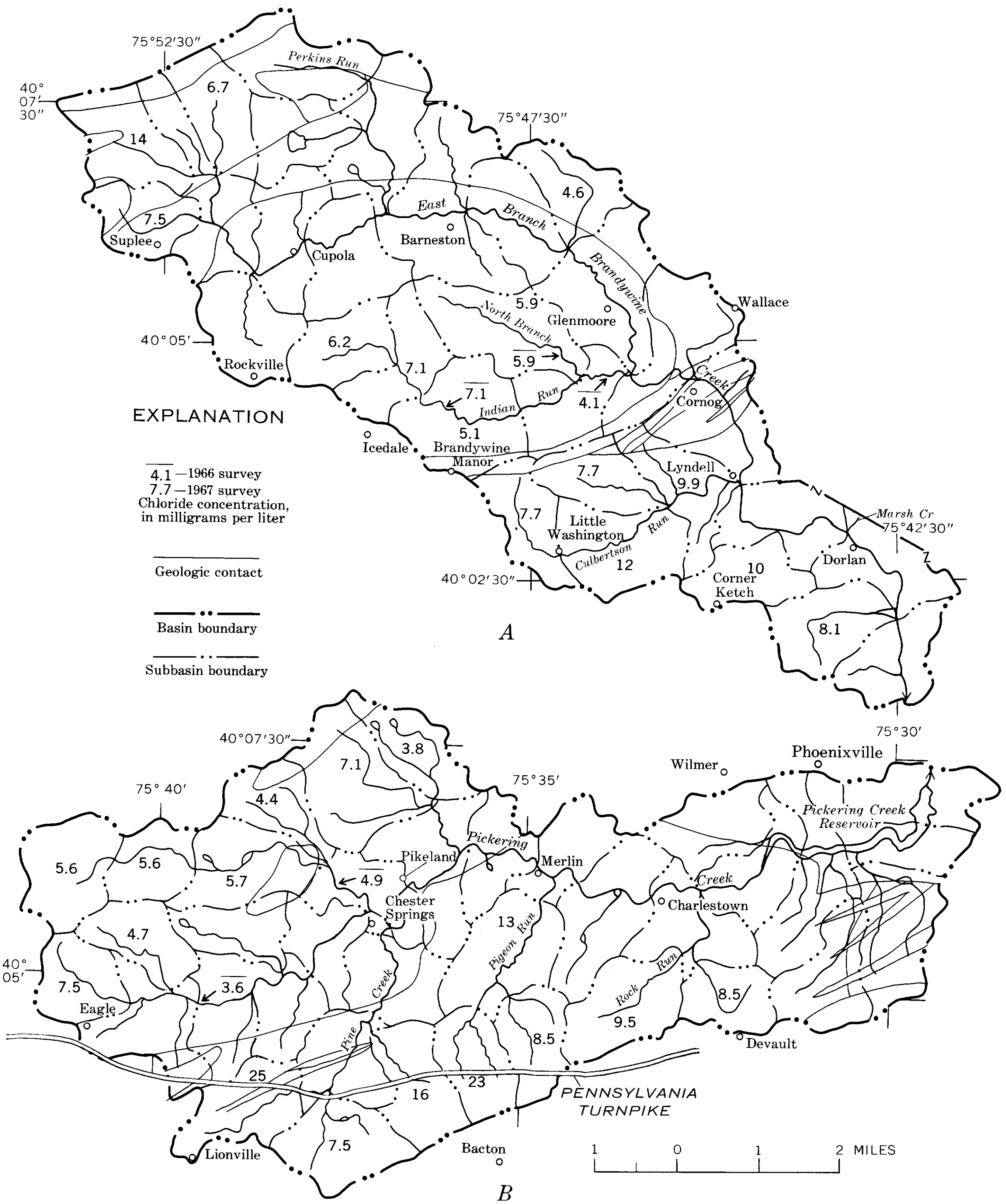


FIGURE 19.—Chloride (Cl) concentrations of steams at low flow during nonstorm period, August–September 1967. *A*, Upper east Branch Brandywine Creek basin; *B*, Pickering Creek basin.

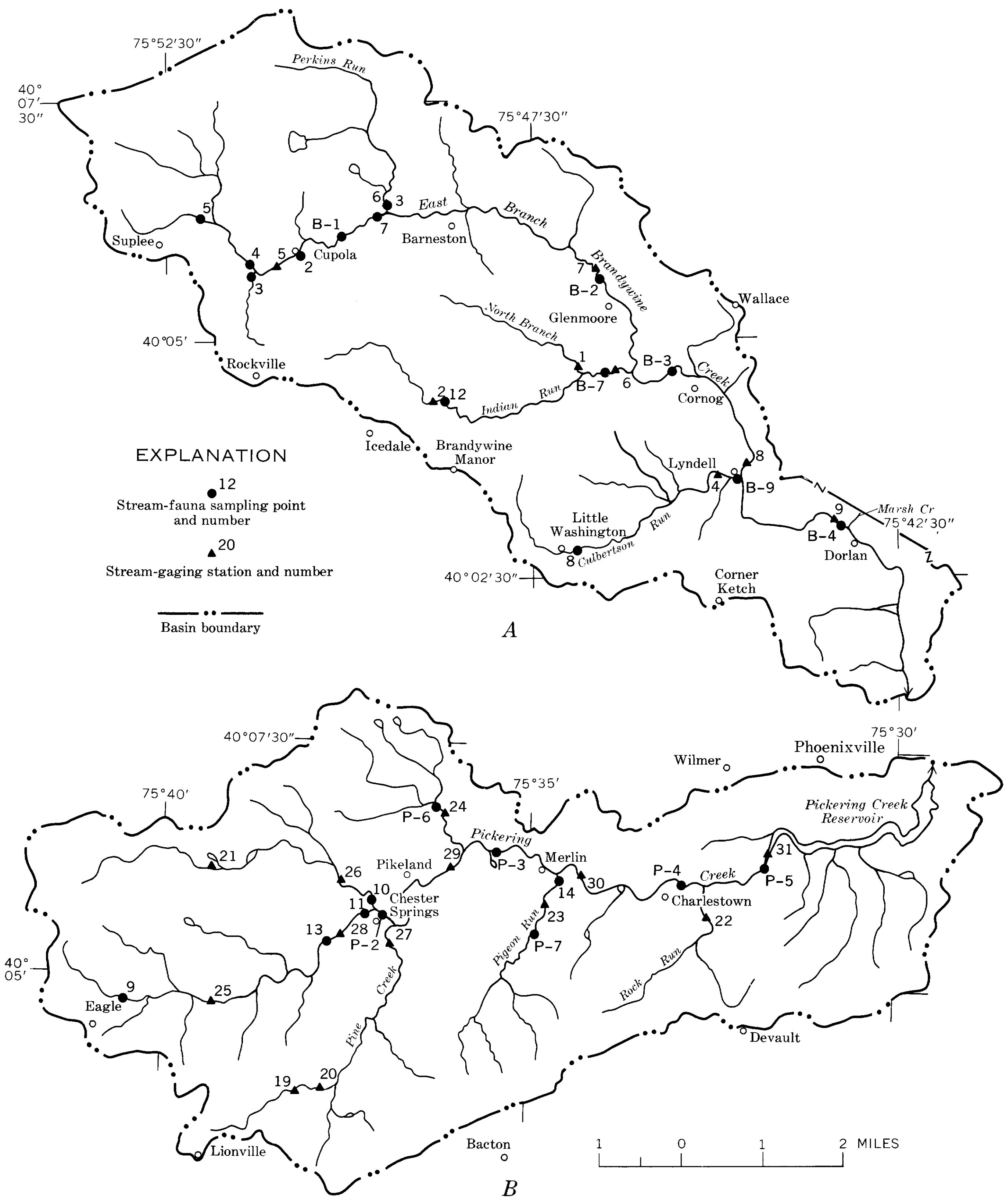


FIGURE 20.—Location of sampling points for stream fauna and gaging stations. *A*, Upper East Branch Brandywine Creek basin *B*, Pickering Creek basin.

present each month; *Physa* snails were present in June July, and September. Crayfish were found in June and July. *Tubifex* worms and flatworms were found in September. Fish seen each of the 4 months included minnows, sunfish, darters, and suckers.

Station B–2 seemed to be healthy but was more enriched than station B–1, as evidenced by the large numbers of rooted aquatics, by the occurrence of fingernail clams (sphaerids) and *Physa* snails through most of the study, and by the presence of tubificids and flatworms in September. This station showed no significant change in water quality during the 4 months it was surveyed.

STATION B–3

Diatoms, the dominant algae were very abundant in May, July, and September and were common in June. *Spirogyra* and *Cladophora* were found in each survey, *Spirogyra* being common in May and July. *Stigeoclonium* was present in May and July. Blue-green algae were collected each survey; *Vaucheria* was observed in July. Rooted aquatics were abundant each month.

Although the population fluctuated somewhat, mayflies were very common in June, common in May and September, and less common in July. Stoneflies, caddisflies, and midge larvae were observed each month. The stoneflies were common in May; the caddisflies were abundant in May and September. Dragonflies were found in June, July, and September; damselflies were collected in July and September. Gilled snails were common in May and observed during other months. *Physa* snails were found in each month. *Tubifex* worms were observed in June, July, and September; flatworms were collected in May and September. Fish observed each month of the survey included minnows, sunfish, suckers, and catfish.

Station B–3 seemed to be healthy, but enriched, as evidenced by the numbers of diatoms, rooted aquatics, *Physa* snails, tubificids, and flatworms. This station showed no significant change in water quality during the 4 months it was surveyed.

STATION B–4

Diatoms were very common in May and July and common in June and September at station B–4. *Spirogyra* and *Oedogonium* were present each month of the survey, *Oedogonium* being common in June and September. *Cladophora* was observed in May, July, and September and was common in September. Blue-green algae were present all 4 months. Rooted aquatics, which shared the dominant role among the plants with diatoms, were very common in July and abundant the other 3 months.

Mayflies were very common in June and common the other 3 months; caddisflies were common in May, July, and September and less common in June. Dragonflies, damselflies, and stoneflies were found all 4 months. Stoneflies were abundant in May; damselflies were common in September. Hellgrammites were found in May and September; midge larvae were collected in July and September. *Physa* snails were observed for each of the 4 months; crayfish were collected each month except May. *Tubifex* worms were present in June and September, gilled snails in June and July. Flatworms were observed in September. Fish were found all 4 months. Those observed included sunfish, suckers, darters, and minnows.

Station B–4 seemed to be healthy, but enriched, as evidenced by the abundance of rooted aquatic plants and the persistent occurence of *Spirogyra*, *Oedognoium*, and *Cladophora*. There was no significant change in water quality during the course of the four surveys.

STATION B–7

Diatoms were the prevalent algae and were abundant in June, very common in May and July, and less common in September. *Oedogonium* was present in each of the 4 months; *Spirogyra* was present the first 3 months, and *Cladophora* the last month. Blue-green algae were present in each of the 4 months.

Mayflies were abundant each month of the survey. Caddisflies were common in May and less common the other 3 months. Hellgrammites were collected in June, July, and September, damselflies in July and September, and midge larvae in September. Both *Physa* snails and gilled snails were present during each of the surveys. Crayfish were collected in May, June, and September. Leeches were found in September. Fish, including minnows, darters, sunfish, and suckers, were observed all 4 months.

This station appeared to be healthy, but enriched, as evidenced by the persistent occurrence of *Oedognium* and blue-green algae and the presence of many organisms commonly found in enriched healthy rivers. There was no significant change in water quality at this station during the 4 months.

STATION B–9

Diatoms, the dominant algae at station B–9 were very common during May, June, and July and common during September. *Cladophora* and *Oedogonium* were observed during each of the 4 months; *Oedogonium* was common. *Spirogyra* was fairly common in September. Blue-green algae, collected in each month of the survey, ranged from less common to common.

Mayflies were the dominant fauna and were very common in June and abundant during the remaining 3 months. Stoneflies, caddisflies, and damselflies were present during each month. Damselflies were common in each month except July, when they were less common; caddisflies were abundant during May and September and less common the other 2 months; stoneflies were common in May and less common the other 3 months. Midge larvae were collected in June, July, and September. Both *Physa* snails and gilled snails were collected each month; crayfish were collected in the first 3 months. Leeches and *Tubifex* worms were observed in July. Fish were common during each month and included sunfish, suckers, minnows, and trout.

Station B–9 seemed to be healthy, as evidenced by the large numbers of diatoms, mayflies, caddisflies, damselflies, and fish but was heavily enriched and showing definite signs of deterioration, owing to organic enrichment from farms. Among these signs are the common occurence of *Oedogonium*, the less common fairly large colonies of *Spirogyra*, and the continual occurrence of blue-green algae patches. The population sizes of *Physa* snails, leeches, and *Tubifex* worms also support these conclusions. There was no significant change in water quality at this station during the four surveys.

STATION P–2

Diatoms, the most abundant algae observed, were very abundant in May and July and common in June and September. *Spirogyra* was found in May and July, *Cladophora* in July, and *Oedogonium* in June, July, and September. *Stigeoclonium* was also present in July. *Vaucheria* was present in June, July, and September. Blue-green algae were present each month.

Mayflies were abundant each month of the surveys. Caddisflies, common in June and September, were less common in May and July. Stoneflies were collected each month. Midge larvae were present in May and July, and damselflies were found in June, July, and September. Crayfish were found each month; *Physa* snails were found in the latter 3 months. In September leeches and flatworms were also collected. Fish present for each survey included minnows and darters.

