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TOPOGRAPHIC CHARACTERISTICS OF DRAINAGE BASINS

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TOPOGRAPHIC CHARACTERISTICS OF DRAINAGE BASINS

By WALTER B. LANGBEIN
AND OTHERS

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TOPOGRAPHIC CHARACTERISTICS OF DRAINAGE BASINS

By WALTER B. LANGBEIN and others

ABSTRACT

River floods are the result of many causes, and one of the primary objectives of scientific hydrology is the segregation and evaluation of the causative factors. The climatic factor and the soil-vegetation complex are variables that exercise their principal influence on the volume of runoff. The topography of drainage basins is a sensibly permanent characteristic which influences mainly the concentration or time distribution of the discharge from a drainage basin. River systems differ in their efficiency as agencies for collecting and conducting water. In some systems, surface waters are quickly assembled, and the discharge reflects somewhat sensitively the variations of the available supply. In others, the surface drainage is longer delayed and the discharge is released slowly.

As a basis for quantitative studies of these evident differences in behavior, selected topographic features for about 340 drainage basins in the northeastern United States were studied, using Geological Survey topographic maps. The data were compiled in cooperation with the Work Projects Administration of the Federal Works Agency and included information on drainage area, length of streams, stream density, land slope, channel slope, area-altitude distribution, and area of water bodies of basins that ranged in extent from 1.64 to 7,797 square miles. Considerable effort was made to assure accuracy of the computations by appropriate checks, and the results are summarized in the table at the end of this report.

The results indicate that none of the topographic factors are unique, but each reflects a condition that also influences the others. For example, steep land slopes are generally associated with steep channel slopes and conversely. A significant variation of slope and altitude with area of basin is found, and stream density tends to vary with the land slope.

INTRODUCTION

This report presents a compilation of topographic data on drainage basins in the northeastern United States. The configuration of the earth reflects the impact of many natural forces, and it in turn exercises profound influence upon man. Most of these influences are so basic that they have shaped life and civilization into conformity with them. Mountains, plains, valleys, and rivers each favor or retard man's search for economic stability. Within human history the first three have remained unchanged. Rivers, on the other hand, fluctuate in size from day to day and from year to year. The amplitude and frequency of these fluctuations, so significant with respect to navigation, water power, irrigation, and such riparian developments as cities and highways, are largely determined by three separate, yet interdependent features, namely climate, physiography, and the soil-vegetation complex. The interrelation of these three features with the behavior of rivers is imperfectly understood and is the subject of much investigation. This report singles out the physiography of the land for attention.

The relations between the rate, volume, and fluctuations of rivers and the topographic characteristics of the land they drain and through which they flow may be readily determined after discerning examination of the terrain and river developments, but expressing them in the quantitative terms necessary for the economic design of structures for river utilization or control requires first, topographic maps, and second, records of river flow of length adequate to define the behavior.

The stream-gaging program of the Geological Survey is Nation-wide and now includes over 4,500 river-measurement stations, at which more than 65,000 station years of record were available in 1942. These records furnish an adequate source of material concerning stream behavior. The mapping program of the Geological Survey, also Nation-wide, is in general not so complete. Although about 50 percent of the country has been mapped, only States in the northeastern part have been completely covered; the scattered areas mapped in other States generally do not cover completely the areas in which stream-gaging has been carried on, so that only a small fraction of them are suitable for use in comparisons of stream-flow characteristics or river morphology.

In the northeastern and north-central States the range in topography is sufficient to furnish a basis for studying its effect on stream flow. The topographic characteristics compiled from the maps and summarized in this report can only be evaluated by a consideration of the hydrology of stream flow, the assembling of waters in a drainage system, and the hydraulic elements that regulate velocity of flow. Many stream-flow characteristics are related either directly or indirectly to topographic features. It would seem, however, that the factors most sensitive to topographic difference would be those relating to floods. In this study, therefore, particular although not exhaustive attention is given to the correlation of flood-flow characteristics with topography. This information will serve as a basis for further study of such correlations and also of other characteristics, such as volume yield, erosion, and deposition of sediments. Similarly the topographic data offers basic material for studies of river morphology, as geologic evidence suggests that a significant portion of river-channel development takes place during flood.

COOPERATION AND PERSONNEL

The cooperative project for the compilation of topographic data was undertaken in 1939 by the Works Progress Administration, which on April 25, 1939, became the Work Projects Administration under the Federal Works Agency. Their cooperation in organizing competent working groups is especially acknowledged. The Geological Survey sponsored the project and furnished technical direction, maps, and supplies. This work was carried on by W. B. Langbein, under the general direction of R. W. Davenport, chief of the Division of Water Utilization. The project at Boston, Mass., was under the supervision of H. B. Kinnison, district engineer, and his associates, particularly C. E. Knox, M. A. Benson, and B. R. Colby. The conduct of the work at Pittsburgh, Pa., was ably managed by Wm. S. Crozier, supervisor for the Works Projects Administration. Mr. Crozier died January 21, 1941, near the close of the project. H. M. Erskine, associate engineer of the Geological Survey at Pittsburgh, maintained close contact with the project there, and its continuity and efficiency may be largely credited to his competent administration.

METEOROLOGIC FACTORS AFFECTING RUNOFF

River floods are the result of many causes, and one of the primary objectives of hydrologic study is the segregation of the causative factors and the evaluation of their effects on the resultant floods under various associated conditions.

Readily apparent is the source of the water, generally an unusual amount of rainfall, which may be characterized by great intensity and in many regions may be augmented by water from melting snow. Water in excess of that which can be absorbed by the ground or evaporated into the air directly or through vegetation collects in the stream channels that drain the area. Once in the stream system, the runoff flows to the mouth through channels which, as the trunk of a network of streams, progressively increase in size as contributions are received from tributary streams.

The quantity of rainfall or snow melt, its time distribution, and the associated soil, vegetal, and climatic conditions that determine the portion of the supply that becomes direct runoff are to a large extent variable characteristics of individual storms. These variable edaphic and climatic factors are separate phases of the rainfall-runoff relation.

The channel system, however, is a relatively permanent characteristic of a drainage basin. Some influential changes may take place in this system; for example, variations in seasonal vegetation along the banks may affect the hydraulic conveyance, floods may scour or deposit sediments, and old bends may be cut through and new ones created. Although the effect of these changes on local flood stages may be considerable, it is assumed that the resultant effect on total discharge from a basin will tend to be compensating and that even the cumulative effect on flood-discharge characteristics during a period as short as the usual stream-gaging record would be minor.

DIFFERENCES IN CHARACTER OF DRAINAGE BASINS

River systems differ in their efficiency as agencies for collecting and conducting water. In some systems the surface waters are quickly assembled, and the discharge therefrom reflects somewhat sensitively the variations of the available supply. In others the surface drainage is longer delayed and the discharge is released slowly. This difference is illustrated in figure 48, which shows the hydrographs of two nearby streams, each draining about 50 square miles of coastal areas of New Jersey, during a flood in June 1938. The rainfall causing these floods and the volume discharged were nearly the same for both areas. The difference in behavior illustrated by the hydrographs is normal for these two basins and may be accounted for largely by the differences in physiographic characteristics, Manasquan River having about twice the gradient of Great Egg River and about one-fifth the swamp area.

PREVIOUS STUDIES

The fact of relationship between the time distribution of discharge during a flood and the size, shape, and gradient of a drainage system is widely recognized. Few attempts have heretofore been made to determine this relationship quantitatively, probably because of the volume of labor required to evaluate the topographic factors.

Horton [1] in 1926 and again in 1932 discussed the desirability and need for a quantitative rational procedure and proposed methods for evaluating certain pertinent physiographic factors.

Pettis [2] in 1927 presented a formula to compute the maximum flood discharge, in which the five-fourths power of the average basin width was used.

Gregory and Arnold [3] in 1932 developed in detail certain expressions

[1] Horton, R. E., in Jarvis, C. S., Flood-flow characteristics: Am. Soc. Civil Eng. Trans., vol. 89, pp. 1081–1086, 1926; Drainage-basin characteristics: Am. Geophys. Union Trans., No. 13, pp. 350–361, 1932.

[2] Pettis, C. R., A new theory of river flood flow (published privately, copyrighted 1927).

[3] Gregory, R. L., and Arnold, C. E., Rational runoff formulas: Am. Soc. Civil Eng. Trans., vol. 96, pp. 1038–1175, 1932.

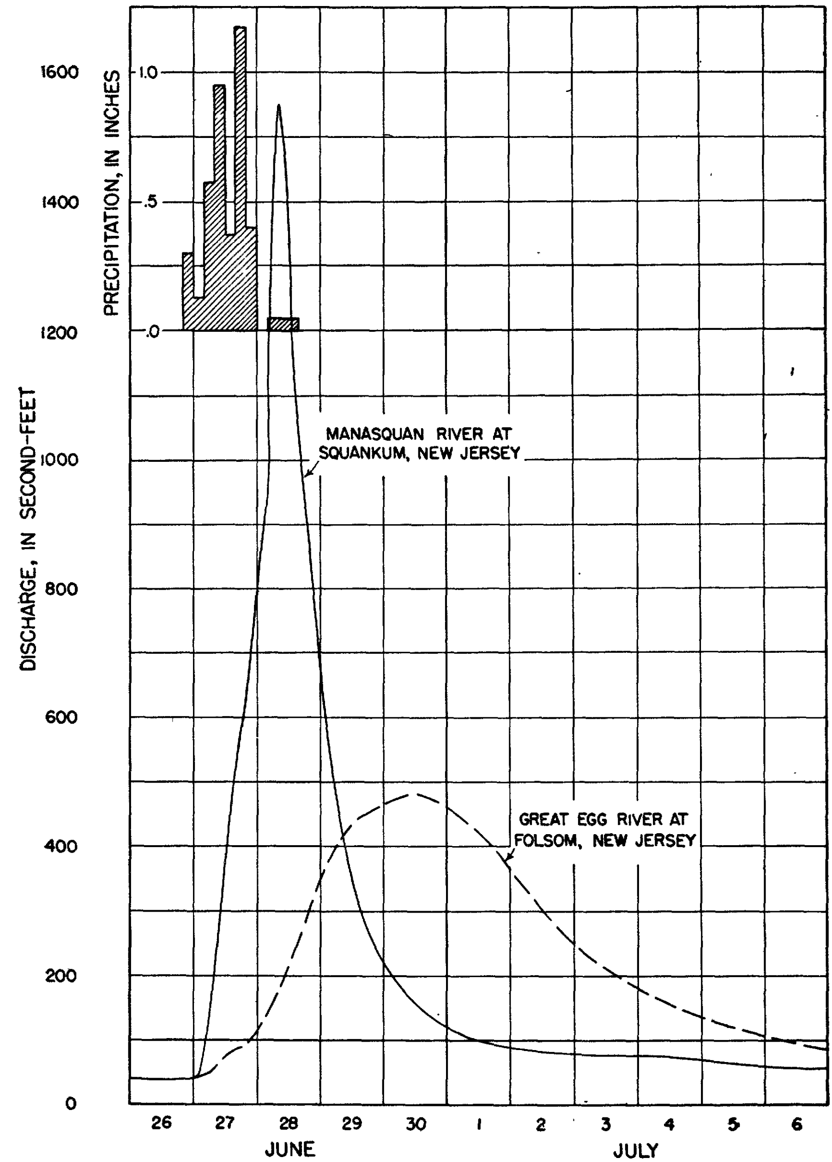

FIGURE 48.—Hydrographs of two streams in New Jersey during flood of June 1938.

and procedures applicable to small drainage areas for translating rainfall into rates of stream flow in terms of basin characteristics.

Bernard[4] carried Gregory and Arnold's expressions somewhat further and presented formulas applicable to a few selected basins.

[4] Bernard, M. M., An approach to determinate stream flow: Am. Soc. Civil Eng. Trans., vol. 100, pp. 347-395, 1935.

Sherman [5] in 1932 presented unit hydrographs for four streams whose drainage areas and slopes differed widely. He explained how the unit hydrographs expressed these differences and suggested that basins having physical characteristics similar to the four types presented would have similar hydrographs.

McCarthy [6] in 1937 also used the unit hydrograph as an expression of the runoff characteristics of a drainage basin, stating further that "the agreements between graphs developed from May and November storms substantiate the contention that primarily the unit hydrograph is a function not of surface cover, which may be subject to seasonal change, but of topographic features of a watershed." From this postulate he derived a working relationship between the crest discharge and the length of base of unit hydrographs of 25 drainage basins in the Connecticut River Basin, in terms of the area, mean slope, and stream pattern, determined by inspection and expressed as one-stem basin, two-stem basin, and so on, for application to flood-control design.

Morgan and Hullinghorst [7] in 1939 stated:

> The factors which determine the discharge characteristics of any watersned are innumerable, some having a major bearing on those characteristics while others are of negligible consequence. It was determined by examination of nine gaged basins having complete unit hydrograph and watershed data, and corroborated by examination of a number of gaged basins with data ranging from almost complete to fragmentary, that the discharge characteristics can be attributed principally to three fundamental, definite watershed characteristics, namely,
>
> a. Area of the watershed in square miles,
> b. Mean length of travel in miles, and
> c. Mean height of watershed above outflow station in feet.

On this basis, empirical relations between these three factors were established for nine streams tributary to the Chemung River in New York.

PURPOSE AND SCOPE OF THE PRESENT STUDY

The present project was designed to provide basic material whereby investigations such as those outlined can be carried further, the range being limited, of course, to areas adequately mapped, which are mainly in the northeastern United States. Prior to this study, references to the subject were read with the view to determining which topographic factors were considered to have major influence upon

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[5] Sherman, L. K., The relation of hydrographs of runoff to size and character of drainage basins: Am. Geophys. Union Trans., No. 13, pp. 332–339, 1932.