Station P–2 should be classified as healthy, but enriched, as evidenced by the persistence of blue-green algae and by the sporadic dominance of *Oedogonium* and *Vaucheria*. The occurrence of leeches and flatworms in September and the sustained occurrence of crayfish also indicate this condition. There was no significant change in water quality at this station during the four surveys.

STATION P–3

Diatoms, the prevalent algae, were very common in May and July and abundant in June and September. *Cladophora* was collected in the latter 3 months, and *Spirogyra* in September. *Stigeoclonium* was found in May and July. Blue-green algae were collected each month of the surveys; rooted aquatics were present for the latter 3 months.

Mayflies were common each month and caddisflies were abundant each month, except July when they were less common. Stoneflies, common in May and June, were less common in July and September. Midge larvae and dragonflies were collected each month. Amphipods were found in May, July, and September. *Tubifex* worms were present each month, and *Physa* snails were collected in June, July, and September. Crayfish were seen in September. A fresh-water clam was collected in May, and flatworms were seen in September. The fish which were seen each month of the survey included minnows, darters, and sunfish.

Station P–3 should be classified as healthy, but enriched, as evidenced by the numbers of diatoms, mayflies, caddisflies, and rooted aquatics. There was no significant change in water quality for the four surveys.

STATION P–4

Diatoms, the common plants collected, were very abundant in May and June and abundant in July and September. *Cladophora* was less common in the first 3 months of the survey and common in September. Blue-green algae were abundant in May and June and less common in July and September. Rooted aquatics were present the last 3 months.

Mayflies were common each month; caddisflies were abundant each month, except July when they were less common. Stoneflies, common in May and June, were less common in July and September. Damselflies and dragonflies were found all 4 months; midge larvae were collected in June and September. Both *Physa* snails and gilled snails were collected each month. Crayfish were observed each month except July, and mussels were present each month except September. Amphipods were present each month, and flatworms were seen in September. Fish present each month included sunfish, suckers, bass, and minnows.

Station P–4 should be classified as healthy, but enriched, as evidenced by the abundance of blue-green algae and the less common occurrence of *Cladophora*, damselflies, *Physa*, and crayfish. There was no significant change in water quality at this station during the course of the four surveys.

STATION P–5

Diatoms, very abundant in May and June and common in July and September, were the dominant algae. *Cladophora* was common each month except July when it was frequent. *Oedogonium* was present each month of the survey, but *Spirogyra* was found only in

September. Blue-green algae were abundant the first 3 months of the surveys and less common in September. Rooted aquatics were common in June and July and less common in May and September.

Mayflies were common each month, and caddisflies were abundant each month, with the exception of July when they were less common. Stoneflies, found each month of the survey, were common in May and June and less common in July and September. Damselflies were present in all months surveyed; hellgrammites, midge larvae, and dragonflies were found only in September. *Physa* snails and gilled snails were found each month, gilled snails being common in June. Crayfish were found in May, and *Tubifex* worms and flatworms in September. Fish, which were seen all 4 months included minnows, darters, suckers, and sunfish.

Station P–5 should be classified as healthy and more enriched than the previous stations, owing to the large populations of *Cladophora*, blue-green algae, and rooted aquatics. There was no significant change in water quality at this station during these surveys.

STATION P–6

Common all 4 months, diatoms were the dominant algae. *Oedogonium* was present each month and common in September. *Stigeoclonium* was collected in July. *Spirogyra*, *Cladophora*, and *Vaucheria* were present in September. Blue-green algae were present each month, and rooted aquatics were found in September. The increase in the diversity of the flora in September seemed to be correlated with some land clearing that took place between July and September and altered the character of the station by creating a number of shallow sunny pools.

Mayflies were abundant each month except September when they were less common. Caddisflies were common in June and September and frequent in May and July. Stoneflies larvae were collected in July and September, midge larvae in June, and blackfly larvae in September. *Physa* snails and amphipods were frequently found during all of the surveys. Fish collected during each survey included minnows and darters.

Station P–6 should be classified as healthy, but slightly enriched, as evidenced by the large diatom populations, the abundance of caddisflies and mayflies, and the frequent occurrence of amphipods and *Physa* snails. There was no significant change in water quality at this station during the course of the four surveys.

STATION P–7

Diatoms were the abundant algae and were very common in May and July and common in June and September. *Spirogyra*, *Oedogonium*, and *Vaucheria* were collected each month of the survey. Blue-green algae were also present each month, and rooted aquatics were present the latter 3 months.

Mayflies were abundant in May and June but were less common in July and September. Midge larvae, dragonflies, and damselflies were collected each month, the latter being common in May. Gilled snails were present each month and *Physa* snails were collected each month except June. Mussels were found in July, and *Tubifex* worms in May, July, and September. Fish were present each month, were common in May, and included minnows, darters, and suckers.

Station P–7 should be considered in a healthy condition, as evidence by the large diatom populations, mayflies, caddisflies, and damselflies (in May). There was no significant change in water quality at this station during the course of the four surveys.

DISCUSSION OF RESULTS

These twelve stations were healthy and indicated the nutrient levels that one would expect for these streams. At times, there were indications of greater than normal enrichment for these stream types, but the enrichment was not excessive. Because this is largely a farming community, one would expect the streams to be somewhat enriched.

In the Brandywine Creek, the upstream station showed the least enrichment; the next three stations all showed roughly equivalent amounts of enrichment. Indian Run (station B–7) showed similar enrichment and Culbertson Run (station B–9) showed evidence of increased enrichment somewhat heavier than that found at the lower stations on Brandywine Creek. This change seemed to be primarily because of the presence of cattle. The three upper stations of Pickering Creek showed evidence of enrichment which was roughly of the same magnitude. The lower station showed evidence of slightly more enrichment than did the upper three. The two tributaries, one of which was small, showed evidence of some enrichment; however, there was less enrichment than was present in the Pickering Creek itself. There were no significant variations in the chemical data at these stations.

RESULTS (OCTOBER AND NOVEMBER)

This study was carried out in October and November 1967. Studies were made once each month.

STATION 1

Station 1 was downstream from a wooded area that enveloped about a half dozen homes. There were some cornfields on the left side of the stream above the station. Discharge-measurement notes for September 2, 1967, showed a width of 5.0 feet, an area of 1.0 square foot, a velocity of 0.49 foot per second, a gage height of 3.74 feet, and a discharge of 0.49 cfs.

Diatoms were common in November but less common in October. *Cladophora* was less common both months, *Vaucheria* was rare in November.

During both surveys, mayflies, caddisflies, and water pennies were abundant and stoneflies were less common. Midge larvae were common in October and less common in November. Blackfly larvae were rare in October; beetles were rare both months. Crayfish were less common both months; *Physa* snails and flatworms were observed during both months. Minnows were abundant in October and less common in November.

This station should be classified as healthy. There was no significant change in water quality at this station for October and November.

STATION 2

Station 2 was downstream from a wood-bordered marsh beyond which were a few homes and one cornfield. Discharge-measurement notes for August 29, 1967, at an area upstream from the station showed a width of 13.8 feet, an area of 9.11 square feet, a velocity of 0.34 foot per second, a gage height of 1.40 feet and a discharge of 3.08 cfs.

At this station the algae showed a similar pattern each month, diatoms being abundant, blue-green algae less common, and *Spirogyra* rare. During the October survey, rooted aquatics were rare; in November, they were less common.

Mayflies, caddisflies, and midge larvae were common in October and less common in November. Stoneflies, damselflies, and water pennies were less common both months; blackfly larvae and beetles were less common in October and present in November. Gilled snails and amphipods were less common during both surveys; *Physa* snails were rare. Isopods and flatworms, less common in October, were rare in November. Minnows were less common both months.

This station should be classified as healthy, but slightly enriched, as evidenced by the numerous diatoms, blue-green algae, rooted aquatics, mayflies, caddisflies, midge larvae, and damselflies. There was no significant change in water quality for the October and November surveys.

STATION 3

Station 3 was downstream from a stretch of woodland through which the stream coursed. This woodland was about 100 yards wide, and at its edge were cornfields and a few scattered houses. There was a trailer camp of ten units just upstream from the station, at the outer edge of the fields. Discharge-measurement notes for August 29, 1967, at this station showed a width of 4.1 feet, an area of 1.65 square feet, a velocity of 0.36 foot per second, a gage height of 3.65 feet, and a discharge of 0.60 cfs.

Diatoms were abundant during both surveys, *Oedogonium* was less common during both surveys, and *Spirogyra* was rare in October. Blue-green algae were rare both months.

Mayflies and caddisflies were common during both surveys; stoneflies and midge larvae were less common. Damselflies were observed both months. Water pennies were less common in October and rare in November. Dragonflies and beetles were found in November, and crayfish were found in both October and November. *Physa* snails were rare in November; flatworms were less common in October and observed in November. Minnows were common in both months.

This station could be classified as healthy, but slightly enriched, as evidenced by the numerous diatoms, mayflies, and caddisflies. There was no significant change in water quality during the two surveys.

STATION 4

Station 4 was downstream from a dairy farm and some cornfields. Discharge-measurement notes for August 29, 1967, at this station showed a width of 13.81 feet, an area of 9.11 square feet, a velocity of 0.34 foot per second, a gage height of 1.40 feet, and a discharge of 3.08 cfs.

Diatoms were less common during both surveys. *Oedogonium* was present in the November survey; blue-green algae were very common at this station during both surveys. Rooted aquatics were rare during the two surveys.

Mayflies, caddisflies, and midge larvae were very abundant during both surveys; beetles were rare. Blackfly larvae were rare in October, damselflies were present in November, and dragonflies were present in October. Water pennies were less common in October and present in November. Flatworms, *Tubifex* worms, and *Physa* snails were rare during both surveys.

This station should be classified as healthy, but enriched, approaching semihealthy, as evidenced by the exceedingly large populations of blue-green algae and midge larvae. There was no significant change in water quality during the two surveys.

STATION 5

Station 5 was downstream from a farm. No cattle were in evidence, but five horses were seen. Farther upstream were more farms and a number of cornfields. Discharge-measurement notes for August 29, 1967, at this station showed a width of 6.4 feet, an area of 4.94 square feet, a velocity of 0.14 foot per second, a gage height of 6.90 feet, and a discharge of 0.71 cfs.

Diatoms were very abundant during both surveys; blue-green algae were rare in October and less common in November. Rooted aquatics were very common during both surveys. Damselflies, very abundant in October, were abundant in November. Mayflies and dragonflies were rare both months, midge larve were observed in November, and beetles were less common in both October and November. Isopods were very common in October and common in November, but amphipods were rare both months. No fish were seen at this station.

This station should be classified as healthy, but enriched, as evidenced by the very large populations of rooted aquatics, damselflies, and isopods. It appeared to verge on the border of being semihealthy. There was no significant change in water quality during the two surveys.

STATION 6

Station 6 was downstream from a wooded area with one or two houses. Farther along, the stream flowed through a wood-bordered marsh. About three-quarters of a mile from the station there was a cornfield along the edge of the woods, and roughly 1½ miles from the station there were some farms and pastures having a few more cornfields. The only animals seen grazing were two horses. Discharge-measurement notes for August 30, 1967, at this station showed a width of 5.4 feet, an area of 1.68 square feet, a velocity of 1.07 feet per second, a gage height of 3.05 feet, and a discharge of 1.80 cfs.

Diatoms and *Cladophora* were present in October and less common in November. Blue-green algae were rare both months.

Stoneflies and water pennies were less common during both surveys; caddisflies, midge larvae, dragonflies, and beetles were rare during both surveys. Mayflies were observed in October and were less common in November. Crayfish were collected in November, amphipods and flatworms in October. Minnows were less common during both surveys.

The condition of the water at this station appeared to be healthy. There was no apparent change in water quality during the two surveys.

STATION 7

Station 7 was downstream from a wooded valley where there were a few houses. About three-quarters of a mile away there were some distant cornfields and a small farm on which were seen 18 sheep and three horses. About 1 mile from the station there was a cluster of several dozen houses in a thinly wooded area. Discharge-measurement notes for August 30, 1967, at this station showed a width of 8.5 feet, an area of 4.47 square feet, a velocity of 0.62 foot per second, a gage height of 3.40 feet, and a discharge of 2.76 cfs.

Diatoms, less common in October, were abundant in November. *Cladophora* was rare in October and less common in November; *Oedogonium* was rare in October; *Vaucheria* was less common in October and present in November. Blue-green algae were rare in October and less common in November. Rooted aquatics were rare both months. Caddisflies were abundant both months, and mayflies, less common in October, were abundant in November. Stoneflies were less common in both months. Water pennies and midge larvae were less common in October and rare in November; beetles were rare both months. *Ferrissia* snails were less common both months; *Physa* snails were present both months and amphipods in October. Fish which were less common during both surveys included minnows, darters, and sunfish.

This station appeared to be healthy. There was no apparent change in water quality at this station during the two surveys.

STATION 8

Station 8 was downstream from a pasture in which were three horses. Farther along there was a group of 18 new houses, then a farm with pastures on which no no cattle or horses were seen, a dairy with 24 head of cattle, 24 new homes, and finally a trailer camp with 18 trailers. All this land use was within 1½ miles of the station. Discharge-measurement notes for September 5, 1967, at this station showed a width of 1.9 feet, an area of 0.485 square foot, a velocity of 1.28 feet per second, a gage height of 6.71 feet, and a discharge of 0.62 cfs.

Diatoms and *Oedogonium* were less common during both surveys. *Spirogyra* was rare in October. *Hydrodictyon*, the dominant algae here, was abundant during both surveys, and blue-green algae were collected during both surveys. Damselflies were less common in October and rare in November; dragonflies were found in October, and beetles, both months. *Physa* snails were collected in November. Fish, less common both months, included minnows, darters, and dace. Large numbers of tadpoles and salamander larvae were seen among the *Hydrodicyton* at this station.