[6] McCarthy, G. T., The unit hydrograph and flood routing (unpublished manuscript presented at conference of North Atlantic Division, Corps of Engineers, U. S. Army, June 24, 1938).

[7] Morgan, R., and Hullinghorst, D. W., Unit hydrographs for gaged and ungaged watersheds: U. S. Engineer Office, Binghamton, N. Y., July 1939. [Processed.]

discharge characteristics, and, so far as practicable, the suggestions thus obtained were incorporated in the project as proposed for cooperation to the Works Progress Administration (succeeded on April 25, 1939, by the Work Projects Administration). The compilation was based upon the topographic maps of the Geological Survey covering areas tributary to gaging stations of the Geological Survey.

In the organization of a surface-water system, and of a large part of the ground-water system as well, the drainage basin is a natural hydrologic land unit. Surface runoff is divided into drainage basins by the watersheds, and within each basin it follows a system of water courses in which the flow undergoes retardation, acceleration, or other changes that are distinctly related to the physical characteristics of that basin. Similar conditions exist with respect to all or most of the ground-water runoff. Essentially all the water within a given basin, except that which is lost by evaporation or transpiration, drains out through a common outlet or mouth.

For purposes of analysis, a major stream basin may be subdivided by considering the area tributary to the stream at any given point, for example, a gaging station, as a basin having its own characteristics. The separate characteristics of several contributory areas may then be combined to obtain the resultant for the major basin.

Geographic and topographic characteristics of drainage basins, based largely on certain horizontal and vertical dimensions, were selected for compilation and study. Geographic characteristics include water bodies, direction of stream flow, latitude, and longitude. Topographic characteristics include horizontal dimensions covering basin area, stream length, and area-distance distribution, and vertical dimensions covering land slope, tributary and principal stream slopes, and basin altitude.

In selecting basins for this study preference was given to those for which long-term stream-flow records are available and to those free from artificial regulation. In addition to areas in the northeastern States and the Ohio River Basin a few surveyed areas in Wisconsin and Kentucky were included to spread the range in geographic extent and topographic characteristics. Many basins in New York, Pennsylvania, and New Jersey that might otherwise have been included were not studied because of insufficient time.

Besides listing topographic and hydrologic data, the original records afford a gazetteer of streams and lakes. Maps were prepared showing the stream skeleton of each basin, with names of streams, length from confluence to confluence, and drainage areas and altitudes pertinent to the subdivisions. A list of lakes and ponds, giving names, locations, and approximate altitudes and areas was also prepared, much of the data for basins in New York State being based on a gazetteer by E. M. Douglas.[8]

The summarized results of the compilation, covering about 340 basins, are given in the table on pages 145–155. The original records are on file at the office of the Geological Survey in Washington, D. C., and the computations for basins in New England (except Maine) are on file also at the Boston office of the Geological Survey.

METHODS OF WORK

MAPS

Quadrangle maps on the scale 1:62,500, are the basis of this compilation, except for a few areas in New Jersey where more detailed maps were available. On these maps the gaging stations were located and the tributary basins with sub-basin divisions were outlined. Generally, each basin was divided into 50 to 75 sub-basins. Care was taken that the sub-basins crossed the streams only at confluence points. To systematize the necessary tabulations, the sub-basins were numbered in accord with the following system, which is illustrated on plate 2.

The headwater basin farthest upstream (the one farthest removed from the gaging station along the main stream) is called no. 1; the sub-basin which it joins at the first confluence point is called no. 2; the sub-basin (or intervening area along the combined channel) below the confluence of sub-basins 1 and 2 is called no. 3; the next tributary sub-basin is called no. 4, and so on. Where a large tributary stream that has been subdivided joins the main stream, the next consecutive number is assigned to the farthest upstream sub-basin of this tributary. This constitutes the lowest number on such tributary, and the sub-basins of the tributary system are then numbered in the same manner as those of the main stream, down to the sub-basin immediately above the confluence of the tributary with the main stream. The succeeding number is assigned to the sub-basin along the main river immediately below the confluence, as before. The highest number in a basin is that of the sub-basin immediately above the mouth of the main stream; it indicates the number of sub-basins into which that drainage area is divided. As shown on plate 2 the number of each sub-basin is the large integer near its center; the smaller figures represent area, length of stream, and altitude.

[8] Douglas, E. M., Gazetteer of the lakes, ponds, and reservoirs of the State of New York: Map Information Office, Board of Surveys and Maps, 44 pp., Washington, 1926. [Processed.]

AREA OF BASINS

The total area of the basin within the watershed lines above the selected gaging station is the primary basin factor. In a humid climate the volume of discharge varies directly with the size of the tributary drainage area. Accordingly, the area in square miles was measured, not only of the main basin above the gaging station but also of a number of sub-basins (generally over 50). The size of the basins included in this compilation ranges from 1.64 to 7,797 square miles. In general, large streams were excluded because the size of sheets became unwieldy, because some contained unsurveyed areas, and because their stream-flow characteristics could best be determined by synthesis of their components.

STREAM DENSITY

The runoff from the several parts of the drainage basin is discharged by the streams, and, other factors being constant, the time required for the water to flow a given distance is directly proportional to the stream length. The stream or drainage density is the ratio between the total length of all streams within the drainage basin and the total area of the basin and is an indication of the drainage development. Accordingly, the length of all streams down to the smallest shown on the topographic maps was measured to determine the stream density and the area-distance distribution.

The number of small headwater streams shown on the topographic maps would vary with the season and the wetness of the particular year during which the survey was made, as well as with the judgment of the topographer and cartographer as to the amount of detail to be shown on the map. These circumstances introduce a measure of inconsistency in stream-density results as determined from maps.

The ratio of stream density for the basins included in this compilation, all of which are in the humid region, ranges from 0.89 to 3.37 miles per square mile and averages 1.65 miles per square mile. Other factors being equal, high drainage density indicates a more effective operation, of the agencies of stream incision. Greater incision, for example, would be associated with steep land slopes. Opportunity for incision would be greater also where most of the discharge occurs as surface runoff rather than through ground-water channels; such a condition exists in areas where the ground is sufficiently impervious to shed storm rainfall. Drainage density is greater in humid regions than in arid regions; it would approach zero in flat, sandy desert regions and would approach a maximum in steep, rocky, humid regions.

The variation of stream density with the land slope is shown by the following data derived from groups of basins in New England.

Variation of stream density with land slope

Range in stream density (miles per square mile)	Average land slope (feet per mile)
1.00 to 1.25	290
1.26 to 1.50	550
1.51 to 2.00	600
2.01 to 2.25	700

The mean land slopes for basins in New England having drainage densities within the ranges indicated in the above data were averaged, and the results indicate that, in general, in a given region the higher drainage densities are associated with the steeper land slopes. The reciprocal of the drainage density is the average distance between streams, and half the reciprocal of drainage density is the average horizontal distance between the streams and appurtenant watershed lines, measured at right angles to the streams. Drainage density appears to be inversely related to the distance of overland flow as distinguished from flow in stream channels. However, in basins sufficiently permeable so that all rainfall can be taken directly into the soil through infiltration, the drainage density approaches zero and is associated with zero overland flow.

AREA-DISTANCE DISTRIBUTION

The concentration of runoff from drainage basins of equal size may be greatly affected by the distribution of the area with respect to distance from the gaging station or outlet. Other factors being equal, the runoff from areas close to the gaging station should reach it sooner than water from remote areas. Accordingly, a drainage basin whose tributaries are compactly organized, so that water from all parts of the basin has a comparatively short distance to travel, will discharge its runoff more quickly and reach greater flood crests than one in which the larger part of the area is remote from the gaging station or outlet. This basin characteristic is expressed in the summary table by the quantity Σal, computed by multiplying each partial area in the basin (a) by the channel distance from the midpoint of the main stem serving it, downstream to the gaging station (l). Distances along the stream channels were measured in 0.1 mile chords.

In a sense this quantity is also a measure of the volume of channel storage in the basin. For example, if under a given regime of flow the cross-sectional area of a river at a given place varies directly as the drainage area above, then the volume in any given reach would vary as the product of a coefficient by mean drainage area above the reach by the length of the reach. The coefficient would be a function of the stage of the regime selected, the slope of the reach, frictional resistance, and other hydraulic factors. No method is proposed for evaluating the coefficient. However, the sum of the products of mean drainage area and length of reaches for a given basin is equal to the product Σal which was derived by both methods of computation.

The most compact drainage basin would be a glory-hole inlet, and the product Σal for such a basin is $0.375\ A^{1.50}$ where A represents total area; for an equilateral triangle, with reference to an outlet at one of the vertices, the product is $0.94\ A^{1.50}$; and for a square, with reference to a corner, it is $0.76\ A^{1.50}$. Figure 49 shows the results of plotting the products Σal against the corresponding drainage area. Only enough points are shown to define the line of regression, whose equation is $0.90\ A^{1.56}$, or more approximately $1.2\ A^{1.50}$, within the range shown. Natural basins are generally less compact than any of the geometric shapes mentioned.

Additional subdivision of a basin beyond the 50 to 75 sub-basins generally used would tend to increase the value of the product Σal. However, a study of West River Basin, above Newfane, Vt., indicates that the product Σal for 20 sub-basins was 6,620, for 50 sub-basins 6,810, and for 100 sub-basins 6,860. The values given in this report may therefore be considered essentially correct limiting values.

Points on the right of the trend line (fig. 49) represent basins less compact than the average, and those on the left the more compact. The regression line therefore furnishes a standard for comparing the relative compactness of different basins.

LENGTH OF BASIN

The table (pp. 145–155) lists the length of longest watercourse in each basin measured in 0.1-mile chords to the source of the most headward stream. This length, when divided by the mean velocity of flow will give the time of concentration as used in the rational formula for the computation of flood discharge.

The mean length of travel of runoff or the distance to the center of gravity of the drainage system may be found by dividing the quantity Σal by the drainage area in square miles. This quotient is commonly identified by the symbol L_{ca}. The table also lists the length of principal streams as defined under "Channel slope."

LAND SLOPE

Rainfall or snow melt which becomes direct runoff flows over the surface of the ground or, where the surface soil is shallow and permeable, immediately beneath it over the bedrock. The average distance water travels before entering a stream channel may be

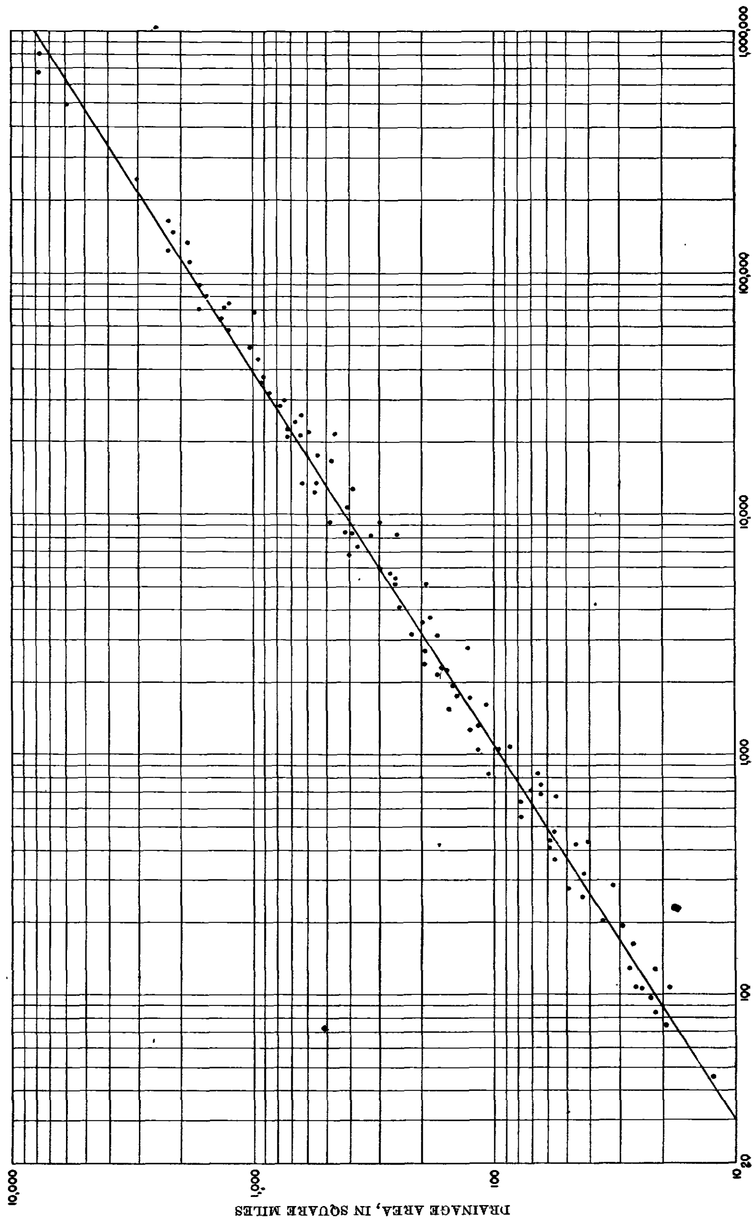

FIGURE 49.—Relation between area of drainage basin and Σal.

expressed in terms of stream density. (See p. 133.) The rapidity with which the water travels to the streams likewise depends on the slope of the land.

The contours on the topographic maps provide a basis for determing the slope of the land by the intersection-line method outlined by Horton [9] as follows:

The intersection-line method.—In order to reduce the labor of computation of slope of large areas the author has utilized the following method. An area the slope of which is to be determined is subdivided into squares of equal size by lines forming the boundaries between adjacent squares. The number of contours crossed by each subdividing line is counted and the lengths of the lines are scaled. Then the average scale-distance l' between contour crossing in the subdivision lines is

$$l' = \frac{\Sigma l}{N}$$

where N is the number of contours crossed and Σl is the total length of the subdividing lines. If α is the horizontal angle at which each of two parallel contours crosses an intersection line, then $l' \sin \alpha$ is the horizontal distance between the two contours measured normal to the contours. Contours may cross the intersection lines at all angles from 0° to 90°. The mean value of sin α for angles from 0° to 90° is

$$\int_0^{\frac{\pi}{2}} \frac{\sin \alpha d\alpha}{\frac{\pi}{2}} = \frac{2}{\pi} = 0.6366$$

If D is the contour interval or difference in elevation in feet, and L is the average normal horizontal distance between contours, then

$$L = 0.6366 \, l'$$

and the mean slope Sg of the area is

$$Sg = \frac{D}{0.6366 \frac{\Sigma l}{N}}$$

$$= 1.571 \frac{DN}{\Sigma l}$$

In applying this method it is assumed that each contour crossed represents a difference of elevation along the subdivisional line equal to the contour interval. Of course it may happen that two adjacent contours are at the same elevation and are separated by land only a little higher or lower. On an average, however, the elevations of summits or depressions between equal contours will differ from that of the adjacent contours by an amount equal to one-half the contour interval, and it can readily be seen that the average declivity between a pair of contours of equal elevation is nearly the same as if the contours were separated by the contour interval D, so that the method gives nearly correct results even where the subdivision lines cross adjoining contours of equal elevation, as in the case of summits and depressions.

[9] Horton, R. E., Drainage-basin characteristics: Am. Geophys. Union Trans., No. 13, pp. 350–361, 1932.

By making the subdivision lines sufficiently frequent, the average slope of an area may be determined with whatever degree of accuracy is required.

This method has been tested by comparison of slope for the same area computed from the measured total lengths of contours, with, in general, good agreement.

In carrying out this computation, the slope along the meridian lines is computed separately from the slope along the parallels of latitude. Where there is a great difference between the land slope in the two directions, the orientation of the basin is determined by the axis of least slope. Where the east-west slope and the north-south slope are nearly the same, the line of orientation may be approximately midway between the two, or it may not be clearly defined in either direction in a cup-shaped or fan-shaped basin. Land slopes listed in the table range from 1,598 feet per mile for the upper Pemigewasset River Basin in New Hampshire to 55 feet for Great Egg River in Coastal New Jersey.

Paulsen [10] found, during the flood of September 1938 in the North Atlantic States, that the infiltration index tends to increase with decrease in mean land slope. He states that "although the slope of the land itself might influence the retentive capacity of the ground, this tendency may be due to other factors related to slope, such as depth of soil cover."

CHANNEL SLOPE

Upon leaving the land the runoff enters the channel system, through which it flows in channels that increase progressively in size with the entrance of additional water. Channels in a drainage basin are classified for study as principal and tributary. The principal streams of a basin are defined as those that drain 10 percent or more of the total area of the basin; tributaries are defined as those that drain less than 10 percent of the area of the basin. The average slope of the tributaries and of the principal streams is computed separately as the quotient of the total fall divided by the corresponding total length and is reported in the summary table.

In computing the slope of the stream channels, only the largest stream in each sub-basin is considered. Thus, if a basin is divided into 75 sub-basins only 75 stream lengths and falls are measured. These stream lengths are classified as principal or tributary, and the average slope of each is computed. As only one stream in each sub-basin is included in the classification, many minor headwater streams are excluded from consideration; consequently, the reported slope of the tributary stream is affected by the number of subareas into which the basin is divided. The reported mean slope of the tributary

[10] Paulsen, C. G., Hurricane floods of September 1938: U. S. Geol. Survey Water-Supply Paper 867, pp. 440–441, 1940.

streams increases as the number of subareas becomes larger, thus embracing more steep minor headwater streams. This is illustrated in figure 50, which shows the result of a comprehensive study of the slope of tributaries of West River at Newfane, Vt. The asymptote resulting from that study is about 225 feet per mile, whereas the channel slope obtained with 53 subareas (see table, No. 1–354) is 200 feet per mile.

The slope information for the several drainage basins listed in the table discloses that a steep land slope is generally associated with

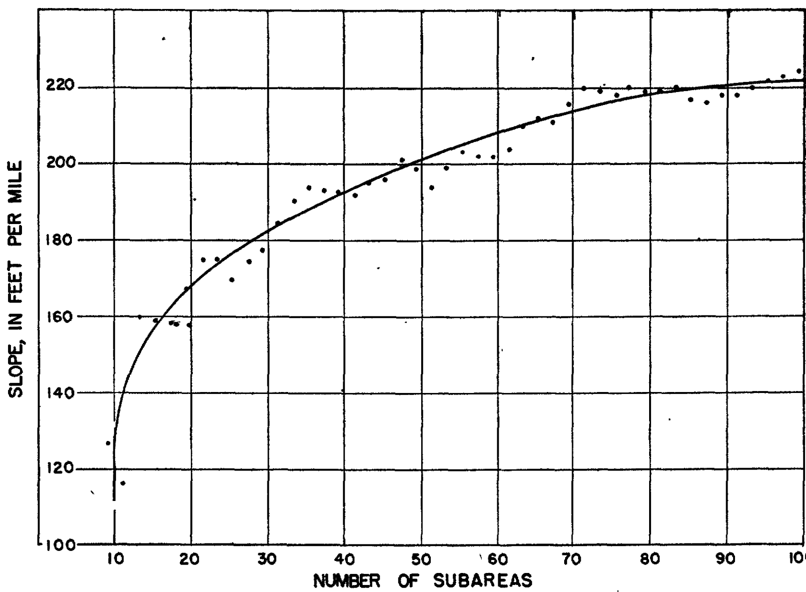

FIGURE 50.—Variation of computed slope of tributary streams with number of subareas, West River at Newfane, Vt.

steep tributary and principal channel slopes and conversely, as might be expected. There is, however, no systematic variation; moreover, according to geometric analysis by Horton,[11] the ratio between principal channel slope and average land slope is a measure of the horizontal angle that the lateral slope makes relative to the stream slope. A low slope ratio indicates that the laterals tend to enter the streams at right angles, whereas the angle of inflow into the stream becomes more acute as the channel slope approaches equality with the ground slope. This slope ratio tends to decrease with increase in drainage area, but varies considerably between drainage basins of equal size.

[11] Horton, R. E., op. cit., p. 360.

AREA-ALTITUDE DISTRIBUTION

Another method of expressing the slope of the basin is by means of the altitude of the several parts with reference to sea level. This is best expressed through the hypsometric curve, as a graph showing the area-altitude distribution is called. Although the area-altitude distribution was derived for each basin, only the maximum, mean, and minimum altitudes as determined from the topographic maps are shown in the table. From this information, however, the area-altitude distribution curve can be readily approximated. Figure 51 shows the hypsometric curves for several basins plotted in terms of percent of range in altitude and percent of area above the indicated altitude. The variations are wide, but in general the mean altitude

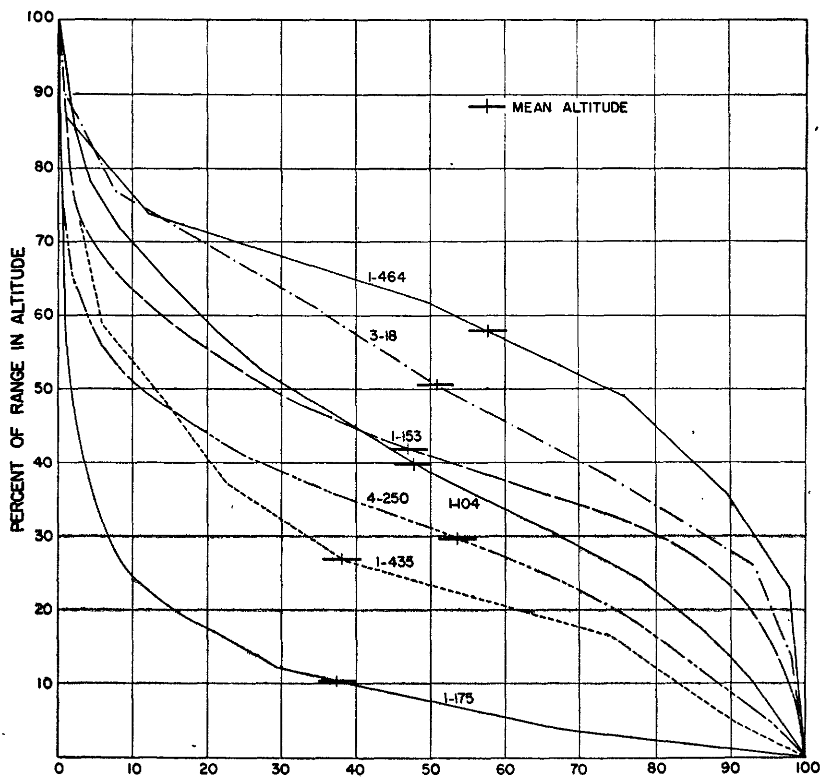

FIGURE 51.—Typical hypsometric curves for drainage basins.

1–104. Swift River near Roxbury, Maine.
1–153. East Branch of Pemigewasset River near Lincoln, N. H.
1–175. Lake Winnipesaukee outlet at Lakeport, N. H.
1–435. Quinnipiac River at Wallingford, Conn.
1–464. Leadmine Brook near Thomaston, Conn.
3– 18. Brokenstraw Creek at Youngsville, Pa.
4–250. Otter Creek at Center Rutland, Vt.

of a basin is located at 0.34 of the range between the minimum and maximum; thus a basin is comparable to the surface of a cone.

The area-altitude distribution curve has several applications. For example, snow surveys generally show an increase in depth of cover and water equivalent with increase in altitude; the area-altitude relation provides a means for estimating the mean depth of snow or its water equivalent over a drainage basin. Barrows[12] describes a significant variation in annual precipitation and runoff in the Connecticut River Basin with respect to altitude. The obvious variation in temperature with change in altitude is further indication of the utility of the area-altitude distribution curve.

The mean altitude of the basin above the altitude at the outlet or gaging station represents the potential head of a uniform depth of water over the basin with respect to the outlet or gaging station, and as such is a factor in determining the rate at which the waters are collected and discharged. The data in the summary table shows that, in general, the land slopes and channel slopes vary with the mean altitude of the basin above the outlet. Thus steep slopes are associated with a high altitude above the outlet, and conversely. A rough average relation between slope and mean altitude is as follows:

$$h=K_1S_1+K_2S_t+K_3S_p$$

where $K_1=0.31$

K_2 ranges from 0.97 at 50 square miles to 3.0 at 1,000 square miles.
K_3 ranges from 3.5 at 50 square miles to 23.4 at 1,000 square miles.
S_1=mean land slope, in feet per mile.
S_t=slope of tributary streams, in feet per mile.
S_p=slope of principal streams, in feet per mile.

AREA OF WATER SURFACES

The effect of storage in retaining flood runoff and prolonging its discharge until the flood in channels farther downstream has begun to subside tends to reduce flood peaks and increase the time lag between rainfall and its consequent runoff. Natural storage in lakes and ponds and artificial storage in reservoirs aids this retardation. A measure of the amount of storage available for such modification of flood discharge can be derived from the surface area of the water bodies shown on the topographic map. (See table.) The computations at Boston included the determination of swamp areas, which had been part of an earlier project carried on in 1936 in cooperation with the Works Progress Administration; this covered compilations for the Merrimac and Connecticut River Basins, both in square miles and

[12] Barrows, H. K., Precipitation and runoff and altitude relations for Connecticut River: Am. Geophys Union Trans., 14th Ann. Meeting, pp. 396–406, 1933.

in drainage percent.[13] The computations made at Pittsburgh did not include swamp areas.

The areas of swamps as reported would be affected by the hydrologic conditions under which the topographic surveys were made. Surveys made in spring or early summer would probably show a greater swamp area than those made in late summer or fall, and surveys in a wet year would show marked contrast with those made in a dry year. It is not known to what extent the results given in the table were affected by hydrologic conditions.

It should be pointed out that the area of water surfaces is only one measure of their effect on the time distribution of flood discharge. The position of the water bodies in the river system is also important; thus a large pond near the headwaters would affect but a small part of the runoff, whereas one of the same size farther downstream would affect a larger part of the runoff.

In addition to the effect of storage in modifying the shape of flood waves or the time distribution of runoff, the total volume of runoff may be influenced by evaporation from lakes, reservoirs, and swamps. The loss of water by evaporation from water surfaces in the northeast is about twice that from land surfaces, per unit of area. Accordingly, basins with a large proportion of water and swamp surfaces may be expected to yield less runoff than those with a small proportion.

In many of the basins listed in the table the proportion of lake and swamp areas exceeds 10 percent, and in a few, especially in New England, it approaches 20 percent; doubtless the effect on water losses is significant. The percentage of lake area is highest in New England and northern New York and generally in the glaciated portions of the areas studied.

SUMMARY OF RESULTS

The summary table that follows gives the results of measurements on topographic maps on a scale of 1:62,500. It includes about 22,000 areas covering 145,000 square miles. A total of 240,000 miles of stream length was measured, and nearly a million contours on the topographic maps were counted and translated into land and channel slopes.