This station should be classified as healthy, but enriched owing to the quantities of rooted acquatics, *Hydrodictyon*, and *Oedogonium*. There was no significant change in water quality at this station during the two surveys.

STATION 9

Station 9 was downstream from an area of alternating pasture and cultivated fields. There were 48 head of cattle in the pasture adjoining the station. At the headwaters of the stream is the small town of Byers.

Diatoms were abundant, *Spirogyra* was less common, and blue-green algae were rare during the two surveys.

Rooted aquatic plants were very common during both surveys.

Caddisflies and damselflies were less common in October and rare in November. Beetles were observed both months, and isopods, abundant in October, were less common in November. Crayfish were rare in October. *Physa* snails were collected in October and were less common in November. Fish were less common in October and rare in November. Suckers and other minnows were seen.

This station appeared to be healthy, but enriched, as evidenced by the large quantity of rooted aquatics and the common isopods. However, the lack of mayflies and the scarcity of caddisflies in November indicates the possibility that toxic material had sporadically entered the stream or that a prolonged dissolved-oxygen deficit occurred. There was no apparent change in water quality for the two surveys.

STATION 10

Station 10 was downstream from an area of alternating farmland and woodland.

Diatoms were abundant, *Oedogonium* was rare, and *Gaucheria* was less common during the two surveys. Rooted aquatics were observed both months.

Midge larvae, mayflies, damselflies, and water pennies were less common during both surveys. Stoneflies were less common in October but rare in November; caddisflies were less common in October and common in November. Beetles were observed during both surveys. *Ferrissia* snails were less common, and isopods and flatworms were rare during the two surveys. Fish, including minnows, darters, and dace, were less common for both October and November.

This station appeared to be healthy, but slightly enriched, as evidenced by the common diatoms and the numbers of *Ferrissia* snails, mayflies, caddisflies, midge larvae, and damselflies. There was no apparent change in water quality for the two surveys.

STATION 11

Station 11 was downstream from several farms having a few wooded areas. Some domestic ducks were seen in a pool upstream from the station.

Diatoms were prevalent in October and less common in November. *Spirogyra* was less common, and *Oedogonium* was rare during the two surveys. *Gaucheria* and blue-green algae were less common during the two surveys.

Mayflies, caddisflies, midge larvae, and *Ferrissia* snails were less common during both surveys; stoneflies were less common in October and observed in November. Damselflies, beetles, and flatworms were present in October; *Physa* snails were rare during both surveys. Fish which were less common during both surveys were minnows and darters.

This station appeared to be healthy, but slightly enriched, as evidenced by the common occurrence of diatoms, *Spirogyra*, *Ferrissia* snails, mayflies, caddisflies, and midge larvae. There was no significant change in water quality for the two surveys.

DISCUSSION OF RESULTS

Although the stations studied in October and November were all fairly near the headwaters of the streams, most of them showed evidence of a little enrichment. The station on Perkins Run (station 6) was healthy and showed no evidence of enrichment. The stations on Indian Run (station 1) and on the tributary to East Branch Brandywine Creek near Cupola (station 3) were healthy, and there was evidence of slight enrichment at the latter. The areas of greatest enrichment appeared to be the upstream stations (stations 4 and 5) on the East Branch Brandywine Creek, both of which were close to the semihealthy category. The water quality had improved at the two lower stations on the East Branch Brandywine Creek (stations 2 and 7) which were healthy. Station 2 showed evidence of slight enrichment. Apparently the stream had utilized some of the enrichment at stations 4 and 5 by the time it reached station 2. Culbertson Run (station 8) and two of the stations in the Pickering Creek basin (stations 10 and 11) showed healthy, but slightly enriched, conditions. The station on Pickering Creek (station 9) also showed evidence of enrichment; however, the absence of mayflies and the fact that caddisflies were scarce in November suggest the possibility that there had been sporadic discharges of toxic materials or instances of low dissolved oxygen. There were no significant variations in the chemical data at these stations.

When the land use is plotted against the water condition at each station, certain correlations can be seen. The station on Perkins Run which showed no evidence of enrichment (station 6) had woods and marshes immediately upstream, the first habitations being more than 1 mile away. Station 2 on the upper East Brandywine had similar upstream land use. However, this land use served merely to neutralize some of the effects of the enrichment at station 4; and station 2 also showed enrichment, although the water condition was an improvement over that of station 4. The two stations that showed the least evidence of enrichment (station 1 on Indian Run and station 3 on a tributary near Cupola) drained a wooded area, broken by a few homes and some cornfields, which were generally separated from the stream by the woods. The two stations which showed the most pronounced enrichment (stations 4 and 5) were the uppermost East Branch Brandywine

Creek stations; both had farms and cornfields upstream. Station 9 (Pickering Creek near Byers), which also showed evidence of significant alteration of the flora and fauna, was actually in a pasture, and more pastured and cultivated farms were upstream. The rest of the stations (stations 7, 8, 10, and 11; see table 9 for locations) showed moderate enrichment and they all had farms upstream. Stations 7 and 8 had some homes as well.

SUMMARY

In the Brandywine Creek basin, the areas showing the most enrichment were stations 4 and 5, at the upper end of the East Branch, and station B–9, on Culbertson Run just upstream from its confluence with the East Branch. The water quality in the East Branch Brandywine Creek which, at station 2, was an improvement over that at stations 4 and 5, had improved still more at station B–1. Station 7 showed results similar to those of station 2. Downstream, the stations on the East Branch Brandywine Creek (stations B–2, B–3, and B–4) showed similar results, having healthy, but more enriched, conditions than those of station 2. The stations on the tributary to Brandywine Creek near Cupola (station 3), on Perkins Run (station 6), and on Indian Run (station 1) all showed only slight evidence of enrichment. Station B–7 on lower Indian Run showed evidence of more enrichment than did the preceding three stations. The upstream station on Culbertson Run (station 8) showed evidence of enrichment, but not as much as station B–9 at the mouth of Culbertson Run.

In the Pickering Creek basin, most stations along the main branch of the Creek (stations 11, P–2, P–3, and P–4) showed evidence of healthy, but enriched, conditions. The downstream station on Pickering Creek (station P–5) showed evidence of slightly more enrichment than did the stations just discussed. The upstream station on Pickering Creek (station 9), near Byers, also showed evidence of healthy, but enriched, conditions. There was, however, evidence of the presence of toxic material or a dissolved-oxygen deficit at this station. All three tributaries to Pickering Creek which were studied showed evidence of enrichment, although there was less enrichment than in Pickering Creek itself. Station P–7 on Pigeon Run showed the least evidence of enrichment. The tributaries near Chester Springs (station 10) and Kimberton (station P–6) showed evidence of slightly more enrichment, but less than that which was noted in Pickering Creek.

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TABLES 7, 8, 10, 11

TABLE 7.—*Data on use of farmland, Pickering Creek basin*

[Sample obtained from interviews of individual landowners]

Subbasin location	Total land area (acres)	Acres in— Woods	Acres in— Pasture	Acres in— Cultivation	Number of cattle or horses	Wells or springs: Water source	Wells or springs: Depth (ft)	Fertilizer used: Type	Fertilizer used: Total (tons per yr)	Acres in— Corn	Acres in— Hay	Acres in— Wheat, barley and oats
Vincent Church (estate)	269	Not known	Not known	0	0	Three springs			0	0	0	0
Hallman	92	2	30	60	50	One well	85	Not known		10	30	20
St. Matthews	250	15	30	185	140	do	70	10–10–10	42	110	75	Not known
Vincent Church	37	0	37	0	4	do	30		0	Not known	Not known	Not known
Vincent Church	85	6	49	30	18	do	60	Not known	20	Not known	Not known	Not known
Oppermans Corner	260	40	45	170	47	Springs		5–10–10	15	Not known	Not known	Not known
Interchange	116	4	10	100	260	Two wells	79, 321	16– 8– 8	100	Not known	Not known	Not known
Trail	200	50	110	40	0	Not known		Not known		40	Not known	Not known
Pine and Bacton	250	25	60	85	9	Springs		Not known		Not known	60	24
Interchange	140	10	40	90	75	do		5–10–10	18	20	60	10
Birch and Kimberton	1, 100	500	200	400	[1] 700	Two wells	200, 390	10–10–10	50	150	150	Not known
Yellow Springs and Hollow.	140	15	40	85	70	Not known		10–20–20	12	Not known	Not known	Not known
Pikeland and Chester Springs.	650	250	100	300	80	Two wells	120, 135	5–10–10	12	Not known	Not known	Not known
Eagle	656	200		321	77	{do {Springs	29, 220	} Not known		Not known	Not known	Not known
Charlestown	400	75	50	110	0	Two wells	45, 75	5–10–10	4	Not known	Not known	Not known
Anselma	135	25	35	75	25	do	30, 100	20–10–10	7	Not known	Not known	Not known
Pikeland	320	110	50	160	0	{do {Springs	90, 210	} Not known		Not known	Not known	Not known
Total	5, 056	1, 120	886	1, 986	1, 555							

[1] All dairy cattle.

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*

[Sediment coefficient=0.00346 (assuming unit weight of water and sediment=80 lb per cu ft). Chemical concentrations in milligrams per liter. TDS, total dissolved solids]

STATION 1

U.S. Geological Survey station designation: 1–4806.57
Name: North Branch at Glenmoore
Latitude: 40°04′37″ Longitude: 75°46′53″

Drainage area: 1.6 sq mi
Mean annual discharge: 1.4 cfs
Mean annual flood: 105 cfs
Gages: crest stage, staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 14		2. 08	9. 3	0. 81	0. 28	7. 56
Sept. 2		. 54	6. 4	. 42	. 20	2. 68

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
39243	Sept. 2			6. 9												5. 9	102						16
	1968																						
40006	Feb. 25			8. 6	9. 5	2. 8				4. 6		28		0. 04	6. 3	5. 7	98		35	12	7. 0	5	1

STATION 2

U.S. Geological Survey station designation: 1–4806.56.
Name: Indian Run at Germany Hollow Road
Latitude: 40°04′25″ Longitude: 75°49′01″

Drainage area: 2.0 sq mi
Mean annual discharge: 1.8 cfs
Mean annual flood: 125 cfs
Gages: staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Sept. 2	[1] 0. 36	0. 49	5	0. 20	0. 49	1. 00
Dec. 3	[1] 1. 80, 1. 73	64. 7	21	1. 58	1. 95	33. 2
Dec. 3	[1] 1. 34, 1. 37	37. 3	18	. 91	2. 29	16. 3
Dec. 4	[1] . 55	3. 47	13	. 57	. 47	7. 45
Dec. 11	[1] . 74	8. 57	15	. 76	. 75	11. 4
1967—Continued						
Dec. 12	[1] 1. 45, 1. 45	46. 0	20	1. 26	1. 83	25. 2
1968						
Mar. 18	[1] 1. 60, 1. 57	43. 0	20	1. 33	1. 62	26. 6
May 28	[1] 2. 35, 2. 38	132	20	2. 32	2. 84	46. 4
June 19	[1] . 45, . 68	1. 78	14. 8	. 59	. 20	8. 70

[1] Gage height at bridge.

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 2—Continued

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)	Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967					*1968*				
Dec. 3	[2] 1.88	105	168	61	Mar. 13	[1] 1.22	26	34	3.1
Dec. 3	[2] 2.40	54	44	8.2	Mar. 18	[1] 1.32	33	25	2.9
Dec. 12	[2] 2.60	42	123	17.9	Mar. 18	[1] 1.09	17.5	68	4.1
Dec. 12	[2] 2.70	37	74	9.4	Mar. 18	[1] 1.64	60	69	14.3
Dec. 28	[1] .93	15.5	116	6.2	May 28	[3] 2.42	137	156	74
Dec. 28	[1] 1.08	22.5	76	5.9	June 19	[3] 2.68	1.78	3	.018

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
39242	Sept. 2	[1] 0.36	0.48	5.3												7.1	146						14
	1968																						
40001	Feb. 5	[1] .47	1.8	15	14	3.8				4.8		34		0.04	9.1	7.0	135		51	23	7.1	7	5
40403	Mar. 18	[1] 1.69	60		7.9	2.2								.10	5.2	4.5	95	81	29				
40404	Mar. 18	[3] 1.09	17.5		8.7	2.5								.02	5.5	5.0	103	82	32				
40405	Mar. 18	[3] 1.32	33		8.3	2.5								.13	5.9	5.0	99	80	31				
40491	May 28	[3] 2.42	137	14	6.0	1.6	5.2					12		.20	2.5	2.2		68	22	12	6.3		
40648	Apr. 14		1.4		16	4.5								.00	11	6.8	143	107	59				

STATION 3

U.S. Geological Survey station designation: 1–4806.52
Name: Perkins Run at Rose Cottage
Latitude: 40°06′30″ Longitude: 75°49′33″
Drainage area: 3.7 sq mi
Mean annual discharge: 3.4 cfs
Mean annual flood: 205 cfs
Gages: crest stage, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)	Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967							*1967*—Continued						
Jan 12	4.60	2.65	12	0.362	0.61	4.35	May 12	4.85	5.82	10.0	0.999	0.583	9.99
Feb. 15	4.68	3.53	15	.525	.447	7.89	June 9	4.52	1.81	8.6	.894	.24	7.68
Mar. 6	5.68	34.0	14.5	1.34	1.75	19.4	July 26	4.46	1.13	5.1	.787	.28	4.01
Mar. 29	5.02	8.68	11.5	.992	.761	11.4	Oct. 12	4.46	.93	4.7	.326	.61	1.53
Apr. 27	5.34	17.8	12.7	1.28	1.09	16.3	Nov. 30	4.50	1.20	8.6	.228	.61	1.96