Reference has already been made to general relationships between the topographic factors listed in the table. Each item is not necessarily unique, but it may reflect a condition that also influences the others, consequently other relationships between them may be found. For example, figure 52 shows that, in general, larger drainage areas are associated with flatter stream slopes; but average land slopes and

[13] Grover, N. C., The floods of March 1936, pt. 1: U. S. Geol. Survey Water-Supply Paper 798, pp. 335–338, 1937.

mean altitudes of drainage basins above outlets or gaging stations show a tendency to increase with drainage area. The points shown on figure 52 correspond to averages of groups of drainage basins within limited ranges in size. If individual basins were plotted on figure 52, material scattering of points would result, the basins plotting on the left being relatively flatter than those on the right. The average curve therefore provides a means for comparing the slopes and alti-

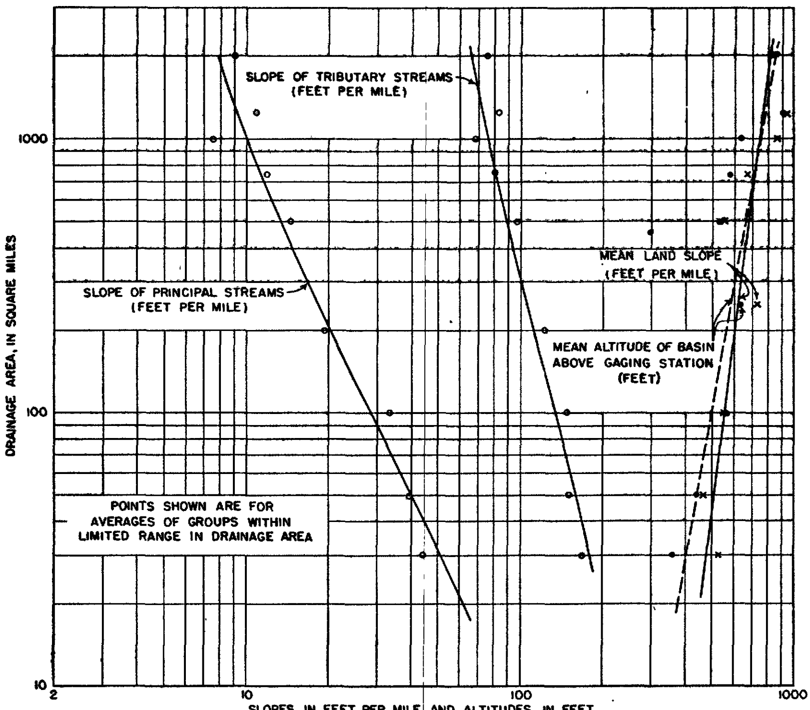

FIGURE 52.—Graph showing general variation in stream slopes and altitude in relation to size of drainage basin.

tudes of basins of different size. The divergent trends of the lines showing principal channel slope and average land slope indicate that the slope ratio of the basins analyzed tends to decrease with increase in drainage area.

A principal shortcoming of the computations of physical characteristics may be that it was not practicable to determine in detail the distribution of stream and land slopes and of lake and swamp areas within every area. Steep slopes on a few tributaries may increase the average slope considerably, yet these slopes may have little effect on flood-peak discharges. Moreover, the course of a river in a given length may be characterized either by uniform slope or by a series of pools with intervening rapids or perhaps cataracts. The velocity in a stretch of uniform slope would probably be the greater if other factors were constant, as pools have a detention storage effect and the fall at rapids or cataracts imparts but little horizontal velocity to the water. A lake on the headwaters of a stream may have no noticeable effect, whereas a lake of the same size on the main channel near the lower reaches of an otherwise flashy stream may greatly modify flood discharges. Also, steep slopes or abnormally high elevations in the part of a drainage basin upstream from a lake may affect considerably the average land slope and the mean elevation of a basin, but the lake may decrease the flood discharges so much that the outflow from the lake would differ little from that of a basin in which the slopes and elevations were much less.

Storage capacity was not computed, as topographic maps furnish no information from which channel and lake cross sections at different stages can be determined, except that they might be crudely correlated with the stream slopes.

Summary of drainage basin topographic characteristics

No.	Name of gaging station	Drainage area (square miles)	Stream density (miles per square mile)	Σ al (cubic miles)	Land slope (feet per mile)			Channel slope (feet per mile)		Longest watercourse (miles)	Length of principal streams (miles)	Altitude of land (feet above mean sea level)			Area of water surfaces (square miles)			Number of subareas into which basin was subdivided
					E.-W.	N.-S.	Average	Tributary	Principal			Maximum	Mean	Minimum	Lakes and reservoirs	Swamps	Total	
1-7	Fish River near Fort Kent, Maine	867	1.18	32,073	456	445	449	52.7	2.56	75.0	82.2	2,000	860	512	53.91	------	------	65
1-17	West Branch of Union River at Amherst, Maine.	148	1.10	2,531	304	294	298	51.1	7.73	30.9	28.6	1,463	451	161	5.32	------	------	31
1-34	Passadumkeag River at Lowell, Maine	299	1.08	7,010	322	303	314	49	5.55	41.5	51.1	1,463	440	159	22.79	------	------	63
1-52	Dead River at The Forks, Maine	872	1.42	35,524	630	742	694	146	12.88	81.3	73.3	4,168	1,765	600	16.44	------	------	81
1-54	Carrabassett River near North Anson, Maine	351	1.79	7,114	797	707	745	165	26.71	41.7	51.6	4,237	1,124	290	3.14	------	------	61
1-58	Sandy River near Mercer, Maine	514	1.47	16,641	687	662	672	147	11.95	61.3	62	4,116	959	201	5.54	------	------	61
1-104	Swift River near Roxbury, Maine	95	1.57	1,051	1,088	1,014	1,044	454	79.57	17.9	20.8	3,535	1,760	604	.17	------	------	63
1-108	Little Androscoggin River near South Paris, Maine.	76.2	2.34	622	867	730	818	258	34.5	15.3	18.4	2,420	935	390	.06	------	------	67
1-153	East Branch of Pemigewasset River near Lincoln, N. H.	104	1.45	824	1,774	1,468	1,598	498	117	15.3	18.7	5,249	2,804	1,020	.09	0	0.09	48
1-153A	Pemigewasset River at Woodstock, N. H	192.6	1.50	2,355	1,636	1,363	1,478	426	76.2	23.6	23.9	5,249	2,492	620	.44	.72	1.16	51
1-155	Pemigewasset River at Plymouth, N. H	622	1.62	13,156	1,262	1,089	1,161	223	21.4	41.8	52.4	5,249	1,853	460	2.36	4.88	7.24	74
1-169	Bakers River at Wentworth, N. H	58.8	1.84	412	1,188	870	1,004	482	109.2	14.7	13.0	4,810	1,744	580	.06	.58	.64	46
1-170	Bakers River near Rumney, N. H	142	1.62	1,735	998	794	878	326	54.9	22.5	29.8	4,810	1,584	500	.72	.86	1.58	64
1-171A	Squam River at Ashland, N. H	57.6	1.42	436	654	565	603	212	11.1	15.0	15.3	2,280	807	560	12.10	1.32	13.42	50
1-174	Smith River near Bristol, N. H	85.8	2.05	1,081	852	697	764	242	33.7	22.0	20.5	2,920	1,258	470	.74	2.57	3.31	42
1-175	Lake Winnipesaukee outlet at Lakeport, N. H	363	1.46	7,274	491	438	460	96	.25	34.0	39.9	2,979	756	495	83.84	8.48	92.32	52
1-183	Contoocook River at Penacook, N. H	766	1.89	28,221	646	522	575	90.2	9.78	72.0	91.5	3,165	1,038	270	9.61	25.56	35.17	62
1-186	North Branch of Contoocook River near Antrim, N. H.	54.8	2.32	669	711	542	610	208	24.9	23.7	21.3	2,496	1,542	880	1.96	2.66	4.62	46
1-188A	Warner River at Davisville, N. H	146.2	1.54	1,970	734	590	652	163	24.3	23.9	26.3	2,722	965	380	2.94	5.38	8.32	49
1-189	Blackwater River near Webster, N. H	129	1.65	2,747	737	627	674	178	16.6	33.1	31.1	2,937	1,101	430	2.05	5.17	7.22	59
1-192	Suncook River at North Chichester, N. H	157	1.93	2,270	519	505	511	109	13.0	26.6	24.7	2,378	820	340	3.93	4.95	8.88	48
1-198	Souhegan River at Merrimack, N. H	170	2.04	3,154	525	475	497	127	34.6	34.1	31.9	2,280	813	140	.64	2.76	3.40	51
1-202	North Nashua River near Leominster, Mass	107	1.59	1,168	474	372	416	115	42.5	20.6	24	1,990	868	290	2.37	.49	2.86	48
1-210	Concord River below River Meadow Brook, at Lowell, Mass.	405	1.50	12,390	285	244	261	24	2.8	51.6	64	755	268	65	11.56	23.94	35.5	49
1-213	Ipswich River near Ipswich, Mass	124	1.23	1,714	197	192	194	15.9	2.33	27.5	21.5	400	126	35	1.42	10.58	12.00	39

Summary of drainage basin topographic characteristics—Continued

No.	Name of gaging station	Drainage area (square miles)	Stream density (miles per square mile)	Σ al (cubic miles)	Land slope (feet per mile) E.-W.	Land slope N.-S.	Land slope Average	Channel slope (feet per mile) Tributary	Channel slope Principal	Longest watercourse (miles)	Length of principal streams (miles)	Altitude of land (feet above mean sea level) Maximum	Altitude Mean	Altitude Minimum	Area of water surfaces (square miles) Lakes and reservoirs	Swamps	Total	Number of subareas into which basin was subdivided
1-213.5	Aberjona River at Winchester, Mass.	23.3	2.34	97	359	257	301	49.6	12.8	8.3	9.4	360	124	15	0.54	0.48	1.02	26
1-216	Charles River at Charles River Village, Mass.	183	1.27	3,638	270	210	236	22.6	4.24	38.7	31.9	580	232	100	2.88	3.54	6.42	60
1-218	Charles River at Waltham, Mass.	251	1.37	8,126	273	223	244	20.7	3.57	59.8	44.1	580	211	20	3.86	8.50	12.36	57
1-220A	Neponset River at Norwood, Mass.	35.2	1.27	202	200	159	176	35.3	19.2	11.6	14.6	540	213	60	1.02	.04	1.06	28
1-222	Taunton River at State Farm, Mass.	260	1.28	3,738	129	105	116	13.5	3.28	26.7	36.6	420	99	10	13.95	12.24	26.19	65
1-223	Wading River near Norton, Mass.	42.2	1.20	327	158	129	141	24.0	11.6	15.0	15.3	440	195	70	.92	.25	1.17	21
1-225	Blackstone River at Worcester, Mass.	31.3	1.69	164	458	308	371	77.9	41.5	11.5	13	1,400	746	480	1.36	.03	1.39	21
1-227	Blackstone River at Northbridge, Mass.	139.2	1.36	1,861	414	279	337	58.7	12.5	26.5	26.5	1,400	611	270	5.90	.08	5.98	49
1-230	Blackstone River at Woonsocket, R. I.	417	1.32	8,184	370	262	307	41.5	12.3	44.5	48	1,400	495	130	12.96	2.29	15.25	72
1-232A	Quinsigamond River at North Grafton, Mass.	26.1	1.57	139	374	248	301	101	20.0	9.8	10.5	760	496	360	1.50	0	1.50	30
1-232B	Mumford River at East Douglas, Mass.	27.8	1.14	117	293	275	283	97.6	46.1	7.6	11.4	910	637	360	1.44	0	1.44	34
1-237A	Branch River at Forestdale, R. I.	93.3	1.47	966	323	213	260	59.0	21.6	17.0	19.9	805	500	200	3.02	1.50	4.52	50
1-249A	Pawtuxet River at Cranston, R. I.	199.8	1.51	3,416	298	228	258	55.6	15.1	27.7	39	805	392	15	4.88	8.02	12.90	57
1-264	Willimantic River near South Coventry, Conn.	121	1.69	1,775	471	312	378	91.4	25.1	25.3	27.9	1,280	698	250	1.82	.06	1.88	51
1-267	Shetucket River near Willimantic, Conn.	401	1.62	6,815	414	293	344	61.7	13.3	32.6	49.6	1,290	620	160	4.12	3.42	7.54	66
1-272	Hop River near Columbia, Conn.	76.2	1.61	707	377	303	334	114	20.7	19.6	16.9	1,015	605	280	.90	.10	1.00	51
1-275	Natchaug River at Willimantic, Conn.	169	1.63	2,320	424	280	341	79.9	22.0	26.5	33	1,290	614	190	1.30	3.22	4.52	57
1-279A	Quinebaug River at Westville, Mass.	93.8	1.46	993	579	330	436	60.2	8.97	19.1	17.8	1,280	825	540	2.94	1.16	4.10	48
1-282	Quinebaug River at Quinebaug, Conn.	157	1.57	2,362	549	319	415	56.1	12.2	28.3	24.7	1,280	779	380	3.46	1.23	4.69	50
1-284	Quinebaug River at Putnam, Conn.	331	1.55	6,332	478	291	369	51.0	13.7	38.1	45.3	1,280	696	240	10.12	3.04	13.16	60
1-289	Quinebaug River at Jewett City, Conn.	711	1.56	22,477	420	261	328	42.1	12.1	65.3	69.5	1,280	553	80	16.19	9.28	25.47	73
1-294A	Little River at Buffumville, Mass.	27.7	1.62	141	449	274	348	76.6	37.4	9.5	13.1	1,080	744	490	1.18	0	1.18	28
1-295.5	Five-Mile River at Killingly, Conn.	58.7	1.61	617	355	237	285	70.9	26.2	17.8	18.3	940	536	220	1.64	.76	2.40	45
1-298	Moosup River at Moosup, Conn.	83.5	1.51	723	319	220	262	68.7	24.3	16.5	20.6	860	512	220	.61	3.16	3.77	44
1-301	Yantic River at Yantic, Conn.	88.6	1.67	738	351	271	305	64.0	24.9	16.4	20.1	760	406	110	2.02	.42	2.44	55
1-329A	Ammonoosuc River at Bethlehem Junction, N. H.	88.5	1.72	968	1,225	1,056	1,130	575	75.8	20.2	22.3	6,288	2,512	1,190	.01	.07	.08	64
1-332	Ammonoosuc River near Bath, N. H.	395	1.53	8,575	1,034	855	931	274	35.9	50.7	52.4	6,288	1,712	460	.83	2.28	3.11	60
1-334	White River near Bethel, Vt.	241	2.09	4,272	1,378	1,236	1,295	350	21.8	31.3	32.8	3,800	1,801	550	0	.08	.08	56
1-336.8A	Ayers Brook at Randolph, Vt.	30.5	1.99	172	1,168	693	890	375	119.0	10.1	11.8	2,300	1,324	640	0	.12	.12	31
1-339A	Mascoma River at West Canaan, N. H.	80.5	1.60	622	734	486	588	234	39.2	15.2	20.2	3,220	1,402	840	1.50	1.33	2.83	50