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)	Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967					*1967*—Continued				
Jan. 27	6.34	87	1,970	593	June 21	4.48	1.37	7	.033
Jan. 27	6.40	94	656	213	June 29	4.65	3.2	82	0.91
Feb. 15	4.70	3.8	7	.09	July 6	4.45	1.1	9	.034
Mar. 6	5.75	38	279	36.7	July 13	4.47	1.25	31	.134
Mar. 7	6.10	64	141	31.3	July 19	4.46	1.15	7	.028
Mar. 7	5.58	29	63	6.3	May 11	5.29	16.6	88	5.05
Mar. 8	5.11	12.5	28	1.22	May 15	4.94	7.4	37	.95
Mar. 29	5.04	9.5	19	.62	Aug. 3	4.98	8.2	226	6.40
Mar. 15	4.95	7.6	14	.37	Aug. 4	4.89	6.5	21	.47
Mar. 22	4.76	4.53	3	.047	Aug. 2	4.70	3.8	12	.16
Mar. 29	4.86	6.0	7	.14	Aug. 10	4.75	4.4	16	.24
Apr. 5	4.62	2.9	3	.030	Aug. 23	4.69	3.7	14	.18
Apr. 12	4.60	2.7	2	.019	Aug. 25	5.90	48	61	10.1
Apr. 17	4.84	5.6	32	.62	Aug. 25	4.90	6.7	25	.58
Apr. 19	4.64	3.1	5	.054	Aug. 25	4.95	7.6	29	.76
Apr. 27	5.41	21	49	3.56	Aug. 31	4.54	2.05	7	.050
Apr. 27	5.35	18.8	29	1.88	Sept. 6	4.49	1.50	6	.031
May 3	4.78	4.8	11	.18	Sept. 27	4.43	.8	8	.022
May 7	4.92	7.0	33	.80	Oct. 6			5	
May 11	5.21	14	47	2.28	Oct. 10			50	
May 17	4.65	3.2	7	.077	Oct. 11	4.60	2.25	16	.124
May 24	4.57	2.35	6	.049	Oct. 19	4.57	1.92	10	.066
May 29	4.65	3.2	26	.29	Nov. 30	4.50	1.26	3	.013
May 29	4.72	4.0	61	.84					
June 8	4.50	1.6	8	.044	*1968*				
June 15	4.51	1.7	10	.059	Jan. 10	4.59	2.5	3	.026

[1] Gage height at bridge.
[2] From bridge to water surface.
[3] Gage height at staff.

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 3—Continued

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
37352	Sept. 2			8.6	14	4.6	18	0.0	0.0	6.8	2.1	60	0.1	0.00	2.6	8.8	144	97	54	6	7.0	3	24
	1967																						
37748	Jan. 27	6.40	94											.30	5.1	8.5	131	97			6.7		
37690	Feb. 14	4.61	2.8											.06	8.3	10	117	95			7.1		
38741	Mar. 7	6.10	64	15	7.1	3.1	5.1	.06	.00	3.2	3.8	15	.2		7.0	6.5	94	66	31	18	7.1	13	1
38735	Mar. 29	4.98	8.2	20	11	4.0	11	.00	.00	5.8	2.8	25	.1		5.3	8.0	127	92	44	24	6.9	10	8
38998	May 9	4.79	5.0	14	9.5	4.1	12	.00	.00	5.1	1.6	28	.1		4.6	7.4	109	85	42	18	6.9	10	13
39231	June 30	4.47	1.25	10												6.0	110						19
39217	July 31	4.46	1.15	10												6.3	116						22
39085	Aug. 3			9.2								17					63						
39087	Aug. 3			18								63					146						17
39666	Aug. 3	4.98	8.2	9.7	8.8	3.5	11			6.2	1.8	36	.2		3.8	7.7	110	81	37	7	6.9	10	23
39086	Aug. 3			12								20					75				7.2		22
40025	Nov. 9	4.48	1.3	11	10	4.1				6.0		37		.08	6.4	5.5	117		42	12	7.5	3	5
39412	July 13	4.48	1.3	9.4	9.8	4.0	20	.00	.01	6.2	1.5	43	.1		6.1	5.5	117	94	41	6	7.3	7	20
	1968																						
40021	Feb. 5	4.69	3.7	16	10	4.2				5.8		26		.06	8.3	7.5	122		43	21	7.0	5	5
40644	Apr. 14	4.59	2.5		11	4.8								.00	5.6	6.5	117	79	47				

STATION 4

U.S. Geological Survey station designation: 1–4806.62
Name: Culbertson Run at Lyndell
Latitude: 40°03′29″ Longitude: 75°45′07″
Drainage area: 3.9 sq mi
Mean annual discharge: 3.8 cfs
Mean annual flood: 215 cfs
Gages: crest stage, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 14	2.29	6.17	10.8	0.50	1.14	5.42
Feb. 16	2.43	9.68	17.5	.40	1.38	7.03
Mar. 6	2.75	25.7	19.0	.77	1.75	14.7
Mar. 31	2.23	4.99	12.2	.96	.43	11.7
Apr. 27	2.59	19.6	18.4	1.12	.95	20.6
May 11	2.46	11.7	14	1.51	.55	21.1
1967—Continued						
June 6	2.07	2.70	13.5	1.03	1.94	13.9
July 26	1.97	1.37	3.20	.36	1.20	1.14
Sept. 18	2.05	2.35	5.0	.41	1.14	2.07
Oct. 12	2.06	2.17	5.2	.40	1.05	2.07
Dec. 1	2.09	2.61	8.1	.46	.70	3.75

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 14	2.3	6.4	5	0.11
Jan. 27	3.21	72	1,970	491
Jan. 27	3.28	84	1,125	327
Jan. 27	2.87	34.4	216	25.7
Feb. 16	2.45	10.5	18	.65
Mar. 6	2.90	36.0	255	31.8
Mar. 6	2.76	25.7	74	6.59
Mar. 7	2.90	36.0	130	16.2
Mar. 7	2.70	21.5	62	4.62
Mar. 31	2.23	4.9	4	.068
Apr. 17	2.39	8.6	38	1.13
Apr. 27	2.56	14.5	28	1.41
May 7	2.70	21.5	322	23.9
1967—Continued				
May 7	2.72	22.5	71	5.5
Mar. 29	2.37	8.4	7	.20
May 11	2.54	13.5	73	3.42
May 11	2.47	11.5	73	2.91
May 11	2.45	10.5	45	1.64
Aug. 4	2.42	9.4	16	.52
Oct. 20	2.10	2.92	2	.02
Dec. 1	2.09	2.90	3	.03
1968				
Jan. 17	2.20	4.40	2	.03
May 28	3.42	115	268	107

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
37744	Jan. 27	3.28	84											0.02	4.5	8.5	119	103			6.6		
37696	Feb. 14	2.17	3.9											.04	11	10	145	101			7.1		0.5
38687	Mar. 7	2.90	36	20	9.2	2.8	6.5	0.00	0.00	.5	.2	13	0.4		6.0	6.6	97	73	35	24	6.8	15	2
38734	Mar. 31	2.23	5.0	27	13	4.5	12	.00	.00	7.0	2.1	24	.0		7.8	10	150	118	51	32	6.8	3	7
39039	May 5	2.16	3.7	24	11	4.7	13	.01	.00	6.4	1.9	26	.0		7.6	9.0	144	97	47	26	7.3	4	16
39232	June 30	2.02	2.0	23												11	153						20
39209	July 26	1.97	1.5	23												11	149						26
39213	Sept. 5	2.10	2.9	24												8.9	153						20
40022	Nov. 9	2.10	2.9	24	13	4.8				7.6		26		.11	9.9	10	158		52	31	7.4	5	6
40023	Dec. 3	3.23	76	20	8.5	3.4				7.8		13		.39	6.2	11	121		35	25	6.7	20	2
	1968																						
40024	Feb. 5	2.22	4.8	25	13	4.9				6.9		22		.13	10	11	160		53	35	7.1	3	6
40651	Apr. 14	2.09	2.9		14	5.2								.00	9.9	11	157	104	57				

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 5

U.S. Geological Survey station designation: 1–4806.5
Name: East Branch Brandywine Creek at Cupola
Latitude: 40°05′55″ Longitude: 75°50′44″

Drainage area: 6.2 sq mi
Mean annual discharge: 5.8 cfs
Mean annual flood: 310 cfs
Gages: continuous stage recorder, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 11	2.71	6.29	16.6	0.74	0.53	12.2
Feb. 5	2.76	6.91	19	.82	.44	15.6
Mar. 6	4.13	79.3	32	1.30	1.91	41.6
Mar. 6	4.38	81.1	32	1.90	1.33	60.9
Mar. 7	4.94	134	41	2.26	1.44	92.8
Mar. 29	2.98	15.7	21	.81	.92	17.0
Apr. 13	2.67	4.76	18	.78	.34	14.0
Apr. 13	2.67	5.66	18.7	.73	.41	13.6
Apr. 18	2.75	7.70	19	.82	.49	15.6
May 25	2.65	4.34	23	1.19	.16	27.3
July 26	2.54	2.22	14.5	.46	.33	6.66
1967—Continued						
Aug. 31	2.46	2.59	6.9	0.51	0.74	3.51
Aug. 31	2.46	3.70	7.0	.89	.59	6.22
Oct. 11	2.60	3.30	14.6	.49	.46	7.13
Dec. 1	2.60	3.35	10.2	.40	.82	4.10
1968						
Jan. 10	2.61	3.53	9.2	.51	.75	4.71
Feb. 22	2.50	3.52	15	.42	.55	6.35
Mar. 19	2.95	16.4	17.5	.77	1.21	13.5
Apr. 2	2.62	4.66	14.6	.53	.60	7.77
May 14	2.58	4.23	17	.42	.60	7.10

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 27	4.96	135	1,470	687
Jan. 27	5.16	154	593	317
Feb. 5	2.76	7.9	5	.14
Feb. 14	2.67	5.0	5	.09
Feb. 15	2.71	6.2	3	.06
Feb. 15	3.12	20.8	16	1.2
Feb. 22	2.73	6.8	5	.12
Feb. 22	2.73	6.8	5	.12
Feb. 22	2.76	7.9	5	.14
Mar. 1	2.64	4.3	5	.07
Mar. 1	2.69	5.5	6	.11
Mar. 1	2.70	5.8	4	.08
Mar. 6	4.00	64	111	26.0
Mar. 6	4.15	73	86	21.6
Mar. 6	4.33	85	343	101
Mar. 6	4.44	93	324	104
Mar. 7	4.60	105	169	61.4
Mar. 7	4.20	76	122	32.1
Mar. 7	3.80	37	60	10.8
Mar. 7	3.57	44	49	7.5
Mar. 8	3.91	59	19	3.9
Mar. 8	3.99	63	14	3.1
Mar. 15	3.5	37	33	4.2
Mar. 15	3.8	52	25	4.5
Mar. 15	3.99	63	25	5.5
Mar. 22	2.80	9.3	5	.16
Mar. 22	3.86	56	4	.77
Mar. 22	3.90	58	8	1.6
Mar. 29	3.05	18.2	17	1.1
Mar. 29	3.85	55	12	2.3
Mar. 29	3.95	61	13	2.7
Apr. 5	2.69	5.5	4	.08
Mar. 29	3.11	20.4	28	2.0
Apr. 5	2.70	5.8	10	.2
Apr. 5	2.72	6.5	2	.04
Apr. 12	2.96	15.0	3	.13
Apr. 12	2.68	5.3	4	.08
Apr. 12	2.67	5.0	8	.14
Apr. 17	2.73	6.8	8	.19
Apr. 19	2.70	5.8	6	.12
Apr. 19	2.70	5.8	4	.08
Apr. 19	2.67	5.0	5	.09
Apr. 26	2.48	1.4	4	.02
Apr. 26	2.70	5.8	5	.10
Apr. 26	2.75	7.6	9	.24
Apr. 27	2.74	7.2	42	1.05
May 3	2.78	8.6	12	.36
May 3	3.87	56	15	2.91
May 3	2.73	6.8	11	.26
May 11	3.23	25	28	2.4
May 11	3.53	38	55	7.2
May 11	3.36	30	58	6.0
May 11	3.18	23	50	4.0
May 15	2.81	9.6	10	.33
May 17	2.71	6.2	13	.28
May 17	2.70	5.8	15	.30
May 17	2.67	5.0	16	.28
May 17	2.72	6.5	14	.32
May 24	2.64	4.3	11	.16
May 24	2.65	4.5	11	.17
May 24	2.68	5.3	11	.20
May 29	2.70	5.8	23	.46
May 29	2.66	4.8	23	.38
June 8	2.61	3.6	22	.27
June 8	2.60	3.4	24	.28
June 8	2.61	3.6	22	.27
June 8	2.61	3.6	19	.24
June 15	2.61	3.6	41	.51
June 15	2.50	1.6	25	.14
June 15	2.49	1.5	159	----------
June 15	2.50	1.6	28	----------
1967—Continued				
June 21	2.62	3.8	23	----------
June 21	2.59	3.1	23	----------
June 21	2.59	3.1	27	----------
June 21	2.57	2.7	22	----------
June 22	2.65	4.5	49	----------
June 29	2.70	5.8	62	----------
June 29	2.73	6.8	64	----------
June 29	2.75	7.6	59	----------
June 29	2.72	6.5	48	----------
July 6	2.58	2.9	47	----------
July 6	2.58	2.9	43	----------
July 6	2.58	2.9	38	----------
July 6	2.58	2.9	37	----------
July 13	2.59	3.1	56	----------
July 13	2.60	3.4	57	----------
July 13	2.60	3.4	123	----------
July 13	2.60	3.4	50	----------
July 19	2.57	2.7	44	----------
July 19	2.57	2.7	39	----------
July 19	2.57	2.7	50	----------
Aug. 2	2.58	2.9	49	----------
Aug. 2	2.58	2.9	23	----------
Aug. 2	2.58	2.9	29	----------
Aug. 3	2.65	4.5	41	----------
Aug. 3	2.77	8.2	108	----------
Aug. 4	3.95	61	72	15.2
Aug. 4	3.90	58	69	13.8
Aug. 4	3.88	57	69	13.6
Aug. 4	2.86	11.4	68	2.68
Aug. 4	2.84	10.7	72	2.66
Aug. 4	2.82	10.0	82	2.84
Aug. 4	2.82	10.0	59	2.04
Aug. 4	2.82	10.0	60	2.08
Aug. 10	2.77	8.2	51	----------
Aug. 10	2.72	6.5	33	----------
Aug. 10	2.70	5.8	32	----------
Aug. 10	2.67	5.0	33	----------
Aug. 23	2.56	2.5	30	----------
Aug. 23	2.59	3.1	15	----------
Aug. 23	2.57	2.7	14	----------
Aug. 23	2.50	1.6	16	----------
Aug. 25	2.85	11.05	47	1.80
Aug. 25	3.91	59	53	10.8
Aug. 25	3.90	58	41	8.24
Aug. 31	2.49	3.8	18	----------
Aug. 31	2.49	3.8	18	----------
Aug. 31	2.53	4.8	15	----------
Aug. 31	2.52	4.5	31	----------
Sept. 6	2.47	3.4	24	----------
Sept. 6	2.45	2.9	14	----------
Sept. 6	2.46	3.1	16	----------
Sept. 6	2.44	2.7	21	----------
Sept. 21	2.46	3.1	25	----------
Sept. 21	2.50	4.0	11	----------
Sept. 21	2.48	3.6	11	----------
Sept. 27	2.44	2.7	17	----------
Sept. 27	2.45	2.9	12	----------
Sept. 27	2.45	2.9	12	----------
Sept. 27	2.43	2.5	12	----------
Oct. 5	2.42	----------	18	----------
Oct. 5	2.45	----------	16	----------
Oct. 5	2.44	----------	20	----------
Oct. 6	2.44	----------	39	----------
Oct. 11	2.63	----------	20	----------
Oct. 11	2.65	----------	21	----------
Oct. 11	2.75	----------	33	----------
Oct. 19	2.61	----------	30	----------
Oct. 20	2.58	----------	12	----------
Oct. 20	2.60	----------	6	----------
1968				
Jan. 10	2.61	----------	7	----------