1-340	Mascoma River at Mascoma, N. H.	153	1.57	1,912	756	512	614	157	23.8	23.9	29.4	3,220	1,285	750	5.17	2.95	8.12	53
1-346	Ottauquechee River at North Hartland, Vt.	221	1.76	4,562	1,215	994	1,090	241	30.0	37.8	34.7	4,241	1,514	360	.23	.05	.28	57
1-347	Sugar River at West Claremont, N. H.	269	1.59	5,211	707	548	615	157	28.4	32.7	39.1	2,781	1,246	370	9.86	3.50	13.36	55
1-350	Black River at North Springfield, Vt.	158	1.45	2,733	969	792	868	227	26.4	34.9	32.6	3,737	1,494	460	.99	1.63	2.62	52
1-352A	Saxtons River near Saxtons River, Vt.	72.2	1.69	666	1,073	823	932	238	53.6	17.6	18.1	2,770	1,318	400	.04	.28	.32	50
1-354	West River at Newfane, Vt.	308	1.53	6,812	879	753	806	200	42.9	39.3	43.6	3,859	1,655	430	.85	.73	1.58	53
1-356	Ashuelot River near Gilsum, N. H.	71.2	2.17	751	665	520	580	175	40.5	22.8	19	2,544	1,517	790	1.82	4.76	6.58	52
1-358	Ashuelot River at Hinsdale, N. H.	420	2.21	11,952	710	544	614	110	22.1	60.9	55.1	3,166	1,204	220	5.48	10.02	15.50	67
1-359	Otter Brook near Keene, N. H.	41.8	2.32	274	700	630	660	193	67.4	11.8	13.4	2,240	1,435	740	0.74	1.88	2.62	35
1-362	South Branch Ashuelot River near Marlboro, N. H.	36.4	2.17	204	630	444	522	246	59.2	10.3	12.2	3,166	1,277	700	.45	.97	1.42	41
1-363	Millers River near Winchendon, Mass.	83.8	1.72	664	376	282	322	63.9	17.9	14.7	19.8	1,848	1,110	850	3.37	1.64	5.01	52
1-363A	Millers River at South Royalston, Mass.	186	1.90	2,236	370	265	310	50.4	16.4	21.5	32.6	1,900	1,070	785	5.66	2.53	8.19	59
1-365	Millers River at Erving, Mass.	370	1.97	8,025	479	320	387	65.4	17.4	39.4	37.9	1,900	988	490	7.78	3.50	11.28	87
1-367	Sip Pond Brook near Winchendon, Mass.	19.0	1.82	74	392	278	328	85.5	31.1	8.0	9.8	1,303	1,038	865	.61	.62	1.23	25
1-368	Priest Brook near Winchendon, Mass.	18.7	1.73	109	376	271	314	126	24.2	11.4	12	1,900	1,108	865	.05	.22	.27	28
1-371	East Branch of Tully River near Athol, Mass.	49.9	2.00	344	537	317	409	120	37.2	13.5	18.4	1,890	1,060	630	.56	.26	.82	39
1-372	Moss Brook at Wendell Depot, Mass.	12.2	1.96	46	766	508	614	173	61.3	6.8	7.5	1,620	873	530	.18	.18	.36	29
1-375	Deerfield River at Charlemont, Mass.	362	1.71	9,838	884	702	778	168	32.3	53.4	47.4	3,839	1,966	520	1.36	.68	2.04	63
	Deerfield River, excluding Somerset Reservoir, at Charlemont, Mass.	332	1.72	8,389	914	722	803	180	31.0		45.5	3,764	1,918	520	1.01	.68	1.69	59
	Deerfield River, excluding Harriman Reservoir, at Charlemont, Mass.	178	1.94	2,418	1,022	850	922	205	56.5		32.9	3,071	1,712	520	.34	.36	.70	35
1-376A	Deerfield River above the mouth	663.5	1.85	24,550	821	649	721	144	26.5	78.0	69.4	3,839	1,557	120	2.01	.68	2.69	75
1-380A	North River at Shattuckville, Mass.	88.4	1.64	890	699	600	642	245	75.8	19.5	22.7	2,440	1,438	460	.18	0	.18	47
1-380.4A	Green River above mouth at Greenfield, Mass.	89.4	1.75	1,125	726	527	610	192	53.1	28.0	24.5	2,440	988	120	.38	0	.38	51
1-383.2	Mill River at Northampton, Mass.	53.3	1.94	446	760	494	608	218	59.3	15.1	17.7	1,720	870	140	.30	.01	.31	41
1-384	Ware River at Cold Brook, Mass.	100	1.67	919	404	246	313	69.3	22.9	17.8	25.7	2,000	990	675	2.42	1.72	4.14	41
1-387	Ware River at Gibbs Crossing, Mass.	201	1.52	4,017	462	281	357	66.5	16.0	36.7	28.4	2,000	910	400	3.08	1.72	4.80	52
1-389	Chicopee River at Bircham Bend, Mass.	702	1.50	22,677	519	318	404	52.2	12.3	57	81	2,000	788	120	9.83	3.73	13.56	72
1-390	Swift River at West Ware, Mass.	188	1.59	2,998	628	347	468	98.5	12.1	28.7	42.7	1,380	800	390	1.64	.08	1.72	55
1-394	Quaboag River at West Brimfield, Mass.	149	1.56	2,413	461	301	371	70.5	17.4	28.2	27.9	1,227	840	380	3.89	1.65	5.54	52
1-396.8	Mill River at Springfield, Mass.	34.1	1.06	216	232	151	186	49.7	11.7	12.1	16.3	905	266	130	.83	.26	1.09	25
1-399	Westfield River at Knightville, Mass.	162	2.05	2,562	722	458	570	125	50.7	30.4	26.8	2,560	1,466	500	.37	.12	.49	50
1-402	Westfield River near Westfield, Mass.	497	1.77	12,258	678	485	567	115	30	51.0	57.2	2,560	1,195	120	3.08	.41	3.49	74
	Westfield River, excluding Westfield Little River, near Westfield, Mass.	448	1.84	11,266	698	487	577	111	29.8	51.0	54.7	2,560	1,192	120	2.68	.41	3.09	51
1-406	Middle Branch of Westfield River at Goss Heights, Mass.	52.6	2.24	544	794	555	655	276	94.9	19.1	17.7	2,295	1,418	420	.01	.22	.23	55
1-407	West Branch of Westfield River at Huntington, Mass.	93.7	1.95	1,051	795	620	695	208	87.6	20.8	21.3	2,295	1,420	400	.95	.07	1.02	56
1-410	Westfield Little River near Westfield, Mass.	48.5	1.12	352	476	422	446	150	71.4	13.3	14.5	1,751	1,290	570	.40	0	.40	44
1-413	Scantic River at Broad Brook, Conn.	98.4	1.58	1,129	485	303	381	105	20.4	21.8	21.6	1,240	407	20	.24	.14	.38	51
1-415	Farmington River near New Boston, Mass.	92.0	1.34	758	580	411	482	113	61.5	17.5	20.9	2,140	1,508	775	2.78	.42	3.20	51
	Farmington River, excluding Otis Reservoir, near New Boston, Mass.	75.3	1.36	582	639	446	526	130	67.7		19.8	2,140	1,503	775	.61	.05	.66	43
1-431	Hockanum River near East Hartford, Conn.	74.5	1.64	749	403	292	339	106	28	22.0	23.9	1,060	432	60	1.35	.78	2.13	51

Summary of drainage basin topographic characteristics—Continued

No.	Name of gaging station	Drainage area (square miles)	Stream density (miles per square mile)	Σ al (cubic miles)	Land slope (feet per mile) E.-W.	Land slope N.-S.	Land slope Average	Channel slope (feet per mile) Tributary	Channel slope Principal	Longest watercourse (miles)	Length of principal streams (miles)	Altitude of land (feet above mean sea level) Maximum	Altitude Mean	Altitude Minimum	Area of water surfaces (square miles) Lakes and reservoirs	Swamps	Total	Number of subareas into which basin was subdivided
1-432	Salmon River near East Hampton, Conn.	104.7	1.62	821	433	286	349	74.6	40.2	17.5	21.4	920	500	90	0.91	0	0.91	51
1-435	Quinnipiac River at Wallingford, Conn.	109	1.66	1,323	452	274	351	91.2	9.42	23.2	22.3	1,000	300	40	1.00	.03	1.03	48
1-438	Housatonic River at Coltsville, Mass.	57.1	1.91	405	567	486	521	165	78.6	12.2	14.5	2,300	1,678	1,030	.60	.10	.70	52
1-444	Housatonic River near Great Barrington, Mass.	280	1.52	6,841	607	513	553	135	13.1	43.0	36.7	2,660	1,432	720	4.74	.36	5.10	72
1-446	Housatonic River at Falls Village, Conn.	632	1.35	21,092	621	487	543	79.8	8.45	68.7	55.6	2,660	1,264	555	9.24	1.72	10.96	69
1-450	Housatonic River at Stevenson, Conn.	1,545	1.57	81,138	666	477	557	54.2	10	111.2	99.3	2,660	981	40	16.87	9.42	26.29	51
1-453	Tenmile River near Gaylordsville, Conn.	204	1.34	3,497	736	480	587	113	17.1	33.0	31.6	1,737	819	320	1.51	2.26	3.77	75
1-455	Still River near Lanesville, Conn.	68.5	1.81	820	593	407	487	85.2	17.1	19.4	17.6	1,070	568	210	.96	1.02	1.98	50
1-458	Shepaug River near Roxbury, Conn.	133	1.98	2,431	574	388	465	88	31.4	34.7	33.1	1,680	1,029	300	2.26	0.62	2.88	50
1-459	Pomperaug River at Southbury, Conn.	75.3	2.29	710	624	366	474	153	33.4	17.1	19.5	1,140	685	310	.37	.48	.85	52
1-462	Naugatuck River near Thomaston, Conn.	71.9	2.21	822	644	475	546	175	41	21.8	21.1	1,700	1,016	410	.19	0	.19	52
1-463	Naugatuck River near Naugatuck, Conn.	245.8	2.05	4,483	598	399	483	103	17.5	40.4	31.4	1,700	801	160	1.69	.12	1.81	74
1-464	Leadmine Brook near Thomaston, Conn.	24.0	2.15	121	552	334	424	147	72.3	10.1	11	1,200	870	420	.10	0	.10	33
1-466	Saugatuck River near Westport, Conn.	77.5	1.84	710	614	368	474	92.6	32.2	19.7	26.4	1,060	459	30	.14	1.10	1.24	53
1-471	Hudson River near Newcomb, N. Y.	192	2.21	2,282	1,148	1,010	1,091	250	13.0	24.4	37.1	5,344	2,193	1,550	5.85	------	------	49
1-475	Hudson River at Hadley, N. Y.	1,664	1.68	89,931	973	882	920	127	12.37	93.7	111.7	5,344	1,848	560	40.97	------	------	234
1-482	Cedar River below Chain Lakes near Indian Lake, N. Y.	160	1.77	2,503	684	883	800	159	32.61	35.0	36.3	3,865	2,231	1,544	3.84	------	------	45
1-485	Schroon River at Riverbank, N. Y.	527	1.58	13,054	1,100	998	1,040	118	16.54	47.3	44.5	4,842	1,450	700	18.55	------	------	63
1-488	Sacandaga River near Hope, N. Y.	491	1.60	9,640	1,022	961	987	124	35.7	35.9	53.9	3,595	1,888	905	13.84	------	------	105
1-492	East Branch of Sacandaga River at Griffin, N. Y.	114	1.37	1,258	1,275	1,074	1,157	183	42.5	22.3	23.1	3,595	1,896	1,248	.63	------	------	53
1-496	Batten Kill at Arlington, Vt.	152	1.51	1,552	1,120	827	953	314	52.7	22.2	23.3	3,816	1,700	620	.20	1.27	1.47	49
1-499	Kayaderosseras Creek near West Milton, N. Y.	90	1.68	894	494	390	432	163	24.36	19.9	21.8	2,020	778	374	.10	------	------	49
1-501	Hoosic River at Adams, Mass.	46.2	1.77	268	842	544	673	397	77	11.1	14.2	3,300	1,580	790	.74	0	.74	39
------------	Hoosic River, excluding Hoosic Lake, at Adams, Mass.	31.4	1.79	142	844	533	669	414	113	------	11.5	3,300	1,650	790	0	0	0	27
1-506	Hoosic River near Eagle Bridge, N. Y.	510	1.68	11,036	1,047	795	900	181	17.7	46.0	53.3	3,764	1,269	370	1.27	------	------	51
1-508	North Branch of Hoosic River at North Adams, Mass.	39.1	1.92	210	1,005	719	841	479	146	9.5	12.2	3,143	1,835	870	.08	0	.08	40
1-510	Walloomsac River near North Bennington, Vt.	111	1.74	1,057	950	653	777	271	80.2	18.3	21.2	3,764	1,649	530	.29	.16	.45	44

1-515	Mohawk River near Little Falls, N. Y.	1,348	1.95	65,630	441	497	474	73	11.04	90.8	112.3	3,626	1,131	320	12.07	------	------	78
1-536	East Canada Creek at Dolgeville, N. Y.	261	1.75	3,475	526	568	543	95.7	51.8	28.1	38.3	2,780	1,821	770	4.35	------	------	66
1-549	Kinderhook Creek at Rossman, N. Y.	329	1.26	8,756	765	612	679	105	26.8	44.4	57.1	2,653	897	40	1.52	------	------	61
1-550	Catskill Creek at Oak Hill, N. Y.	98	1.47	832	709	820	770	309	56.4	15.9	17	2,885	1,347	648	.10	------	------	61
1-562	Rondout Creek at Rosendale, N. Y.	386	1.38	9,603	748	660	702	144	26.8	46.7	46.3	3,863	930	55	.65	------	------	51
1-563.5	Wallkill River near Unionville, N. Y.	144	1.97	1,769	636	500	554	102	11.2	23.9	26.7	1,809	695	390	1.11	------	------	51
1-566	Wallkill River at Gardiner, N. Y.	711	1.60	26,284	498	412	449	63.7	4.7	72.6	74.7	2,273	624	196	3.09	------	------	65
1-569	Wappinger Creek near Wappinger Falls, N. Y.	182	1.35	3,335	663	358	471	70.2	16.1	30.6	34.2	1,440	493	140	1.06	------	------	69
1-577	Passaic River near Millington, N. J.	55.4	1.89	365	266	315	294	67.1	9.8	11.9	17.7	857	319	208	.08	------	------	49
1-582	Passaic River at Paterson, N. J.	785	1.73	25,065	609	473	533	49.6	7.1	59.9	92.9	1,496	456	100	13.90	------	------	118
1-583.5	Rockaway River above Reservoir at Boonton, N. J.	116	1.90	1,648	632	578	602	88.9	14.9	31.0	27.2	1,406	822	360	3.29	------	------	49
1-587	Whippany River at Morristown, N. J.	29.4	1.70	190	580	562	574	181	23.9	11.3	12.1	1,092	534	265	.27	------	------	49
1-593	Ramapo River near Mahwah, N. J.	118	1.76	1,307	860	648	743	21.8	12.3	23.9	25.1	1,420	687	258	2.13	------	------	57
1-595	Ramapo River at Pompton Lakes, N. J.	160	1.67	2,927	825	596	661	112	15.0	35.4	30.4	1,420	654	180	2.78	------	------	66
1-606	Saddle River at Lodi, N. J.	54.6	2.25	600	302	154	214	66.9	19.2	18.0	22.4	710	275	29	.45	2.55	3.00	54
1-609	Rahway River at Rahway, N. J.	40.9	2.02	437	320	305	309	114	19.9	18.4	19	643	204	12	.20	------	------	49
1-611	South Branch Raritan River near High Bridge, N. J.	65.3	1.55	886	506	497	501	151	31.3	23.7	23	1,227	778	282	.79	------	------	56
1-614	South Branch of Raritan River at Stanton, N. J.	147	1.61	2,408	449	453	451	108	19.6	35.1	32.7	1,220	562	130	.84	------	------	45
1-616	Raritan River at Manville, N. J.	490	1.85	12,849	389	370	378	71.6	10.1	58.2	60.3	1,220	370	29	.99	------	------	148
1-619	Neshanic River at Reaville, N. J.	25.7	1.86	109	255	262	259	92.3	24.1	7.8	10.3	680	229	113	0	------	------	33
1-619.5	Walnut Brook near Flemington, N. J.	2.24	1.43	1.84	------	------	------	300	112	1.9	1.6	660	480	275	0	0	0	7
1-620	North Branch of Raritan River near Far Hills, N. J.	26.2	2.37	163	414	529	473	191	73.7	11.6	13.4	1,122	587	192	.28	------	------	60
1-622	North Branch of Raritan River at Milltown, N. J.	190	2.00	2,911	453	427	437	75.7	23.80	33.3	37.7	1,160	378	52	0.16	------	------	55
1-623	Black River near Pottersville, N. J.	32.8	1.98	288	434	450	443	125	28.46	17.6	14.9	1,205	732	294	.15	------	------	56
1-624	Millstone River near Kingston, N. J.	171	1.58	2,128	131	154	140	23.3	5.80	26.6	36.2	540	154	42	.28	------	------	45
1-625	Millstone River at Blackwells Mills, N. J.	258	1.72	4,288	152	167	158	29.3	4.15	35.6	36.4	563	137	30	.29	------	------	53
1-625.5	Green Brook at Plainfield, N. J.	9.75	1.08	40	365	379	373	145	47.3	7.47	6.7	561	265	72	.03	0	.03	20
1-632	Swimming River near Red Bank, N. J.	48.5	2.41	275	240	250	244	46.4	13.6	9.8	18.9	391	113	10	.12	------	------	40
1-633	Manasquan River at Squankum, N. J.	43.4	1.98	318	114	132	121	27.1	8.02	12.3	11.1	308	112	22	.01	1.81	1.82	56
1-634	Toms River near Toms River, N. J.	124	1.22	1,260	166	151	158	13.6	6.99	21.8	28.9	346	106	13	.19	------	------	49
1-635	Cedar Creek at Lanoka Harbor, N. J.	56	1.39	474	70	72	71	18.2	8.98	14.7	18.7	212	84	8	.20	------	------	31
1-636	Batsto River at Batsto, N. J.	70.5	.96	734	54	57	55	10	5.57	17.1	20.8	190	64	10	.18	------	------	25
1-637	East Branch of Wading River at Harrisville, N. J.	64	1.00	693	71	69	70	15.6	6.77	17.6	15.8	205	93	10	.07	------	------	55
1-639	Great Egg River at Folsom, N. J.	56.3	.96	543	53	53	53	12.8	6.05	16.7	19	199	125	55	.01	9.24	9.25	53
1-640	Maurice River at Norma, N. J.	113	1.14	1,036	61	54	57	10.1	5.46	16.9	22.7	177	108	48	.56	------	------	70
1-641	Manantico Creek near Millville, N. J.	22.3	1.16	89	59	61	60	11.7	7.2	7.3	7.4	131	79	40	0	------	------	19
1-644	East Branch of Delaware River at Fishs Eddy, N. Y.	783	1.38	26,360	1,241	982	1,092	126	13.3	62.3	75.1	3,905	1,849	955	2.30	------	------	65
1-646	Delaware River at Port Jervis, N. Y.	3,076	1.37	244,482	860	710	775	90.1	7.66	157.9	173.4	3,905	1,555	420	33.08	------	------	338

Summary of drainage basin topographic characteristics—Continued

No.	Name of gaging station	Drainage area (square miles)	Stream density (miles per square mile)	Σ al (cubic miles)	Land slope (feet per mile) E.-W.	Land slope (feet per mile) N.-S.	Land slope (feet per mile) Average	Channel slope (feet per mile) Tributary	Channel slope (feet per mile) Principal	Longest watercourse (miles)	Length of principal streams (miles)	Altitude of land (feet above mean sea level) Maximum	Altitude of land (feet above mean sea level) Mean	Altitude of land (feet above mean sea level) Minimum	Area of water surfaces (square miles) Lakes and reservoirs	Area of water surfaces (square miles) Swamps	Area of water surfaces (square miles) Total	Number of subareas into which basin was subdivided
1-648	Delaware River at Riegelsville, N. J.	6,344	----	610,833	----	----	----	----	----	209.2	201.7	----	----	----	36.30	----	----	52
1-657	West Branch of Delaware River at Delhi, N. Y.	142	1.43	1,892	1,005	829	917	154	16.40	25.8	18.3	3,253	1,911	1,335	.15	----	----	49
1-658	West Branch of Delaware River at Hale Eddy, N. Y.	593	1.38	20,781	964	857	905	130	85.8	73.3	60	3,365	1,738	955	.65	----	----	114
1-664.5	Lackawaxen River at Hawley, Pa., (including Wallenpaupack Reservoir).	519	1.27	9,260	527	426	469	75.4	18.7	34.6	54.3	2,654	1,429	874	16.21	----	----	94
----	Lackawaxen River at Hawley, Pa., (excluding Wallenpaupack Reservoir).	290	1.38	4,857	601	422	498	82	19.1	34.6	41.1	2,654	1,358	874	3.55	----	----	51
1-668	Neversink River at Oakland Valley, N. Y.	222	1.41	5,520	848	705	633	129	30.7	50.7	46.2	4,204	1,644	645	2.95	----	----	51
1-671	Flat Brook near Flatbrookville, N. J.	65.1	1.58	827	641	593	617	174	31.9	22.8	23.6	1,653	819	348	0.09	----	----	47
1-672	McMichaels Creek at Stroudsburg, Pa.	64.4	1.80	747	502	630	571	154	40.67	22.3	25.3	2,131	883	410	.32	----	----	55
1-673	Paulins Kill at Blairstown, N. J.	126	1.59	2,093	472	467	469	82	11.9	28.7	27.3	1,600	666	335	2.58	----	----	53
1-673.5	Pequest River at Huntsville, N. J.	31.4	1.99	138	534	476	515	78.1	10.75	8.5	10.7	1,127	706	560	.55	----	----	41
1-674	Pequest River at Pequest, N. J.	108	1.70	1,611	509	476	497	80.3	7.07	28.4	27.6	1,248	689	404	.75	----	----	51
1-675	Beaver Brook near Belvidere, N. J.	36.2	1.78	304	515	535	526	122	15.55	13.5	13.7	1,141	539	296	.16	----	----	49
1-676	Lehigh River at Tannery, Pa.	322	1.25	7,183	288	277	283	59.4	22.9	41.5	48.3	2,320	1,724	1,060	4.75	----	----	49
1-677	Lehigh River at Bethlehem, Pa.	1,280	1.27	57,905	416	557	497	55.3	16.5	99.3	72.1	2,320	1,166	210	5.08	----	----	128
1-681	Tohickon Creek near Pipersville, Pa.	97.4	1.75	1,263	244	222	233	40.5	12.9	23.9	21.4	960	463	260	.01	----	----	44
1-683	Assunpink Creek at Trenton, N. J.	89.4	1.60	810	99	118	109	22	4.75	20.5	20	340	97	28	.24	----	----	57
1-685	Neshaminy Creek near Langhorne, Pa.	210	1.69	4,077	212	237	225	43.7	8.0	37.5	36.8	660	275	45	.05	----	----	51
1-686	North Branch of Rancocas Creek at Pemberton, N. J.	111	1.18	1,197	57	66	62	12.7	6.5	18.4	26.8	213	97	30	.30	----	----	47
1-688	Schuylkill River at Pottstown, Pa.	1,147	2.07	49,456	540	654	605	70.7	6.77	79.8	95	2,020	873	120	.75	----	----	119
1-691	Little Schuylkill River at Tamaqua, Pa.	42.9	1.36	256	443	780	621	202	53.7	10.6	16.9	2,020	1,293	798	0	----	----	48
1-693	Perkiomen Creek at Graters Ford, Pa.	279	1.68	4,277	357	364	360	65.2	14.08	27.8	49.3	1,200	438	125	.06	----	----	73
1-694A	Mantua Creek near Pitman, N. J.	6.75	1.14	12	96	98	98	54.2	20.4	2.7	5.1	172	113	70	0	----	----	13
1-695	Crum Creek at Woodlyn, Pa.	33.3	2.44	335	509	463	484	104	23.1	7.8	15.8	595	305	25	0	----	----	47
1-696	Ridley Creek at Moylan, Pa.	31.9	2.19	267	378	438	412	106	24.6	15.7	13.4	600	321	85	.01	----	----	52
1-698	Oldmans Creek near Woodstown, N. J.	19.3	1.73	76	138	155	148	47	13.73	8.2	7.5	166	86	12	.04	----	----	39
1-701	Brandywine Creek at Chadds Ford, Pa.	287	2.26	5,283	402	459	434	51.5	12.8	38.7	41	1,100	447	150	.16	----	----	51
1-702A	Salem Creek at Woodstown, N. J.	14.6	1.75	63	130	154	144	39.3	11.1	7.2	7.2	164	90	30	.17	----	----	----
1-706	Big Elk Creek at Elk Mills, Md.	52.6	3.03	604	414	373	389	96.3	20.1	20.8	20.1	640	340	85	.02	----	----	57