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 5—Continued

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
37353	Sept. 1		0.69	8.2	14	4.9	22	0.0	0.02	7.5	2.8	55	0.2	0.0	5.3	12	155	104	55	10	6.8	4	23
	1967																						
37749	Jan. 27	5.16	154											.06	4.4	7.5	120	101			6.8		
36794	Feb. 14	2.67	4.9											.08	14	10	139	120					
38744	Mar. 7	4.60	105	17	8.0	2.7	4.9	0	0	3.0	4.3	17	.2		4.2	4.9	96	71	31	17	6.8	17	1
38737	Mar. 29	2.95	14.5	23	14	4.4	13	.02	0	7.0	3.1	32	0		4.9	11	149	102	53	27	7.2	2	8
39009	May 9	2.78	8.5	19	15	4.7	16	0	0	6.3	1.6	37	.2		5.8	14	141	111	57	27	7.2	14	13
39233	June 30	2.57	2.70	10												9.0	136						22
39208	July 31	2.57	2.7	13												10	142						25
39277	Aug. 31	2.46	3.1	10												9.5	149						19
40014	Nov. 9	2.62	3.7	13	13	4.3				8.0		44		.04	7.7	8.5	143		50	14	7.6	5	5
40015	Dec. 3	5.95	240	19	3.5	3.3				9.4		13		.37	6.3	14	127		35	24	6.7	25	.5
	1968																						
40016	Feb. 5	2.73	6.8	18	13	4.6				7.6		34		.14	9.6	10	155		52	24	7.4	5	4
40649	Apr. 14	2.66	4.7		14	5.0								0	7.7	8.0	145	97	56				

STATION 6

U.S. Geological Survey station designation: 1–4806.58
Name: Indian Run at Glenmore
Latitude: 40°04′41″ Longitude: 75°46′19″
Drainage area: 6.3 sq mi
Mean annual discharge: 5.8 cfs
Mean annual flood: 310 cfs
Gages: crest stage, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Mar. 5	5.15	7.05	15	0.81	0.58	12.2
Mar. 7	6.85	233	26	2.14	4.76	55.7
Mar. 7	6.03	66.2	31	1.22	1.76	37.7
Mar. 29	5.33	14.6	15.7	.90	1.04	14.1
Apr. 20	5.04	5.52	18.4	.68	.44	12.4
May 11	5.75	36.7	28	1.03	1.27	28.9
1967—Continued						
June 5	4.96	4.12	15.4	0.60	0.44	9.28
July 26	4.90	2.16	5.7	.70	.54	4.02
Aug. 7	5.00	3.54	7.2	.97	.70	5.07
Oct. 12	4.96	2.38	8.75	.45	.61	3.90
Nov. 30	5.03	1.87	5.4	.77	.45	4.13

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Mar. 6	5.15	7.5	2.5	0.065
Mar. 6	6.26	96	101	33.5
Mar. 7	7.22	380	287	378
Mar. 7	6.50	140	137	66.3
Mar. 7	6.31	105	84	30.5
Mar. 7	5.98	59	37	7.6
Mar. 29	5.60	26	22	2.0
Apr. 17	5.24	10	13	.45
Apr. 27	5.90	50	45	7.8
May 7	5.37	14.5	20	1.0
1967—Continued				
May 7	6.21	88	63	19.2
May 11	5.62	27.5	55	5.23
May 11	5.80	41	63	8.94
Aug. 4	5.37	14.5	25	1.25
Oct. 19	5.13	5.5	13	.25
Nov. 30	5.03	1.87	1	.006
1968				
Jan. 20	5.13	7	4	.097
May 28	7.28	400	126	175

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
37349	Sept. 2		0.66	4.0	10	2.6	2.3	0.0	0.0	5.6	1.0	47	0.1	0.00	1.8	4.1	97	78	36	0	6.8	4	18
	1967																						
37746	Jan. 27													.02	2.8	7.5	94	88					
37698	Feb. 14													.03	5.2	5.5	106	88					.5
38692	Mar. 7	6.50	142	16	6.0	2.0	4.5	.0	.0	3.8	2.1	8	.3		2.4	6.4	79	59	23	17	6.8	15	2
38693	Mar. 29	5.60	26	16	10	3.0	14	.0	.0	8.0	1.4	28	.2		4.4	11	122	91	38	15	7.6	2	7
38997	May 9	5.25	10.2	15	11	2.7	18	.00	.00	5.0	.9	27	.2		2.5	5.5	102	86	39	17	7.2	9	13
39230	June 30	4.94	3.25	7.1												4.8	105						18
39413	July 13	4.94	3.25	6.9	11	2.8	25	.00	.00	6.2	.9	48	.2		3.8	4.5	109	98	39	0	7.4	8	19
39207	July 1	4.91	2.37	7.6												5.3	105						21
39994	Nov. 9	5.06	4.0	9.2	12	3.0				6.0		43		.02	4.2	5.3	114		43	8	7.6	2	5
39997	Dec. 3	6.93	260	18	9.0	2.4				5.1		10		.27	5.2	9.3	102		33	25	6.4	30	1
	1968																						
39996	Feb. 5	5.15	7.4	14	12	3.0				4.6		29		.01	4.4	7.5	115		43	19	7.0	2	5
40642	Apr. 14	5.05	5.3		11	2.8								.02	4.1	5.1	109	82	39				
40493	May 28	7.28	400	16	7.0	1.6	6.4					12		.12	2.9			68	24	14	6.3		

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 7

U.S. Geological Survey station designation: 1–4806.55
Name: East Branch Brandywine Creek at Glenmore
Latitude: 40°05′48″ Longitude: 75°46′44″

Drainage area: 16.5 sq mi
Mean annual discharge: 17 cfs
Mean annual flood: 700 cfs
Gages: crest stage

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 13	4.85	19.5	21.7	0.885	1.02	19.2
Feb. 3	4.61	[4] 14.6	33.0	1.26	.35	41.5
1967—Continued						
May 8	5.03	[4] 42.5	33.2	1.93	0.66	64.0

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 16	4.79	24	38	3.16
Mar. 29	5.27	70	18	4.36
May 7	5.20	57	51	9.2
May 8	5.00	40	11	1.52
1967—Continued				
Dec. 3	7.11		346	
1968				
May 28	8.01		280	

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
	Sept. 5		1.43	8.2	12	3.7	15	0.0	0.0	6.4	1.7	52	0.2	0.09	1.4	6.6	122	81	45	3	6.9		20
	1967																						
	Feb. 14													.03	8.6	10	135	112			7.2		
39995	Dec. 3	8.18		15	9.0	3.0				4.8		14		.14	6.5	9.5	111		35	24	6.7	10	
	1968																						
40492	May 28	8.01		15	8.5	2.2	6.5					18		.17	4.1	5.0		82	30	15	6.1		

STATION 8

U.S. Geological Survey station designation: 1–4806.6.
Name: East Branch Brandywine Creek at Lyndell
Latitude: 40°03′34″ Longitude: 75°44′40″

Drainage area: 27.1 sq mi
Mean annual discharge: 28 cfs
Mean annual flood: 1,000 cfs
Gages: crest stage

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 13	0.53	31.8	35	0.577	1.57	20.2
Apr. 11	.51	23.9	36	.97	.69	34.8
Sept. 6	.04	11.3	32	.84	.42	26.8
1968						
Mar. 18	2.65	461	49	2.66	3.54	130

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1968				
Mar. 18	2.89	580	381	765
Mar. 18	2.35	350	254	308

[4] Includes tributary.

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 8—Continued

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
------	Sept. 1		4.03	13	14	3.9	15	0.0	0.0	6.2	2.2	5.5	0.0	0.0	1.4	6.6	131	90	51	6	6.9		21
	1967																						
------	Jan. 27													.02	3.1	26.0	159	93			6.7		
------	Feb. 14													.04	7.0	9.0	131	96			7.3		
39220	Sept. 6	0.04	11.3	12												7.5	131						
	1968																						
40406	Mar. 18	2.89	800	------	9.6	3.2								.19	6.6	8.5	122	93	37				
40407	Mar. 18	2.55	350	------	9.3	3.3								.19	7.5	9.0	124	87	37				

STATION 9

U.S. Geological Survey station designation: 1–4806.65
Name: East Branch Brandywine Creek at Dorlan
Latitude: 40°03′08″ Longitude: 75°43′28″

Drainage area: 33.4 sq mi
Mean annual discharge: 35 cf
Mean annual flood: 1,200 cfs
Gages: continuous stage recorder, staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1966						
Dec. 19	1.94	27.8	38	0.83	0.88	31.5
1967						
Jan. 16	1.70	44.3	47	.72	1.31	34.0
Feb. 17	1.63	39.0	38	.87	1.18	33.1
Mar. 6	3.63	288	48	1.97	3.05	94.5
Mar. 7	4.85	823	61	2.58	5.24	157
Mar. 29	2.57	87.4	38	1.26	1.82	47.9
Apr. 18	2.25	44.7	37	.99	1.22	36.7
Apr. 24	2.15	37.3	36	.98	1.06	35.3
Apr. 26	2.04	27.7	37	.88	.86	32.3
Apr. 26	2.04	30.0	55	1.50	.36	82.8
Apr. 27	3.31	217	41	1.80	2.94	73.7
Apr. 28	2.45	66.4	37	1.20	1.49	44.6
May 11	2.92	134	40	1.48	2.26	59.2
June 5	1.94	20.9	37	.83	.68	30.8
June 13	1.85	17.1	38	.73	.62	27.6
1967—Continued						
June 16	1.88	19.2	33	0.82	0.71	27.0
July 28	1.80	11.1	30.4	.81	.45	24.5
July 28	1.95	19.4	33.4	.86	.68	28.5
July 28	1.91	15.4	32	.86	.56	27.4
July 30	2.34	45.8	38.6	1.03	1.15	39.7
July 30	2.26	38.5	37	1.01	1.03	37.4
July 30	2.17	14.6	37	.95	.42	35.1
Aug. 4	2.74	92.3	39	1.33	1.78	51.8
Oct. 12	1.94	16.2	33	.85	.58	28.0
Nov. 30	1.85	12.1	40	.79	.38	31.5
1968						
Jan. 17	2.36	42.7	38	1.30	.87	49.2
Feb. 23	2.14	32.4	34	.94	1.02	31.9
Apr. 5	2.22	40.9	38	.96	1.13	36.3
May 17	3.02	146	40	1.55	2.35	62.1