1-707	Susquehanna River at Colliersville, N. Y.	351	1.54	8,829	671	566	621	94.9	3.90	42.5	61.1	2,301	1,489	1,152	10.63	......	......	97
1-708	Susquehanna River at Conklin, N. Y.	2,240	1.44	163,292	710	574	632	64.4	3.32	128.4	124.4	2,740	1,431	842	14.23	......	......	198
1-712	Susquehanna River at Towanda, Pa.	7,797	......	670,664	......	......	......	......	......	176.9	197	......	......	......	23.01	......	......	67
1-717	Oaks Creek at Index, N. Y.	103	1.59	1,405	626	513	576	93.5	15.40	25.0	22.	2,080	1,508	1,175	3.11	......	......	49
1-723	Unadilla River at Rockdale, N. Y.	518	1.53	15,249	661	524	585	75.3	5.16	58.3	71.7	2,120	1,430	999	.57	......	......	68
1-727	Chenango River near Chenango Forks, N. Y.	1,492	1.46	57,740	653	489	559	59.1	4.63	76.5	112.3	2,160	1,315	880	6.28	......	......	128
1-734	Tioughnioga River at Itaska, N. Y.	735	1.33	23,148	693	481	572	59.6	6.99	58.8	79.4	2,160	1,430	920	2.61	......	......	61
1-740	Owego Creek near Owego, N. Y.	186	1.36	2,961	740	575	641	134	17.45	31.7	40.4	2,133	1,280	825	.01	......	......	51
1-742	Tioga River at Lindley, N. Y.	770	1.29	19,033	768	793	782	78.5	12.30	44.4	69	2,540	1,573	970	.04	......	......	57
1-743	Tioga River near Erwins, N. Y.	1,370	1.36	43,398	776	783	780	101	7.49	57.3	90.5	2,540	1,579	934	.01	......	......	210
1-746	Chemung River at Chemung, N. Y.	2,530	......	140,000	......	......	......	50.2	6.1	93.0	122	......	......	......	2.64	......	......	54
1-747	Canisteo River at Arkport, N. Y.	30.5	1.23	201	590	688	646	242	68	11.3	11.5	2,240	1,770	1,190	0	......	......	41
1-758	Tuscarora Creek near South Addison, N. Y.	114	1.63	1,155	645	716	685	141	36	19.2	25.2	2,360	1,597	1,060	0	......	......	49
1-761	Cohocton River near Campbell, N. Y.	472	1.47	9,429	683	545	603	80.1	10.30	42.2	43.7	2,260	1,520	1,010	2.52	......	......	65
1-777	Wapwallopen Creek near Wapwallopen, Pa.	45.8	1.67	427	394	482	442	152	43.88	18.4	17.4	2,080	1,307	775	.59	......	......	41
1-778.5	Fishing Creek near Bloomsburg, Pa.	274	1.80	4,648	755	802	778	148	22	30.6	48.6	2,593	1,189	560	.37	......	......	57
1-781	West Branch of Susquehanna River at Bower, Pa.	315	1.72	6,191	664	744	710	78.5	13.10	39.3	50.1	2,320	1,589	1,225	.08	......	......	47
1-790	North Bald Eagle Creek at Beech Creek Station, Pa.	559	1.34	12,376	829	954	897	111	16.34	43.4	62.3	2,440	1,241	582	.05	......	......	64
1-798	Mahantango Creek East near Dalmatia, Pa.	162	1.55	3,283	494	958	758	89.5	16.42	36.8	42.5	1,813	894	420	0	......	......	51
1-799	Frankstown Branch of Juniata River at Williamsburg, Pa.	291	1.13	5,340	921	835	873	143	16.80	31.9	32.4	3,136	1,488	820	.13	......	......	52
1-802.5	Little Juniata River at Spruce Creek Pa.	220	1.50	3,180	897	902	900	218	24.2	28.1	29.2	2,620	1,477	754	0.15	......	......	57
1-808	Standing Stone Creek near Huntingdon, Pa.	128	1.31	1,950	902	991	945	167	19.5	27.7	29.6	2,400	1,056	620	.03	......	......	57
1-810	Raystown Branch of Juniata River at Saxton, Pa.	756	1.23	35,640	997	775	871	88.2	7.2	78.6	85.3	3,136	1,487	792	.06	......	......	75
1-818	Sherman Creek at Shermandale, Pa.	200	1.66	3,971	811	1,032	895	136	15.2	40.4	37.6	2,240	985	424	0	......	......	53
1-818.5	Clark Creek near Carsonville, Pa.	21.6	.89	130	872	1,284	1,084	298	17.3	11.2	10.3	1,700	959	552	0	......	......	49
1-820	Conodoquinet Creek near Hogestown, Pa.	470	1.25	19,025	449	486	465	71.6	7.2	80.8	63.3	2,340	831	354	.06	......	......	57
1-833	Conestoga Creek at Lancaster, Pa.	322	1.61	6,368	337	403	363	54.5	6.3	35.7	41.3	1,320	507	260	.09	......	......	57
1-851	North Branch of Potomac River at Blooming- Md.	287	1.36	7,717	748	744	746	198	55.2	48.7	56.6	4,150	2,455	970	.58	......	......	78
1-863	Georges Creek at Franklin, Md.	72.4	1.72	678	950	775	850	337	55.7	17.8	13.4	3,022	1,932	1,005	0	......	......	55
1-866	Wills Creek near Cumberland, Md.	247	1.49	4,107	1,125	999	1,053	192	51.7	33.7	37.8	2,942	1,633	651	0	......	......	67
1-867	Evitts Creek near Bedford Valley, Pa.	30.2	1.67	165	1,329	891	1,072	409	39.0	11.5	10.4	2,720	1,474	1,022	0	......	......	47
1-903	Monocacy River at Jug Bridge, near Frederick, Md.	817	2.02	26,587	464	417	438	69.2	5.1	63.4	57.9	1,980	623	239	.01	......	......	165
1-904	Owens Creek at Lantz, Md.	5.7	2.01	10	808	617	715	356	223	3.5	3.2	1,880	1,366	970	0	......	......	15
1-905	Linganore Creek near Frederick, Md.	82.3	1.80	901	567	483	524	78	14.9	18.6	17	880	496	270	0	0	0	65
1-910	Rock Creek at Sherrill Drive, Washington, D. C.	62.2	1.92	781	399	418	410	73.4	15.2	21.7	21.6	600	349	155	0	......	......	51
1-913	Northwest Branch of Anacostia River near Colesville, Md.	21.3	1.56	85	361	278	315	80.2	22.2	6.9	8.8	560	384	270	0	......	......	29
3-2	Allegheny River at Red House, N. Y.	1,690	......	70,663	......	......	......	......	......	83.2	76.6	......	......	......	.85	......	......	57

Summary of drainage basin topographic characteristics—Continued

No.	Name of gaging station	Drainage area (square miles)	Stream density (miles per square mile)	Σ al (cubic miles)	Land slope (feet per mile)			Channel slope (feet per mile)		Longest watercourse (miles)	Length of principal streams (miles)	Altitude of land (feet above mean sea level)			Area of water surfaces (square miles)			Number of subareas into which basin was subdivided
					E.-W.	N.-S.	Average	Tributary	Principal			Maximum	Mean	Minimum	Lakes and reservoirs	Swamps	Total	
3-3	Allegheny River at Franklin, Pa.	5,982		495,220						178.4	184.7				25.53			123
3-4	Allegheny River at Parkers Landing, Pa.	7,671		800,000						214.7	259.2				25.92			175
3-18	Brokenstraw Creek at Youngsville, Pa.	304	1.38	5,626	500	442	467	59.8	11.2	36.9	45.4	1,982	1,595	1,195	.16			52
3-18.5	Tionesta Creek at Lynch, Pa.	233	1.61	3,543	633	721	677	101	16.8	25.5	35	2,140	1,619	1,220	.08			57
3-24	French Creek at Saegerstown, Pa.	629	1.46	21,800	378	311	339	33.6	6.6	68.9	66.8	1,880	1,385	1,100	1.25			49
3-26	French Creek at Utica, Pa.	1,028	1.43	48,700	344	308	323	34.6	3.6	95.9	68.3	1,880	1,307	1,021	2.71			100
3-33.5	Mahoning Creek at Punxsutawney, Pa.	153	1.78	1,700	665	702	684	97.2	15.6	22.1	25.1	2,240	1,491	1,220	.03			51
3-34	Mahoning Creek near Dayton, Pa.	321	1.90	8,169	750	777	764	87.3	7.7	44.8	56.9	2,240	1,458	1,100	.04			98
3-34.5	Crooked Creek at Idaho, Pa.	191	2.31	2,700	922	766	845	67.8	8.2	27.2	33.2	1,700	1,220	970	0			53
3-42.5	Conemaugh River at Seward, Pa.	715	1.65	20,880	622	575	596	111	29.1	50.4	72	2,949	1,979	1,080	1.71			99
3-47	Kiskiminetas River at Vandergrift, Pa.	1,825	1.75	111,100	704	663	680	97.6	9.2	106.3	125.5	2,949	1,590	776	2.05			280
3-55	Blacklick Creek at Blacklick, Pa.	390	1.70	8,230	619	608	612	64.8	22	39.0	62.7	2,480	1,535	950	.01			53
3-59	Loyalhanna Creek at New Alexandria, Pa.	265	1.64	5,695	724	724	724	155	12.4	36.2	35.6	2,920	1,477	920	.19			49
3-63	Tygart River at Fetterman, W. Va.	1,340	1.80	71,600	1,231	1,179	1,202	84.7	9.7	113.7	115.5	4,775	1,950	972	0			73
3-70	West Fork River at Clarksburg, W. Va.	384	2.07	12,930	1,258	1,270	1,265	45	2.9	66.5	52.8	1,900	1,222	928	0			59
3-71	West Fork River at Enterprise, W. Va.	750	2.29	29,520	1,260	1,290	1,277	43.7	3.3	86.7	75.5	1,960	1,209	880	.05			122
3-81	Blackwater River at Davis, W. Va.	86.2	1.11	795	541	500	520	114	13.3	19.8	27.4	4,375	3,370	3,060	0	2.3	2.3	35
3-95	Youghiogheny River at Connellsville, Pa.	1,326	1.71	65,400	719	695	705	88.5	20.3	92.2	107.5	3,340	2,138	865	.21			136
3-98	Casselman River at Markleton, Pa.	382	1.62	8,373	586	527	553	84.1	16	50.3	42.8	3,213	2,247	1,670	.03			63
3-100	Big Piney Run near Salisbury, Pa.	24.5	2.07	108	649	495	583	151	73.59	8.5	9.2	3,027	2,505	2,175	0			50
3-111	Mahoning River near Berlin Center, Ohio	247	1.52	3,882	224	199	211	28.2	6.3	30.4	30.8	1,380	1,110	975	.04			49
3-114	Mahoning River at Youngstown, Ohio	899	1.46	36,418	166	151	158	23.8	3.1	82.2	91.2	1,380	1,038	828	.15			106
3-117	Beaver River at Wampum, Pa.	2,235	1.48	123,609	216	208	211	38.2	3.4	111.1	145.1	1,540	1,051	752	.23			275
3-125.5	Shenango River at Sharpsville, Pa.	588	1.56	18,071	190	207	197	47	2.87	58.8	69.8	1,470	1,078	860	.08			106
3-130	Little Shenango River near Greenville, Pa.	104	1.52	1,026	269	306	290	89.9	10.5	20.9	23.4	1,480	1,138	950	0.07			47
3-135	Slippery Rock Creek at Wurtemburg, Pa.	406	1.60	10,808	480	413	443	36.4	11.52	42.3	54.5	1,600	1,254	805	.12			51
3-141	Tuscarawas River at Clinton, Ohio	165	1.56	2,297	225	196	214	30.7	6.21	25.8	32.2	1,300	1,055	940	1.93	2.18	4.11	45
3-148.5	Sandy Creek at Waynesburg, Ohio	254	2.13	3,608	615	529	580	39.2	6.64	26.2	29.8	1,400	1,132	952	.02			75
3-150	Nimishillen Creek at North Industry, Ohio	175	2.03	2,115	233	233	233	35.3	8.66	25.6	28.4	1,320	1,120	972	.28			83
3-151.2	Home Creek near New Philadelphia, Ohio	1.64	3.37	1.71	1,098	794	922	334	54.4	1.8	2.5	1,140	978	870	0			13
3-158	Jerome Fork at Jeromeville, Ohio	120	1.77	1,293	180	200	191	54	7.1	20.9	21.7	1,320	1,072	952	0			65
3-160	Kokosing River near Millwood, Ohio	472	1.83	11,232	322	379	345	34.3	7.45	50.8	47	1,480	1,101	850	.03			59

3-161	Killbuck Creek at Killbuck, Ohio	466	1.87	12,196	421	414	417	39.5	3.01	56.8	46.2	1,400	999	796	.01			61
3-163	Mill Creek near Coshocton, Ohio	27.5	2.22	129	882	731	799	127	19.23	9.4	10.4	1,280	958	785	0			41
3-166	Wakatomika Creek near Frazeysburg, Ohio	140	2.26	1,891	650	667	660	74.5	9.97	29.3	28.7	1,260	960	745	0			82
3-167	Licking River at Toboso, Ohio	672	1.98	16,414	368	358	363	26.4	8.21	51.4	62.2	1,400	1,002	754	4.42			66
3-169	Little Kanawha River at Glenville, W. Va	386	2.26	10,822	1,661	1,610	1,642	76.6	6.99	61.6	55.4	2,800	1,195	702	0			53
3-170	Little Kanawha River at Grantsville, W. Va	913	2.40	35,364	1,677	1,670	1,673	54.6	3.97	86.9	85.4	2,800	1,081	664	0			112
3-175	Hocking River at Enterprise, Ohio	460	2.09	10,582	546	532	540	32.7	4.97	44.1	53.3	1,240	915	730	0			67
3-176	Hocking River at Athens, Ohio	944	2.29	40,234	737	746	742	29.5	2.44	81.8	76.9	1,240	879	638	.07			104
3-203	Bluestone River at Lilly, W. Va	438	2.03	15,130	1,345	1,332	1,338	108	22.76	74.3	63.3	4,300	2,392	1,444	.10			69
3-205	Greenbrier River at Buckeye, W. Va	540	2.14	17,475	1,534	1,606	1,575	154	17.19	64.4	75.7	4,842	3,068	2,080	0			61
3-206	Greenbrier River at Alderson, W. Va	1,357	1.42	91,988	1,431	1,474	1,455	114	10.52	139.2	128.1	4,842	2,764	1,522	.04			115
3-208	Gauley River at Camden-on-Gauley, W. Va	236	1.46	5,597	1,317	1,349	1,335	275	27.19	43.3	51.2	4,710	2,990	1,995	0			74
3-211	Gauley River above Belva, W. Va	1,315	1.56	74,848	1,344	1,302	1,321	148	25.15	105.5	116	4,710	2,703	675	0			258
3-213	Williams River at Dyer, W. Va	128	1.40	2,041	1,257	1,373	1,318	347	44.12	31.6	29.1	4,710	3,166	2,185	0			47
3-216	Cherry River at Fenwick, W. Va	150	1.40	1,569	1,334	1,481	1,414	259	72.76	21.1	34.8	4,524	3,079	2,076	0			45
3-217	Meadow River at Nallen, W. Va	287	1.26	7,542	1,212	1,133	1,183	130	18.59	44.3	47.4	4,372	2,761	1,856	0			58
3-220	Elk River at Centralia, W. Va	281	1.56	11,004	1,764	1,774	1,768	285	35.41	64.8	65.6	4,839	2,587	925	0			69
3-222	Elk River at Queen Shoals, W. Va	1,145	1.80	88,456	1,832	1,722	1,770	145	11.56	152.6	142	4,839	1,856	608	0			172
3-224	Coal River at Ashford, W. Va	393	1.87	12,726	2,260	2,149	2,218	140	24.1	61.9	61	3,400	1,581	635	0			55
3-227	Little Coal River at Madison, W. Va	267	2.12	4,740	2,294	2,169	2,244	198	18.21	34.7	50.9	3,350	1,370	674	0			53
3-230	Raccoon Creek at Adamsville, Ohio	587	1.59	23,203	802	853	830	26.5	2.28	79.9	85.5	1,100	761	574	.14			67
3-232	Guyandot River at Man, W. Va	762	2.10	32,960	2,013	1,993	2,002	130	11.26	86.3	85.2	3,536	1,723	704	0			95
3-233	Guyandot River at Branchland, W. Va	1,226	2.12	91,646	2,098	2,061	2,077	118	7.01	142.7	119.7	3,536	1,399	561	0			180
3-235.3	Levisa Fork at Fishtrap, Ky	389	2.09	15,246	2,594	2,511	2,563	171	18.06	69.1	63	3,095	1,665	694	0			61
3-235.7	Levisa Fork at Pikeville, Ky	1,225	2.17	56,421	2,343	2,268	2,302	113	13	86.8	94.3	3,765	1,649	639	.01			120
3-236	Levisa Fork at Paintsville, Ky	2,150	1.77	149,121	2,281	2,211	2,242	86.1	8.02	135.5	137.7	3,765	1,378	569	.01			215
3-238.5	Johns Creek near Prestonburg, Ky	198	1.64	5,436	2,495	2,077	2,325	120	7.79	52.2	57.9	2,500	1,129	618	0			37
3-238.5A	Johns Creek near Van Lear, Ky	209	1.64	6,708	2,113	2,496	2,339	120	7.30	58.4	64.1	2,500	1,111	601	0			40
3-243	Scioto River at Larue, Ohio	255	1.39	5,373	103	100	102	19.4	2.19	43.0	33.8	1,220	997	910	0	0	0	87
3-250.5	Little Scioto River above Marion, Ohio	73.3	1.16	967	64	56	60	11.9	4.8	22.8	27.4	1,050	972	905	0			31
3-252	Olentangy River near Delaware, Ohio	387	1.37	9,778	96	102	100	17.8	5.4	54.0	64.4	1,420	1,038	879	.04			93
3-253	Olentangy River at Stratford, Ohio	438	1.37	13,733	97	118	110	18.1	4.85	63.4	65.4	1,420	1,018	830	.04			108
3-254.5	Big Walnut Creek at Central College, Ohio	195	1.42	3,533	147	134	140	29	12.04	36.2	33.8	1,420	1,061	820	.01			83
3-255	Big Walnut Creek at Rees, Ohio	544	1.32	17,090	132	130	131	26.6	6.47	60.0	87.5	1,420	989	708	.01			164
3-256	Alum Creek at Columbus, Ohio	190	1.37	5,060	136	149	146	28	6.75	51.1	44	1,220	927	735	.03			65
3-257	Darby Creek at Darbyville, Ohio	533	1.62	21,339	110	116	114	22.7	5.28	68.0	86.5	1,490	950	715	.08			92
3-258	Deer Creek at Williamsport, Ohio	331	1.05	9,800	83	107	96	16.8	7.32	57.7	53.3	1,300	963	720	.01			75
3-261	Paint Creek near Bourneville, Ohio	808	1.64	31,960	227	226	227	24.2	7.51	80.5	84.8	1,343	970	667	.01			134
3-261.5	Salt Creek near Londonderry, Ohio	286	2.09	6,271	1,059	983	1,016	59.9	7.07	38.4	34.8	1,200	856	584	0			87
3-262	Little Salt Creek near Jackson, Ohio	76.5	2.17	551	811	802	806	64.5	7.06	14.8	15.7	1,000	749	630	0			45
3-267	Little Miami River at Milford, Ohio	1,195	1.62	60,323	214	218	216	19.6	6.72	92.4	101.4	1,200	868	500	.03			81
3-269	East Fork of Little Miami River at Perintown, Ohio.	477	1.73	16,837	199	162	183	21.4	8.5	77.5	70	1,200	884	516	0			57
3-278	Miami River at Sidney, Ohio	545	1.44	13,509	136	118	126	17	2.52	44.4	38.1	1,550	1,036	928	8.96			89

Summary of drainage basin topographic characteristics—Continued

No.	Name of gaging station	Drainage area (square miles)	Stream density (miles per square mile)	Σ al (cubic miles)	Land slope (feet per mile)			Channel slope (feet per mile)		Longest watercourse (miles)	Length of principal streams (miles)	Altitude of land (feet above mean sea level)			Area of water surfaces (square miles)			Number of subareas into which basin was subdivided
					E.-W.	N.-S.	Average	Tributary	Principal			Maximum	Mean	Minimum	Lakes and reservoirs	Swamps	Total	
3-289	Stillwater River at Pleasant Hill, Ohio	502	1.31	12,496	92	103	97	12	5.11	46.5	60.9	1,220	1,032	850	0.03			76
3-293	Greenville Creek near Bradford, Ohio	195	1.33	4,008	117	136	124	14.8	5.56	36.1	37.2	1,220	1,069	952	0			45
3-296	Mad River near Springfield, Ohio	485	1.54	9,232	191	193	192	27.8	8.29	40.8	39.8	1,550	1,079	880	.16			67
3-298A	Wolf Creek at Dayton, Ohio	70	2.19	714	174	160	166	50.4	18.2	19.7	20.8	1,060	910	732	0			91
3-300A	Talawanda Creek near Sevenmile, Ohio	315	1.54	6,070	216	221	220	36.3	15.7	39.6	53	1,220	927	601	0			51
3-321	Elkhorn Creek, at Knights Bridge, near Frankfort, Ky.	463	1.46	21,271	320	328	324	23.1	5.23	85.5	111.8	1,060	845	485	.04			57
4-50	Cedar Creek near Cedarburg, Wis.	113	1.16	1,781	177	165	170	30.2	9.18	28.8	27.9	1,280	911	790	2.05			74
4-119	Sandusky River near Bucyrus, Ohio	89.8	1.40	1,346	112	85	121	23.4	9.34	28.1	24.4	1,360	1,089	955	.06			38
4-120	Sandusky River near Upper Sandusky, Ohio	299	1.38	9,138	112	103	106	17.4	6.15	58.5	72.9	1,340	988	784	.07			53
4-122	Sandusky River near Freemont, Ohio	1,248	1.55	74,555	95	91	93	12.3	3.96	119.5	130.7	1,340	880	578	.10			131
4-134	Little Cuyahoga River at Akron, Ohio	42	.65	230	260	262	261	19.6	15.4	11.1	10.6	1,280	1,120	990	.86			17
4-139.5	Buffalo Creek at Gardenville, N. Y.	145	1.71	3,510	386	340	359	78.3	15.05	39.7	31.1	1,860	1,055	610	.04			29
4-140.3	Cayuga Creek near Lancaster, N. Y.	93.3	1.94	1,222	295	294	295	72	26.38	26.0	30.9	1,800	986	675	0			33
4-140.7	Cazenovia Creek at Ebenezer, N. Y.	136	1.64	2,855	451	409	426	112	22.5	33.0	40.9	1,920	1,111	605	0			32
4-142	Little Tonawanda Creek at Linden, N. Y.	22	1.06	88	560	412	476	229	69.2	7.9	8.6	1,800	1,349	1,060	0			19
4-143	Genesee River at Scio, N. Y.	309	1.39	4,989	697	736	717	107	15.7	29.4	35	2,565	1,877	1,435	.06			56
4-144	Genesee River at St. Helena, N. Y.	1,017	1.45	49,429	570	562	566	78.3	14.8	85.1	73.9	2,565	1,741	655	.23			112
4-146	Genesee River at Jones Bridge, near Mount Morris, N. Y.	1,419	1.49	74,938	557	526	539	98.2	10.58	101.9	105.3	2,565	1,527	553	1.69			220
4-148	Canaseraga Creek near Dansville, N. Y.	153	1.52	1,578	641	514	589	166	82.9	22.4	26.8	2,140	1,491	632	.28			69
4-172	Fall Creek near Ithaca, N. Y.	124	1.53	2,014	454	374	408	115	23.18	29.5	33.6	2,028	1,319	800	.29			56
4-180	East Branch of Fish Creek at Taberg, N. Y.	189	2.26	3,497	483	322	363	56.1	45.06	38.3	35.2	2,080	1,408	490	.16			71
4-197	Black River near Boonville, N. Y.	295	1.87	5,964	404	388	397	61.6	28.6	40.0	41.9	2,700	1,494	930	7.85			53
4-201	Black River at Watertown, N. Y.	1,876	1.80	133,714	450	482	469	56.9	17.09	118.5	131.8	3,670	1,576	375	40.1			230
4-204	Moose River at McKeever, N. Y.	365	2.18	8,704	634	870	730	73	12.36	39.5	60.5	3,670	2,076	1,488	.01			55
4-209	Independence River at Sperryville, N. Y.	85	1.68	1,052	472	519	489	61.2	33.74	24.2	26.5	2,300	1,650	1,195	.76			39
4-227	OswegatchieRiver near Heuvelton, N. Y.	973	1.62	68,586	498	470	481	39.7	11.29	124.3	127.9	2,460	1,049	286	18.58			140
4-229	West Branch of Oswegatchie River near Harrisville, N. Y.	258	1.53	5,176	500	499	479	60.6	24.18	44.5	64.1	2,400	1,256	736	2.15			53
4-230	Grass River at Pyrites, N. Y.	335	1.59	10,163	495	450	469	47.7	28.3	58.7	66.2	2,620	1,272	361	3.14			63
4-233	Raquette River at Piercefield, N. Y.	722	1.88	28,408	691	819	764	81.9	6.01	78.5	72.7	4,621	2,036	1,500	55.71			91
4-236	St. Regis River at Brasher Center, N. Y.	616	1.51	24,457	378	447	417	48.8	25.18	71.6	106.3	3,305	1,311	226	11.25			81

4-238	Salmon River at Chasm Falls, N. Y	132	1.38	1,493	766	675	712	132	38.63	19.8	27.8	3,355	1,760	1,012	2.09	------	------	53
4-239	Chateaugay River near Chateaugay, N. Y	112	1.42	1,757	610	523	559	218	27.49	25.1	25.5	3,830	1,716	880	4.97	------	------	51
4-240	Great Chazy River at Perry Mills, N. Y	247	1.42	5,948	285	279	283	122	42.4	40.3	47.1	3,830	1,105	168	2.33	------	------	64
4-243	West Branch of Ausable River near Newman, N. Y	116	1.85	1,242	1,071	1,051	1,059	413	36.29	17.4	21	5,112	2,434	1,630	3.73	------	------	63
4-244	Ausable River near Ausable Forks, N. Y	448	1.65	9,913	1,256	1,211	1,230	351	36.96	40.4	54.9	5,344	2,059	524	6.03	------	------	140
4-246	East Branch of Ausable River at Ausable Forks, N. Y.	198	1.94	3,615	1,524	1,548	1,538	433	47.2	38.3	30.5	5,344	1,905	546	.57	------	------	50
4-247	Bouquet River at Willsboro, N. Y	275	2.08	5.516	1,107	1,027	1.061	271	24.44	42.7	49.8	4,842	1,191	165	.87	------	------	53
4-248	Poultney River below Fair Haven, Vt	186.5	1.70	2.566	1.017	690	828	177	24.0	25.0	35.8	2,727	914	150	4.78	.58	5.36	54
4-250	Otter Creek at Center Rutland, Vt	307	1.79	5.259	949	717	814	248	34.9	33.1	42.7	4,241	1,617	510	.80	.58	1.38	58
4-252	Otter Creek at Middlebury, Vt	628	1.56	25.960	881	621	729	178	9.9	74.0	71.0	4,241	1,329	320	2.86	8.26	11.12	69
4-264	Dog River at Northfield Falls, Vt	76.1	2.24	571	1,196	895	1,022	318	64.1	14.0	15.7	2,923	1,486	620	.02	.29	.31	45
4-265	Mad River near Moretown, Vt	139.0	2.40	1,649	1,230	1,037	1,120	455	37.6	22.8	19.8	4,135	1,656	550	0	.33	.33	47
4-279	Clyde River at Newport, Vt	140	1.94	2,566	651	523	578	197	19.6	32.2	32.7	3,315	1,526	760	7.10	6.42	13.52	50
5-186	Little La Crosse River near Leon, Wis	77.1	1.98	627	910	1,160	1,039	127	15.27	15.2	14.6	1,420	1,005	770	0	------	------	35
5-187	Coon Creek at Coon Valley, Wis	77.2	1.71	552	1,044	980	1,012	145	30.14	13.3	20.7	1,362	1,025	725	0	------	------	41
5-188	Coon Creek near Stoddard, Wis	119	1.72	1,616	1,149	1,006	1,090	136	14.56	23.7	20.6	1,362	977	660	0	------	------	62
5-216	Kickapoo River at Steuben, Wis	699	1.85	34,720	844	899	876	63.3	3.43	91.5	83	1,441	960	660	.02	------	------	89
5-255	Ralston Creek at Iowa City, Iowa	3.01	2.63	5.2	------	------	475	115	32.9	3.3	3.2	840	780	690	0	0	0	17

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