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 16	1.75	10.5	11	0.40
Jan. 16	1.68	8.5	7	.21
Feb. 17	1.58	6.5	3	.06
Mar. 7	5.85	1,330	1,005	4,640
Mar. 7	5.22	960	461	1,530
Mar. 7	4.96	810	360	1,010
Mar. 7	4.50	600	296	615
Mar. 8			16	
Mar. 9			6	
Mar. 29	2.51	82	9	2.55
Mar. 29	2.55	80	15	4.16
Apr. 17	2.22	46	5	.80
Apr. 26	2.16	41	3	.42
Apr. 27	3.30	290	103	103
Apr. 28	2.45	66.2	7	1.60
1967—Continued				
May 7	2.61	95.0	26	8.55
May 7	3.80	345	354	424
May 8	2.75	115	21	8.37
May 9	2.45	66.2	6	1.37
May 11	2.95	147	48	24.4
May 12	2.60	93	38	12.2
June 22	2.75	115	153	61.0
June 22	2.80	125	276	120
Aug. 4	2.90	137	96	46
Aug. 4	2.75	115	64	25.4
Aug. 4	2.65	103	35	12.5
Aug. 10	2.95	147	52	26.5
Oct. 19	2.24	50	10	1.73
Dec. 1	2.14	40	1	.14

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 9—Continued

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
37361	Sept. 2		5.22	13	13	3.7	15	0.00	0.00	5.8	2.0	50	0.1	0.01	0.8	7.0	127	85	48	7	6.8	5	21
	1967																						
37745	Jan. 27	4.02	650											.00		12	124	116			6.7		
37691	Feb. 14		24											.06	7.5	10	134	100			7.1		
38740	Mar. 7	5.22	1,030	15	6.6	2.2	4.7	.00	.00	4.0	3.5	10	.1		4.9	7.1	90	60	26	18	7.0	7	1
38736	Mar. 29	2.55	79	19	12	3.2	12	.00	.00	10	1.8	26	.2		3.6	16	143	116	43	22	6.7	5	10
38768	Apr. 27	3.28	210	22	10	2.8	12	.02	.00	6.8	2.0	21	.1		4.0	8.5	119	90	37	20	7.2	25	8
39229	June 30	2.10	27	16												8.5	129						21
39210	July 27	1.80	11.2	14												7.6	125						27
39224	Sept. 7	1.90	15.5	15												8.5	131						21
40017	Nov. 9	1.98	25	16	13	4.0				7.4		39		.05	5.4	8.5	141		49	17	7.5	5	4
40018	Dec. 3	4.47	580	18	8.1	2.6				9.0		11		.26	6.6	12	116		31	22	6.6	20	2
40019	Dec. 12	3.75	330	26	12	4.0				6.0		21		.22	5.2	8.0	135		47	30	6.9	30	7
	1968																						
40020	Feb. 5	2.23	49	20	12	4.1				7.8		27		.06	6.7	11	142		47	25	7.3	5	4
40398	Mar. 18	4.63	700		9.2	2.9								.21	6.4	9.5	122	89	35				
40652	Apr. 14	2.10	36		12	3.9								.00	5.2	8.0	126	87	46				

STATION 19

U.S. Geological Survey station designation: 1–4721.81
Name: Pine Creek at Sharp Farm
Latitude: 40°03′40″ Longitude: 75°38′28″
Drainage area: 0.5 sq mi
Mean annual discharge: 0.4 cfs
Mean annual flood: 41 cfs
Gages: Staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1968						
Mar. 17	2.10	19.7	9.0	1.29	1.70	11.6
Mar. 17	1.86	14.8	8.4	1.07	1.65	8.96
Mar. 18	.91	3.65	4.0	.58	1.58	2.31
1968—Continued						
Mar. 18	0.79	2.81	4.1	0.38	1.81	1.55
Apr. 21	.50	.36	1.1	.26	1.24	.29
Jun. 12	2.22	37.4	14.8	1.06	2.38	15.7

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1968				
Mar. 13	1.06	5.0	128	2.25
Mar. 17	2.04	10.8	3,760	140
Mar. 17	2.12	19.5	1,980	133
Mar. 17	1.80	14.0	918	44.5
Mar. 17	1.86	15.0	1,360	70.5
Mar. 17	1.38	8.4	571	16.6
Mar. 18	2.12	19.5	914	61.6
Mar. 18	.97	4.2	202	2.94
1968—Continued				
May 28	0.84	3.15	683	7.44
May 28	1.30	7.4	2,441	62.5
May 28	1.68	12.4	2,799	120
May 28	1.86	15.0	1,407	73
May 28	2.04	18.2	1,696	107
May 29	1.30	7.4	458	11.7
June 12	2.80		6,220	

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1968																						
40009	Feb. 29	0.56	0.8	35	22	10				4.1		30		0.02	18	21	253		96	72	6.9	3	4
40400	Mar. 17	2.14	20.		14	5.4								.16	7.6	38	252	176	57				
40655	Apr. 14	.51	.41		22	10								.00	21	23	248	166	96				
40487	May 28	1.68	12.3	19	14	4.8						40		.31	6.0	17		182	55	22	6.6		
40488	May 28	2.04	18.2	19	13	4.0	5.3					34		.24	5.2	17		152	49	21	6.6		
40489	May 29	.98	4.3	29	19	5.8	8.4					43		.17	9.2	29		169	72	37	6.8		
40803	June 12	2.80		16	10	3.8	8.6					22		.42	5.1	14		86	41	23	6.7		
40753	June 26	.58	.95		19	10	15					50		.04	17	28		193	89	48	7.0		19
40754	June 27	.60	1.1		18	9.8	15					50		.00	19	24		200	86	45	6.9		
40755	June 27	.70	2.0		20	10	14					64		.01	14	32		247	91	39	7.0		17
40830	July 14	.54	.64		19	9.0	17					44		.27	21	25	258	183	85	49	7.2		18
40831	July 15	.54	.64		19	9.6	17					48		.18	20	24	259	180	87	48	7.0		17
40832	July 15	.54	.64		20	9.5	16					44		.10	21	26	257	184	89	53	7.0		18
41083	July 22	.52	.5		21	9.4	17					44		.09	24	25	255	185	91	55	7.3		15

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 20

U.S. Geological Survey station designation: 1–4721.82
Name: Pine Creek near Lionville
Latitude: 40°03′50″ Longitude: 75°37′55″
Drainage area: 1.1 sq mi
Mean annual discharge: 1.0 cfs
Mean annual flood: 78 cfs
Gages: crest stage

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 19	3.20	1.08	3.4	0.24	1.32	0.82
Feb. 3	3.21	1.39	7.0	.45	.44	3.13
Mar. 22	3.37	3.25	4.3	.46	1.63	2.00
Oct. 3	3.11	.628	2.4	.21	1.15	.50

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Mar. 22		3.25	14	0.16
Mar. 29	3.43	4.0	21	.29

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1968																						
40007	Feb. 26		0.7	27	14	8.5				11		28		0.03	11	24	222		70	47	6.9	4	5

STATION 21

U.S. Geological Survey station designation: 1–4721.75
Name: Tributary to Pickering Creek at Art School Road
Latitude: 40°06′07″ Longitude: 75°39′32″
Drainage area: 1.9 sq mi
Mean annual discharge: 1.7 cfs
Mean annual flood: 118 cfs
Gages: crest stage, staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Sept. 28		0.83	4.3	0.52	0.37	2.22
Dec. 7		2.99	7.1	.48	.86	3.46
Dec. 11		8.63	7.2	.71	1.69	5.12
Dec. 12		20.7	8.0	1.09	2.37	8.75
Dec. 12		36.8	12.4	1.43	2.08	17.7
1968						
Mar. 17	1.70	43.5	11.5	1.51	2.50	17.4
Mar. 18	1.94	58.3	11.5	1.79	2.83	20.6
Mar. 18	1.07	17.7	10	1.04	1.70	10.4
Apr. 21	.49	1.67	6	.39	.71	2.35
June 19	.60	3.47	9.2	.49	.76	4.52

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Dec. 12		29	118	11.8
Dec. 12		31	598	64.1
Dec. 12		44	215	32.8
Dec. 12		38	210	27.6
Dec. 12		10	53	1.8
Dec. 28		21	343	24.9
Dec. 29		31	368	39.4
1968				
Mar. 13	1.12	25	229	19.8
Mar. 17	1.80	53	652	120
1968—Continued				
Mar. 17	1.80	53	606	111
Mar. 17	1.66	46	320	50.8
Mar. 18	2.00	62	1200	258
Mar. 18	1.82	53	401	73.5
Mar. 18	1.10	24	126	10.5
May 28	1.00	15	362	18.8
May 28	1.64	42	808	117
May 28	2.00	62	857	184
May 28	1.98	61	381	80.4
May 29	1.20	22.5	78	6.06
June 19	.60	3.47	12	.144

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 21—Continued

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1968																						
40000	Feb. 4	0.60	4.2	19	13	3.7				5.5		29		0.04	4.9	8.0	128		48	24	7.0	5	4
40402	Mar. 17	1.68	44		7.9	2.9								.16	4.9	8.5	113	89	32				
40643	Apr. 14	.51	1.9		12	2.8								.00	4.9	6.5	111	77	42				

STATION 22

U.S. Geological Survey station designation: 1–4721.89
Name: Rock Run at Charlestown
Latitude: 40°15′43″ Longitude: 75°32′34″
Drainage area: 2.6 sq mi
Mean annual discharge: 2.4 cfs
Mean annual flood: 160 cfs
Gages: crest stage, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)	Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967							*1967*—Continued						
Jan. 25	.99	4.20	18.5	0.69	0.33	12.7	Aug. 27	1.55	45.4	22	1.44	1.43	31.7
Feb. 19	.95	3.75	17.6	.80	.26	14.0	Aug. 27	1.41	27.7	22	1.27	1.00	27.9
Mar. 16	.75	5.53	14.0	1.43	.28	20.0	Dec. 5	1.04	2.80	8.1	.62	.56	5.04
Apr. 10	.62	2.82	17	.83	.20	14.1							
May 7	1.20	23.7	22.5	.92	1.14	20.7	*1968*						
June 14	.36	2.04	15	.70	.19	10.5	Jan. 18	.96	3.49	8.1	.65	.66	5.28

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)	Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967					*1967*—Continued				
Jan. 25	0.99	4.20	5	0.073	Aug. 27	1.45	36	1,890	236
Jan. 25	.99	4.20	5	.073	Aug. 27	1.46	37	5,980	766
Feb. 19	.96	3.75	7.5	.097	Aug. 27	1.57	48	1,720	286
Mar. 16	.74	5.50	23	.44	Aug. 27	1.45	36	578	72
Mar. 16	.75	5.53	13	.25	Aug. 27	1.36	22.5	319	22.9
Apr. 10	.65	2.82	9	.088	Oct. 20	.93	4.1	8	.11
May 7	1.34	33	828	94.6	Dec. 5	1.04	2.8	6	.058
Aug. 3	1.38	31	616	66	*1968*				
Aug. 27	1.28	18.5	9,610	615	Jan. 18	.97	3.5	29	.35

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
38682	Feb. 2		5.0	32	20	6.5	14	0.00	0.00	7.0	2.1	57	0.2		4.4	8.5	195	135	77	30	7.6	2	
38996	May 5	0.60	4.6	28	19	6.1	15	.00	.00	6.3	2.2	54	.1		1.7	8.5	180	125	73	28	7.2	4	17
39234	Aug. 27	1.52	43	16												5.8	156						21
	1968																						
40005	Feb. 4	.93	9.2	27	17	7.4				4.6		41		0.02	4.0	13	183		73	40	7.1	10	3
40654	Apr. 14	.93	9.2		20	7.0								.00	3.7	16	194	130	79				

STATION 23

U.S. Geological Survey station designation: 1–4721.86
Name: Pigeon Run at Merlin
Latitude: 40°05′37″ Longitude: 75°34′54″
Drainage area: 2.8 sq mi
Mean annual discharge: 2.7 cfs
Mean annual flood: 170 cfs
Gages: crest stage, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)	Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967							*1967*—Continued						
Jan. 23	1.62	8.14	9.6	1.02	0.83	9.81	Oct. 13	1.23	1.76	4.4	0.36	1.12	1.57
Feb. 20	1.41	3.91	7.0	.61	.91	4.30	Nov. 28	1.21	1.75	4.4	.37	1.06	1.65
Mar. 24	1.64	9.08	8.6	.71	1.48	6.12							
Apr. 27	1.96	18.3	12.0	.71	2.33	8.50	*1968*						
May 12	1.25	2.24	6.3	.50	.71	3.17	Jan. 19	1.37	3.96	6.1	.57	1.14	3.47

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 23—Continued

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 23	1.61	7.8	13	0.35
Feb. 20	1.41	4.0	1	.014
Mar. 24	1.64	9.1	7	.22
Mar. 28	1.74	11.7	21	.85
Apr. 24	1.53	6.8	7	.16
Apr. 27	1.92	17	48	2.82
Apr. 27	1.98	19	41	2.70
1967—Continued				
May 7	2.34	35	443	53.6
Oct. 19	1.31	2.8	8	.078
Nov. 28	1.21	1.75	2	.012
1968				
Jan. 19	1.37	4.0	6	.083

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
38689	Feb. 20	1.41	4.6	24	12	5.2	13	0.00	0.00	7.5	1.6	26	0.1		4.4	14	152	107	52	30	7.2	2	
38773	May 5	1.35	3.6	23	12	4.5	14	.00	.00	6.0	1.5	29	.1		3.1	10	138	95	49	25	7.4	5	19
	1968																						
40004	Feb. 4	1.45	5.3	24	14	6.0				6.2		26		0.04	4.9	16	166		60	38	7.0	6	3
	1967																						
40266	Sept. 21	1.21	1.8	17	13	5.7				6.0		36		.00	2.9	14	149		56	27	7.3	6	18
	1968																						
40647	Apr. 14	1.32	3.2		13	5.2								.00	4.1	11	142	98	54				

STATION 24

U.S. Geological Survey station designation: 1–4721.85
Name: Tributary to Pickering Creek near Kimberton
Latitude: 40°06′49″ Longitude: 75°36′18″

Drainage area: 3.1 sq mi
Mean annual discharge: 2.8 cfs
Mean annual flood: 180 cfs
Gages: crest stage, staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1976						
Jan. 20	2.28	1.24	11.8	0.61	0.17	7.20
Feb. 28	2.34	1.37	5.8	.45	.52	2.60
Mar. 16	2.52	4.28	5.5	.72	1.08	3.96
July 31		.65	1.9	.20	1.63	.39
Oct. 13	2.28	.60	2.2	.24	1.15	.52
1967—Continued						
Nov. 28	2.28	0.58	2.2	0.28	0.93	0.62
1968						
Jan. 18	2.37	1.76	4.6	.36	1.05	1.68

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 20	2.28	1.23	8	0.034
Feb. 28	2.34	1.37	6	.028
Mar. 16		4.1	8	.113
May 7	2.90	14	73	3.53
Oct. 19	2.34	1.37	8	.038
1967—Continued				
Nov. 28		0.78	7	0.019
1968				
Jan. 18	2.38	1.92	45	.30

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
38733	May 5	2.27	0.46	17	16	3.8	14	0.00	0.00	3.1	1.1	47	0.0		2.4	5.1	134	106	56	17	7.2	2	18
	1968																						
40029	Feb. 4		2.15	22	18	5.0				2.1		41		0.02	4.3	7.0	153		66	32	7.4	3	
40263	Sept. 20		.76	13	20	4.3				6.4		66		.00	5.0	7.0	157		68	14	7.6	3	18
40645	Apr. 14		1.17		16	4.0								.06	5.4	6.1	134	89	57				

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 25

U.S. Geological Survey station designation: 1-4721.7
Name: Pickering Creek near Eagle
Latitude: 40°04′43″ Longitude: 75°39′14″

Drainage area: 3.1 sq mi
Mean annual discharge: 2.8 cfs
Mean annual flood: 180 cfs
Gages: crest stage

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 18	10.09	2.78	8.6	0.26	1.22	2.28

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
37345	Sept. 1			8.8	23	3.2	23	0.00	0.00	4.6	1.4	83	0.2	0.00	2.6	3.6	160	112	71	3	6.9	4	23

STATION 26

U.S. Geological Survey station designation: 1-4721.76
Name: Tributary to Pickering Creek at Chester Springs
Latitude: 40′06′03″ Longitude: 75°37′38″

Drainage area: 4.3 sq mi
Mean annual discharge: 4.0 cfs
Mean annual flood: 230 cfs
Gages: crest stage, staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Feb. 2	4.32	7.50	22	0.99	0.35	21.7
Feb. 28	4.28	5.65	10	1.01	.56	10.1
Apr. 6	4.33	5.36	11.1	.97	.50	10.8
June 14	4.17	2.35	5.2	.57	.80	2.94
July 31	4.19	2.45	3.8	.52	1.23	1.99
1967—Continued						
Oct. 27	4.25	2.38	5.5	0.53	0.81	2.92
Nov. 28	4.20	1.91	4.4	.56	.77	2.48
1968						
Jan. 19	4.28	4.24	10.8	.53	.74	5.76

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Feb. 2	4.32	7.5	6	0.16
Feb. 28	4.29	5.9	3	.06
Apr. 5	4.33	5.4	7	.13
Apr. 24	4.36	6.1	15	.21
May 7	4.89	31	284	30.5
1967—Continued				
Nov. 28	4.20	2.1	2	0.014
1968				
Jan. 19	4.28	4.2	7	10

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1966																						
37343	Sept. 1		0.43	12	16	3.2	18	0.00	0.00	4.5	1.8	56	0.2	0.00	0.8	4.9	129	92	53	7	6.9	5	22
	1967																						
38559	Feb. 2	4.23	7.50	18	11	3.2	15	.01	.00	4.5	2.5	31	.2		4.4	5.7	114	80	41	15	7.4	9	7
38731	May 5	4.27	4.0	14	12	2.8	10	.00	.00	4.5	1.1	36	.0		.7	5.4	106	86	42	12	7.1	5	18
	1968																						
40028	Feb. 4	4.35	5.9	19	11	3.3				6.0		26		.08	2.8	7.0	119		41	20	7.2	5	3
40641	Apr. 14	4.23	3.2		12	3.0								.00	2.3	5.6	106	71	43				

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 27

U.S. Geological Survey station designation: 1–4721.83.
Name: Pine Creek at Chester Springs
Latitude: 40°05′14″ Longitude: 75°36′45″

Drainage area: 5.1 sq mi
Mean annual discharge: 4.8 cfs
Mean annual flood: 270 cfs
Gages: crest stage, staff

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Mar. 6	4.60	21.7	15	1.15	1.26	17.2
Mar. 15	4.30	10.2	14.5	.99	.71	14.3
Mar. 24	4.44	16.5	14.5	1.07	1.06	15.5
Apr. 6	4.22	7.14	15.5	.85	.54	13.2
June 8	4.10	3.63	12.2	.88	.33	10.7
Aug. 7	4.23	4.12	10.3	1.05	.38	10.8
1967—Continued						
Oct. 13	4.28	3.35	11.0	0.46	0.66	5.06
Nov. 28	4.32	3.24	10.4	.44	.71	4.57
1968						
Jan. 18	4.30	5.66	15.9	.58	.61	9.23

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Mar. 6	4.63	31	87.5	9.4
Mar. 16	4.30	10.2	2	.07
Mar. 24	4.45	17.5	22	1.33
Mar. 29	4.53	23	25	2.00
Apr. 6	4.22	7.2	5	.12
Apr. 24	4.29	9.8	10	.34
Apr. 27	4.72	39	81	10.9
1967—Continued				
May 7	5.10	90	433	135
Oct. 19	4.31	3.7	7	.09
Nov. 28	4.32	3.2	2	.02
1968				
Jan. 18	4.30	5.7	5	.10

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
38769	May 5	4.20	6.6	21	13	4.4	15	0.00	0.00	7.5	1.5	32	0.1	------	2.7	13	144	94	51	25	7.3	2	18
	1968																						
40026	Feb. 4	4.35	7.0	22	13	5.5	------	------	------	12	------	27	------	0.03	6.6	22	182	------	55	33	7.4	3	3
40653	Apr. 14	4.28	5.2	------	13	5.5	------	------	------	------	------	------	------	.00	3.7	10	151	107	55	------	------	------	------
40833	July 14	4.19	3.3	------	12	5.5	15	------	------	------	------	36	------	.42	4.2	20	154	110	53	23	7.4	------	19
40834	July 15	4.19	3.3	------	12	5.4	15	------	------	------	------	39	------	.41	4.6	18	154	111	52	20	7.2	------	19
40835	July 15	4.19	3.3	------	12	5.5	15	------	------	------	------	36	------	.18	3.6	20	154	114	52	23	7.3	------	20

STATION 28

U.S. Geological Survey station designation: 1–4721.74
Name: Pickering Creek near Chester Springs
Latitude: 40°05′22″ Longitude: 75°37′50″

Drainage area: 6.0 sq mi
Mean annual discharge: 5.7 cfs
Mean annual flood: 300 cfs
Gages: continuous stage recorder, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1966						
Dec. 20	1.46	4.03	13.8	0.62	0.47	8.58
1967						
Jan. 20	1.35	6.34	10	.55	1.16	5.48
Feb. 19	1.51	10.3	15.5	.82	.81	12.7
Mar. 24	1.53	10.5	13	.78	1.04	10.1
Apr. 6	1.42	7.72	13.2	.72	.82	9.47
Apr. 27	1.99	32.2	13.8	1.28	1.82	17.7
June 2	1.28	4.86	12.5	.66	.59	8.20
June 16	1.23	3.76	12.4	.58	.55	7.18
July 27	1.18	2.90	11.1	.58	.45	6.40
1967—Continued						
Oct. 11	1.28	4.21	11.1	0.86	0.44	9.58
Dec. 5	1.42	7.00	10.8	.86	.75	9.30
Dec. 13	1.56	11.7	12.1	.84	1.15	10.2
1968						
Jan. 15	1.73	17.9	12.8	1.21	1.15	15.5
Feb. 20	1.33	5.41	15.5	.52	.67	8.08
Mar. 17	2.92	74.1	16	2.16	2.14	34.6
Mar. 18	3.81	177	16	3.24	3.42	51.8
Apr. 4	1.41	7.16	11.2	.74	.87	8.24

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 28—Continued

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)	Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967					*1968*				
Jan. 20	1.34	6.00	7	0.14	Jan. 15	1.73	17.9	53	3.28
Feb. 19	1.51	10.3	38	1.36	Mar. 17	3.52	130	754	338
Mar. 24	1.54	11.3	16	.63	Mar. 17	3.43	120	592	246
Apr. 6	1.42	7.9	10	.27	Mar. 17	3.41	118	737	300
Apr. 24	1.51	10.3	19	.68	Mar. 17	2.23	36	303	37.8
Apr. 27	1.93	28.1	275	26.8	Mar. 17	2.82	68	356	83.8
Apr. 27	2.00	32.7	154	17.4	Mar. 18	3.89	195	1,080	728
May 7	2.25	50.0	786	136	May 28	1.66	15.3	379	20.1
May 7	2.22	48.0	203	33.8	May 28	2.66	60	986	205
Aug. 10	2.00	32.7	113	12.8	May 28	3.32	109	942	356
Aug. 10	1.86	24.5	86	7.3	May 28	3.62	147	380	193
Oct. 20	1.30	4.5	3	.05	May 29	2.50	52	128	23
					June 12	4.00	207	959	687

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
38754	Feb. 19	1.51	10.3	19	15	4.9	17	0.00	0.00	7.6	1.8	39	0.0	...	7.8	12	159	105	58	26	7.6	1	...
38764	May 5	1.40	7.4	16	15	3.2	14	.00	.00	5.5	1.5	42	.1	...	5.1	7.5	132	95	51	16	7.5	2	19
39841	Sept. 20	1.20	3.05	13	17	4.5	19	...	...	5.0	2.3	56	.1	...	5.1	7.1	146	103	61	15	7.5	2	19
	1968																						
40027	Feb. 4	1.51	10.5	19	15	5.0	...	...	...	6.7	...	37	...	0.02	6.4	12	162	...	58	28	7.4	3	3
40401	Mar. 17	3.43	118	...	10	3.8	...	...	...	...	...	...	...	.18	8.0	12	145	103	41	...	...	...	...
40646	Apr. 14	1.32	5.2	...	15	4.5	...	...	...	...	...	...	...	.00	6.6	7.5	138	96	56	...	...	...	...
40490	May 28	3.32	110	18	12	3.5	7.6	...	...	...	...	29	...	.10	3.8	11	...	97	45	21	6.5	...	...

STATION 29

U.S. Geological Survey station designation: 1–4721.84
Name: Pickering Creek at Pikeland
Latitude: 40°06′13″ Longitude: 75°36′03″

Drainage area: 17.7 sq mi
Mean annual discharge: 18 cfs
Mean annual flood: 720 cfs
Gages: crest stage

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 22	2.36	17.7	34.5	1.18	0.43	40.7
Apr. 10	2.45	23.2	30	.94	.82	28.1

STATION 30

U.S. Geological Survey station designation: 1–4721.87
Name: Pickering Creek at Charlestown
Latitude: 40°06′05″ Longitude: 75°34′17″

Drainage area: 26.0 sq mi
Mean annual discharge: 28 cfs
Mean annual flood: 1,000 cfs
Gages: crest stage

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1967						
Jan. 22	1.74	30.0	44	1.17	0.58	51.4
Mar. 22	2.10	43.9	68	1.86	.35	126.1

TABLE 8.—*Discharge measurements by current meter and sediment and chemical data*—Continued

STATION 31

U.S. Geological Survey station designation: 1–4721.9
Name: Pickering Creek near Phoenixville
Latitude: 40°06′33″ Longitude: 75°31′42″
Drainage area: 31.4 sq mi
Mean annual discharge: 34 cfs
Mean annual flood: 1,150 cfs
Gages: continuous stage recorder, wire weight

Discharge measurements by current meter

Date	Stage (ft)	Discharge (cfs)	Width (ft)	Mean depth (ft)	Mean velocity (fps)	Area (sq ft)
1966						
Dec. 20	1.84	18.4	38	1.03	0.47	39.0
1967						
Jan. 23	1.68	39.4	40	1.68	.58	67.4
Feb. 2	1.71	43.5	40	.84	1.30	33.4
Mar. 8	2.13	85.0	62	1.16	1.20	71.9
Mar. 21	1.78	48.2	39	.90	1.44	35.2
Apr. 7	1.95	74.6	62	1.11	1.08	68.9
Apr. 19	1.65	34.8	48	1.28	.56	61.6
Apr. 24	1.78	46.7	49	1.37	.69	67.4
Apr. 27	2.57	159	64	1.50	1.66	96.0
June 2	1.53	26.0	39	1.45	.46	56.5
June 14	1.45	20.0	40	1.56	.31	62.2
1967—Continued						
Sept. 21	1.38	15.1	40	1.28	0.29	51.2
Oct 11	1.53	22.8	41	1.43	.39	58.5
Dec. 5	1.67	35.2	42	1.15	.73	48.1
1968						
Jan. 15	2.55	135	49	1.86	1.48	91.1
Feb. 20	1.63	29.6	36	.85	.97	30.6
Mar. 17	3.48	412	49	3.61	2.33	177
Mar. 18	4.10	623	49	4.23	3.01	207
Apr. 3	1.64	36.5	46	1.11	.71	51.2
Apr. 4	1.65	36.4	46	1.16	.68	53.4
May 15	1.55	31.4	36	1.03	.85	37.0
June 19	1.77	51.8	48	1.17	.92	56.0

Sediment data

Date	Stage (ft)	Discharge (cfs)	Sediment concentration	Sediment discharge (tons per day)
1967				
Jan. 23	1.64	34.2	1	0.12
Jan. 23	1.66	36.1	1	.12
Feb. 2	1.68	38	4	.49
Mar. 8	2.12	84	24	7.0
Mar. 8	2.12	84	24	7.0
Mar. 8	2.12	84	38	11.0
Apr. 6	1.92	61	12	2.5
Apr. 24	1.65	36	4	.49
Apr. 27	2.53	152	68	35.8
May 7	2.42	131	349	158
May 7	3.10	292	286	290
1967—Continued				
May 7	3.21	325	258	291
May 8	2.16	90	31	9.6
Aug. 10	2.60	165	87	49.7
Aug. 10	2.50	145	111	55.7
Aug. 27	2.37	122	122	51.6
Oct. 20	1.48	19.1	5	.33
1968				
Jan. 15	2.52	131	57	25.8
Mar. 17	365	460	339	540
Mar. 18	4.21	690	892	2,130
June 12	5.10	1,160	448	1,800

Chemical data

Sample	Date	Stage (ft)	Discharge (cfs)	SO_4	Ca	Mg	SiO_2	Fe	Mn	Na	K	HCO_3	F	PO_4	NO_3	Cl	Conductance (micromhos)	TDS	Ca and Mg hardness	Noncarbonate hardness	pH	Color	Temperature (°C)
	1967																						
38753	Feb. 2	1.71	41	22	14	4.9	16	0.14	0.00	5.8	1.6	38	0.0	--	3.6	9.5	149	104	55	24	7.5	2	--
38775	May 5	1.58	30	20	16	4.0	13	.00	.00	6.0	1.6	44	.0	--	2.5	8.0	146	100	57	21	7.3	2	17
39999	Dec. 12	3.60	440	23	11	4.3	--	--	--	5.1	--	22	--	0.13	4.6	7.4	128	--	45	27	6.8	30	7
	1968																						
39998	Feb. 4	1.80	49	24	15	5.6	--	--	--	7.1	--	34	--	.01	4.4	14	166	--	61	33	7.1	3	--
40399	Mar. 18	4.21	690	--	9.3	3.6	--	--	--	--	--	--	--	.11	5.3	9.5	129	91	38	--	--	--	--
40650	Apr. 14	1.63	34	--	16	5.2	--	--	--	--	--	--	--	.00	3.4	7.5	149	103	62	--	--	--	--
41064	June 12	5.20	1,230	--	9.0	3.0	--	--	--	--	--	--	--	.81	4.3	5.0	102	--	35	--	--	35	--
41081	July 18	1.48	22	--	6	4.6	18	--	--	--	--	53	--	.00	3.7	12	157	107	57	13	7.3	--	25
41080	July 19	1.44	19	--	15	4.6	17	--	--	--	--	52	--	.11	3.9	13	156	106	57	14	7.4	--	24
41079	July 22	1.38	15	--	15	4.6	17	--	--	--	--	51	--	.02	3.9	12	156	114	57	15	7.4	--	21
41082	July 22	1.41	17	--	15	4.6	17	--	--	--	--	52	--	.18	3.6	12	154	104	57	14	7.4	--	22

TABLE 10.—*Chemistry data, 1967, upper Brandywine Creek and Pickering Creek basins*

[Total hardness as $CaCO_3$, in milligrams per liter. Stations do not correspond to those in tables 1–8]

Station	May 23–24		June 15–16	July 5–6		Sept. 16–17	
	$CaCO_3$	pH	$CaCO_3$	$CaCO_3$	pH	$CaCO_3$	pH
B-1	57.6	8.4	40.0	54.0	7.2	54.0	7.8
B-2	--	8.4	40.0	46.0	7.0	52.0	7.6
B-3	42.4	8.4	42.2	43.0	7.2	47.0	7.6
B-4	44.4	8.4	45.2	46.8	6.8	--	7.6
B-7	35.6	7.6	45.2	40.0	7.0	42.0	7.6
B-9	55.6	7.4	59.2	52.4	6.9	55.0	7.4
P-2	52.4	7.8	53.2	109.2	7.0	58.0	7.6
P-3	56.0	8.2	53.6	56.8	6.9	56.0	7.4
P-4	54.0	8.2	56.0	54.4	6.8	60.0	7.7
P-5	56.4	8.2	59.8	52.4	6.8	--	8.1
P-6	--	--	65.8	39.0	6.9	68.0	7.3
P-7	55.8	7.7	58.0	49.0	7.0	56.0	7.5

Station	Nov. 14–15	
	$CaCO_3$	pH
1	36.0	7.2
2	49.0	7.2
3	65.0	7.2
4	46.0	7.4
5	52.0	7.6
6	54.0	7.2
7	56.0	7.4
8	52.0	7.5
9	64.0	7.2

TABLE 11.—*Frequency of faunal forms at sampling points*

[V, very abundant. C, common; occurs on about one rock out of three, usually in colonies. L, less common; found occasionally. R, rare; found only once or twice in the sampled zone. Stations do not correspond to those in tables 1–8]

Station	Date	Algae									Insects										Invertebrates										Fishes	
		Diatoms	Blue-greens	*Spirogyra*	*Cladophora*	*Oedogonium*	*Stigeoclonium*	*Vaucheria*	Rooted aquatics	*Hydrodictyon*	Mayflies	Caddisflies	Stoneflies	Hellgrammites	Water beetles	Water pennies	Tendipedids	Blackfly larvae	Damselflies	Dragonflies	Crayfish	Amphipods	Isopods	Mussels	*Physa* snails	Gilled snails	Leeches	Flatworms	Tubificids	Sphaerids	Centrarchids	Others
Pickering Creek:																																
9	Oct. 1967	C	R	L					V			L			R				L		R		C		R							L
	Nov. 1967	C	R	L					V			R			R				R				L		L							R
13	Nov. 1966	C						C			R	L	L												R	R		R	L			R
11	Nov. 1966	C	R						R		C	C	L		R	R	R		R		R				R	R						R
	Oct. 1967	C	L	L		R		L			L	L	L		R		L		R						R	L		R				L
	Nov. 1967	L	L	L		R		L			L	L	R				L								R	L						L
P-2	May 1967	V	R	R							C	L	R				R				R											R
	June 1967	C	R			R		R			C	C	R						R		R				R							R
	July 1967	V	R	R	R	R	R	R			C	L	R				R		R		R				R							R
	Sept. 1967	C	R			R		R			C	C	R						R		R				R		R	R				R
P-3	May 1967	V	R				R				C	C	C				R			R		R		R					R		R	R
	June 1967	C	R		R				R		C	C	C				R			R					R				R		R	R
	July 1967	V	R		R				R		C	L	L				R			R		R			R				R		R	R
	Sept. 1967	C	R	R	R				R		C	C	L				R			R	R	R			R			R	R		R	R
P-4	May 1967	V	C		L						C	C	C						R	R	R	R		R	R	R					R	R
	June 1967	V	C		L				R		C	C	C				R		R	R	R	R		R	R	R					R	R
	July 1967	C	L		L				R		C	L	L						R	R		R		R	R	R					R	R
	Sept. 1967	C	L		C				R		C	C	L				R		R	R	R	R			R	R		R			R	R
P-5 (USGS sta. 31)	Nov. 1966	C	R		C	R			R		C	C	C		R				R	R					C	R				R	R	R
	May 1967	V	C		C	R			L		C	C	C						R		R				R	R					R	R
	June 1967	V	C		C	R			C		C	C	C						R						R	C					R	R
	July 1967	C	C		L	R			C		C	L	L						R						R	R					R	R
	Sept. 1967	C	L	R	C	R			L		C	C	L	R			R			R					R	R		R	R		R	R
Tributary to Pickering Creek:																			L													
10	Oct. 1967	C				R		L	R		L	L	L		R	L	L		L				R			L		R				L
	Nov. 1967	C				R		L	R		L	C	R		R	L	L						R			L		R				L
P-6 (USGS sta. 24)	Nov. 1966										R	R	R				R					V	R		R							R
	May 1967	C	R			R					C	F										L			L							R
	June 1967	C	R			R					C	C					R					L			L							R
	July 1967	C	R			R	R				C	L	R									L			L							R
	Sept. 1967	C	R	R	R	C		R	R		L	C	R									L			L							R
Pigeon Run:																			C													
P-7 (USGS sta. 23)	May 1967	V	R	R		R		R			C	C						R	R	R					R	R		R				C
	June 1967	C	R	R		R		R	R		C	C						R	R	R						R						R
	July 1967	V	R	R		R		R	R		L	C						R	R	R				R	R	R		R				R
	Sept. 1967	C	R	R		R		R	R		L	C						R		R					R	R		R				R
14	Nov. 1966	C									R	C	R				L			R					L	R		R				R
East Branch Brandywine Creek:																			V													
5	Oct. 1967	V	R						V		R				L				C	R		R	V									---
	Nov. 1967	V	L						V		R				L		R			R		R	C									---
4	Oct. 1967	L	V						R		V	V			R	L	V	R	R	R					R			R	R			---
	Nov. 1967	L	V			R			R		V	V			R	R	V		R						R			R	R			---
2	Nov. 1966				R				C		C	C	C		R	R	C		L					L	C	R		C			R	---
	Oct. 1967	C	L	R					R		C	C	L		L	L	C	L	L			L	L		R	L		L				L
	Nov. 1967	C	L	R					L		L	L	L		R	L	L	R	R			L	R		R	L		R				L
B-1	May 1967	V	R	R		R					C	C	C						R		R										R	R
	June 1967	V	R	R		R					C	R	R	R					R		R										R	R
	July 1967	C	R		R	R			R		C	R	R						R		R				R						R	R
	Sept. 1967	C	R	R		C			R	R	C	C	C	R			R	R			R				R	R					R	R
7	Oct. 1967	F	R		R	R		L	R		L	C	L		R	L	L								R	L					L	L
	Nov. 1967	C	L		L			R	R		C	C	L		R	R	R					R			R	L					L	L
B-2 (USGS sta. 7)	May 1967	V	R		R	R		R	C		C	C	C																	R	R	R
	June 1967	C	R		R	R			C		C	R	R								R				R					R	R	R
	July 1967	V	R		R	R		R	C		C	R	R								R				R					R	R	R
	Sept. 1967	C	R		R	R		R	C		C	C	R				R		R						R			R	R	R	R	R
B-3	Nov. 1966				C		C		C			R	R		R		R				R			R	L	L					R	--
	May 1967	V	R	C			R		C		C	C	C												R	C		R			R	R
	June 1967	C	R	R					C		V	R	R						R	R					R	R			R		R	R
	July 1967	V	R	C			R	R	C		L	R	R						R	R					R	R			R		R	R
	Sept. 1967	V	R	R					C		C	C	R						L	R					R	R		R	R		R	R
B-4 (USGS sta. 9)	Nov. 1966						R		C		L	V	V		R	R	R	R	R		R			R	C	L			C		R	R
	May 1967	V	R	R	R	R			C		C	C	C	R					R	R					R						R	R
	June 1967	C	R	R	R	C			C		V	L	R						R	R	R				R	R			R		R	R
	July 1967	V	R	R		R			V		C	C	R				R		C	R	R				R	R					R	R
	Sept. 1967	C	R	R	C	C			C		C	C	R	R			R			R	R				R			R	R		R	R
Tributary to East Branch Brandywine Creek:																			R													
3	Oct. 1967	C	R	R		L					C	C	L			L	L		R		R							L				C
	Nov. 1967	C	R			L					C	C	L		R	R	L			R	R				R			R				C
Perkins Run:																																
6 (USGS sta. 3)	Oct. 1967	R	R		R						R	R	L		R	L	R			R		R						R				L
	Nov. 1967	L	R		L						L	R	L		R	L	R			R	R											L
Indian Run:																																
12	Nov. 1966										R	C	R			R	R								R		R					R
1	Oct. 1967	L			L						C	C	L		R	C	C	R			L				R			R				C
	Nov. 1967	C			L			R			C	C	L		R	C	L				L				R			R				L
B-7 (USGS sta. 6)	Nov. 1966[1]		R				C				C	C	L			L	C			R					R	R						R
	May 1967	V	R	R		R					C	C									R				R	R					R	R
	June 1967	C	R	R		R					C	L		R					R		R				R	R					R	R
	July 1967	V	R	R		R					C	L		R					R						R	R					R	R
	Sept. 1967	L	R		R	R					C	L		R				R			R				R	R	R				R	R
Culbertson Run:																			L													
8	Oct. 1967	L	R	R		L			L	C	L	L			R				R	R												L
	Nov. 1967	L	R			L			L	C	L	L			R				C						R							L
B-9	Nov. 1966		C				C				R	C	C			R	C		C									C				R
	May 1967	V	L		R	C					C	C	C						L		R				R	R					C	C
	June 1967	V	C		R	C					V	L	L				R		C		R				R	R					C	C
	July 1967	V	C		R	C					C	L	L				R				R				R	R	R		R		C	C
	Sept. 1967	C	L	C	R	C					C	C	L				R		C						R	R					C	C

[1] The bacteria *Sphaerotilus* was rare (R) at this station.

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[redacted]